MKTECH INDUSTRIAL ABRASIVES HANDBOOK

Grinding • Cutting • Surface Finishing • Polishing • Filtration

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ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 001

How to Use This Handbook

01

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: How to navigate and apply the MKTECH Industrial Grinding & Surface Finishing Handbook. This chapter does not replace product instructions, engineering specifications, workplace risk controls or legal requirements.

Safety-critical boundary — Use this handbook as a decision aid, not as permission to operate equipment or use a product. The current machine manual, abrasive or chemical product instructions, safety data sheet, workplace risk assessment, customer specification and applicable legal requirements take precedence. Stop and escalate whenever the material, product, machine, speed, guard, exposure control or acceptance criterion is uncertain.

Chapter objectives

After this chapter, the reader should be able to:

- identify which parts of the handbook apply to a production, quality, maintenance or purchasing question;
- distinguish general technical guidance from product-specific instructions and mandatory requirements;
- interpret warnings, application notes and product-information markers;
- use process maps, decision trees, comparison tables, checklists and SOPs correctly;
- record the information needed for a repeatable technical decision; and
- request product and application support from MKTECH with the relevant operating details.

1. Who this handbook is for

This handbook supports people who select, use, supervise, inspect or purchase industrial grinding and surface-finishing products. Readers do not all need the same level of detail, but they do need a common process language.

Operators

Operators use the handbook to understand the purpose of each process stage, recognise abnormal cutting or finishing behaviour, complete pre-use checks and report the actual setup when a result is unacceptable. It does not authorise an operator to change machine speed, remove a guard, substitute a mounting system, use an unidentified chemical or decide an engineering acceptance limit.

Supervisors and production engineers

Supervisors and engineers use it to define the operation, choose representative trials, control variables, approve work instructions and investigate variation between operators, shifts or batches. Their focus should be the complete system: workpiece, machine, abrasive, contact geometry, workholding, exposure control, inspection method and required finish.

QA/QC personnel

Quality personnel use the inspection, defect-separation and acceptance sections to determine what must be measured, photographed or escalated. The handbook can help organise evidence, but acceptance still comes from the drawing, customer specification, approved procedure or authorised engineering decision.

Maintenance and safety personnel

Maintenance personnel use machine-condition and process-symptom guidance to identify faults that may alter speed, contact, vibration or heat. Safety personnel use the hazard boundaries and stop-work conditions as prompts for workplace assessment. Neither function should treat a chapter summary as a substitute for current manufacturer documentation or a formal risk assessment.

Procurement and technical sales personnel

Procurement and technical sales teams use the handbook to ask better questions before recommending or purchasing a product. A product family name, diameter or grit alone is rarely enough. Compatibility, maximum rated speed, mounting method, material, operation, finish target and exposure controls must also be known.

2. How the handbook is organised

The handbook follows the logic of an industrial process rather than a catalogue sequence.

1. **Engineering foundations** explain materials, process variables, heat, force, speed and finish terminology.

2. **Abrasive and process technology** explains grinding, cutting, blending, finishing and polishing stages.
3. **Supporting systems** cover filters, chemicals, measurement, inspection, safety and maintenance.
4. **Decision and improvement tools** cover procurement, cost, troubleshooting and process improvement.
5. **Factory application tools** contain practical case studies, work-method guidance, checklists, forms and reference tables.

Start with the production question, not with a favourite product. If the problem is a blue stainless-steel surface, begin with the troubleshooting and heat-control guidance, then trace the result back to material, abrasive, machine and technique. If the task is a new weld-finishing operation, start with the complete process map and work forward through stock removal, blending, scratch refinement, inspection and final acceptance.

Each technical chapter uses a consistent pattern where applicable:

- purpose and scope;
- safety-critical boundary;
- process mechanism;
- variables and their interactions;
- controlled method;
- inspection and acceptance;
- troubleshooting;
- factory checklist or SOP;
- technical references; and
- product-information notes where exact values depend on the selected item.

3. Guidance hierarchy

Not every statement has the same authority. Use the following hierarchy when instructions differ.

Priority	Control	Typical examples
1	Applicable legal and regulatory requirements	Workplace safety, chemical exposure, waste, machinery and environmental controls
2	Customer and engineering requirements	Drawing, finish specification, corrosion requirement, dimensional tolerance and approved procedure
3	Current manufacturer instructions	Machine manual, abrasive instructions, maximum rated speed, mounting method, TDS and SDS
4	Approved workplace controls	Risk assessment, work instruction, permit, isolation method and inspection standard
5	This handbook	General explanation, selection framework, troubleshooting method and factory tools

The handbook must not be used to weaken a higher-priority requirement. If a handbook example differs from the current product document, follow the product document and report the conflict so the chapter can be corrected.

4. Technical guidance versus product instructions

Technical guidance explains mechanisms and decision principles that can apply across more than one product. Examples include the effect of local dwell on heat accumulation, the need to match machine speed to an abrasive's rated speed, or the importance of separating stock removal from scratch refinement.

Product instructions apply to an identified product, size, machine, configuration and document revision. Examples include maximum rated speed, permitted mounting system, operating angle, required backing pad, chemical dilution, contact time and storage life.

A general principle helps define the application, but product-specific limits always come from the identified product. Whenever a recommendation depends on an exact SKU, check the controlled product information:

Refer to the product label, Technical Data Sheet, or MKTECH representative.

Do not substitute a value from memory, an undated catalogue image, a competitor's product or a different size or construction.

5. How to interpret warning markers

The handbook uses warning markers to communicate the consequence of ignoring a condition. They are not decorative labels.

Danger

An immediate condition that can lead to death or severe injury if it is not avoided. Work must not begin or continue while the condition exists.

Warning

A hazardous condition or foreseeable misuse that can cause serious injury, major equipment damage or loss of process control. The required control must be confirmed before proceeding.

Caution

A condition that can cause minor injury, product damage, poor finish, rework, contamination or premature consumable failure.

Application note

Useful process guidance whose applicability depends on the product, material, machine, geometry or finish target. An application note is not a mandatory limit unless the controlling document says so.

Product information

A prompt to check the exact product declaration, compatibility and operating limit before selection or use.

When several markers apply, follow the most protective instruction and escalate the unresolved conflict.

6. Using decision trees

A decision tree converts a broad symptom into a sequence of checks. Begin at the defined entry condition and answer each question using observed or recorded evidence. Do not jump directly to the branch that matches the preferred product.

For example, a blue surface after grinding should first trigger stop, identification and acceptance checks. Only after confirming that the observation is fixed to the surface should the reader investigate heat-related causes such as pressure, dwell, contact area, abrasive condition or machine performance.

If a branch says **quarantine**, **stop** or **check product information**, end the operating decision at that point. Continue only after the responsible supervisor, engineer, quality or safety authority has resolved the condition.

7. Using comparison tables

Comparison tables organise trade-offs; they do not automatically rank products. Check the column headings, units, product scope and technical basis before using a row.

A sound comparison distinguishes:

- verified technical limits from typical observations;
- manufacturer claims from independent evidence;
- product attributes from proven factory results;
- normal process cost from defect and rework cost; and
- representative examples from verified production results.

If two options appear equivalent, examine the actual operation: required removal, finish sequence, material, access, machine power, speed compatibility, operator control, replacement rule and inspection requirement.

8. Using checklists and SOPs

A checklist confirms that defined items were considered. It does not explain every item and it cannot rescue an unsuitable process. Complete it at the stated time—before, during or after the operation—and record exceptions instead of ticking them automatically.

An SOP defines an approved sequence, responsibility, stop-work conditions and required records. Before using an SOP, confirm:

- the component, material and operation match its scope;
- referenced product and machine documents are current;
- required competency and authorisation are in place;
- tools, guards, workholding and exposure controls are available;
- inspection and acceptance criteria are defined; and
- deviations require an authorised change rather than operator improvisation.

When a controlled trial changes the process, update the SOP, source record and training evidence together. A good result from one unrecorded trial is not yet a repeatable factory method.

9. Recording a technical decision

The minimum useful process record identifies what was done, with what, by whom and against which acceptance criterion.

Record group	Information to capture
Workpiece	Component ID, material grade, thickness, geometry, initial condition and service environment
Required result	Removal target, final finish, dimensions, corrosion requirement and visual standard
Machine system	Make, model, no-load speed or setting, guard, flange, backing system and condition
Product	Manufacturer, full product name, SKU, dimensions, grit/grade, batch where relevant and maximum rated speed
Method	Operation stage, contact angle, pass pattern, pressure cue, elapsed contact and replacement rule
Controls	Workholding, dust/fume, spark/fire, noise, PPE and contamination controls
Result	Inspection method, measured values, photographs, defects, acceptance decision and approver

Record unsuccessful trials as carefully as successful ones. Failed trials show the boundary of the process and prevent the same mistake from being repeated.

10. Requesting product and application support

“Which disc is best?” is not a complete application question. Use the following structure.

Information that supports a useful recommendation

6. Company, site and contact person.
7. Workpiece material and, where known, grade.
8. Thickness, diameter or representative geometry.
9. Current process stage: cutting, stock removal, weld grinding, blending, finishing or polishing.
10. Current product, full size, grit/grade and observed product condition.
11. Machine make/model, disc diameter, speed or speed range, power and mounting system.
12. Required finish, dimensional tolerance and customer acceptance criterion.
13. Current result and defect: cut rate, scratch, heat tint, loading, glazing, vibration, distortion or short life.
14. Photographs of the whole component, contact area, machine label, product label and defect under consistent lighting.
15. Current work instruction, inspection method and trial history.
16. Relevant safety, exposure, contamination, food, pharmaceutical or corrosion constraints.
17. Required production rate, batch size and cost objective, separated from safety and quality requirements.

Do not send customer-confidential drawings, personal data or restricted factory information unless the authorised communication channel and permission are confirmed.

Example enquiry

Incomplete: “Need a cooler disc for stainless.”

Useful: “We are blending a TIG weld on 1.5 mm 304 stainless sheet using a specified variable-speed angle grinder and an identified flap disc. A blue band appears during final high-spot removal and the panel exceeds the specified flatness limit after release. Attached are the machine and disc labels, overall and close photographs, the current pass sequence and the customer finish requirement. Please advise on a suitable current product family and the application checks to complete.”

The useful enquiry does not assume that the abrasive is the only cause. It gives the MKTECH representative enough context to review compatibility, identify the likely process variables and recommend appropriate next checks.

11. Key takeaways

18. Start with the operation and acceptance requirement, not a preferred product.
19. Higher-priority legal, customer, engineering, manufacturer and workplace requirements override this handbook.
20. Product-specific limits must come from current information for the exact item.
21. Warning markers, decision trees, tables, checklists and SOPs must be used within their stated scope.
22. Product-information markers identify values that must be checked for the exact item.
23. A complete support request describes the workpiece, machine, product, method, controls, result and required acceptance.

Using current product information

Product designs, labels and application ranges can change. Confirm that the product code, dimensions, mounting system, declared material/application, maximum permitted speed and storage condition match the exact item being used. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

When sharing drawings, photographs or production information for technical support, follow the organisation's confidentiality and information-handling requirements.

ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 002

The Complete Grinding and Finishing Process

02

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: A controlled process for planning, performing and accepting industrial grinding and surface-finishing work. This chapter defines process logic, not a universal product sequence, grit progression or acceptance limit.

Safety-critical boundary — Cutting, grinding, finishing and polishing can expose people to wheel or workpiece breakage, entanglement, sparks, fire, sharp edges, airborne particles, hazardous substances, vibration and noise. Before work, verify the current machine and product instructions, speed and mounting compatibility, guarding, workholding, competence, exposure controls and workplace risk assessment. Stop if any product, machine, material, coating, chemical, control or acceptance requirement is uncertain. [S007; S009; S014; S017; S018]

Chapter objectives

After this chapter, the reader should be able to:

- map a job through thirteen controlled stages from identification to acceptance;
- distinguish stock removal, weld grinding, blending, scratch refinement, finishing and polishing;
- define the input, purpose, output and hold point for each stage;
- prevent a cosmetic improvement from concealing a dimensional, metallurgical or corrosion problem;
- design an authorised rework loop rather than repeating uncontrolled grinding; and
- create a process traveller that makes the result traceable and repeatable.

1. The process is a chain, not a product list

A satisfactory surface is the output of a controlled chain. The result depends on the workpiece, material, defect, required geometry, machine, abrasive, contact method, operator technique, cleaning, inspection and acceptance rule. A high-performing abrasive cannot correct an unidentified alloy, an unacceptable weld, an unsuitable machine or an undefined finish requirement.

Manufacturer application guides commonly separate weld levelling, blending and final finishing rather than treating them as one operation. [S004; S006; S015] This chapter extends that principle into a complete factory workflow. The thirteen-stage map organises decisions, hold points and records while keeping product selection tied to the exact application.

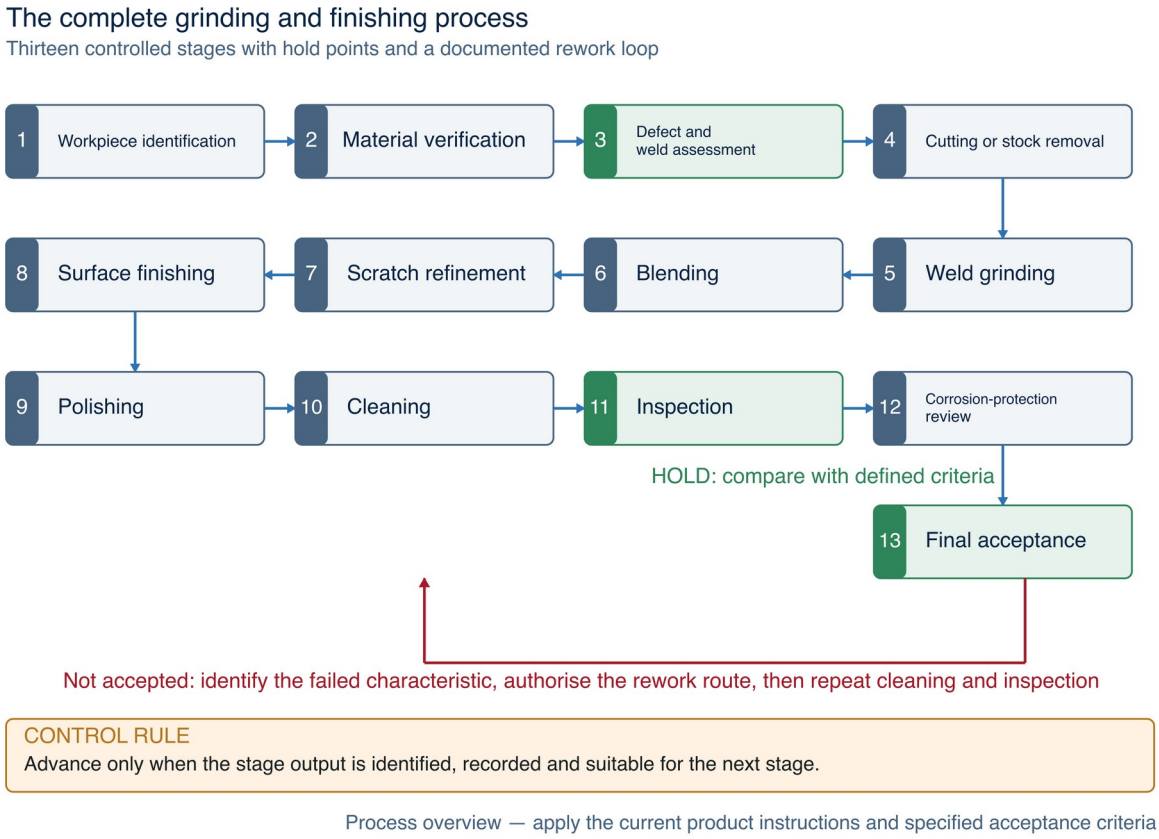

Figure 1. Complete controlled process. Green stages are formal hold points. A failed result returns through the authorised rework route rather than automatically returning to the coarsest abrasive.

The four control zones

The thirteen stages form four practical zones.

Zone	Stages	Control question
Define	1–3	Do we know what the workpiece is, what condition it is in and what result is required?
Remove and shape	4–6	What material must be removed, and how will geometry be preserved?
Refine and restore	7–10	What scratch, appearance and cleanliness must be created without introducing a new defect?
Verify and release	11–13	Does the result meet every defined requirement, including corrosion-related requirements?

Stage boundaries matter. If weld reinforcement remains above the approved profile, a fine finishing product is being asked to perform stock removal. If deep stock-removal scratches remain, polishing will make the surface brighter without necessarily removing them. If contamination remains after polishing, appearance alone cannot prove corrosion suitability.

2. Define acceptance before removing material

Grinding is usually irreversible. Before the first cut, identify the required geometry, finish, dimensional tolerance, corrosion condition, cleanliness, inspection method and authority for acceptance. The controlling requirement may come from a drawing, weld procedure, customer specification, approved visual comparator, surface-roughness requirement, hygiene requirement or engineering disposition.

Avoid descriptions such as “smooth,” “clean,” “polished” or “good enough” unless the workplace has translated them into an approved reference. A complete requirement might identify:

- the area that may be processed and any protected surface;

- whether weld reinforcement is to remain, be reduced or be made flush;
- the required edge radius, contour, flatness and dimensional minimum;
- direction and uniformity of the scratch pattern;
- permitted and prohibited visual features under defined lighting;
- measured surface-roughness requirement and measurement method, if applicable;
- removal of heat tint, embedded contamination or process residue;
- cleaning and corrosion-restoration method, if required; and
- inspection authority and required records.

Product-specific control — Select the abrasive and machine as a complete system. Confirm product-to-machine compatibility, operating limits and replacement criteria from current product information. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

3. The removal-to-finish hierarchy

The stages between cutting and polishing do different jobs. Combining their names can hide the real cause of slow production or rework.

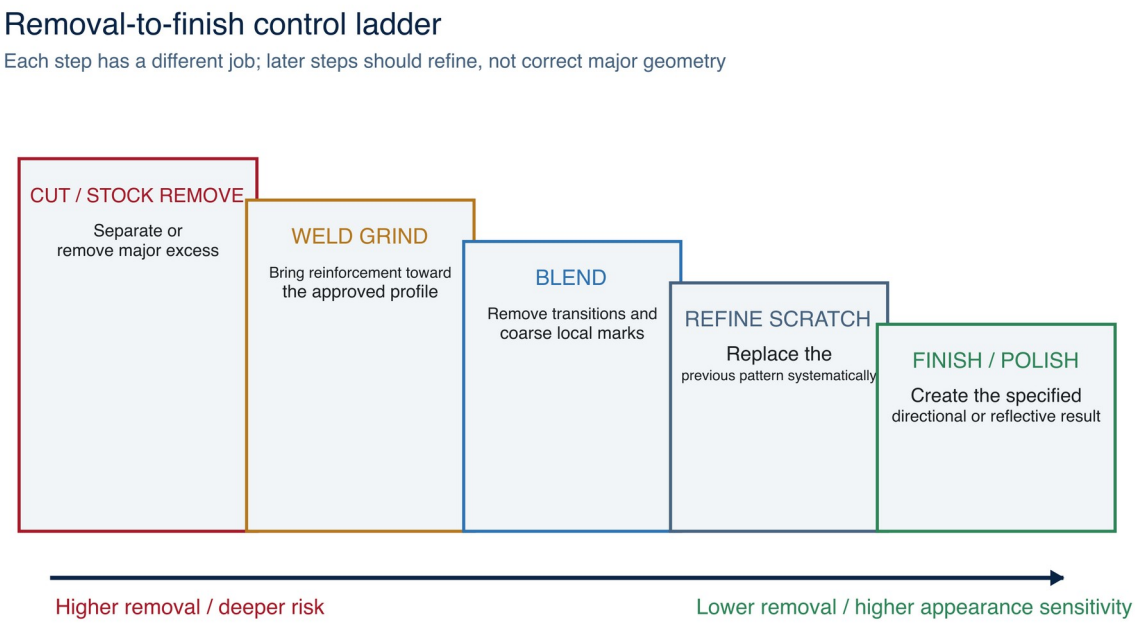

Figure 2. Removal-to-finish progression. Material removal normally decreases as appearance sensitivity increases. Select the actual abrasive sequence from the material, starting condition and required finish.

Cutting or stock removal

The purpose is separation or major reduction of excess material. The dominant risks are loss of dimension, heat, burrs, edge damage and an excessively deep starting scratch. The chosen system must suit the material, geometry and machine; a cutting product must never be used for side grinding unless its current instructions expressly permit it.

Weld grinding

The purpose is to reduce weld reinforcement toward an approved profile while protecting parent material. It is controlled geometry work. Operators need a visible or measurable stop reference and must avoid undercutting beside the weld, thinning the parent material or flattening a required contour.

Blending

The purpose is to remove abrupt transitions and make the repaired zone flow into the surrounding surface. Blending should widen control, not widen damage. A blend can look smooth yet fail because the component has become hollow, crowned, wavy or dimensionally thin.

Scratch refinement

The purpose is to replace the preceding scratch pattern with a finer, controlled pattern. Progress only after the deeper scratches are removed under suitable lighting and viewing direction. Skipping a required refinement stage often transfers the defect to the final finish, where correction becomes slower and more expensive.

Surface finishing and polishing

Surface finishing creates the specified directional, satin, matte or otherwise controlled texture. Polishing reduces visible scratch contrast and may build a reflective appearance. They are not synonyms, and polishing is not always required. Neither operation proves cleanliness, passivity or corrosion resistance.

4. Stage-by-stage controlled method

Stage 1 — Workpiece identification

Purpose: establish the identity, scope and traceability of the job before any irreversible action.

Record the component or batch number, drawing revision, customer or internal order, process area, initial photographs and any protected surfaces. Mark the exact weld, defect or zone to be processed using an approved method that will not contaminate or damage the material.

Confirm the process traveller accompanies the workpiece. If several similar components are present, use positive identification rather than location, memory or appearance. Quarantine any workpiece whose identity conflicts with its documents.

Output and hold condition: the physical workpiece and controlled documents agree; the permitted work area and required result are traceable.

Stage 2 — Material verification

Purpose: determine what material and surface state will actually be processed.

Verify material grade, thickness, heat or batch where required, coating or plating, cladding, hardness or heat-treatment state, and existing surface finish. Use the specified identification method. If positive material identification is required, record the instrument, method, result and operator. Do not infer stainless grade from colour, magnet response alone or the previous job.

Material verification also includes contamination risk. Separate tools and abrasives may be required for stainless steel, aluminium, titanium, nickel alloys or hygiene-sensitive work. Existing paint, oil, galvanising, thermal oxide, plating or unknown residue can change both process behaviour and exposure controls.

Stop condition: unidentified material, uncertain coating, unexpected thickness or conflicting certification.

Stage 3 — Defect and weld assessment

Purpose: decide whether grinding is permitted and define the removal boundary.

This is the first formal hold point. Assess the weld or defect before hiding evidence. Record location, length, width, depth, orientation and relationship to an edge, bend, hole, heat-affected zone or critical dimension. Use the approved examination method. Visual assessment may need to be supplemented by dimensional inspection or non-destructive testing.

Distinguish features that grinding may correct from conditions needing engineering or welding disposition. Cracks, suspected lack of fusion, repeated porosity, deep undercut, distortion, minimum-wall risk or an unexplained defect pattern must not be cosmetically blended away. Where repair welding is authorised, complete that route and repeat assessment before grinding.

Define the maximum permitted removal and the method for checking it. If no acceptance criterion exists, quarantine the workpiece and obtain one.

Release to removal: authorised assessor, defined removal boundary, confirmed remaining-section requirement and documented acceptance criteria.

Stage 4 — Cutting or stock removal

Purpose: separate the part or remove major excess efficiently while leaving controlled allowance for later stages.

Verify the machine, guard, mounting system, product identity, dimensions and maximum rated speed against current instructions before use. [S007; S018] Inspect the product and machine condition. Secure the workpiece and protect adjacent surfaces. Confirm spark, fire, dust, fume and noise controls from the workplace assessment. [S009; S014; S017]

Plan the cut or removal direction so that heat, burr, breakout and loss of support do not damage the component. Leave only the allowance needed for the next stage; excess allowance wastes time, while insufficient allowance can force the next stage to correct rough geometry. Mark and measure critical dimensions rather than relying on visual judgement.

Output: major excess removed, no unauthorised gouge or thermal damage, and adequate controlled allowance remains.

Stage 5 — Weld grinding

Purpose: bring weld reinforcement toward the specified profile without reducing parent material below its approved condition.

Work from the highest weld areas toward the stop reference. Maintain a supported, controlled contact area and a pass pattern appropriate to the product instructions. Avoid stationary dwell and repeated concentrated contact at thin edges. Inspect frequently from more than one direction; a weld that appears flush from one angle may remain high or contain a hollow transition.

Use a template, straightedge, contour gauge, thickness method or other approved aid where geometry matters. Stop before the weld disappears into the parent surface if later blending still requires material. Do not use colour as a universal temperature measurement or acceptance criterion.

Output: reinforcement is within the blending allowance, critical geometry remains protected and no new crack-like mark, undercut, gouge or unacceptable heat tint is present.

Stage 6 — Blending

Purpose: remove the visible or tactile step between the processed zone and adjacent surface.

Blend over the smallest practical area that produces the specified transition. Follow the component geometry rather than forcing a flat tool path onto a curve. Cross-check profile using grazing light and a physical reference where permitted. Maintain the defined scratch direction if the surrounding finish must be matched.

Blending is complete when the transition meets geometry requirements, not merely when the weld line becomes difficult to see. If the operator must keep expanding the blend zone to hide a dip, stop and assess the profile; continued blending can convert a local defect into widespread thinning.

Output: approved transition and contour with the parent material protected.

Stage 7 — Scratch refinement

Purpose: remove the unwanted scratch pattern from the previous stage and establish a controlled foundation for the final finish.

Clean loose debris between changes so that a coarse particle is not carried forward. Use consistent lighting and, where useful, change the direction of the next scratch pattern so remaining previous-stage marks can be distinguished. Advance only when the preceding scratch is removed throughout the complete process zone.

The correct sequence depends on starting condition, product construction, material, geometry, machine and required finish. Manufacturer application guides can illustrate staged combinations, but those combinations remain product-specific. [S004; S005; S006; S015]

Stop condition: isolated deep scratches, embedded particles, loading, smearing, unexpected heat tint or a finish zone that continues to grow.

Stage 8 — Surface finishing

Purpose: create the specified direction, texture, uniformity and boundary.

Define the finish direction before starting. Establish a controlled start and stop beyond the acceptance area where the design permits, or use an approved masking and feathering method. Overlap passes consistently and inspect for stripes, cross-scratches, swirls, edge rounding, patchiness and colour variation.

For an existing architectural or mill finish, prepare an approved comparator or representative trial coupon. A nominal abrasive grade alone does not define the resulting appearance; tool type, pressure, speed, wear, contact geometry and pass pattern also contribute.

Output: specified texture and direction across the defined area, ready for polishing if polishing is required.

Stage 9 — Polishing

Purpose: achieve an approved low-scratch or reflective appearance after geometry and refinement are already correct.

Confirm that polishing is required. Prepare a clean, controlled area and prevent transfer of compounds or particles between materials or polishing stages. Use the product and compound exactly within current instructions and workplace chemical controls. Inspect the surface under the specified lighting for haze, residual lines, drag marks, compound staining, waves and local overheating.

Polishing should not be used to conceal geometry, deep scratches or incomplete blending. It may increase reflectivity and make waviness more visible. If the target is a directional satin finish, polishing may be inappropriate.

Output: approved appearance without residue or concealed defects.

Stage 10 — Cleaning

Purpose: remove abrasive debris, loose metal, polishing compound, oil, fingerprints, marking residue and other process contamination before inspection.

Cleaning is a process stage, not housekeeping after acceptance. Select the method for the material, contamination and service requirement. Use identified chemicals with current safety data, approved dilution and contact controls, suitable rinsing and complete drying. The Malaysian chemical-control framework requires assessment and control of hazardous chemical exposure; local exhaust is one recognised engineering-control context for applicable grinding operations. [S009; S017]

Use clean tools and wipes suitable for the material. Prevent recontamination from carbon-steel benches, dirty gloves, shared brushes, shop dust, chloride-containing cleaners or uncontrolled water quality. Cleaning must not erase identification or introduce a new finish difference.

Output: dry, residue-free surface suitable for reliable inspection and corrosion-protection review.

Stage 11 — Inspection

Purpose: compare the cleaned result with every defined acceptance criterion.

This is the second formal hold point. Inspect identity, dimensions, contour, remaining thickness where required, finish direction, visual uniformity, scratches, burrs, heat tint, cleanliness and any specified roughness or non-destructive test result. Use the required lighting, viewing distance, comparator, instrument and calibration status. Record the result rather than relying on an untraceable verbal release.

Inspect the full affected zone, including transition edges and the reverse side where heat, distortion or breakthrough could appear. Separate observations from decisions: first record what is present; then compare it with the controlled criterion.

Decision: pass to corrosion-protection review, or identify the precise failed characteristic and initiate an authorised rework or rejection route.

Stage 12 — Corrosion-protection review

Purpose: determine whether mechanical appearance and cleaning are sufficient for the alloy and intended service, or whether an approved restoration treatment is required.

Stainless-steel heat tint and iron contamination can require attention beyond cosmetic finishing. Pickling and passivation are distinct chemical surface treatments, and their need depends on material, fabrication history, contamination, service and specification. [S001; S016] Do not claim that a bright or uniform surface is automatically passive or corrosion-ready.

The authorised engineering or quality function should review heat tint, embedded contamination, free-iron control, chemical cleaning or passivation requirements, rinse-water and waste controls, verification method and service environment. Chemical restoration must follow an approved procedure, current technical and safety data, and the workplace chemical assessment. If treatment changes the appearance or condition, repeat the required cleaning and inspection.

Output: documented determination that corrosion-related requirements are satisfied or a controlled treatment and reinspection route is defined.

Stage 13 — Final acceptance

Purpose: release only a workpiece that meets the complete requirement and has a complete record.

The authorised acceptor verifies that all hold points are signed, deviations are resolved, required treatment and inspection records are attached, identification remains intact and the workpiece is protected for storage or the next operation. Acceptance is not the absence of a visible complaint; it is a positive, traceable decision against defined criteria.

Photograph the accepted surface when the procedure requires it. Protect the finish from handling damage, condensation, cross-contamination and unsuitable packaging. Transfer any storage, transport or installation restrictions with the workpiece.

Final output: accepted component, complete process traveller, recorded approver and controlled status.

5. The authorised rework loop

A failed inspection does not automatically justify repeating the last abrasive operation. Record the failed characteristic and determine the earliest stage capable of correcting it without violating dimensional or material limits.

Failed characteristic	Possible return point	Required check before rework
Excess weld reinforcement	Stage 5	Remaining material and weld-repair disposition
Hollow or abrupt transition	Stage 3 or 6	Geometry, remaining thickness and engineering authority
Coarse scratch remains	Stage 7	Scratch source, contamination and refinement route
Non-uniform directional finish	Stage 8	Finish reference, boundary and remaining allowance
Polishing haze or compound mark	Stage 9 or 10	Cleanliness, compound compatibility and finish target
Contamination or residue	Stage 10	Contaminant identity and approved cleaning method
Heat tint or corrosion concern	Stage 3 or 12	Alloy, service, acceptance and restoration route

After any abrasive or chemical rework, repeat cleaning, inspection and the corrosion-protection review. Record the rework cycle, changed variables and remaining dimensional margin. Escalate repeated failure; more passes are not a process-improvement method.

6. Process traveller — minimum record

Section	Required record
Job identity	Component/batch ID, drawing and revision, order, area to process
Material	Grade, thickness, certification or identification method, coating and initial finish
Assessment	Defect/weld description, measurements, photographs, removal boundary and authorisation
Requirement	Geometry, finish, cleanliness, corrosion and inspection criteria
Equipment	Machine ID, guard, mounting system, speed setting where applicable, condition check
Consumable	Manufacturer, full product/SKU, size, grade/grit, batch where required, rated-speed check
Method	Stage, sequence, pass direction, process boundary and replacement rule
Controls	Workholding, dust/fume, chemical, fire/spark, noise, contamination and PPE controls
Result	Measurements, visual comparison, test results, photographs and rework history
Release	Inspector, corrosion review, final approver, date and status

7. Application example — stainless enclosure

A fabricated stainless enclosure has a welded external corner that must visually match the specified directional reference while retaining the required corner profile. The example shows how to organise the operation without assigning an unverified abrasive specification.

24. The traveller links the enclosure serial number to the current drawing and marks the permitted process zone.
25. Material certificate and thickness are confirmed; the surface is checked for protective film, oil and carbon-steel contamination.
26. The weld is examined before grinding. The assessor records reinforcement, undercut status, corner geometry and minimum remaining thickness.
27. Major excess is reduced only if required, leaving allowance for controlled weld grinding.
28. The weld is brought toward the approved corner profile using the verified machine-product system.
29. The transition is blended without flattening the corner.
30. Coarse scratches are replaced through the trial-approved refinement sequence.
31. The directional finish is recreated across the authorised zone using the reference comparator.
32. Polishing is omitted because the specified result is directional, not reflective.

33. The enclosure is cleaned with the approved material-compatible method and dried.
34. QA checks profile, finish direction, scratch uniformity, heat tint, cleanliness and relevant dimensions.
35. Engineering confirms the approved fabrication-cleaning route satisfies the corrosion requirement for the intended service.
36. QA records acceptance and the surface is protected for packing.

The example shows why “grind and polish the weld” is an inadequate instruction. It omits identification, assessment, geometry, contamination, finish reference, corrosion review and release authority.

8. Factory process checklist

Before removal

- [ ] Workpiece and current documents agree.
- [ ] Material, thickness, coating and initial finish are verified.
- [ ] Defect or weld has been assessed before evidence is removed.
- [ ] Permitted removal, protected surfaces and acceptance criteria are defined.
- [ ] Machine, guard, mounting, product and rated-speed compatibility are verified.
- [ ] Workholding and exposure, spark, fire, noise and contamination controls are in place.

During removal and refinement

- [ ] Each product is performing the intended stage rather than compensating for a skipped stage.
- [ ] Geometry and remaining material are checked before the visual stop point is exceeded.
- [ ] Abrasive condition, loading, vibration, heat tint and scratch pattern are monitored.
- [ ] Loose debris and cross-contamination are controlled between stages.
- [ ] Process changes and abnormal observations are recorded.

Before release

- [ ] The surface is cleaned and dry before inspection.
- [ ] All dimensional, profile, finish, roughness, cleanliness and test criteria are checked as applicable.
- [ ] Corrosion-protection requirements have been reviewed by the authorised function.
- [ ] Any rework returned through a documented stage and was reinspected.
- [ ] Final acceptance is signed and the finished surface is protected.

9. Key takeaways

37. Define the workpiece, material, defect and acceptance requirement before removing material.
38. Cutting, weld grinding, blending, scratch refinement, finishing and polishing are separate jobs.
39. A later, finer stage should not be used to correct major geometry or deep uncontrolled scratches.
40. Cleaning, inspection and corrosion-protection review are independent of cosmetic appearance.
41. Failed inspection requires an authorised return point, not automatic repeated grinding.
42. Final acceptance must be positive, traceable and based on the complete requirement.
43. Product-specific sequences and operating limits must be taken from current product information and confirmed on representative work.

Applying the process to a product

For each operation, match the exact abrasive to the material, machine, mounting system, dimensions and intended action. Establish the required finish with a drawing, measurable criterion or approved physical comparator, then confirm the sequence on representative material before repeat work.

Cleaning, passivation and corrosion-restoration treatments must be compatible with the alloy and intended service. Use current chemical information, the workplace chemical assessment and the specified inspection method. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 003

Understanding Industrial Materials

03

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: A verification-first guide to predicting material response during cutting, grinding, blending, finishing and polishing. It does not provide universal product, grit, pressure, angle or speed recommendations.

Safety-critical boundary — A material name is not a safe operating instruction. Before abrasive contact, verify the alloy or material system, heat-treatment or hardness condition, coating, contamination controls, dust and fire characteristics, machine and abrasive compatibility, current product instructions and workplace risk assessment. Stop when any material, coating or composite constituent is unknown. [S009; S014; S017; S018; S020; S022; S026]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish material family from verified grade, condition and surface system;
- explain how heat, work hardening, loading, smearing, scratching, burrs and contamination develop;
- anticipate different responses from mild steel, carbon steel, stainless steel, aluminium, cast iron, tool steel, galvanised steel, other non-ferrous metals, coated surfaces and composites;
- identify when a material-specific tool, dust control, cleaning route or coating repair is required;
- set a controlled trial without inventing a universal cutting speed or grit sequence; and
- recognise when product identity or application conditions require confirmation before use.

1. The material label is only the first input

Industrial materials cannot be selected or processed reliably from colour, magnet response, weight or a broad description such as “steel” or “aluminium.” Within one family, alloy content, manufacturing route, heat treatment, hardness, cold work, casting structure, coating and previous processing can change how a surface cuts and how it fails.

Established machinability classifications separate steels, stainless steels, cast irons, non-ferrous metals, heat-resistant alloys and hardened materials because each group presents different cutting characteristics. They subdivide those groups because material family alone does not provide enough information for process selection. [S019] Abrasive work demands the same discipline: group-level behaviour helps form a hypothesis, but grade and condition must control the trial.

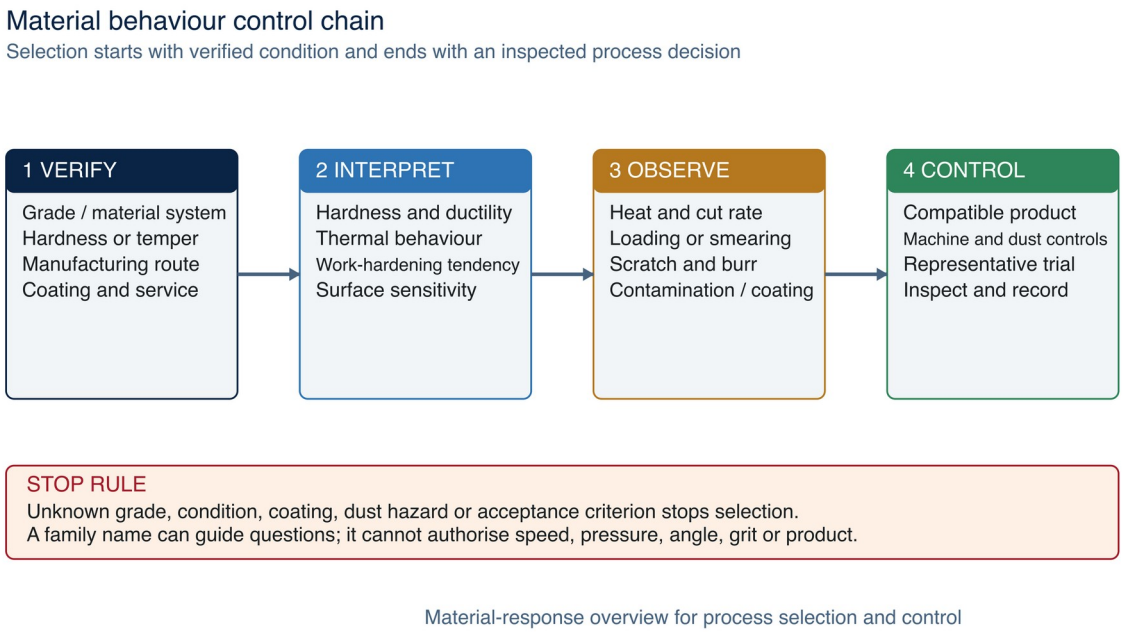


Figure 1. Material-response control chain. Material identity and condition influence properties; properties influence the observed process response; and the response determines the control decision.

Minimum material record before selection

- material family and verified grade or specification;
- thickness, geometry and critical dimensions;
- heat treatment, hardness, temper or cold-worked condition where relevant;
- manufacturing route, including rolled, forged, cast, powder-metallurgy or composite construction;
- coating, plating, cladding, conversion layer, paint, oxide or unknown residue;
- required final texture, direction, roughness, gloss, coating condition or corrosion performance;
- service sensitivity, including food, pharmaceutical, marine, high-temperature or fatigue-critical use; and
- contamination, dust, fire, chemical and waste-control requirements.

If the material identity or condition is uncertain, do not select solely on a “general-purpose” description. Confirm the work material and starting condition, then compare suitable product families on representative work.

2. What the operator actually observes

Heat generation

Grinding converts mechanical work into heat at the contact. The temperature pattern depends on speed, pressure, contact area, duration, abrasive sharpness, loading, workpiece thermal properties, geometry and cooling conditions. OSHA's archived aluminium guidance specifically notes that heat cannot be reduced to a single amount because process speed, composition, contact area, duration and pressure all matter. [S020] Treat colour, touch and spark appearance as observations, not universal temperature measurements.

Heat may soften a coating, distort a thin section, temper a hardened steel, accelerate loading, produce stainless heat tint, degrade a composite resin or create a fire and dust-control problem. Control begins by limiting unnecessary dwell and by choosing a product and process proven for the verified material.

Work hardening

Work hardening is local strengthening caused by plastic deformation. Austenitic stainless steels and some nickel or titanium alloys can harden at the worked surface. [S003; S019] If an abrasive rubs instead of cutting, the next pass may encounter a harder skin, increasing force and heat. A sharp, stable cutting action and frequent inspection are therefore more important than continuing with extra pressure.

Do not describe every hard-to-grind surface as work hardened. A hard heat treatment, hard oxide, embedded grit, glazing, abrasive loading or loss of tool support can create similar symptoms. Verify the cause before changing the process.

Loading and glazing

Loading occurs when removed material or residue packs into the working surface of an abrasive. Glazing occurs when active cutting points become dull or ineffective while the product continues to rub. Ductile or adhesive materials can promote loading; excessive heat, unsuitable pressure, a closed product structure or contamination can worsen it. The practical signs are reduced cut, increased force, surface drag, streaks, heat and transferred material.

Replacing pressure with evidence is the key control. Stop, inspect the abrasive and surface, identify whether the product may be cleaned or dressed under its instructions, and verify that its construction is intended for the material. Never improvise cleaning, lubrication or dressing on a product whose instructions do not permit it.

Smearing and transfer

Smearing is displaced material spread across the surface rather than cleanly removed. It can conceal graphite in cast iron, close or drag a soft non-ferrous surface, cover a defect or redistribute contamination. Cast-iron preparation and machinability references identify matrix smearing, graphite pull-out and adhesive material flow as distinct process concerns. [S019; S024]

Smearing can make a surface look uniform while leaving a mechanically damaged layer. Inspect under directional light and, where necessary, use magnification, cleaning, metallography or another approved method rather than appearance alone.

Scratch formation

Every abrasive creates a distribution of scratches. Depth and uniformity depend on grain size and shape, backing or bond, contact geometry, force, speed, product condition, loose contamination and the workpiece response. A single hard particle carried forward can create a scratch much deeper than the intended stage.

Scratch refinement must therefore be verified, not assumed from the printed grit. Clean between stages, control direction, use suitable lighting and advance only when the unwanted preceding pattern has been removed.

Burr formation and edge change

Ductile materials tend to displace and form burrs; brittle materials may chip, fracture or break out. Burr shape changes with alloy, hardness, edge support, approach direction and tool condition. A burr is not only a sharpness problem: it can change dimension, interfere with assembly, retain contamination or indicate that the process is rubbing and pushing material.

Define the acceptable edge condition before grinding. A requirement to “remove the burr” must not become permission to remove a designed radius, chamfer, coating or minimum section.

Contamination

Particles transferred from tools, benches, brushes, dust collectors, gloves, compounds or another workpiece can change corrosion, appearance, coating adhesion or fire risk. Stainless steel may require stainless-only controls to prevent embedded iron. Aluminium dust mixed with iron oxide can contribute to a thermic reaction; OSHA's archived guidance recommends material-specific tools as one safeguard in that context. [S001; S020]

Segregation is a controlled system, not a coloured label alone. It includes storage, identification, cleaning, extraction, workholding, consumables and records.

3. Material-family response guide

The following profiles describe likely behaviour and the questions to ask. They do not replace grade-specific data or a representative trial.

Mild steel

“Mild steel” normally indicates low-carbon steel, but it is not a complete grade designation. Low-carbon steels can be ductile and may produce adhesive transfer or built-up material during cutting; scale, rust, weld metal and coatings can behave very differently from the base metal. Steel machinability changes with carbon content, hardness, heat treatment, alloying and manufacturing route. [S019]

Likely process observations

- burrs and edge rollover when the process pushes rather than cuts;
- loading or transferred material on some products and low-carbon conditions;
- sparks and scale debris that can obscure the true surface;
- deep scratches if heavy removal is allowed to define the final finish; and
- rapid visual brightening that does not prove rust, scale or a coating has been uniformly removed.

Control response

Verify the grade, scale, coating and weld condition. Select the product for the actual operation—cutting, weld reduction, blending or finishing—and define the dimensional stop. Keep carbon-steel tools and dust away from contamination-sensitive stainless, aluminium and non-ferrous work.

Carbon steel

Carbon steel spans a wide range. Increasing carbon content and hardening can increase hardness and abrasive resistance; carbide-forming alloy additions and heat treatment can further change the response. [S019] Treat “carbon steel” as a family requiring grade and hardness confirmation.

Likely process observations

- a soft or annealed condition may cut readily and form burrs;
- a hardened or tempered condition may cut slowly, generate concentrated heat and wear the abrasive rapidly;
- overheating can change the surface condition of heat-treated parts even when the geometry looks acceptable; and
- the same visual finish can hide different remaining hardness or thermal damage.

Control response

Record hardness or heat-treatment state when function depends on it. For springs, shafts, gears, blades, dies and other treated parts, define the permitted stock removal and thermal acceptance before work. Stop on unexpected colour, cracking, soft spots, rapid abrasive wear or a sudden change in cut.

Stainless steel

Stainless steel includes ferritic, martensitic, austenitic and duplex families. Austenitic grades can have high work-hardening rates and relatively low thermal conductivity compared with common carbon steels. [S003; S019] Grinding heat can create oxide colour; carbon-steel contamination can reduce corrosion performance; a bright finish does not prove passivity. [S001; S016]

Likely process observations

- concentrated heat and heat tint, especially on thin edges or with dwell;
- rising force if rubbing work-hardens the surface;
- loading, smearing or drag marks on an unsuitable product;
- directional scratches that become more visible as reflectivity increases; and
- embedded iron or dirty compound affecting corrosion-related acceptance.

Control response

Verify stainless family and grade, use the required stainless-only segregation, maintain a cutting rather than rubbing action and inspect heat tint and contamination separately from appearance. Any pickling, passivation or chemical restoration must follow an approved procedure; mechanical brightness alone is not release evidence.

Aluminium

Aluminium alloys are not one material. Strength, silicon content, temper, casting structure and coating alter their response. Many aluminium, copper and brass alloys are comparatively soft, while aluminium with higher silicon content can be abrasive. [S019]

Likely process observations

- rapid loading, smearing and surface transfer on unsuitable abrasives;
- burrs and feathered edges from ductile displacement;
- embedded coarse particles producing conspicuous scratches;
- local heat affecting thin sections, coatings or temper-sensitive parts; and
- fine aluminium dust creating a combustible-metal hazard under relevant conditions. [S020]

Control response

Use only abrasives, extraction and cleaning methods approved for the alloy and operation. Separate aluminium grinding from ferrous dust and contaminated tools. Do not assume “non-sparking” means no fire hazard. Assess combustible dust, thermic-reaction, hot-work and waste issues through the workplace risk assessment.

Cast iron

Cast iron behaviour depends on graphite form, matrix and hardness. Grey, ductile, compacted-graphite, malleable, white and austempered irons cannot be treated as one surface. Some graphitic irons machine comparatively readily, while hard white or austempered conditions can be substantially more demanding. [S019]

Likely process observations

- short, dusty debris rather than a long ductile burr on many graphitic grades;
- graphite pull-out, edge breakout or matrix smearing;
- hard chilled zones, carbides, casting skin, sand or inclusions causing abrupt changes in cut;
- a dark or apparently smooth surface concealing smeared matrix; and
- rapid flash staining or corrosion on freshly prepared surfaces in some conditions. [S024]

Control response

Confirm cast-iron type and hard spots before selecting the abrasive. Use dust controls suited to the casting and any residual sand or coating. If graphite integrity or metallurgical acceptance matters, process and inspect using the approved metallographic procedure rather than an appearance-only shop finish.

Tool steel and hardened steel

Tool steels may contain hard carbides and may be supplied annealed, pre-hardened, through-hardened, case-hardened or surface treated. Hardened steel requires separate process consideration because hardness increases heat, force and abrasive demand. [S019]

Likely process observations

- slower cut and rapid abrasive wear on hard grades;
- local overheating, temper colour, cracking or grinding burn;

- persistent deep scratches from an overly aggressive first stage;
- difficulty removing the disturbed layer before polishing; and
- orange peel, pitting or other poor finish from unsuitable or excessive polishing in some mould steels. [S023]

Control response

Verify grade, hardness, heat treatment, case depth, surface treatment and final function. Use small, verified refinement steps where high finish is required. Do not polish through a hard layer or use visual gloss as proof that the tool retains its specified hardness and geometry.

Galvanised steel

Galvanised steel is a steel substrate with a zinc coating. Grinding can change both profile and corrosion protection. The American Galvanizers Association advises minimising field fabrication that removes coating and repairing bare areas under the governing specification. [S021]

Likely process observations

- coating removal revealing a different-coloured substrate;
- zinc loading, smearing or debris on the abrasive;
- local thinning around edges and welds;
- an apparently blended area that no longer has the specified coating; and
- dust or fume requiring material-specific exposure controls.

Control response

Identify the galvanising specification, original coating condition, permitted repair area and approved repair method before grinding. Mark the minimum process zone. Inspect both smoothness and remaining or restored coating. Do not accept bare steel because the repair looks cosmetically uniform.

Other non-ferrous metals

“Non-ferrous” includes copper and copper alloys, nickel alloys, titanium, magnesium, zinc and many others. Their behaviour ranges from soft and adhesive to work-hardening, heat-concentrating or combustible. Common machining classifications group aluminium, copper and brass separately from nickel-based heat-resistant alloys and titanium because work hardening, adhesion and heat behaviour differ materially. [S019]

Likely process observations

- copper and some soft alloys may load, smear and form heavy burrs;
- nickel alloys may work harden and retain heat at the cutting zone;
- titanium may gall, concentrate heat and react with unsuitable process conditions;
- magnesium, aluminium and titanium fines can require combustible-metal controls; and
- each alloy can impose different contamination, coolant and surface-cleanliness requirements.

Control response

Never select from the word “non-ferrous” alone. Identify the alloy and service, obtain current manufacturer guidance and determine fire, dust, extraction and cross-contamination controls before the trial.

Coated surfaces

A coated surface is a material system: substrate, preparation layer, primer, conversion coating, plating, paint, thermal spray or other layer may each have a function. Abrasive work can release hazardous constituents, change adhesion, expose the substrate or make the original specification impossible to verify. HSE documentation shows that sanding or grinding chromium-VI-treated surfaces can create inhalation exposure in relevant uses. [S026]

Likely process observations

- coating softening, melting, loading or feathering;
- dust colour or odour that is not a reliable identification method;
- breakthrough at peaks, edges or welds before the full area looks clean;
- loss of corrosion protection, electrical insulation, friction or adhesion function; and
- mixed dust containing coating, corrosion product, substrate and abrasive.

Control response

Stop on every unknown coating. Obtain the coating specification, safety data and removal or repair procedure. Define whether the task is cleaning, keying, stripping, feathering or defect repair. Control exposure and waste under the Malaysian chemical framework. [S009; S017] Inspect the required remaining profile, clean boundary and restored coating—not only appearance.

Composite materials

Composites combine a matrix with fibres, particles, cores, skins, adhesives or coatings. Glass-fibre, carbon-fibre and aramid systems respond differently, and thermoset and thermoplastic matrices behave differently under heat. NIOSH testing demonstrates that sanding carbon-fibre-reinforced nanocomposites can release fibres and particles; the measured emission depends on the tested panel and process. [S022]

Likely process observations

- resin heating, glazing, melting or smearing;
- fibre fraying, pull-out, delamination or exposed core;
- dust with fibre, resin, filler and coating constituents;
- electrical or equipment contamination from conductive carbon-fibre dust; and
- a smooth surface concealing subsurface delamination or heat damage.

Control response

Process composites only under a material-specific procedure. Verify lay-up, fibre and resin system, thickness, repair limits, dust capture, cleaning and inspection method. Use the approved cutting or sanding product and support. Stop on discolouration, odour, softening, fibre breakout, delamination or uncertain dust control.

4. The product-selection logic

Product selection is an engineering match between the verified material system and the required operation. It is not a lookup from one material name.

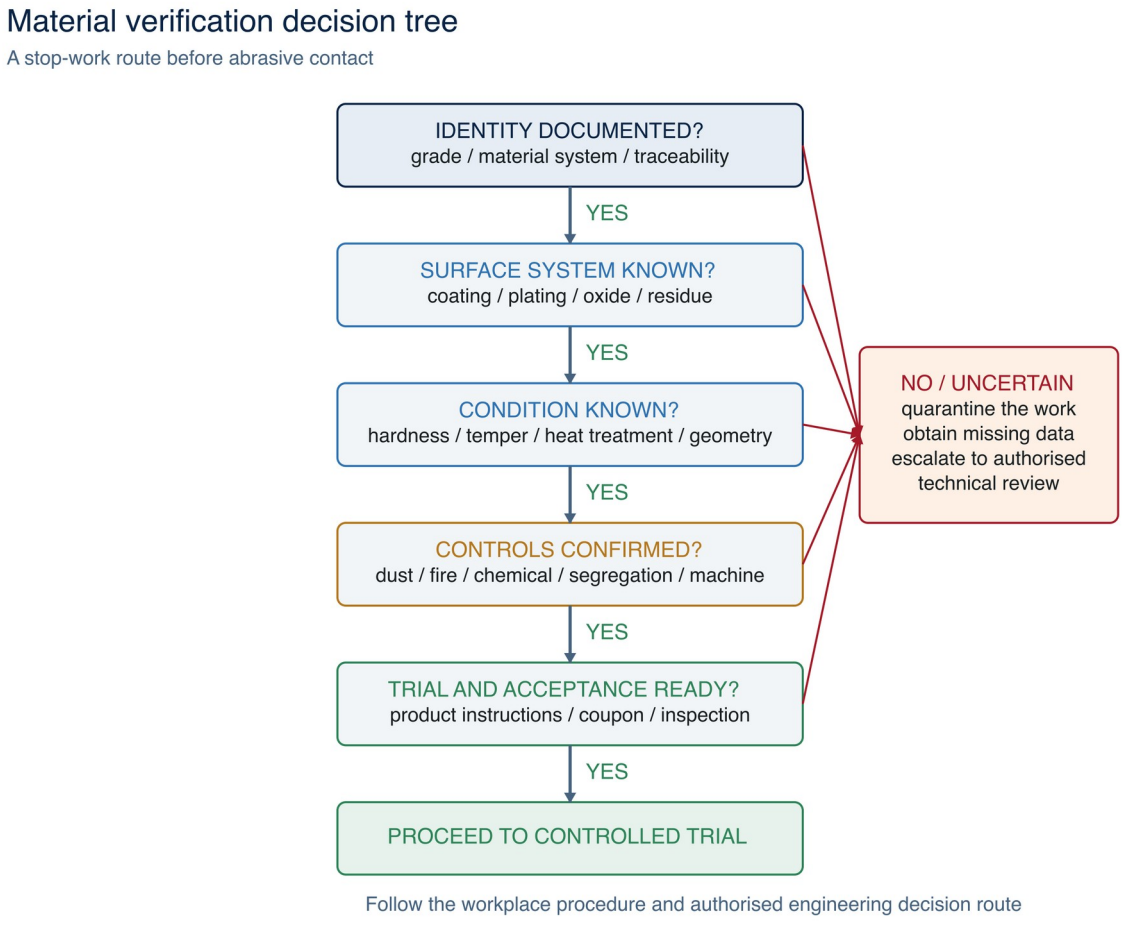


Figure 2. Pre-contact decision route. Resolve material identity, surface condition, compatibility and process controls before abrasive contact.

Step 1 — Verify identity and condition

Confirm grade, hardness or temper, coating, manufacturing route, initial surface and prior repair. Resolve conflicts between marking, certificate, drawing and physical condition.

Step 2 — Define the required change

Separate stock removal, weld reduction, burr removal, coating preparation, scratch refinement and final finishing. Each has a different removal rate, contact geometry and acceptance method.

Step 3 — Identify the dominant failure risks

Select from heat, work hardening, loading, smearing, burrs, edge breakout, contamination, coating loss, dust, fire, distortion, grinding burn and appearance mismatch. Rank the risks for the actual component.

Step 4 — Verify machine and product compatibility

Use the current machine and abrasive instructions. Confirm dimensions, mounting, guard, permitted use, maximum rated speed, support, direction and condition. [S007; S018] Product-specific operating speed, angle, force, lubrication and replacement rules must come from the identified current data—not this chapter.

Step 5 — Establish a controlled trial

Use a representative coupon or approved non-critical zone where possible. Record material, product, machine, speed setting, contact method, time, wear, loading, temperature-control observations, scratch result, burr and cleaning outcome. Change one meaningful variable at a time.

Step 6 — Inspect against function

Compare geometry, finish, coating, cleanliness and material condition with the controlled requirement. A faster cut is not an improvement if it creates a deeper scratch, wider heat-affected zone, coating breakthrough, contamination or rework.

5. Cutting speed is controlled, not guessed

Surface speed influences cutting action, heat, wear, loading and finish, but the safe and effective range depends on the product, machine, diameter, material and operation. There is no universal “steel speed,” “aluminium speed” or “stainless speed.”

The operator must distinguish three different limits:

- the machine's available and selected speed;
- the abrasive product's maximum permitted speed and application range; and
- the validated process setting for the verified material and required result.

Never treat the maximum rated speed as the recommended process speed, and never exceed it. Set the machine only within the declared range for the complete machine-product combination. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

6. Appearance is evidence only when the criterion defines it

Materials create different visual signals: steel sparks, stainless heat tint, aluminium drag marks, cast-iron darkening, zinc breakthrough, coating feather edges and composite fibre exposure. These signals help diagnosis but do not by themselves prove acceptance.

Visible observation	Possible meaning	Required confirmation
Cut rate falls while force rises	Loading, glazing, work-hardened skin or harder local structure	Inspect product and surface; verify material condition and product suitability
Surface becomes shiny but lines remain	Smearing or polishing over a deeper scratch	Clean and inspect under directional light; verify previous pattern removal
Blue, straw or dark colour on metal	Oxide or thermal effect	Material-specific acceptance; do not infer a universal temperature
Dark cast-iron surface	Graphite, smear, oxide or debris	Clean and use approved magnification or metallographic method if required
Bright steel visible through zinc or paint	Coating breakthrough	Measure or inspect against coating-repair specification
Frayed or pale composite edge	Fibre breakout, resin removal or delamination	Stop and use approved composite inspection method

7. Contamination-control minimum

- identify and segregate tools, abrasives, compounds, brushes and wipes where the procedure requires it;
- clean workholding, benches and extraction systems before contamination-sensitive work;
- prevent ferrous dust entering aluminium or combustible-metal collection routes;
- prevent carbon-steel particles embedding in stainless surfaces;
- prevent coarse abrasive or polishing compound carrying into a finer stage;
- label material-specific consumables and quarantine any whose history is uncertain; and
- record cleaning and segregation checks on the process traveller.

8. Illustrative factory example

Application example — material identity controls selection. A fabrication cell receives three visually similar parts: low-carbon steel, austenitic stainless steel and aluminium alloy. Each requires removal of a small weld transition and a uniform directional finish.

The team does not apply one disc and one speed to all three. It first confirms identity and finish criteria. The steel route focuses on burr, geometry and scale; the stainless route adds heat-tint and iron-contamination controls; the aluminium route uses a material-approved product and segregated dust-control route because loading, smearing and combustible dust are credible concerns. Each route is trialled and recorded separately. The final finishes may look similarly uniform, but the control evidence is different.

9. Pre-process material checklist

- [ ] Workpiece identity agrees with the drawing, certificate or approved identification method.
- [ ] Grade, condition, thickness and critical dimensions are recorded.
- [ ] Heat treatment, hardness, temper or cold work is known where relevant.
- [ ] Coating, plating, oxide, paint, cladding or residue is identified.
- [ ] Required geometry, texture, roughness, gloss, coating and corrosion condition are defined.
- [ ] Dust, fire, chemical, noise, vibration and waste controls are approved.
- [ ] Contamination segregation and cleaning controls are ready.
- [ ] Machine, guard, mounting and abrasive rated-speed compatibility are verified.
- [ ] Product application instructions cover the material and operation.
- [ ] A representative trial and inspection method are authorised.
- [ ] Stop conditions and technical escalation contact are known.

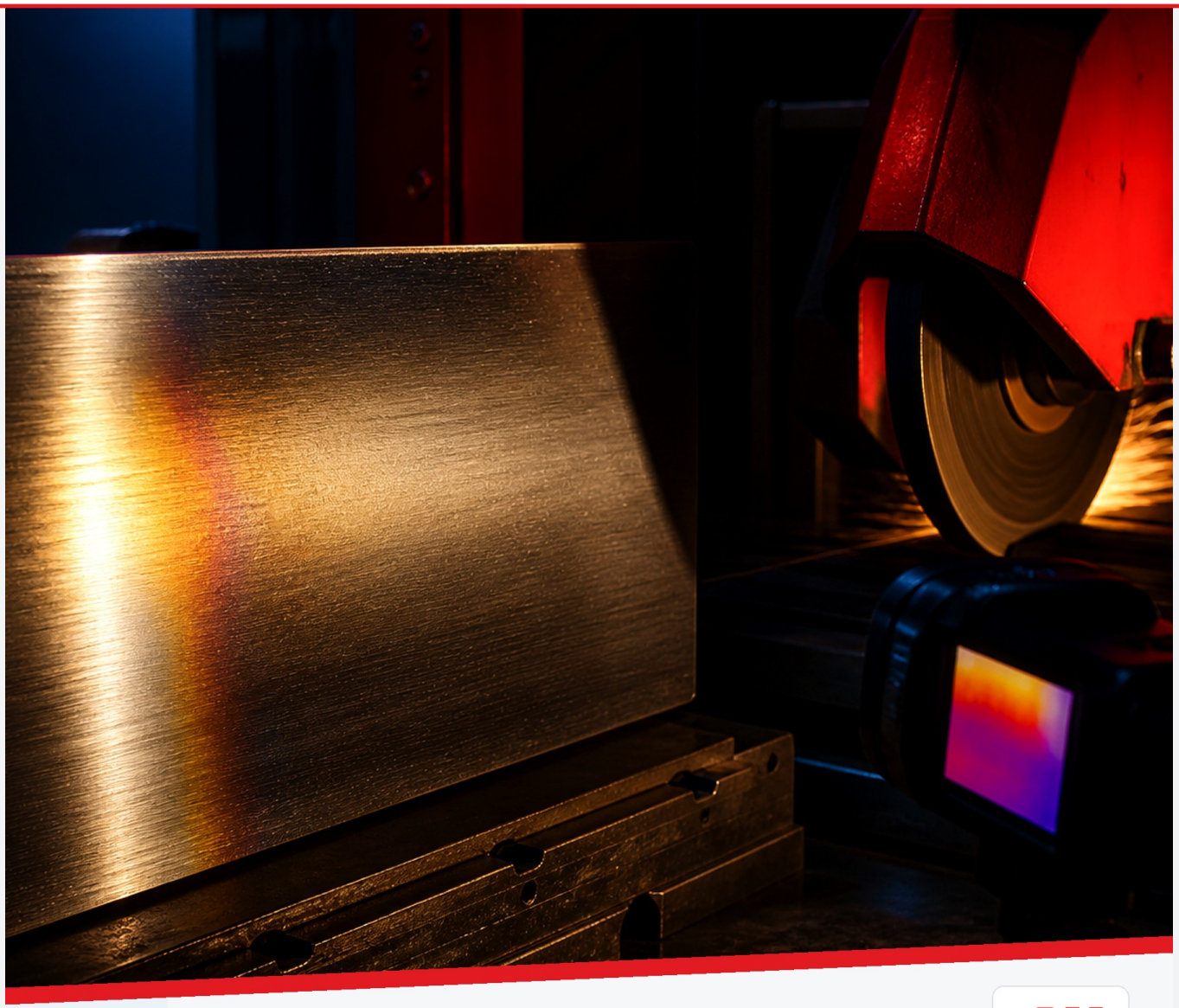
10. Applying product information to the material

Confirm the exact abrasive declaration against the verified material, coating, hardness or heat-treatment condition and the intended operation. Check machine compatibility, working method, permitted coolant or lubricant use, and any special handling or extraction requirements before use.

Compare candidate products on representative work using consistent geometry, contact method and inspection. Judge the complete result: removal, heat, loading, edge condition, dimensional control, surface finish and downstream suitability. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Source-code key

Every [Sxxx] citation in this chapter resolves in the **Complete source index** at the end of the handbook. Source codes identify the publication supporting the stated principle and do not create an MKTECH product specification.



ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 004

Stainless-Steel Behaviour During Grinding

04

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: Stainless-steel behaviour during cutting, grinding, blending and finishing. This chapter explains control logic but does not establish an MKTECH product sequence, universal grit, operating speed, pressure, angle or chemical procedure.

Safety-critical boundary — Verify the stainless grade, condition, service duty, required finish, contamination controls, machine and abrasive compatibility, dust controls and approved cleaning route before abrasive contact. Stop when the alloy, coating, contamination status, acceptance criterion or chemical procedure is unknown. [S001; S009; S014; S017; S018; S027]

Chapter objectives

After this chapter, the reader should be able to:

- explain the function and limitations of the chromium-rich passive surface;
- recognise how thermal behaviour and work hardening change the grinding response;
- distinguish heat tint, smearing, embedded iron and ordinary surface soil;
- prevent contamination through stainless-only tools, media, storage and work areas;
- define a controlled before-and-after inspection rather than judging by brightness alone; and
- route cleaning, pickling or passivation to an approved procedure.

1. Stainless is a material system, not a cosmetic finish

Stainless steel is corrosion resistant because alloying and a clean, oxygen-exposed surface support a thin chromium-rich passive film. The film is not paint, and it is not immune to damage. Heat tint, embedded iron, scale, chloride-bearing deposits, unsuitable chemicals, rough damaged areas and poor cleaning can interfere with the intended surface condition. Worldstainless and BSSA both emphasise cleanliness and the continuous passive condition. [S001; S016; S027]

Grinding can change several things at once: geometry, roughness, scratch direction, residual contamination, oxide condition and local strain. A bright surface may therefore be visually improved but technically unacceptable. The operator must know which function is being restored: dimension, weld profile, directional finish, cleanability, passive-surface readiness or appearance.

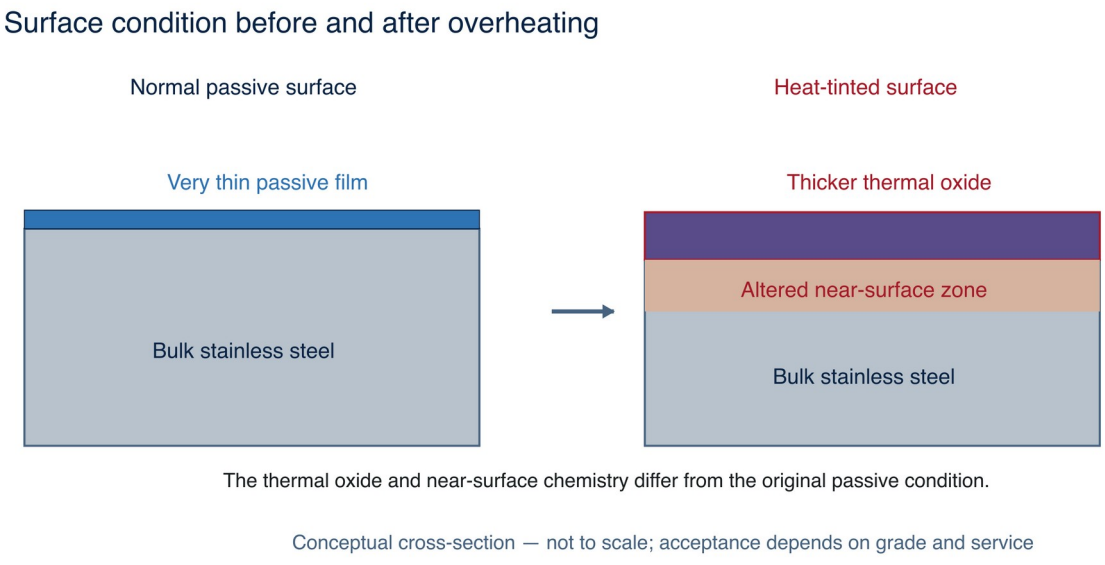

Figure 1. Heat-tint surface response. The schematic separates the visible surface oxide from the affected near-surface region beneath it.

Minimum job record

- verified grade and product form;
- heat-treatment or cold-worked condition where relevant;
- thickness, geometry, weld condition and distortion limit;
- service environment and corrosion-critical zones;
- required finish, direction, comparator and measurable criterion;
- permitted cleaning, pickling, passivation and rinsing route;
- stainless-only zoning, tools, extraction and handling controls; and
- inspection and release authority.

If these inputs are incomplete, quarantine the work or establish an authorised trial on a representative coupon. Do not invent a finish from a grit number or a product name.

2. Why stainless behaves differently under an abrasive

Thermal conductivity and local heat

Many common austenitic stainless grades conduct heat less readily than carbon steel and can expand more for a given temperature rise. Grade-specific Outokumpu data show these differences, but the magnitude varies by alloy and temperature. [S003] During grinding, local heat is also controlled by product sharpness, loading, contact area, speed, force, dwell, support, thickness and cooling. A thin sheet, edge or weld transition can heat and distort rapidly even when the surrounding component remains cool.

The operator should watch the trend: falling cut rate, rising force, increased drag, concentrated tint, softened backing, waviness or loss of flatness. These signs trigger inspection; they are not temperature measurements.

Work hardening

Austenitic stainless steels are characterised by strong work hardening. [S003] When an abrasive cuts cleanly, it removes material. When it rubs, ploughs or dwells, it can deform the surface and leave the next pass confronting a harder local layer. The usual reaction—more pressure—can increase rubbing, heat and distortion.

Work hardening is not the only explanation for a difficult cut. A loaded or glazed abrasive, hard weld deposit, scale, local cold work, loss of support or an incorrect product can look similar. Stop and inspect both abrasive and workpiece before changing settings.

Smearing and surface transfer

Ductile stainless can smear when the action displaces and drags metal instead of removing it cleanly. Smearing may brighten the surface while retaining a deeper scratch or folded material. Loaded media, polishing compound, adhesive residue and transferred metal can add streaks that resemble base-metal defects.

Use clean directional light. Clean the surface by an approved non-damaging method, inspect across and along the lay, and use magnification or another specified method where function demands it. Brightness alone is never closure evidence.

Distortion and edge loss

Thermal expansion, residual stress, thin geometry and one-sided removal can produce bowing, oil-canning, edge draw or local waviness. Excessive grinding can also thin a weld, flatten a designed radius or change a sealing face. Check geometry during the job, not only after the surface looks uniform.

3. Heat tint: evidence of an oxide change

Heat tint forms when heating changes the oxide on the stainless surface. Colour depends on oxide thickness and optical interference, but it also depends on grade, atmosphere, surface condition and time-temperature history. Research and industry guidance link heat-tint oxides and the chromium-depleted region beneath them with reduced local corrosion resistance. [S001; S002; S011; S012]

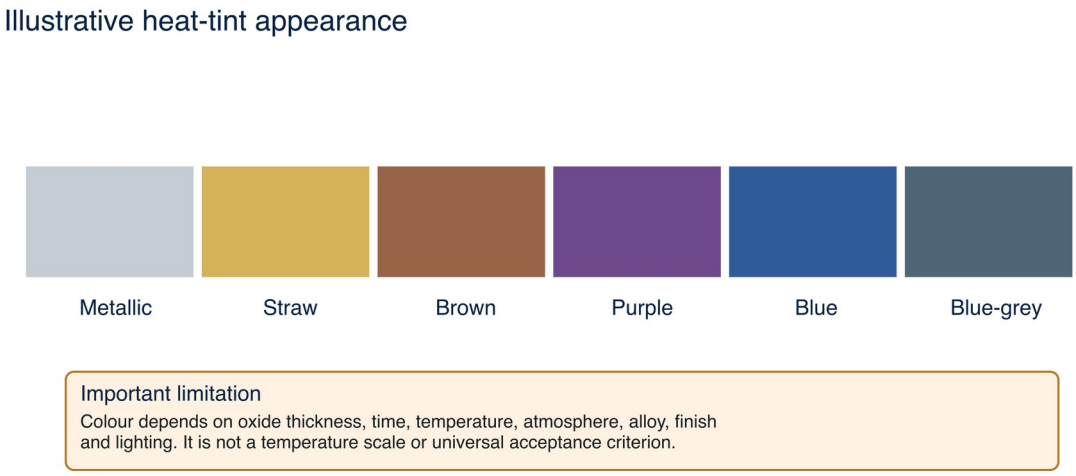

Figure 2. Illustrative heat-tint colour progression. Colour is a visual indicator; evaluate acceptance against the material, service condition and applicable specification.

What colour can and cannot tell you

Colour can locate a thermally affected area and help compare a process trial. It cannot, by itself:

- identify the stainless grade;
- state a universal peak temperature;
- prove the depth or chemistry of the affected region;
- prove corrosion resistance after removal; or
- define how much material must be removed.

Grinding response to heat tint

The visible oxide may cut differently from the base metal. Aggressive local removal can erase colour while creating a low spot, deeper scratch pattern or another hot zone. A finer brightening stage can hide rather than remove the preceding damage. The controlled route is to define the required oxide-removal and corrosion-restoration method, remove only within the geometry allowance, and verify the complete surface condition.

Worldstainless describes pickling as removing a thin metal layer and passivation as improving the passive layer; both are controlled chemical treatments, not interchangeable workshop cleaning labels. [S001; S016] This handbook intentionally gives no acid recipe, concentration, dwell time or neutralisation instruction. Current product data, SDS, Malaysian chemical controls and an approved procedure are mandatory. [S009; S017]

4. Embedded iron contamination

Iron contamination is foreign ferrous material on or embedded in stainless steel. BSSA identifies non-stainless processing equipment, mixed-metal tools, handling equipment, cutting debris and grinding dust as common pathways. When contamination becomes wet, rust staining can appear. [S027]

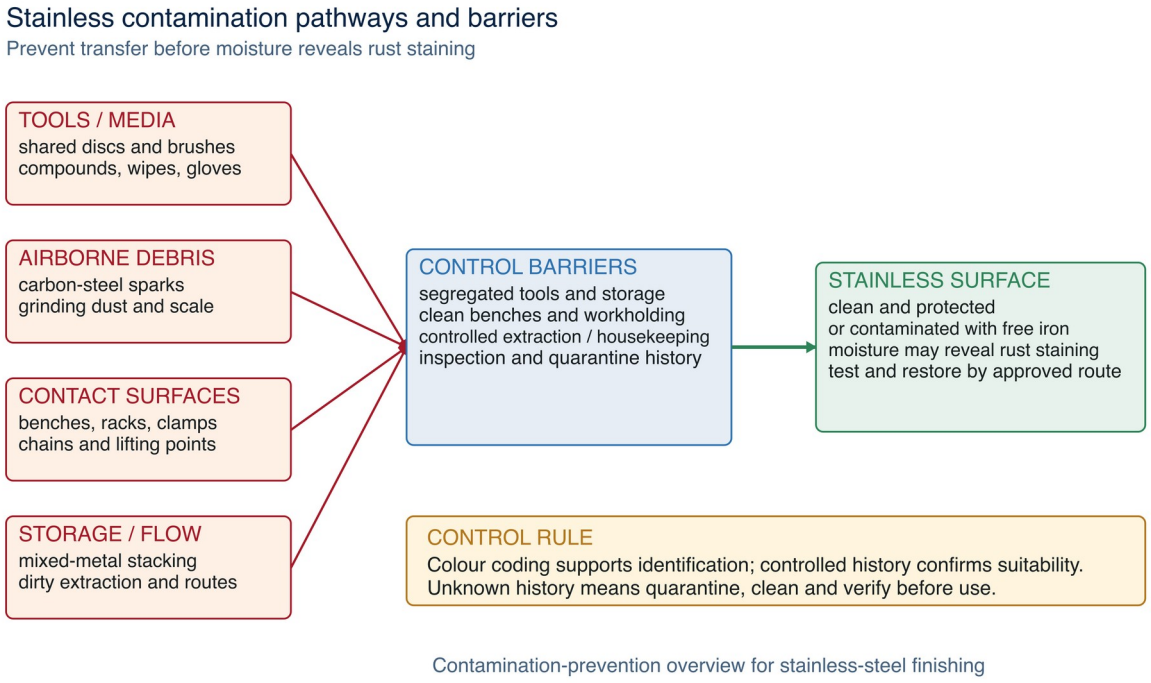

Figure 3. Contamination-prevention map. Multiple contamination pathways can converge on the same surface, so segregation, handling and cleaning controls must operate as a system.

Typical contamination examples

- a flap disc previously used on carbon steel is moved to a stainless job;
- carbon-steel grinding sparks or dust settle on stored stainless sheet;
- a stainless component is placed on a dirty steel bench or rack;
- a carbon-steel wire brush is used to clean a stainless weld;
- shared clamps, chains or fork surfaces leave contact marks;
- contaminated polishing compound, wipes or extraction debris are carried into a final stage; or
- clean parts are stored beneath active carbon-steel fabrication.

These are preventable process failures. A stain is the visible effect; embedded or deposited iron is the cause. Removing only the brown colour without controlling the source allows recurrence.

Stainless-only means controlled history

A “stainless-only” label is credible only when the history is controlled. The system should include:

- dedicated or validated-clean tools, abrasives, brushes, compounds and wipes;
- physically separated, identified storage;
- clean benches, workholding, lifting equipment and protective surfaces;
- extraction and housekeeping that prevent carbon-steel dust migration;
- gloves and handling practices that do not transfer debris;
- inspection before use and quarantine of uncertain items; and
- records linking tools and consumables to the permitted material route.

Colour coding helps identification but does not remove contamination. If the history is uncertain, treat the item as contaminated until it is cleaned and accepted under the authorised method.

5. Finish control: grit is an input, not the result

BSSA notes that grinding, polishing, brushing, buffing and a final grit number do not fully define a stainless finish. Pressure, time, feed, wet or dry operation, starting condition and abrasive medium also affect the result; agreed samples may be required. [S028]

Visible observation	Possible interpretation	Required confirmation
Cut rate falls while force rises	Loading, glazing, local work hardening or harder weld region	Inspect abrasive and workpiece; verify product suitability and condition
Blue, straw or dark band	Heat-tint oxide or other thermal effect	Compare with specified removal and corrosion-restoration requirement
Bright surface with lines remaining	Smearing or polishing over a deeper scratch	Clean and inspect under directional light; verify previous pattern removal
Brown specks after moisture exposure	Deposited or embedded ferrous contamination	Use the specified contamination test and trace the source
Wavy reflection or changed edge line	Distortion, thinning or geometry loss	Measure against drawing and process allowance
Uniform colour but inconsistent lay	Mixed contact direction, dwell or media condition	Compare with approved comparator and direction requirement

Scratch direction and matching

Directional finishes require control of lay, overlap, contact support and lighting. A repair that matches from one viewing angle can stand out after installation. Record the approved sample, viewing direction, illumination and protected boundary. Feathering must not widen indefinitely into accepted parent surface.

Before-and-after examples

The following examples show how starting condition and finish direction change the application approach.

- **Weld blend on a visible panel.** Before: raised weld transition, surrounding mill finish protected, no tint outside the controlled zone. After: profile within drawing allowance, preceding scratches removed, lay aligned to the comparator, no new tint, distortion or contamination, and cleaning route completed.
- **Carbon-steel dust exposure.** Before: brown specks after wetting and mixed-metal work nearby. After: contamination source isolated, surface tested and restored under the approved procedure, complete rinse and inspection recorded, and storage controls corrected.
- **Heat-tinted thin sheet.** Before: concentrated blue band and local waviness. After: stop-work investigation completed; geometry and corrosion requirement determine repair or rejection. Colour removal alone is not acceptance.
- **Brushed handrail scratch.** Before: isolated scratch crossing the original lay. After: repair boundary, direction and gloss match the approved comparator without flattening the profile or spreading contamination.

6. Cleaning and surface-restoration flow

Cleaning removes soil; decontamination removes foreign material; pickling removes oxide and a thin metal layer; passivation supports the passive surface. These words must not be used interchangeably. [S001; S016; S027]

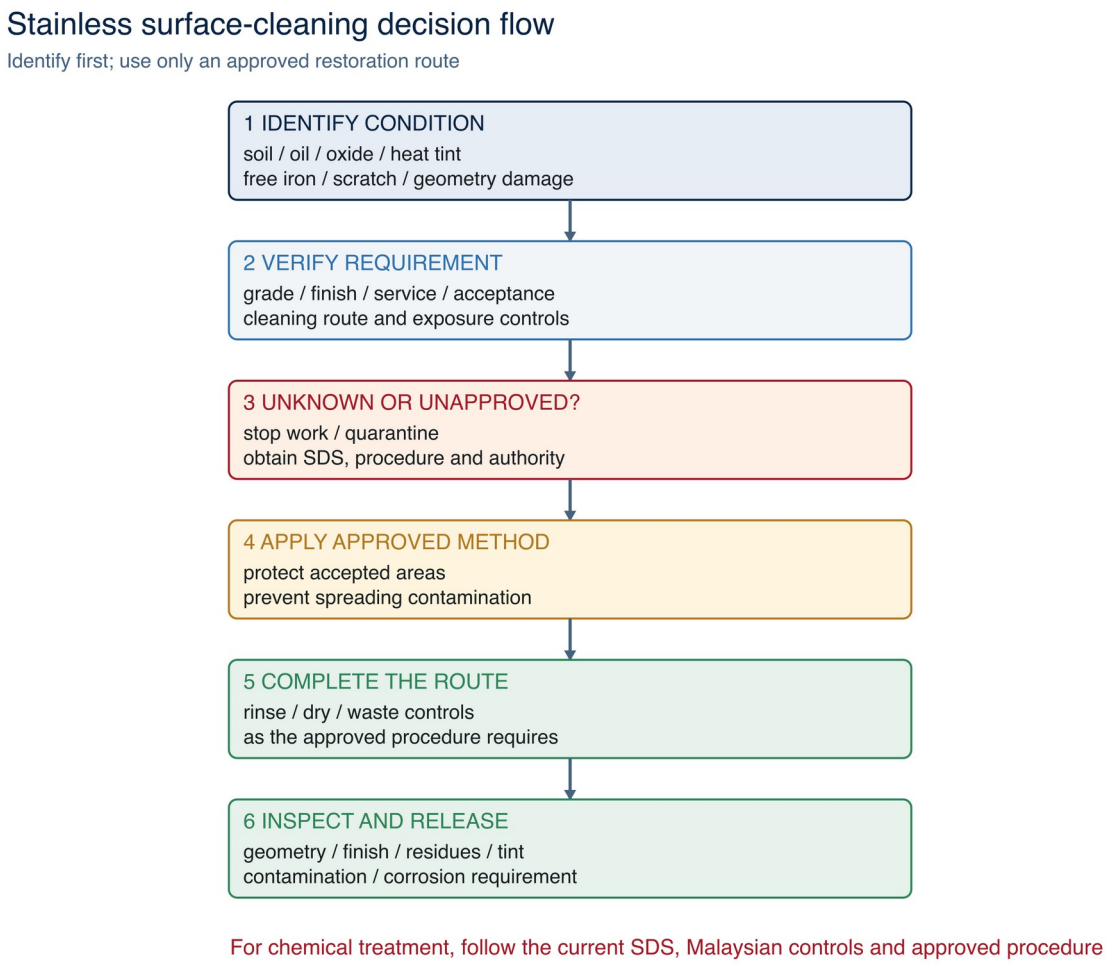

Figure 4. Stainless-surface decision flow. The route separates mechanical cleaning from chemical treatment and directs chemical work to the applicable approved procedure.

Controlled route

44. Identify the soil, oxide, contamination or damage and its likely source.
45. Confirm grade, finish, service duty and acceptance requirement.
46. Stop if the contaminant or coating is unknown or if a chemical route lacks current SDS and approval.
47. Protect accepted surfaces and segregate the work from ferrous debris.
48. Apply the least damaging authorised method that can achieve the specified result.
49. Rinse, dry and manage waste exactly as the approved procedure requires.
50. Inspect geometry, finish, residues, tint and contamination using the specified method.
51. Record acceptance or route the work to rework, engineering review or rejection.

Chemical cleaning can etch or change an appearance, and abrasive cleaning can spread embedded particles or change texture. BSSA advises ensuring contamination is removed rather than redistributed. [S027] The selected method must therefore be evaluated against both corrosion function and visible finish.

7. Process-control checklist

- [ ] Stainless grade, condition and service duty are verified.
- [ ] Required geometry, finish code, lay, comparator and inspection method are available.
- [ ] Weld, heat tint, scale, coating, oil and suspected contamination are identified.
- [ ] Machine, guard, mounting and abrasive rated-speed compatibility are confirmed.
- [ ] Product instructions cover the stainless grade and intended operation.
- [ ] Tools, media, workholding, bench, extraction and storage have controlled stainless-only history.
- [ ] Carbon-steel sparks and dust cannot reach the work or clean consumables.
- [ ] Thin sections, edges and distortion-sensitive zones have defined checks and stop limits.

- [ ] Cleaning, pickling or passivation work has an approved procedure, current SDS and waste controls.
- [ ] A representative trial records product, machine, settings, time, wear, heat, scratches and finish.
- [ ] Final inspection covers geometry, texture, direction, cleanliness, tint, contamination and corrosion requirement.
- [ ] Rework and escalation authority are known before production begins.

8. Practical stainless-steel application guidance

Choose abrasives declared suitable for the stainless grade and operation, and keep them segregated from carbon-steel use. Progress from geometry correction to scratch refinement with the fewest effective stages, inspecting heat tint, distortion, embedded contamination and finish direction separately.

Acceptance depends on the component's service: decorative work, food-contact equipment, pharmaceutical fabrications and corrosion-critical assemblies may require different cleaning, restoration and inspection routes. Chemical treatment must follow its current technical and safety information and the workplace chemical assessment. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Source-code key

Every [Sxxx] citation in this chapter resolves in the **Complete source index** at the end of the handbook. Source codes identify the publication supporting the stated principle and do not create an MKTECH product specification.

ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 005

How Abrasives Remove Material

05

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: The mechanics of abrasive material removal in hand-held and related industrial grinding and finishing. This chapter explains control logic but does not establish an MKTECH product recommendation, universal speed, pressure, angle, removal rate or service-life claim.

Safety-critical boundary — Use an abrasive only for its intended operation and only when its identity, condition, dimensions, maximum operating speed, mounting system, guard, machine compatibility and work-material suitability are verified. Never exceed the abrasive or machine rating. Stop for damage, unknown history, missing instructions, abnormal vibration or an unverified application. [S007; S018; S032]

Chapter objectives

After this chapter, the reader should be able to:

- describe how individual grains rub, plough and cut as engagement changes;
- explain chip formation, side flow and the origin of heat at the contact;
- distinguish grain fracture, bond fracture and useful edge renewal;
- diagnose glazing, loading and ordinary abrasive wear separately;
- relate contact force, contact area and surface speed to the cutting response;
- measure removal rate without ignoring finish, geometry, heat or abrasive consumption; and
- design a controlled trial that identifies a stable process window.

1. An abrasive is a field of small cutting edges

A grinding product is not a single blade. It presents many hard grains to the workpiece. Each active grain has its own protrusion, orientation, edge radius and local support. Only a portion of the visible abrasive surface is carrying useful load at any instant.

In a bonded grinding wheel, abrasive grains are held by a bond and separated by pores. The pores provide clearance for chips and can assist fluid or air movement in processes designed for them. [S029] Coated abrasives place grain on a backing with adhesive layers; flap discs arrange coated abrasive pieces around a hub; nonwoven products hold abrasive in a compliant fibre network. The removal mechanism is related, but the support, chip clearance, wear and failure modes are not identical.

This distinction matters when diagnosing a problem. A hard bonded wheel, a flexible fibre disc and a nonwoven finishing product cannot be corrected by the same generic instruction. Product construction, work material, operation and machine must be identified first.

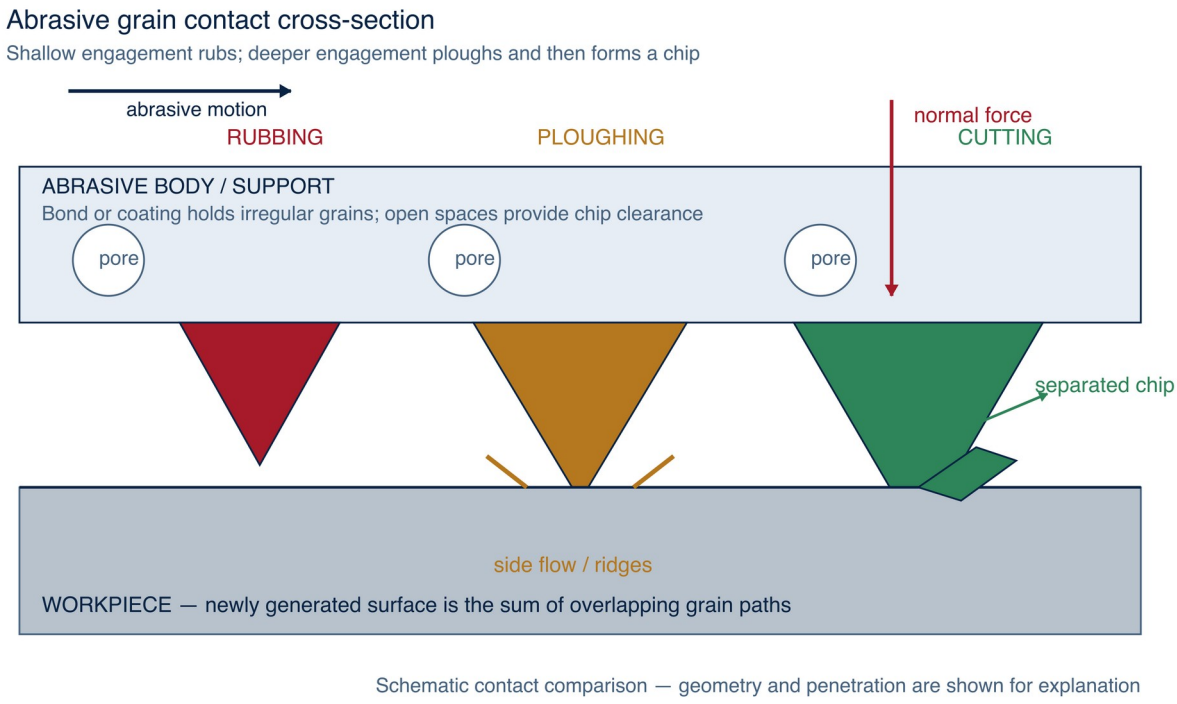

Figure 1. Abrasive contact modes. The schematic compares rubbing, ploughing and chip-forming contact as penetration and cutting efficiency change.

2. Rubbing, ploughing and cutting

Grinding research commonly separates grain–workpiece interaction into rubbing, ploughing and chip-forming cutting. The modes can exist together across one contact zone; they are not three independent machines or a simple switch at one universal depth. [S030; S031]

Rubbing

At very shallow engagement, a rounded or poorly oriented grain slides across the surface without forming a useful chip. Elastic and small plastic deformations occur, friction rises and energy is spent with little volume removed. Rubbing is therefore not “no effect”: it can heat, polish, smear or work the surface while the operator sees a weak cut.

Typical contributors include a dull or capped grain, insufficient engagement for the selected abrasive, excessive support compliance, a loaded face, poor approach geometry, dwelling on a broad contact patch or a product not suited to the material.

Ploughing

With greater engagement, the grain pushes material sideways and ahead. Ridges or pile-up form along the groove. Some material may later be removed by following grains, but the first interaction has displaced more material than it has separated as a chip.

Ploughing consumes force and produces plastic deformation. On ductile material it may create side flow or smearing. On thin, edge-sensitive or finished components, the displaced material and concentrated force can change surface form even before a visible chip stream appears.

Cutting

When engagement and grain geometry permit, material shears and separates as a chip. Cutting converts a larger share of the interaction into useful removal, but it still generates heat and force. The chip must leave the contact without repeatedly welding, clogging clearance spaces or damaging the newly generated surface.

The practical objective is not to eliminate all rubbing and ploughing; a real abrasive contact contains many grain orientations. The objective is to maintain a stable population of effective cutting edges so removal, force, wear and surface condition remain within the approved process window.

3. How a chip forms

Chip formation starts when an active grain penetrates far enough to overcome the work material's resistance to deformation and separation. The local engagement depends on more than a nominal grit size. It is influenced by:

- grain protrusion, shape, sharpness and orientation;
- the number of grains sharing the load;
- contact force and actual contact area;
- abrasive stiffness, backing or bond support;
- surface speed and work motion;
- material hardness, ductility, microstructure and temperature;
- previous scratches, scale, weld condition and local geometry; and
- the ability of the product to clear chips and expose active edges.

The grain first meets a surface that is not perfectly flat. It may touch a high point, slide, indent, create side flow and then form a chip. A following grain encounters the groove and ridges left behind. The final surface is the combined result of many overlapping interactions, not a copy of one ideal groove.

This explains why nominal grit alone cannot predict cut rate or finish. Two products with the same marked grit can differ in grain type, shape, orientation, coating, bond, spacing, backing, flexibility and active-grain density. The workpiece and machine add further variation.

A useful observation rule

When removal falls, do not automatically add force. First inspect whether the abrasive is still presenting open, sharp cutting edges. More force applied to a glazed or loaded surface can increase heat, smearing, wear or damage without restoring efficient chip formation.

4. Grain fracture, bond fracture and self-sharpening

An abrasive edge changes during use. It can wear flat, fracture, become covered by adhered work material, pull out of its support or break away with part of the bond or backing. These changes determine whether the cutting surface renews or deteriorates.

Grain fracture

Grain fracture breaks an abrasive particle and can expose a new sharp edge. Controlled microfracture can be useful when the new edge remains supported. Large or premature fracture can waste abrasive, disturb the finish or create unstable cutting.

Bond fracture or grain release

In a bonded wheel, fracture of the bond or loss of retention can release a dull grain and expose another. The required balance depends on the wheel specification and application. A bond that retains dull grains too long can contribute to glazing; a system that releases grains too readily wears rapidly and may lose form. [S025; S029]

For coated and nonwoven products, edge renewal occurs through different combinations of grain fracture, coating wear, grain loss, flap exposure or fibre breakdown. Use the manufacturer's construction-specific explanation rather than calling every wear event "bond fracture."

Self-sharpening

Self-sharpening is the controlled renewal of useful cutting edges through grain fracture, grain release or exposure of fresh abrasive. Manufacturer claims about self-sharpening apply to identified products and conditions; they are not proof that an abrasive will remain sharp in every material or at every load. [S004; S005]

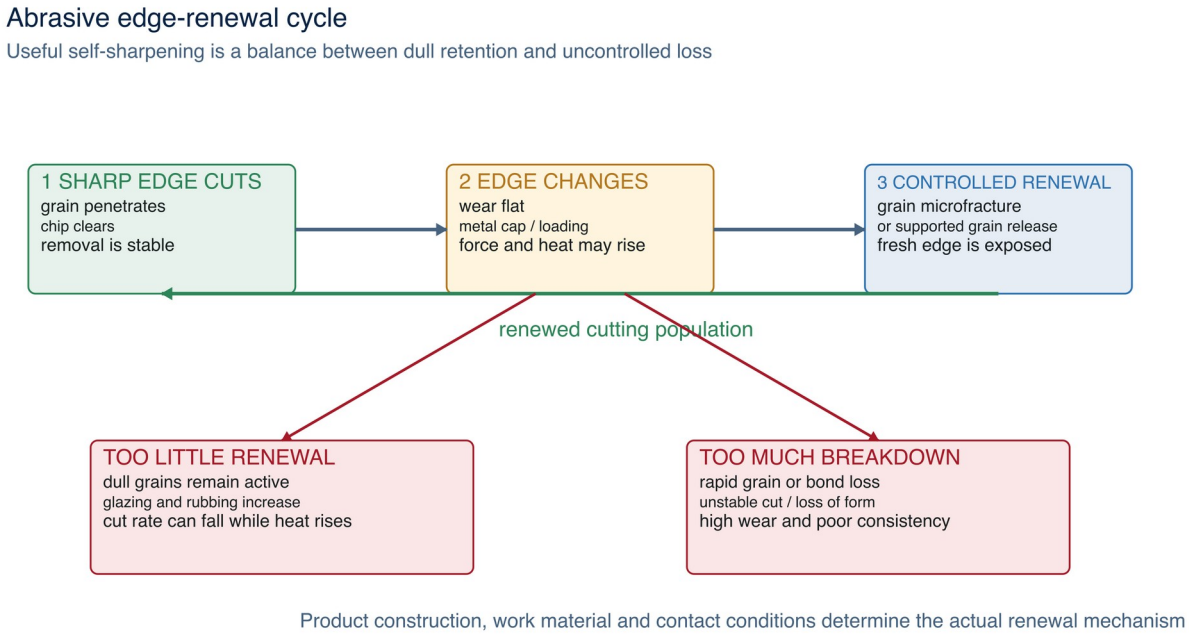

Figure 2. Abrasive edge-renewal cycle. Useful renewal lies between insufficient breakdown and uncontrolled abrasive loss.

5. Glazing, loading and wear are different diagnoses

Glazing and loading can both produce a falling cut rate and rising force, but the corrective logic differs.

Condition	Surface evidence	Confirmation and control
Glazing	Smooth, shiny or flattened abrasive points; cut rate falls	Inspect under suitable light or magnification; compare force and removal trend
Loading	Work material or debris packed between or over grains	Identify the deposit and confirm chip clearance and product/material suitability
Normal wear	Predictable edge and backing or bond consumption	Compare with the validated wear pattern and replacement criterion
Excessive breakdown	Rapid grain loss, edge collapse or loss of form	Stop; inspect mounting, contact, product and work condition
Smearing or capping	Metallic streaks or adhered caps on active areas	Use only an authorised cleaning method; reassess sharpness and chip clearance

Do not “dress,” clean, strike, scrape or otherwise modify an abrasive unless that action is specifically permitted for the product and equipment. A method appropriate for a stationary bonded wheel may be unsafe for a hand-held coated or bonded product.

Diagnostic sequence

- **Stop:** isolate the machine safely.
- **Identify:** verify the product and confirm that inspection or cleaning is permitted.
- **Examine:** inspect the active surface, edge, backing or bond and the workpiece scratch pattern.
- **Compare:** assess removal, force, heat, sound and vibration against the established baseline.
- **Diagnose:** determine whether the dominant issue is glazing, loading, wear, damage, work-material change or machine condition.
- **Correct:** act only through the product instructions and approved process; replace uncertain or damaged abrasive products.

6. Force, contact area and surface speed

Contact force is not the same as pressure at each grain

Operator force is distributed through the product, contact patch and active grains. The same applied force on a narrow edge contact and a broad supported contact produces different local loading. Contact angle, product flexibility, backing, wheel geometry, work shape and surface irregularity all change the real patch.

Increasing force can increase grain penetration and removal while the abrasive continues to cut stably. Beyond the useful range it can overload grains, collapse a flexible backing, widen the contact, increase ploughing and rubbing, accelerate wear, overheat the work or damage the product. [S005; S025; S030]

The controlled variable is therefore not “push harder.” Record the machine, product, contact geometry and an objective force method where the application permits. For hand-held work without force instrumentation, use a validated technique, stable posture and observable process limits rather than a guessed kilogram value.

Surface speed changes the interaction

Surface speed is the linear speed at the abrasive contact. It depends on rotational speed and product diameter. As a product wears and its diameter changes, surface speed can change even if machine rpm remains constant.

Speed influences the number of grain contacts per unit time, load sharing, chip thickness, force, heat, wear and finish. The relationships are not universally linear: a higher permitted speed can distribute load across more contacts, but it can also alter heat generation, backing behaviour or product wear. [S025; S029]

Maximum operating speed is a safety ceiling, not a recommended production target. The selected machine setting must satisfy both the abrasive and machine instructions and remain within the validated application window. [S032]

Motion and dwell

Travel speed, overlap and dwell determine how repeatedly the abrasive visits one location. A process can have the correct machine speed and still overheat or gouge because contact motion is unstable. Record how the tool is moved, not only the dial setting.

7. Where the energy goes

The machine supplies mechanical power. At the contact, energy is spent in chip-forming shear, plastic displacement, friction, abrasive fracture, bond or backing deformation, vibration and other losses. A significant portion becomes heat in the workpiece, chip, abrasive and surrounding air or fluid. [S031]

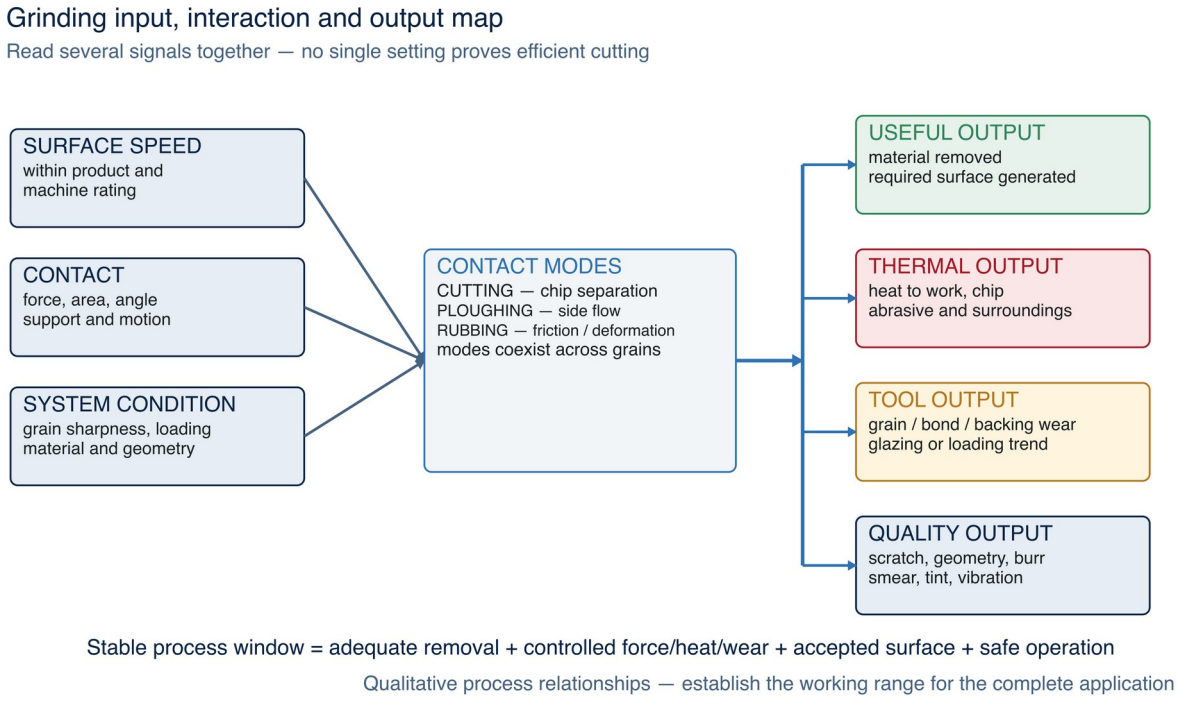

Figure 3. Qualitative process-response map. Read cutting action, heat, loading, wear and surface condition together when establishing the working range.

Heat formation is therefore a process signal, not a single-variable diagnosis. A rising workpiece temperature may accompany dull grains, loading, excessive dwell, a broad or edge-concentrated contact, unsuitable force, poor chip clearance, high removal demand or a material change. The same visible temperature can conceal different causes.

Monitor a useful set of signals together:

- removal per unit time;
- force or a repeatable force proxy;
- workpiece temperature or approved thermal indicator;
- abrasive mass, diameter or other wear measure;
- spark, chip or debris behaviour where safe and relevant;
- scratch pattern, burr, smear, tint and geometry; and
- sound and vibration trend.

8. Material-removal rate without false productivity

Material-removal rate is removed volume divided by grinding time. In a controlled coupon trial, volume can be measured directly or estimated from mass loss divided by verified material density. The measurement method, scale resolution, cleaning method and timing boundary must be recorded.

A high removal rate is not automatically a good process. A trial fails if it achieves fast removal by overheating the work, changing geometry, consuming excessive abrasive, contaminating the surface, creating an unacceptable scratch pattern or exceeding safety and product limits.

Use a balanced trial record:

- starting and final mass or dimensions;
- active grinding time and total cycle time;
- product identity, batch where required and initial/final condition;
- machine identity, rpm setting and measured speed where required;
- contact geometry, tool motion and force-control method;
- material identity, hardness/condition, geometry and starting surface;
- removal rate and abrasive-consumption measure;
- temperature or thermal observation method;
- final surface, dimensional and defect results; and

- stop events, replacements and operator observations.

Controlled comparison rule

Change one planned factor at a time where practical, or use an authorised structured experiment when interactions must be studied. Repeat enough trials to separate a stable trend from operator and material variation. Do not publish a percentage improvement from one unreplicated coupon.

9. Establishing a stable process window

A useful process window is the region in which the abrasive cuts predictably, removal is adequate, force and heat remain controlled, wear is acceptable, and the resulting geometry and surface meet the requirement. It sits inside the safety and product limits; it does not redefine them.

52. Verify the material, starting condition, required removal and acceptance criteria.
53. Verify machine, guard, mounting, abrasive identity, rated speed and intended operation.
54. Choose a conservative manufacturer-supported starting condition.
55. Run a representative coupon or sacrificial-zone trial with recorded motion and contact.
56. Measure removal, time, abrasive wear, heat, geometry and surface condition.
57. Inspect the abrasive for glazing, loading, damage and edge-renewal behaviour.
58. Adjust only one authorised variable or follow the approved experiment plan.
59. Repeat and confirm the result across realistic variation.
60. Define replacement, stop-work and escalation criteria.
61. Release the method only after technical, safety, quality and MKTECH approval.

10. Process-control checklist

- [ ] Material identity, condition, geometry and required result are verified.
- [ ] Abrasive construction, product code, dimensions and intended operation are known.
- [ ] Machine, guard, flange/backing system and rated-speed compatibility are confirmed.
- [ ] The active surface is undamaged and free from unverified modification.
- [ ] Contact geometry and tool motion are defined for the actual product.
- [ ] Removal, force, heat, wear, vibration and surface signals have a baseline.
- [ ] Glazing, loading and normal wear have separate inspection criteria.
- [ ] Product replacement and stop-work limits are established before production.
- [ ] The trial measures removal rate together with geometry and surface acceptance.
- [ ] Dust, spark, fire, noise and exposure controls match the material and process.
- [ ] Results are recorded by product, machine, material and operator technique.
- [ ] Every product or performance statement is supported by the cited technical source or measured application result.

11. Applying removal principles in practice

Select a product whose declared construction and application suit the work material, machine, contact geometry and required output. Maintain a cutting action by using stable contact, controlled travel and only the working face permitted by the product instructions. If removal slows, inspect for loading, glazing, wear, machine-speed loss and poor support before changing force.

Compare products by accepted output rather than removal rate alone. Include finish, heat, geometry, rework, operator exposure and consumable use in the comparison. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 006

Abrasive Grain Types

06

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: Aluminium oxide, zirconia alumina, ceramic alumina, silicon carbide, diamond, cubic boron nitride and abrasive-grain blends. This chapter explains selection logic but does not approve an MKTECH SKU, universal pressure range, speed, removal rate, service life or cost-per-part claim.

Safety-critical boundary — Verify the complete abrasive product, work material, operation, machine, mounting, guard, dimensions, maximum operating speed and current manufacturer instructions before use. Grain name alone never authorises an application. Stop for an unknown product, damaged abrasive, missing marking, incompatible machine or unverified material. [S032; S033]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish hardness, toughness, friability and controlled edge renewal;
- compare the principal conventional and superabrasive grain families;
- explain why a grain that performs well at one load may rub or break down at another;
- separate grain behaviour from bond, backing, coating and product geometry;
- use material family, removal duty, finish and heat sensitivity to shortlist a grain system;
- interpret relative purchase cost without confusing it with total process cost; and
- define a controlled trial before releasing a product recommendation.

1. Grain name is a starting point, not a specification

Abrasive grains are hard cutting particles, but a working abrasive is a system. In a bonded wheel, grain is retained by a bond and separated by pores. In a coated product, grains are fixed to a backing by adhesive layers; a grinding aid or top coating may modify heat, loading or chip behaviour. Superabrasive grains can be held in resin, vitrified or metal bonds, or plated to a metal body. [S029; S033; S037]

The same nominal grain family can therefore produce different results when crystal size, grain shape, grit size, concentration, orientation, bond, spacing, backing, coating or product geometry changes. Machine power, surface speed, contact area, work material and motion then determine how the system is loaded.

Do not convert a grain description into a production instruction. “Ceramic,” for example, does not define one construction or one pressure. “Diamond” does not mean suitable for every hard material. A product code and current technical data are required.

2. Four behaviours to compare

Hardness

Hardness is resistance to indentation or scratching. A grain must be hard enough to penetrate the work, but hardness alone does not predict useful life. A very hard grain can still fracture in an unsuitable way, be pulled from its support, load with work material or react chemically at the grinding interface.

Toughness

Toughness is resistance to fracture. Tough grains tolerate impact and severe contact, which can benefit heavy stock removal. If the load is too light to renew their edges, however, they can wear flat and rub. Toughness is therefore useful only when matched to the product construction and load.

Friability and fracture scale

Friability describes how readily a grain fractures. A friable grain can expose new edges at lower stress, helping on hard or heat-sensitive work. Excessive or large-scale fracture wastes abrasive and can destabilise the finish. Controlled microfracture renews smaller edges; macrofracture removes larger parts of a grain. Real grains do not occupy one fixed point on this spectrum.

Heat behaviour

“Cool cutting” is a system result, not an intrinsic temperature guarantee. Sharp grains can reduce rubbing, but heat also depends on contact, speed, chip clearance, loading, grinding aid, dwell, material and removal demand. Temperature must be verified on the real process.

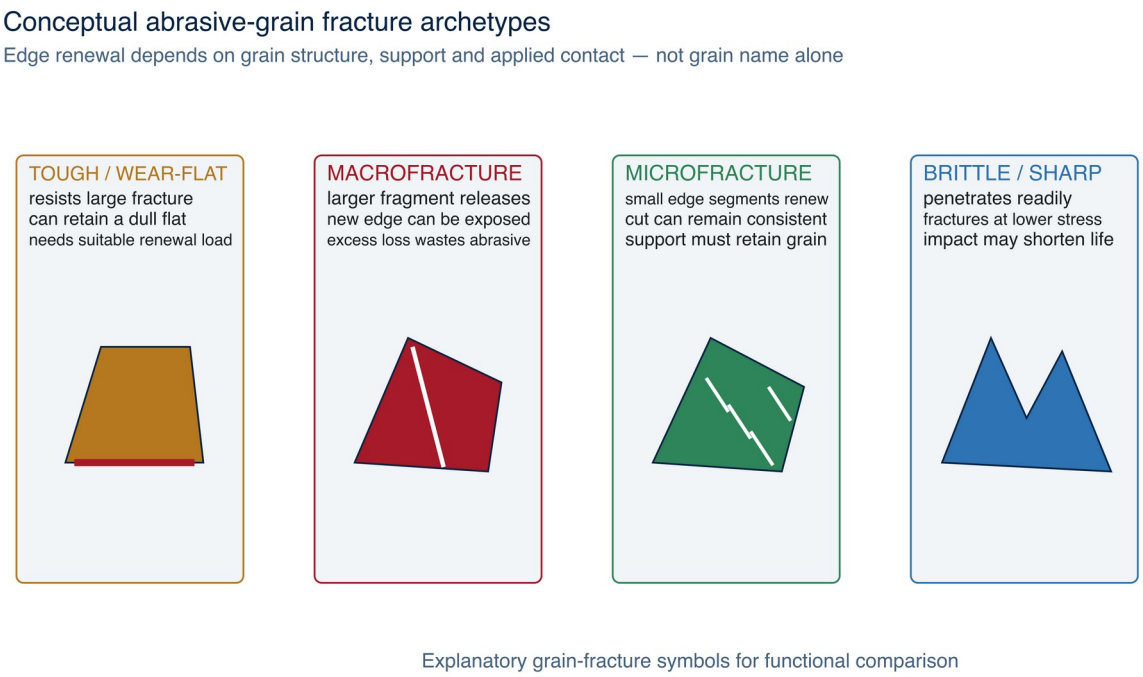

Figure 1. Abrasive-grain fracture archetypes. The explanatory symbols compare edge-renewal behaviour without ranking suppliers.

3. Aluminium oxide

Grain structure and fracture behaviour. Fused aluminium oxide is manufactured in multiple purities and variants. Conventional forms are generally tough enough for broad metalworking use, while more friable alumina variants are available for harder steels and different contact conditions. The name “aluminium oxide” therefore covers a family, not one fracture response. [S029; S034]

Cut and heat behaviour. It provides a balanced general-purpose cut. When the selected construction renews properly, it can support predictable grinding and finishing. When dull grains remain in contact or the product loads, rubbing and heat rise.

Suitable materials and qualitative load demand. Common starting applications include carbon and alloy steels, stainless steel, tool steel and other relatively high-tensile materials. Product forms span lower-load finishing to moderate or heavy removal; the grain name alone does not fix the load range.

Applications, limitations, cost and expected performance. Typical uses include general fabrication, weld blending, deburring, dimensioning and surface finishing. Its principal strengths are availability, versatility and relatively low purchase cost. Limitations include lower potential cut persistence than some engineered zirconia or ceramic systems in severe or high-productivity duty. Expected performance is dependable when the product is matched and kept cutting, not premium performance in every application.

4. Zirconia alumina

Grain structure and fracture behaviour. Zirconia alumina is a fused alumina–zirconia abrasive with a fine internal structure. Manufacturer evidence describes a tough grain able to enter the cut and renew by controlled microfracture when stress becomes sufficient. [S035]

Cut and heat behaviour. Its toughness and edge renewal suit aggressive removal. A suitable zirconia system can maintain a strong cut and resist premature grain loss. At insufficient load, a tough grain may not renew efficiently; added force is not an automatic correction because contact and product construction may be wrong.

Suitable materials and qualitative load demand. Common starting points include carbon steel, alloy steel and stainless steel, with some products formulated for nonferrous, titanium or nickel-alloy work. It is generally associated with moderate-to-higher load and stock-removal duty, although manufacturer-specific products can be designed for lower-load work. [S034–S036]

Applications, limitations, cost and expected performance. Weld grinding, edge preparation, heavy blending and robust belt or disc work are common. Relative purchase cost is normally above conventional aluminium oxide and below many premium ceramic or superabrasive systems. Expected benefits are good stock removal, toughness and usable life in demanding contact. Limitations are weak renewal under the wrong load, possible loading on unsuitable materials and the need for a backing and bond strong enough to exploit the grain.

5. Ceramic alumina

Grain structure and fracture behaviour. Ceramic alumina is a microcrystalline form of aluminium oxide engineered for controlled small-scale fracture. Manufacturer guidance describes a hard, sharp grain whose microcrystalline structure renews cutting edges. [S034]

Cut and heat behaviour. Sustained sharpness can reduce rubbing and support a cooler cutting response than a dull conventional system. This is conditional: a ceramic product can still overheat a workpiece if it is loaded, misapplied, dwelled, over-forced or used outside its intended speed and contact.

Suitable materials and qualitative load demand. Common applications include hardened steels, stainless steels, tool steels, nickel-based alloys and other difficult-to-grind metals. Ceramic products may be engineered for moderate or high load; some shaped-grain and blend constructions are designed to cut at lower force. Only the specific product data can establish the intended range.

Applications, limitations, cost and expected performance. Typical uses include high-productivity weld removal, precision grinding and difficult-alloy work. Relative purchase cost is high among conventional abrasives, but productive life and cycle time may change total cost. Expected performance is a persistent cut and controlled renewal when the system is correctly loaded. Limitations include higher initial price, potential premature breakdown or finish change if mismatched, and wide variation among “ceramic” products.

6. Silicon carbide

Grain structure and fracture behaviour. Silicon carbide is harder and generally sharper but more brittle than conventional aluminium oxide. It fractures readily, exposing edges but potentially consuming grain quickly under impact or severe steel-grinding duty. [S029; S034]

Cut and heat behaviour. Its sharp penetration can suit materials that resist cutting by conventional alumina or that tend to smear. The same brittleness that assists renewal can shorten life in heavy, interrupted or high-impact contact.

Suitable materials and qualitative load demand. Common starting applications include aluminium and other nonferrous metals, cast iron, glass, stone, ceramics, some composites and cemented carbide. The required load is often lower-to-moderate for brittle or heat-sensitive work, but bonded products for carbide and mineral processing follow their own manufacturer-defined conditions.

Applications, limitations, cost and expected performance. Deburring nonferrous castings, grinding cast iron, finishing mineral or ceramic materials and working cemented carbide are typical examples. Relative purchase cost is generally low-to-moderate. Expected performance is a sharp, free-cutting action on compatible material. Limitations include brittle breakdown in severe duty, possible loading without suitable product structure and poor general suitability for heavy steel removal compared with tougher alumina systems.

7. Diamond

Grain structure and fracture behaviour. Diamond is the hardest common abrasive grain. Synthetic diamond is produced in grades with different crystal shape, strength and friability. Its hardness and wear resistance can provide long life on compatible hard, brittle or abrasive materials.

Cut and heat behaviour. Diamond conducts heat well, but the complete wheel or tool governs heat removal. At grinding temperatures diamond can react with iron; specialist manufacturer guidance therefore treats it as generally unsuitable for iron-based materials and uses CBN for many ferrous applications. [S037]

Suitable materials and qualitative load demand. Typical material families include cemented carbide, ceramics, glass, quartz, stone, ferrite, silicon, composites and other nonferrous or nonmetallic hard materials. Load may range from controlled precision contact to robust cutting, entirely dependent on bond, grain concentration, grit and tool design.

Applications, limitations, cost and expected performance. Carbide-tool grinding, ceramic and glass processing, composite trimming and precision nonferrous work are common. Purchase cost is very high relative to conventional grain, but long life, accuracy or reduced dressing may justify it. Limitations include iron reactivity, bond-specific dressing and cooling needs, sensitivity to impact in some constructions and the need for specialist machine capability.

8. Cubic boron nitride

Grain structure and fracture behaviour. Cubic boron nitride, or CBN, is a synthetic superabrasive with hardness second to diamond. Available grain grades and bond systems vary in toughness, friability, heat transfer, retention and dressability. [S037]

Cut and heat behaviour. CBN has higher thermal stability than diamond and is less reactive with iron. Those characteristics support sustained precision grinding of many hardened ferrous materials. The work can still burn if wheel specification, coolant, dressing, contact or process energy is wrong.

Suitable materials and qualitative load demand. Common starting applications include hardened carbon and alloy steels, high-speed steel, tool and die steel, bearing steel and selected heat-resistant alloys. ASSAB specifically identifies CBN for hardened high-carbide tool steel and high-speed steel. [S038] Load varies greatly by resin, vitrified, metal or plated construction.

Applications, limitations, cost and expected performance. Precision external, internal, surface and form grinding of hardened ferrous components are common. Purchase cost is very high, often above diamond according to specialist guidance, while wear resistance and shape retention can improve process economics. [S037] Limitations include high capital and dressing requirements, dependence on machine stiffness and coolant strategy, and poor justification where a conventional abrasive already meets cost and quality requirements.

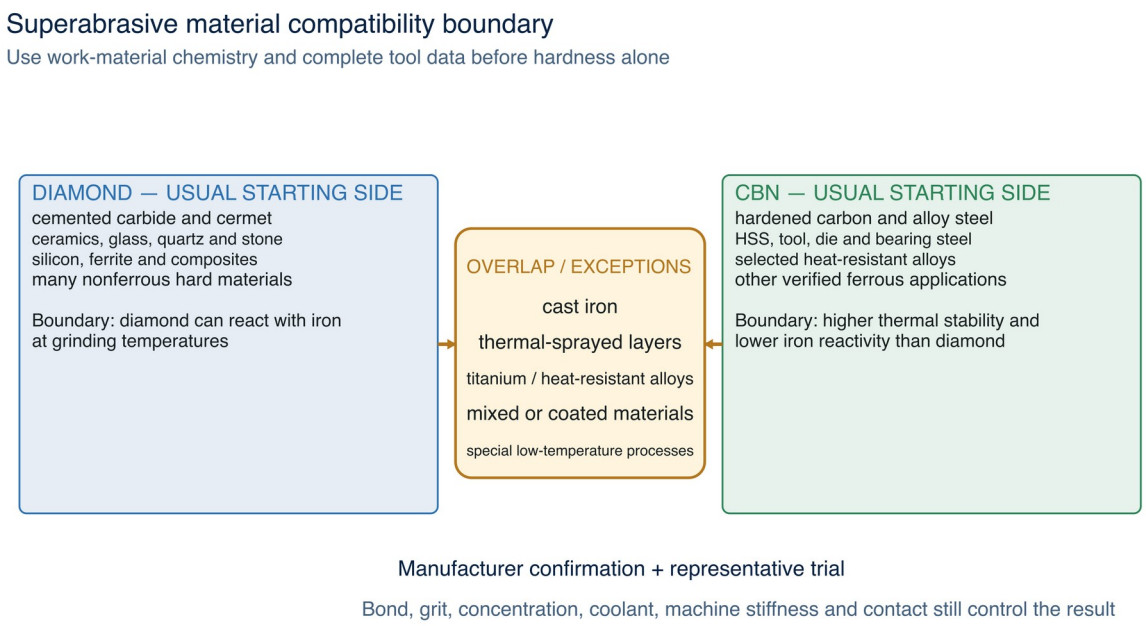

Figure 2. Diamond and CBN material boundary. The qualitative map supports initial screening; confirm material compatibility and the exact product selection with the tool manufacturer.

9. Abrasive-grain blends

A blend combines grain families or grain variants to balance cutting, edge renewal, toughness, finish and cost. Examples include ceramic alumina with zirconia alumina, or zirconia alumina with conventional aluminium oxide. Manufacturer selection guides show that blend composition is tailored to product form, work material and operation; it is not a generic recipe. [S036]

One grain may provide durable stock removal while another renews at lower stress or moderates cost. Yet the blend percentage alone cannot predict the result. Grain placement, grit mix, bond, backing and grinding aid can matter as much as the names on the label.

Treat a blend as its own product specification. Do not infer that a 50/50 verbal description exists, that both grains act independently, or that a blend will outperform either constituent in every test.

10. Controlled comparison

Grain family	General behaviour	Common starting material families	Qualitative load demand	Relative purchase cost	Main limitation
Aluminium oxide	Balanced toughness and cut; many variants	Steels, stainless, tool steel; selected alloys	Low to high, product-dependent	Low	Broad name hides major construction differences
Zirconia alumina	Tough, stress-assisted microfracture	Steels, stainless; selected alloys	Usually moderate to high	Medium	Can rub if the product is under-loaded
Ceramic alumina	Microcrystalline controlled renewal	Hardened steels, stainless, difficult alloys	Moderate to high; some low-force designs	High	Premium grain still depends on full product design
Silicon carbide	Very hard, sharp and relatively brittle	Nonferrous metals, cast iron, glass, stone, carbide	Usually low to moderate	Low–medium	Rapid breakdown in severe or impact-heavy steel duty
Diamond	Extreme hardness and wear resistance	Carbide, ceramics, glass, stone, composites, nonferrous	Product-dependent	Very high	Generally unsuitable for iron-based grinding at heat
CBN	Superhard, thermally stable, iron-compatible	Hardened ferrous steels and selected heat-resistant alloys	Product-dependent	Very high	Specialist machine, bond, dressing and economics
Blend	Tuned compromise among renewal, toughness and cost	Defined by the complete product	Product-dependent	Medium–high	Blend name or percentage does not prove performance

“Low,” “moderate” and “high” are comparison words, not force values. Actual force depends on product construction, machine, contact patch, material, condition and manufacturer data.

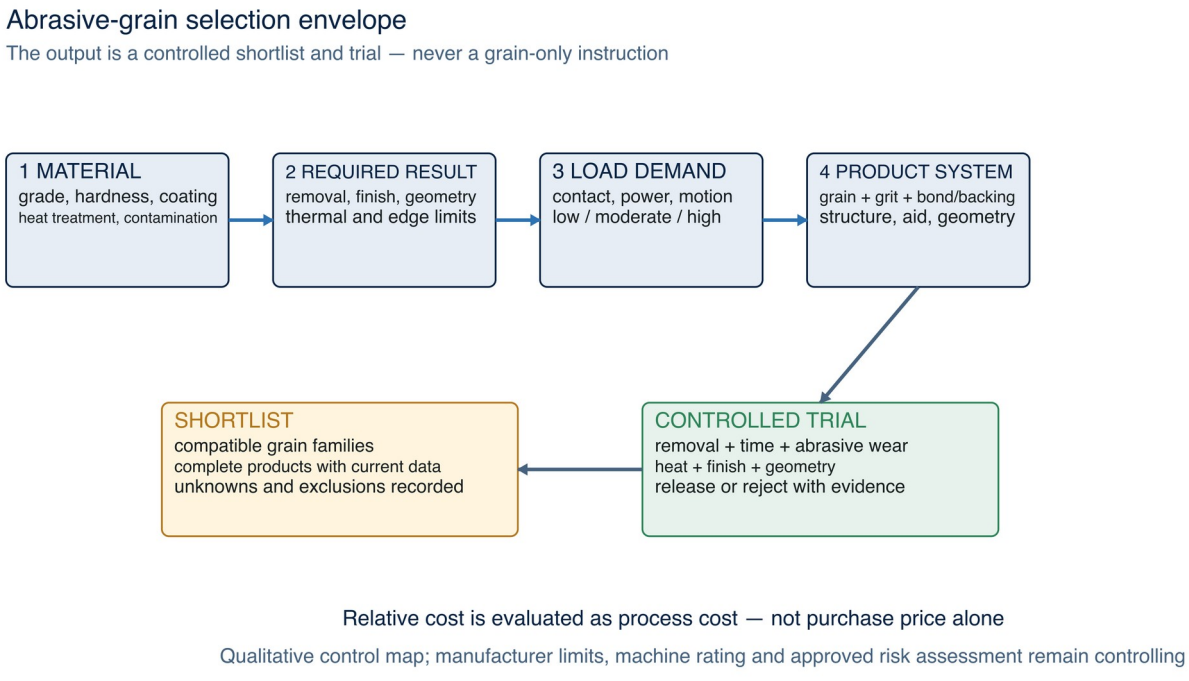

Figure 3. Superabrasive selection envelope. Verify work material, operation, machine, coolant, geometry and finish requirements before selecting the exact product and operating method.

11. Grain-selection workflow

62. Verify work-material grade, hardness, coating, heat treatment, geometry and contamination constraints.
63. Define the operation: removal, blending, dimensioning, scratch refinement or precision generation.
64. Define the required surface, dimensional tolerance, thermal limit and allowable edge change.
65. Identify machine type, power, speed range, guarding, mounting, contact area, wet/dry duty and extraction.
66. Shortlist grain families using material compatibility and the expected fracture/load behaviour.
67. Obtain the complete product specification and current manufacturer application data.
68. Reject any product whose identity, rating, mounting or intended operation cannot be verified.
69. Trial on representative material, recording removal, time, force method, temperature, wear, surface and geometry.
70. Compare total process cost, including abrasive use, labour, dressing, rework, downtime and disposal—not purchase price alone.
71. Release only after technical, safety, quality and MKTECH approval, with stop and replacement criteria.

12. Applying grain selection in practice

Use grain family as one part of the selection. The backing or wheel structure, bond, coating, grit distribution, product shape and machine interface can change how the same grain family behaves. Confirm that the exact product is declared for the work material and operation.

For difficult-to-grind alloys, hardened materials or heat-sensitive components, compare cutting stability, loading, heat, edge retention and finish on representative work. Do not assume that products with the same grain name are interchangeable. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 007

Grit Size and Scratch Depth

07

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: Coarse, medium, fine and micro-finishing abrasive stages; FEPA P-grades; grit progression; scratch formation, removal and inspection. This chapter does not approve an MKTECH SKU, universal grit sequence, scratch depth, removal allowance, speed, pressure, dwell time or acceptance limit.

Safety-critical boundary — Verify the complete abrasive product, work material, machine, mounting, guard, dimensions, maximum operating speed and current manufacturer instructions before use. Stop for an unknown product, damaged abrasive, missing marking, incompatible machine, unverified coating or unapproved dust control. Grit number alone never authorises an application. [S032]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish functional coarse, medium, fine and micro-finishing stages without treating them as universal numeric bands;
- explain what a FEPA P-grade does and does not specify;
- recognise why equal-looking numbers from different grit systems may not be equivalent;
- describe how grain size, shape, distribution, support and contact affect scratch topography;
- plan a progression in which each stage removes the previous stage's unwanted scratches;
- identify the risks of an excessive grit jump;
- inspect a directional surface using controlled cleaning and changing light direction; and
- release a sequence only after representative trials and defined acceptance checks.

1. A grit number describes a grading system, not the finished surface

Grit designations classify abrasive grain size within a defined standard or manufacturer system. They do not directly state the depth of every scratch, the roughness value of the finished surface or the amount of material that one pass will remove.

A real scratch is created by the grains that actually protrude and engage the workpiece. Grain shape, size distribution, orientation, bond or adhesive, backing compliance, product wear, loading, contact pressure, speed, contact area, motion, lubricant, work-material hardness and pre-existing damage all change the result. A nominally finer product can still leave an isolated deep line if a coarse particle, detached chip or contamination becomes trapped at the interface. [S025; S029]

Therefore, use the complete product identity and its declared grading system. Never compare two labels by number alone.

2. Functional grit stages

The words **coarse**, **medium**, **fine** and **micro-finishing** are useful process roles, not fixed international bands.

Coarse stage

The coarse stage removes scale, weld excess, coating, damage or unwanted geometry. It normally establishes the deepest intentional scratch pattern in the sequence and consumes the greatest material allowance. Starting coarser may shorten initial removal time but increases the work required later to remove the deepest valleys.

Medium stage

The medium stage converts the coarse pattern into a more uniform and shallower texture while continuing limited blending or shaping. It should not be expected to correct large geometric errors economically if the coarse stage was stopped too early.

Fine stage

The fine stage refines visible scratches, reduces texture contrast and prepares the surface for the specified directional, coating, polishing or functional finish. At this point contamination, inconsistent contact and local dwell become increasingly visible.

Micro-finishing stage

Micro-finishing uses very fine graded abrasives or engineered finishing products to control a shallow texture, prepare for polishing or meet a defined surface-function requirement. “Micro-finish” is not proof of mirror appearance or a roughness value. The product system, process and measurement method still control.

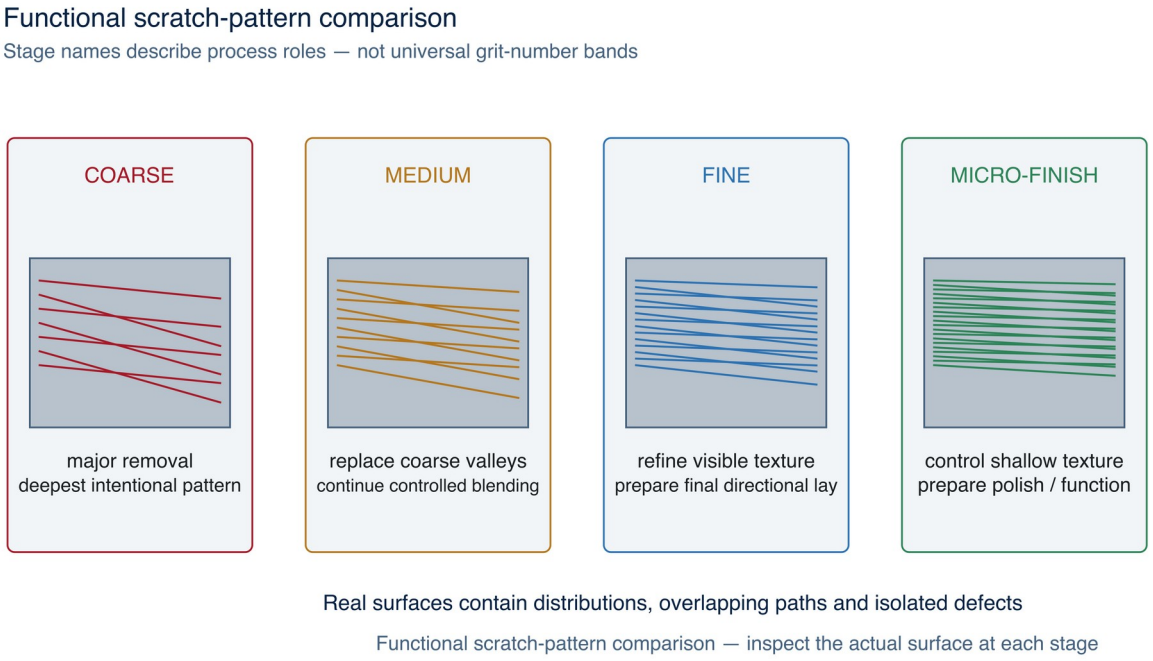


Figure 1. Functional scratch-pattern comparison. Compare pattern uniformity, retained deep lines and current-stage scratches under consistent inspection conditions.

3. FEPA P-grades

FEPA distinguishes abrasive-product families by designation: F-grit sizes for bonded abrasives, P-grit sizes for coated abrasives, and D or B prefixes for diamond or cBN superabrasives. FEPA also explains that a macrogrit diameter is controlled as a distribution rather than one single particle diameter. [S039]

The current ISO coated-abrasive standards divide P-grades into macrogrits P12 to P220 and microgrits P240 to P5000 for electro-fused aluminium oxide and silicon carbide. ISO 6344-2:2021 covers macrogrit distribution and designation; ISO 6344-3:2021 covers microgrits. [S040; S041]

Read a P-grade correctly:

- the **P prefix** identifies the coated-abrasive grading family;
- the **number** is a designation within that family, not a measured scratch depth;
- a **higher P number** generally represents a finer nominal grade within the P system;
- the grade controls a particle-size distribution, not identical grains; and
- the complete coated product still includes grain type, coating density, backing, adhesive, treatment and geometry.

Do not use an F-grade table, a bare mesh number or a supplier's informal “grit” label as if it were automatically a P-grade equivalent.

4. P-grade and other grit systems

ANSI/CAMI, JIS, FEPA F, FEPA P, micron-labelled films and proprietary finishing scales can use similar numbers for different particle distributions. Conversion charts are approximations for shortlisting, not proof that two products will cut or finish identically. The differences can become more important at fine and microgrit sizes. [S039; S043]

For a substitution or cross-supplier comparison, record:

72. the full standard or grading system;
73. the exact grade and product code;
74. abrasive mineral and construction;
75. backing, bond or film type;
76. open/closed coating or other distribution feature;
77. intended material and application; and
78. the representative trial result.

If the grading system is missing, treat the product as unidentified for sequence design.

5. How scratch depth is created

Abrasive grains create many overlapping grooves. Each active grain can cut, plough or rub. The resulting surface contains peaks, valleys, displaced material, torn material and occasional isolated defects. The deepest observed line may come from the largest effective protrusion or contamination rather than the nominal average grain.

Scratch depth tends to increase with larger effective cutting points and deeper engagement, but it is not a fixed fraction of particle size. A compliant backing can follow surface geometry while also changing local contact. A worn or loaded product can rub, smear or trap debris. A rigid, sharp product can cut a more defined pattern. Work-material hardness and ductility affect whether material is separated, displaced sideways or smeared.

This is why a visual “looks fine” check is insufficient for a controlled specification. When surface function matters, define an appropriate measurement such as comparator assessment, surface roughness, profile, microscopy, coating adhesion or customer-approved reference panels.

6. The purpose of grit progression

A progression is a sequence of controlled surface-generation stages. Each finer stage must remove the unwanted valleys and damaged layer left by the previous stage while preserving required geometry.

The governing question is not “What number comes next?” It is “Can this complete next-stage product remove the remaining deepest defects within the permitted time, heat, edge change and material allowance?”

A robust sequence has four controls:

- **entry condition:** the starting defect and geometry are known;
- **stage objective:** the pattern that must be removed or created is defined;
- **inspection gate:** the surface is cleaned and checked before changing products; and
- **exit condition:** no previous-stage scratch remains above the approved acceptance threshold.

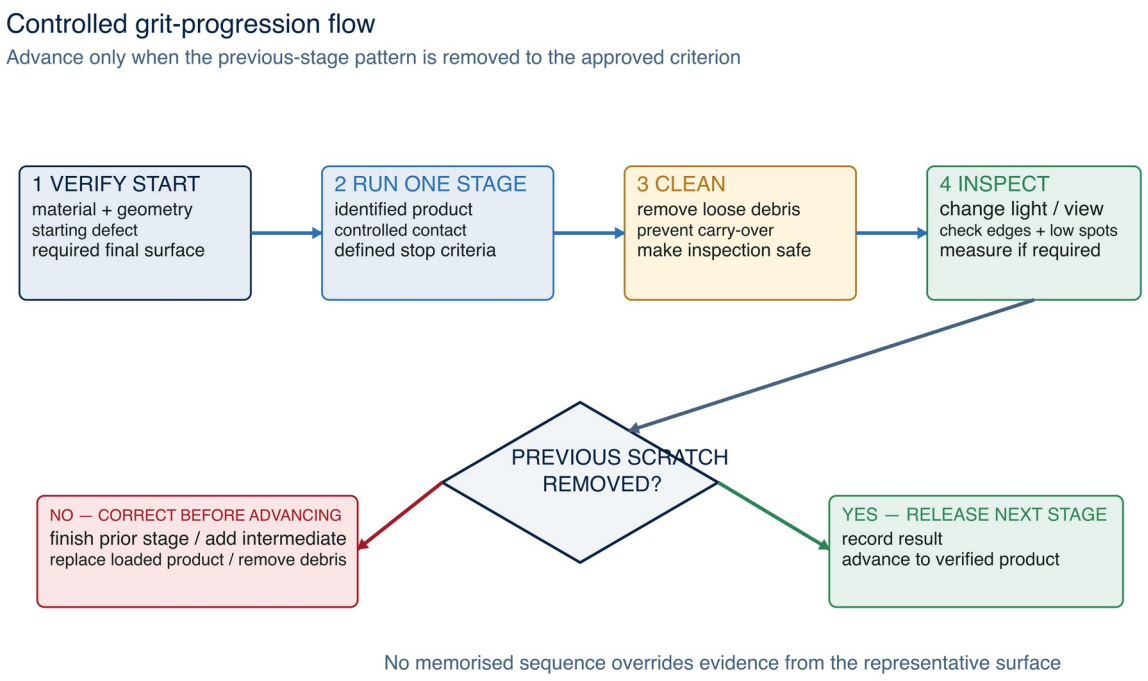


Figure 2. Controlled grit progression. Advance only after the preceding scratch family has been removed to the required criterion.

7. Risks of an excessive grit jump

An excessive jump occurs when the next stage lacks enough cutting capacity to remove the previous stage's deepest scratches within the controlled process window. A large numerical gap is not automatically excessive, and a small gap is not automatically safe; the result depends on both products and the work.

Common failure modes include:

- polishing the peaks while deep coarse valleys remain;
- extending dwell or force until heat, distortion or edge rounding develops;
- using many fine consumables to do work that belongs to an intermediate stage;
- leaving isolated coarse scratches that appear only after coating or final lighting;
- losing the original directional pattern through random corrective motion; and
- misreading temporary shine or smear as scratch removal.

If the finer stage is slow, do not automatically increase force. Stop, clean, inspect and decide whether the previous stage was complete, an intermediate stage is needed, the abrasive is loaded or worn, contamination is present, or the product construction is unsuitable.

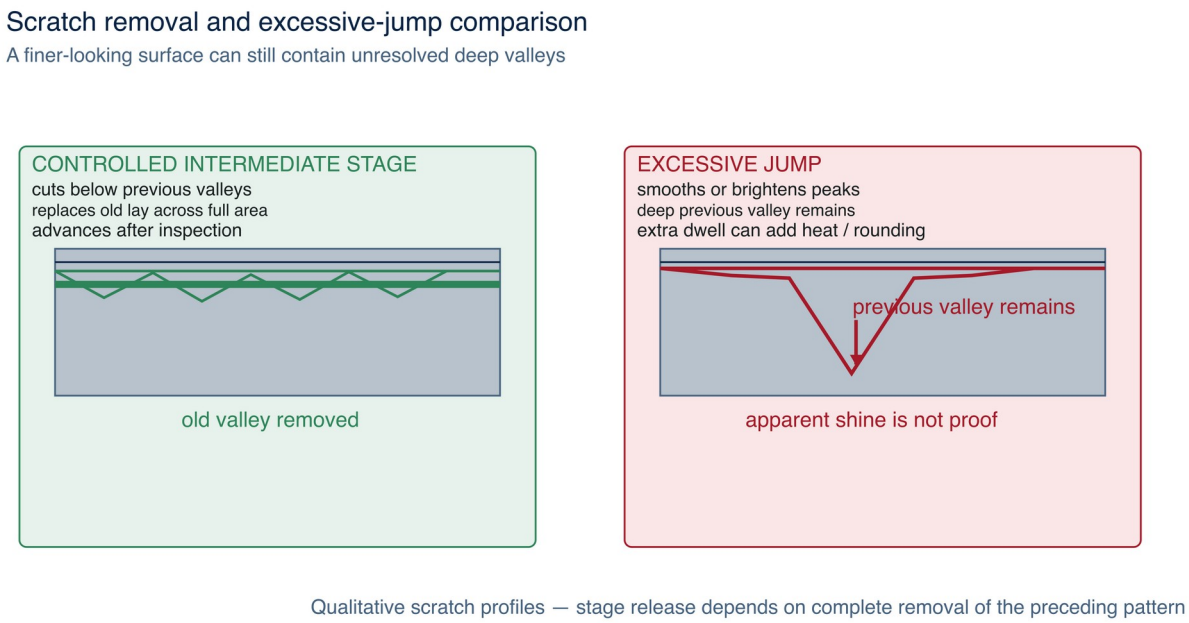


Figure 3. Scratch-erasure check. A successful stage removes the previous valleys; an excessive jump can brighten the peaks while leaving deep defects.

8. Alternating direction as an inspection aid

Where geometry and the required final lay permit, change the working direction between consecutive stages. A new directional pattern makes residual scratches from the previous stage easier to distinguish. Do not use this method where the product, joint, edge, machine or specified grain direction prohibits cross-working.

Direction change is an inspection aid, not a substitute for complete coverage. The stage is complete only when the old-direction lines are removed to the approved criterion across the entire controlled area, including edges, transitions and low spots.

For a final directional finish, the last approved stage must re-establish the specified lay consistently. British Stainless Steel Association guidance notes that mechanically polished stainless finishes are directional and that appearance depends on process variables; a descriptive grit label alone does not define the result. [S028]

9. Inspection under directional lighting

Use a repeatable inspection method:

79. Stop the machine and make the area safe.
80. Remove loose abrasive debris with the approved cleaning method; do not wipe contaminated particles back across the surface.
81. Use a clean, controlled light source at a shallow angle to the surface.
82. Inspect with the light across the scratch direction, then change the light or viewing direction.
83. Mark isolated previous-stage scratches without damaging the acceptance area.
84. Check edges, curves, weld transitions and shadowed zones separately.
85. Compare with the approved reference panel or measurement requirement.
86. Record the product, grade system, stage, surface condition and result before continuing.

Directional lighting increases visual contrast but does not measure depth. Scratch patterns can be compared visually, while objective profiling can reveal depth and consistency that a casual view cannot quantify. Use visual screening to locate defects and the specified measurement method to assess controlled surface requirements. [S042]

10. Controlled progression table

Stage role	Primary purpose	Evidence before advancing	Typical failure signal
Coarse	Remove major defect or geometry	Defect removed; allowance and heat remain controlled	Deep isolated gouges, edge loss, tint or distortion
Medium	Replace coarse texture with uniform shallower lay	Coarse-direction scratches removed across the area	Bright peaks with persistent coarse valleys
Fine	Create coating-ready, directional or pre-polish surface	Uniform appearance under changed light direction; defined measurement passes	Swirls, contamination lines, patchiness or over-blending
Micro-finishing	Control shallow texture or prepare for polish	Approved comparator or instrumental criterion passes	Shine without uniformity; embedded debris; unresolved deeper marks

The stage names do not prescribe grit numbers. Use the product manufacturer's sequence guidance and confirm it on representative material.

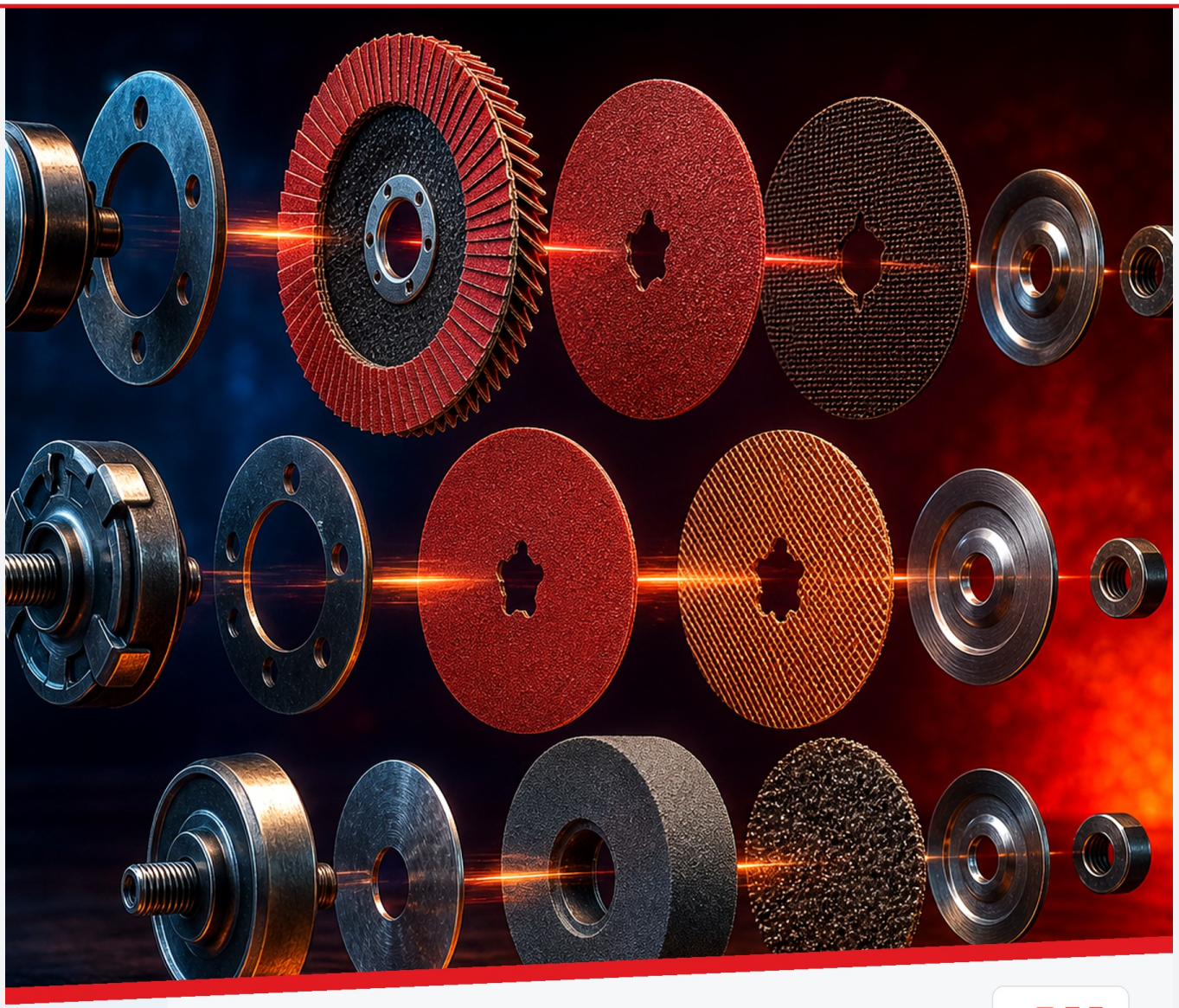
11. Controlled trial and release

87. Verify material grade, hardness, coating, geometry, starting damage and required final surface.
88. Record the complete abrasive product, grading system and grit designation for every proposed stage.
89. Define speed, contact, motion, cooling, extraction and replacement criteria from current product and machine data.
90. Prepare a representative trial coupon or non-critical area with the same material condition and geometry.
91. Photograph and, where required, measure the starting condition.
92. Run one stage at a time with controlled technique.
93. Clean and inspect under at least two useful light/viewing directions.
94. Record whether the previous-stage pattern has been removed, along with time, consumable use, heat, geometry and surface result.
95. Add an intermediate stage or revise the product if the next stage cannot remove the deepest defects inside the allowed window.
96. Release the sequence only after technical, safety, quality and MKTECH approval.

12. Building an application-specific grit sequence

Begin with the least aggressive grade that removes the stated defect or allowance efficiently. Add only the refinement stages needed to replace the previous scratch pattern and reach the specified visual or measured finish. Inspect under consistent lighting and change direction between stages where the geometry permits.

Do not treat FEPA P, FEPA F, ANSI/CAMI, JIS, micron and proprietary grades as directly interchangeable. Verify the grading system printed for the exact product and compare the complete process on representative material. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**



ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 008

Abrasive Product Construction

08

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: Bonded, coated, non-woven and structured abrasive construction; flexible grinding discs; grinding and cutting wheels; flap, fibre and sanding discs; belts, sheets, rolls, mounted points, non-woven wheels and polishing products. This chapter does not approve an MKTECH SKU, product substitution, machine, mounting system, speed, angle, pressure, duty cycle or finish result.

Safety-critical boundary — Product shape alone does not establish safe use. Verify the complete product identity, dimensions, mounting, wheel or disc type, guard, backing pad or flange, direction, maximum operating speed, machine compatibility and current manufacturer instructions. Do not use an unknown, damaged, expired where applicable, wet-damaged, distorted, delaminated or incorrectly mounted abrasive. [S032]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish construction family from product format;
- identify the working layers in bonded, coated, non-woven and structured abrasives;
- explain the functions of backing, make or base coat, abrasive layer, size coat, bond, pores, reinforcement and optional top coatings;
- recognise how grinding wheels, cutting wheels, flexible discs, flap discs, fibre discs, sanding discs, belts, sheets, rolls, mounted points and non-woven wheels package those constructions;
- identify when an attachment, hub, backing plate, shank or reinforcement is load-bearing;
- screen products for construction damage before use; and
- select candidates for a controlled trial without inferring performance from shape, colour or product name alone.

1. Why construction matters

An abrasive product is a load path as well as a cutting surface. Contact force travels from the machine through a flange, pad, hub, shank, backing or wheel body to the active abrasive. Heat and debris must leave through the work contact, the product structure, coolant or the surrounding air. Wear must expose or release cutting points without uncontrolled separation.

Construction determines how those functions are shared. A rigid bonded wheel carries load through a three-dimensional body of grain, bond and pores. A coated abrasive anchors grain to a flexible backing. A non-woven product distributes mineral through an open fibre network. A structured abrasive places mineral inside repeated three-dimensional features on a carrier. Products that look similar from the working face can therefore differ greatly in stiffness, grain support, debris clearance, edge behaviour, mounting and failure mode. [S029; S033; S044-S046]

The practical rule is simple: identify the **architecture**, the **format** and the **attachment** separately.

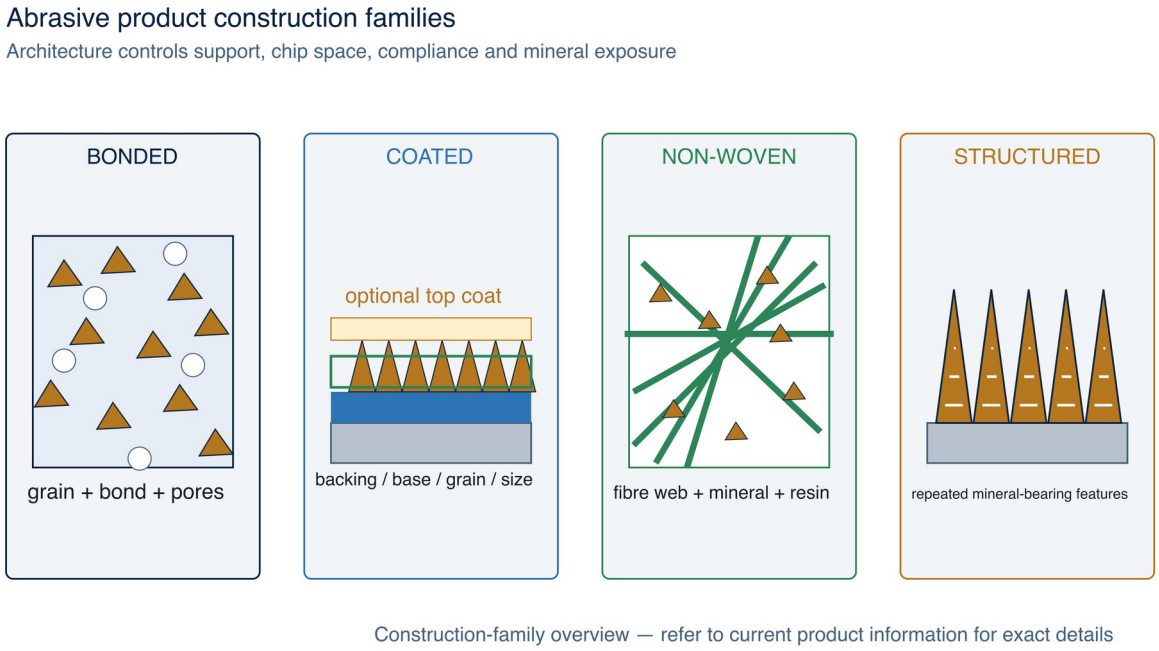

Figure 1. Abrasive construction families. The schematic compares the functional arrangement of coated, bonded, non-woven and superabrasive constructions. Refer to current product information for exact construction details.

2. Four construction families

Bonded abrasives

In a bonded abrasive, abrasive grains are held throughout a shaped body by a bonding agent. Voids or deliberately controlled porosity separate parts of the grain-and-bond network. The principal wheel components are abrasive grain, bond and air space; a superabrasive layer may instead be carried on a separate hub or core. [S033]

The bond retains grains and transmits force. The pores provide chip space and paths for coolant or air, while the abrasive grains create the cutting points. Bonded does not mean one bond chemistry: vitrified, resin and other systems behave differently, and the complete manufacturer specification controls.

Coated abrasives

A coated abrasive normally has a backing, a first adhesive layer, abrasive grit, a size coat and sometimes an additional coating. The base coat positions the grain; the size coat bonds the grains to one another and to the backing. Backing options include paper, cloth, film, vulcanised fibre, foam and combinations, each contributing different flexibility, stretch, tear resistance, tensile strength and stability. [S044]

The optional top coating may alter loading, friction, cooling or grinding behaviour, but its chemistry and intended material must be verified from the product data. A visible colour is not a reliable identifier of that coating.

Non-woven abrasives

In a typical non-woven abrasive, mineral is bonded into a network of synthetic fibres rather than coated as one dense, flat grain layer. Open-web constructions combine abrasive mineral, non-woven fibres and a bonding system; spaces in the web allow swarf to escape, while progressive fibre wear can expose fresh mineral. [S045]

The open and compliant structure can follow contours and reduce the tendency to gouge, but non-woven is not automatically a light-duty product. Web density, fibre size, mineral, resin, compression and product geometry can produce hand pads, belts, discs, convolute wheels or compressed unitised wheels with very different stiffness.

Structured abrasives

Structured abrasives place graded mineral in engineered features rather than relying only on a random single-layer grain distribution. Precisely formed three-dimensional abrasive structures can be designed to expose fresh mineral progressively as they wear. The feature geometry and grading system remain product-specific. [S046]

The feature geometry, mineral distribution, carrier and grade system are product-specific. A structured product must not be assigned a FEPA P-grade or treated as equivalent to conventional coated paper unless the manufacturer declares that relationship.

3. Product format is not construction family

Terms such as disc, wheel, belt, sheet and roll describe geometry or delivery form. They do not by themselves identify the abrasive architecture.

Product form	Common construction possibilities	Construction questions to verify
Grinding wheel	Bonded grain-bond-pore body; sometimes reinforced resin; superabrasive layer on a core	Bond system, structure, reinforcement, wheel type, dimensions and mounting
Cutting wheel	Thin bonded wheel, often resin-bonded and reinforced for its declared machine and cut	Wheel type, reinforcement layout, side-load restriction, flanges and machine class
Flexible grinding disc	Resin-bonded abrasive body with engineered reinforcement and controlled flexibility	Disc type, support, permitted surface, guard and mounting
Flap disc	Overlapping coated-abrasive flaps fixed to a backing plate or hub	Flap material, arrangement, plate material, adhesive, shape and wear limit
Fibre disc	Coated abrasive on heavy vulcanised-fibre backing, used with a compatible backing pad	Disc and pad diameter, hole or attachment, backing condition and rated speed
Sanding disc	Paper, film, cloth, mesh or non-woven construction with PSA, hook-and-loop or mechanical attachment	Backing, coating density, hole pattern, attachment and pad interface
Belt, sheet or roll	Usually coated abrasive; may also be non-woven or structured	Backing, joint or edge, width, direction, waterproof status and storage condition
Mounted point	Small bonded abrasive body fixed to a shank or spindle	Shape, shank size, overhang, rated speed and runout
Non-woven wheel	Open web, convolute web or compressed/unitised layers around a centre or hub	Density, direction, bore or shank, side exposure and wear limit
Polishing product	May be structured abrasive, non-woven, bonded compound, loose compound plus buff, film or pad system	Carrier, compound, lubricant, contamination control and required final criterion

Fibre, flap, hook-and-loop, pressure-sensitive adhesive and quick-change discs may share a general disc format, but their structures, support requirements and attachments differ. Fibre discs use a coated abrasive layer on a strong fibre backing, while flap discs use overlapping abrasive flaps fixed to a backing plate. [S047]

4. Bonded wheels, cutting wheels and flexible discs

Grinding wheels

A conventional bonded grinding wheel is a three-dimensional composite. Grain type and size describe only part of it; bond type, bond strength, grade, structure or porosity, dimensions and wheel shape determine how the wheel supports grains and clears chips. [S029; S033]

Do not confuse wheel hardness with abrasive-mineral hardness. In wheel terminology, grade commonly describes the strength with which the bond holds the grain, while structure describes the spacing of grains. Exact codes vary by manufacturer and must be read from the controlled specification.

Cutting wheels

A cutting wheel is thin because it must create a narrow kerf, not because it is a general-purpose side-grinding wheel. Reinforcement is an engineered part of some products, not permission to apply side load. Wheel type, reinforcement, mounting and declared machine class must always be read together; a wheel intended for a stationary chop saw must not

be transferred to a portable cut-off machine unless the product marking and manufacturer instructions expressly permit it. [S048]

Flexible grinding discs

Flexible bonded discs use a bond and reinforcement system designed to permit controlled conformance while transmitting load. Their flexibility, permitted working surface and support method are part of the specification. Never flex, trim, stack or mount a disc merely because another product of similar diameter tolerates that practice.

Mounted points

A mounted point packages a small bonded body on a shank for internal or local work. The shank, bond body and interface form one rotating system. Shank diameter, mounted overhang, point shape, machine collet and maximum operating speed must be compatible; a point must not be treated as a miniature wheel with automatically transferable wheel settings.

Figure 2. Four MKTECH rotary abrasive product families. Official MKTECH product-page images show grinding discs, flap discs, cutting discs, and mounted points and carbide burrs as four distinct constructions. Product form, backing, hub, shank and support method determine how load is transmitted during use. Refer to the product label, Technical Data Sheet, or MKTECH representative.

5. Coated formats

Fibre discs

The heavy vulcanised-fibre backing of a fibre disc supports an aggressive coated layer but normally depends on a compatible backing pad during use. Moisture damage, cupping, edge cracking, an incorrect pad or incomplete seating changes how load reaches the abrasive. A fibre disc is not a cutting wheel and is not self-supporting merely because it is stiff in the hand. [S047]

Sanding discs

Sanding discs may use paper, cloth, film, mesh, foam-laminated or other backings. Their attachment may be pressure-sensitive adhesive, hook-and-loop, centre fastening or a proprietary quick-change system. Hole patterns can support dust extraction, but only when disc, pad and extraction paths align. The attachment layer and pad are therefore part of the operating system, not packaging accessories.

Belts, sheets and rolls

A roll is a supply format; a sheet is a cut format; a belt adds a joint and a running direction. The same coated construction can behave differently after conversion because edge quality, joint type, splice thickness, grain direction and backing tension matter. Verify belt direction marks and machine width. Never repair a failed belt joint or cut an unidentified roll into machine belts without an approved conversion specification.

Flap discs

A flap disc converts coated abrasive into many overlapping working elements fixed to a backing plate. As the exposed flap tips wear, later portions of the flaps enter contact. Flap length, overlap, density, plate shape and adhesive determine the supported contact zone. Flat and angled flap-disc geometries create different contact conditions, so the declared working face and angle must be confirmed from the product marking and instructions. [S047; S049]

Do not continue after flaps separate, the plate becomes exposed beyond the permitted wear limit, the product is loaded or the backing is damaged. The current product marking and manufacturer instructions define the usable surface and working angle.

6. Non-woven wheels, discs and belts

An open-web product stores compliance in the fibre network. A denser, compressed or resin-rich product stores less geometric freedom and may act more like a firm wheel. This explains why the label “non-woven” cannot predict pressure tolerance, edge action or surface result.

Inspect the web for tears, hard contamination, glazing, uneven wear, core damage and separation from any hub or attachment. Do not use loose fibres as proof that a product is self-sharpening; abnormal shedding can indicate damage, overload or incompatible contact.

Where stainless cleanliness matters, segregate products by material family and prevent embedded ferrous debris from transferring to the work. Construction that can retain swarf also creates a contamination-control obligation.

7. Structured and polishing products

Structured abrasives can provide repeatable feature geometry and controlled mineral exposure, but they still require the correct carrier, contact pressure, coolant or lubricant where specified, and sequence. The grade symbol may be proprietary. Record the exact product code and grading system at every stage. [S046]

“Polishing product” is a process label, not one construction. It can refer to a fine structured belt, a non-woven wheel, an abrasive film, a bonded rubberised product, a buff carrying compound or a pad-and-liquid system. Before use, identify which component supplies the abrasive, which component carries it, whether lubricant is required, how contamination is controlled and what measured or approved visual result defines completion.

8. Cooling, grinding-aid and top layers

Additional coatings can change loading, heat generation, friction or chip release. In coated products they sit above or among the size coat and exposed grain. In some products fillers or grinding aids are incorporated into a resin system rather than applied as a visually separate layer.

Treat every claimed cooling or grinding-aid feature as product-specific. It does not override the machine rating, maximum operating speed, extraction requirement, combustible-dust assessment or work-material compatibility. Do not infer chemistry from colour or smell, and do not add liquid to a product unless both product and machine are approved for that use.

9. Construction-led candidate selection

Use the construction questions before comparing brands or prices:

97. Define the required action: cutting, stock removal, blending, deburring, scratch refinement, cleaning or polishing.
98. Identify the work material, coating, geometry, edge sensitivity and required final surface.
99. Choose the needed support: rigid, controlled-flex, backing-pad supported, flap-supported, open-web or structured.
100. Verify debris clearance, cooling and contamination controls.
101. Match the complete attachment and machine class.
102. Confirm dimensions and maximum operating speed from the product marking and manufacturer data.
103. Inspect storage condition and physical integrity.
104. Trial the candidate on representative material with defined stop and acceptance criteria.

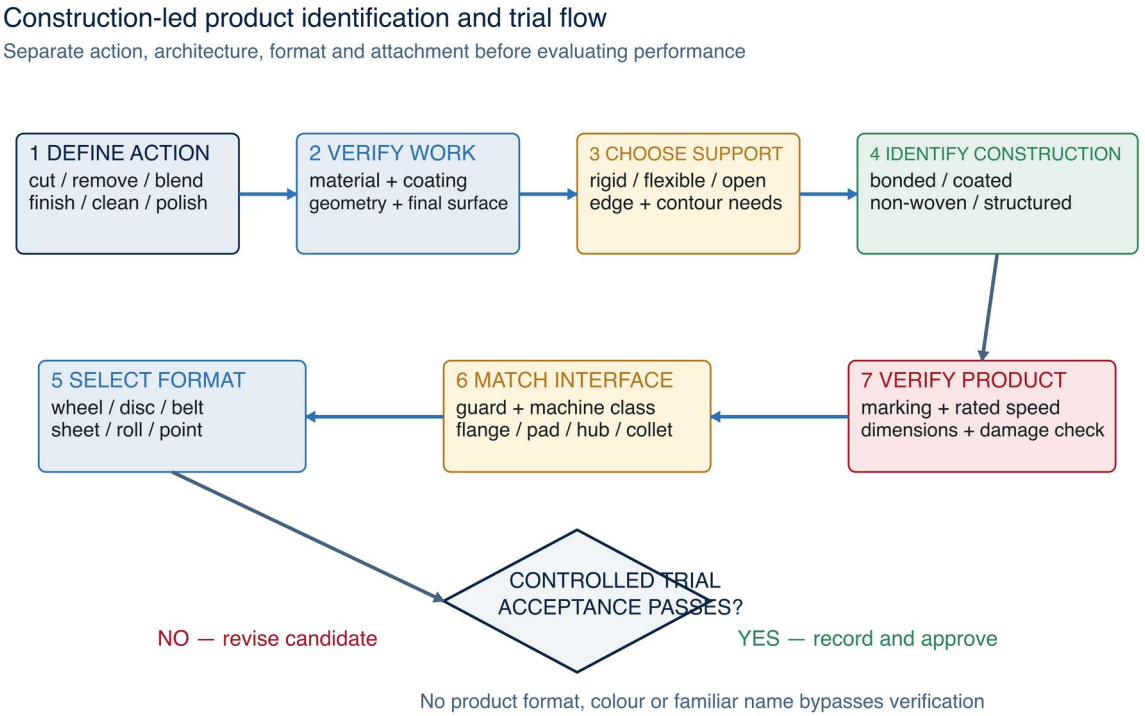

Figure 3. Construction-led selection flow. Product architecture narrows the candidate set; complete the selection using the product label, Technical Data Sheet or MKTECH representative.

10. Common construction mistakes

- selecting by colour, diameter or familiar trade name instead of the complete specification;
- treating a product format as a construction family;
- fitting a self-supporting-looking coated disc without its required backing pad;
- using a reinforced cutting wheel for side grinding;
- assuming every non-woven product is soft or every bonded product is rigid;
- ignoring the flap adhesive, backing plate, belt joint, shank or attachment because it is not abrasive;
- continuing after delamination, cupping, cracks, abnormal shedding, exposed support or uneven wear;
- mixing product families across stainless steel and carbon steel without contamination control; and
- replacing a declared proprietary grade with a similar-looking FEPA number.

11. Construction troubleshooting

Observed signal	Construction-related possibilities	Controlled response
Grain sheds unusually fast	Wrong contact, damaged bond, excessive force, incompatible material or product deterioration	Stop; inspect product, machine and work; compare with manufacturer limits
Coated disc curls, cups or delaminates	Moisture, heat, storage damage, wrong pad, edge loading or attachment failure	Remove from service; inspect the batch and storage; verify pad and method
Flaps separate or backing plate appears early	Snagging, wrong surface or angle, overload, damage or end of usable life	Stop immediately; quarantine damaged product; verify product instructions
Non-woven product smears or loads	Incompatible grade or density, trapped debris, heat, contamination or worn web	Stop, clean and reassess construction and process; do not add force blindly
Belt tracks poorly or joint strikes	Wrong direction, damaged edge or joint, incorrect tension, machine alignment or width mismatch	Stop; inspect belt and machine; do not repair the joint in production
Wheel vibration or runout	Damage, contamination at mounting faces, wrong flange, poor seating, machine fault or wheel imbalance	Stop and isolate; inspect by the approved wheel-mounting procedure

The table is diagnostic screening, not permission to repair or re-use a damaged abrasive.

12. Practical example: weld blending on a stainless enclosure

A team needs to remove a weld crown, blend the transition and create a controlled directional pre-finish. A construction-led trial separates three roles:

105. **Geometry correction:** shortlist a product with enough support to remove the crown without collapsing into the adjacent sheet.
106. **Blend transition:** shortlist a controlled-flex coated or flap construction that can spread contact without hiding a remaining ridge.
107. **Surface refinement:** shortlist a clean, segregated coated, structured or non-woven product whose construction can follow the enclosure without destroying the required lay.

For each role, the team records the complete product, attachment, machine, speed limit, construction, trial technique, time, wear, heat indication, geometry and surface result. The lowest purchase price is not automatically the lowest process cost. A product that loads, sheds, contaminates stainless, requires excess rework or damages edges may have a higher cost per accepted part.

13. Construction checks before use

Identify the complete product construction and attachment system before comparing formats. Check the declared work material and operation, dimensions, backing or wheel structure, bond, reinforcement, hub or bore, permitted working face, rotation direction where marked, and required pad, flange, collet or contact element.

Inspect storage condition and product integrity before mounting. Never substitute an adapter, support element, belt joint or product format solely because it appears to fit. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 009

Backing Materials and Bond Systems

09

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: Paper, cloth, film, fibre, vulcanised-fibre and polyester backings; resin-over-resin, glue and flexible resin systems; reinforcement; and their qualitative effects on flexibility, edge durability, tear resistance, water resistance, finish, product life and operator control. This chapter does not approve an MKTECH SKU, backing grade, bond chemistry, wet-use method, machine, speed, pressure, sequence, finish result or product-life claim.

Safety-critical boundary — A backing or bond name is not an operating instruction. Verify the complete abrasive product, attachment, support pad or contact wheel, dimensions, maximum operating speed, machine compatibility, wet-or-dry marking, storage condition and current manufacturer instructions. Stop for missing identification, cracks, cuts, creases, cupping, delamination, joint damage, softened bond, abnormal grain loss or any product that has been wetted without approval. [S032; S051]

Chapter objectives

After this chapter, the reader should be able to:

- identify the backing and bond as separate parts of a coated-abrasive system;
- distinguish paper, cloth, polyester cloth, film and vulcanised-fibre backings;
- explain the roles of the base or make coat and the size coat;
- distinguish resin-over-resin, glue-containing and flexibilised resin systems without assuming universal performance;
- recognise reinforcement by backing weight, weave, impregnation, lamination, vulcanisation, joint design and required support;
- explain how backing and bond choices influence control and surface generation; and
- screen a candidate product for a controlled trial without converting a backing code into an unsupported process setting.

1. Backing and bond work as one system

In a coated abrasive, the backing carries tensile load, bends around the tool or work, supports the mineral and transfers force from the operator or machine. The bond anchors and laterally supports the grains while accommodating the strain imposed by that backing. Neither part acts alone. A very flexible carrier with an unsuitable brittle coating can shed or crack; a tough bond on a damaged or poorly supported carrier still cannot provide a stable cutting face.

Common coated-abrasive backings include paper, cloth, plastic film, vulcanised fibre, foam and paper-cloth combinations. Backing selection affects grip and adhesion, stretch, tear resistance, tensile strength, flexibility and dimensional stability. The construction also separates the base coat, which positions the grain, from the size coat, which bonds grains to each other and to the backing. [S044]

The practical rule is to read four fields together: **backing material**, **backing weight or flexibility treatment**, **bond system**, and **required support**.

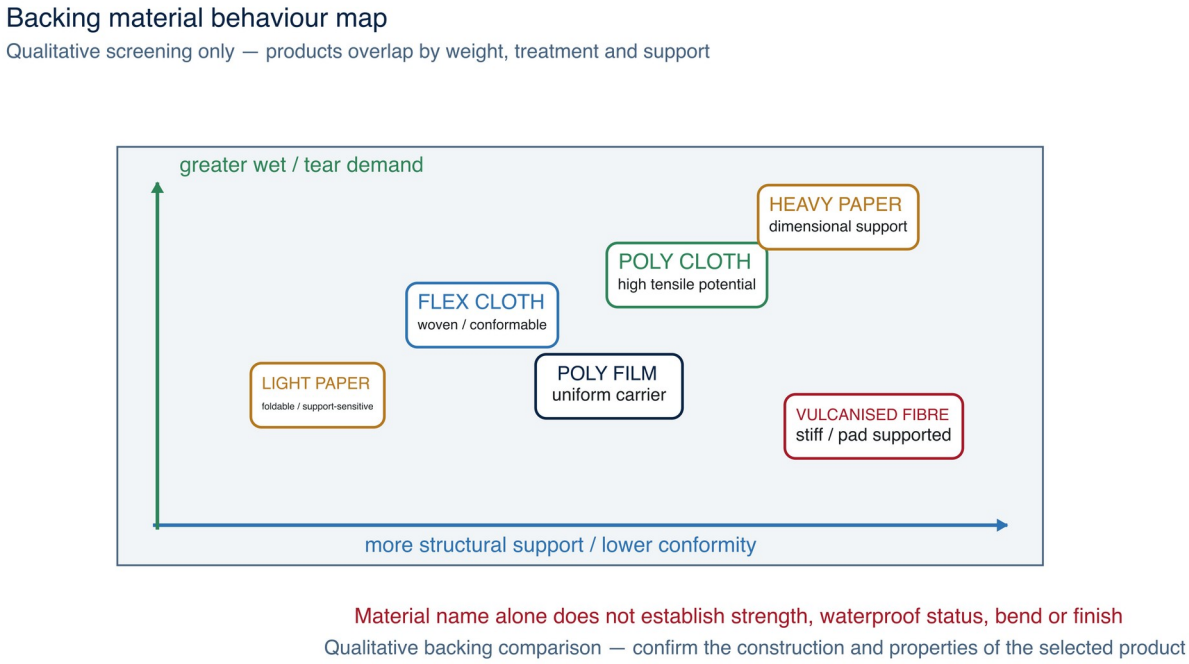

Figure 1. Backing-material behaviour map. The qualitative positions show common tendencies; actual behaviour varies with backing weight, treatment, bond and product construction.

2. Identification before comparison

Backing labels are families, not complete specifications. Paper letters, cloth weight codes, film thicknesses and proprietary flexibility suffixes vary by supplier and product line. They are useful only when tied to the current manufacturer record.

Before comparing products, record:

- backing material and declared weight, thickness or flex treatment;
- fibre composition where the backing is cloth;
- base or make-coat chemistry and size-coat chemistry where declared;
- wet-or-dry approval and permitted liquid;
- coating density, top coating and attachment layer;
- product form, dimensions, direction, joint or edge construction;
- required pad, contact wheel, platen, block or other support; and
- storage limits, rated speed and inspection criteria.

Do not translate one manufacturer's A, J, X, Y or film designation into another manufacturer's product without confirmation. A familiar letter can describe a relative weight within one convention, but it does not establish tensile strength, waterproof status, joint design, bond flexibility or safe machine use.

3. Paper backings

Paper provides a broad range of weights and can be cut, folded and converted economically. Lighter papers are typically more conformable and suitable for hand sheets or supported discs; heavier papers provide more dimensional support and can be used in selected belt constructions. Lettered paper-weight systems are manufacturer and product-family conventions rather than a universal performance code; work shape, moisture, belt dimensions and grade must be checked for the selected product. [S050]

A lighter paper can improve feel on a shaped hand block or supported finishing disc, but edge contact, creasing and local overstress can initiate a tear. A heavier paper can improve support and resist deformation, but it does not become cloth and may still kink or split if forced around a contour.

Paper is not automatically dry-only or waterproof. A paper abrasive may be suitable for wet use only when the complete backing, bond, coating and attachment system is expressly declared for that duty. Never infer wet-use suitability from paper weight or appearance alone. [S053]

4. Cloth and polyester backings

Cloth is a woven carrier. Fibre type, yarn, weave, weight, finishing treatment and flexing process all affect tensile behaviour, stretch, edge response and conformability. Lettered cloth-weight families and flex treatments vary by manufacturer, so the complete backing and bond description must be read rather than interpreting one letter in isolation. [S050; S054]

A lighter or flex-treated cloth can wrap a contour and maintain contact where a stiff sheet would bridge. A heavier cloth can stabilise a belt or resist tearing under higher mechanical demand, but increased strength often comes with reduced conformability. The weave can also print through under unsuitable support or pressure, so cloth does not guarantee a finer finish than paper or film.

Polyester can appear as woven cloth or as a continuous film. In cloth form it is commonly selected where high tensile demand, moisture resistance or wet processing is declared. A moisture-resistant carrier does not automatically approve the adhesive system, belt joint, attachment or machine for wet operation; the complete product must carry the required declaration. [S050]

5. Film backings

Film is a continuous polymer carrier rather than a woven fabric or paper network. Its uniform thickness and surface can support even grain presentation and consistent finishing, while its tear behaviour differs from paper because there is no paper-fibre network. Thickness, polymer, coating, perforation and attachment still matter.

Film backings can provide a uniform surface, controlled thickness, flexibility and tear resistance for selected contour-finishing and precision-finishing duties. Thickness and wet-or-dry status are product-specific fields and must be verified on the exact product. [S052]

Do not generalise that example into “film is always best.” A thin film can be cut by a sharp edge, a perforated film can initiate a tear at a damaged hole, and an unsupported film can wrinkle or concentrate pressure. Film also changes the operator's feedback because its smooth, dimensionally stable carrier can transmit tool motion differently from a soft paper or cloth.

6. Vulcanised-fibre backings

Vulcanised fibre is a dense, chemically consolidated cellulose-based sheet used where a stiff, strong carrier is required, notably in fibre discs. It is formed by consolidating cellulose-based plies through controlled chemical, heat and pressure processes. [S044; S050]

The fibre backing distributes load over a compatible backing pad. It is not a self-supporting grinding wheel. Moisture, cupping, edge cracks, an incorrect pad profile, incomplete seating or pad damage changes the support condition and can overload the disc. Verify the exact disc format and attachment rather than selecting by diameter alone. [S047]

7. Base coat, size coat and bond system

The first adhesive layer is commonly called the base coat or make coat. It holds the grain in the required position while the abrasive layer is formed. The size coat covers and links the grain roots, supporting grains against cutting force and binding the abrasive layer to the carrier. Some constructions add a further top coating for loading, heat or friction control. [S044; S050]

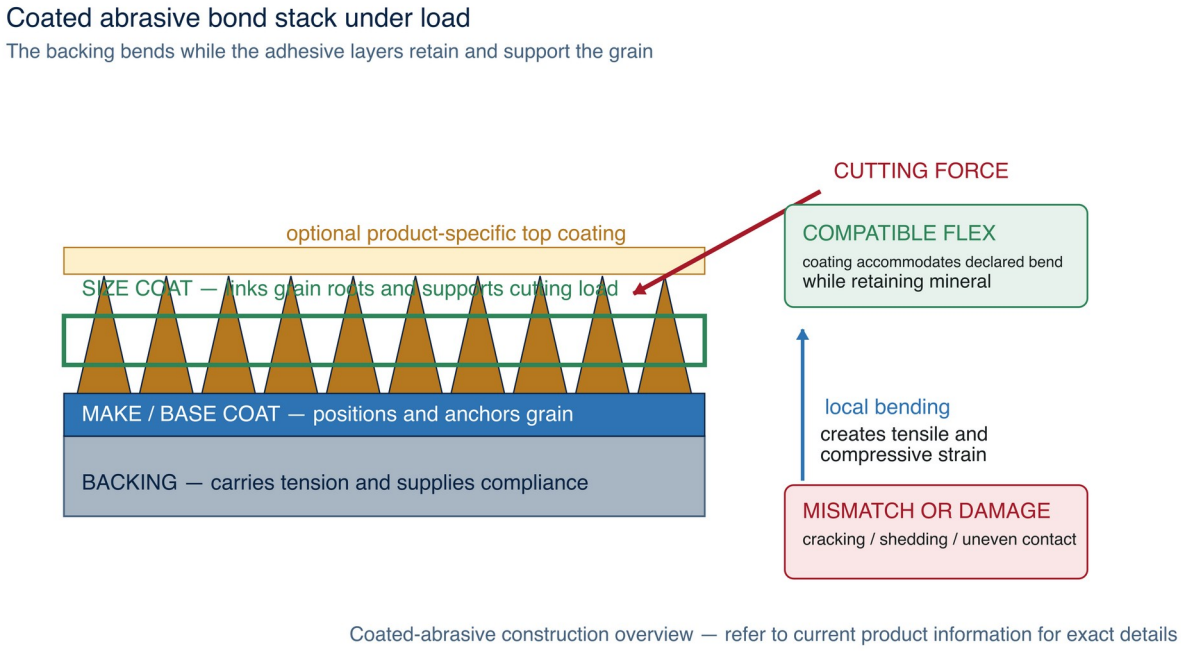

Figure 2. Coated-abrasive bond stack. The schematic shows the load path and strain accommodation through the backing, bond layers and abrasive grain.

Resin-over-resin systems

“Resin-over-resin” commonly means resin is used for both the make and size functions. Phenolic or other thermosetting resin systems can provide heat resistance and strong grain support, but resin type, cure, filler, coating weight and flexibility treatment are product-specific. Tougher binder systems generally provide firmer grain support, while the delivered cutting action and durability still depend on the complete construction and application. [S044; S050]

This does not mean the hardest bond is always preferable. A bond that is too rigid for the backing's bend radius or the work contour can crack, shed mineral or create an uneven contact pattern. “Resin-over-resin” is therefore an architecture label, not a universal ranking.

Glue-containing systems

Traditional glue systems generally soften more readily with heat and moisture than thermosetting resin systems. Their more cushioning response can suit selected finishing duties, but heat resistance, aggressiveness and service life depend on the complete declared construction. [S050]

Glue-containing products require disciplined storage and duty control. They must not be assumed water-resistant, high-temperature capable or interchangeable with a resin-over-resin product. A softer scratch response can be useful only when the complete product is declared for the task and retains adequate grain.

Flexible resin systems

Flexible resin is not a single chemistry. Manufacturers can modify a binder with dispersions or other formulation choices to accommodate bending while still retaining the grain. Flexibilised resin systems can therefore range from firm, high-performance constructions to highly flexible finishing products. [S044]

The correct flexibility is a balance. The coating must survive repeated bending, but must also support the grain at contact. Confirm the minimum bend, converted form, joint, product direction and intended contact element; do not manually “break in” or over-flex an unidentified abrasive.

8. Reinforcement systems

Reinforcement can be built into the backing or supplied by the operating interface. Examples include:

- heavier paper weight or latex impregnation;
- stronger yarn, tighter weave or polyester content in cloth;

- paper-cloth laminates or polymer film;
- chemical consolidation into vulcanised fibre;
- a belt joint and edge treatment designed for the declared running direction;
- a disc backing pad, hook-and-loop layer or pressure-sensitive adhesive; and
- a platen, contact wheel or hand block that controls local bending.

Reinforcement is not permission to misuse the product. A strong carrier can transmit a damaging load instead of tearing first. The complete construction must still be inspected and used on the declared machine and support system.

9. How backing and bond change the process

Property	Construction influence	What the user must verify
Flexibility and operator control	Carrier thickness, weave, flex treatment and bond elasticity control how readily the product follows a contour and how concentrated contact feels	Work geometry, support hardness, permitted bend and representative trial
Edge durability and tear resistance	Fibre network, yarn, film continuity, impregnation, vulcanisation, holes and edge quality affect crack initiation and propagation	Edge condition, perforations, joint, pad support and snag risk
Water resistance	Carrier, bond, joint and attachment must all tolerate the declared liquid and exposure	Explicit wet-or-dry marking, approved liquid, machine and extraction method
Finish quality	Dimensional stability, grain support, carrier texture and contact compliance affect scratch uniformity and surface following	Required texture, inspection method, support and stage acceptance criterion
Product life	Grain retention, heat resistance, backing fatigue, loading, joint and storage condition can end service before the mineral is exhausted	Product instructions, damage limits, controlled wear record and stop criteria

These are screening relationships, not rankings. Product life is an outcome of the complete abrasive, machine, work, environment and method. No carrier or bond family is universally longer-lived.

10. Storage, conditioning and moisture control

Backing and bond can respond differently to humidity. Paper, cloth and fibre backings may exchange moisture at different rates from resin or glue bonds, producing curl, bowing, loose backing, creasing, loading, premature grain loss or brittleness. Preserve original packaging, protect products from dampness and condition unpacked belts in accordance with the manufacturer instructions. [S051]

Treat storage limits as controlled product data. Do not copy one supplier's temperature, humidity or conditioning time to another product without confirmation. Quarantine distorted, damp, brittle or delaminated stock and investigate the storage environment and batch history.

11. Backing-and-bond selection workflow

Use a controlled sequence:

108. Define the action, work material, coating, geometry and required surface.
109. Define the needed contact support and conformability.
110. Shortlist the backing family, weight or flex treatment.
111. Verify the bond system, wet-or-dry declaration and top coating.
112. Match the converted form, attachment, joint, pad, platen or contact wheel.
113. Check marking, rated speed, storage history and physical condition.
114. Trial on representative work with defined stop and acceptance criteria.
115. Record the exact product identity, result, wear and approval decision.

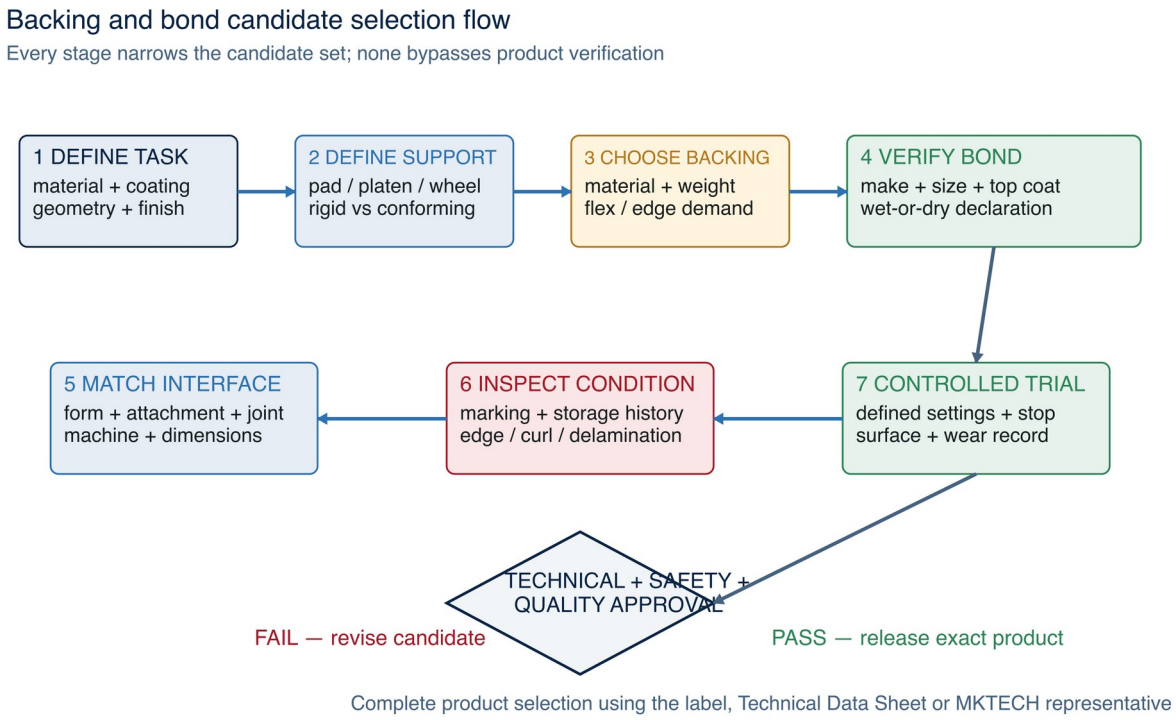

Figure 3. Backing-and-bond selection flow. Verify flexibility, strength, interface compatibility, condition and intended use before approving the selected product.

12. Common failure signals

Observed signal	Backing-or-bond possibilities	Controlled response
Disc curls, cups or will not seat	Humidity change, moisture exposure, heat, storage damage or incompatible attachment	Remove from service; inspect batch, storage and support system
Edge tears or holes elongate	Snagging, wrong pad, insufficient edge support, excessive local load or damaged carrier	Stop; discard damaged product; correct interface before retrial
Grain sheds in patches	Bond cracking, overheating, moisture, contamination, excessive flex or product deterioration	Stop and quarantine; compare with current product instructions
Belt strikes, tracks poorly or breaks at joint	Wrong direction, joint damage, edge damage, wrong tension, alignment or conditioning	Stop machine; inspect belt and machine; do not repair for production use
Finish varies across the contact	Wrinkled carrier, inconsistent support, local bond damage, backing texture or uneven pressure	Stop; inspect product and support; verify on a controlled sample
Product loads or smears rapidly	Wrong coating or bond for the material, trapped debris, heat, contamination or exhausted product	Reassess construction and extraction; do not add pressure blindly

The table is diagnostic screening only. A damaged abrasive is not returned to service by trimming, gluing, flattening or reconditioning unless an approved manufacturer procedure explicitly allows it.

13. Practical example: controlled refinement of a stainless radius

A fabricator needs to blend a formed stainless radius without flattening the profile and then produce a controlled directional pre-finish. The team does not start with a brand or grit. It first defines a flexible contact requirement, segregated stainless tooling and a visible acceptance boundary.

For the blend stage, the team shortlists a flex-treated cloth product because the carrier must survive repeated bending and maintain contact through the radius. For refinement, it trials a supported film or light paper construction because dimensional stability and even grain presentation may improve scratch uniformity. These are hypotheses, not approvals.

The trial records exact products, backing and bond declarations, support-pad hardness, machine, speed, contact method, temperature signal, wear, edge condition and surface result. The chosen sequence is released only if both stages pass the technical, safety and quality criteria. A different radius, finish, machine or product revision reopens the selection.

14. Selecting the backing and bond in practice

Choose the backing for the required balance of conformity, edge stability, tear resistance and dimensional control. Paper and film can support fine, consistent finishing; cloth and polyester can provide flexibility and durability; vulcanised fibre depends on correct backing-pad support. The bond system must suit the work material, heat, loading tendency, moisture exposure and required product form.

Check wet-or-dry suitability, storage conditions, belt direction and joint construction, attachment method, and the required pad, platen, contact wheel or block. Inspect edges, joints and backing condition before use. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

15. Application setup record

For repeatable work, record the material and coating, geometry, required finish, abrasive identity, backing family and weight, bond system, product form, attachment, machine, support element, dimensions, rated speed, wet-or-dry status, storage condition, process setting, observed condition and inspection result.

ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 010

Abrasive Product Selection Matrix

10

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: Qualitative comparison of grinding wheels, flexible grinding discs, flap discs, fibre discs, ceramic-grain discs, sanding discs, non-woven discs, belts, mounted points, carbide burrs and polishing wheels. This chapter does not approve an MKTECH SKU, machine, speed, pressure, backing pad, contact wheel, compound, sequence, finish result, productivity claim or cost claim.

Safety-critical boundary — A matrix cell is not an operating instruction. The exact product, machine, guard, attachment, support element, dimensions, maximum operating speed, work material, work geometry and current manufacturer instructions must all be compatible. Stop for missing identification, damage, wrong support, uncertain stainless segregation or any condition outside the declared use. [S032]

Chapter objectives

After this chapter, the reader should be able to:

- separate a product family from its grain, grit, backing, bond and converted form;
- use removal, finish, flexibility, heat, edge, geometry, stainless, skill and cost criteria as screening questions;
- recognise where product families overlap and where comparison is not meaningful;
- choose a short list for a representative controlled trial; and
- record the technical basis for selecting an exact abrasive product.

1. What this matrix can and cannot decide

An abrasive family describes the architecture that presents a cutting or finishing medium to the work. It does not determine performance by itself. A coarse fibre disc, a fine non-woven disc and a bonded grinding wheel can all be circular, yet their support, contact, wear and surface effects differ. Conversely, ceramic abrasive grain may be supplied in a fibre disc, flap disc, belt or other coated format. “Ceramic disc” therefore means a **disc using ceramic abrasive grain or a shaped ceramic-grain technology**; it is not a separate attachment system. [S044; S047; S060; S061]

The matrix uses **screening tendencies**, not universal rankings. “High removal potential” means that suitable products in the family can be selected for stock removal. It does not mean every product in that family removes more material than every alternative. “Finish-led” means that the family is commonly selected for refinement or polishing, not that it produces a guaranteed roughness or appearance.

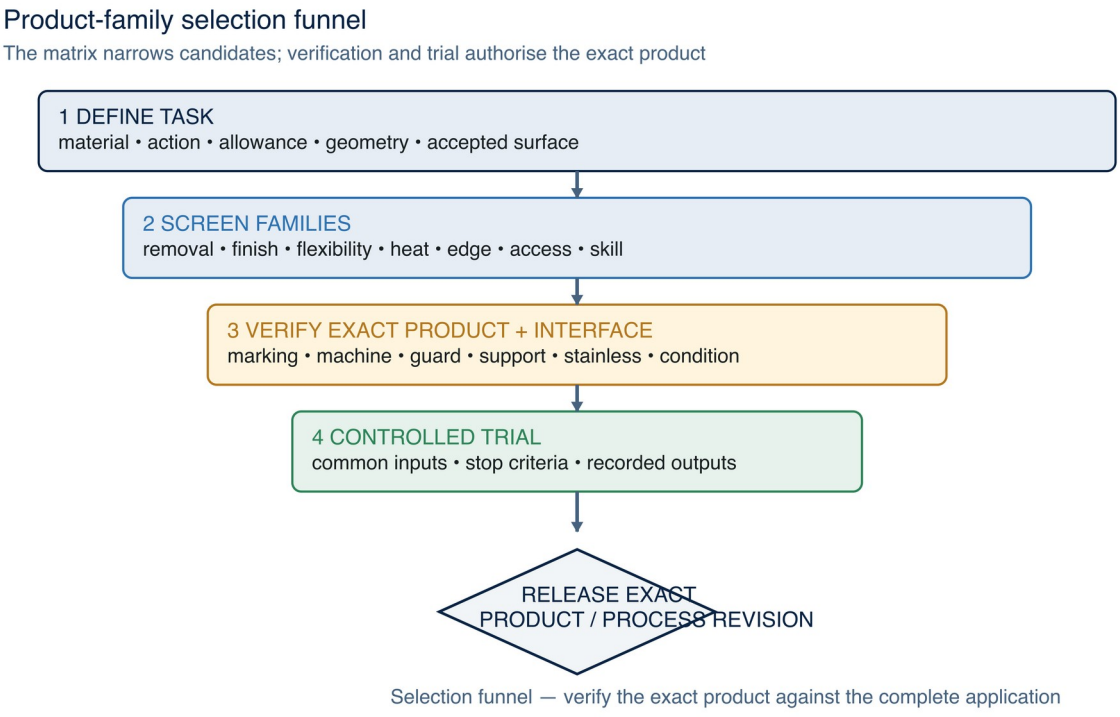

Figure 1. Product-family selection funnel. The matrix narrows the field before exact product verification and application confirmation.

2. Define the comparison task first

Do not compare unlike tasks. Record the following before using the matrix:

- work material, grade, hardness, coating and contamination controls;
- action required: cut, heavy remove, blend, deburr, clean, refine or polish;
- stock to remove and geometry that must remain;
- flat, edge, radius, bore, groove, fillet, tube or free contour;
- required texture, direction, roughness or visual standard;
- machine type, spindle, guard and available speed range;
- permitted support pad, platen, contact wheel, mandrel or arbor;
- wet-or-dry status, extraction and thermal limits;
- acceptable process time, changeover and consumable use; and
- operator competence, inspection method and stop criteria.

Complete these fields before using the matrix to select a product family.

3. Matrix key and interpretation rules

Term	Meaning in this chapter	Required verification
High / medium / low potential	Relative capability available within the family for the defined action	Exact grain, grit, construction, machine and trial result
Rigid / semi-flexible / flexible	How the working face can follow geometry when correctly supported	Product construction, support hardness, angle and permitted bend
Heat risk	Likelihood of harmful local heating under an unsuitable method; not a measured temperature	Material limit, contact time, pressure, speed, loading and cooling method
Edge durability	Ability of the complete product to retain a usable cutting face near an edge; not snag immunity	Product edge, pad or wheel support, angle, damage and work geometry
Stainless suitability	A candidate exists only when explicitly declared, segregated and contamination-controlled	Product marking, chemistry, tooling history and approved cleaning process
Relative cost	Must be assessed as cost per accepted part, metre, weld or area	Local price, life, cycle time, changeover, rework and disposal data

The words **conditional** and **product-dependent** are deliberate controls. They prevent a family-level table from being mistaken for a product specification.

4. Product-family identity and primary role

Product family	Working architecture	Primary role	Required interface
Grinding wheel	Bonded abrasive body; rigid or shaped wheel	Heavy stock removal, weld removal, shaping	Correct spindle, flange or hub, guard and declared working face
Flexible grinding disc	Thin flexible bonded or coated construction, product-specific	Controlled grinding or blending where some compliance is required	Declared pad or hub, guard and permitted angle
Flap disc	Overlapping coated-abrasive flaps fixed to a backing plate	Weld blending, stock removal and finish improvement	Correct Type 27/29 geometry, guard and working angle
Fibre disc	Coated abrasive on vulcanised-fibre backing	Fast right-angle stock removal and blending	Compatible backing pad, retainer and guard
Ceramic-grain disc	Disc format using ceramic or shaped ceramic abrasive grain	Product-dependent: from heavy removal to controlled refinement	The underlying disc format controls the pad, hub, guard and use
Sanding disc	Paper, cloth, film or other coated disc; PSA, hook-and-loop or quick-change variants	Sanding, defect removal, blending and finish preparation	Declared attachment and compatible support pad

Product family	Working architecture	Primary role	Required interface
Non-woven disc	Abrasive mineral distributed through an open synthetic-fibre web	Cleaning, blending, light deburring and surface conditioning	Declared attachment, support and product density
Belt	Continuous coated-abrasive loop	Stock removal, deburring, dimensioning or finishing over a contact element	Correct belt size and direction, tension, tracking, platen or contact wheel
Mounted point	Small bonded-abrasive shape on a shank	Bores, grooves, fillets, small radii, local deburring and blending	Correct collet, clamping depth, speed and unsupported length
Carbide burr	Toothed tungsten-carbide rotary cutter on a shank	Local machining, deburring, edge work and shape correction	Rigid collet and drive, correct cut, speed and controlled engagement
Polishing wheel	Cloth, felt, non-woven or other resilient wheel, with or without compound	Fine finishing, cosmetic refinement and polishing	Correct arbor, guard, wheel/compound system and speed

Grinding wheels, flap discs and fibre discs can overlap in right-angle weld-removal duties, but their construction and support requirements differ. Mounted points suit local geometries, chamfering and cleaning, while carbide burrs are rotary cutting tools selected by material and application. Abrasive belts can cover duties from stock removal through controlled finishing. [S055-S057; S059]

5. Removal, finish and thermal-response matrix

Product family	Removal-rate tendency	Finish-quality tendency	Heat-generation control
Grinding wheel	High potential for suitable heavy-duty products	Coarse to intermediate; usually followed by refinement when appearance matters	High risk if angle, pressure, loading or dwell is wrong; monitor work and wheel
Flexible grinding disc	Medium to high, construction-dependent	Intermediate; can blend more readily than a rigid wheel	Compliance can spread contact, but dwell and over-flexing still create heat
Flap disc	Medium to high; fresh coated abrasive is exposed as flaps wear	Intermediate to good, grit- and construction-dependent	Broad contact may moderate peaks, but capping, glazing and excess pressure add heat
Fibre disc	High short-duration potential with the correct pad	Coarse to intermediate; pad hardness changes the response	Efficient cutting can limit rubbing, but worn or loaded discs rapidly generate heat
Ceramic-grain disc	Potentially high when the exact grain and format are designed for cutting	Coarse through fine; “ceramic” does not set finish	Grain technology may cut efficiently, but cooler cutting is product- and condition-specific
Sanding disc	Low to medium; broad range by grit and backing	Intermediate to fine; strong candidate for scratch refinement	Loading, wrong pad, dwell and fine-grit rubbing can overheat thin work
Non-woven disc	Low to medium; generally not for dimensional stock removal	Good for blending, cleaning and controlled texture	Open web clears swarf, but pressure can collapse the web and increase friction
Belt	Low to high depending on machine, backing, grain and contact element	Coarse through fine with high process repeatability potential	Contact-wheel/platen hardness, speed, force, cooling and belt condition control heat
Mounted point	Medium local removal potential	Coarse to intermediate on small features	Small contact area creates high local heat risk; avoid dwell and loading
Carbide burr	High local removal potential with correct cut and engagement	Machined texture; fine cuts can refine but do not equal polishing	Sharp cutting can be efficient; chatter, wrong speed or excessive engagement raises heat and damage risk
Polishing wheel	Very low stock-removal intent	Fine to high-lustre potential within an approved sequence	Friction, compound loading and dwell can heat and smear the surface

Manufacturer tests may show one product outperforming another under stated conditions, but those results cannot be transferred to other diameters, grains, operators, materials or machines. Use comparative literature only to identify possible application roles, never as a universal speed, life or productivity ranking. [S055]

6. Geometry, flexibility, edge and operator-control matrix

Product family	Flexibility / edge behaviour	Flat-surface suitability	Curved or confined-surface suitability	Operator skill requirement
Grinding wheel	Rigid; durable face but edges and working angles are product-specific	Strong for accessible heavy removal; easy to dish or gouge if uncontrolled	Limited on gentle external contours; poor for deep confined features unless specially shaped	High for angle, pressure, profile preservation and thermal control
Flexible grinding disc	Flexible to semi-flexible; edge support is critical	Good for blending when uniformly supported	Good for shallow contours within declared bend	Medium to high; avoid edge snagging and over-flexing
Flap disc	Semi-flexible; plate stiffness and flap wear control conformity	Good for weld blending and broad accessible surfaces	Good for external radii and mild contours; limited in recesses	Medium; angle and pressure must expose abrasive without damaging flaps
Fibre disc	Pad-controlled flexibility; exposed disc edge needs care	Very good for accessible planar work with the correct pad	Good for shallow contours with suitable pad; poor for deep cavities	Medium; pad selection and disc-edge control are decisive
Ceramic-grain disc	Inherits flexibility and edge behaviour from its disc format	Product-dependent	Product-dependent	Product-dependent; do not infer from grain name
Sanding disc	Flexible with a soft pad; more stable with a firm pad	Very good for refinement and finish preparation	Good on broad curves; small quick-change forms suit local features	Medium; scratch progression and pad control matter
Non-woven disc	Compliant; resists loading by open structure but can round edges	Good for cleaning and blending without intended dimensional change	Very good on contours, transitions and irregular profiles	Low to medium for light work; pressure control is still required
Belt	Contact element sets rigidity; belt edges and joints are vulnerable to misuse	Excellent on platen-supported flat work	Excellent around contact wheels or slack sections when the belt is designed for it	Medium to high; tracking, tension, feed, edge and work support matter
Mounted point	Rigid small shape; good local access, fragile if side-loaded or overhung	Poor for broad flatness control	Excellent for bores, grooves, fillets and small radii	High; collet, runout, speed, contact and dwell require control
Carbide burr	Rigid toothed cutter; strong local edge capability but can grab or chatter	Poor for broad finish uniformity	Excellent for holes, contours, edges and local geometry	High; cut, direction, engagement and two-hand control are critical
Polishing wheel	Highly compliant to semi-rigid by wheel construction	Good for accessible faces if waviness and edge roll are controlled	Good for external contours; access depends on wheel diameter and profile	High for compound, pressure, direction, cleanliness and edge safety

Carbide-burr choice depends on material and application, requires a suitable rigid drive and clamping system, and relies on controlled contact rather than excessive engagement. Carbide burrs therefore offer strong local capability and demand operator skill, but provide limited control of broad flatness. [S056]

7. Stainless-steel suitability and contamination boundary

No family is automatically suitable for stainless steel. The complete product must be declared for the alloy and task, and tools must be segregated from carbon-steel contamination. A product sold for multiple materials is not clean after it has contacted carbon steel.

Screening question	Acceptable evidence	Stop condition
Is the exact product declared for stainless?	Current manufacturer product data and marking	Family name, colour or seller description only

Screening question	Acceptable evidence	Stop condition
Is the tool and support system segregated?	Identified storage, dedicated pad/wheel/brush and clean handling record	Unknown prior use or shared contaminated support
Is heat-tint and smear controlled?	Approved sequence, inspection and cleaning/passivation requirement	Uncontrolled colour, embedded debris or smeared surface
Is the finish functionally acceptable?	Drawing, sample, roughness/appearance criterion and inspection method	“Looks polished” without the required acceptance standard

Examples of manufacturer-declared stainless products exist among grinding wheels, fibre and flap discs, belts, mounted points, non-woven products and polishing systems. That establishes availability, not interchangeability. [S045; S055-S061]

8. Typical application shortlist

If the task is primarily…	Start the shortlist with…	Do not assume…
Remove a heavy accessible weld or large stock allowance	Grinding wheel, fibre disc, suitable flap disc or belt	The fastest initial cut gives the lowest total cost or best profile
Blend a normal weld into adjacent surface	Flap disc, fibre disc, flexible disc or belt	One stage will also produce the final specified finish
Refine scratches on a broad surface	Sanding disc, belt, structured/ceramic-grain disc or non-woven disc	Grit labels across systems are equivalent
Clean oxide, light corrosion, sealant or handling marks	Non-woven disc or a purpose-declared sanding/cleaning product	Cleaning is dimensionally neutral or contamination-free
Work a bore, groove, fillet or tight radius	Mounted point, carbide burr or small quick-change disc	A broad-face disc can be forced safely into the feature
Chamfer, deburr or correct a local edge	Carbide burr, mounted point, fibre/flap disc or belt depending on access	Edge contact is safe without declared support and direction
Produce a fine cosmetic or reflective finish	Fine sanding/structured abrasive, non-woven stage and polishing wheel in a validated sequence	A polishing wheel will remove deep defects or produce a specified roughness by itself

This shortlist is a hypothesis generator. The final choice depends on the exact product construction and the controlled trial.

9. Relative cost: use cost per accepted output

Unit price is not relative process cost. A lower-priced abrasive can cost more if it cuts slowly, changes frequently, distorts the work or creates rework. A higher-priced product can still be uneconomic if its potential is not realised on the available machine.

Use one consistent basis:

Cost per accepted output = abrasive consumption + labour time + changeover + machine time + rework + inspection + disposal.

Record the numerator and denominator: per accepted part, metre of weld, square metre or defined batch. Include rejected work. Compare candidates only under the same material, geometry, operator method, machine condition and acceptance criterion. Use “low/medium/high cost” only when supported by measured results for the stated application.

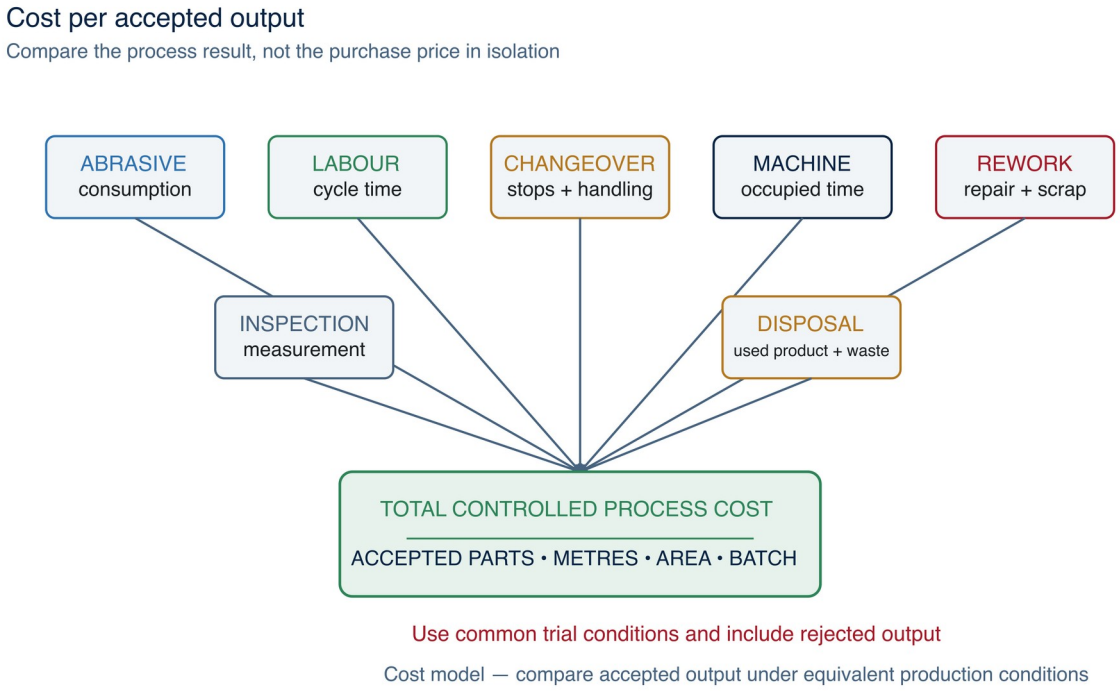

Figure 2. Cost-per-accepted-output model. Purchase price is one input; service life, cycle time, changeover, rework and scrap determine the complete production cost.

10. Controlled selection workflow

116. Define material, geometry, action, removal allowance and accepted surface.
117. Eliminate families that cannot reach the feature or maintain the geometry.
118. Eliminate products without a complete compatible machine and support system.
119. Verify current manufacturer use, safety, stainless and storage information.
120. Shortlist two or three exact products, not generic families.
121. Trial them on representative work with fixed inspection and stop criteria.
122. Record removal, surface, temperature signal, wear, changeover, defects and operator observations.
123. Calculate cost per accepted output and approve the exact product/process revision.

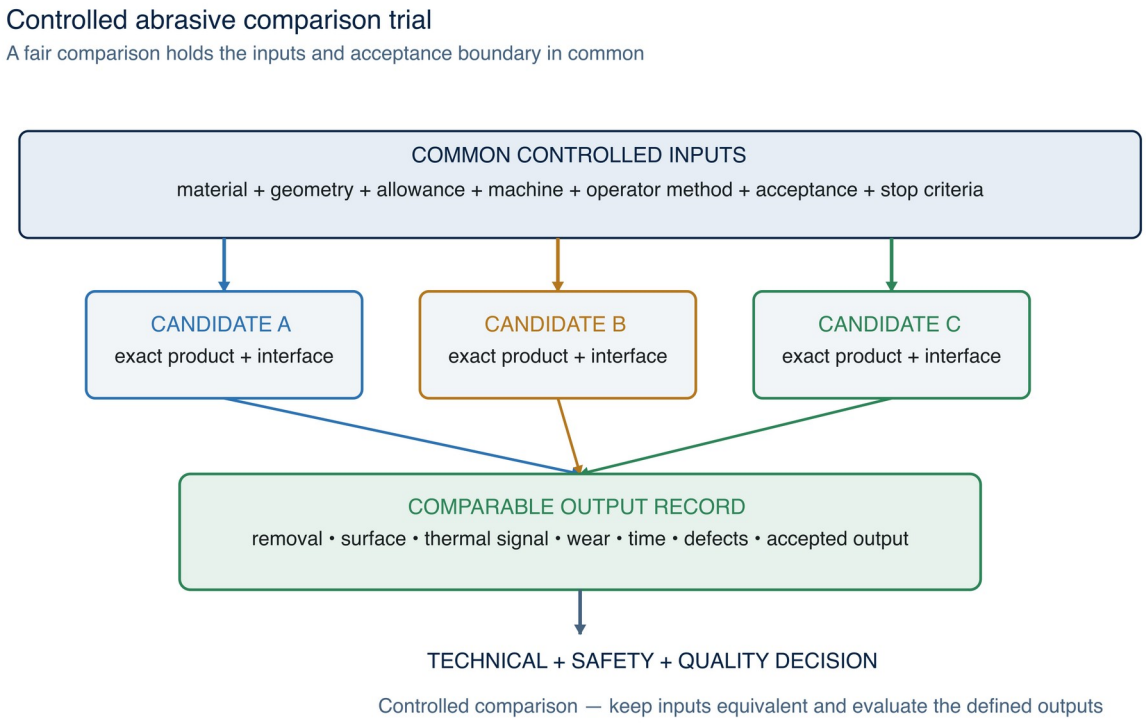

Figure 3. Controlled product comparison. Hold the relevant inputs constant and compare the candidates against the same acceptance criteria.

11. Failure signals that invalidate the comparison

Signal	Why the result is invalid	Required response
Different material, weld size, access or operator method	Candidate results are not on a common basis	Repeat with controlled representative work
Wrong pad, platen, contact wheel, collet or guard	Product architecture is not being tested as declared	Stop and correct the interface
Loaded, glazed, damaged, curled or contaminated abrasive	Heat, cut, finish and life no longer represent normal use	Remove from service; investigate product and storage
Workpiece colour, smear, gouge, edge roll or dimensional loss	Acceptance boundary has been crossed	Stop; quarantine work and review the sequence
Different change-out criteria	Life and cost comparison is biased	Define one approved end-of-life rule
Unrecorded speed, pressure, time or cooling	Performance cannot be reproduced	Treat result as exploratory only

12. Practical example: stainless weld blend and directional finish

A fabricator must level a stainless weld on a formed enclosure and reproduce the surrounding directional finish. The geometry includes a broad face and a shallow external radius. The team first separates the task into **level**, **blend** and **refine** stages.

For levelling, it shortlists an explicitly stainless-suitable fibre disc with the declared pad and a flap disc with a compatible geometry. A grinding wheel remains an option only where removal allowance and profile risk justify it. For the radius, the team evaluates the conformity of the pad or flap construction. For refinement, it shortlists a sanding or structured-abrasive disc followed, if necessary, by a non-woven product that matches the directional texture. A polishing wheel is excluded because a reflective finish is not the acceptance target.

Each candidate is trialled on representative coupons. The record captures exact product identity, settings, contact method, time, disc consumption, temperature signal, edge condition, visual direction and measured requirement where applicable. The team releases the sequence with the lowest controlled cost per accepted enclosure—not the lowest disc price or the fastest single pass.

13. Product-family selection in practice

Shortlist the product family by the action required: cutting, heavy removal, weld levelling, blending, scratch refinement, deburring or polishing. Then check material suitability, geometry and access, machine and mounting interface, finish target, contamination control and operator exposure. Select for the complete accepted result rather than maximum removal or lowest unit price alone.

Use a representative comparison when more than one family is suitable. Keep the workpiece, machine, contact method and inspection consistent, and compare removal, heat, finish, geometry, product condition, rework and cost per accepted output. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

14. Selection and comparison record

For a repeatable comparison, record work material and condition, geometry, action, allowance, required finish, product family, exact product code, grain and grit system, backing/bond or cut, attachment, support element, machine, guard, dimensions, rated speed, actual setting, contact method, wet-or-dry status, stainless segregation, inspection result, change-out point, cycle time, consumable use, rework and cost per accepted output.

ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 011

Grinding Machines and Power Tools

11

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, maintenance teams, safety personnel, QA/QC personnel, procurement staff, automation engineers and technical sales personnel

Scope: Angle, straight, die, bench, pedestal and belt grinders; automated and robotic grinding systems; pneumatic, electric and variable-speed drives; and the control of power, torque, RPM, spindle, diameter, guarding, flanges, vibration, maintenance and machine-product compatibility. This chapter does not approve an MKTECH machine, abrasive SKU, operating speed, pressure, air setting, power rating, guarding arrangement, robot path or production result.

Safety-critical boundary — A machine name or power rating is not permission to mount an abrasive. Verify the complete machine, abrasive product, dimensions, spindle or collet, flange or support element, guard, maximum permitted speeds, energy supply, work material, operation and current instructions. Isolate energy before adjustment or maintenance. Stop for missing identification, damaged parts, abnormal vibration, incorrect guard or interface, uncontrolled dust/sparks, unstable workholding or any condition outside the declared use. [S032; S063; S069]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish the main grinder and power-tool families by load path and access;
- interpret power, torque and RPM without treating any one value as performance proof;
- verify spindle, collet, flange, pad, contact wheel, diameter and guard compatibility;
- compare electric, pneumatic and variable-speed drive implications;
- recognise vibration and maintenance as system-control issues;
- separate automated machinery from a validated robotic grinding cell; and
- create a controlled machine-product compatibility record.

1. The machine is one part of the abrasive system

A grinding result is created by a chain: energy supply, motor, transmission, spindle, mounting interface, abrasive product, contact zone, work support, extraction and operator or automation control. A strong motor cannot correct a wrong flange. Variable speed cannot make an unapproved product safe. A robot cannot compensate for an unstable process unless the cell is designed, sensed, guarded and validated for the variation.

Machine selection should therefore begin with the task: material, action, stock allowance, geometry, access, accepted surface, production volume and hazards. It then narrows through machine architecture and interface before any exact abrasive is released.

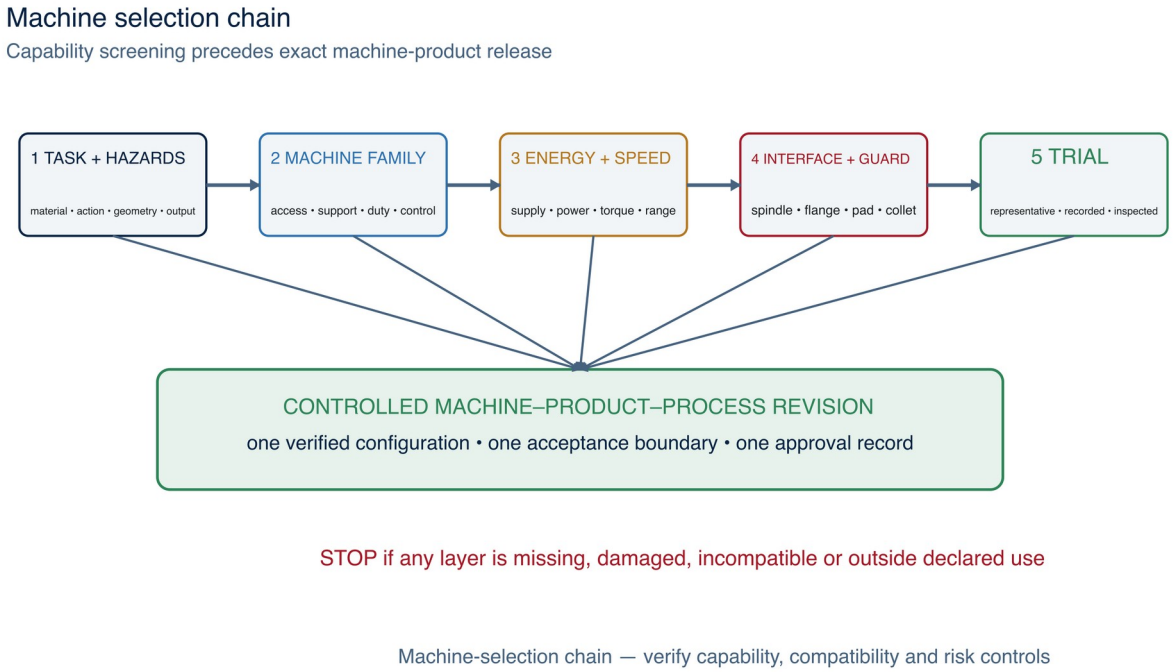


Figure 1. Machine-selection chain. Capability screening is followed by interface verification, risk control and application confirmation.

2. Machine-family comparison

Machine family	Characteristic load path and access	Typical controlled role	Principal verification points
Angle grinder	Motor axis turns through a right-angle head to a side-access spindle	Cutting, grinding, blending, sanding and conditioning on accessible faces and edges	Product type, diameter, spindle thread, backing pad/flange, side handle, guard type, speed and working face
Straight grinder	Motor and spindle share a common axis; larger or slower arrangements may carry wheels or arbors	Straight-line access, internal or external grinding, deburring and polishing	Arbor or spindle, wheel/flange arrangement, guard, overhang, balance and rated speed
Die grinder	Compact straight or angle head, usually using a collet and small shank-mounted tool	Bores, grooves, fillets, radii, moulds, local deburring and shape correction	Collet size and condition, shank, clamping depth, unsupported length, runout, speed and engagement
Bench grinder	Fixed machine mounted to a bench; operator presents the work to the wheel	Tool-room grinding, deburring and controlled offhand work	Wheel and flange, guard, tongue/spark control, work rest, mounting, wheel condition and work support
Pedestal grinder	Floor-mounted fixed grinder, often larger or more heavily used than a bench unit	Foundry, fabrication and maintenance grinding with supported work	Foundation, wheel/flange, guard openings, adjustable work rest, extraction, work handling and exposure time
Belt grinder	Endless abrasive belt runs over drive/idler wheels and a platen, contact wheel or slack section	Stock removal, weld blending, flat finishing, edge work and contour finishing	Belt size/direction, tracking, tension, platen/contact wheel, guarding, dust collection, speed and work support
Automated grinding machine	Purpose-built machine executes a defined cycle with controlled work and tool motion	Repetitive stock removal, edge finishing or surface generation	Machine guarding, interlocks, workholding, axes, tool wear compensation, inspection, hazardous energy and change control

Machine family	Characteristic load path and access	Typical controlled role	Principal verification points
Robotic grinding system	Programmable robot moves the part or abrasive within an integrated cell	Variable geometry, multi-face processing, deburring, blending and finishing	Risk assessment, payload, reach, stiffness, end-of-arm tooling, force/vision sensing, ancillary equipment, guarding, interlocks and validated program

These families overlap. A right-angle machine may drive a bonded wheel, flap disc, fibre disc or non-woven product, but each format can require a different guard and support. A belt grinder may be hand-guided, fixed or integrated into a robot cell. Select by the complete configuration, not the family label.

3. Power, torque and RPM

Power describes the rate at which mechanical work can be delivered. **Torque** is rotational turning effort. **RPM** describes rotational speed. In an ideal rotating system, mechanical power equals torque multiplied by angular speed. Real machines also have losses, controls and thermal limits.

Three controls follow:

124. A higher input-power number does not establish greater abrasive removal on the work. Transmission efficiency, available torque under load, product geometry, contact area, abrasive sharpness and operator control all intervene.
125. No-load RPM is not the same as speed under grinding load. Excessive speed drop may indicate overload, insufficient supply, a worn machine or an unsuitable process; the response is to stop and diagnose, not press harder.
126. Product speed compatibility is a safety boundary. The machine's possible speed must not exceed the abrasive product's maximum permitted speed, and the product must also be suitable for the intended operating range and diameter. [S032; S063]

Abrasive surface speed also changes with diameter. At the same RPM, a larger diameter produces a higher peripheral speed. As a wheel wears smaller, peripheral speed falls unless an approved controlled-speed system compensates. Motor speed, wheel wear and abrasive change are therefore linked factors in automated abrasive performance. [S070]

4. Variable speed: a controlled process window

Variable speed is useful when approved products or process stages require different operating ranges. It can help manage smaller diameters, heat-sensitive finishing stages, brushes, pads and other product-specific needs. It does not authorise low-speed use of a product whose stability, support or cutting behaviour is unsuitable there.

An angle-grinder specification normally includes rated input power, declared no-load speed range, spindle interface and the specified guard, flange and handle. These characteristics must be checked on the exact machine rather than generalised across angle grinders. [S066]

For each released stage, record:

- the machine identity and available speed range;
- the exact abrasive product and permitted speed range;
- diameter and resulting interface configuration;
- approved selected setting and method of verification;
- response under normal load;
- material, geometry and thermal/finish acceptance; and
- who authorised the revision.

5. Spindle, collet, flange and support compatibility

Mounting components transmit torque and position the product. They are safety-critical machine parts, not generic accessories.

Interface	Required match	Common invalid assumption
Threaded spindle or hub	Thread form, diameter, direction, seating face, product type and manufacturer instructions	“It threads on, so it fits”
Collet and shank	Nominal sizes, clean undamaged surfaces, insertion/clamping requirement, runout and permitted overhang	Tightening can correct a worn collet or undersized shank

Interface	Required match	Common invalid assumption
Wheel flanges	Correct matched pair, diameter, relief, seating surfaces, blotters where required and tightening method	Any washer or nut can replace the specified flange
Backing pad	Product diameter, attachment, hardness/flexibility, rated speed, centre system and guard clearance	A softer or harder pad changes only comfort
Belt contact element	Belt size, tracking/tension range, platen/contact-wheel geometry and speed	The belt alone determines flatness or conformity

OSHA's abrasive-wheel rule requires grinding machines within its scope to use specified safety guards and flanges, and it treats work rests and exposure openings as controlled features. FEPA likewise places dimensions, maximum operating speed, machine condition and correct mounting at the centre of abrasive safety. Local Malaysian applicability must be confirmed against current law and the employer's risk controls. [S032; S062; S063]

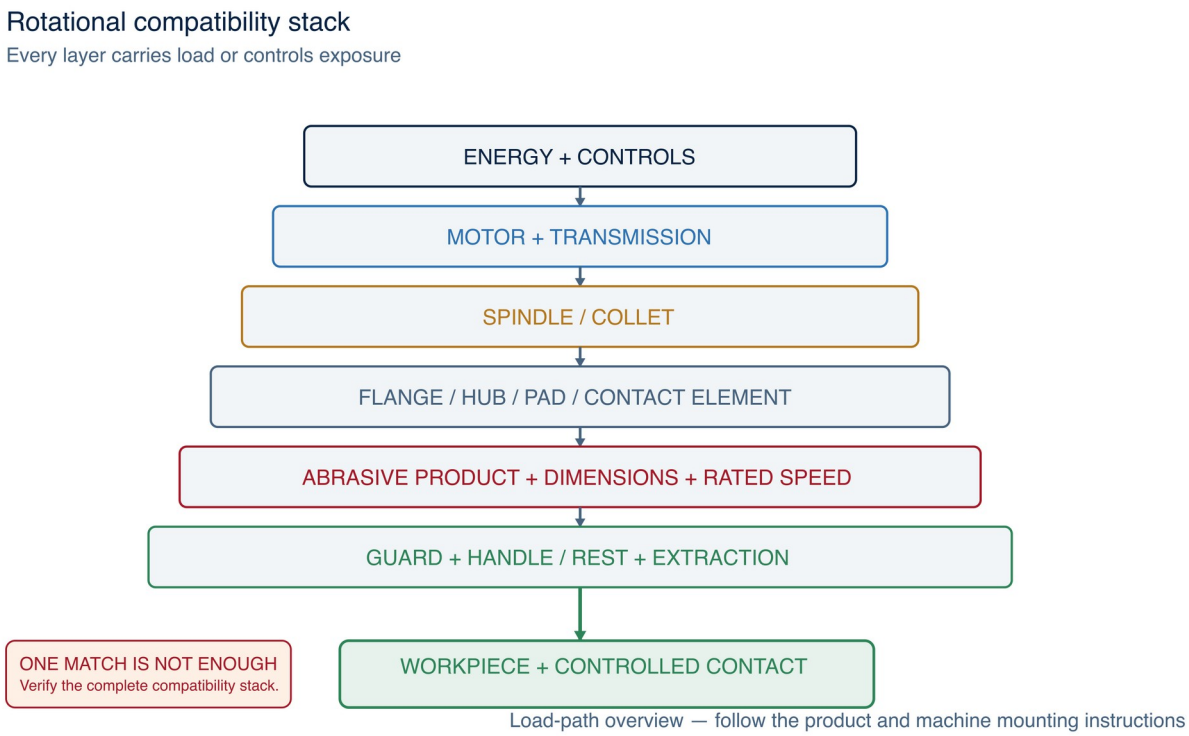


Figure 2. Rotational compatibility stack. Verify every layer of the machine, mounting system and abrasive assembly; one matching dimension is insufficient.

6. Guarding, flanges and fixed-machine work support

A guard must be the type and configuration required for the machine, abrasive and operation. It should be correctly aligned, securely mounted and positioned so the intended working area is available without exposing more of the product than allowed. A spark shield, visor or extraction hood does not automatically replace an abrasive-wheel guard.

For bench and pedestal grinding, the work is presented to the rotating wheel. The work rest therefore controls support and the gap where work could become trapped. OSHA 1910.215 specifies a closely adjusted, securely clamped rest and prohibits adjustment while the wheel is moving; it also controls guard exposure and flange arrangements. These numeric US provisions are not copied into an MKTECH operating instruction. The exact current Malaysian requirement, machine manual and site risk assessment govern local use. [S063]

Stop the fixed machine when:

- the wheel, belt, flange, guard, rest or mounting is damaged or uncertain;
- the rest, guard opening or contact element cannot be maintained as required;
- tracking, runout, noise or vibration changes;
- work cannot be held and supported without the hands entering the hazard zone;
- sparks, dust or fragments are not contained and extracted; or

- isolation cannot prevent unexpected start or stored-energy movement.

7. Electric and pneumatic drives

The choice between electric and pneumatic drive is a system choice, not a universal ranking.

Drive	Useful considerations	Dependencies and controls
Corded electric	Continuous supply without battery change; broad power and speed-control options	Rated supply, cable/plug condition, electrical protection, restart control, overload behaviour and dust/environment suitability
Battery electric	Mobility and no trailing mains cable at the contact area	Approved battery/tool system, charge state, thermal control, restart behaviour, battery damage and task duration
Pneumatic	Compact power unit, high speed options and suitability for established compressed-air systems	Pressure and flow at the tool, hose/coupling size, filtration, water control, lubrication where required, exhaust, noise and compressor capacity

Pneumatic grinder performance depends on regulated air pressure, supply condition and lubrication requirements. Straight and die grinders also differ by speed, collet, inlet and hose characteristics. Verify every field at the exact tool rather than generalising across pneumatic machines. [S067; S068]

For either energy source, a falling speed under load does not justify additional force. Check the process demand, product condition, supply, filters, cables, batteries, air lines and tool maintenance against current instructions.

8. Vibration and operator exposure

Vibration is both a health exposure and a condition signal. HSE identifies hand-held grinders, sanders and pedestal grinding among processes that can expose hands and arms to vibration. Its control guidance prioritises alternative methods, suitable efficient lower-vibration equipment, maintenance, workstation design, training and exposure-time management. It warns that unsuitable or under-powered equipment can prolong the job and exposure. [S064; S065]

Do not compare declared emission numbers as if they guarantee actual exposure. Work material, abrasive balance, product wear, bearings, contact force, posture, grip, duty cycle and maintenance affect the task. A changed vibration signature can indicate damage, imbalance, runout, loose mounting, bearing wear, incorrect contact or belt-tracking problems.

The controlled response is:

127. Stop for sudden or unexplained vibration, noise or handling change.
128. Isolate the machine and inspect the permitted items.
129. Quarantine damaged or uncertain abrasive and mounting parts.
130. Correct the process or arrange competent maintenance.
131. Reassess exposure and health-surveillance requirements through the employer's occupational-safety system.

9. Maintenance and pre-use control

Maintenance preserves both safety and process capability. HSE recommends appropriate maintenance to prevent avoidable vibration increases and to keep consumables efficient. [S065]

Before use: confirm machine identity, controls, guard, handle, spindle/collet/flanges, support element, supply, cables/hoses, extraction, workholding and abrasive condition. Perform only the checks authorised by the machine and product instructions.

During use: monitor speed response, vibration, noise, temperature signals, tracking, sparks, dust, workpiece stability and surface condition. Do not defeat a guard, interlock, restart control or extraction device to continue production.

After use: isolate energy, allow rotation to stop, clean by an approved method, inspect for damage, record defects and store the tool and abrasive to prevent contamination and impact.

Planned maintenance: use competent personnel, manufacturer intervals, approved parts and recorded post-maintenance verification. Maintenance must cover safety functions as well as bearings, brushes, lubrication, air treatment, belts, cables, guards and fasteners.

10. Automated machines and robotic grinding cells

Automation repeats a process; it does not automatically make the process controlled. A purpose-built automated machine generally constrains axes, tooling and workholding around a defined cycle. A robot offers programmable reach and

orientation but requires an integrated cell whose risks, payload, stiffness, sensing, tooling and safeguards are designed together.

OSHA's robotics guidance points to machinery guarding, hazardous-energy control and industrial-robot risk assessment and safeguarding standards. Cell design must also address ancillary equipment, payload, motor power and speed, abrasive change, sequence, dust collection, force control, re-gripping and operator safety. [S069; S070]

Force control can help manage part and abrasive variation, but it is not a substitute for stable workholding or an approved process window. Vision may locate or inspect parts; temperature sensing may support heat control. Each sensor requires defined accuracy, failure response and validation.

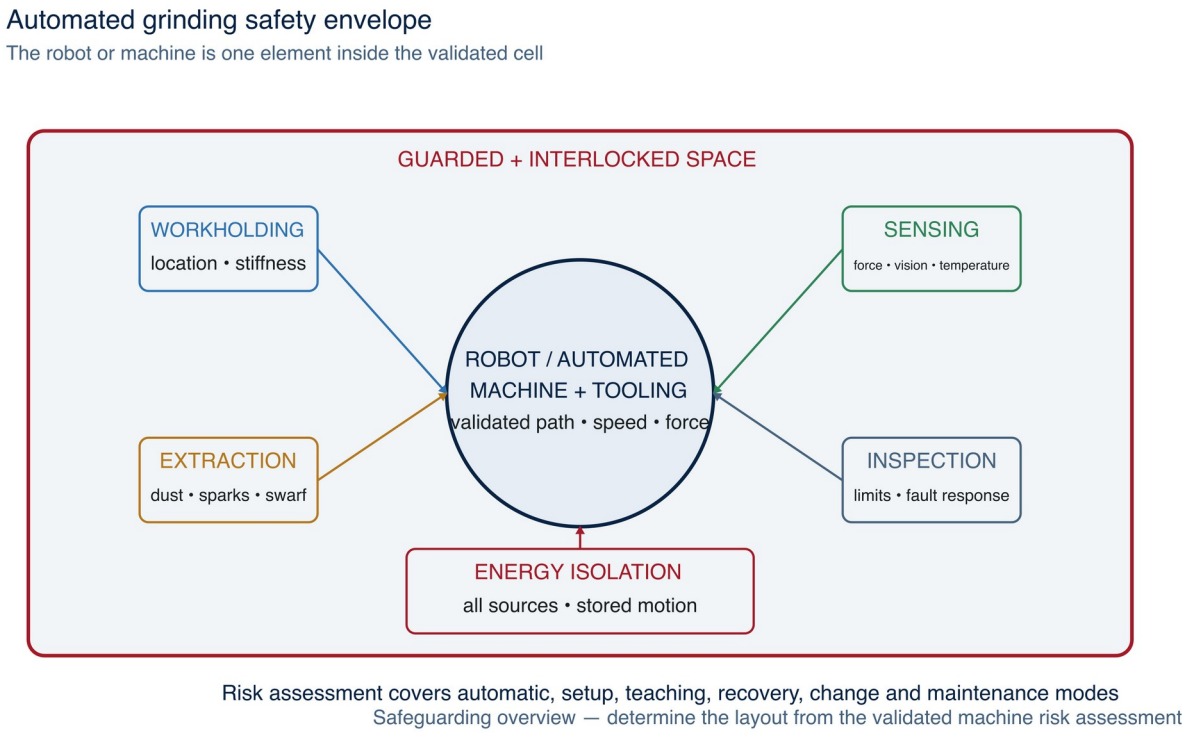


Figure 3. Automated-grinding safety envelope. The robot or machine operates within a guarded, interlocked and validated process that also controls tooling, workholding and access.

Cell release must include:

- risk assessment for automatic, setup, teaching, recovery, abrasive change, cleaning and maintenance modes;
- safeguarded space, access control, interlocks, emergency stops and safe restart;
- hazardous-energy isolation for every energy source and stored motion;
- validated payload, reach, speed, path, stiffness, force and workholding;
- abrasive identity, wear/change rule and machine-product compatibility;
- extraction, spark, fire, swarf and noise controls;
- inspection method, process limits and fault response; and
- controlled program, tooling and parameter revision history.

11. Machine-product compatibility workflow

132. Define the material, action, geometry, access, allowance and accepted output.
133. Select a machine architecture capable of reaching and controlling the contact zone.
134. Verify energy supply, power/torque behaviour and approved speed range under the task.
135. Match exact product type, dimensions, rated speed and intended working face.
136. Match spindle/collet, flange/hub/pad/contact element and permitted mounting method.
137. Match guard, handle, rest, workholding, extraction and environment controls.
138. Inspect machine, interface and abrasive condition; stop for uncertainty.
139. Conduct a representative trial with defined load, exposure and acceptance limits.
140. Record results and release one controlled machine-product-process revision.

12. Troubleshooting by system signal

Signal	Possible system causes	Controlled response
Speed collapses under normal contact	Excess load, unsuitable abrasive, weak supply, blocked air path, low battery, motor or transmission fault	Stop; verify task, supply and tool condition; do not add pressure
Vibration or noise changes	Damage, imbalance, runout, loose mounting, worn bearing, belt tracking or unstable work	Isolate; quarantine uncertain parts; inspect and maintain
Repeated guard or rest interference	Wrong product, diameter, flange, pad, guard or setup	Stop; correct the complete approved configuration
Heat or finish drifts	Worn/loaded abrasive, changed speed/force/contact, weak extraction/cooling or work variation	Hold output; restore the controlled process and revalidate
Robot path or force becomes inconsistent	Part location, workholding, tool wear, payload, sensor, program or mechanical stiffness change	Stop cell; enter controlled recovery; inspect revision and sensing

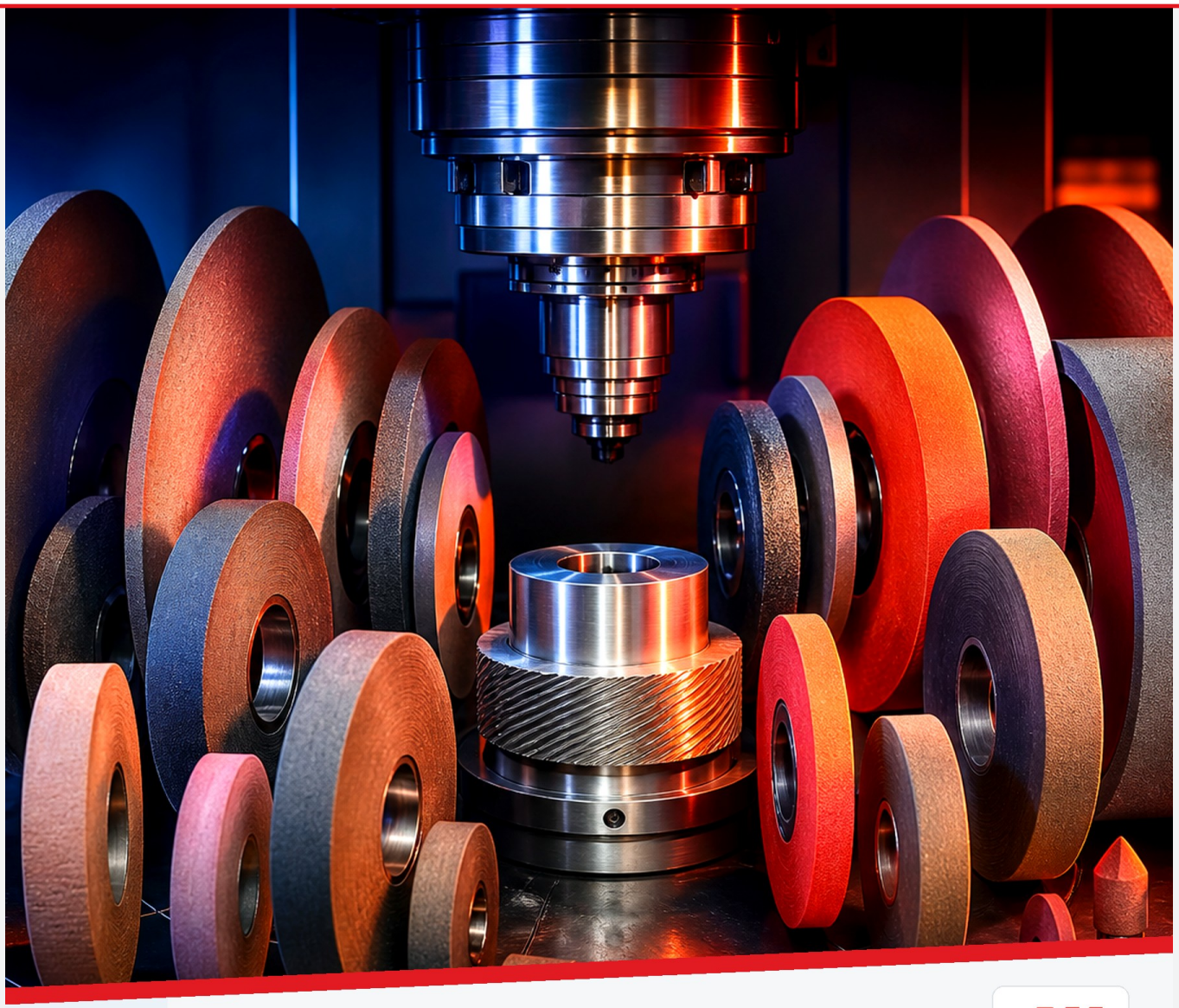
13. Pairing the machine and abrasive in practice

Treat the machine, abrasive and mounting system as one assembly. Confirm the machine type, spindle or collet, speed range, permitted diameter, guard, flanges, hub, backing pad or contact element, power source and current condition. The abrasive must be declared for the intended operation and every interface must match without improvised adapters.

For pneumatic tools, verify regulated pressure, flow, hose and lubrication requirements; for electric tools, verify supply, cable or battery condition and restart control. Investigate abnormal vibration, speed loss, heat or noise before continuing. Follow the current machine instructions. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

14. Machine-product setup record

For repeatability and maintenance traceability, record the task, material, geometry, machine model or asset number, energy source, power, speed range and selected setting; spindle or collet; flange, hub, pad or contact element; product code, type, dimensions and rated speed; guard, handle, rest or workholding; extraction; vibration information; inspection status; maintenance revision; operator or automation program; and output inspection result.



ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 012

Grinding-Wheel Selection

12

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, maintenance teams, safety personnel, QA/QC personnel, procurement staff and technical sales personnel

Scope: Bonded grinding wheels selected by diameter, thickness, centre type, bond grade, grain, grit, reinforcement, maximum permitted speed, application geometry, material suitability, contact load, expiry and storage. This chapter does not approve an MKTECH wheel, machine, operating speed, angle, pressure, material result or shelf-life rule.

Safety-critical boundary — Select and mount only an identified wheel whose product type, dimensions, centre, reinforcement, maximum permitted speed, material/application declaration, mounting parts, guard and current instructions match the machine and operation. Do not use a wheel that is damaged, altered, unidentifiable, expired where an expiry applies, improperly stored or outside its declared use. [S032; S063; S072; S073]

Chapter objectives

After this chapter, the reader should be able to:

- read a grinding wheel as a complete controlled specification;
- distinguish diameter, thickness, centre and reinforcement functions;
- explain grain, grit and bond grade without treating them as independent rankings;
- verify maximum permitted speed against the machine;
- screen material, application geometry and contact load;
- control expiry, storage, stock rotation and quarantine; and
- create a minimum wheel-selection record.

1. A wheel name is not a specification

“Grinding wheel” describes a broad product form. Two wheels with the same diameter can differ in thickness, centre geometry, abrasive grain, grit, grade, bond, structure, reinforcement, mounting arrangement, speed rating and declared application. Colour is not a reliable cross-manufacturer code.

Start with the task: material, feature, stock allowance, access, required geometry, accepted surface and hazards. Then verify the wheel form, machine interface and declared use. Exact selection ends only after a representative controlled trial and approval.

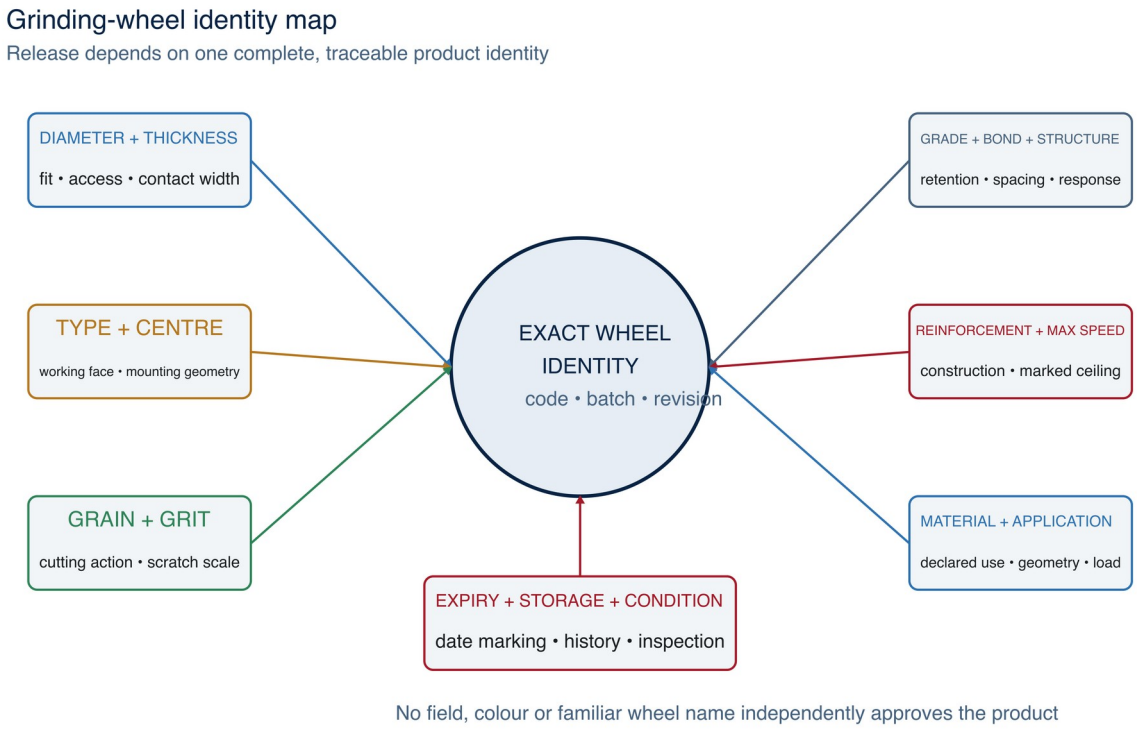

Figure 1. Grinding-wheel identity map. Read the complete marking set as one product identity before selection and use.

2. Diameter, thickness and centre type

Field	What it controls	Invalid shortcut
Outside diameter	Guard fit, machine capacity, peripheral speed and access	“A smaller wheel is always interchangeable”
Thickness	Contact width, stiffness, stock-removal behaviour, clearance and flange support	“Thicker always means stronger or faster”
Centre/bore type	Mounting geometry, flange/hub arrangement and wheel orientation	“If the bore fits, the wheel is approved”
Wheel shape/type	Working face, approach geometry and mounting system	“All bonded wheels can grind on the side”

A depressed-centre wheel creates mounting clearance for right-angle grinding. A straight wheel, cup wheel or dish wheel carries a different load path and requires its declared machine, guard, flange and working face. Wheel types must not be improvised by adding washers, adapters or altered flanges.

Diameter also changes peripheral speed at a given RPM. The machine’s possible speed, wheel diameter and wheel maximum permitted speed must therefore be verified together. [S032; S063; S073]

3. Reinforcement and wheel construction

Reinforcement is an engineered part of some resin-bonded wheels. It supports the declared product design and intended loading, but it does not make every surface or operation permissible. The location, number and type of reinforcing layers are manufacturer-controlled design features.

Do not infer reinforcement from colour, thickness or appearance. Do not expose, trim, drill, reshape or repair a bonded wheel. A product marketed for combined cutting and grinding must be identified as such; a cutting wheel is not automatically approved for side grinding.

A Type 27 grinding-wheel specification should separately identify wheel construction, reinforcement, centre hole, declared applications, material coverage and maximum operating speed. Check every field on the exact wheel being selected. [S073]

4. Grain, grit and bond grade work together

The abrasive grain performs the cutting. Grit describes nominal grain-size classification. Bond holds the grains in the wheel. Grade describes the bond’s relative holding power; it is not the hardness of the abrasive grain itself.

Selection field	General screening tendency	What prevents a universal rule
Grain family	Different fracture and chemical behaviours suit different materials and duties	Exact grain blend, bond and product design control actual response
Coarser grit	Larger chip space and stronger stock-removal tendency	May increase scratch depth, force and edge damage
Finer grit	Smaller scratch scale and finish-development tendency	Can load, rub or generate heat if the system is unsuitable
Softer grade	Releases dull grain more readily	May wear rapidly or lose form
Harder grade	Retains grain and form longer	May glaze or burn if dull grain is not released

oSa explains that coarser grits generally support rough grinding while finer grits support higher surface quality. It also distinguishes grit size from wheel hardness and notes that harder work materials commonly call for a softer bond response. Grain, grit, grade, structure and bond must be considered as related specification factors. These are screening principles only; exact wheels require product data and representative trials. [S071; S072; S075]

5. Material suitability is a declared property

Material suitability is not established by wheel colour, a generic grain name or successful use on another job. Obtain the exact manufacturer declaration for the substrate and application.

For stainless steel, confirm that the exact wheel is declared suitable and that contamination-control requirements are met. For aluminium and other non-ferrous materials, loading, heat and reactive-dust hazards require a product specifically

intended for the material and a suitable extraction/fire-control assessment. For masonry, concrete and stone, confirm the wheel and machine are intended for mineral materials and control silica exposure.

Mixed-material use can transfer contamination and invalidate surface acceptance. Segregate and identify wheels where the process requires it.

6. Maximum RPM is a ceiling, not a target

The wheel's marked maximum permitted speed must be greater than or equal to the machine's maximum possible speed for the fitted diameter and configuration. The operator does not "average" two ratings or rely on normal loaded speed. Variable-speed control does not justify mounting a wheel that is incompatible with the machine's possible speed or declared operating range.

The abrasive maximum operating speed must be at least the machine's maximum spindle speed, and the specified guard must suit the wheel type and size. OSHA and FEPA separately address machine guarding, mounting and speed compatibility. [S032; S063; S073]

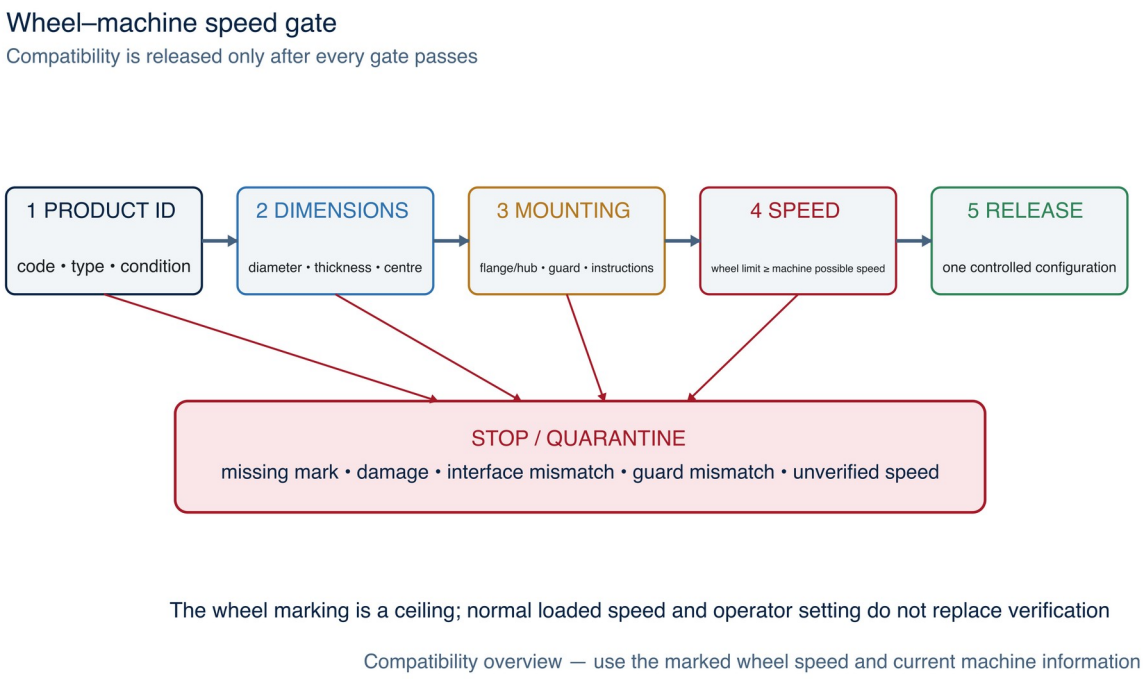

Figure 2. Wheel–machine speed gate. Verify product identity, diameter, centre, mounting, guard and marked maximum operating speed before releasing the configuration.

Stop when the wheel marking is missing, unreadable or contradictory; the machine speed cannot be verified; an adapter changes the approved interface; or the wheel/guard combination does not match current instructions.

7. Application angle and grinding pressure

Application angle determines which part of the wheel contacts the work and how load is distributed. Exact angles belong to the identified wheel type and manufacturer instructions; Chapter 013 will explain contact-area effects with original diagrams. This chapter does not prescribe one universal angle.

Pressure is likewise a process variable, not an operator-strength test. Too little effective load can encourage rubbing and glazing; excessive load can stall the machine, overheat the contact, damage the work, accelerate wheel wear or overload the wheel and operator. The acceptable range depends on wheel design, machine power/torque, contact area, material, geometry and cooling/extraction.

Product, machine, contact geometry and applied load must be validated as one operating system. Never transfer pressure or performance expectations from a different wheel construction or test condition. [S073]

8. Expiry, shelf life and storage

“Bonded wheel” does not imply one universal expiry rule. Resin-bonded hand-held wheels may carry a use-by date under the manufacturer’s applied safety standard. Other wheel families can have different manufacturer recommendations. Never replace a marked date with a generic handbook interval.

oSa states that expiry marking applies to specified resin-bonded tools for hand-held machines under EN 12413 and explains dry, frost-free, stable storage in original packaging on a flat surface. Moisture can reduce resin-bonded wheel strength. The exact marked date and current manufacturer instruction control the product. [S072; S074]

Control stock by:

141. recording manufacturer, product code, batch/lot and date markings at receipt;
142. inspecting packaging and wheels for impact, moisture, distortion and contamination;
143. storing by wheel type in the original packaging with suitable support;
144. maintaining dry, stable environmental conditions required by the manufacturer;
145. issuing by earliest valid use-by date or approved first-in/first-out rule;
146. quarantining expired, damaged, wet, dropped, altered or unidentifiable wheels; and
147. documenting disposition through an authorised process.

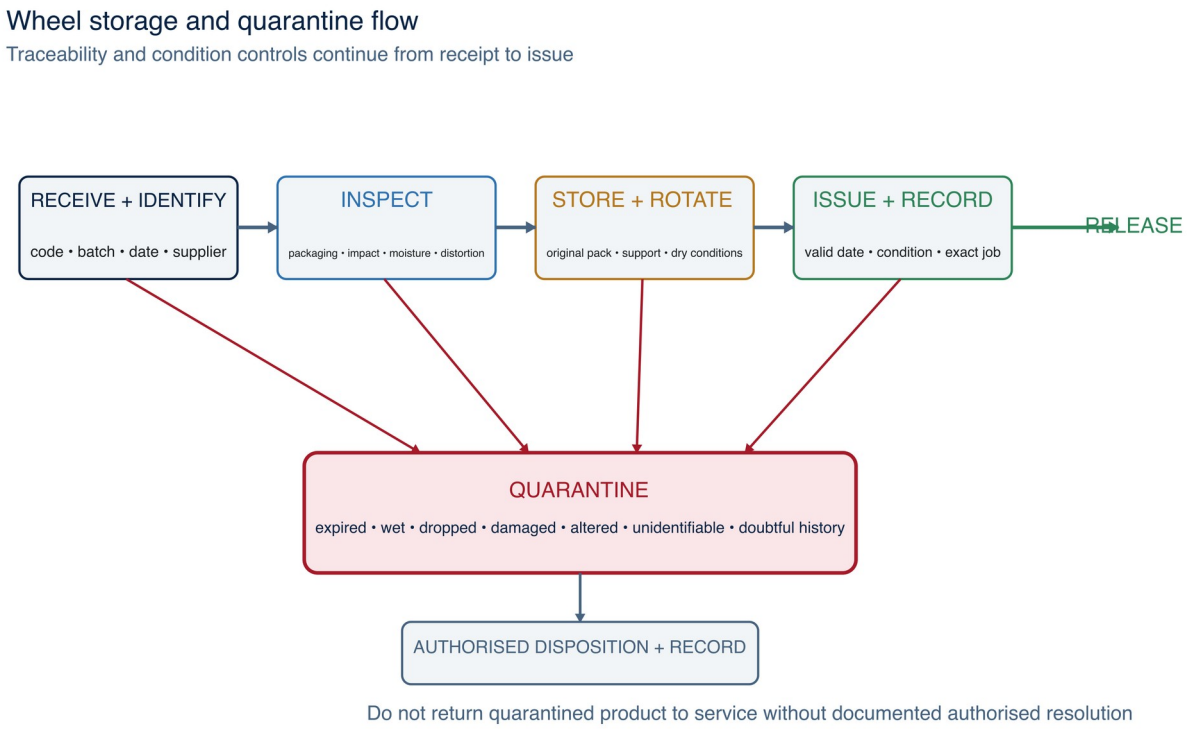

Figure 3. Wheel storage and quarantine flow. Receipt inspection and condition controls precede release; damaged or uncertain wheels move to quarantine.

9. Controlled selection workflow

148. Define material, feature, stock allowance, access and accepted output.
149. Identify the machine, guard, flange/hub and maximum possible speed.
150. Select the declared wheel type and working face for the operation.
151. Match diameter, thickness, centre and mounting arrangement.
152. Match grain, grit, grade, bond, structure and reinforcement to the declared duty.
153. Verify material suitability, contamination controls and environment.
154. Verify marked maximum permitted speed and any expiry/use-by requirement.
155. Inspect wheel, packaging, storage history and mounting parts.
156. Apply the manufacturer’s angle, load, mounting and start-up instructions.
157. Run a representative controlled trial and record removal, heat, geometry, finish, wear and safety observations.
158. Release one exact wheel–machine–material–operation revision.

10. Troubleshooting by wheel signal

Signal	Possible selection causes	Controlled response
Wheel glazes or stops cutting	Grade too hard for the system, insufficient effective load, wrong grain/grit, low machine response	Stop; verify complete specification and process; do not add uncontrolled force
Wheel wears unusually fast	Grade too soft, excessive load, wrong angle/contact, unsuitable material or damaged wheel	Hold output; inspect wheel, machine and application
Burning or discolouration	Rubbing, loading, excessive contact, unsuitable grit/grade, weak cooling/extraction	Stop; protect the part; correct and revalidate
Edge digging or poor geometry	Wrong wheel shape/thickness, angle, contact width, pressure or operator control	Stop; reassess wheel form and approach
Vibration, noise or runout	Damage, contamination, mounting error, flange mismatch, imbalance or machine defect	Isolate; quarantine wheel and inspect system

11. Wheel selection in practice

Read the complete wheel marking before selection. Match shape and centre type, diameter, thickness, bore, grain, grit, grade, bond, structure and reinforcement to the declared material and operation. Confirm the guard, flanges and machine speed are suitable for that exact wheel; maximum marked speed is a ceiling, not a recommended setting.

Store wheels dry and protected from impact, temperature extremes and uncontrolled stock rotation. Inspect the wheel and its marking before mounting, and remove damaged, expired or unidentified items from service. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

12. Wheel selection and setup record

For repeatable selection, record the task, material, geometry, allowance, required finish, machine or asset, machine maximum speed, guard, flange or hub, wheel manufacturer, code, batch or lot, shape/type, diameter, thickness, centre/bore, grain, grit, grade, bond, structure, reinforcement, marked maximum speed, declared material/application, expiry or use-by marking, storage condition, working method and inspection result.

ABRASIVE FUNDAMENTALS & MATERIALS

CHAPTER 013

Grinding Angles and Contact Area

13

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, safety personnel, QA/QC personnel, maintenance teams, trainers, procurement staff and technical sales personnel

Scope: Application angle and contact-area control for depressed-centre grinding wheels, flexible grinding discs, flap discs and fibre discs on flat surfaces, edges, fillet welds, bevels, internal corners and external corners. This chapter does not approve an MKTECH product, angle, speed, force, pass count, removal rate, finish value or working method.

Safety-critical boundary — Angle is not an isolated setting. Use only the declared working face of an identified product on a compatible machine, guard, flange or backing pad. Follow the current manufacturer instructions for angle, speed, support and direction. Stop for missing markings, damaged products, guard or support interference, unstable work, loss of control, abnormal vibration, digging, edge breakage, glazing, excessive heat or any contact outside the declared use. [S032; S055; S063; S073]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish application angle from contact area and effective load;
- recognise how product construction changes the permitted contact geometry;
- compare shallow, intermediate and steep approaches without treating them as universal degree settings;
- plan contact for flat grinding, edge work, fillet welds, bevel preparation and corners;
- identify angle-related signals such as digging, glazing, excessive wear, heat and poor finish;
- create a repeatable angle/contact trial and approval record; and
- stop when product identity, compatibility or operating instructions are unclear.

1. Angle controls the contact system

Application angle is the orientation of the abrasive’s declared working face relative to the local work surface. Contact area is the portion of that face carrying load at a particular moment. The two are related, but they are not interchangeable.

A change in angle can move contact toward an edge, reduce or widen the footprint, change how stiffly the product presents itself, and alter the direction in which the machine reacts. The same nominal angle can create a different footprint when product diameter, wear, backing-pad stiffness, wheel profile, work curvature, pressure or operator motion changes.

The practical control is therefore not “hold one number.” It is to verify the product family and working face, establish a stable contact footprint on representative work, control force and motion, and inspect the result. [S032; S055; S073]

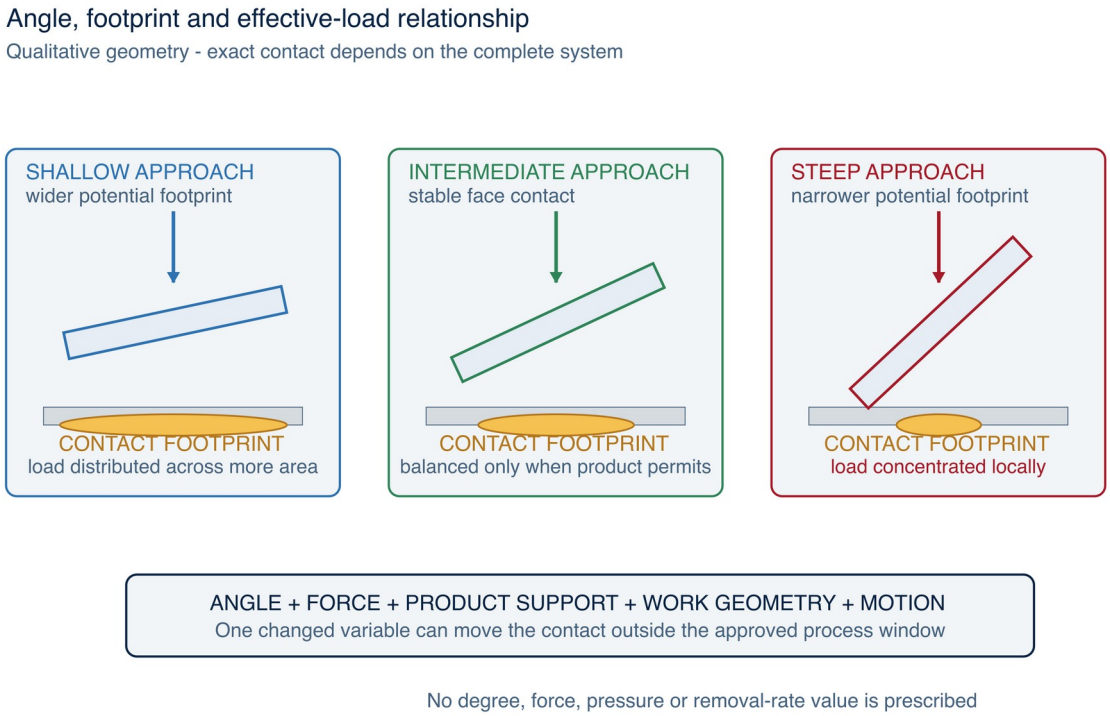

Figure 1. Angle–contact relationship. A change in approach changes the contact footprint and load concentration across the product–machine–work system.

2. Contact area changes load concentration

For a given applied force, a smaller effective footprint concentrates load into a narrower region. A wider footprint distributes load across more abrasive and more work surface. This is a qualitative relationship, not a pressure calculation: real contact is uneven and changes as abrasive grains cut, the product flexes and the work geometry moves.

A narrower footprint can:

- increase local cutting intensity and geometry sensitivity;
- make edge digging, gouging or undercut more likely;
- raise local heat input when motion or cutting action is poor; and
- accelerate local product wear.

A wider footprint can:

- spread force and support smoother blending;
- reduce access to narrow features;
- increase total rubbing area if the abrasive is loaded or the force is too low; and
- make guard, pad or hub clearance more important.

Neither narrow nor wide contact is automatically correct. The accepted footprint is the smallest controlled contact that performs the defined task without violating the product's declared working face, damaging adjacent geometry or creating unacceptable heat, finish or wear.

3. Product family determines the permitted approach

Product construction controls how contact is supported. A depressed-centre bonded wheel, a flexible grinding disc, a flap disc and a fibre disc may fit a right-angle machine, but they do not share one working face, stiffness, backing requirement or angle instruction. Treat each as a distinct construction and verify wheel type, dimensions, reinforcement, declared use, guarding and maximum operating speed on the exact product. [S055; S073]

Product family	Contact structure	Controlled angle principle	Stop condition
Depressed-centre grinding wheel	Rigid bonded body with a declared grinding face	Keep contact on the permitted face and inside the manufacturer's angle range; do not lever or side-load an undeclared surface	Hub/guard interference, edge-only contact, wheel chatter, glazing, digging or damage
Flexible grinding disc	Flexible abrasive body or reinforced construction intended to conform within limits	Use only the declared support and flex direction; avoid folding, creasing or concentrating load at an unsupported edge	Excessive flex, crease, backing exposure, delamination, snagging or unstable contact
Flap disc	Overlapping coated-abrasive flaps carried on a shaped backing	Match flat or conical construction to the task; maintain enough face contact for multiple flaps to cut without striking the backing	Backing contact, flap tearing, severe bounce, local burn or loss of shape
Fibre disc	Coated-abrasive fibre disc supported by a backing pad	The pad and disc form one contact system; keep the supported abrasive face engaged and avoid exposing the disc edge or pad	Pad contact, disc edge catch, centre interference, tear, heat distortion or loss of support

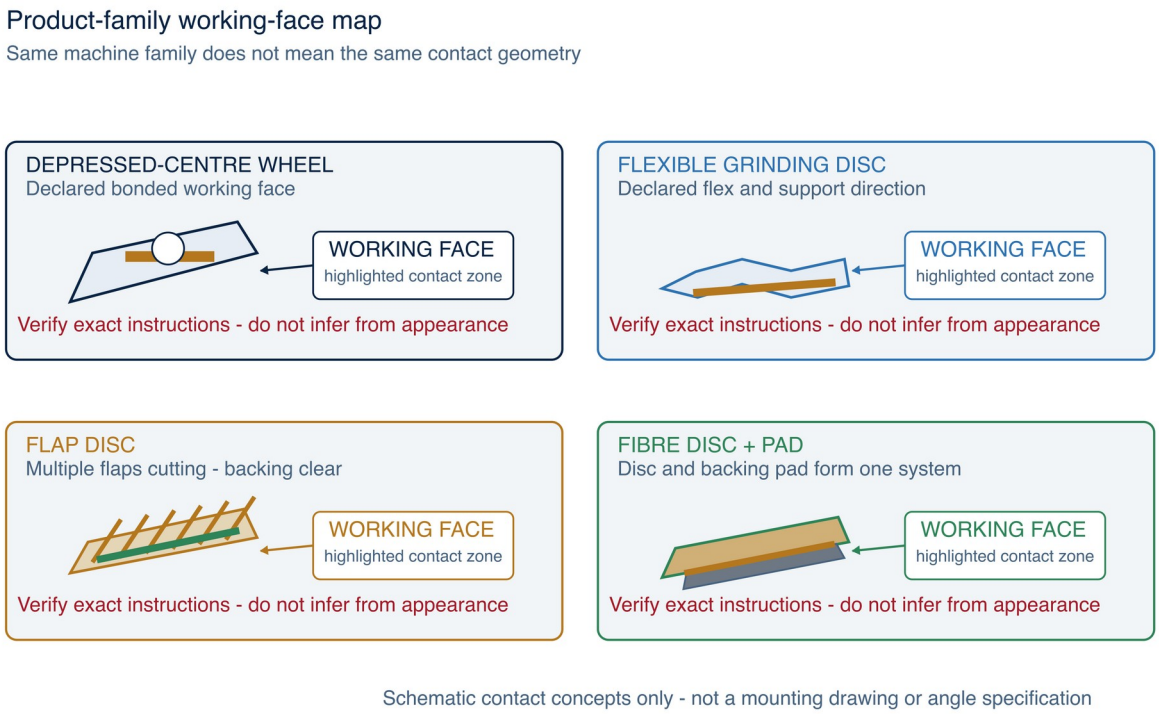

Figure 2. Product-family angle map. The shaded zones compare functional contact behaviour. Refer to the product label, Technical Data Sheet or MKTECH representative for the permitted working angle.

Depressed-centre grinding wheels

The wheel is comparatively rigid. Tilting changes which part of the declared grinding face carries load and how strongly the wheel edge enters the work. Too shallow an approach can encourage rubbing or hub/guard interference on some configurations. Too steep an approach can narrow the footprint, increase digging and create side loading that the product was not intended to carry. Never infer permitted side grinding from reinforcement, wheel shape or past practice. [S032; S073]

Flexible grinding discs

Flexibility can help the abrasive follow a blend or contour, but flex is not unlimited. Support, disc construction and rotation direction control how the face enters the work. Excessive deflection can crease the body, expose the backing, overheat a small region or allow the edge to catch.

Flap discs

Flap-disc profile changes presentation. A flatter construction generally presents its face differently from a conical construction. The controlled objective is to keep several flaps cutting with stable overlap while preventing the backing from touching the work. A steeper approach is not a substitute for a product profile suited to the feature.

Fibre discs

The backing pad defines stiffness, support and local conformity. The disc cannot be evaluated separately from the pad. Excessively shallow or offset contact can bring the pad or centre into the work; concentrated edge contact can catch or tear the disc. Verify pad diameter, hardness, attachment, speed rating and condition with the exact fibre disc.

4. Geometry changes the local reference surface

“Angle to the work” must be measured against the surface at the contact point, not against the floor, bench or overall part. Curves and corners change that local reference continuously.

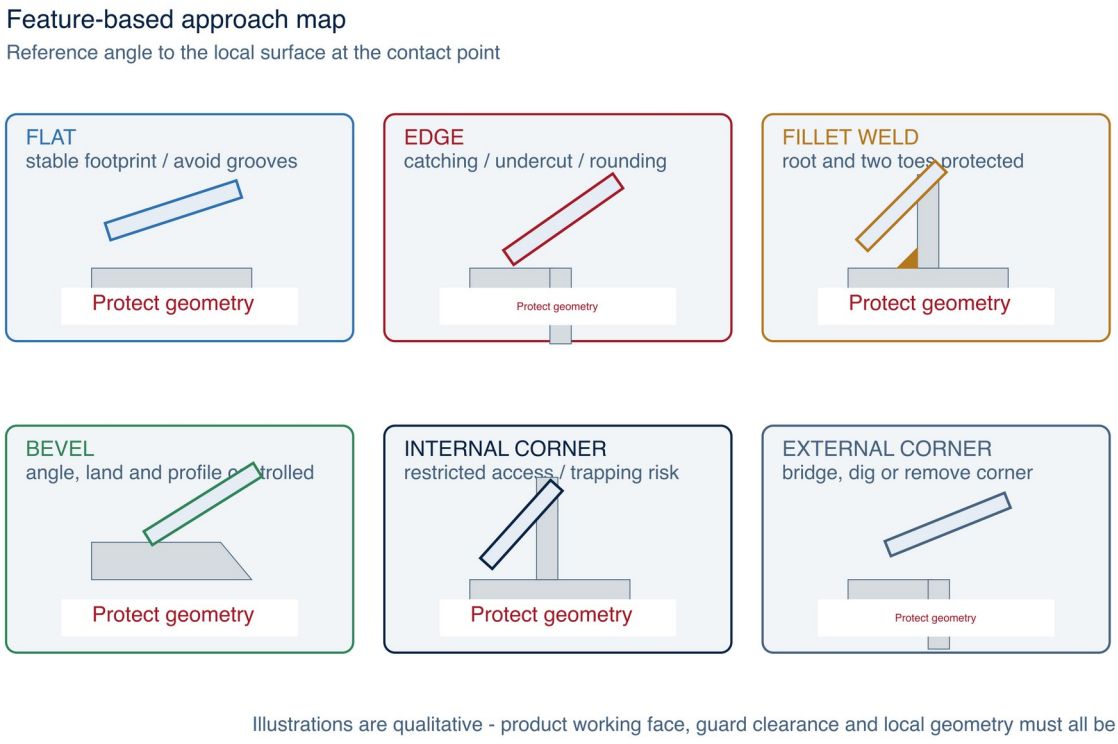

Figure 3. Feature-based approach map. Flat surfaces, edges, welds and corners change access, local surface direction and risk to adjacent geometry.

Flat grinding

Flat work offers the largest opportunity for a stable footprint. Approach so the declared abrasive face contacts before the hub, backing pad or guard can interfere. Use overlapping motion and maintain the product in a plane that does not introduce unintended grooves. Verify flatness or blend acceptance with suitable inspection rather than judging only spark pattern.

Edge grinding

An edge creates a narrow support line and a high risk of catching, chipping, undercut or excessive rounding. Control the direction of rotation and travel so the abrasive cannot climb unpredictably onto or off the edge. Do not let the product’s unsupported edge perform work unless the exact product is declared for that use.

Fillet welds

A fillet joins two surfaces and limits access near the root and toes. The contact must remove the defined weld or transition without gouging either parent surface or thinning the root. Choose a product form that can reach the feature while keeping its declared face supported. Work from controlled reference surfaces and inspect both sides of the fillet.

Bevel preparation

Bevel grinding creates geometry, not merely material removal. The abrasive approach must support the required bevel angle, root face and land without rounding the edge or introducing a hollow profile. Use gauges or templates suitable for the joint design. Do not attempt to “correct” bevel geometry by increasing force or steepening the abrasive after the process drifts.

Internal corners

Access is restricted and adjacent surfaces can trap the product or force guard interference. Confirm that the product diameter, profile and machine head can reach the feature without contacting an undeclared face. Short, controlled contact and frequent inspection are preferable to blind pressure into the corner.

External corners

The local surface direction changes abruptly across the corner. A wide footprint can bridge and round the corner; a narrow footprint can dig into one face or cut the corner away. Define whether the corner must remain sharp, receive a controlled radius or be blended, then protect the adjacent faces accordingly.

5. What changes when the angle changes

Observed change	Contact mechanism	Possible process result	Controlled response
Footprint becomes narrower	Load moves toward a smaller part of the abrasive face	Faster local cutting, digging, grooves, local heat or rapid wear	Reduce contact intensity; restore the approved face and motion
Footprint becomes wider	More abrasive and work surface share the load	Smoother blend or increased rubbing/heat if cutting action is weak	Verify product condition, force, motion and support
Product becomes effectively stiffer	Geometry or support reduces conformity	Stronger shape generation but less forgiveness	Protect adjacent geometry; inspect more frequently
Product becomes effectively more flexible	Face or pad follows the work more closely	Better blending but possible rounding or loss of dimensional control	Use reference surfaces, templates or gauges
Reaction direction changes	Tangential force acts through a different contact point	Pull, push, climb, bounce or loss of control	Stop; correct stance, workholding, rotation/travel and approach
Edge or backing enters contact	Working face is lost or support is exposed	Snagging, tearing, gouging, backing damage or ejection hazard	Stop and quarantine damaged product; correct the configuration

Angle interacts with force. If the footprint narrows while the applied force remains similar, local load rises. If the footprint widens without enough cutting action, the system may rub. Adding pressure is not a valid response to glazing, loading or weak cutting until product condition, material suitability, speed, contact and machine response have been verified. [S071; S075]

6. Heat, wear and finish signals

Heat is generated by cutting, ploughing and friction. Angle can shift the balance by changing footprint, grain engagement and motion. Discolouration, resin odour, backing distortion, rapid wheel wear, local glazing or a polished track can signal that contact is no longer controlled.

Finish quality also records contact history. Deep isolated scratches, scallops, directional grooves, edge rounding and an uneven blend often indicate changes in angle, dwell, travel path, abrasive condition or support. Inspect the surface under consistent lighting and use the specified dimensional or finish method where acceptance depends on geometry or roughness.

Product wear changes contact geometry over time. A bonded wheel becomes smaller and its edge profile changes. Flaps shorten and can expose the backing. Fibre discs lose abrasive and may soften or distort. The approved process therefore needs a change-out rule based on product condition and output, not only elapsed time.

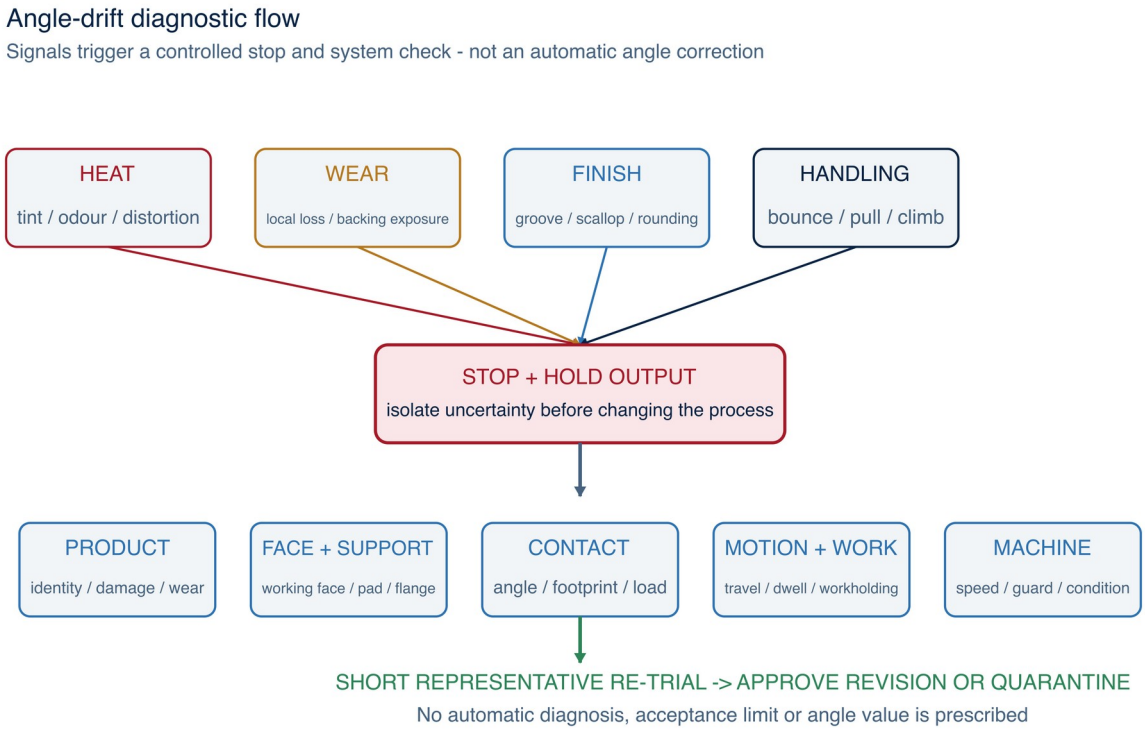

Figure 4. Angle-drift diagnostic flow. Surface, heat, wear and handling signals direct the operator to stop, inspect the complete system and correct the cause before resuming.

7. Controlled setup and trial

159. Define the material, feature, stock allowance, protected geometry and accepted output.
160. Identify the exact abrasive, declared working face, support element, machine, guard and speed range.
161. Obtain the current manufacturer angle and application instructions.
162. Mark or fixture reference surfaces where geometry must be preserved.
163. Secure the work and establish a stance or programmed path that controls reaction direction.
164. Begin with stable face contact and the lowest effective load within the approved method.
165. Use repeatable travel, overlap and dwell; do not pivot on one point.
166. Inspect geometry, heat, scratch pattern, product wear and handling response after short intervals.
167. Adjust only one controlled variable at a time.
168. Record the approved product–machine–feature–angle–load–motion revision.

For automated work, the record must also define tool orientation, path frame, commanded force or displacement, compliance device, approach/retract behaviour, workholding, sensing, wear compensation and fault response. A programmed angle does not prove the actual contact angle when part location, wheel wear, compliance or robot stiffness changes. [S070]

8. Troubleshooting by contact signal

Signal	Possible angle/contact causes	Controlled response
Digging or gouging	Footprint too narrow, excessive dwell, steep entry, unstable edge contact	Stop; protect the part; restore supported face contact and re-trial
Glazing or polished track	Rubbing, weak effective load, wrong face, unsuitable product or speed response	Stop; inspect product and system; do not add uncontrolled pressure
Rapid local wear	Concentrated contact, edge loading, excessive force or unsuitable product profile	Hold output; verify angle, support and product suitability
Heat or discolouration	Excess dwell, rubbing, wide loaded contact, poor motion or weak extraction/cooling	Stop; isolate affected output; correct and revalidate
Bounce, pull or climb	Reaction direction, entry path, workholding or product damage is uncontrolled	Stop; secure work and reassess rotation, travel and approach

Signal	Possible angle/contact causes	Controlled response
Rounded edge or lost bevel	Footprint bridges the feature, product conforms excessively or inspection is too late	Restore reference control; use gauges and shorter inspection intervals
Backing, pad or hub marks	Product face is no longer the only contact surface	Stop immediately; inspect and quarantine damaged parts

9. Applying angle and contact guidance

Begin with the working face and angle permitted for the exact product. Keep the guard and support system correctly positioned, approach the work under control and use the smallest contact area that remains stable for the required operation. Maintain consistent travel and avoid edge digging, side loading, excessive dwell and angle drift.

Watch the process signals together: cut, spark pattern, sound, vibration, heat, scratch shape, product wear and geometry. A change in one signal is a reason to inspect the complete system before applying more force. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

10. Angle and contact setup record

For repeatability, record the task, material, feature, protected geometry, allowance, required output, machine and speed, guard, exact abrasive and batch, product profile, declared working face, flange/hub/pad, manufacturer angle instruction, selected angle where measurement is required, contact-width reference, load method, travel direction, overlap, dwell control, workholding, inspection intervals, heat, finish, geometry results and product wear.

GRINDING & CUTTING APPLICATIONS

CHAPTER 014

Weld Grinding

14

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, welding supervisors, welders, grinding operators, inspectors, QA/QC personnel, safety personnel, trainers, maintenance teams and technical sales personnel

Scope: Controlled abrasive treatment of fillet, butt, lap and tack welds; stainless-steel, aluminium, structural and cosmetic welds; and internal and external weld locations. This chapter does not define weld acceptance, approve a weld repair, replace a welding procedure, authorise removal of parent metal or prescribe an MKTECH product, speed, angle, force, grit sequence, pass count, removal rate or finish value.

Safety-critical boundary — Weld grinding can remove design section, erase evidence of an imperfection, expose an internal discontinuity, change a fatigue-sensitive toe, contaminate a corrosion-resistant surface or create hazardous dust and sparks. Work only to a documented weld profile and inspection requirement. Use an identified abrasive on a compatible guarded machine, control dust, fire, hot work and nearby materials, and stop for unknown weld status, unknown material or coating, cracks, porosity, lack of fusion, unexpected cavities, parent-metal contact, undercut, heat tint, distortion, unstable work or any result outside the approved repair or finishing instruction. [S008; S009; S020; S032; S063; S076–S079]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish weld-metal removal, toe blending, cosmetic finishing and weld repair;
- identify how fillet, butt, lap and tack geometry changes the accessible grinding route;
- recognise correct, under-ground, over-ground, undercut, thinned and excessively blended profiles;
- protect weld throat, root, toes, parent metal, coating and adjacent geometry;
- separate structural acceptance from cosmetic appearance;
- respond correctly when grinding reveals an imperfection;
- plan material-specific controls for stainless steel and aluminium; and
- create a traceable weld-grinding and inspection record.

1. Acceptance comes before abrasive contact

A weld is not automatically approved for grinding merely because it is high, rough or visually uneven. Before work begins, identify why material is to be removed:

- to reach a specified weld contour or flush condition;
- to prepare an approved repair excavation;
- to remove a temporary attachment or tack under a controlled instruction;
- to create a smooth transition at a permitted weld toe;
- to remove surface oxide or contamination using an approved method; or
- to produce a defined cosmetic finish after structural acceptance.

The controlling drawing, weld procedure, fabrication specification, repair procedure and inspection plan determine what must remain. ISO 5817:2023 provides quality levels for imperfections in fusion-welded joints in steel, nickel, titanium and their alloys, while ISO 10042:2018 provides quality levels for aluminium arc welds. Their published scopes confirm that quality levels are application frameworks, not permission to grind every weld flush. ISO 17637:2016 establishes visual testing of fusion welds and can also apply before welding. [S076–S078]

Do not reproduce a limit from a different contract, material, thickness, weld class or service. The project specification and current controlled standard determine acceptance. Where the instruction is silent, hold the component and obtain an engineering or welding decision.

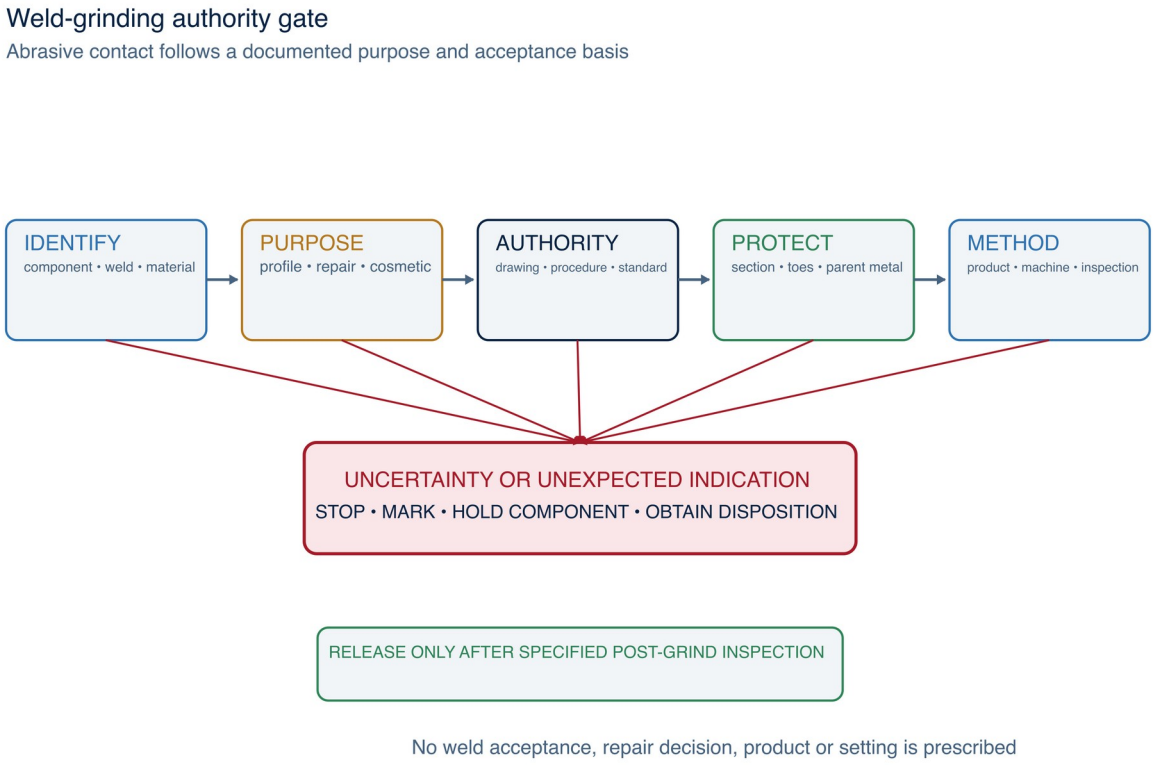

Figure 1. Weld-grinding authority gate. Abrasive work begins only after weld identity, purpose, acceptance basis, inspection status and protected geometry are known.

2. Weld type changes the grinding problem

The joint geometry defines which surfaces carry load, which weld dimensions matter and which areas the abrasive can reach.

Weld type	Geometry to protect	Typical grinding objective	Primary risk
Fillet weld	Effective throat, leg relationship, root region and both toes	Remove permitted excess, smooth a specified toe or create a documented contour	Throat loss, root thinning, toe undercut or gouging either parent surface
Butt weld	Joint section, cap, toes, root condition and alignment	Reduce a permitted cap, flush a specified surface or prepare an approved repair	Parent-metal thinning, hollow profile, hidden lack of fusion or loss of section
Lap weld	Sheet edge, upper and lower members, weld toe and overlap region	Remove spatter or blend a specified exposed edge	Cutting the sheet edge, opening the lap, thinning the lower member or trapping debris
Tack weld	Final-joint location, base surface and any crack-sensitive start/stop region	Incorporate, dress or remove only as the procedure allows	Tearing, crater cracking, local gouging or leaving an uninspected remnant

Fillet welds

A fillet weld is not simply a triangular ridge to be flattened. Its usable section and toe transition belong to the joint design. Work from visible reference surfaces and inspect both toes repeatedly. If the root or throat cannot be verified from the grinding side, do not infer adequacy from appearance.

Butt welds

A butt-weld cap can be removed only when the required final profile allows it. Flush grinding should end at the specified surface reference without producing a trough across the joint or lowering adjacent parent metal. A smooth appearance does not prove fusion or penetration.

Lap welds

Lap joints combine an exposed sheet edge with a narrow transition. A broad abrasive can bridge the step and remove the upper edge; a narrow contact can dig into the lower member. Clean the overlap without driving debris into the joint and protect coatings that must remain.

Tack welds

Tacks can be part of the final weld, temporary attachments or fit-up aids. Their treatment belongs to the welding procedure. Never grind out a tack because it “looks temporary” without confirming its status, crack inspection and required surface restoration.

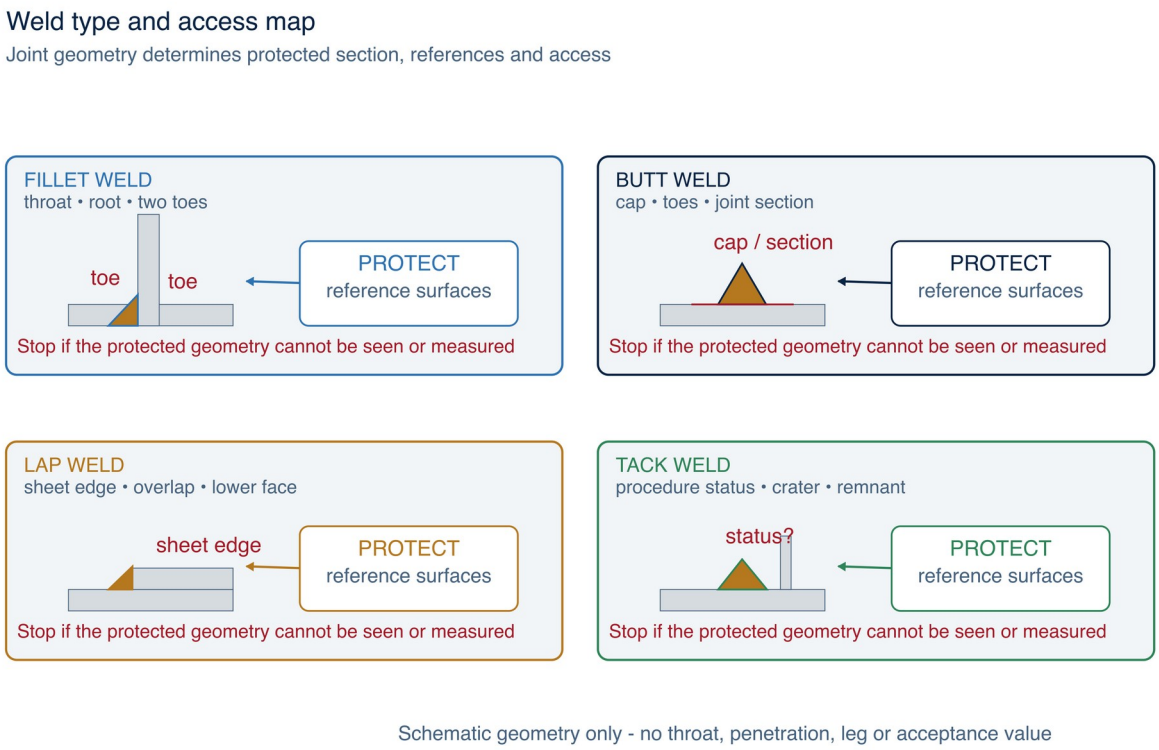

Figure 2. Weld type and access map. Each joint presents different protected dimensions, reference surfaces and trapping risks.

3. Profile language must be unambiguous

The words *flush*, *blended*, *smooth* and *cosmetic* are not interchangeable. A useful instruction defines the surface reference, permitted transition, protected section, inspection method and stop point.

Original weld means the as-welded profile presented for inspection or authorised processing.

Correctly blended weld means a controlled transition that meets the specified contour without removing protected weld or parent-metal section.

Under-ground weld means required excess, irregularity or transition remains.

Over-ground weld means abrasive removal has passed the allowed contour or section.

Undercut is a groove at a weld toe in the parent metal. TWI describes it as a geometric imperfection whose acceptability must be determined from the application standard or contract; blending or additional welding can be appropriate only in a controlled critical application. [S079]

Parent-metal thinning means the base material has been lowered below the approved reference or minimum remaining section.

Excessive blend zone means an unnecessarily wide or deep area has been altered, even if the centre of the weld appears smooth.

Acceptable profile means the completed and inspected profile satisfies the controlling requirement. It cannot be established from a generic illustration.

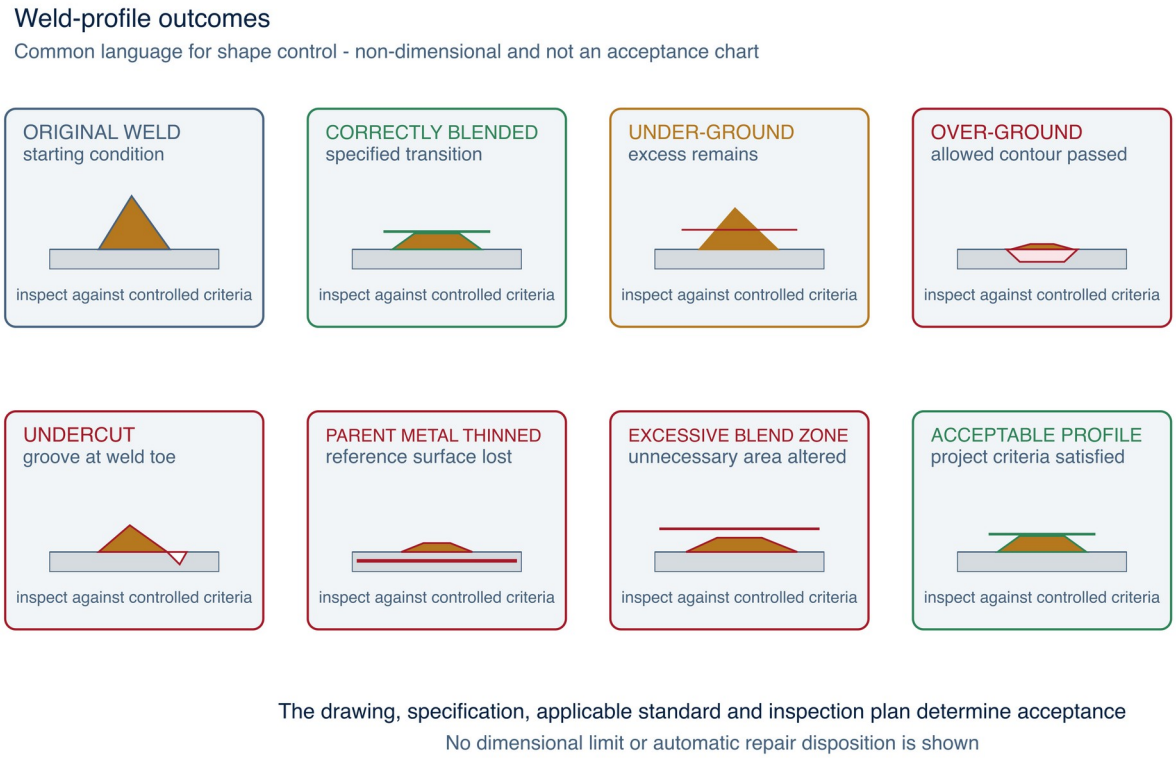

Figure 3. Weld-profile outcomes. The diagrams identify common shape errors; evaluate dimensions against the drawing, weld specification and inspection plan.

4. Grind in controlled phases

Phase 1 — Establish references

Clean and identify the weld, material and coating. Confirm the required contour, protected dimensions and inspection hold points. Mark boundaries where permitted and provide stable workholding, access, lighting and extraction. Photograph or record the starting condition when traceability or repair control requires it.

Phase 2 — Remove only authorised high material

Choose a product form that reaches the weld without forcing an undeclared abrasive edge, backing pad, hub or guard into adjacent surfaces. Keep contact on the weld crown or authorised excavation. Use repeatable travel and short inspection intervals. Do not pivot on a toe or dwell at a start/stop.

Phase 3 — Approach the stop reference

As the profile nears the reference surface, reduce the process intensity by moving to the approved controlled method—not by improvising with machine angle, pressure or unsupported product edges. Check contour from more than one direction. A highlight, spark pattern or smooth touch can conceal a hollow or step.

Phase 4 — Blend only where specified

Blend width is a controlled geometry, not a visual preference. Protect both parent surfaces, edges, holes, radii and nearby welds. On fatigue-sensitive details, the direction, smoothness and extent of toe treatment require an engineering-approved process.

Phase 5 — Clean and inspect

Remove abrasive residue using a material-compatible method. Conduct the specified visual, dimensional, surface-finish or non-destructive examination after grinding and at any intermediate hold point. Grinding does not close a weld inspection requirement; it creates a new surface that must be accepted. [S078]

5. Structural and cosmetic work have different authorities

Structural weld grinding changes a load-carrying detail or its stress transition. The instruction must protect effective section and comply with the design, fabrication and repair controls. A smooth surface is not a substitute for a weld acceptance decision.

Cosmetic weld grinding targets appearance, hygiene, cleanability or a finish match. It still cannot reduce required joint section, conceal porosity or cracks, introduce cross-contamination or erase traceability. Cosmetic acceptance belongs after structural and repair acceptance unless the approved workflow explicitly combines them.

Internal welds often have restricted access, poor visibility and trapping risks. Confirm that the product, machine head and guard can enter and leave without touching an undeclared surface. Use inspection aids and stop when the root, toe or parent surface cannot be seen or measured adequately.

External welds offer more access but can encourage an unnecessarily wide blend. Establish visual and dimensional boundaries before work so the operator does not chase a uniform appearance across sound parent metal.

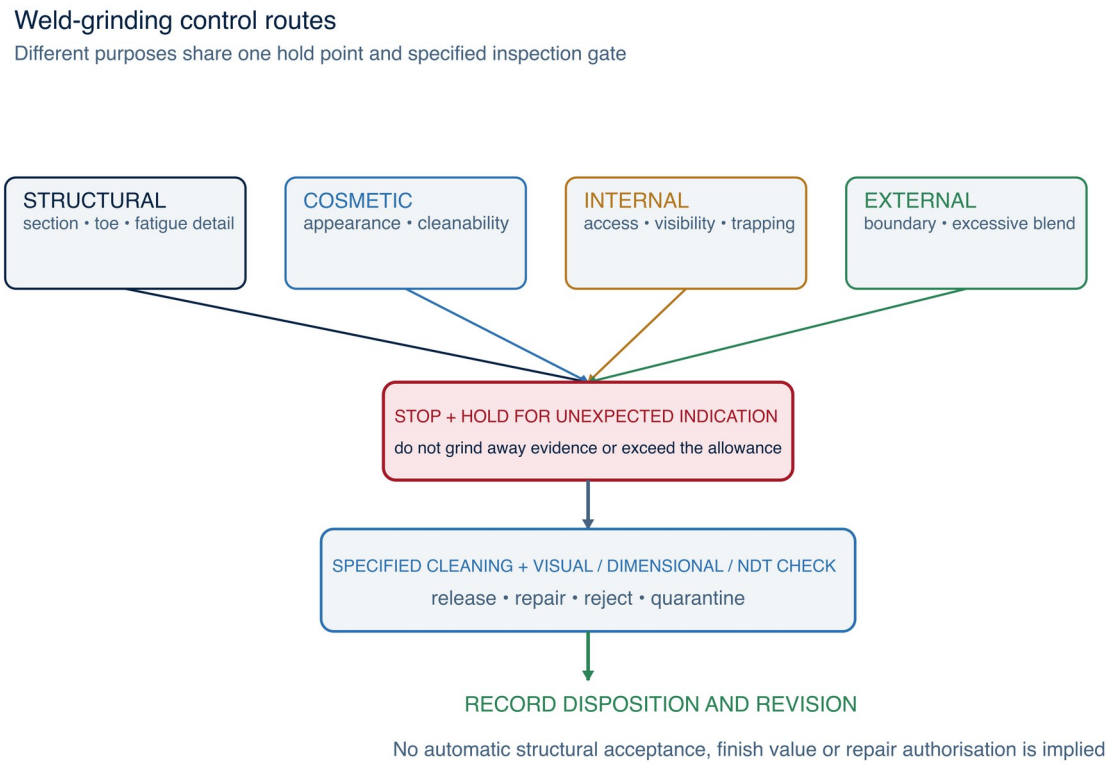

Figure 4. Weld-grinding control routes. Structural, cosmetic, internal and external work share one stop-and-inspect gate while retaining their applicable acceptance criteria.

6. Material condition changes the controls

Material or service	Additional control	Do not assume
Stainless steel	Segregated tools and abrasives, contamination control, heat-tint assessment and approved cleaning/passivation route	A bright surface is chemically clean, corrosion performance is restored or one abrasive sequence fits every grade
Aluminium	Confirm alloy, temper, section, loading/smearing behaviour, combustible-metal dust controls and separation from incompatible metal dust	Carbon-steel practice transfers safely, a loaded abrasive is cutting correctly or colour reveals temperature
Structural carbon or alloy steel	Confirm weld category, required profile, remaining section, toe treatment and post-grind inspection	Flush appearance proves adequacy or parent-metal loss can be accepted visually
Coated or galvanised work	Identify coating hazards, removal boundary and approved coating repair	Coating can be ground away without exposure controls or restoration

Material or service	Additional control	Do not assume
Hygienic or cosmetic service	Define finish direction, cleanability, contamination control and inspection lighting	Surface finish replaces weld integrity or an invisible blend is automatically acceptable

Stainless-steel weld grinding may be followed by refinement, oxide removal, cleaning or passivation, but those are separate controlled operations. Worldstainless guidance treats heat tint, embedded contamination and surface treatment as corrosion-control matters; product-specific abrasive sequences remain conditional. [S001; S015; S016]

Aluminium can load an abrasive and produce fine combustible-metal dust. OSHA’s archived aluminium-grinding interpretation warns that heat and reaction risk depend on the complete material/process system and that aluminium and iron/steel dust interactions require control. Use a current local risk assessment and dedicated collection strategy; do not mix metal dust streams casually. [S009; S017; S020]

7. Grinding can reveal or create a repair condition

Stop immediately when abrasive removal reveals a crack-like indication, linear lack of fusion, clustered porosity, slag, an unexpected cavity, disbonded coating, severe undercut or a profile deeper than the authorised allowance.

Do not feather the indication until it disappears from view. That can enlarge the excavation, remove traceability and make the actual extent harder to establish. Mark and hold the component, preserve the location, notify the responsible welding/inspection authority and follow the approved excavation, examination and re-welding procedure.

TWI guidance distinguishes geometric imperfections from other discontinuities and notes that lack of fusion, penetration defects and porosity commonly require controlled removal to sound metal and re-welding. The exact repair route must follow the agreed welding procedure. [S079]

8. Controlled weld-grinding workflow

169. Identify the component, weld number, material, thickness, joint type, location and service.
170. Confirm weld acceptance status and the exact reason for abrasive work.
171. Obtain the current drawing, fabrication specification, weld procedure, repair instruction and inspection plan.
172. Define the target profile, protected section, parent-surface references, blend boundary and stop conditions.
173. Verify machine, guard, mounting, speed compatibility, abrasive identity, working face and material suitability.
174. Establish workholding, access, lighting, extraction, fire controls and contamination segregation.
175. Record the starting profile and any pre-grind inspection result required by the plan.
176. Remove authorised high material in short, repeatable passes while protecting toes, root and parent metal.
177. Inspect at defined intervals and before changing product or process stage.
178. Stop and quarantine for any unexpected indication or geometry loss.
179. Clean with the approved material-specific method.
180. Complete specified visual, dimensional, finish or NDT inspection and record disposition.

9. Troubleshooting by weld-profile signal

Signal	Possible process cause	Controlled response
Weld remains high or transition remains sharp	Inadequate access, unsuitable product form, premature finishing stage or poor reference visibility	Hold; reassess access and authorised removal route; do not add uncontrolled force
Hollow across butt weld	Concentrated dwell, pivoting, narrow footprint or chasing local lows	Stop; measure remaining section and obtain disposition
Fillet toe or root is thinning	Contact crossed protected geometry or product cannot reach without side contact	Stop immediately; hold the joint for weld/engineering review
Blend zone keeps widening	No marked boundary, broad contact bridging the profile or appearance-driven rework	Restore a defined limit; inspect parent-metal level and finish
Pores or cavities appear	Internal discontinuity exposed during removal	Mark, hold and route to the approved weld-repair/NDT procedure
Surface smears, loads or overheats	Unsuitable or worn abrasive, poor cutting action, excessive dwell or wrong material controls	Stop; isolate affected output and verify the complete material–product–machine system
Stainless surface shows contamination or tint	Mixed tooling, embedded debris, excessive heat or incomplete cleaning route	Hold; apply the approved contamination and surface-restoration assessment

Signal	Possible process cause	Controlled response
Aluminium dust accumulates or mixes with other dust	Inadequate segregation, collection or housekeeping	Stop work; isolate the hazard and correct the approved dust-control system

10. Applying weld-grinding guidance

Define the required weld profile and inspection method before grinding. Select an abrasive declared for both weld and parent material, then work in controlled phases: establish reference surfaces, remove only authorised high material, approach the required contour gradually, blend where specified, clean and inspect.

Structural, cosmetic and hygienic welds can have different acceptance routes. Stop if grinding reveals cracks, lack of fusion, porosity, undercut beyond the stated limit or unexpected section loss; these conditions require the specified welding or quality disposition. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

11. Weld grinding and inspection record

For traceable work, record the component and weld ID, drawing and specification revision, joint type, material and thickness, location, service category, welding procedure, pre-grind inspection status, reason for grinding, target and protected profile, machine and guard, exact abrasive and batch, speed compatibility, support element, working face, angle/contact method, pass and inspection intervals, contamination and dust controls, dimensional and finish results, indications exposed, repair disposition, cleaning route and NDT result where required.

GRINDING & CUTTING APPLICATIONS

CHAPTER 015

Heavy Stock Removal

15

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, grinding operators, welders, fettlers, inspectors, QA/QC personnel, safety personnel, maintenance teams, trainers and technical sales personnel

Scope: Controlled heavy removal of excess metal, casting gates and riser remnants, weld reinforcement, temporary attachments, flash, scale and machining allowance using identified abrasive systems. This chapter does not prescribe an MKTECH product, speed, pressure, angle, pass length, overlap, removal rate, wheel-change point, temperature limit, finish value or dimensional acceptance criterion.

Safety-critical boundary — Heavy stock removal combines high power, high reaction force, rapidly changing geometry, sparks, hot particles, dust, noise, vibration and abrasive wear. Work only from an authorised removal boundary and inspection plan. Use an identified abrasive on a compatible guarded machine, secure the work, control ejected material and exposure, and stop for wheel damage, loss of control, abnormal vibration, loading, glazing, overheating, distortion, parent-surface contact, uncertain remaining section or any condition outside the approved method. [S007; S008; S009; S014; S017; S018; S032; S063; S080; S081]

Chapter objectives

After this chapter, the reader should be able to:

- define the removal boundary before selecting a product;
- select a product family by material, geometry, machine and required transition;
- distinguish insufficient cutting action from useful cutting and overload;
- plan pass length, travel and inspection intervals to manage heat and geometry;
- recognise wheel wear, loading, glazing, imbalance and damage signals;
- protect edges, adjacent faces, thin sections and finished references;
- transition from bulk removal to blending before the final contour is endangered;
- control distortion and workholding throughout the operation; and
- create a traceable heavy-stock-removal and inspection record.

1. Define the material that may be removed

Heavy stock removal is not a licence to grind until the surface “looks right.” Identify the starting condition, the material that is authorised for removal and the geometry that must remain. Typical purposes include reducing a casting gate or riser remnant, removing flash, dressing an approved weld profile, removing a temporary attachment, correcting a documented machining allowance or preparing an authorised repair.

The release package should identify:

- component and material;
- removal purpose and responsible authority;
- protected surfaces, edges, section and datum features;
- final contour or remaining allowance;
- inspection stages and stop conditions;
- permitted process families; and
- disposition for cracks, cavities, inclusions or other unexpected indications.

HSE heavy-fabrication guidance advises minimising manual rework through accurate preparation and alternative processes where reasonably practicable. Its foundry guidance similarly treats casting and runner design, automatic fettling, cut-off, cropping and jigs as possible ways to reduce unnecessary manual grinding. These are risk-control principles, not a universal process substitution. [S080; S081]

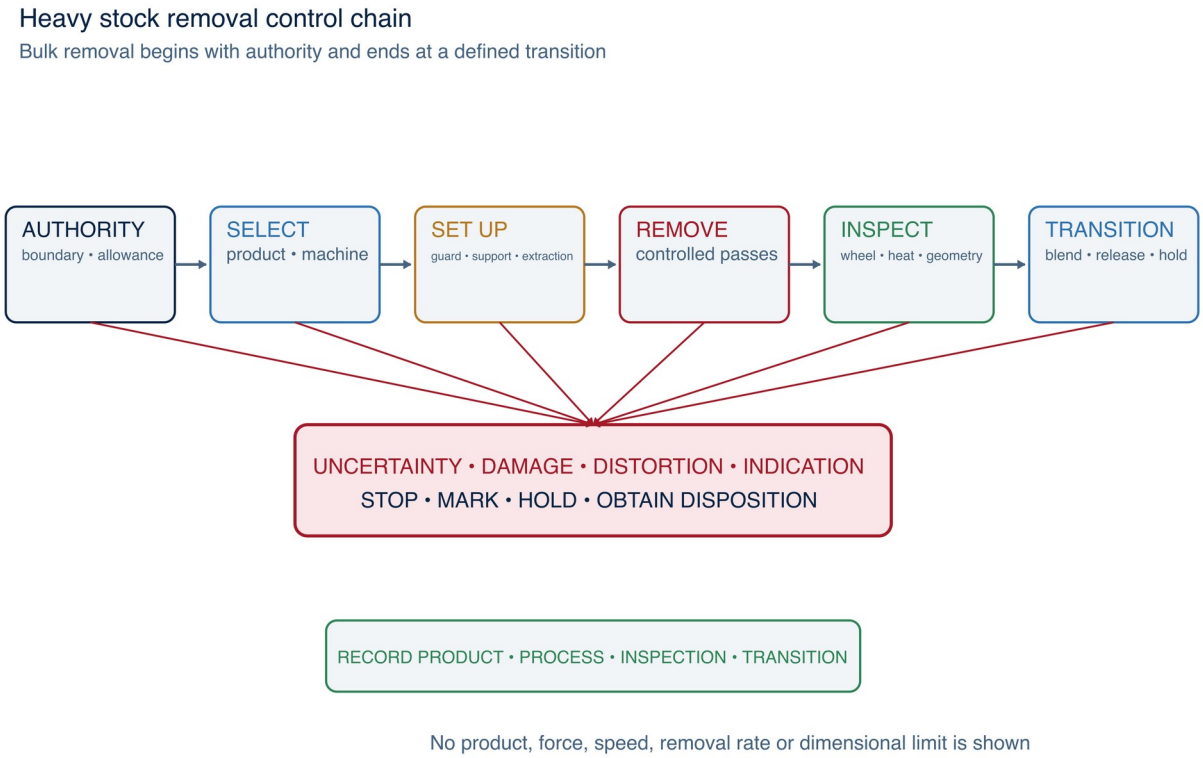

Figure 1. Heavy-removal control chain. Bulk removal begins with an authorised boundary and ends at a defined transition and inspection gate.

2. Select the complete removal system

Select the abrasive product, machine, support element and workholding as one system. Grain, grit, grade, structure, bond, reinforcement, wheel form, diameter and thickness influence response; machine power, speed, guard, spindle, handle position and access determine whether that response can be controlled. A product described as aggressive is not automatically suitable for the material, edge, cavity or remaining allowance. [S025; S029; S032; S055; S063; S071–S075]

Application condition	Selection question	Primary control risk
Broad, accessible excess on robust section	Can the declared working face remove material while preserving the stop reference?	Excessive footprint, heat spread or uncontrolled breakthrough
Narrow gate, riser, lug or weld crown	Can the product reach the high material without contacting the parent surface or adjacent face?	Side contact, edge gouging or concentrated heat
Internal corner or restricted feature	Can the guard, hub, machine head and product enter and leave safely?	Trapping, kickback, hidden contact or poor inspection access
Thin, unsupported or distortion-sensitive part	Is heavy grinding the correct process, and can the part be supported and monitored?	Warping, vibration, local thinning or loss of datum
Coated, stainless, aluminium or mixed-material work	Is the abrasive and collection route compatible and segregated?	Contamination, loading, hazardous dust or coating damage

Manufacturer examples can help define fields for a trial, but their product rankings, grit choices, service life and productivity claims do not transfer to an MKTECH product. Compare candidate systems under one controlled test method using material removed, elapsed contact time, abrasive use, geometry, heat, finish, exposure and operator-control observations. [S036; S073]

3. Pressure is a controlled response variable

Pressure should produce stable cutting action without forcing the product, stalling the machine, deforming the wheel, enlarging the contact area or making the operator fight the reaction. Grinding energy is divided among rubbing, ploughing and chip formation; a bright spark stream or loud sound alone does not prove efficient removal. [S025; S030; S031]

Insufficient cutting action may present as rubbing, polishing, glazing, smearing, slow removal or rising heat with little useful output. Before adding force, check product suitability, wheel condition, working face, machine power and speed under load, access and material compatibility.

Useful cutting action is stable and repeatable. The machine remains controllable, the product cuts on its declared face, chips and sparks discharge safely, the reference remains visible, and removal occurs without abnormal heat, vibration or surface damage.

Overload may present as falling speed, severe reaction, wheel deflection, harsh vibration, rapid edge breakdown, local gouging, excessive heat or loss of path control. Release pressure and stop. Do not convert inadequate selection or a worn product into a force problem.

HSE foundry guidance warns that a wheel that has lost cutting action can encourage operators to press harder, increasing distortion, vibration and the risk of wheel breakage. It recommends selection for cutting efficiency rather than maximum wheel life. [S080]

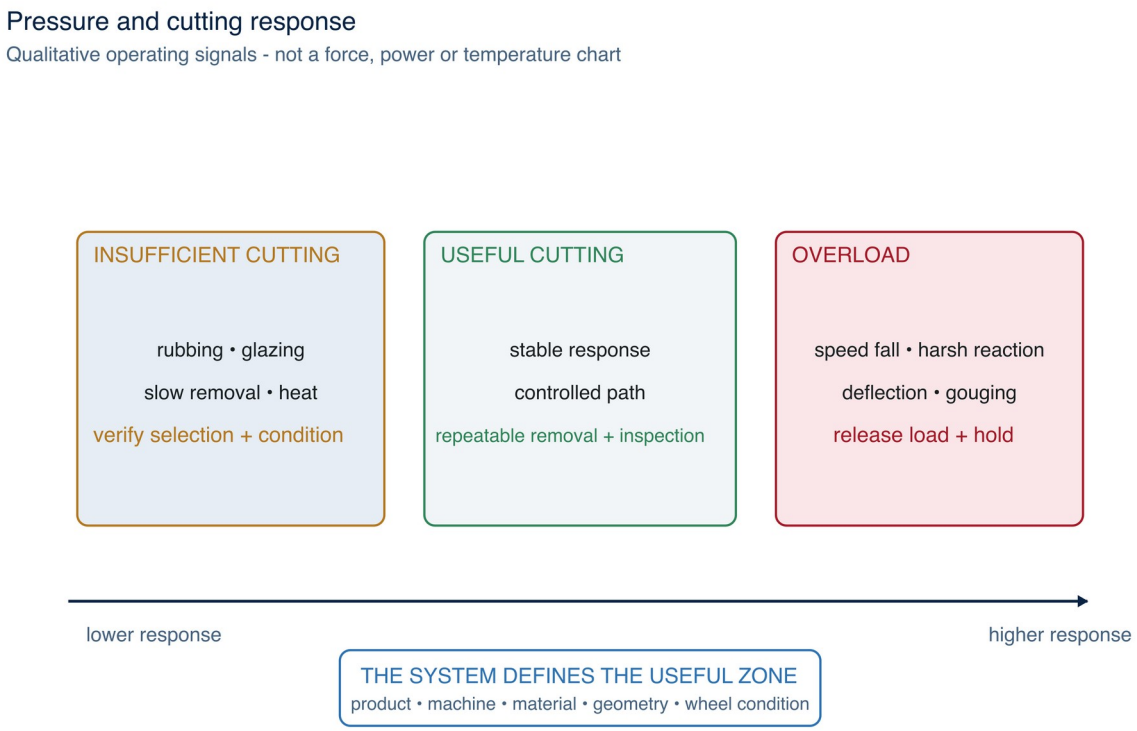

Figure 2. Pressure-response zones. The useful zone is established by the complete product–machine–material system; no universal force value is shown.

4. Design passes to control heat and geometry

A heavy pass should have a defined start, direction, length, exit and inspection interval. Do not dwell at starts, stops, high spots, edges or corners. Use a repeatable travel pattern that prevents one location from receiving continuous contact while nearby areas remain untouched.

Pass length is not a universal distance. It depends on available high material, part stiffness, heat path, access, wheel width, contact footprint, machine control and the visibility of the stop reference. A long pass can spread energy but may cross protected geometry; a short pass can improve access but may concentrate heat and create scallops. Record the representative method rather than relying on “keep moving.”

Heat management begins with cutting efficiency. When more input becomes rubbing or ploughing instead of chip formation, local heat can rise without useful removal. Control heat by correcting the complete system: selection, condition, contact, travel, dwell, sequence, workholding and approved cooling or pause method. Never introduce water, compressed air or another coolant unless the product, machine, material, electrical controls and workplace procedure allow it. [S025; S030; S031]

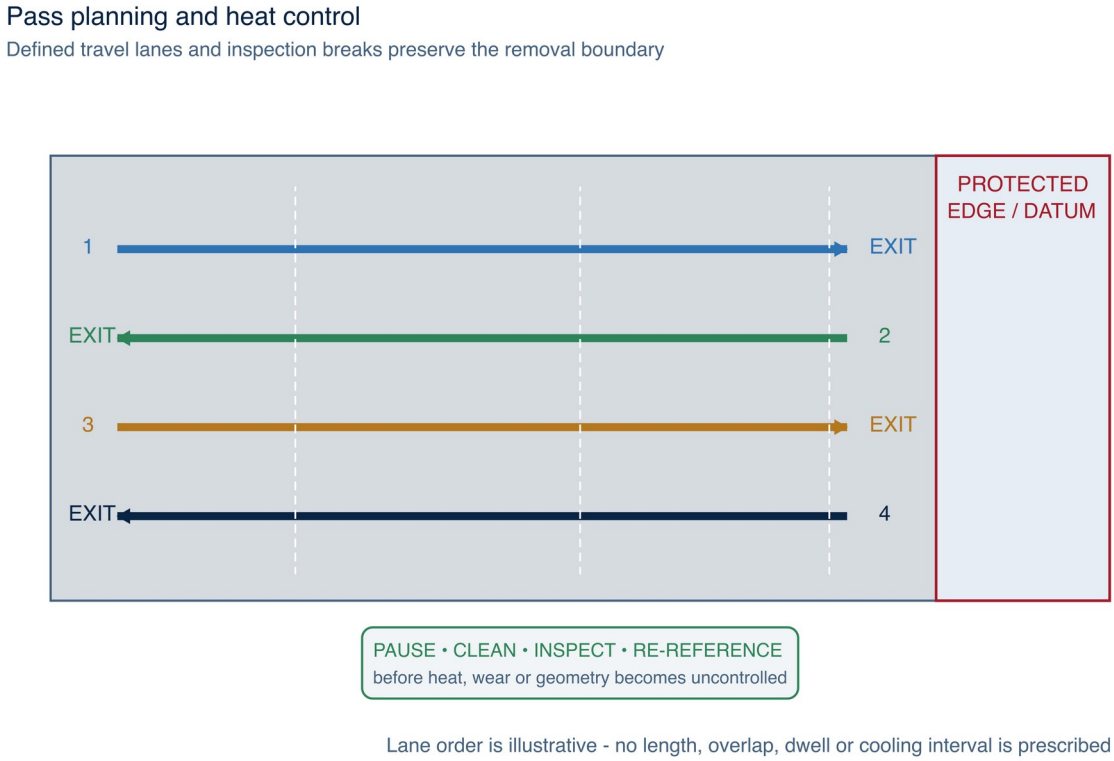

Figure 3. Pass and heat-control map. Alternating controlled lanes and inspection breaks protect the removal boundary; the diagram supplies no pass length or overlap value.

5. Protect edges, references and adjacent surfaces

Edges concentrate contact and reduce the margin for correction. Establish a protected offset from finished edges, holes, radii, sealing faces, machined datums and thin walls. Approach the final boundary with the approved lower-intensity process rather than carrying a bulk-removal product across it.

On external edges, avoid rolling the product over the corner and rounding a feature that must remain sharp. On internal corners, avoid trapping the product or using an undeclared side face. On raised bosses, ribs and welds, confirm which surface is the datum and protect the surrounding parent material.

Where a part can flex, provide support close enough to control movement without concealing the work or creating a pinch point. If the support, clamp or fixture moves, stop and re-establish the references. Heavy removal on a loose or resonant part is not corrected by gripping the machine harder.

6. Wheel condition changes the process

Wheel wear changes diameter, contact footprint, exposure, balance, edge condition and the relationship between guard, work and handles. The operator must inspect the product before use and at defined intervals, not only when removal becomes slow. FEPA and OSHA sources require product inspection, correct use, compatible speed, guarding and removal of damaged wheels from service. [S007; S018; S032; S063]

Normal controlled wear is expected only within the product instructions and trial record. **Glazing** is a dull working surface with reduced cutting action. **Loading** is retained work material or debris that obstructs cutting. **Uneven wear** changes contact and may cause vibration or path drift. **Damage** includes cracks, chips, impact marks, exposed reinforcement outside the declared condition, hub damage or any suspect change.

Do not dress, clean, trim or reshape a hand-held bonded or coated product unless that action is expressly permitted by its manufacturer and the workplace method. Never strike, drop or improvise a wheel-restoration action. When cutting action deteriorates, inspect the complete system and change the product at the approved condition—not after higher force has hidden the problem.

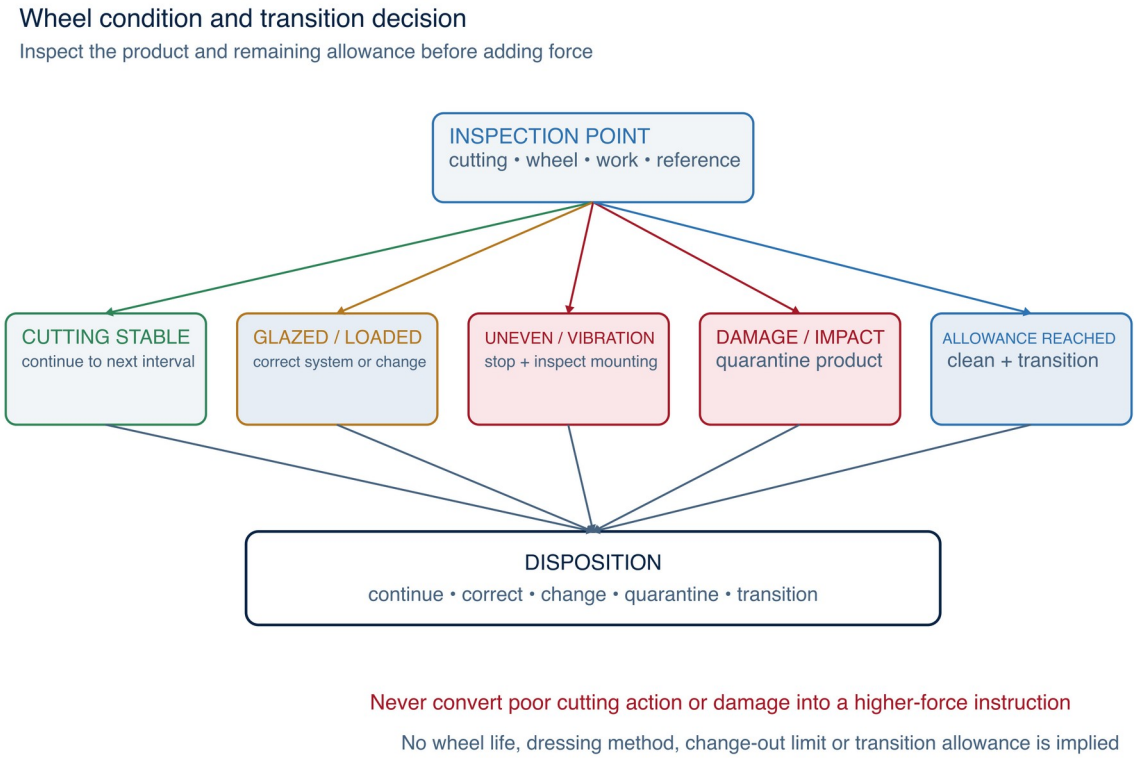

Figure 4. Wheel-condition and transition decision. Condition signals route to continue, correct, change, quarantine or move to blending; no automatic life limit is implied.

7. Transition to blending before the final contour

The bulk-removal stage should stop with a defined allowance for the next process. Waiting until the wheel reaches the final surface leaves no controlled margin for correcting scallops, heat tint, wheel marks or local lows.

Transition when any of the following occurs:

- the remaining high material equals the approved blending allowance;
- the bulk product can no longer contact only authorised material;
- the reference surface or edge is approaching the contact footprint;
- the required contour, finish or inspection sensitivity exceeds the bulk process capability;
- heat, vibration or wheel condition becomes unstable; or
- a hold-point inspection is due.

Clean the area, inspect from more than one direction and record the remaining condition before changing products. The blending stage requires its own product identity, compatibility, working-face declaration and acceptance criteria. Do not use a finer product merely to conceal heavy-grinding damage.

8. Control distortion and residual geometry

Distortion risk depends on part thickness, stiffness, restraint, residual stress, material, heat input, removal pattern and the amount and location of metal removed. The safest control may be reducing the need for manual grinding through better preparation, cutting, machining or fixture design. HSE specifically identifies precision preparation and alternative processes as ways to reduce grinder rework in heavy fabrication. [S081]

Where grinding remains authorised:

- support and clamp the part to the approved fixture plan;
- retain access to datum and inspection surfaces;
- distribute removal according to the approved sequence;
- avoid continuous work at one edge, corner or thin section;
- stop for movement, bowing, twist, clamp release or reference drift; and
- inspect geometry after unclamping when the plan requires a free-state result.

Do not straighten a distorted component by additional grinding. Hold it for engineering disposition.

9. Controlled heavy-removal workflow

181. Identify the component, material, starting condition and traceability.
182. Confirm the exact removal purpose, boundary, remaining allowance and protected geometry.
183. Verify the drawing, procedure, risk controls and inspection plan.
184. Decide whether grinding is the correct process or whether cutting, machining, cropping or automation is more suitable.
185. Select and record the machine, guard, handle arrangement, abrasive specification, support element and working face.
186. Verify speed compatibility, condition, mounting, workholding, access, lighting, extraction and ejected-particle controls.
187. Mark references where permitted and record the starting profile.
188. Establish the approved pressure-response, travel, pass and inspection method on representative work.
189. Remove material in controlled passes without crossing protected boundaries.
190. Inspect wheel condition, part heat, geometry, workholding and remaining allowance at defined intervals.
191. Stop and quarantine for damage, abnormal vibration, unexpected indications, distortion or loss of reference.
192. Clean, inspect and record the condition at the transition to blending or final release.

10. Troubleshooting heavy-removal signals

Signal	Possible system cause	Controlled response
Slow removal with rising heat	Glazing, loading, unsuitable specification, low power under load or rubbing contact	Stop; verify wheel condition, specification, machine delivery and working face before changing force
Machine speed falls or reaction becomes severe	Excessive load, large contact footprint, wrong product, unstable access or weak machine	Release load; hold and reassess the complete system
Deep scallops or local lows	Dwell, short repeated strokes, pivoting, narrow contact or chasing a high spot	Stop; inspect remaining allowance and restore a controlled pass pattern
Edge rounds or adjacent face is marked	Contact crossed the boundary, product width is unsuitable or support moved	Stop immediately; measure the protected feature and obtain disposition
Wheel wears unevenly or vibration increases	Side loading, incorrect working face, damage, mounting issue or changing access	Stop; isolate the product and inspect machine, mounting, guard and work
Part bows, twists or moves in the fixture	Local heating, uneven removal, inadequate support, restraint change or released residual stress	Stop; allow the approved stabilisation condition and obtain geometric/engineering review
Surface smears or wheel loads	Material incompatibility, poor chip clearance, contaminated product or excessive dwell	Stop; segregate affected work and verify the approved material-specific system
Final contour is close but bulk marks remain	Transition occurred too late or no allowance was reserved	Hold; do not chase the marks below the boundary—obtain disposition

11. Applying heavy-removal guidance

Mark the removal boundary and the geometry that must remain before work begins. Choose a product declared for the material, machine and heavy-removal action, then use controlled passes that keep the abrasive cutting without excessive dwell. Inspect the wheel, heat pattern, edges, thin sections and reference surfaces at planned intervals.

Transition to a less aggressive stage while sufficient allowance remains to remove the heavy-grinding scratch pattern. Do not pursue removal rate at the expense of parent-material thickness, weld profile, distortion, cracking, vibration or operator exposure. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

12. Heavy-removal process record

For repeatability, record the component and material; drawing and procedure revision; removal purpose; starting profile; authorised boundary; protected geometry; target and remaining allowance; machine, guard and handles; exact abrasive and batch; speed compatibility; support element and working face; workholding; access and extraction; load-control method; pass direction, length and inspection interval; wheel condition; heat and distortion observations; material removed where measured; transition condition; product change; unexpected indications; disposition; and dimensional and finish results.

GRINDING & CUTTING APPLICATIONS

CHAPTER 016

Grinding Thin Sheet

16

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, grinding operators, welders, sheet-metal workers, inspectors, QA/QC personnel, safety personnel, maintenance teams, trainers and technical sales personnel

Scope: Controlled grinding and blending of authorised weld and surface high spots on thin, distortion-sensitive sheet. This chapter does not define “thin” by a universal thickness and does not prescribe an MKTECH product, speed, pressure, angle, pass length, lane order, cooling interval, weld sequence, support spacing, temperature, finish value, remaining section or profile tolerance.

Safety-critical boundary — Thin sheet can move, vibrate, buckle, dish, bow, twist or lose section before the change is obvious. Grinding adds local heat and force to geometry that may already contain welding stress and restraint. Work only from the current drawing, welding and grinding procedures, support plan and inspection plan. Use an identified abrasive on a compatible guarded machine; secure the work without hiding movement or creating a hard fulcrum; and stop for heat concentration, reference drift, flexing, vibration, discolouration, surface damage, unexpected indications, loss of support or any uncertainty about remaining section or free-state profile. [S007; S008; S009; S014; S017; S018; S032; S063; S082–S084]

Chapter objectives

After this chapter, the reader should be able to:

- explain why thin sheet is sensitive to local heat, force, restraint and metal removal;
- define the approved profile and protected section before grinding;
- distinguish fixture support from an abrasive backing or support product;
- control pressure, footprint, pass direction, dwell and inspection intervals;
- select a controllable product family without transferring generic settings;
- coordinate grinding with the approved welding and distortion-control sequence;
- inspect the part both supported and free-state when the plan requires it;
- respond correctly to flexing, heat concentration, bowing and reference drift; and
- create a traceable thin-sheet grinding and profile-inspection record.

1. Establish the profile authority

“Thin sheet” is an application condition, not a universal thickness category. Sensitivity depends on alloy, thickness, span, formed shape, stiffeners, openings, weld position, residual stress, restraint and the amount and location of material removed. The drawing, engineering plan or qualified procedure must define the applicable part and acceptance criteria.

Before selecting an abrasive, identify:

- component, material, nominal thickness and traceability;
- weld, seam, attachment or surface condition to be treated;
- material that may be removed and material that must remain;
- finished face, edge, datum, feature and cosmetic zones;
- required weld profile, remaining section and surface condition;
- fixture and support condition during processing and inspection;
- required free-state inspection after release from restraint; and
- hold points for distortion, unexpected indications or uncertain profile.

Grinding cannot convert an unapproved weld, distorted assembly or dimensional nonconformance into an acceptable condition by appearance alone. If the controlling requirement is missing or contradictory, mark the area, protect the evidence and obtain disposition.

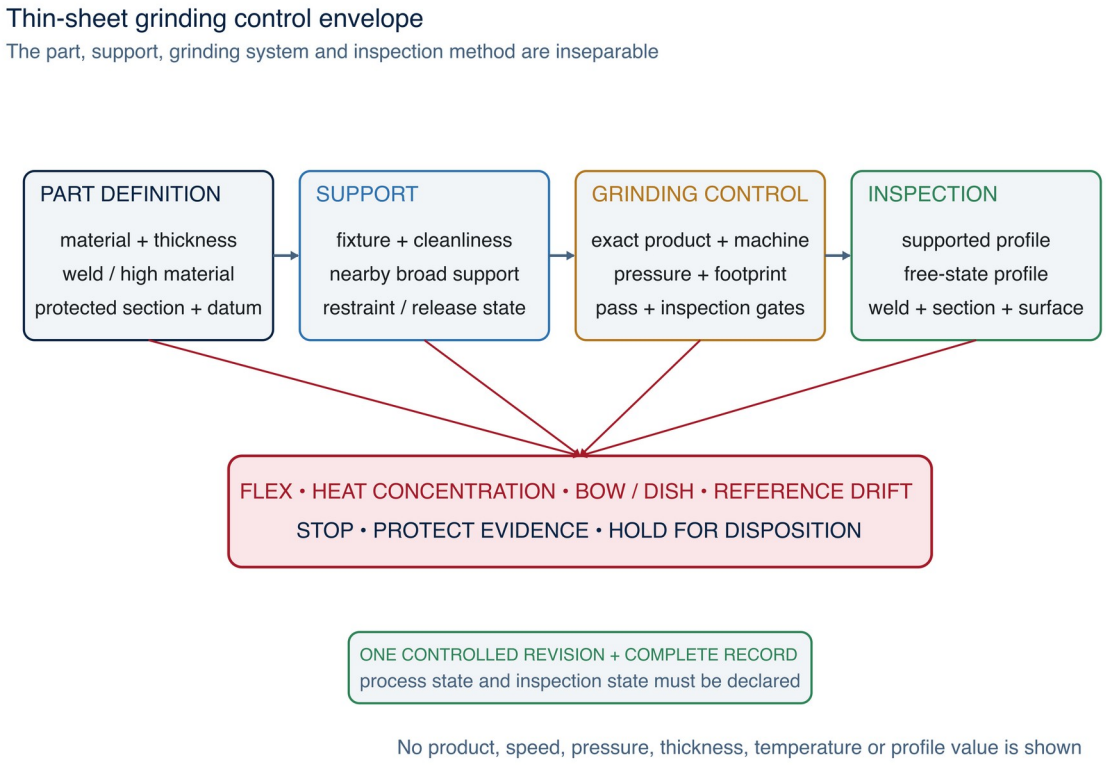

Figure 1. Thin-sheet control envelope. Part definition, support, grinding controls and inspection form one controlled system; uncertainty routes to hold.

2. Why thin sheet distorts

Thin sheet has limited bending stiffness compared with a thicker or more deeply formed part. A local grinding footprint can deflect the surface under force, while friction and chip formation create a concentrated heat source. Removing weld or parent material can also release locked-in stress or change the local stiffness.

TWI describes welding distortion as the result of non-uniform expansion and contraction under restraint, with permanent deformation possible when local stresses exceed the material response. It identifies longitudinal and transverse shrinkage, angular distortion, bowing or dishing, buckling and twisting as distinct outcomes. Thin plate may buckle elastically and appear rippled or dished. [S082]

A 2024 peer-reviewed study of thin-walled bearing grinding similarly found machining heat and stress to be principal deformation mechanisms, with greater heat entering the workpiece associated with higher thermal stress and deformation. Its geometry and precision process differ from hand-held sheet grinding, so only the mechanism is retained here; its parameters are not transferable. [S084]

The practical consequence is that grinding variables cannot be managed separately. Pressure changes deflection and contact; contact changes heat; heat changes stress and profile; support changes apparent profile; and removing restraint can reveal movement that was hidden while clamped.

3. Support the work without falsifying it

The work-support or fixture plan must control vibration and excessive flex while preserving access, visibility, cleanliness and the intended datum condition. This support is different from an abrasive backing pad, contact wheel or support element, which is part of the abrasive–machine system.

Use broad, stable support close to the working zone where the approved fixture plan permits it. Avoid point supports, unprotected hard edges or clamp positions that turn grinding force into a local bend. Do not place support over hot debris, abrasive grain, swarf or contamination that can imprint or scratch the reverse face.

Support can hide distortion. Record whether the profile is inspected:

- in the processing fixture;
- on the specified inspection support;

- after clamps are released; or
- in a defined free state after the approved stabilisation condition.

If the part changes shape as a clamp is released, do not force it flat for measurement or grind the new high point automatically. Preserve the condition and obtain engineering or quality disposition.

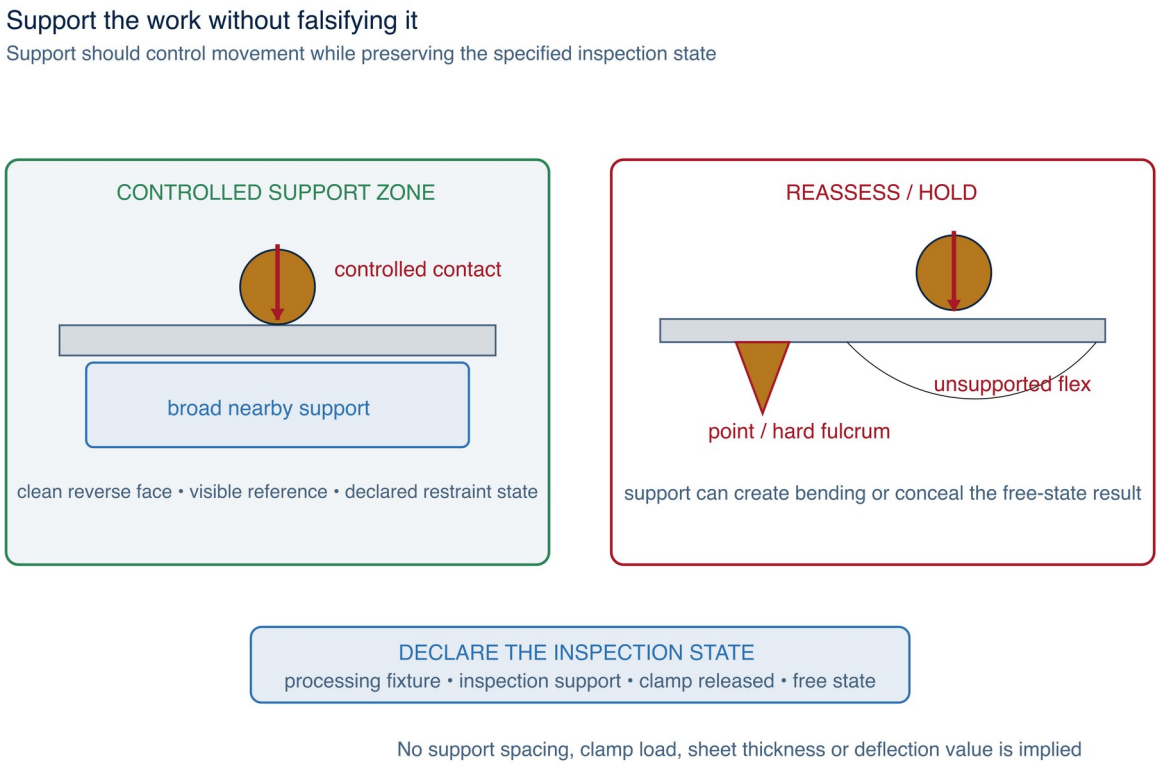

Figure 2. Work-support zones. Broad nearby support improves control; point support, a hard fulcrum and a long unsupported span can magnify deflection or hide the free-state result.

4. Control pressure through system response

The objective is stable cutting without visible sheet deflection, machine overload, abrasive smearing or loss of path control. Pressure is not a transferable number. It is a controlled response of the exact abrasive, support element, machine, working face, material, sheet geometry, fixture and operator method.

Before increasing pressure, check whether the abrasive is suitable, sharp, clean and used on its declared face; whether the machine maintains the required operating condition; and whether the footprint is too wide, rigid or concentrated for the available high material.

Insufficient cutting may show as rubbing, glazing, loading, smearing, discolouration or rising heat with little removal. **Stable cutting** gives a predictable path, controllable reaction and visible reference without sustained deflection. **Overload or poor support** may show as oil-canning, flutter, harsh vibration, falling speed, edge digging, rapid heat, gouging or the sheet moving with the tool.

If the surface flexes under contact, stop. Adding force can remove material from the temporarily deflected shape and leave a low area when the sheet springs back.

5. Plan direction, sequence and dwell

A controlled pass has an identified start, travel direction, exit and inspection point. Do not dwell at the start, end, weld stop, edge, corner, hole or isolated high spot. Do not repeatedly chase the brightest spark or highest-looking point without cleaning and re-referencing the surface.

The pass sequence should distribute contact so that one zone does not receive repeated heat and force while the surrounding sheet remains untouched. Alternating or separated lanes can be assessed during a representative trial, but there is no universal left-to-right, cross-hatch or skip pattern. The approved sequence depends on the high material, weld layout, sheet stiffness, support, access, abrasive footprint and inspection method.

TWI advises that weld run order and technique can be crucial to distortion control and describes balanced, back-step and skip approaches for welding. These are welding-fabrication principles, not automatic grinding instructions. Grinding must follow the specified weld and distortion-control sequence. [S083]

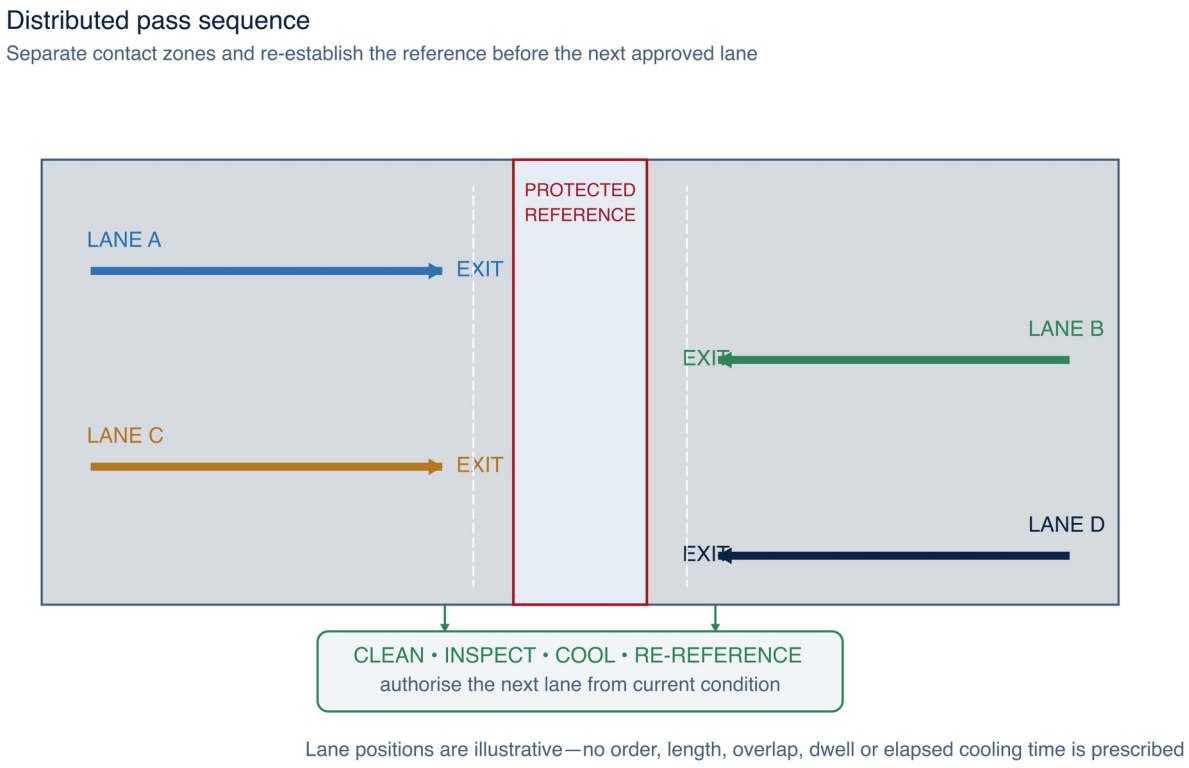

Figure 3. Distributed pass sequence. Separated lanes alternate around a protected reference, with clean–inspect–re-reference gates; no pass length, overlap, time or lane order is prescribed.

6. Use cooling intervals as inspection gates

A cooling interval is not merely elapsed time. It is a controlled pause in which contact stops, the surface is cleaned by an approved method, heat distribution and part condition are observed, the reference is restored, and the next action is authorised.

Set interval criteria during representative validation using the actual material, thickness, weld, support, abrasive, machine, access and environment. Useful observations can include:

- growing local heat relative to nearby material;
- heat tint or coating change where relevant;
- abrasive loading, glazing or reduced cutting;
- sheet flutter, oil-canning, bow, dish or reference movement;
- fixture or clamp movement;
- loss of the high-material boundary; and
- a scheduled dimensional, profile or visual hold point.

Do not prescribe a fixed number of seconds from generic guidance. Do not apply water, compressed air, solvent or another cooling or cleaning medium unless the abrasive, machine, electrical controls, material, coating, contamination plan and workplace procedure expressly permit it. Rapid or uneven cooling may itself affect condition and inspection evidence.

7. Select for control, not maximum removal

Heavy stock-removal products may have a footprint, stiffness or removal response that is unsuitable for a distortion-sensitive sheet. Select the least aggressive system that can meet the authorised removal and quality requirement with adequate control. Product-family names do not establish suitability.

Candidate system characteristic	Thin-sheet screening question	Control concern
Rigid bonded wheel or rigid contact	Can it remain only on authorised high material without side contact or local bending?	Gouging, concentrated heat, edge attack or undeclared working-face use
Coated disc with separate support element	Are disc, support element, fastener, speed and flexibility compatible as a declared system?	Excess compliance can round features; excess rigidity can concentrate force
Flap construction	Does wear preserve a controllable footprint and visibility through the full trial interval?	Footprint and edge exposure change as flaps wear
Belt or contact-wheel system	Are contact wheel, belt joint, tracking, support and access controlled for this geometry?	Long contact path can conceal heat, tracking or edge contact
Nonwoven or surface-conditioning product	Is the task light blending rather than removal of structural weld or required section?	Slow cutting can encourage dwell, heat and unsupported over-processing

Verify exact identity, dimensions, working face, speed compatibility, mounting, guard, support element and material suitability from current product instructions. Manufacturer selection guides can inform fields for a controlled trial, but their product rankings or application labels do not release an MKTECH process. [S004; S015; S055; S060; S061]

8. Coordinate with welding and fabrication sequence

Grinding should be planned with welding, not added after distortion has developed. Confirm the approved tack, restraint, stiffener, weld-run, inspection and clamp-release sequence before grinding. TWI notes that tack welding, back-to-back assembly, stiffening and balanced welding can assist distortion control, while the location and removal of tacks require care. [S083]

Do not grind:

- a tack, temporary attachment or weld reinforcement before its removal is authorised;
- a weld face that still requires as-welded visual or NDT evidence;
- one side of a balanced assembly without confirming the sequence;
- a clamped part solely to make its restrained profile look flat; or
- a suspected crack, lack of fusion, cavity or other indication into invisibility.

If grinding is an intermediate welding operation, the procedure must state the inspection, cleanliness and profile needed before the next weld. If it is final finishing, the final weld, surface and dimensional acceptance routes must all be closed.

9. Inspect profile and remaining section

Inspection begins before grinding. Record the starting high condition and the surrounding references so that removal can be distinguished from pre-existing distortion. Use the drawing and inspection plan to select the required straightedge, template, gauge, profile method, dimensional system, surface-finish method, visual testing or NDT.

ISO 17637 establishes a current framework for visual testing of fusion-welded joints, including possible use before welding, but it does not replace component-specific dimensions, quality levels or inspection responsibility. Use the acceptance values stated by the controlling drawing, specification or inspection plan. [S078]

At each hold point:

193. stop contact and make the machine safe;
194. clean the surface using the approved method;
195. inspect the abrasive, workholding and support;
196. re-establish the drawing datum or profile reference;
197. inspect the ground zone and adjacent parent sheet from more than one direction;
198. compare supported and free-state condition where required;
199. confirm remaining section and weld-profile requirements; and
200. record accept, continue, hold, repair or reject disposition.

Do not use reflected light, colour or touch alone as a profile measurement. A flush appearance can conceal a local low, rounded edge, thinned section or restrained distortion.

10. Thin-sheet distortion decision

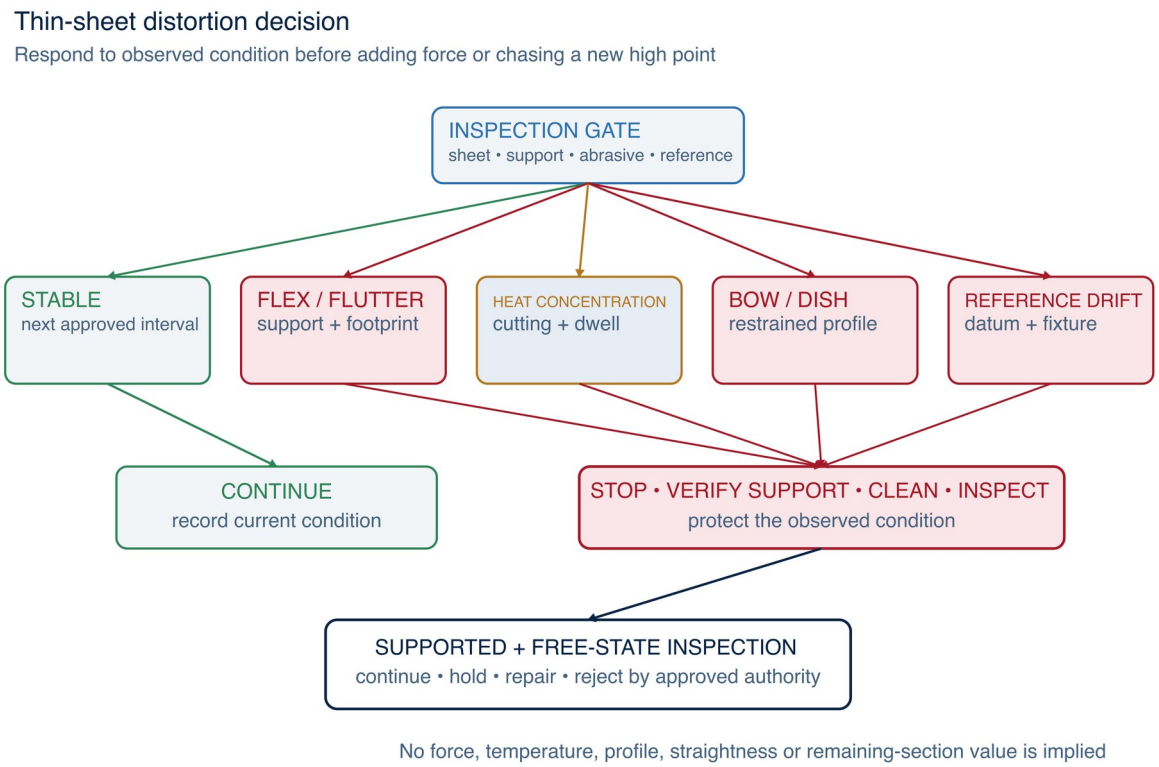

Figure 4. Distortion decision route. Stable condition can continue to the next approved interval; flex, heat concentration, bowing or reference drift routes through stop, support verification and controlled inspection.

Signal	Possible system cause	Controlled response
Sheet flexes or oil-cans under the product	Unsupported span, point support, excessive footprint or pressure	Stop; inspect both faces and verify the fixture and product system before continuing
Local heat rises but removal slows	Rubbing, loading, glazing, dwell or unsuitable product	Stop; clean, inspect and correct the system—do not add pressure
Panel bows or dishes while clamped	Uneven heat/removal, fixture movement or restraint change	Stop; preserve the fixture condition and obtain profile disposition
Shape changes after unclamping	Released residual stress or the fixture concealed distortion	Record the free-state result; do not force flat or grind the new high point automatically
Edge, hole or formed feature loses reference	Footprint crossed the boundary, support moved or datum was inadequate	Stop immediately; measure the feature and obtain disposition
Weld line becomes locally low	Dwell, excessive removal, hidden weld irregularity or deflection during grinding	Hold; verify remaining section, weld quality and repair authority
Surface ripples or shows alternating highs and lows	Repeated short strokes, unstable support, pass overlap or sheet vibration	Stop; inspect profile across the full affected span and reassess sequence
Unexpected line, cavity, colour change or contamination appears	Pre-existing indication, process damage, coating issue or mixed-material contamination	Stop, segregate and route through the specified inspection or material-control plan

11. Controlled thin-sheet workflow

201. Identify the component, material, thickness, weld or surface condition and traceability.
202. Confirm the authorised removal, protected section, finished profile, surface requirement and acceptance route.
203. Review the welding sequence, residual-stress or distortion-control plan, fixture plan and inspection hold points.
204. Record the starting supported and free-state profile where required.
205. Select and record the exact machine, guard, handles, abrasive, support element, working face and work-support system.
206. Verify speed compatibility, mounting, condition, access, lighting, extraction, dust, sparks and contamination controls.

207. Mark high material and protected references where the procedure permits.
208. Validate pressure response, footprint, pass direction, distributed sequence and cooling/inspection criteria on representative work.
209. Grind only authorised high material using the approved sequence without dwell or sustained deflection.
210. Stop, clean, inspect, cool and re-reference at each condition-based gate.
211. Hold for movement, heat concentration, unexpected indications, loss of section, reference drift or any unsupported result.
212. Complete supported and free-state profile, weld, surface and remaining-section inspection; record disposition and release.

12. Applying thin-sheet grinding guidance

Establish the required profile, remaining section and free-state dimensional condition before grinding. Support the sheet close enough to the work zone to control movement without concealing distortion. Use a product and contact system that provide controllable removal, then apply short, distributed passes with frequent inspection rather than prolonged local dwell.

Check both the supported and released condition where clamping can mask movement. Stop on rapid temperature rise, oil-canning, edge draw, loss of flatness, unexpected weld indications or remaining-section concern. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

13. Thin-sheet grinding record

For repeatability, record the component, material and nominal thickness; drawing, welding, grinding and inspection revisions; starting weld or surface condition; authorised removal; protected section, features and datum; fixture and support identity; starting supported and free-state profile where required; machine, guard and handles; exact abrasive, support element and batch; speed compatibility; working face; access, extraction and contamination controls; load-control method; pass direction and sequence; cooling and inspection gates; abrasive and sheet-condition observations; clamp changes; unexpected indications; remaining section; weld, profile, dimensional and finish results; final supported and free-state condition; and disposition.

GRINDING & CUTTING APPLICATIONS

CHAPTER 017

Grinding Tube, Pipe and Curved Surfaces

17

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, grinding operators, welders, tube and handrail fabricators, inspectors, QA/QC personnel, safety personnel, maintenance teams, trainers and technical sales personnel

Scope: Controlled grinding, blending and directional finishing of authorised external tube, pipe, bends, handrails and comparable convex curved surfaces. This chapter does not prescribe an MKTECH product, belt, contact wheel, wrap angle, contact pressure, machine speed, pass length, overlap, clocking sequence, grit sequence, finish value, wall thickness, diameter, ovality, radius or profile tolerance.

Safety-critical boundary — Curved work can rotate, pull a belt sideways, trap fingers, expose an edge, concentrate contact at a weld or lose wall and profile before the change is obvious. Work only from the current drawing, weld disposition, finish specification, machine manual and qualified method. Secure the component without crushing or distorting it; use an identified belt or abrasive on its compatible guarded machine; keep hands, clothing and measurement tools clear of the moving belt; and stop for unstable work, tracking change, belt-edge contact, joint impact, heat concentration, flatting, ovality, wall uncertainty, unexpected indications or loss of the specified scratch direction. [S007; S008; S009; S014; S017; S018; S032; S050; S051; S063; S078; S085]

Chapter objectives

After this chapter, the reader should be able to:

- define the controlled geometry, weld condition and finish direction before grinding;
- explain how wrap angle, contact footprint and support interact;
- prevent flat spots, local thinning and radius loss;
- distinguish contact-wheel, platen and slack-belt behaviour;
- verify tube-belt identity, direction, joint, tension and tracking;
- create axial, circumferential or other specified lay without treating grit as a finish specification;
- blend bends, junctions and handrail welds while preserving inspection evidence;
- inspect curved profiles at declared clock positions and datums;
- troubleshoot bands, spirals, flatting, edge lines and transition marks; and
- create a traceable curved-surface grinding record.

1. Establish geometry and finish authority

The tube or pipe diameter is not the process definition. The controlling record must identify material, wall, formed or welded condition, bend radius, section shape, seam or weld location, exposed face, datum, permitted removal, protected features and final finish. A nominally round component may arrive oval, locally high, dented, bent or restrained by fabrication. Record the starting condition before treating it.

Define the finish in drawing and inspection terms:

- axial, circumferential, helical, non-directional or sample-matched lay;
- visual zone and viewing direction;
- required weld profile and transition;
- surface-texture symbol, comparator, approved sample or instrument method;
- diameter, radius, wall, straightness, roundness or profile requirements;
- inspection clock positions and support condition; and
- hold points for uncertain indications, section or geometry.

ISO 21920-1:2021 is the published ISO framework for indicating profile surface texture in technical product documentation. It supports drawing-controlled texture specification; it does not supply an MKTECH finish value or convert a belt grade into acceptance. [S086]

If the finish is described only as “satin,” “polished” or “No. 4,” obtain an approved sample and measurement method. BSSA notes that process names and final grit alone do not fully define a stainless finish; pressure, contact time, feed and dry or wet operation also affect the result. [S028]

2. Control wrap angle and contact area

On a convex surface, the active abrasive may touch at a narrow tangent, over a contact-wheel footprint or around a longer slack-belt arc. “Wrap angle” describes how much of the circumference is engaged at one time; it is not a universal operating value. It changes with component diameter, belt path, machine geometry, contact-wheel position, belt tension, abrasive stiffness, applied force and operator orientation.

A narrow tangent contact can isolate a high weld or local defect but can also dig, stripe or flatten the surface if the path is not controlled. A longer wrap can distribute contact and follow a curve, yet it also removes from a wider area, reduces visibility and may copy an existing out-of-round condition. Flexible pipe sanders can use compliant sanding belts to follow pipe bends and perform circumferential work, but the permitted material, contact geometry and operating range remain product- and machine-specific. [S085]

Use a representative trial to establish the permitted contact mode. Mark the high area and protected reference, bring the abrasive into stable contact without impact, and confirm that the belt is cutting only where intended. Recheck contact after the belt wears, the component diameter changes or the path reaches a bend.

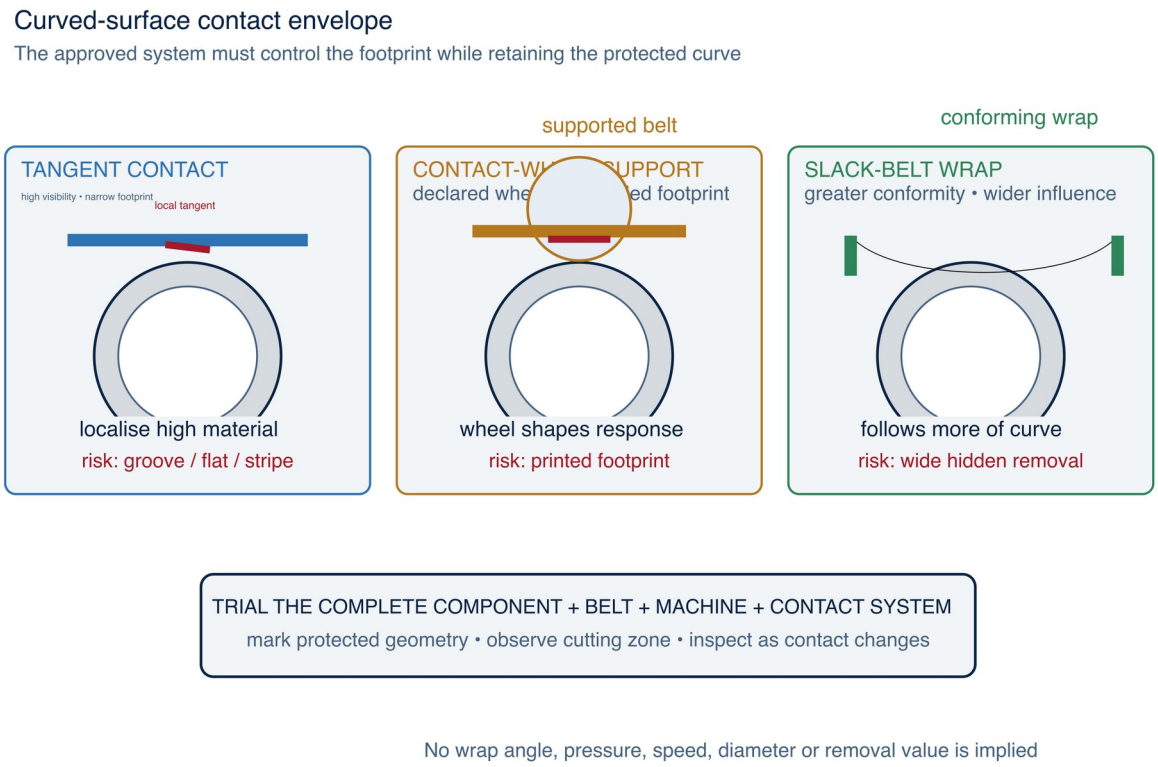

Figure 1. Curved-surface contact envelope. Tangent, contact-wheel and slack-wrap modes create different footprints; the approved system must retain the protected geometry.

3. Retain roundness, radius and wall

Geometry retention is a removal-control problem. The highest visual point may be weld reinforcement, a local bulge, a lighting highlight or the edge of an existing flat. Grinding it without a datum can enlarge the error.

Establish references outside the treatment zone and inspect more than one clock position. For a round section, use the approved combination of diameter measurement, radius or profile template, circumferential comparator, runout method, straightness check or scanned/CAD comparison. For a formed handrail or decorative tube, the controlled sample may add visual transition requirements, but it cannot replace wall or weld inspection.

A peer-reviewed study of belt grinding on shaped surgical-instrument surfaces assessed surface structure and roughness together with geometric accuracy and cross-section shape error. Its robotic system and numeric parameters are not transferable to hand-held tube finishing, but the quality principle is relevant: surface appearance and retained shape must be evaluated together. [S087]

Stop when the developing surface shows:

- a straight chord or flat reflection on a round section;
- a sudden change in radius at the blend boundary;
- an asymmetric profile across a weld;
- local diameter reduction or wall uncertainty;
- edge thinning at a tube end, slot, hole or junction;
- a bend that no longer matches the approved template; or
- a condition that changes after the work is released from its fixture.

Do not “round out” an uncertain section by grinding the opposite side. Protect the evidence and obtain engineering or quality disposition.

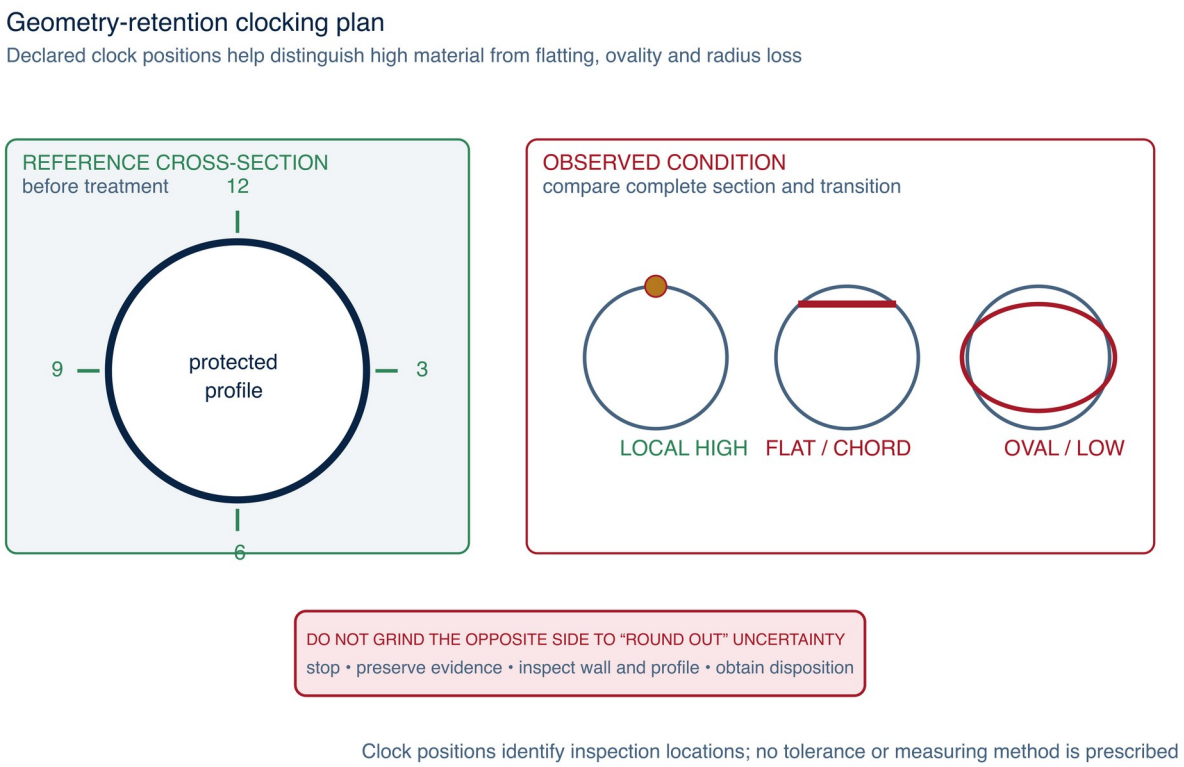

Figure 2. Geometry-retention clocking plan. Cross-section checks at declared clock positions distinguish a local high from a flat, oval or low condition.

4. Select the contact system

The belt, contact element and machine form one system. Belt grain and grade do not determine conformity by themselves. Backing weight and flex, joint construction, width, edge condition, tension and tracking interact with the contact wheel, platen or slack section. [S050; S059]

Contact mode	Appropriate screening question	Principal geometry risk
Narrow contact wheel	Can the footprint stay on authorised high material while the wheel follows the local radius?	Flat spots, grooves, edge lines or heat concentration
Wider compliant contact wheel	Does compliance support the specified curve without printing wheel shape or crossing protected zones?	Excessive blend width, radius loss or concealed local low
Slack belt or pipe-wrap system	Is the belt designed, tracked and guarded for the declared wrap and component size?	Wide uncontrolled removal, joint impact, belt-edge cutting or work pull
Platen-backed belt	Is the task truly a controlled flat or straight tangent feature?	A platen can impose a flat on a curved component
Non-woven or finishing belt	Is the task scratch refinement or visual blending rather than structural weld removal?	Slow cutting can encourage dwell, heat and over-processing

Contact-wheel hardness, face pattern, diameter and compliance affect the footprint and response, but no universal ranking is issued here. Obtain the machine and belt manufacturer’s declared combination and validate it on representative geometry.

5. Set up and monitor a tube belt

Before use, record the exact machine, belt designation, dimensions, direction mark, joint, maximum speed, material suitability and intended contact element. Inspect the belt edges and joint for cuts, creases, lifting, contamination, moisture damage or impact. Do not repair a failed production belt.

Set tracking and tension by the machine manufacturer’s instructions before contact. Run the machine in a protected no-load condition when required and confirm that the belt remains centred without hunting, edge rub or joint strike. Recheck after belt change, contact-wheel change, tracking adjustment or abnormal vibration.

During grinding, keep the component stable and the belt path visible. A tube belt must not be allowed to climb over a fitting, catch a tube end, run onto a clamp or contact an unprotected adjacent finish. Stop if the belt moves sideways, the joint becomes audible or felt, the machine reaction changes or one belt edge produces a persistent line.

Storage and humidity can affect belt shape, backing and bond. Unsuitable conditions can contribute to curl, bowing, creasing, loading and grain-retention problems. Apply the exact product's storage instructions rather than a generic interval or humidity limit. [S051]

6. Control scratch direction

Every abrasive contact leaves a lay, even when the final surface appears visually non-directional. On tube, the principal paths are axial along the tube, circumferential around it, and helical when axial feed and rotation occur together. The required direction must be named before the first refining pass.

Circumferential scratches can form visible rings or bands when the belt dwells at one station. Axial scratches can wander, fan or cross at a bend. A helical trace can appear when the tool advances while the work or belt wraps around the circumference. These patterns are not automatically defects; they become defects when they conflict with the drawing, approved sample, functional requirement or adjacent surface.

BSSA describes ground and brushed stainless finishes as directional and warns that grit alone does not define the result. Therefore match the approved lay, texture and viewing condition rather than merely repeating the last belt grade. [S028]

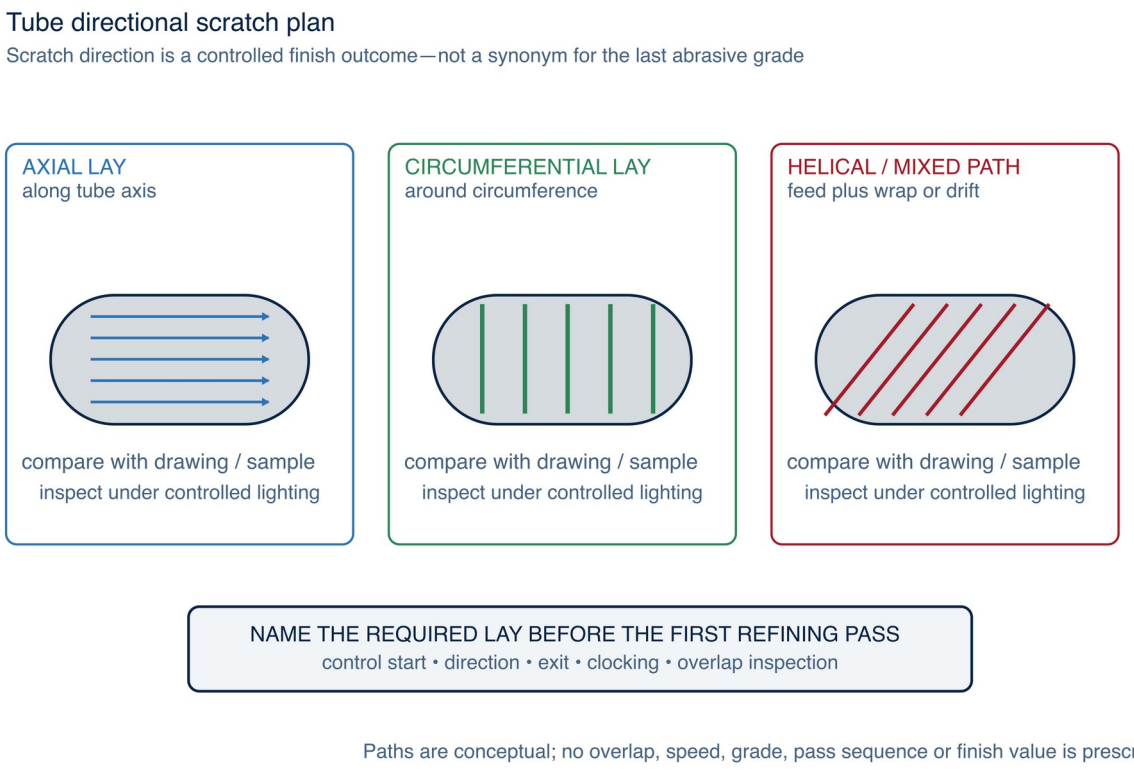

Figure 3. Directional scratch plan. Axial, circumferential and helical paths are distinct controlled outcomes; mixed or wandering lay routes to correction or hold.

7. Plan the pass and clocking sequence

Divide the component into identifiable zones using the approved drawing or fixture references. A controlled pass has a declared start, direction, exit and inspection gate. Avoid stopping at the same clock position on every pass, and avoid short repeated strokes that produce a ring, hollow or local heat band.

For local weld blending, remove only the authorised high material before expanding the transition. Re-establish the profile after each controlled interval. For full-circumference finishing, use an approved sequence that covers the complete circumference without leaving an untreated stripe or repeatedly overworking an overlap band. No universal clocking order, overlap or number of revolutions is prescribed.

At a bend, keep the belt orientation aligned with the local surface normal and the specified lay. The inside and outside radii do not present the same contact condition. Stop and reconfigure rather than twisting the belt or forcing the machine through a changing radius.

8. Blend welds, bends and handrail junctions

Handrails combine cosmetic visibility with functional geometry. Straight tube, elbows, mitres, posts, returns and branch junctions can require different access and scratch paths within one assembly. Establish a zone plan before grinding so that one corrected weld does not create a broad mismatched halo.

Confirm that the specified as-welded visual or NDT inspection has been completed before grinding. ISO 17637 provides a framework for visual testing of fusion-welded joints, while the component drawing, weld quality level and repair procedure remain controlling. [S078]

For a handrail junction:

213. document the starting weld and surrounding finish;
214. identify the weld reinforcement permitted for removal and the protected parent-metal profile;
215. select the smallest controllable system that can access the joint without striking the adjacent tube;
216. blend the weld in short controlled stages while checking both intersecting profiles;
217. refine scratches into the specified direction on each member;
218. match the agreed sample under controlled lighting; and
219. inspect weld, wall, junction radius, adjacent finish and cleanability before release.

Do not erase a junction line, sharpen a comfortable handrail transition, thin the toe region or create a local flat merely to make the reflection look continuous.

9. Manage heat, loading and contamination

Curved contact can hide the active interface. Heat may concentrate under the wrap while the visible belt appears to be moving normally. Stop for rising local heat, discolouration, smearing, reduced cutting, loading, glazing, belt-edge marking or an altered machine reaction. Clean and inspect by the approved method; do not add force to restore cutting.

For stainless steel, segregate abrasive products and cleaning tools from carbon-steel use. BSSA identifies contaminated finishing media as a source of rust staining on mechanically finished stainless surfaces. [S028]

Do not introduce water, compound, solvent or another lubricant unless the complete belt, machine, electrical system, material, contamination plan and workplace procedure are declared for it. Manufacturer product examples cannot be converted into a universal wet-use instruction.

10. Inspect the curved surface

Inspect before, during and after grinding. Use lighting that reveals both the lay and the profile. Rotate or view the component from controlled clock positions instead of accepting one favourable reflection.

At each inspection gate:

220. stop and make the machine safe;
221. clean the work by the approved method;
222. inspect belt, joint, edges, tracking, contact element and workholding;
223. re-establish the datum and clock references;
224. compare the treated zone with the required profile or template;
225. inspect diameter, wall, radius, straightness, roundness or transition as specified;
226. inspect scratch direction, depth, overlap bands and adjacent finish;
227. verify weld and indication disposition; and
228. record continue, correct, hold, repair or reject.

Do not measure against a hot, contaminated or elastically restrained condition unless the inspection plan expressly defines it.

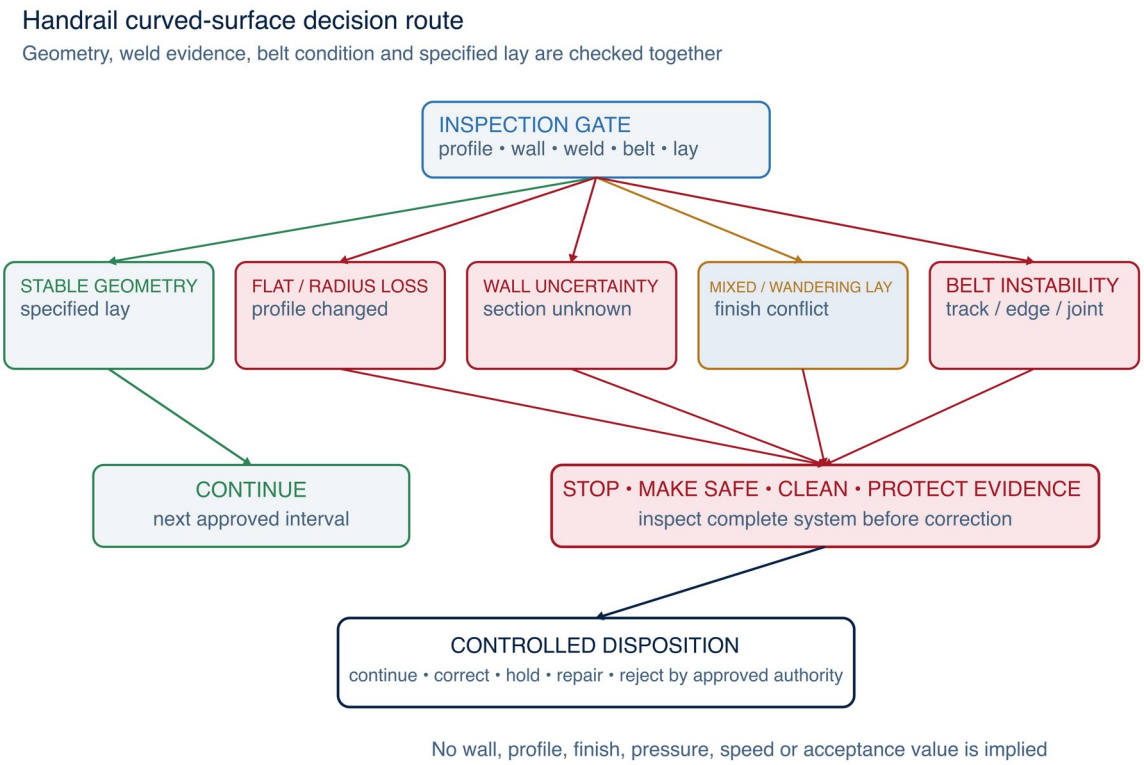

Figure 4. Curved-surface decision route. Stable geometry and specified lay may continue; flatting, uncertain wall, mixed lay or belt instability routes through stop and controlled disposition.

11. Troubleshooting curved-surface defects

Signal	Likely system cause	Controlled response
Flat reflection or chord develops	Narrow repeated path, excessive local removal, rigid contact or poor clocking	Stop; compare the full cross-section with the approved profile and obtain disposition
Circumferential rings or bands	Dwell, repeated start/stop position, uneven overlap or loaded belt	Stop; inspect profile before any wider blending; correct the process cause
Helical scratch where axial lay is required	Simultaneous wrap and feed, drifting tool angle or moving work	Stop; identify the actual path and revalidate the finishing method
One belt edge cuts a line	Tracking drift, tilted machine, damaged edge, joint or contact-wheel misalignment	Stop machine; quarantine uncertain belt and inspect the complete belt path
Weld disappears but a low remains	Excess removal, starting underfill, deflection or wrong datum	Hold for weld, wall and profile inspection; do not widen the low
Bend shows different gloss or scratch density	Changing contact footprint, pressure, belt speed response or viewing angle	Recheck contact mode and approved sample under controlled lighting
Work rotates, pulls or vibrates	Inadequate restraint, belt snag, unstable wrap, unbalanced contact or poor access	Stop immediately; make safe and redesign support or access
Rust staining or dark transfer appears	Mixed-metal contamination, dirty support or contaminated finishing media	Segregate, preserve evidence and follow the approved stainless-cleaning disposition

12. Controlled curved-surface workflow

229. Identify component, material, wall, diameter or profile, bend and traceability.
230. Confirm authorised removal, weld disposition, protected geometry and final lay.
231. Record starting profile and finish at declared clock positions.

232. Select the exact machine, belt, contact element, guard and workholding system.
233. Verify belt size, direction, joint, condition, speed compatibility, tension and tracking.
234. Protect ends, holes, fittings, adjacent tubes, finished zones and datums.
235. Validate contact mode, wrap response, footprint, pass direction and inspection gates on representative work.
236. Remove only authorised high material while preserving the profile reference.
237. Stop, clean, inspect and re-reference at each approved interval.
238. Refine scratches into the specified lay without overworking one clock position or overlap band.
239. Hold for flatting, ovality, wall uncertainty, mixed lay, heat, instability or unexpected indications.
240. Complete geometry, weld, texture, cleanliness and visual inspection; record disposition and release.

13. Applying curved-surface grinding guidance

Match the contact system to the diameter, radius, wall thickness, weld location and finish direction. Keep wrap and contact controlled: excessive wrap or dwell concentrates heat and can create flats, while insufficient contact can create narrow bands or unstable tracking. Index or clock the work systematically so adjacent passes overlap consistently around the circumference.

Inspect roundness, wall, radius, straightness and transition shape as required, together with scratch direction, banding, heat and contamination. Blend bends and handrail junctions with a planned direction that connects the adjacent surfaces. Follow the current machine instructions. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

14. Curved-surface grinding record

For repeatability, record the component and traceability; material, wall, nominal diameter or profile and bend radius; drawing, weld, grinding and inspection revisions; starting weld, geometry and finish; authorised removal; protected zones, datums and clock positions; workholding; machine, guard and guide system; exact belt, joint, direction, batch and condition; contact wheel or slack-belt configuration; speed compatibility; tracking and tension checks; contact and wrap mode; pass and clocking sequence; inspection gates; heat, loading and belt observations; geometry results; scratch direction and finish comparison; weld indication result; contamination check; and repair disposition.

GRINDING & CUTTING APPLICATIONS

CHAPTER 018

18

Cutting-Wheel Construction and Selection

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, cutting and grinding operators, fabricators, maintenance teams, safety personnel, QA/QC personnel, procurement staff, trainers and technical sales personnel

Scope: Construction and selection of identified bonded cutting-off wheels by type, thickness, diameter, bore, grain, bond, fillers, reinforcement, marked maximum speed, material declaration and stainless compatibility. Cutting speed, expected kerf, edge quality and burr level are treated as controlled trial outputs. This chapter does not prescribe an MKTECH product, wheel size, grain, bond, reinforcement, bore, machine, RPM, peripheral speed, feed, force, cut time, kerf, burr or edge-acceptance value.

Safety-critical boundary — A cutting wheel is a high-speed bonded tool, not a thin grinding disc. Use only an undamaged, identifiable wheel whose declared cutting use, type, dimensions, bore, reinforcement, material suitability, expiry where applicable and marked maximum operating speed match the current machine, guard, spindle, flanges and instructions. Never alter the bore, force the wheel onto the spindle, exceed its marked maximum speed or use the side of a cutting-only wheel for grinding. Stop for missing or contradictory marking, damage, distortion, moisture, incorrect fit, abnormal vibration, edge breakdown, binding, heat, loss of control or an unapproved material/application. [S032; S063; S090–S092; S095]

Chapter objectives

After this chapter, the reader should be able to:

- read a cutting wheel as one complete controlled identity;
- distinguish type 41 flat and type 42 depressed-centre constructions;
- explain how thickness, diameter and bore affect selection without using them as shortcuts;
- explain how grain, grit, bond, fillers and reinforcement work together;
- verify material and stainless compatibility from the exact product declaration;
- separate wheel maximum RPM, peripheral speed and cutting progress;
- treat expected kerf, edge quality and burr as measured trial outputs;
- compare candidate wheels using a controlled cut-quality record;
- recognise selection-related warning signals; and
- create a traceable cutting-wheel selection record.

1. Begin with the cut requirement

“Cutting wheel” describes an operation, not a complete specification. Start by defining what must be separated and what the accepted cut must leave behind.

Record:

- material, grade, coating and contamination restrictions;
- sheet, tube, profile or solid cross-section and the section actually intersected;
- machine type, asset, guard, spindle, flange set and maximum possible speed;
- required access, remaining-wheel clearance and cut depth;
- dimensional allowance and whether the cut is rough, intermediate or final;
- permitted kerf and material loss;
- required squareness, edge profile, heat/discolouration and burr condition;
- downstream welding, machining, coating, cleaning or inspection;
- production quantity and accepted-output target; and
- the current drawing, work instruction, risk controls and acceptance authority.

Do not select by wheel diameter or familiar colour first. The exact wheel must be declared for the material, operation and machine interface, then proven against the required output.

2. Read the complete wheel identity

ISO 525:2020 defines the general system of bonded-abrasive shape types, dimensional symbols, specification, designation and marking. ISO 603-16:2022 identifies common nominal dimensions for hand-held type 41 flat and type 42 depressed-centre cutting-off wheels. These standards organise product identity; they do not make two products interchangeable or supply an MKTECH selection. [S088; S089]

A controlled cutting-wheel identity includes:

- manufacturer, product family and exact code;
- type or shape and declared working edge;
- outside diameter, thickness and bore or threaded interface;

- abrasive grain family, grit or manufacturer grade where declared;
- bond system, fillers and reinforcement construction;
- material and application declaration;
- maximum operating speed in RPM and any peripheral-speed marking;
- conformity, restriction and safety symbols;
- batch/lot, expiry or use-by marking where applicable; and
- package, storage and wheel condition.

Colour, label design, thickness or successful past use cannot replace those fields.

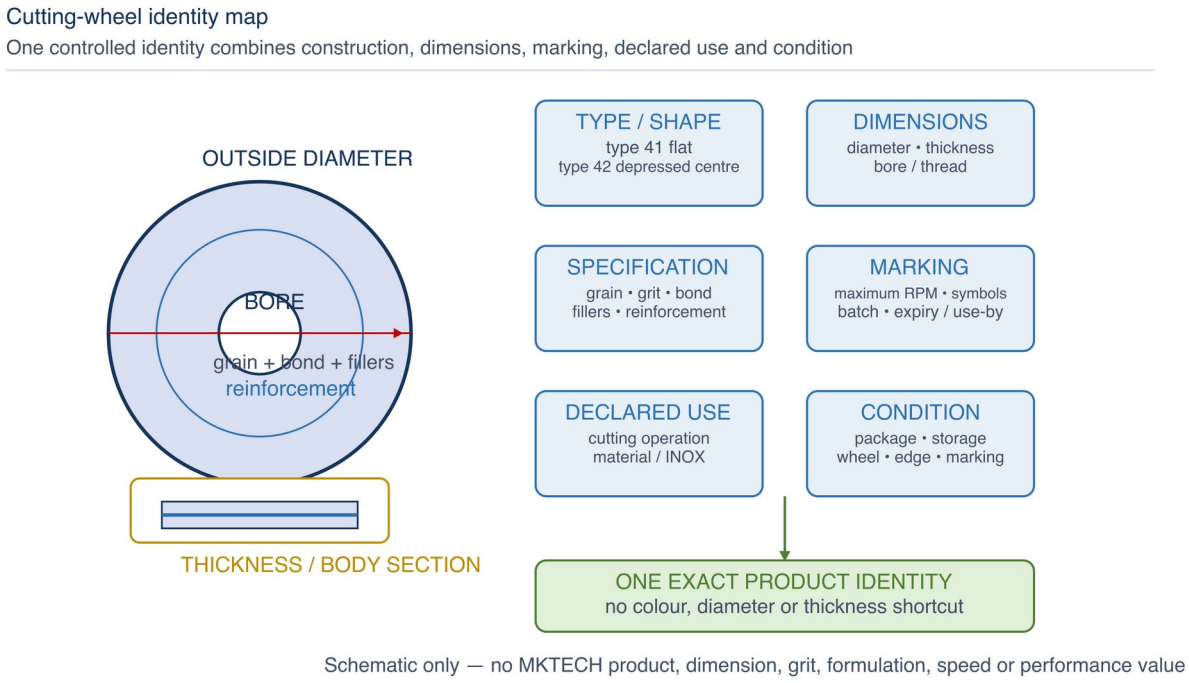

Figure 1. Cutting-wheel identity map. Construction, dimensions, marking, material declaration and condition belong to one exact product identity.

3. Distinguish type, thickness, diameter and bore

Field	What it changes	Invalid shortcut
Type or shape	Centre geometry, mounting clearance and declared use	“Any thin wheel is a type 41 cutting wheel”
Thickness	Nominal body width, lateral stiffness, clearance and material engaged	“Wheel thickness equals finished kerf”
Outside diameter	Machine and guard fit, available depth, peripheral speed and changing clearance as the wheel wears	“A smaller wheel is always safer or interchangeable”
Bore or thread	Spindle and flange interface, centring and clamping arrangement	“If it enters the spindle, it fits”

Type 41 is a flat cutting-off form. Type 42 is a depressed-centre cutting-off form. A product intended for combined cutting and grinding is a separate declared construction; reinforcement or a depressed centre does not by itself authorise side grinding. [S088; S091; S092]

Thickness

Thickness is a construction field and a trial variable. Manufacturer catalogues often position thinner wheels for narrow cuts, low material loss or reduced burr, but those are product-specific claims. A thinner wheel may offer lower nominal material engagement, while a thicker wheel may offer different stiffness or durability. Neither tendency approves a wheel for the machine or predicts the accepted edge. [S093]

Actual kerf can be wider than nominal wheel thickness because the wheel, machine and work form a dynamic system. Run-out, flange condition, wheel deflection, side motion, wear, cut length, work movement, material response and loss of line control can all widen or vary the cut. Measure kerf on representative work.

Diameter

Diameter must match the machine capacity, guard and mounting system. It also participates in peripheral speed at a given RPM and controls available reach. As a consumable wheel wears, remaining diameter, clearance and machine response change; the acceptable replacement point comes from the exact product and machine instructions, not from fitting a worn large wheel to a faster small machine.

Bore

The bore must fit freely on the intended spindle and work with the correct, clean, undamaged flange set. Do not enlarge, drill, file or force a bore. Do not improvise washers, bushings, flanges or adapters. OSHA requires speed verification, free fit and clean, flat contact surfaces; any bushing must not interfere with the flanges. [S095]

4. Grain, grit, bond, fillers and reinforcement work together

The abrasive grain cuts, but cutting behaviour is not determined by grain name alone. Grit size and shape, the grain blend, bond chemistry, fillers, reinforcement, wheel density and the bond–grain interface all influence cutting action, wear, heat and stability.

A peer-reviewed cut-off-wheel study states that cutting properties depend on abrasive properties together with the bonding agent, fillers and reinforcement fabric. Its experimental wheel results are not transferable, but the construction principle is important: changing one field can change the complete response. [S094]

General screening questions include:

- Is the grain and complete formulation declared for the work material?
- Does the product specification favour the required cross-section and duty?
- Is the bond intended to release or retain grain appropriately in that application?
- Do fillers support the declared cutting behaviour and material restrictions?
- Is the reinforcement construction declared for the machine and wheel type?
- Does the wheel remain stable without glazing, rapid wear, edge crumbling or abnormal heat?

Do not convert a grain abbreviation, grit number or reinforcement layer count into a universal performance ranking.

5. Reinforcement does not remove the lateral-load limit

Reinforcement is an engineered component of many resin-bonded cutting wheels. It contributes to the declared construction and safety performance, but it does not turn a cutting-only wheel into a grinding wheel.

Reinforcement does not convert a cutting wheel into a side-grinding wheel: the declared wheel edge is the working zone for cutting. FEPA distinguishes flat and depressed-centre cutting wheels and addresses fitting, guarding and condition. oSa notes that even a slight tilt or curved cut can create large lateral loads on a wheel approved only for straight cuts. [S091; S092]

Selection must therefore preserve the declared use:

- cutting-only wheel: use only for the declared cutting operation;
- combined cut-and-grind wheel: verify that exact combined declaration and all machine requirements;
- stationary or mobile saw wheel: verify the separate machine, mounting and operating standard; and
- non-reinforced wheel: use only where the manufacturer and machine specifically permit it.

Chapter 019 will address correct cutting technique. This chapter establishes only the product-use boundary.

6. Verify material and stainless compatibility

Material compatibility is an exact product declaration. Do not infer it from wheel colour, a generic aluminium-oxide label or successful use on another metal.

For stainless steel:

- obtain the exact wheel manufacturer’s stainless or INOX declaration;
- verify any controlled iron, sulfur and chlorine limits from the current TDS;
- segregate the wheel, flanges, supports and cleaning tools where the process requires stainless-only use;

- prevent cross-use on carbon steel when contamination controls prohibit it;
- confirm compatibility with the stainless grade, cross-section and downstream service; and
- record the product document revision and batch/lot.

A stainless-suitability or INOX declaration belongs to the exact product and may be supported by controlled impurity limits. Never generalise that declaration to another wheel with similar colour, dimensions or appearance. [S092]

For aluminium, non-ferrous alloys, cast iron, nickel alloys, coated materials and mineral products, obtain the exact material and application declaration and assess loading, heat, dust, fire, coating and contamination hazards separately.

7. Maximum RPM is a compatibility ceiling

The wheel's marked maximum operating speed must be equal to or greater than the machine's maximum possible speed for the fitted configuration. Compare maximum with maximum; do not rely on typical loaded speed, operator habit or an assumed variable-speed setting.

The speed gate also includes:

- exact wheel diameter and type;
- machine model and declared capacity;
- guard type and size;
- spindle, bore, thread and flange compatibility;
- machine condition and speed-control integrity; and
- wheel marking, condition and expiry where applicable.

OSHA requires the machine spindle speed to be checked against the wheel marking before mounting. CCOHS and FEPA repeat the same essential compatibility principle. [S090; S091; S095]

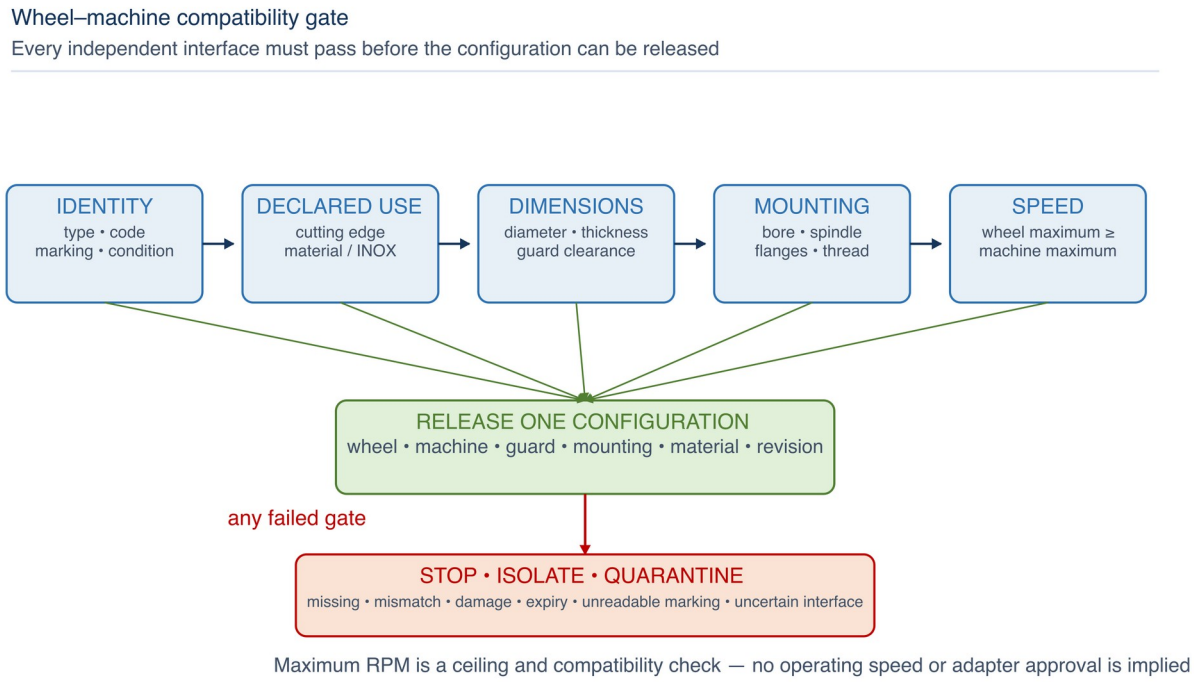

Figure 2. Wheel–machine compatibility gate. Product identity, declared use, dimensions, mounting, guard, condition and maximum-speed compatibility must all pass.

8. Separate RPM, peripheral speed and cutting progress

"Cutting speed" can mean different things and must be labelled.

- **Machine or wheel RPM** is rotational speed.
- **Peripheral speed** is the linear speed at the wheel circumference and depends on diameter and RPM.
- **Cutting progress** is how quickly the wheel advances through the work or completes a defined cut.
- **Production rate** is accepted cuts or components per unit time, including changeover and rework.

The wheel maximum RPM or peripheral-speed marking is a limit, not proof of the best cutting condition. Cutting progress also depends on material, section, wheel construction, available machine power, wheel wear, work stability and the approved technique. Do not increase speed, force or feed to meet a time target unless the exact system permits it and the trial remains within safety and quality controls.

Record these quantities separately so “faster” cannot hide a speed violation, wider kerf, excessive burr, heat, wheel wear or rejected parts.

9. Treat kerf, edge quality and burr as outputs

Nominal thickness helps form a hypothesis; the controlled trial establishes the output.

Trial output	What to record	Why wheel specification alone is insufficient
Cut time and production rate	Time for the defined cut, interruptions, changes and accepted parts	Material, cross-section, machine response, wheel wear and technique interact
Kerf	Width and consistency at declared locations, material loss and variation through the cut	Thickness, run-out, deflection, side motion, wear and work movement interact
Edge geometry	Squareness, straightness, profile, breakout, rounding and remaining allowance	Wheel stability, mounting, access, material and cut path interact
Burr	Location, direction, continuity, height or approved rating and removal requirement	Ductility, section, wheel response, exit condition and support interact
Thermal condition	Discolouration, recast/smear, coating damage and temperature checks specified by the plan	Cutting action, loading, contact time, material and heat flow interact
Wheel condition	Diameter loss, edge condition, glazing, loading, cracking, chipping and balance	Bond, grit, reinforcement, duty and misuse interact

Thin cutting wheels may be intended to reduce kerf, material loss or burr under stated application conditions. Define how kerf, edge quality and burr will be measured, then compare the exact wheel-machine-material combination on representative work. [S093]

Do not call an edge “burr-free” merely because no large burr is visible. Inspect the complete circumference or profile under the declared method, and account for any downstream deburring, welding, cleaning or machining.

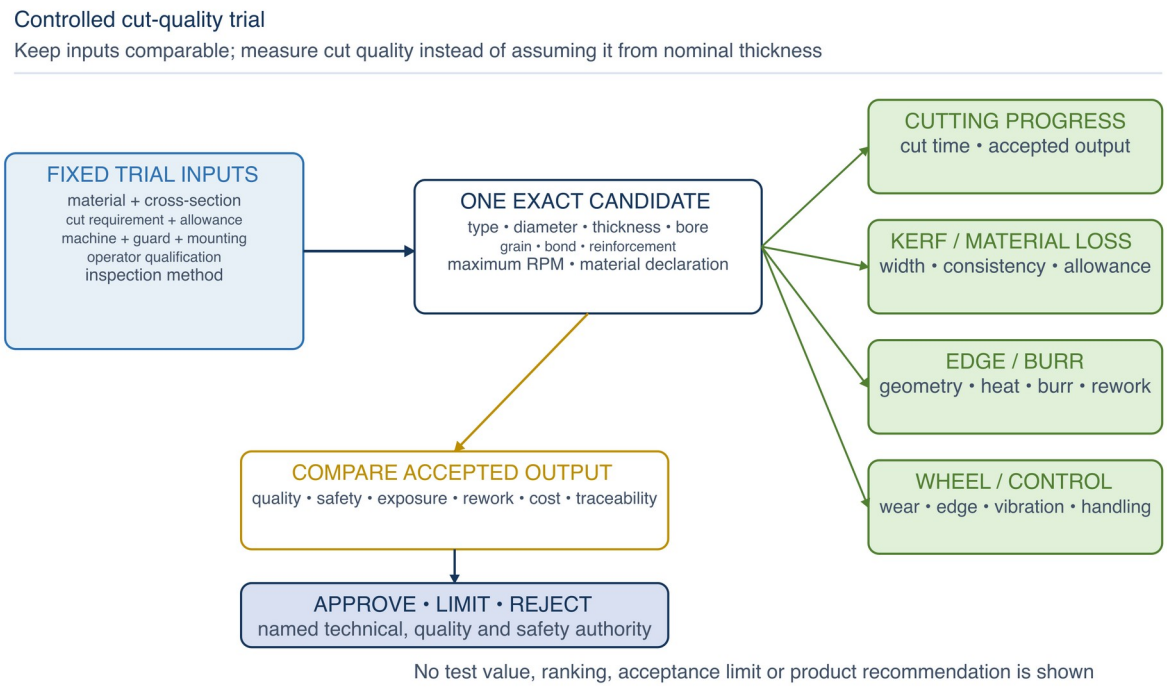

Figure 3. Controlled cut-quality trial. Fixed inputs are separated from measured outputs; nominal wheel thickness does not become an assumed kerf or burr result.

10. Compare candidate wheels fairly

A comparative trial changes one controlled candidate at a time while keeping the work definition, machine, mounting, guard, operator qualification, acceptance method and recording method consistent.

For every candidate, record:

241. exact product, code, batch and document revision;
242. type, diameter, thickness, bore, grain, grit, bond, reinforcement and maximum speed;
243. material declaration and stainless-control status;
244. machine, guard, spindle, flanges and maximum possible speed;
245. starting and ending wheel condition and diameter;
246. number and cross-section of accepted cuts;
247. cut time, interruptions and changeover;
248. measured kerf and material loss;
249. edge geometry, heat/discolouration and burr;
250. dust, spark, noise, vibration and operator-control observations;
251. downstream deburring, grinding, cleaning or rework; and
252. acceptance, rejection, limitation and approver.

Compare cost per accepted output, not wheel price or fastest single cut. A candidate that cuts quickly but produces variable kerf, heavy burr, heat damage, rapid wear or rework is not automatically the better system. [S036]

11. Selection-related warning signals

Signal	Possible selection or compatibility cause	Controlled response
Wheel will not cut or glazes	Wrong material declaration, unsuitable grain/bond, loading, worn wheel or inadequate machine response	Stop; verify the complete product–machine–material specification
Rapid wheel wear	Unsuitable bond/duty, excessive load, speed response, unstable work or damaged wheel	Hold output; inspect wheel, machine and cut record
Edge crumbles or wheel chips	Side load, binding, incorrect flange, damage, work movement or unsuitable construction	Stop immediately; isolate the machine and quarantine the wheel
Kerf is wide, tapered or inconsistent	Run-out, flange/spindle condition, wheel deflection, wear, work movement or path instability	Stop; inspect the complete system before further cutting
Heavy or variable burr	Unsuitable wheel/section combination, changing wheel condition, work movement or unqualified process	Measure the burr and revalidate candidate selection
Blue, smeared or heat-damaged edge	Loading, rubbing, unsuitable construction, poor cutting progress or excessive heat input	Stop; protect the part and obtain material/quality disposition
Vibration or abnormal sound	Wheel damage, imbalance, incorrect fit, dirty or damaged flanges, machine defect or binding	Make safe; quarantine the wheel and inspect the machine
Rust staining or contamination concern	Wrong material declaration or mixed-metal product/tool history	Segregate, preserve evidence and follow the stainless disposition

Do not respond by adding uncontrolled force, exceeding marked speed, dressing the wheel by improvised contact or using the side of a cutting-only wheel.

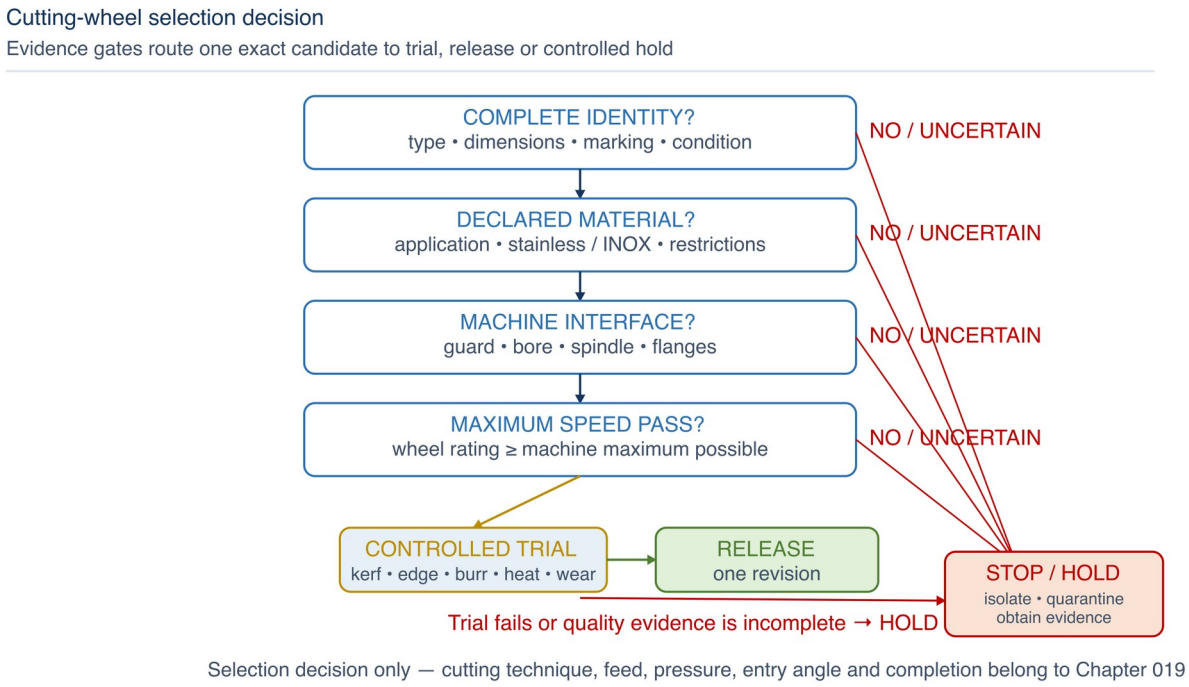

Figure 4. Cutting-wheel selection decision. Unclear identity, incompatibility, damage or an undefined quality criterion routes to stop, quarantine or controlled verification.

12. Controlled selection workflow

253. Define material, cross-section, quantity, downstream process and accepted cut.
254. Identify the exact machine, guard, spindle, flange set and maximum possible speed.
255. Select only a wheel type declared for the cutting operation and machine class.
256. Verify diameter, thickness, bore and mounting interface.
257. Verify grain, grit, bond, fillers and reinforcement from the current product data.
258. Verify material and stainless compatibility, segregation and contamination controls.
259. Verify the wheel maximum operating speed against the machine maximum possible speed.
260. Verify conformity, restrictions, expiry where applicable, batch and condition.
261. Define measurable cut-time, kerf, edge, burr, heat, wear and control criteria.
262. Run a representative controlled trial under the approved Chapter 019 technique.
263. Compare accepted output, wheel condition, rework, exposure and cost.
264. Release one exact wheel–machine–material–cut requirement revision or hold the decision.

13. Selecting a cutting wheel in practice

Start with the work material, section geometry, cut quality and downstream operation. Read the complete wheel marking and confirm type, diameter, thickness, bore, declared application, reinforcement, maximum permitted speed and expiry or use-by information. Match the wheel to the machine, guard, spindle and flanges without improvised adapters.

Thinner wheels can reduce kerf and cutting force but demand accurate alignment and strong control against side loading; thicker wheels may provide greater robustness but remove more material. Compare candidates by straightness, squareness, burr, heat, wheel condition and accepted output—not speed or wheel life alone. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

14. Cutting-wheel selection record

For repeatability, record the task, component, material and grade, coating, cross-section, quantity, downstream process, drawing and acceptance criteria, machine or asset, guard, spindle, flanges, machine maximum speed, wheel manufacturer, family, code, batch or lot, type, diameter, thickness, bore or thread, grain, grit, bond, fillers, reinforcement, maximum-speed marking, material declaration, conformity and expiry marking, storage condition, cutting method, cut time, kerf, edge geometry, burr, heat or discolouration, wheel wear, exposure observations, rework, accepted output and cost basis.

GRINDING & CUTTING APPLICATIONS

CHAPTER 019

Correct Cutting Technique

19

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, cutting and grinding operators, fabricators, maintenance teams, safety personnel, QA/QC personnel, trainers and technical sales personnel

Scope: Straight cutting with a hand-held angle grinder and an identified bonded cutting-off wheel: machine alignment, entry, maintaining the cut line, avoiding twist and side load, work support, pinch prevention, spark direction, interruption and safe completion. Exact product selection, machine settings, travel direction, numerical feed or force, support dimensions and acceptance values come from the identified machine and wheel instructions and the task requirements.

Safety-critical boundary — Use this chapter only after the complete wheel–machine–material system has passed Chapter 018. Follow the current wheel and machine instructions, task risk controls and local hot-work requirements. Use the correct guard, both hands and stable footing; keep people outside the line of fire; secure and support the work so it cannot move or pinch the wheel; maintain one cutting plane; and never steer, deepen or recover a cut by twisting, swinging or side loading a cutting-only wheel. If the wheel binds, walks, chips, vibrates, slows abnormally or control is lost, release the switch and hold the tool motionless until the wheel stops. Isolate and inspect before any re-entry. [S032; S090–S092; S095; S097]

Chapter objectives

After this chapter, the reader should be able to:

- define a straight cut as a controlled alignment problem;
- align the machine, guard, wheel plane and marked cut line;
- plan first contact without treating entry angle as a universal number;
- maintain the cut line without twist, swing or side load;
- support the stock and off-cut while preventing kerf closure;
- place the operator and others outside credible kickback and debris paths;
- control spark direction and hot material;
- interrupt, inspect and restart a cut safely;
- complete the cut without losing control of the wheel or off-cut; and
- create a traceable cutting-technique qualification record.

1. Correct technique is a controlled relationship

A straight cut is not produced by one hand angle or by pushing harder. It is produced when the intended kerf, wheel plane, machine, guard, operator, work support and material response remain compatible from first contact through separation.

The technique must control six relationships:

- **wheel to machine:** the selected wheel, guard, spindle, flanges and speed remain compatible;
- **wheel plane to cut line:** the wheel edge follows one intended plane without lateral steering;
- **machine to operator:** both hands, handle positions, footing and view permit stable control;
- **work to support:** the stock and off-cut cannot move, sag, rotate or close the kerf;
- **rotation to line of fire:** body, bystanders, cables, hoses and combustibles remain outside credible fragment, kickback and spark paths; and
- **cut to acceptance:** kerf, edge, burr, heat and remaining allowance are inspected under the approved plan.

ISO 11148-7:2012 covers safety requirements for operator-supported non-electric grinders used for cutting-off. HSE, FEPA and CCOHS provide regulator and industry best-practice controls, while current manufacturer manuals define the exact controls for their machine families. This chapter combines those compatible principles into an actionable baseline without inventing machine-specific numbers. [S090–S091; S096–S098]

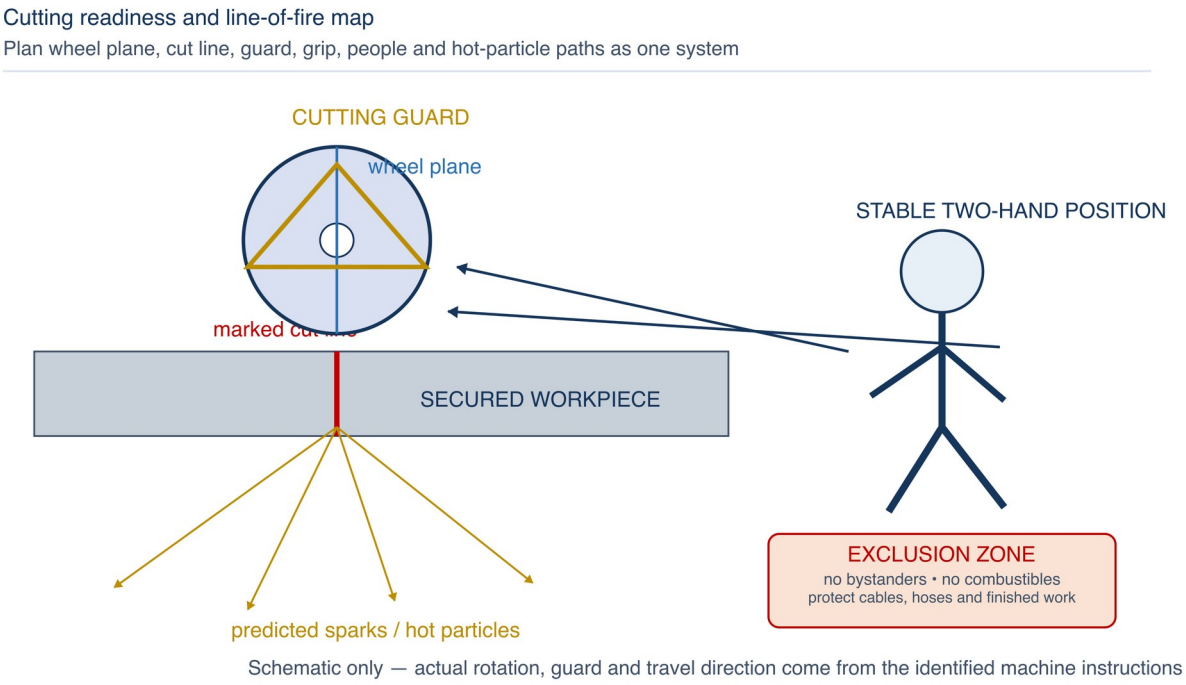


Figure 1. Cutting readiness and line-of-fire map. The wheel plane, cut line, guard, grip, operator position, exclusion zone and spark path must be planned together.

2. Establish the cut plan before starting

Confirm the cut requirement before the wheel rotates:

- exact material, grade, coating, contamination restriction and cross-section;
- drawing, cut line, allowance, datum and required downstream edge condition;
- exact machine, wheel, guard, handles, flanges and maximum-speed compatibility;
- access for the complete cut without guard removal or an unstable body position;
- stock support, off-cut control and predicted kerf-opening or kerf-closing movement;
- hidden services, pressure, stored energy, residual stress and structural consequence;
- spark, fragment, dust, noise, fire and hot-material controls;
- bystander exclusion and the operator’s escape path;
- inspection method for line, kerf, edge, burr, heat and wheel condition; and
- the authority to stop, hold, rework or reject.

Do not begin a blind or structural cut until the work has been identified and made safe. A wheel entering an unknown wall, vessel, assembly or enclosed section can contact electrical conductors, pipes, pressure, combustible residue or restrained material. Manufacturer warnings require extra caution in blind areas because the wheel can encounter hidden services and kick back. [S097]

3. Align the machine and operator

Machine alignment begins before entry. Hold the machine firmly with both hands using its intended gripping surfaces and auxiliary handle. Establish stable footing and a body position that can resist start-up torque and a credible kickback reaction. Do not stand in line with and directly behind the rotating wheel or place a hand near the wheel plane. [S097]

Set the guard required for cutting and position it as the exact manual directs. The guard must not be removed or opened to obtain a view or reach. Plan a line of sight that does not place the face or torso in the fragment path.

Align three visual references:

265. the marked or fixtured cut line;
266. the plane of the wheel; and
267. the direction in which the machine can travel without wrist rotation, body overreach or guard interference.

If the required path cannot be reached while maintaining both-hand control, guard coverage and stable footing, change the work arrangement or machine. Do not compensate by one-handed cutting, reaching around the wheel, rotating the guard away or fitting an unapproved wheel.

4. Support the stock and control the off-cut

The work must remain stable under gravity, cutting force and final separation. “Clamped” is not enough if the arrangement closes the kerf, lets the off-cut rotate, or releases stored stress into the wheel.

Assess:

- which portion is retained stock and which is the off-cut;
- whether either side can sag, roll, spring, twist or drop;
- whether the kerf tends to open, remain neutral or close as the cut deepens;
- whether a clamp or support can become loose after separation;
- whether residual forming, welding, straightening or assembly stress may be released;
- whether the off-cut can strike the operator, wheel, cable, floor or nearby equipment; and
- whether support can remain effective through the last ligament of material.

Large panels and other flexible work require support near the cut and edges to reduce pinching risk, but exact support positions depend on geometry, stiffness, restraint and the intended separation. A person must not substitute for a fixture by holding the off-cut. Unknown movement, stored stress or support behaviour is a hold condition. [S090; S097]

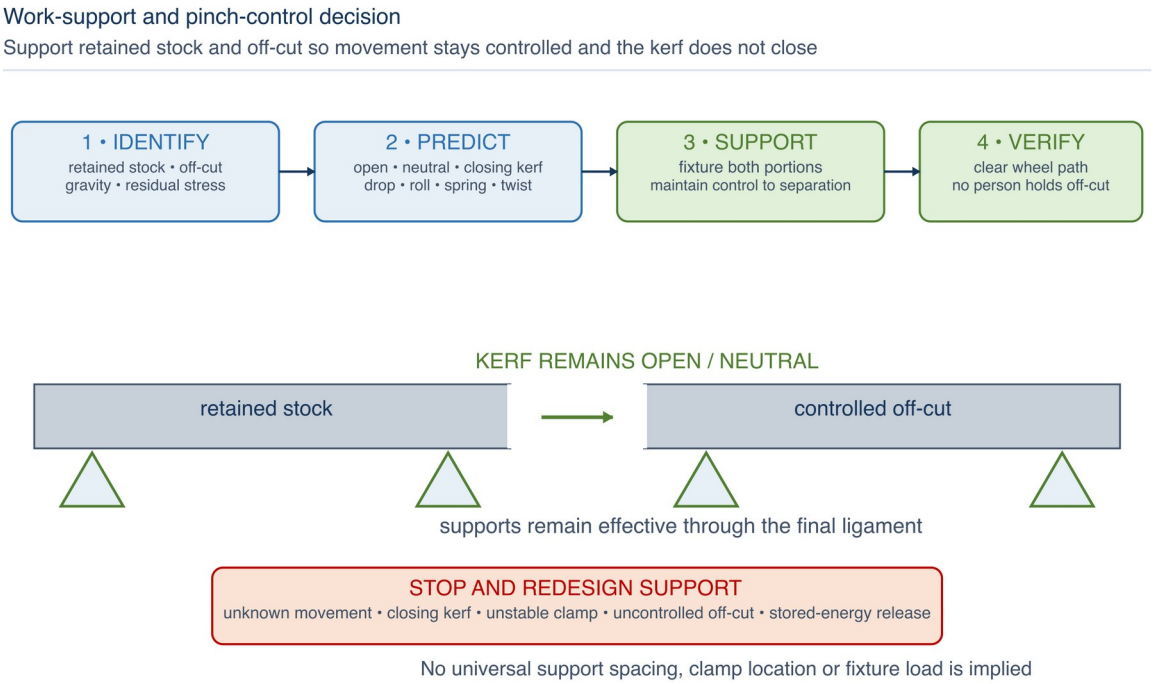


Figure 2. Work-support and pinch-control decision. Support must stabilise stock and off-cut while preventing the kerf from closing on the wheel; no universal clamp spacing is implied.

5. Enter the cut under control

Entry angle describes the relationship between the wheel plane, its working edge and the work at first contact. It is not a universal degree value.

Before contact:

- verify the wheel and work are clear of people, loose items and services;
- start in the position and direction required by the exact machine manual;
- allow the wheel to reach the operating state required by that manual;
- confirm normal sound, vibration, guard position and wheel tracking; and
- approach the marked line without bumping the work.

Establish a shallow, controlled kerf that confirms the line and plane before committing to depth. The wheel plane must agree with the intended cut plane at entry. Do not start with the wheel trapped in the work, stab the edge into the material, or use side pressure to make the wheel “find” the line.

Machine instructions may prescribe moderate feed, prohibit pressure, tilt or swing, and require a particular travel direction. Follow the exact machine and abrasive instructions rather than generalising travel direction or feed technique across grinders. [S097]

6. Maintain one cutting plane

Once the kerf is established, progress along the planned line while keeping the wheel in the same plane. The operator guides the machine; the cutting edge removes material. Added force is not a substitute for wheel suitability, machine power, support or a straight path.

Use the following control logic:

- maintain both-hand control and a neutral, stable stance;
- look ahead along the cut line rather than watching only the contact point;
- use a qualified, moderate feed that keeps the cutting action stable;
- keep the wheel plane aligned with the kerf as depth and wheel diameter change;
- let the guard and handles remain in their approved positions;
- prevent the cable, hose or extraction equipment from entering the wheel or off-cut path;
- monitor sound, vibration, motor response, sparks, heat, wheel edge and work movement; and
- pause for inspection before drift becomes a forced correction.

Never twist the machine to steer a rotating cutting-only wheel. Do not swing the rear of the machine, lean the wheel against a kerf wall, widen the cut by side motion or use the wheel side to remove a high spot. These actions add lateral load, can cause binding and can fracture the wheel. [S090–S092; S097]

If the line is lost, do not bend the wheel back toward it. Interrupt the cut, wait for full stop and inspect whether the existing kerf can be safely re-entered, whether a new controlled kerf is permitted, or whether the part must be held for disposition.

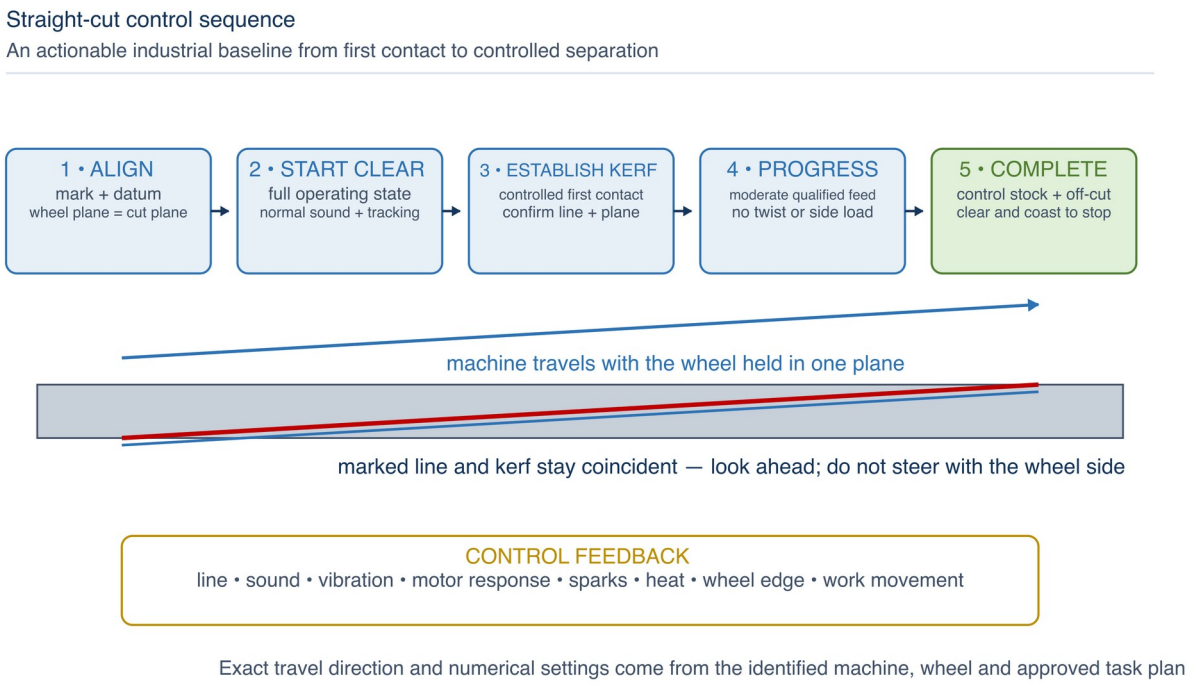


Figure 3. Straight-cut control sequence. Controlled entry, single-plane progress, qualified feed and stable completion replace numerical-angle or force shortcuts.

7. Prevent binding, walk-up and kickback

Kickback can follow a pinched or snagged wheel. The stalled contact can drive the machine opposite the wheel movement at the binding point, toward or away from the operator. A wheel may also break under the same conditions. [S097]

Binding risk rises when:

- the work closes the kerf or moves after support changes;
- the operator twists, swings or applies side pressure;
- the wheel is forced so deeply or heavily that the machine slows;
- the cut changes direction inside the material;
- a corner, sharp edge, weld, coating or section change catches the wheel;
- the off-cut drops, rolls or strikes the wheel;
- the wheel is damaged, unsuitable, worn or incorrectly mounted; or
- the cut is restarted with the wheel trapped in the work.

Do not solve slow progress by forcing the wheel. CCOHS states that the wheel must not be jammed, bent or pinched and cutting must not be forced until the motor slows. A slowing motor is a diagnostic signal: reduce demand, then verify wheel selection, machine response, support and material condition. [S090]

8. Interrupt and re-enter safely

If the wheel binds or the cut must be interrupted:

268. release the switch;
269. hold the machine motionless in the cutting plane;
270. wait until the wheel comes to a complete stop;
271. do not pull a rotating wheel from the kerf;
272. isolate the energy source as required;
273. inspect the wheel, guard, flanges, machine, kerf, support, work and off-cut;
274. identify and remove the cause of binding or instability;
275. quarantine a damaged or doubtful wheel; and
276. re-enter only if the exact instructions, work condition and approval permit it.

Do not restart with the wheel inside the work. Manufacturer guidance directs the operator to let the wheel reach the required speed and carefully re-enter, because an in-cut restart can bind, walk up or kick back. [S097]

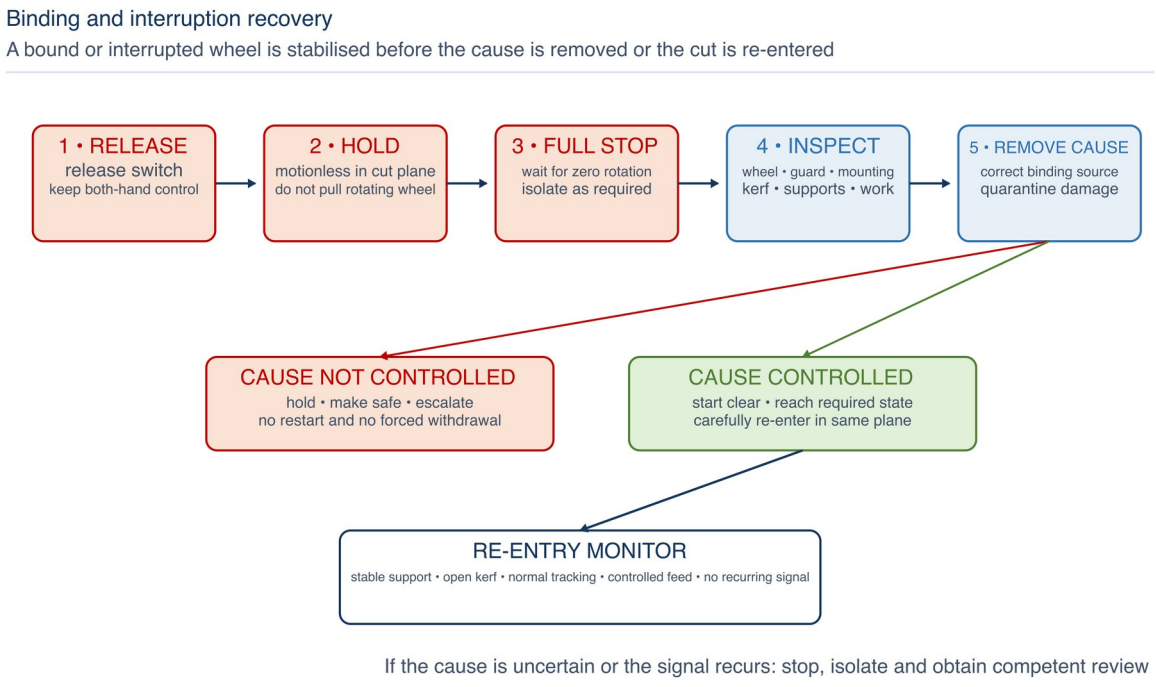


Figure 4. Binding and interruption recovery. Release, hold, full stop, isolate and inspect come before any controlled re-entry.

9. Control sparks, debris and hot material

“Spark direction” is not a single compass direction. It is the predicted path created by wheel rotation, contact point, guard position, machine travel and changing cut geometry.

Before cutting, confirm that sparks and fragments are directed away from:

- the operator’s face, torso, clothing and escape path;
- bystanders and adjacent workstations;
- flammable or combustible materials and residues;
- gas cylinders, hoses, cables, batteries and electrical equipment;
- finished surfaces, glass, vehicles and contamination-sensitive equipment;
- open containers, drains, voids and concealed spaces; and
- the intended support, clamp or off-cut control.

Do not rely on the visible main spark stream alone; fragments can travel outside it. Apply the current workplace hot-work, fire-watch, ventilation, respiratory, eye, face, hearing and clothing controls. The cut edge, off-cut, wheel and machine parts may remain hot after the visible sparks stop. Do not touch or release them until the approved cooling and handling method permits it. [S032; S090; S095; S097]

For stainless work, keep the wheel, supports, clamps, cleaning tools and surrounding debris under the approved contamination-control plan. Spark direction must not carry carbon-steel debris onto protected stainless work.

10. Complete the cut without losing the system

The final ligament can change the system suddenly. The off-cut may drop, rotate or spring; the kerf may close; the remaining stock may shift; and the wheel may break through into a new path.

Before final separation:

- confirm that stock and off-cut remain controlled;
- confirm the wheel has clear travel after breakthrough;
- maintain the same cutting plane and both-hand control;
- anticipate any change in support or stored stress;
- keep the body outside the expected tool and off-cut paths; and
- avoid a last-second push, twist or side correction.

After separation, maintain control until the wheel is clear and comes to a complete stop as the exact manual directs. Never slow a coasting cutting wheel with side pressure and never set down a machine with the wheel rotating. Preserve the cut part and off-cut for inspection if any abnormal signal occurred. [S097]

Geometry-specific completion paths for sheet, plate, tube, profile, hollow section and solid bar belong to Chapter 020.

11. Stop signals and controlled response

Signal	Credible mechanism	Required response
Wheel binds or machine kicks	Kerf closure, snag, twist, side load, support movement or section change	Release; hold motionless to full stop; isolate and inspect
Motor slows or cutting action collapses	Excessive demand, unsuitable wheel, loading, unstable work or machine limitation	Stop adding force; hold and verify the complete system
Cut line drifts or kerf tapers	Misalignment, wheel deflection, side steering, run-out or work movement	Interrupt; do not twist back to the line; inspect and obtain disposition
New vibration, sound or wheel-edge change	Damage, looseness, imbalance, incorrect fit, chipping or contact instability	Stop immediately; quarantine the wheel and inspect the machine
Sparks or debris enter an unsafe zone	Guard, travel, body or work orientation is wrong or has changed	Stop; re-plan the line of fire and hot-work controls
Work or off-cut moves	Clamp/support change, sag, rotation, stored stress or final-ligament release	Stop; make safe; redesign support before continuing
Heat, discolouration, smear or coating damage	Rubbing, loading, slow progress, excessive contact or material response	Hold the part and process for technical and quality review
Guard, handle or view becomes obstructed	Access or arrangement no longer supports controlled cutting	Stop; change the arrangement or machine—do not remove controls

12. Qualify the technique on representative work

A controlled trial must use the exact wheel, machine, guard, handles, flanges, work support and material form intended for production. Record the operator qualification and hold constant every input that is not being studied.

Evaluate:

- ability to establish and maintain the intended cut plane;
- stable machine response without forcing, twist or side load;
- stock, kerf and off-cut behaviour through final separation;
- spark, debris, dust, noise, vibration and hot-work control;
- interruption and safe re-entry where the plan requires it;
- cut time and accepted output without turning time into a speed target;
- kerf, line position, straightness, squareness and remaining allowance;
- burr, edge breakout, heat, discolouration and coating condition;
- wheel wear, edge condition and any damage; and
- downstream deburring, welding, cleaning, machining or rework.

Approve one exact revision of machine, wheel, material, support, cut path, operator method and inspection plan. Any material change returns the technique to controlled review. [S036; S097]

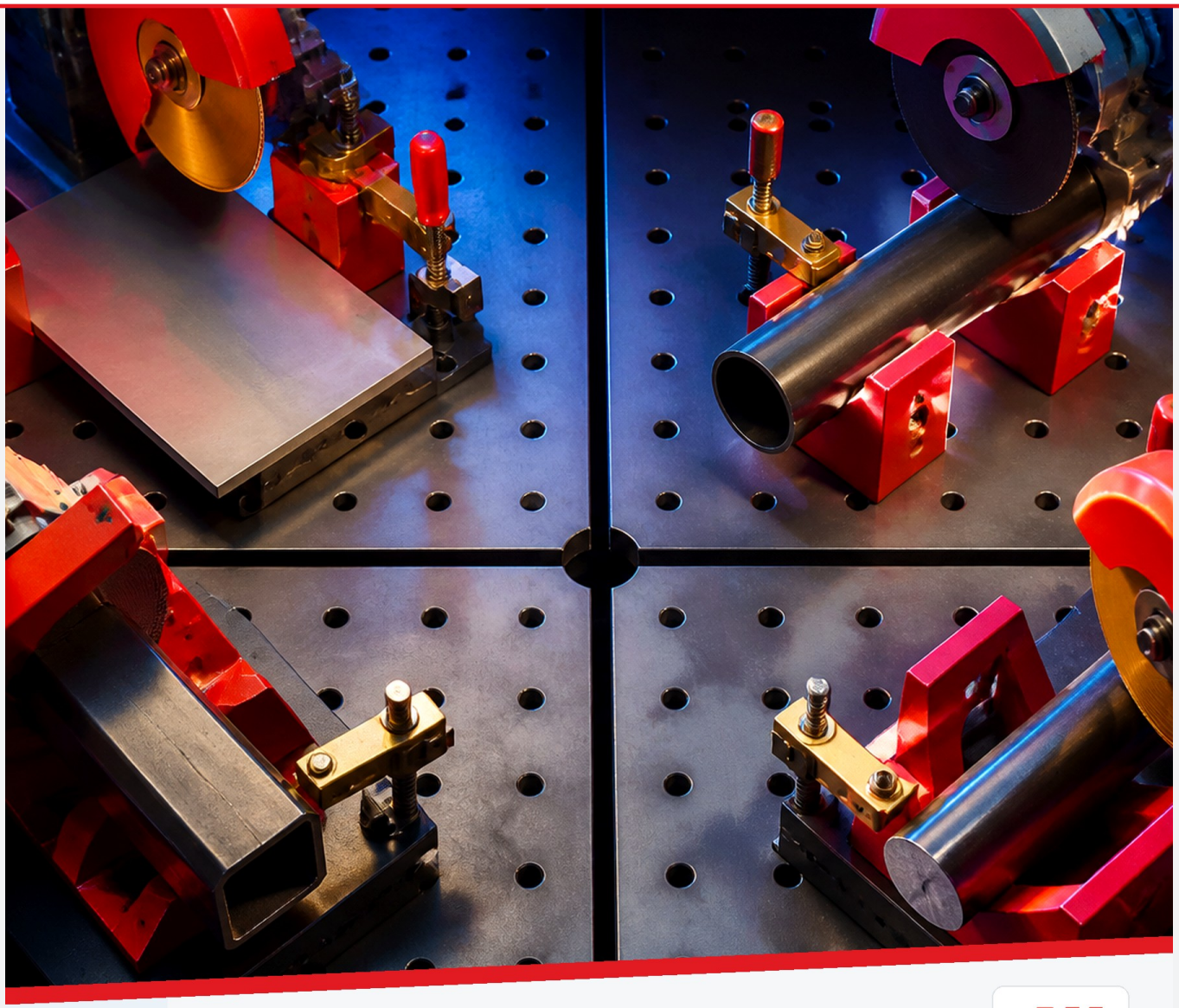
13. Applying correct cutting technique

Begin with a complete compatibility check: identified wheel, suitable machine, correct guard and flanges, secure work support and a clear cut line. Position the operator outside the likely line of kickback and debris, enter without impact, maintain one cutting plane and let the wheel cut without twisting or forcing.

Plan how the kerf and off-cut will move before starting. For interrupted cuts, release the switch and wait for a complete stop before inspecting or repositioning. Confirm cut line, squareness, burr, heat and wheel condition after the cut. Follow the current machine instructions. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

14. Cutting-technique record

For repeatability, record the task, component, material and grade, coating, cross-section, drawing, datum, cut line, allowance, downstream process, acceptance method, machine and asset, machine manual revision, wheel manufacturer/family/code/batch, wheel type and dimensions, guard, handles, spindle, flanges, maximum-speed check, work support, clamps, off-cut control, predicted kerf movement, stored-energy check, operator position, line of fire, spark/fire controls, PPE and exposure controls, entry method, machine-prescribed travel direction, feed or depth control, interruption and completion methods, cut time, kerf, line, squareness, burr, edge, heat, wheel condition, abnormalities and rework.



GRINDING & CUTTING APPLICATIONS

CHAPTER 020

Cutting Sheet, Tube, Profile and Solid Bar

20

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, cutting and grinding operators, fabricators, maintenance teams, safety personnel, QA/QC personnel, trainers and technical sales personnel

Scope: Geometry-specific planning and execution for abrasive cutting-off with a hand-held angle grinder and an identified bonded cutting wheel. It covers thin sheet, thick plate, round tube, square tube, angle iron, channel, hollow section, solid bar, stainless pipe and aluminium profile. Chapters 018 and 019 remain mandatory for wheel–machine selection and correct cutting technique. Finished-cut defect diagnosis belongs to Chapter 021.

Safety-critical boundary — Do not cut live, pressurised, contaminated, unidentified or inadequately isolated pipe, equipment or structural work. Establish the material, contents, stored energy, residual stress, support, off-cut movement and hot-work controls before selecting a cut path. Secure both retained stock and off-cut. Maintain the cutting wheel in one plane. When a hollow or open section must be indexed, release the switch, hold the tool until the wheel stops completely, place the tool safely, then reorient and re-clamp the work before aligning the next segment. Never roll or rotate a workpiece while a hand-held cutting wheel is engaged. Use a safer machine or cold-cutting method when guarded reach, support, spark control or geometry cannot be maintained. [S090; S097; S099–S102]

Chapter objectives

After this chapter, the reader should be able to:

- classify work as flat, hollow, open-profile or solid geometry;
- transfer one cut plane across faces or around a circumference;
- support retained stock and off-cut so the kerf stays open or neutral;
- select a controlled wall-by-wall or face-by-face sequence;
- apply separate methods to the ten specified material forms;
- identify pipe-isolation and locked-in-stress hold points;
- control the final ligament and breakthrough path;
- choose a safer alternative when the wheel cannot reach while guarded;
- inspect the completed cut without assuming it is ready for downstream work; and
- qualify and record one exact geometry-specific cutting system.

1. Geometry changes the cutting system

Material chemistry tells the selector which product declaration is required. Geometry tells the planner how the work can move, how the wheel enters, how many walls or faces must be crossed, and what happens at final separation. These are separate decisions.

Use four geometry families:

- **flat work:** thin sheet and thick plate expose one broad face but differ greatly in stiffness, heat response and required reach;
- **hollow work:** round tube, pipe, square tube and hollow section contain multiple walls and a void, so the cut line must be transferred and each wall controlled;
- **open profiles:** angle and channel combine legs, flanges, webs and corners that change contact and stiffness; and
- **solid sections:** solid bar maintains continuous engagement and can exceed the safe guarded reach or practical capacity of a hand-held wheel.

The identified wheel must be declared for the material and application. Cutting-wheel ranges commonly distinguish steel, stainless steel and aluminium, and may further separate sheet, profiles and solid material. Read the exact declaration for each wheel; catalogue performance claims do not transfer to another product. [S093]

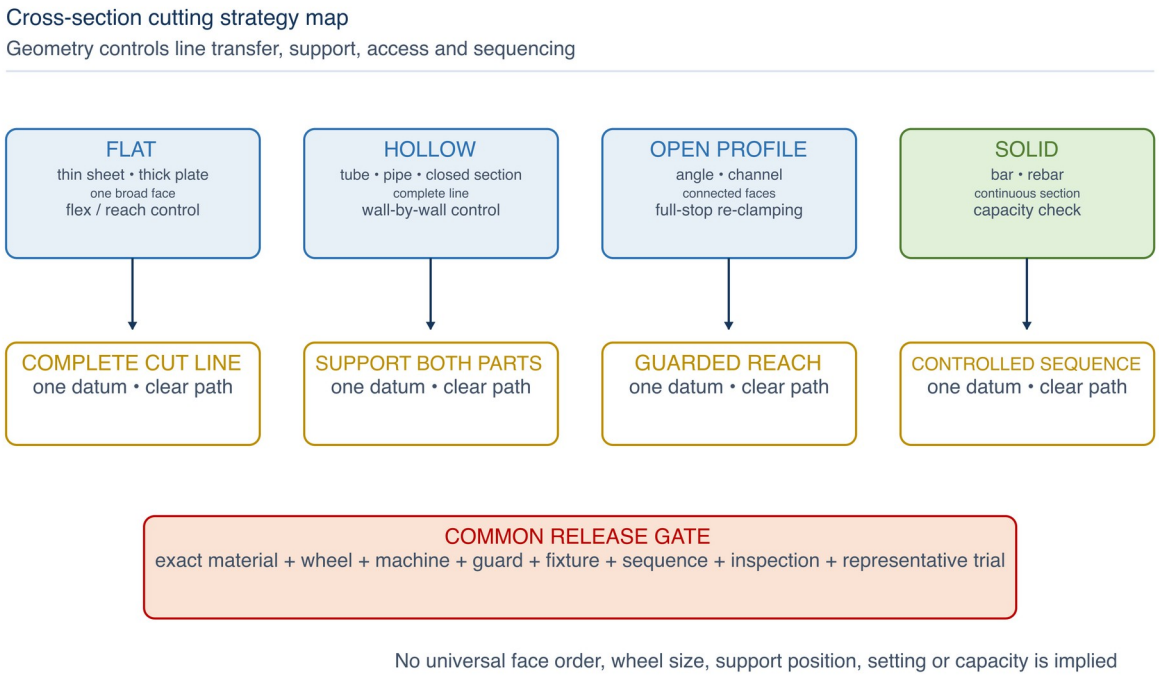


Figure 1. Cross-section cutting strategy map. Classify the form before selecting supports, line transfer and a face- or wall-sequencing method.

2. Common geometry-control method

Apply this sequence before the form-specific sections:

277. identify material, grade, coating, cross-section, wall condition and downstream requirement;
278. establish that the work is not live, pressurised, contaminated, energised or structurally loaded beyond the approved task boundary;
279. select the exact compatible wheel–machine–guard system under Chapter 018;
280. choose one datum and mark the complete cut plane on all accessible faces or around the full circumference;
281. predict roll, sag, spring, twist, drop and kerf closure for both stock and off-cut;
282. secure and support both portions through the final ligament, leaving a clear guarded wheel path;
283. choose the accessible face or wall segments that can be cut while the wheel remains in one plane and both hands remain on the machine;
284. define every stop, full-stop, reorientation, re-clamping and alignment point;
285. plan final-ligament movement and a clear breakthrough path; and
286. define inspection, hold, rework and acceptance authority before starting.

The line on a multi-face component must come from one datum. Independent marks made “by eye” on separate faces can produce offset kerfs and tempt the operator to twist the wheel to join them. If the line cannot be transferred accurately, use an approved template, wrap, square, fixture or machine.

Clamping is effective only when it prevents movement without distorting thin work or closing the kerf. HSS guidance requires work to be secured and supported on both sides of the cut; the exact support locations remain a task-design decision. [S102]

3. Thin sheet

Thin sheet is flexible, heat-sensitive and easily pulled into vibration. First decide whether abrasive cutting is appropriate. A shear, nibbler, guillotine or other assessed cold-cutting method may provide better fire, distortion, burr or coating control. CCOHS identifies substitution as a valid hot-work risk-reduction option, provided the alternative is also assessed. [S099]

For an approved abrasive cut:

- support the sheet flat on a clean, non-combustible arrangement that leaves wheel clearance below the line;
- clamp the retained sheet and control the off-cut so neither portion flutters, lifts, tears, drops or contacts the wheel;
- protect finished or coated surfaces from clamp damage, sparks and embedded debris;
- align the complete cut path before contact and confirm that the guard and handles remain clear;
- establish a controlled kerf, then progress along the same plane without deep plunging into an unsupported flexible span; and

- reduce demand and stop if the sheet vibrates, buckles, discolours, pulls into the wheel or loses support.

Do not hold thin sheet by hand, ask another person to hold it, or use body weight as a fixture. Do not bridge a long flexible span in a way that lets the kerf close. If support blocks wheel travel, redesign the arrangement; do not remove the guard or tilt the wheel around the obstruction.

At completion, keep both portions supported. A narrow strip or small off-cut can become hot, sharp and mobile. Allow it to separate without pushing the wheel sideways, then control it with the approved handling method after the wheel stops.

4. Thick plate

Thick plate has greater stiffness and thermal mass, but it increases engagement, cutting time and guarded-reach demand. Before using a hand-held grinder, verify that the wheel can complete the intended path within the usable capacity permitted by the current machine and wheel instructions. Nominal wheel diameter is not usable cutting depth.

Use this method:

- support retained plate and off-cut so the kerf will open or remain neutral as the cut deepens;
- provide an accessible straight path with stable footing and two-hand control for the entire length;
- establish one kerf and deepen or progress it in the same plane using qualified moderate feed;
- monitor motor response, vibration, heat, wheel condition and plate movement; and
- plan the last ligament before cutting demand or support behaviour changes.

Do not chase a wandering kerf by leaning on the wheel side. If the intended thickness cannot be reached while guarded, or the plan depends on blindly meeting cuts from opposite faces, stop and select a more suitable saw, cutting machine or qualified fixture. A second-face method may be used only when the line-transfer and re-clamping process has been specifically qualified for that plate and system.

5. Round tube

Round tube can roll, collapse under poor clamping and misalign at the join between indexed segments. Mark the cut around the full circumference with an approved wrap or squaring method. The line must return to its starting point without a step.

Use a cradle, pipe vice or qualified fixture that prevents rolling and excessive ovalisation. Support the retained tube and off-cut on both sides. Orient the first accessible wall segment so the wheel can enter in one plane with the guard, handles and body clear.

Cut only the accessible segment that can be controlled in that setup. If another segment requires reorientation:

287. release the switch;
288. hold the machine motionless until the wheel stops completely;
289. place or isolate the tool as the procedure requires;
290. reorient the tube without exposing a person to roll, spring or hot edges;
291. re-clamp and re-check both supports;
292. align the wheel to the continuous circumference mark and existing kerf; and
293. start clear and continue under Chapter 019.

Never roll a tube against an engaged hand-held wheel and never use the kerf as a rotating guide. That motion can add side load, trap the wheel and place the operator in an uncontrolled reaction path.

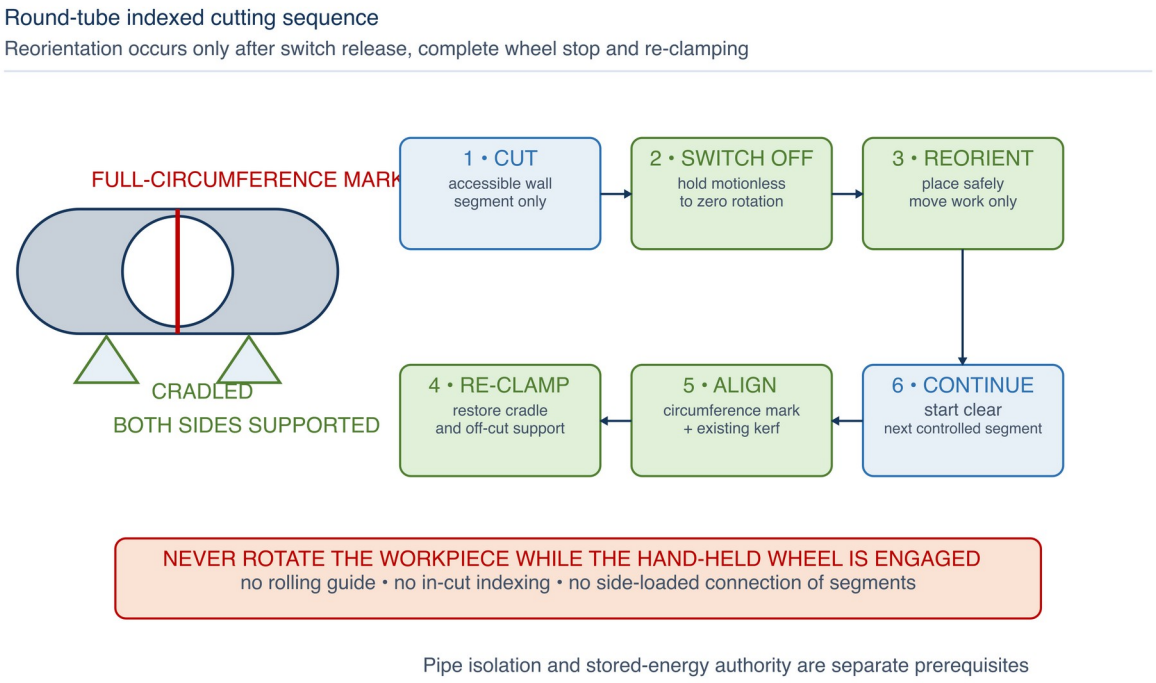


Figure 2. Round-tube indexed cutting sequence. Every change of tube orientation occurs only after switch release, complete wheel stop and controlled re-clamping.

6. Square tube and rectangular hollow section

Square and rectangular hollow sections have faces joined by radiused corners. Mark every face from one datum. Verify that the last line closes accurately around the section. If coatings, weld seams or internal features change the cut response, include them in the plan.

Choose the most stable orientation that gives a visible, guarded path. Cut an accessible wall segment while maintaining one wheel plane. Do not swing the rear of the grinder around a corner to continue onto a hidden face. Instead, stop completely, reorient and re-clamp the section, then align the next face to the transferred line and the existing kerf.

The exact first face is not universal. Fixture access, section proportions, machine travel direction, weld seam, coating, support and final-ligament plan can change the safest order. A “corner-first” practice is acceptable only where the exact instructions and a representative trial have qualified it; it is not a handbook default.

Control the final wall or corner so the off-cut cannot twist, drop or close onto the wheel. If the section begins to rack, ovalise or spring, stop and redesign the restraint.

7. Angle iron

Angle iron comprises two legs and an included heel. Its open form can rock or spring when one leg is severed. Establish one square cut plane across both legs and the heel. Choose an orientation that supports the section without hiding the line or forcing the machine into the included corner.

Treat the profile as three connected features: accessible leg, heel transition and remaining leg. The exact order depends on fixture and machine access. Complete only the feature that can be cut in one plane; stop, reorient and re-clamp before the next feature when required.

Support the off-cut across both legs so the first cut does not turn the remaining leg into a hinge that closes the kerf. Do not twist the wheel through the heel to “turn the corner.” If the corner cannot be reached without side loading or guard interference, use a more suitable machine or qualified setup.

8. Channel

Channel contains two flanges and a web. The open side can make the profile unstable, while severing one flange can let the remaining section twist. Mark both flanges and the web from one datum.

Choose a stable supported orientation and identify an accessible flange, web and remaining flange sequence. Cut each accessible face in one plane. Stop completely and re-clamp before changing orientation. The exact flange-first or web-first order is not universal; it must agree with the fixture, current machine instructions, guarded reach and predicted movement.

Support the off-cut so a severed flange cannot drop against the wheel. The remaining web or flange must not carry uncontrolled bending load at final separation. Unexpected opening, closing or twisting indicates residual stress or inadequate support and requires a stop.

9. Hollow section

“Hollow section” includes square, rectangular and other closed structural profiles not already covered as simple tube. Begin by identifying walls, corners, seams, internal reinforcement, coatings, enclosed contamination and any structural load.

Use the square-tube principle: transfer one closed cut line, secure stock and off-cut, cut only accessible wall segments, and stop/re-clamp before reorientation. Complex hollow sections may require a purpose-built fixture, cold saw, band saw or other machine because a hand-held wheel cannot maintain guarded reach and alignment across every face.

Do not assume an enclosed section is empty or harmless. Openings can contain moisture, combustible residue, cable, insulation or pressure. Unknown contents or structural duty are hold conditions.

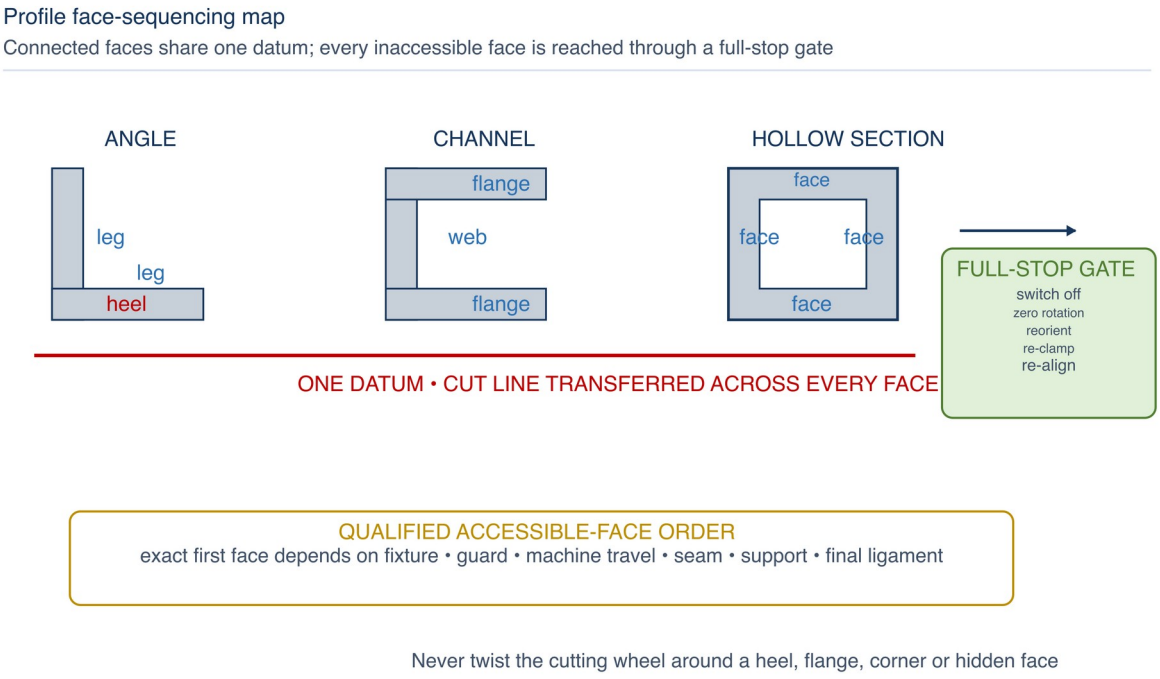


Figure 3. Profile face-sequencing map. Angle, channel and hollow sections are connected faces; reorientation occurs only at controlled full-stop and re-clamping gates.

10. Solid bar

Solid bar keeps the wheel engaged across a continuous cross-section. It can roll, impose sustained demand and exceed guarded reach. Verify the exact wheel's declared application and the machine's usable capacity before choosing a hand-held method. The existence of products declared for rebar or solid material does not make every bar, machine or cutting wheel suitable. [S093; S101]

Cradle or fixture the bar against rolling and support the off-cut. Establish a square line and maintain one straight kerf. Do not rotate the bar while the wheel is engaged. If an indexed method is necessary, it must be qualified and must use the same switch-off, full-stop, reorientation and re-clamping gate as round tube.

If the wheel cannot reach through the cross-section while guarded, do not remove the guard, fit an oversized wheel or complete an uncontrolled rotating cut. Use a suitable chop saw, cold saw, band saw or other assessed cutting system.

11. Stainless pipe

Stainless pipe combines round-tube geometry, possible process contents and contamination-sensitive material. Before the abrasive method is considered, determine whether the item is unused stock, removed spool, installed service or formerly live pipework.

For process-connected or formerly live pipe, competent isolation authority must confirm that the cut cannot release fluid, create uncontrolled ignition or introduce another unsafe condition. HSE guidance calls for isolation, depressurisation, venting/draining and purging/flushing as appropriate, prevention of hazardous ingress, and support/restraint around the cut against pipe spring from locked-in stress. CCOHS likewise requires pressurised vessels, piping and equipment to be secured, isolated and vented for hot work. [S099–S100]

Only after those controls are proved may the round-tube sequence be applied. In addition:

- use a wheel whose exact current declaration covers the stainless grade/application;
- segregate the wheel, supports, clamps, marking and cleaning tools from carbon-steel contamination;
- keep carbon-steel sparks and debris away from the pipe and downstream clean area;
- control heat tint, burr and edge damage under the drawing and welding/cleaning plan; and
- treat the cut edge as unaccepted until inspected and prepared for its downstream duty.

An “INOX” or stainless declaration is a selection gate, not proof that the cut is weld-ready, corrosion-ready or contamination-free. [S009; S017; S028; S092–S093]

12. Aluminium profile

Aluminium profiles can be thin, hollow, open, coated and easily distorted. Aluminium can also load an unsuitable abrasive. Use only a product whose exact declaration covers the aluminium alloy, application and named machine. The availability of aluminium-specific wheels does not make an unidentified or general-purpose wheel suitable. [S093]

Apply the matching geometry method: flat support for sheet-like extrusion, face-by-face control for hollow profiles, or separate legs/webs for open profiles. Use clean protected supports that prevent collapse and surface damage. Remove or control combustible debris and assess the job as hot work.

Do not apply coolant or lubricant unless the exact wheel and machine instructions permit it. Loading, smearing, rising heat, unstable sparks, vibration, motor slowdown or edge tearing requires stop and inspection. Added force is not a remedy. Where finish, heat, fire or distortion cannot be controlled, use an assessed aluminium-suitable saw or machining process.

13. Final-ligament and breakthrough control

The final ligament is the last connected material before separation. Its location changes as walls and faces are cut. Before reaching it, verify:

- retained stock and off-cut remain supported in their expected final positions;
- the kerf will stay open or neutral rather than clamp the wheel;
- no remaining wall, flange or leg carries uncontrolled bending or torsional load;
- the off-cut cannot roll, swing, spring, drop or strike a person, wheel, cable or equipment;
- the wheel has a clear guarded breakthrough path; and
- both hands, body and escape path remain clear.

Do not accelerate separation with a final push or side twist. If movement differs from the prediction, stop before the ligament breaks and redesign the support.

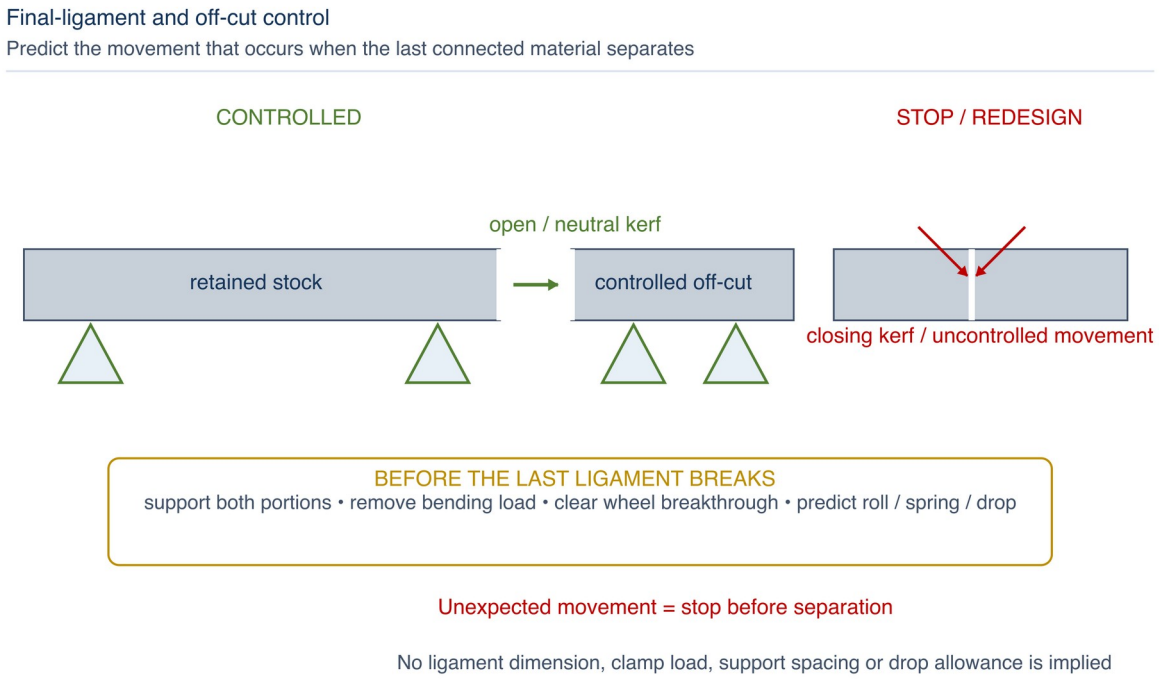


Figure 4. Final-ligament and off-cut control. Controlled separation requires a supported stock and off-cut, an open or neutral kerf and a clear breakthrough path.

14. Geometry selection and stop matrix

Form	Primary movement risk	Support objective	Controlled sequence	Stop or change method when
Thin sheet	Flutter, buckling, tearing, hot mobile strip	Flat support near line; both portions controlled	Establish and progress one kerf without deep unsupported plunge	Sheet vibrates, pulls, discolours or loses support
Thick plate	Closing kerf, long engagement, inadequate reach	Keep kerf open/neutral and path accessible	One-plane progressive cut; qualified second-face method only	Guarded reach or straight access is inadequate
Round tube	Roll, ovalisation, segment mismatch	Cradle and support both sides	Wall segment; full stop; reorient/re-clamp; align	Tube rolls, line does not close, or final ligament is uncontrolled
Square/rectangular tube	Twist, corner catch, face mismatch	Stabilise section and final wall	Accessible face segments with full-stop re-clamping	Reaching a face requires wheel twist or guard interference
Angle	Rock, hinge action, heel binding	Support both legs and off-cut	Leg/heel/leg features in qualified accessible order	First feature loads or closes the remaining feature
Channel	Twist after flange separation	Support flanges, web and off-cut	Accessible flange/web/flange faces with re-clamping	Remaining face carries uncontrolled bending load
Hollow section	Hidden contents, multi-face mismatch	Prove contents; stabilise all walls	Transferred line and accessible wall segments	Contents, structure, reach or alignment is uncertain
Solid bar	Roll, sustained demand, incomplete reach	Cradle and support off-cut	Straight one-plane cut; qualified stopped index only	Wheel cannot pass while guarded or machine response deteriorates
Stainless pipe	Process release, spring, contamination	Prove isolation; restrain; segregate	Isolation gate, then round-tube sequence	Status, contents, gas-free condition, stress or cleanliness is unproved

Form	Primary movement risk	Support objective	Controlled sequence	Stop or change method when
Aluminium profile	Collapse, loading, smear, finish damage	Clean protected geometry-specific support	Matching face/flat sequence with aluminium-declared product	Loading, heat, vibration, tearing or finish damage appears

15. Post-cut inspection and controlled disposition

After the wheel stops and the part is safe to handle, inspect against the drawing and task plan:

- line position, length and remaining allowance;
- squareness, angularity or end-face orientation using the approved datum;
- kerf join at indexed walls and faces;
- burr, breakout, tearing, local deformation and sharp edges;
- heat tint, coating damage, smear or embedded contamination;
- tube ovalisation, profile twist and section change;
- wheel edge, wear and any abnormal damage;
- retained stock and off-cut condition; and
- downstream deburring, machining, welding, cleaning or passivation requirements.

Do not force parts together, dress away evidence or automatically re-cut a stepped join. Protect the evidence and use the approved rework or disposition route. Detailed defect mechanisms and troubleshooting remain gated for Chapter 021.

16. Qualify the geometry-specific method

A representative trial must use the exact material form, chemistry, wall or section range, machine, guard, handles, wheel, flanges, supports, clamps and planned sequence intended for production. Record every stop/reorientation gate and the final-ligament arrangement.

Evaluate:

- line transfer around or across the complete section;
- secure support without distortion, roll or kerf closure;
- guarded access and two-hand control for every segment;
- stable machine response without forcing or side load;
- alignment between face or wall segments;
- stock and off-cut behaviour at final separation;
- hot-work, spark, debris, dust, noise and contamination controls;
- cut time as a recorded output, not a speed target;
- kerf, line, squareness, burr, heat, deformation and downstream allowance; and
- wheel condition, abnormalities, holds, rework and disposition.

For pipe, the trial record must reference the isolation and stored-energy authority. For stainless and aluminium, include segregation and material-specific inspection. Approve one revision of the complete system. A change in geometry, material, wheel, machine, guard, support, sequence, setting or acceptance method returns the process to controlled review. [S036; S093; S097; S100]

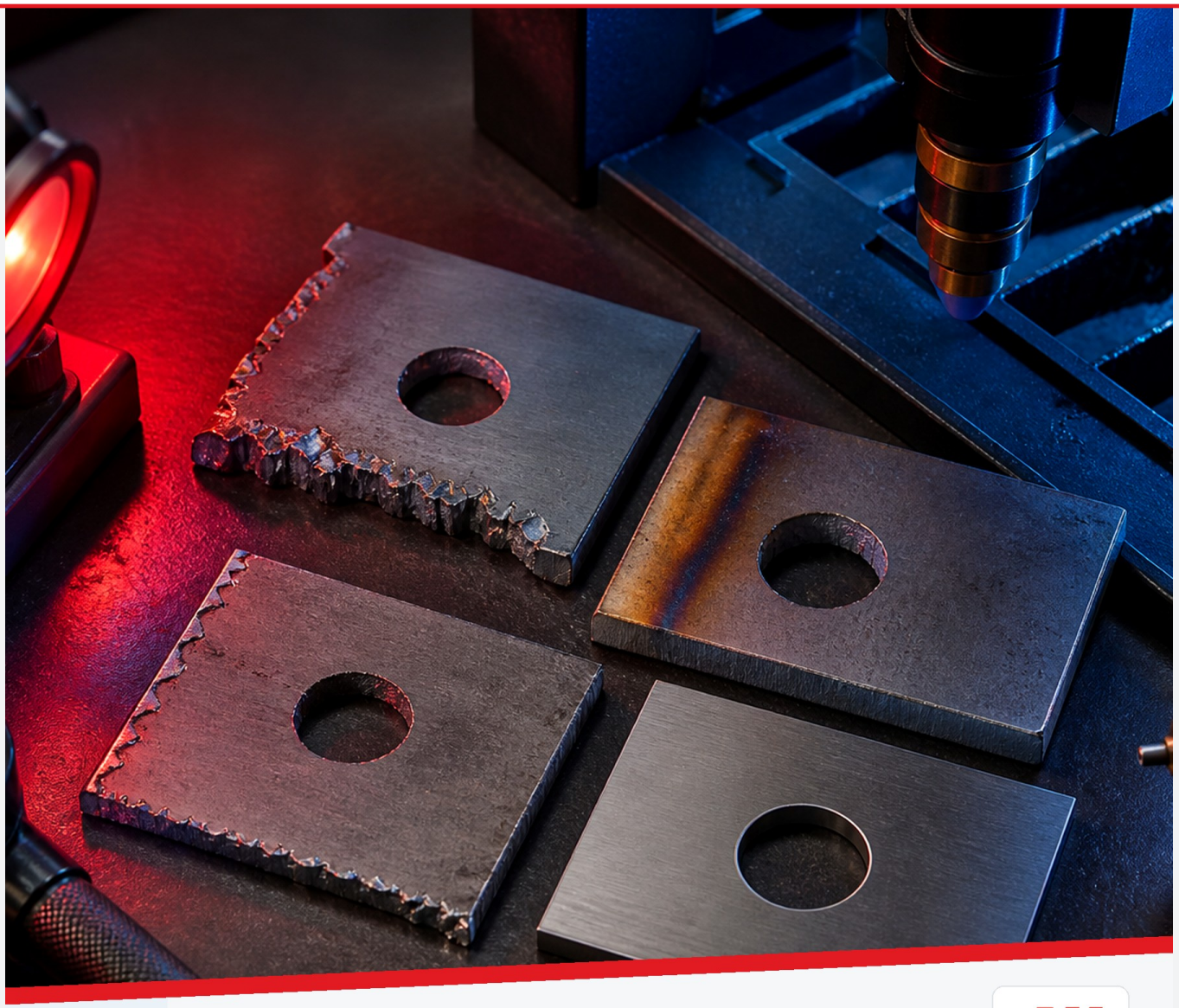
17. Applying the method to different sections

Select the cut path from the geometry, support and guarded reach. Sheet and plate require control of heat and line stability; tube and hollow sections require a transferred cut plane and controlled wall-by-wall sequence; angle and channel require attention to open faces and spring movement; solid bar creates a longer engagement; pipe requires verified isolation and stored-energy control.

Secure both the retained material and off-cut, keep the kerf neutral or opening, and complete each reachable segment in one plane. Stop the wheel fully before reorienting or re-clamping. Use stainless segregation where required and manage aluminium loading in accordance with the selected product. Follow the current machine instructions. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

18. Geometry-specific cutting record

For repeatability, record the task, drawing, material, grade, coating, form, dimensions, wall or section range, contents or service history, isolation or gas-free status where applicable, stored energy, residual stress, datum, line-transfer method, machine and asset, manual revision, wheel manufacturer/family/code/batch, declaration, dimensions, maximum-speed check, guard, handles, spindle, flanges, supports, clamps, cradle, off-cut control, predicted kerf movement, guarded reach, face or wall sequence, reorientation gates, entry and travel method, final ligament, hot-work controls, segregation controls, cut time, line, squareness, kerf joins, burr, heat, deformation, contamination, wheel condition, abnormalities and rework.



GRINDING & CUTTING APPLICATIONS

CHAPTER 021

Cutting Defects and Corrective Action

21

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, cutting and grinding operators, fabricators, maintenance teams, safety personnel, QA/QC personnel, trainers and technical sales personnel

Scope: Troubleshooting abrasive cutting-off with a hand-held angle grinder and an identified bonded cutting wheel. It covers slow cutting, wheel breakage, burnt edges, excessive burr, wandering cuts, chipping, glazing, premature wear, vibration and wheel pinching. Chapters 018–020 remain mandatory for selection, technique and geometry control.

Safety-critical boundary — Wheel breakage, cracking, edge loss, wheel pinching, abnormal vibration, loss of control, guard contact, machine damage, unexpected work movement or a slowing/stalling machine requires immediate release of the switch and controlled coastdown. Hold the tool motionless until the wheel stops; do not restart in the cut or attempt to free, dress, grind or reuse a suspect cutting wheel. Isolate the machine, control the hot and sharp work, preserve relevant evidence, and investigate before any representative trial. Never correct slow cutting by forcing the wheel, side loading it, increasing speed beyond a rating, removing the guard or fitting an unapproved product. [S032; S090–S091; S095; S097–S098; S103–S104]

Chapter objectives

After this chapter, the reader should be able to:

- separate an observed defect from its possible causes;
- classify a condition as safety-critical, quality-critical or process-performance related;
- apply a stop, contain, inspect, correct, trial and release workflow;
- diagnose all ten specified cutting defects without changing several variables at once;
- protect wheel, machine, workpiece and setup evidence after abnormal events;
- choose corrective actions at the correct level of the cutting system;
- define a representative verification trial and acceptance record; and
- use established industrial practice while taking exact settings and acceptance values from current product and job information.

1. A symptom is not a root cause

“The wheel is slow,” “the edge is blue,” or “the cut wandered” describes an observation. It does not identify why the observation occurred. One symptom may arise from several mechanisms, and one mechanism may create several symptoms.

For example, slow cutting may be associated with a wheel that is unsuitable for the material or section, a glazed or loaded cutting edge, inadequate machine power, speed loss under load, excessive engagement, poor access, a closing kerf or an operator forcing an unstable system. The same speed loss can increase rubbing and heat, encourage more pressure, accelerate wander and raise breakage risk. Manufacturer troubleshooting information recognises links among wheel hardness or thickness, peripheral speed, machine power, pressure, movement and side force; those links are diagnostic prompts, not permission to change an unidentified system. [S080; S090; S094; S103]

Use three defect classes:

- **Safety-critical:** wheel breakage or damage, pinching, severe or new vibration, guard/flange contact, machine damage, loss of control, unexpected work movement or repeated stall.
- **Quality-critical:** cut outside drawing limits, burnt or contamination-sensitive edge, excessive burr, chipping, breakout, unacceptable wander, deformation or insufficient downstream allowance.
- **Performance-related:** slower-than-qualified cutting, glazing, loading or premature wear when no safety or quality hold is present.

A performance symptom becomes safety-critical when it leads to force, overload, side loading, heat, unstable contact or loss of control.

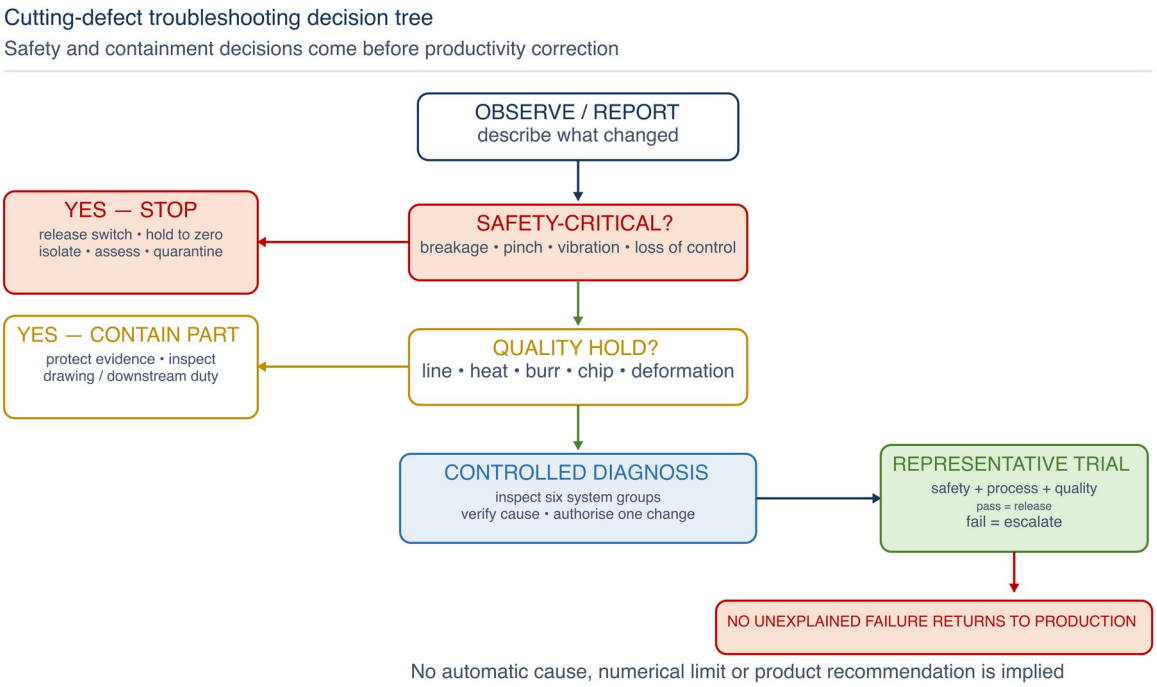

Figure 1. Cutting-defect troubleshooting decision tree. Safety and containment decisions come before productivity correction.

2. The controlled troubleshooting method

Apply this sequence to every defect:

294. **Stop safely.** Release the switch, maintain control, and wait for zero rotation. Follow the machine manual for binding or interrupted cuts.
295. **Contain.** Prevent access, movement, re-energisation, reuse of a suspect wheel, loss of fragments and accidental release of a nonconforming part.
296. **Describe the symptom.** Record what was seen, heard, felt and measured; identify when and where it began.
297. **Protect evidence.** Keep the wheel identity, batch, machine, guard, flanges, workpiece, off-cut, supports and relevant fragments available for examination.
298. **Inspect by system.** Check work/material, wheel, machine/mounting, support/geometry, technique and environment.
299. **Test the cause.** Change only a verified or strongly evidenced cause through an authorised action. Do not tune around damage.
300. **Run a representative trial.** Use the exact proposed system on representative work under controlled conditions.
301. **Inspect the output.** Compare line, squareness, burr, heat, chipping, deformation, contamination, wheel condition, time and machine response with the approved criteria.
302. **Release or escalate.** Record the decision and approvers. Repeat failure, unexplained damage or inconsistent output remains on hold.

This method prevents “trial-and-error” changes that conceal the cause. It also separates three controls: current manufacturer instructions define product and machine limits; the drawing or customer specification defines output acceptance; and a representative verification confirms that the complete combination is repeatable. [S036; S090–S091; S097–S098]

3. Inspect the six parts of the cutting system

Before choosing a corrective action, inspect all six groups:

- **Work and material:** grade, coating, hardness/condition, cross-section, wall, seam, contamination, temperature, residual stress and downstream requirement.
- **Wheel:** manufacturer, family, code, type, dimensions, declaration, maximum speed, expiry, storage history, batch, edge condition, glazing, loading, wear and damage.
- **Machine and mounting:** asset, current manual, rated/no-load speed, power supply or air condition, guard, handles, spindle, flanges, threads, runout, bearings and maintenance status.
- **Support and geometry:** datum, line transfer, access, retained stock, off-cut, kerf movement, clamp security, distortion, final ligament and wheel clearance.

- **Technique:** alignment, entry, contact, travel direction, feed, interruption, re-entry, indexing, side loading and forcing.
- **Environment and controls:** hot work, extraction, debris, lighting, visibility, footing, cable/hose routing and contamination segregation.

Do not assume that a new wheel corrects a support problem, that more power corrects a wrong product, or that deburring corrects an out-of-position cut.

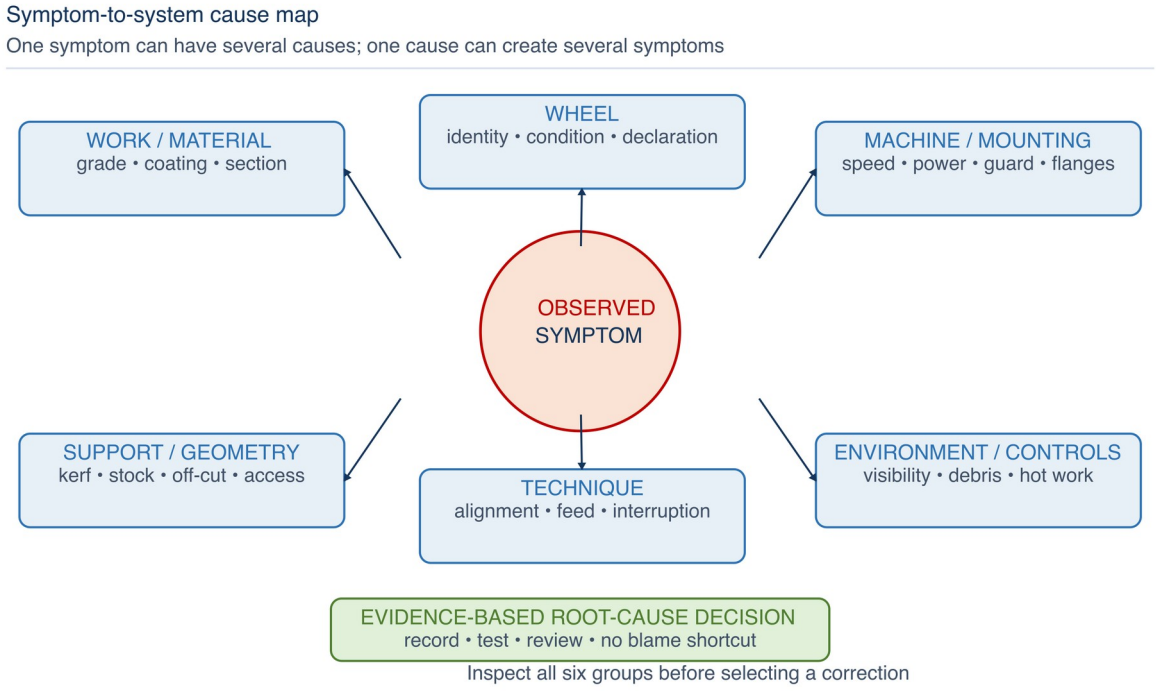

Figure 2. Symptom-to-system cause map. Trace every observation across the complete system before selecting one controlled correction.

4. Slow cutting

Recognise it. Cutting time rises against the approved baseline; progress slows while contact continues; sparks or motor response change; the operator is tempted to press harder; or the wheel rubs without stable material removal.

Stop and inspect. Check for glazing or loading, an incorrect material declaration, unsuitable wheel construction or thickness, speed loss under load, inadequate power supply, excessive engagement, guard or flange contact, a closing kerf, poor access, work movement and forced technique. CCOHS explicitly warns against forcing a cut until the motor slows. HSE warns that selecting for long wheel life rather than cutting efficiency can reduce abrasiveness, increase time and tempt excessive pressure, distortion, vibration and breakage. [S080; S090]

Correct. Restore support and a neutral/open kerf; repair an approved machine or supply fault; replace a damaged, loaded or unsuitable wheel with an exact declared product selected under Chapter 018; and repeat the qualified Chapter 019 technique. A manufacturer may recommend a different grade, thickness or speed within a named product system, but only that manufacturer's current instructions and a controlled trial can authorise the change. Do not add force or exceed either rating. [S090; S097; S103]

Verify. Record cut time, machine response, wheel condition, edge heat, burr and dimensional output together. A faster cut that creates unsafe vibration, damage or rejected edges is not a correction.

5. Wheel breakage, cracks and edge loss

Wheel breakage is an incident, not a productivity defect. It may involve full fracture, centre or arbor-hole breakout, radial cracking, missing edge, crumpled edge, delamination or unexplained fragment loss.

Immediate response:

303. release the switch and maintain the safest available control position;
304. do not reach toward the rotating system or attempt to stop it with side pressure;
305. isolate the machine after coastdown and apply the workplace incident response;
306. assess injury, fire, secondary damage and the stability of stock and off-cut;
307. quarantine the machine, wheel, packaging/label, flanges and retrievable fragments;

308. record photographs and orientation before disturbing the setup where safe; and
309. prevent reuse or informal disposal until the investigation authority releases the evidence.

Possible mechanisms include prior impact or poor storage, expired or unidentified product, wrong wheel or mounting, mismatched/damaged/dirty flanges, excessive tightening, overspeed, guard or component contact, grinding on a cut-off wheel, side pressure, twist, work movement, pinching, a closing kerf, uncontrolled breakthrough, machine defect or repeated stall. FEPA requires careful pre-fit examination and destruction/disposal of damaged wheels; CCOHS prohibits cracked or damaged wheels, unequal or damaged mounting surfaces, side grinding, jamming, bending, pinching and forced slowdown. [S090–S091]

Do not decide from fracture appearance alone that an operator, wheel or machine was at fault. A competent investigation must reconcile evidence from the complete system and the event sequence. Repeated or unexplained breakage requires supplier/manufacturer and safety escalation before another trial.

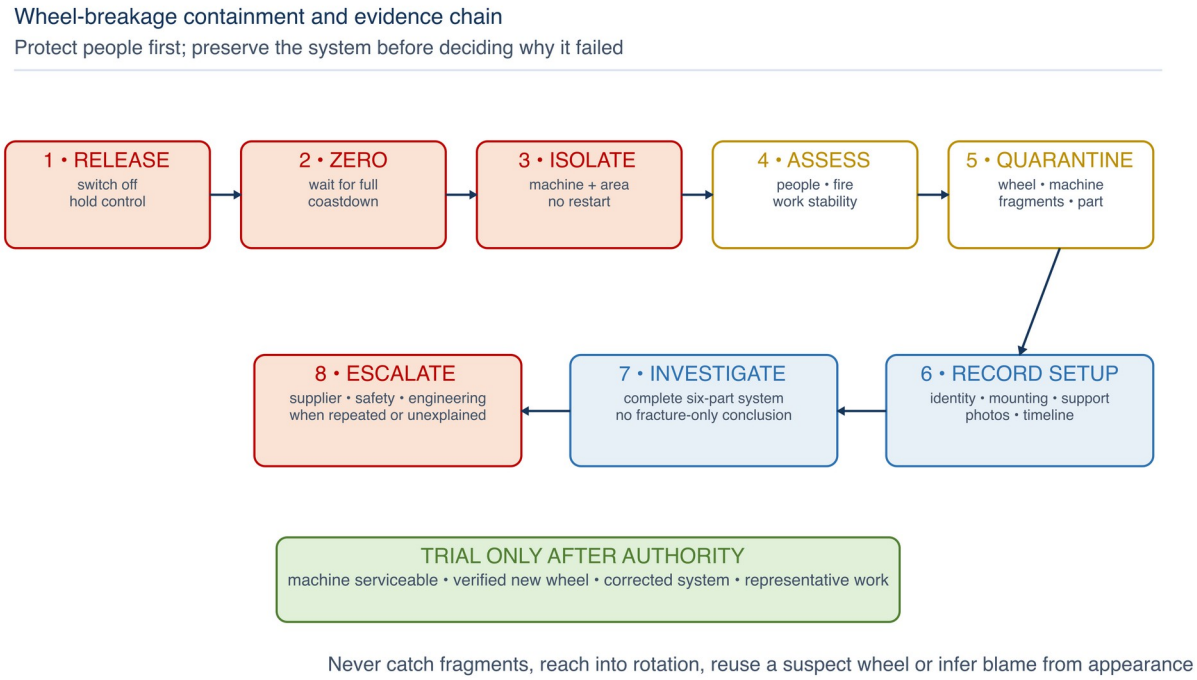

Figure 3. Wheel-breakage containment and evidence chain. Protect people first, then isolate, preserve evidence, investigate and authorise any trial.

6. Burnt edges and heat damage

Burnt edges may appear as heat tint, oxide, coating damage, blackening, smearing, local melting, loss of edge definition or heat-related distortion. Appearance alone does not prove material condition or acceptability.

Possible contributors include a glazed or loaded wheel, unsuitable wheel/product, prolonged dwell, excessive engagement, forced feed, speed loss, repeated passes, poor support, a closing kerf, an inappropriate process for thin or coated work, and material-specific contamination or loading. [S004; S016; S080; S090; S103]

Corrective route: hold the part; record the location and extent; identify the material, coating and downstream duty; inspect wheel, machine response, support, engagement and technique; correct the verified mechanism; then trial on representative material. The drawing, welding procedure, coating specification or customer acceptance plan decides whether the edge may be cleaned, reworked, machined, cut back or rejected. Do not remove colour before the evidence and disposition are recorded. For stainless steel, a visually cleaned edge is not automatically corrosion-ready or weld-ready. For coated work, lost coating requires the specified repair route. [S004; S021; S028]

7. Excessive burr

A burr is displaced or attached material at the exit edge or along the cut. Record its location, continuity, direction, sharpness and any associated rollover, tear, heat or deformation. Do not use “low burr” or “burr-free” as a generic promise: product claims apply only to identified products and conditions. [S093]

Investigate wheel suitability and condition, cut direction under the machine manual, exit support, final-ligament behaviour, section vibration, line angle, heat, material smearing, wheel wear and whether the abrasive method is appropriate for the required edge. An excessive burr may accompany slow cutting, loading, poor support, unstable breakthrough or a cut outside the intended plane.

Correct the cause before specifying deburring. Deburring is a downstream operation; it does not make an incorrect line, heat-damaged edge, thin wall, contaminated stainless surface or unsafe fracture acceptable. Verify the cut and the subsequent edge preparation against drawing allowance, minimum thickness, edge radius/chamfer and downstream welding or coating requirements.

8. Wandering or out-of-line cut

Wander is deviation of the kerf from the intended cut plane. It may appear as curvature, taper, a stepped join between faces, loss of squareness or a second corrective kerf.

Inspect line transfer, visibility, datum, work movement, machine alignment, wheel plane, guard/handle clearance, wheel damage or excessive wear, side loading, deep unsupported engagement, operator stance and whether the geometry can be reached while guarded. Pinching and sudden changes in engagement may also pull the system away from the line. [S097]

Stop before the operator tries to steer the wheel by twisting or side pressure. If enough allowance remains and an approved rework can restore the part without violating section, heat or downstream requirements, disposition it through QA. Otherwise reject or escalate. The prevention is a complete datum line, stable support, accessible one-plane path, full-stop re-clamping between faces and a representative trial—not a stronger grip on an unsuitable setup.

9. Chipping, breakout and ragged edges

Chipping may describe loss from the wheel edge or breakout from the workpiece. Record which one occurred.

- **Wheel-edge chipping:** treat as suspect wheel damage. Stop, isolate and investigate product condition, contact impact, side load, pinch, mounting, guard contact, work movement and breakthrough. Do not continue until an authorised inspection determines the machine and mounting are serviceable and a new verified wheel is fitted.
- **Workpiece breakout:** hold the part and inspect material/coating condition, exit support, final ligament, engagement, vibration, line and process suitability. Brittle coatings, cast features, thin edges or interrupted sections may require a different support, sequence or cutting process.

Never smooth away wheel damage or use the side of a cutting wheel to blend a chipped work edge. [S090–S092; S097]

10. Glazing and loading

Glazing is a cutting surface that has become smooth or shiny because effective cutting edges are not renewing as required. **Loading** is work material or debris adhering to and blocking the cutting surface. They are different observations but both can reduce cutting action and increase heat.

Check product suitability for the material, wheel condition, material transfer, storage history, contact and engagement, speed loss, heat, technique and the manufacturer’s declared remedy. Aluminium and other non-ferrous materials require a product explicitly declared for that application; do not assume a steel or stainless wheel is suitable. [S005; S080; S093]

Do not dress a reinforced cutting wheel, scrape loading away, apply lubricant/coolant or alter speed unless the exact current wheel and machine instructions expressly authorise the action. The safe default for an unidentified, damaged or persistently loaded/glazed cutting wheel is removal from service and replacement with a verified suitable product.

11. Premature wheel wear

Premature wear means the wheel consumption is greater than the approved reference for the same controlled system and acceptable output. A short life by itself does not prove a defective wheel.

Inspect material and section, wheel grade/construction and dimensions, machine speed and power, contact duration, excessive force, repeated starts, deep engagement, work movement, side pressure, pinching, heat, storage and batch identity. Manufacturer troubleshooting guidance links excessive wear to wheel selection, operating speed and speed reduction under load, but any grade or speed change remains product-specific and must stay within the marked ratings and machine instructions. [S094; S103]

Compare wear with cut time, burr, heat and dimensional quality. Selecting only for maximum life can reduce cutting efficiency and encourage unsafe pressure; selecting only for speed can increase cost or fail the quality requirement. [S080]

12. Vibration and unstable cutting

New, increasing or unusual vibration is a stop signal. Possible causes include wheel damage, poor mounting, damaged or dirty flanges, spindle/bearing condition, work movement, poor support, wheel/work mismatch, unequal wear, resonance, side loading, pinching, guard contact and inappropriate machine capacity.

Do not “cut through” vibration or use hand force to suppress it. After coastdown, quarantine a suspect wheel and inspect the machine, mounting and work support. A wheel that was dropped, struck, cracked, chipped, wet/damaged or involved in a pinch is not returned to service. FEPA requires careful handling and pre-fit inspection; CCOHS requires clean, flat mounting surfaces and prohibits damaged wheels and misuse. [S090–S091]

If vibration persists with a verified new wheel and corrected support, remove the machine from service for competent inspection. Repeated vibration may indicate a machine, mounting, fixture or system issue rather than a consumable issue.

13. Wheel pinching and binding

Pinching occurs when the work closes on, traps or laterally loads the wheel. Binding may also occur when the wheel is misaligned, twisted, forced, driven into an unstable section or caught by off-cut movement.

Release the switch and hold the tool motionless until the wheel stops, following the current machine manual. Do not restart while trapped. Do not pull a rotating bound wheel from the kerf. After stop, isolate the tool, secure both portions, relieve the load by an engineered work-support method that does not expose people to stored energy, and inspect wheel, machine and kerf. [S090; S097]

Correct the support arrangement so the kerf opens or remains neutral; control stock and off-cut through the final ligament; restore one-plane alignment; and use a different machine or fixture if guarded reach or geometry cannot be maintained. Any wheel exposed to damage, side load or uncertain pinch history is removed from service.

14. Defect interaction map

The ten symptoms often form a feedback loop:

- unsuitable or degraded cutting action increases contact time;
- added pressure and speed loss increase heat and instability;
- heat and smearing can increase loading, burr and edge damage;
- instability can increase wander, chipping and pinching;
- pinching or side load can damage or break the wheel; and
- repeated re-cuts increase wear, heat and dimensional loss.

The safe correction breaks the loop at the verified cause. It does not compensate at the next symptom.

15. Troubleshooting matrix

Symptom	Plausible mechanisms to inspect	Immediate response	Correction and release evidence
Slow cutting	Glazing/loading; wrong declaration; speed/power loss; long engagement; closing kerf; force	Stop if response is abnormal or force is increasing	Restore support or machine condition; select verified product; trial time + heat + burr + wheel condition
Wheel breakage/damage	Impact/storage; expiry; mounting; overspeed; side load; pinch; movement; machine defect	Stop, isolate, assess injury/fire, quarantine evidence	Competent investigation; machine/mount inspection; verified new wheel; authorised representative trial
Burnt edge	Dwell; rubbing; loaded/glazed wheel; force; speed loss; repeated pass; poor process choice	Hold part and preserve condition	Correct mechanism; material/drawing disposition; representative heat and quality check
Excessive burr	Exit support; unstable breakthrough; wheel condition; heat/smear; line/angle; wrong process	Hold sharp part and inspect related defects	Correct support/product/process; verify burr and downstream allowance
Wandering cut	Incomplete line; movement; misalignment; side load; poor access; pinch	Stop; do not steer by twist	Restore datum/support/access; QA disposition; trial line and squareness

Symptom	Plausible mechanisms to inspect	Immediate response	Correction and release evidence
Chipping/breakout	Wheel damage; impact; pinch; brittle coating/material; unsupported exit	Wheel chip = isolate; work chip = hold part	Investigate correct object; replace suspect wheel; verify exit support and part acceptance
Glazing/loading	Product/material mismatch; dull surface; material transfer; heat; speed loss	Stop if heat or force rises	Follow exact manufacturer remedy; otherwise replace with verified suitable product
Premature wear	Product mismatch; force; speed/load; repeated contact; pinch; storage/batch	Stop if wear is uneven or damage appears	Compare time, wear and quality; approve balanced system, not life alone
Vibration	Wheel/mount/machine damage; work movement; resonance; side load; pinch	Stop immediately and isolate suspect wheel	Competent inspection; corrected support; verified new wheel; stable trial
Pinching/binding	Kerf closure; unsupported off-cut; residual stress; twist; unstable final ligament	Release switch; hold to zero; no in-cut restart	Secure and unload by engineered method; inspect; redesign support and sequence

16. Corrective action and representative verification

One correction record should contain:

310. defect ID, part/lot, date, location and reporter;
311. photographs, measurements and description before rework;
312. wheel manufacturer/family/code/batch, label, expiry and retained condition;
313. machine asset, manual revision, guard, handles, spindle, flanges and maintenance state;
314. material, form, drawing, datum, support, clamps, sequence and environment;
315. event timeline and operator observations without blame language;
316. tested mechanism and evidence for the root-cause decision;
317. containment and disposition of wheel, machine, part and work in progress;
318. one authorised correction and affected documents/training;
319. representative trial plan with unchanged and changed variables identified;
320. results for safety, machine response, line, squareness, burr, heat, chipping, deformation, contamination, wheel wear and time; and
321. engineering, production, quality and safety approval or escalation.

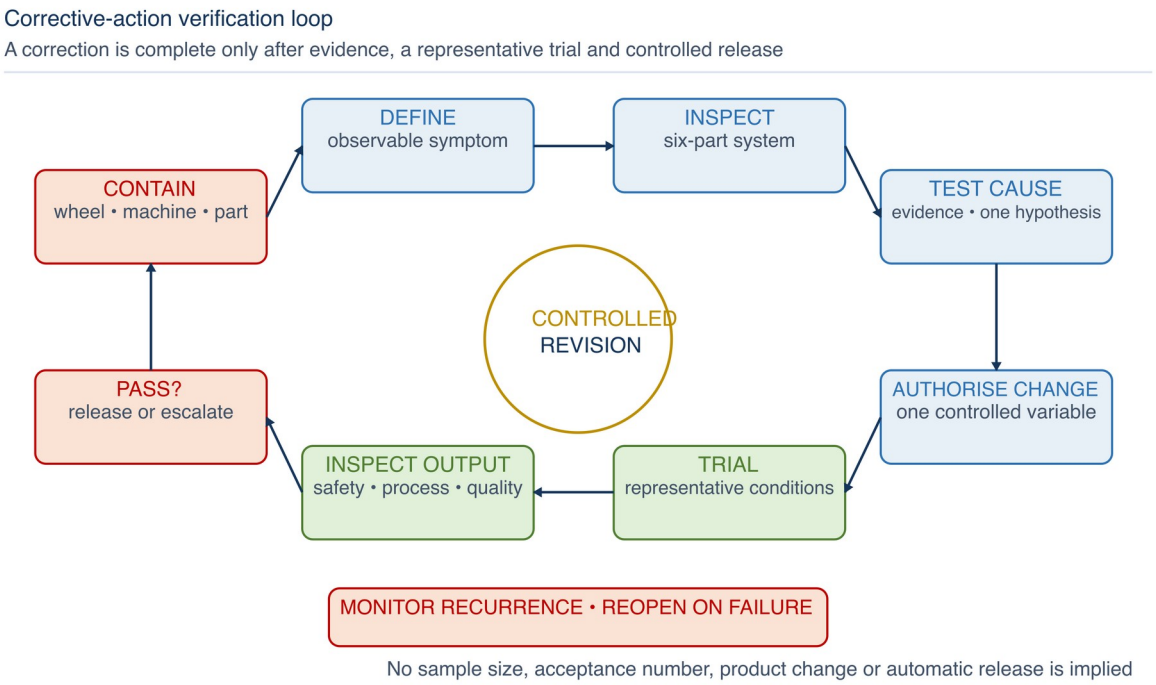

Figure 4. Corrective-action verification loop. A correction is complete only after a representative trial passes the defined release criteria.

17. Stop, hold, rework or release

- **Stop:** active unsafe condition or loss of control; bring the system to zero rotation and isolate.
- **Hold:** prevent use of a machine, wheel, part, lot or method while evidence and conformity are assessed.
- **Rework:** use only a documented method that retains required dimensions, material condition, finish, coating, cleanliness and downstream allowance.
- **Release:** named authority accepts the exact system and output against controlled criteria after representative evidence.

Production pressure, a visually improved edge or one successful cut does not close a corrective action. Repeatability and control of the changed condition are required.

18. Applying corrective-action guidance

Correct the verified mechanism at the correct level of the system. Restore work support and kerf control before changing a wheel; correct machine or power-supply faults before changing technique; replace damaged or unsuitable wheels rather than increasing force; and use the drawing or customer requirement to decide whether the workpiece may be reworked or must be rejected.

After a change, repeat the cut on representative material and inspect cut time, line, squareness, burr, heat, chipping, wheel condition and downstream allowance together. Never correct a defect by overspeeding, side grinding, removing the guard, forcing the wheel or reusing a suspect product. Follow the current machine instructions. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

SURFACE FINISHING & POLISHING

CHAPTER 022

Surface-Finish Fundamentals

22

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, grinding and finishing operators, fabricators, coating personnel, hygienic-design teams, maintenance personnel, QA/QC inspectors, designers, trainers and technical sales personnel

Scope: The controlled language and decision framework for surface texture, lay direction, roughness, waviness, gloss, reflectivity, scratch pattern, visual appearance, functional finish, cosmetic finish, cleanability and coating preparation. Chapter 023 develops roughness parameters and visual-finish assessment in more detail. Product selection and exact operating values are confirmed for the identified abrasive, machine and application.

Safety-critical boundary — A finish requirement never overrides safe abrasive selection, guarding, extraction, work support, chemical control, contamination control or the current machine and product instructions. Stop before finishing an unidentified material, coating, pressure boundary, food-contact surface, sealing surface, fatigue-critical feature or corrosion-critical surface without its governing specification and rework authority. Control dust, fibres, metals, compounds, solvents and residues under the workplace risk assessment. [S007–S009; S014; S017]

Chapter objectives

After this chapter, the reader should be able to:

- separate surface form, waviness, roughness, lay and local defects;
- explain why a grit designation or one roughness value does not define a complete finish;
- distinguish profile measurement from areal measurement;
- distinguish gloss, reflectivity, haze and visual appearance;
- define functional and cosmetic finish requirements without treating them as opposites;
- recognise how scratch direction and rogue scratches affect inspection and service;
- treat cleanability as a validated surface-and-system requirement;
- separate coating cleanliness from coating profile;
- create a controlled visual-comparison protocol; and
- write a complete finish requirement and representative verification record.

1. Surface finish is a controlled surface state

“Surface finish” is an umbrella term. It can refer to measured texture, visible appearance, process route or service behaviour. These are related, but they are not interchangeable.

A usable finish definition has five linked parts:

322. **Function:** what the surface must do — seal, slide, retain lubricant, accept coating, resist soiling, drain, clean, bond, reflect, diffuse or provide a chosen appearance.
323. **Topography:** form, waviness, roughness, lay, peaks, valleys and local defects at defined scales.
324. **Appearance:** gloss, reflectivity, haze, image clarity, colour, directional contrast and visible scratch pattern under controlled viewing.
325. **Condition:** contamination, oxide, embedded material, smearing, burr, pits, cracks, heat tint, coating residue and surface integrity.
326. **Verification:** the parameter, instrument, filter, measurement direction, sample, lighting, viewing geometry, locations and acceptance decision.

ISO 21920-1 provides the current published framework for indicating profile surface texture in technical product documentation. ISO 21920-2 defines terms and parameters for profile methods, while ISO 25178-2 covers areal parameters. These standards provide a specification language; they do not select an abrasive process or supply an MKTECH acceptance value. [S086; S105–S106]

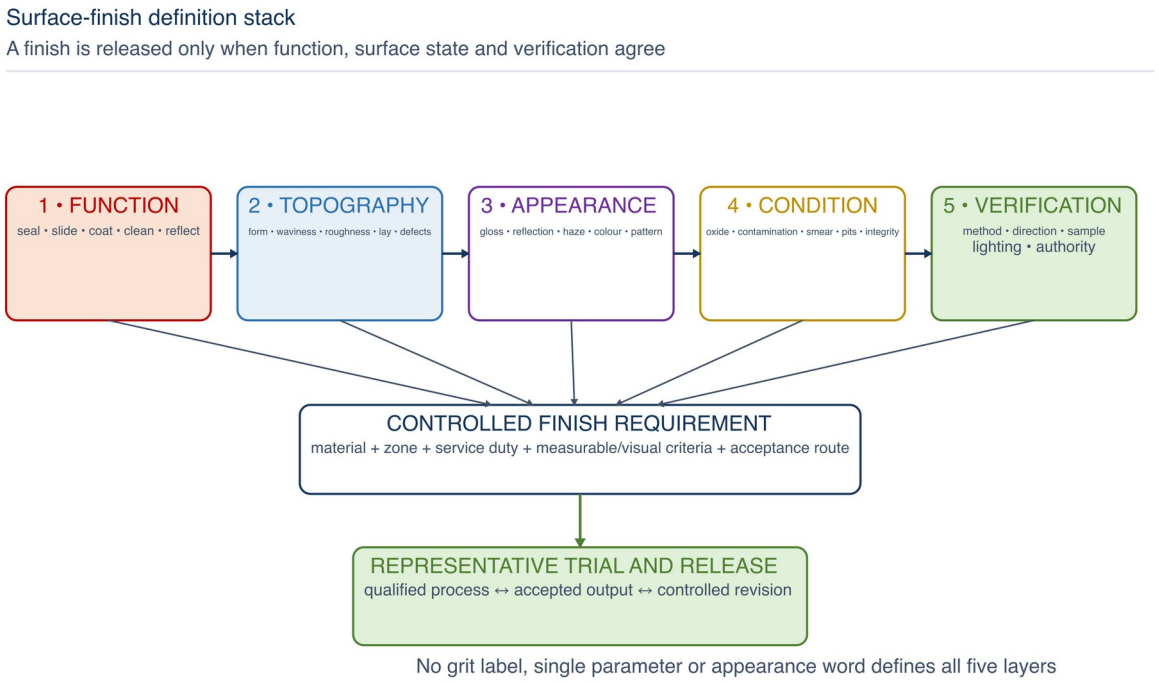


Figure 1. Surface-finish definition stack. Function, topography, appearance, condition and verification must agree before a finish is released.

2. Separate form, waviness, roughness, lay and defects

A manufactured surface contains features at different scales. The inspection method must separate the scale of interest from the others.

- **Form** is the long-scale geometry relative to the nominal shape: flatness, straightness, roundness, taper or other overall deviation.
- **Waviness** consists of more widely spaced surface variations. Machine vibration, chatter, thermal movement, support behaviour and process rhythm may contribute.
- **Roughness** consists of the more closely spaced irregularities remaining after the specified separation of longer-scale components.
- **Lay** is the predominant direction of the surface pattern. Grinding, belt finishing, brushing, turning and blasting can create different directional structures.
- **Local defects or features** include isolated scratches, pits, cracks, dents, embedded particles, pull-outs and other discontinuities that a statistical roughness value may not represent.

NIST separates roughness, waviness and form and identifies process marks and grinding grit as potential roughness sources, with vibration or chatter as potential waviness sources. The separation is conceptual until the governing filter and measurement procedure are defined. [S105; S107]

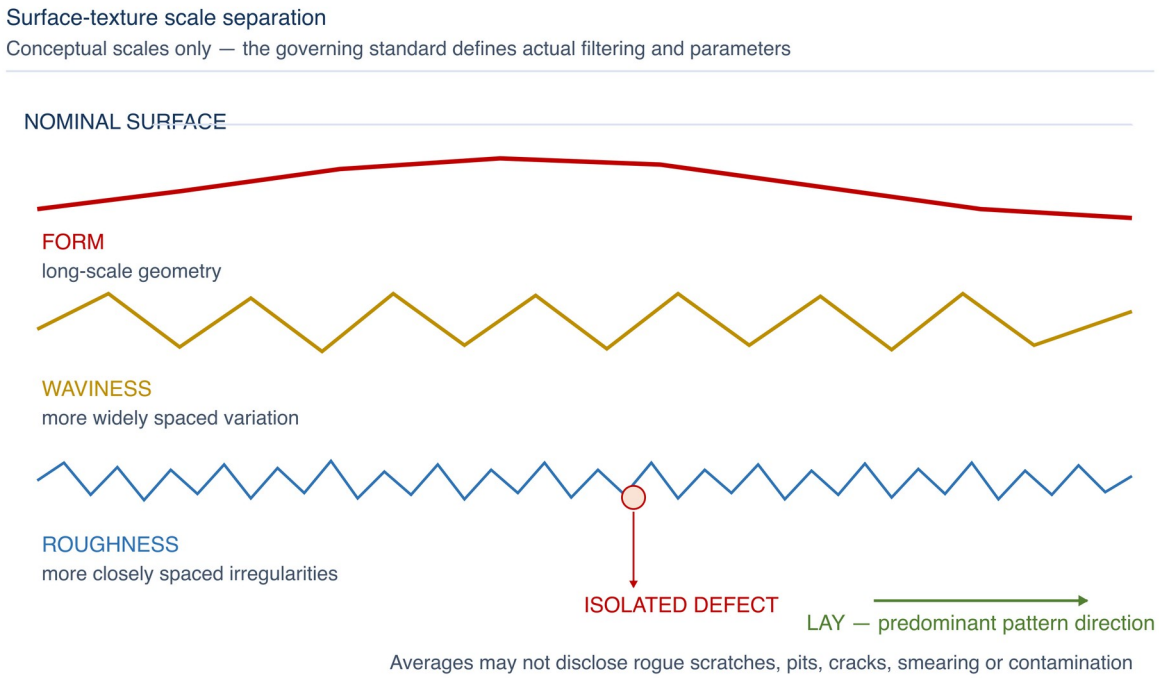


Figure 2. Surface-texture scale separation. Long-scale form, waviness, roughness, lay and isolated features must not be collapsed into one informal description.

3. Roughness is a filtered measurement, not the whole finish

A roughness result is produced by a defined measurement chain. The chain includes the surface, instrument, sampling, trace direction or measured area, filtering, evaluation length or area, parameter calculation, calibration and uncertainty. Change the chain and the result may change.

Profile methods evaluate a line trace. Areal methods evaluate a surface area. They can reveal different information and their parameter names, filters and evaluation rules must come from the same declared standard and revision. Do not substitute an areal value for a profile requirement, or a profile value for an areal requirement, merely because both use micrometres. [S105–S106]

A complete roughness requirement records:

- standard and revision;
- profile or areal method;
- parameter and units;
- filter or nesting-index/cut-off settings required by the governing method;
- evaluation length or area and number of locations;
- measurement direction relative to lay;
- instrument, tip or optical configuration where material;
- calibration/reference artefact and uncertainty control;
- treatment of edges, curvature, steps, pores and excluded defects; and
- acceptance rule, including how repeated readings are handled.

One number cannot reveal whether the surface contains a deep rogue scratch, periodic banding, directional mismatch, smeared metal or contamination. Two surfaces with a similar average-height result can have different spacing, peak shape, lay, appearance and service behaviour. [S105–S108]

4. Lay direction and scratch pattern

Lay is not decorative vocabulary. Direction changes how a surface looks, how a stylus crosses features, how a seal or sliding contact interacts with the pattern, how liquid drains or is wiped, and how repair marks become visible.

Define the required direction from a part datum: longitudinal, transverse, circumferential, radial, cross-hatched, multidirectional, non-directional or sample-matched. Identify transitions, corners, weld zones and visible faces. “Brush with the grain” is not enough unless the grain direction is shown or tied to an approved sample.

Scratch pattern must be assessed for:

- dominant direction and permitted angular variation;
- continuity across adjoining panels, welds and repaired areas;
- scratch width, spacing and contrast where specified;
- cross-grain or hook marks;
- isolated deep scratches and start/stop marks;
- banding, overlap lines and edge brightening; and
- consistency at changes of curvature or viewing direction.

The final abrasive grade does not uniquely determine the result. Backing, grain shape, wear state, contact support, pressure, speed, feed, overlap, heat, lubricant and prior scratches all influence the delivered surface. BSSA therefore recommends controlled roughness definitions or agreed reference samples instead of relying on words such as “brushed” or “satin” alone. [S028]

5. Gloss, reflectivity and visual appearance are different

Specular gloss is an appearance attribute associated with light reflected near the mirror direction relative to a reference standard and a defined geometry. **Reflectivity** describes how much incident light is reflected under a stated spectral and geometric measurement arrangement. **Diffuse reflection** is light distributed away from the mirror direction. **Haze** and **distinctness of image** describe other aspects of how reflected light is spread or how clearly an image is reproduced.

NIST notes that gloss perception changes with the source, sample and observer geometry. ASTM D523-25 also distinguishes specular gloss from distinctness of image, reflection haze and texture. ISO 2813:2014 uses 20°, 60° and 85° geometries for non-textured coatings on plane opaque substrates; that scope does not automatically make the method suitable for bare directional metal, curved work or every polished surface. [S108–S110]

A bright surface is not automatically smooth, and a smooth measured surface is not automatically mirror-like. Directional scratches can produce strong highlights in one orientation and a dull appearance in another. Colour, oxide, coating, cleanliness, curvature, light size, viewing angle and surrounding reflections also change what an observer sees.

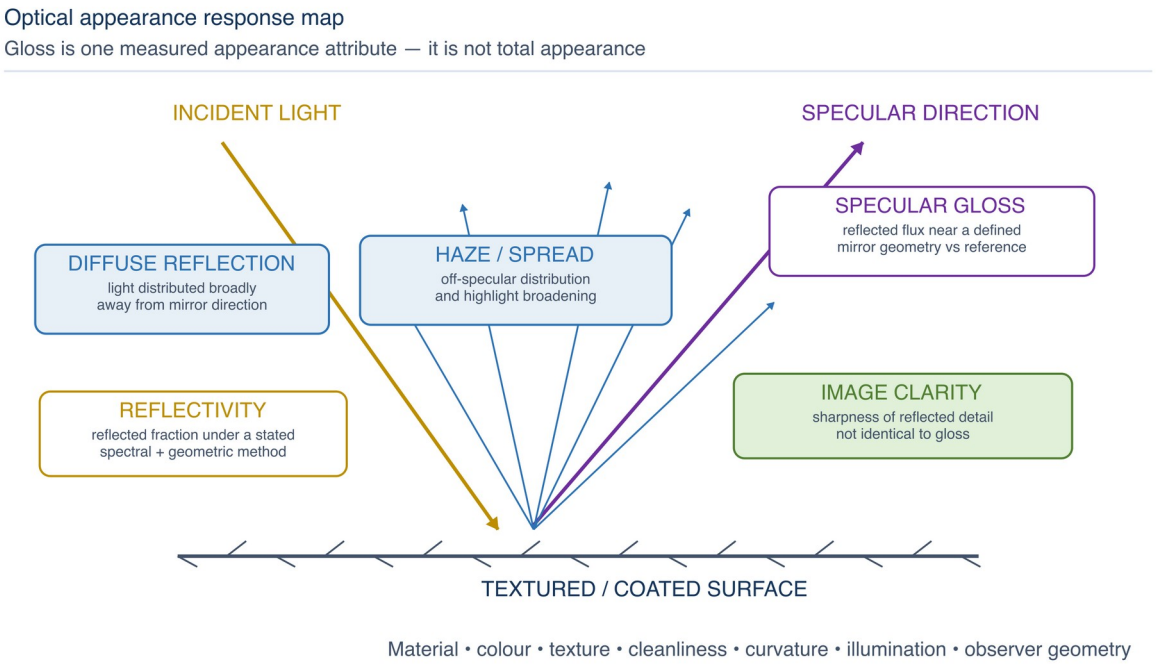


Figure 3. Optical appearance response map. Gloss, diffuse reflection, haze and image clarity describe different parts of the optical response.

6. Visual appearance requires a controlled protocol

Visual inspection is a measurement activity when appearance is an acceptance requirement. Control the conditions so different reviewers see substantially the same task.

Record:

327. part cleanliness and dry/wet condition;
328. inspection zone and protected or excluded regions;
329. light source, colour quality, intensity range and position;
330. viewing distance, angle and observation movement;
331. part orientation and lay direction;
332. background, surrounding reflections and glare control;
333. approved physical sample, master panel or image reference;
334. defects to report separately from overall appearance;
335. permitted variation between adjacent pieces, batches and repair zones; and
336. reviewer, date, photographs and disposition.

Photographs support traceability but do not automatically reproduce appearance. Camera exposure, white balance, focal length, polarisation, compression and screen conditions can hide or exaggerate scratches and gloss. Use photographs under a fixed protocol and retain the physical reference where contractual appearance matters.

7. Functional and cosmetic finish

A **functional finish** is controlled because it influences service, manufacturing or inspection. A **cosmetic finish** is controlled because the visible result is part of the acceptance requirement. These categories can overlap.

Finish characteristic	Functional question	Appearance question	Verification route
Roughness/topography	Does the surface support sealing, friction, adhesion, drainage or cleaning?	Is the texture visibly uniform?	Declared profile/areal method plus visual review
Lay/scratch direction	Does direction affect motion, wiping, drainage or stress concentration?	Does the pattern align across visible faces?	Datum-based direction check and approved sample
Waviness/form	Does long-scale deviation affect fit, contact or coating thickness?	Are bands, ripples or oil-canning visible?	Geometry/waviness method plus controlled lighting
Gloss/reflection	Is optical response part of sensing, glare or identification?	Is shininess, haze or image clarity consistent?	Applicable optical method plus viewing protocol
Surface condition	Are oxide, contamination, pits or embedded particles acceptable?	Are stains, marks or repair zones visible?	Cleanliness/material test plus defect inspection
Coating preparation	Is the surface clean and profiled for the coating system?	Is exposed prepared work visually consistent?	Coating specification, cleanliness and profile tests
Cleanability	Can the complete system be repeatedly cleaned and verified?	Does the surface appear free of soil after cleaning?	Validated cleaning method; visual check is supplementary

A cosmetic requirement may be contract-critical even when it does not change mechanical performance. A functional surface may look uneven yet meet its engineered requirement. The drawing, customer specification and validation plan decide; operators must not downgrade either category informally.

8. Cleanability is a system property

Cleanability depends on more than average roughness. Surface topology, pits, folds, burrs, cracks, joints, weld profile, dead spaces, drainage, material compatibility, soil, temperature, chemistry, time, flow or mechanical action and verification method all interact.

EHEDG guidance and conference material use roughness as one hygienic-design input while emphasising that finishing technology changes topography and that required cleanability must be achieved. A widely quoted numerical value from food-equipment guidance is not a universal rule for every material, process or industry, and it does not override a validated hygienic-design requirement. [S114]

For cleanability-critical work:

- identify the product/soil and microbiological or chemical risk;
- define accessible and inaccessible zones, joints and drain paths;
- prohibit pits, cracks, folds, embedded contamination and unapproved repairs;
- specify material and surface-treatment compatibility;
- define the texture measurement and visual defect controls;
- qualify the cleaning method under representative worst-case conditions; and
- release only after the specified residue, microbiological or process verification passes.

For stainless steel, smoother and cleanly produced finishes can support corrosion performance and reduce dirt retention, but alloy, environment, fabrication, contamination and maintenance remain part of the system. [S028]

9. Coating preparation: cleanliness and profile are separate

A coating surface must be both suitably clean and suitably prepared for the exact coating system. “Rough enough” does not mean clean. “Bright metal” does not prove that soluble salts, oil, dust, oxide or embedded contamination are within limits.

ISO 8501-1 defines visual rust grades and preparation grades for relevant steel substrates. Its reference photographs and written descriptions assess visual cleanliness; they are not a universal roughness scale. ISO 8503-1 defines comparators for visual and tactile grading of abrasive blast-cleaned steel profile. Its comparators are not generic grinding comparators and do not establish a coating manufacturer’s target profile. ISO 8504-1 sets general surface-preparation principles and reinforces that the method must be selected for the protective-paint system and substrate condition. [S111–S113]

The coating readiness record should identify:

- substrate material, grade, previous coating and initial condition;
- coating system, manufacturer and current technical data;
- required preparation method and cleanliness grade;
- required profile parameter/range and measurement method;
- oil, grease, dust, soluble-salt, moisture and environmental controls;
- edges, welds, pits, laminations and repair areas;
- time between preparation and coating and any flash-rust limit;
- calibrated inspection equipment and locations; and
- hold, repair and release authority.

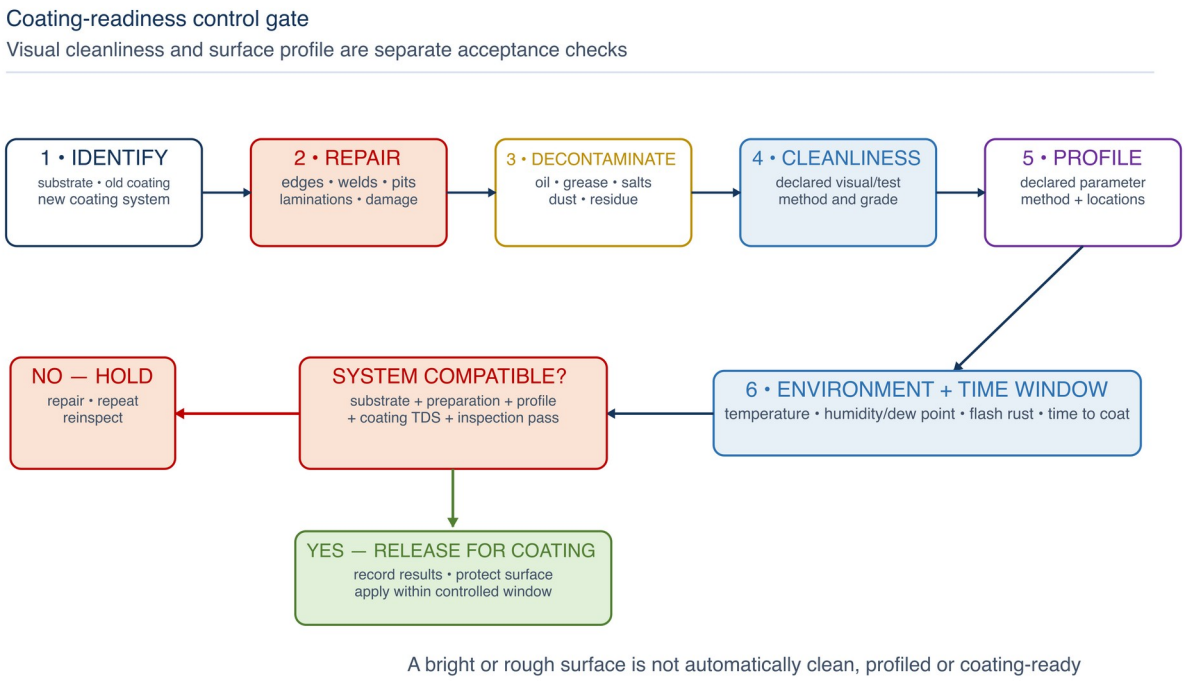


Figure 4. Coating-readiness control gate. Substrate identity, defects, contamination, visual cleanliness, profile and coating compatibility are separate release checks.

10. Translate vague finish words into controlled requirements

Terms such as “satin,” “brushed,” “polished,” “mirror,” “grain,” “smooth,” “clean,” “low glare” and “No. 4” are useful for initial communication but incomplete for production release.

Translate the requested word into:

- material, product form and visible/service faces;
- functional and cosmetic duties;
- reference standard and revision;

- texture parameter(s), method and direction;
- required lay and scratch-pattern rules;
- gloss, reflection or colour method if applicable;
- surface-condition and contamination limits;
- coating or cleanability requirements;
- physical master/reference sample and controlled viewing conditions;
- representative trial and repair method; and
- acceptance locations, frequency and named approver.

Do not promise that a named abrasive grit will reproduce a previous finish across different suppliers, backing types, wear states, machines, operators or geometries. The qualified process and its accepted output are the controlled pair.

11. Representative finish trial and record

Before repeat production, trial the exact proposed material, geometry, starting condition, abrasive sequence, machine, support, compound, cleaning method and inspection system. Include edges, welds, curves, transitions and repair zones that represent the production difficulty.

The record should contain:

337. drawing/customer finish requirement and service duty;
338. material, heat/lot, coating and starting surface;
339. finish zones, datum and lay direction;
340. each abrasive/product identity, sequence and revision-controlled instruction;
341. machine, support/interface, extraction and contamination controls;
342. texture instrument, standard, parameter, filter, direction and locations;
343. lighting, viewing geometry, reference sample and photographs;
344. cleanliness, coating-preparation or cleanability tests where applicable;
345. dimensional, surface-integrity and downstream checks;
346. nonconformities, permitted repair and reinspection;
347. approved reference panel or retained part; and
348. engineering, quality, customer and production release as required.

12. Applying a finish requirement

Translate the finish description into a usable specification: material and starting condition, functional purpose, lay direction, roughness or gloss parameter where relevant, permitted local defects, master panel or visual reference, lighting and viewing method, inspection locations, cleaning condition and repair boundaries.

Choose the abrasive sequence only after the required surface state is defined. Confirm the result on representative material that includes the difficult geometry—edges, welds, curves, transitions and repair zones. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

SURFACE FINISHING & POLISHING

CHAPTER 023

Surface Roughness and Visual Finish

23

SELECT • APPLY • FINISH • TROUBLESHOOT

MKTech Industry Sdn Bhd | www.mktechindustry.com

Audience: Production engineers, supervisors, grinding and finishing operators, fabricators, quality personnel, designers, inspectors, trainers and technical sales personnel

Scope: Practical interpretation and control of Ra, Rz and Rt; measurement direction and method; directional and random texture; mill, satin, brushed, No. 4, bright and mirror finish language; comparison, visual inspection and acceptance. This handbook is an educational and application-selection guide. Follow the current machine instructions. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Safety-critical boundary — Surface inspection does not make an unsafe process acceptable. Current machine and abrasive instructions, speed compatibility, guarding, work support, extraction, contamination control, chemical control and workplace risk assessment remain mandatory. Stop if the material, coating, required service, permissible stock removal, finish zone, defect authority or governing specification is unidentified. Never continue polishing merely to chase appearance when doing so could reduce thickness, change geometry, damage a coating or pressure boundary, embed contamination or overheat the work. [S007–S009; S014; S017]

Chapter objectives

After this chapter, the reader should be able to:

- explain what Ra, Rz and Rt reveal and what they do not reveal;
- recognise why the standard, revision and measurement operator must accompany a roughness value;
- define measurement direction relative to lay;
- separate roughness, local defects and visual appearance;
- distinguish directional and random texture;
- interpret mill, satin, brushed, No. 4, bright and mirror as controlled finish descriptions;
- avoid unsupported grit-to-roughness conversions and false cross-standard equivalence;
- establish a representative master-panel and viewing protocol; and
- create a complete surface-finish inspection and release record.

1. Roughness parameters are evidence, not finish names

Ra, Rz and Rt are profile-height parameters produced by a defined measurement chain. They are not abrasive grades, scratch directions, gloss levels, defect limits or complete finish descriptions. A result has meaning only with the governing standard and revision, units, filter or nesting-index settings, sampling and evaluation conditions, direction, instrument configuration, locations and acceptance rule.

The current published ISO profile route is ISO 21920: Part 1 for indication, Part 2 for terms and parameters and Part 3 for the complete specification operator. ISO 4287 and ISO 4288 have been withdrawn. A legacy drawing that cites either withdrawn standard must still be interpreted under the cited revision or formally changed; it must not be silently converted to ISO 21920. ASME B46.1-2019, reaffirmed in 2026, is a separate current surface-texture route. Do not mix ISO and ASME parameter meanings, filters, symbols or acceptance logic in one requirement. [S086; S105; S115–S116]

The practical rule is simple: write the whole measurement requirement, not just “Ra 0.8” or “Rz 6.3.” A unitless roughness value is incomplete, and a parameter named without its standard can be ambiguous.

2. Ra — useful average, incomplete picture

Ra expresses the arithmetic-average magnitude of profile height deviations over the declared evaluation. It is widely used because it condenses many profile points into one stable summary. It is useful for process monitoring and drawing requirements when the method is controlled.

Ra does not disclose:

- whether the profile contains rounded plateaus or sharp peaks;
- whether valleys are shallow and frequent or isolated and deep;
- the spacing or periodicity of the texture;
- the direction of lay;
- waviness or form that the chosen filtering removes;
- a rogue scratch, pit, crack, burr, embedded particle or smear outside the statistical response; or
- gloss, reflectivity, haze, image clarity or colour.

Two surfaces can produce a similar Ra indication while differing materially in peak/valley structure, spacing, direction, appearance and service behaviour. Therefore Ra must be supplemented when sealing, sliding, fatigue, coating, cleanability, optical appearance or defect sensitivity requires more information. [S105–S107; S117]

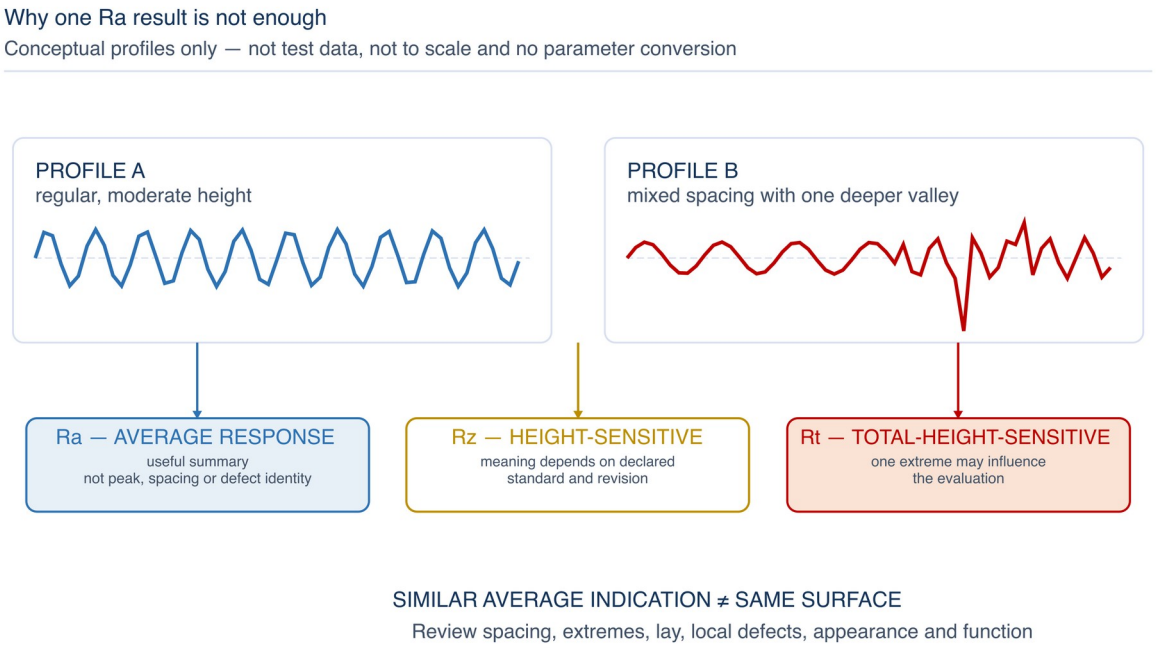


Figure 1. Why one Ra result is not enough. Conceptual profiles with similar average-height indication can have different extremes and spacing; the profiles are not test data and are not to scale.

3. Rz — state the standard and revision

Rz gives more emphasis to profile peak-to-valley height than Ra, but the exact definition and evaluation have varied among ISO, ASME, JIS and legacy usage. Some instruments and old reports also expose legacy variants under similar names. “Rz” alone is therefore not a complete requirement.

Under the current chosen system, Rz can help reveal a surface whose height range is more severe than its average suggests. It can support control of deeper valleys or higher peaks, but it still depends on filtering, sampling, trace location and the specified evaluation. It does not identify the cause of an extreme or guarantee detection of every isolated defect.

Whenever Rz is specified or reported, record:

- the standard and revision that defines it;
- whether an instrument setting represents a legacy or regional variant;
- the profile filter and evaluation conditions;
- trace direction and measurement locations;
- repeated-reading and acceptance rules; and
- any separate defect inspection.

Do not convert Ra to Rz using a fixed multiplier. The relationship changes with process, profile shape, spacing, material, abrasive condition and measurement method. [S105–S107; S116–S117]

4. Rt — total profile height within the evaluation

Rt represents the total height spanned by the roughness profile over the declared evaluation length under the chosen standard and filtering. Because one high peak or deep valley can influence the result, Rt can be useful as a warning indicator for extremes that an average may soften.

That sensitivity is also a limitation. Rt may change because of a real local feature, contamination on the surface, a trace crossing an edge or pore, poor levelling, vibration, instrument condition or an unrepresentative location. It must be interpreted with the profile trace and visual/defect evidence, not used alone to condemn or release a surface.

Ra, Rz and Rt are complementary, not interchangeable. A functional specification may need one, two or all three—or a different profile/areal parameter altogether—based on the engineering duty. Parameter selection must follow the governing specification and function, not convenience. [S105; S116–S117]

5. Control the complete measurement chain

A reliable roughness result starts before the probe touches the part.

349. **Identify the requirement.** Confirm drawing, customer specification, standard, revision, parameter, units, limit, acceptance rule and finish zone.
350. **Stabilise the surface.** Clean using an approved non-damaging method; define whether the part is dry, coated or otherwise conditioned. Do not polish the inspection area during cleaning.
351. **Select the method.** Confirm contact stylus or optical method, instrument range, tip or optical configuration, calibration/reference artefact and environmental suitability.
352. **Define separation and evaluation.** Apply the governing filter, nesting index or cut-off, sampling/evaluation length or area and form-removal rule. Do not accept an instrument's default without checking it.
353. **Define direction.** State the trace relative to the predominant lay and part datum. On directional surfaces, across-lay measurement often exposes height variation more strongly, but the drawing or method controls.
354. **Select representative locations.** Include process zones, repairs, weld transitions, curvature and risk areas while avoiding edges or features only where the method permits.
355. **Measure without corrupting the trace.** Prevent rocking, skid errors, vibration, tip contamination, excessive stylus force, unsuitable traverse speed or optical artefacts.
356. **Review the profile and context.** Check for outliers, edge crossings, non-measured length, levelling error and disagreement with the visible surface.
357. **Apply the acceptance rule.** Use the required number of readings and stated treatment of repeated results; do not average away a prohibited defect.
358. **Preserve traceability.** Record raw traces or native data where practical, settings, calibration status, operator, date, locations, photographs and disposition.

NIST calibration work demonstrates that measurement conditions and uncertainty sources are part of a credible result. Manufacturer guidance likewise identifies probe, speed, calibration and direction as practical controls, but the instrument maker does not replace the governing standard or customer specification. [S117; S121]

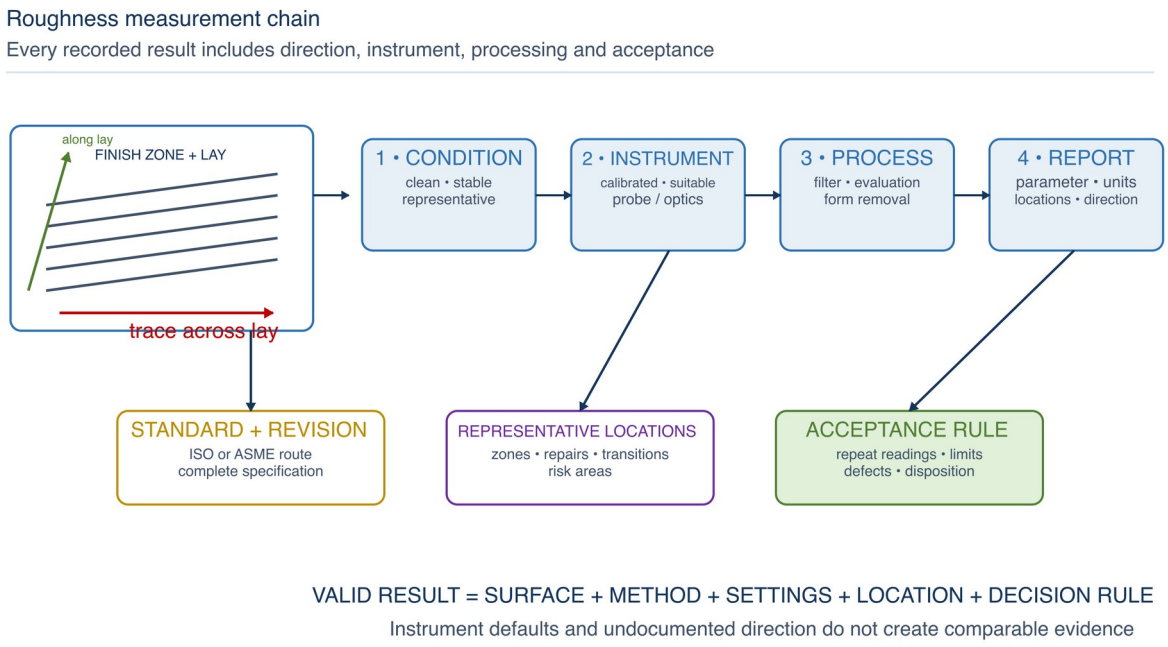


Figure 2. Measurement chain and direction relative to lay. The trace direction, instrument, filtering, evaluation, locations and acceptance rule are all part of the result.

6. Directional and random texture

A **directional finish** has a predominant visible or measured lay. Grinding, belt finishing and brushing commonly produce aligned marks. Define direction from a part datum: longitudinal, transverse, circumferential, radial or another drawing-controlled orientation. Control continuity across panels, welds, repairs, corners and curved surfaces.

A **random** or **non-directional finish** has no intentionally dominant macroscopic direction under the specified viewing or measurement method. It still has microtexture and can show local swirls, clouds, overlap marks or directional patches. “Random” does not mean uncontrolled.

For either type, specify:

- visible and functional zones;
- required direction or permitted lack of direction;
- reference sample or measured texture requirement;
- lighting and viewing orientation;
- prohibited cross-grain, hook, swirl, start/stop and repair marks;
- transition rules at welds, edges and adjoining panels; and
- separate roughness and defect acceptance.

Trace direction can change the measured result on an anisotropic surface. When direction is not stated, reports from different operators may not be comparable. Record the direction relative to lay for every controlled trace. [S028; S105; S120–S121]

7. Finish families and controlled terminology

Finish names usually describe a process family, appearance, lay or supply condition. They do not automatically establish Ra, Rz, Rt, gloss or a grit sequence.

Finish term	Typical controlled meaning	Acceptance method	Critical warning
Directional	Predominant lay tied to a part datum	Direction map, master panel, roughness traces in stated direction, defect limits	Direction alone does not define roughness or gloss
Random / non-directional	No intended dominant macroscopic lay under stated viewing	Master panel, viewing protocol, texture/defect checks	Not a synonym for uncontrolled or defect-free
Mill finish	Surface supplied by a defined manufacturing route such as hot/cold rolling, annealing, pickling or bright annealing	Material/product standard, finish code, supplier certificate and accepted sample	Not simply “unfinished” and not one Ra value
Brushed	Intentionally directional mechanical texture	Declared system, direction, sample, texture and appearance limits	Contractor and supplier terms vary; final grit alone is insufficient
Satin	Low-to-moderate sheen appearance, often with controlled fine texture	Named standard/supplier system, master panel, optical/texture checks where required	May be directional or differently processed; not a universal roughness band
No. 4	ASTM flat-product polished-finish designation where ASTM A480/A480M applies	Exact standard/revision, product form, supplier sample, pattern and acceptance record	Not a universal name for all metals, forms or vendors
Bright	High-reflectance appearance from a named route, which may include bright annealing or mechanical polishing	Process designation, reflectance/gloss/image requirements and master panel	Bright-annealed 2R and mechanically polished 2P are not the same process
Mirror	Highly reflective finish with controlled image clarity and low visible disturbance	Named finish system, master panel, optical protocol, texture and defect limits	“Mirror” is not one grit, one Ra value or guaranteed optical performance

The table is a control chart, not a conversion table. BSSA and worldstainless show useful indicative relationships among ASTM and EN stainless flat-product finish families—for example No. 4 with 2J, satin-related No. 6 with 2K and mirror-related No. 8 with 2P—but explicitly treat such mappings as contextual rather than exact equivalence. [S028; S118–S120]

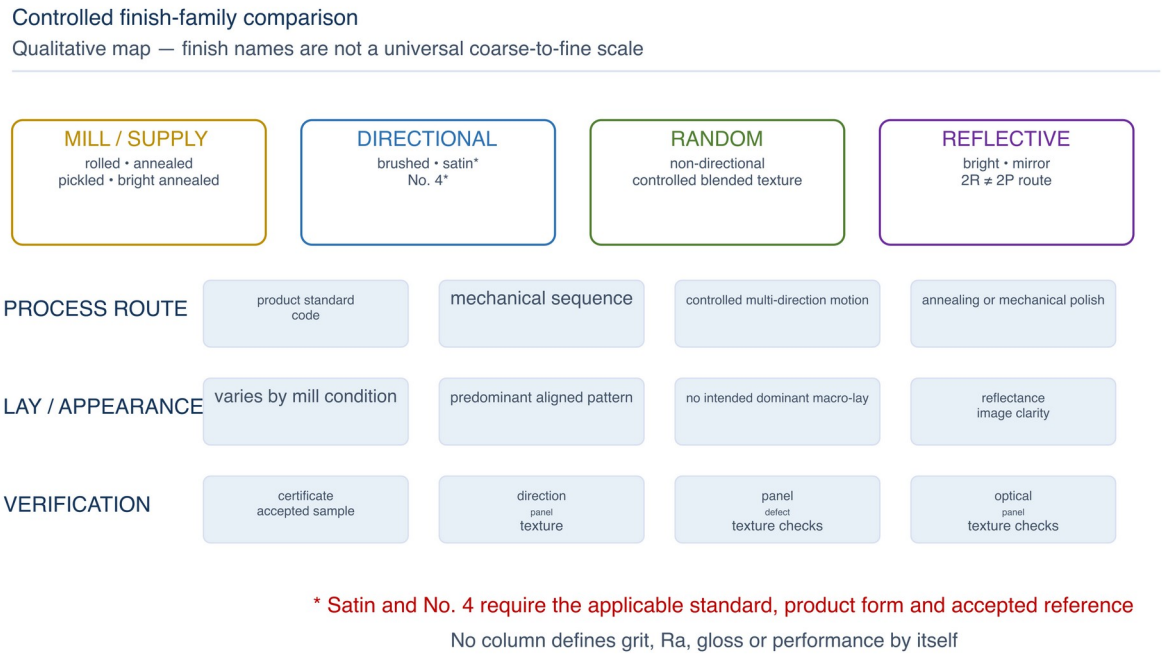


Figure 3. Controlled finish-family comparison. Process route, lay, appearance and verification are separate attributes; finish names do not form a universal coarse-to-fine numerical scale.

8. Mill finish is a specified supply condition

Mill finish describes a surface resulting from a controlled manufacturing route. Stainless flat products may be hot rolled, annealed, pickled, cold rolled, skin passed or bright annealed under named codes. Different mill finishes can therefore be scale-bearing, matte, smooth, reflective or prepared for later polishing.

Specify the applicable product standard, finish code, product form, thickness range, visible face, protective film condition and permitted defects. Retain supplier certificates and accepted samples where appearance is contractual. Do not assume that mill finish from different mills, coils, batches or thicknesses will be visually identical merely because the same broad word appears on an order. [S119–S120]

9. Brushed, satin and No. 4 finishes

Brushed commonly describes a directional mechanical finish. The delivered pattern depends on the starting surface, abrasive construction and grading system, machine, support, speed, pressure, feed, overlap, wear, lubrication, cleaning and operator control. The last grit designation cannot define the result by itself.

Satin commonly communicates a subdued sheen with a controlled texture, but its process and direction vary. In stainless flat-product contexts, EN 2K and ASTM No. 6 may be used as related satin-family references, while supplier and contractor language can differ.

No. 4 is meaningful only when tied to the applicable ASTM A480/A480M flat-product context and a controlled supplier/customer interpretation. It is often associated with a general-purpose directional polished appearance and may be related indicatively to EN 2J, but neither relationship establishes a universal grit, Ra or appearance.

For production, replace the isolated word with a complete requirement: material and product form, starting condition, applicable finish designation and revision, direction, master panel, roughness method and limits if needed, viewing protocol, permitted variation, local-defect limits, repair route and approver. [S028; S118–S120]

10. Bright and mirror finishes

Bright finish may describe high reflectance produced by different routes. Bright-annealed stainless flat product, commonly designated 2R in EN practice, obtains its surface through controlled annealing conditions and rolling history. A mechanically bright-polished surface follows another route. Similar visual brightness does not make the metallurgy, texture or repair response equivalent.

Mirror finish usually communicates high reflectivity and strong image clarity with very low visible disturbance. In stainless flat-product references, mechanically bright polished 2P and ASTM No. 8 are often treated as related mirror-family designations. This is an indicative crosswalk, not automatic equivalence.

A mirror requirement should define image clarity, haze/distortion, directional trace, waviness, orange peel, pinholes, pits, edge condition, weld and repair zones, colour, cleanliness and viewing geometry. Ra alone cannot release a mirror surface: long-scale waviness or fine directional marks may distort reflected images even when average roughness is low. [S108; S119–S120]

11. There is no universal grit-to-Ra conversion

Abrasive grit indicates a particle-size distribution within a named grading system; it does not state the depth of the delivered scratch or the final Ra. The workpiece material and starting surface, grain type and shape, coated/bonded/non-woven construction, backing and support, pressure, speed, feed, overlap, lubrication, loading, wear state, heat, prior defects and measurement method all affect the outcome. [S028; S039–S043]

Published grit-to-Ra tables can be useful only when they represent the same controlled material, abrasive product, process, machine and measurement method. They are trial data, not universal physics. Do not use a supplier’s typical finish number as a universal acceptance limit outside the conditions in which it was established.

A defensible local relationship is developed by:

359. defining material, geometry, starting condition and finish duty;
360. identifying complete abrasive and machine systems;
361. controlling settings, contact support, wear state, sequence and cleaning;
362. producing representative coupons and difficult production features;
363. measuring under a declared standard and method;
364. assessing visual pattern, local defects and downstream function;
365. establishing variation across operators, lots and consumable life;
366. retaining accepted master panels and raw measurement data; and
367. approving a revision-controlled process window and change rule.

12. Visual comparison requires a physical control system

A finish photograph is useful evidence but is not automatically a master. Camera exposure, focal length, white balance, sharpening, compression, screen brightness, part curvature and reflected surroundings can change the apparent finish.

For appearance-critical work, create a physical master-panel system:

- use the same material, product form and representative geometry;
- identify master, limit and defect samples separately;
- assign a unique ID, revision, owner and approval date;
- mark viewing orientation and lay direction without damaging the comparison face;
- define light source, position, distance, angle, background and inspection movement;
- define cleanliness, handling, gloves, storage and protective packaging;
- prohibit touching or reworking the comparison face;
- record photographs under fixed camera conditions for traceability;
- inspect master condition periodically and replace only through controlled approval; and
- keep obsolete panels segregated but traceable.

Visual inspection should separately record overall match, lay/pattern continuity, local defects, repair visibility and adjacent-part consistency. A part can match the overall sheen yet fail because of a deep rogue scratch; conversely, a measured roughness result can pass while the visible direction or image clarity fails.

13. Controlled inspection and release

Release requires both the specified quantitative and visual evidence. Neither route should be used to override the other.

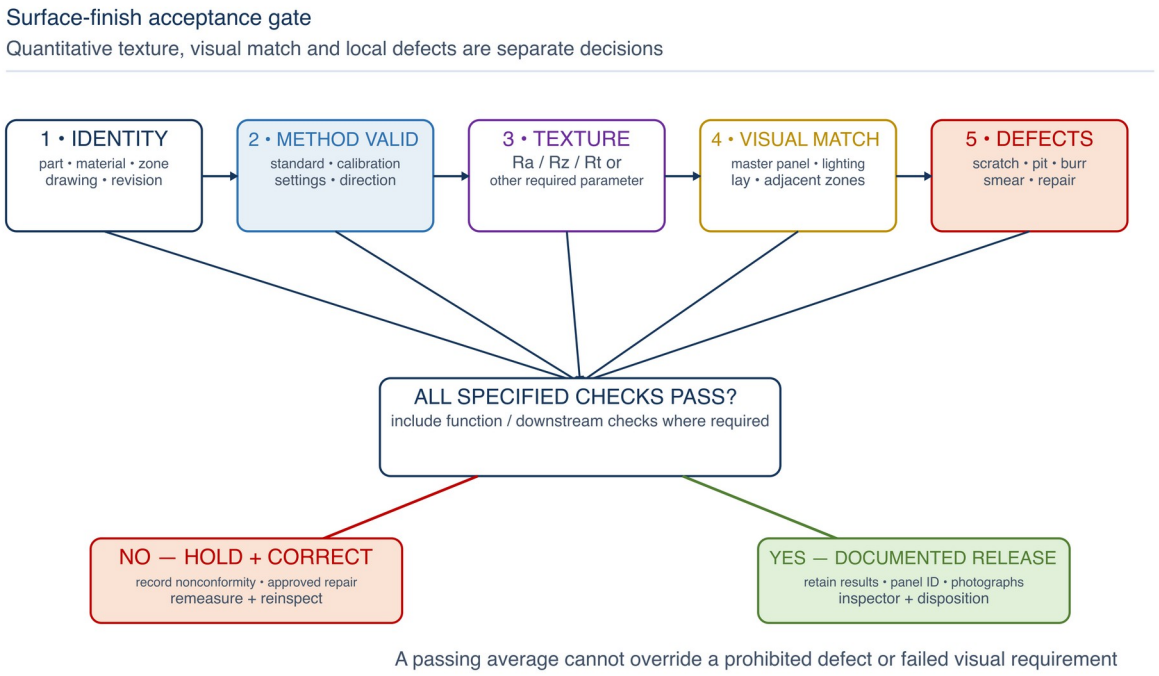


Figure 4. Surface-finish acceptance gate. Identity, measurement validity, texture result, master-panel comparison and local-defect inspection converge on a documented release or hold.

The inspection record should include:

368. part, material, product form, batch/heat and drawing revision;
369. finish zone, datum, service duty and applicable standard/revision;
370. required parameter(s), units, filters, evaluation and acceptance rule;
371. instrument, probe/optical configuration, calibration and uncertainty control;
372. measurement direction, locations, repeated results and native data references;
373. finish name and process designation without treating either as a measured value;
374. master-panel ID/revision and controlled viewing conditions;
375. overall appearance, lay, local defects, welds, edges, transitions and repair zones;
376. photographs tied to the controlled camera/viewing protocol;
377. dimensional, contamination, coating, cleanability or service checks where required;
378. nonconformity, permitted repair, remeasurement and reinspection; and
379. inspector, date and named engineering, quality, customer or production disposition.

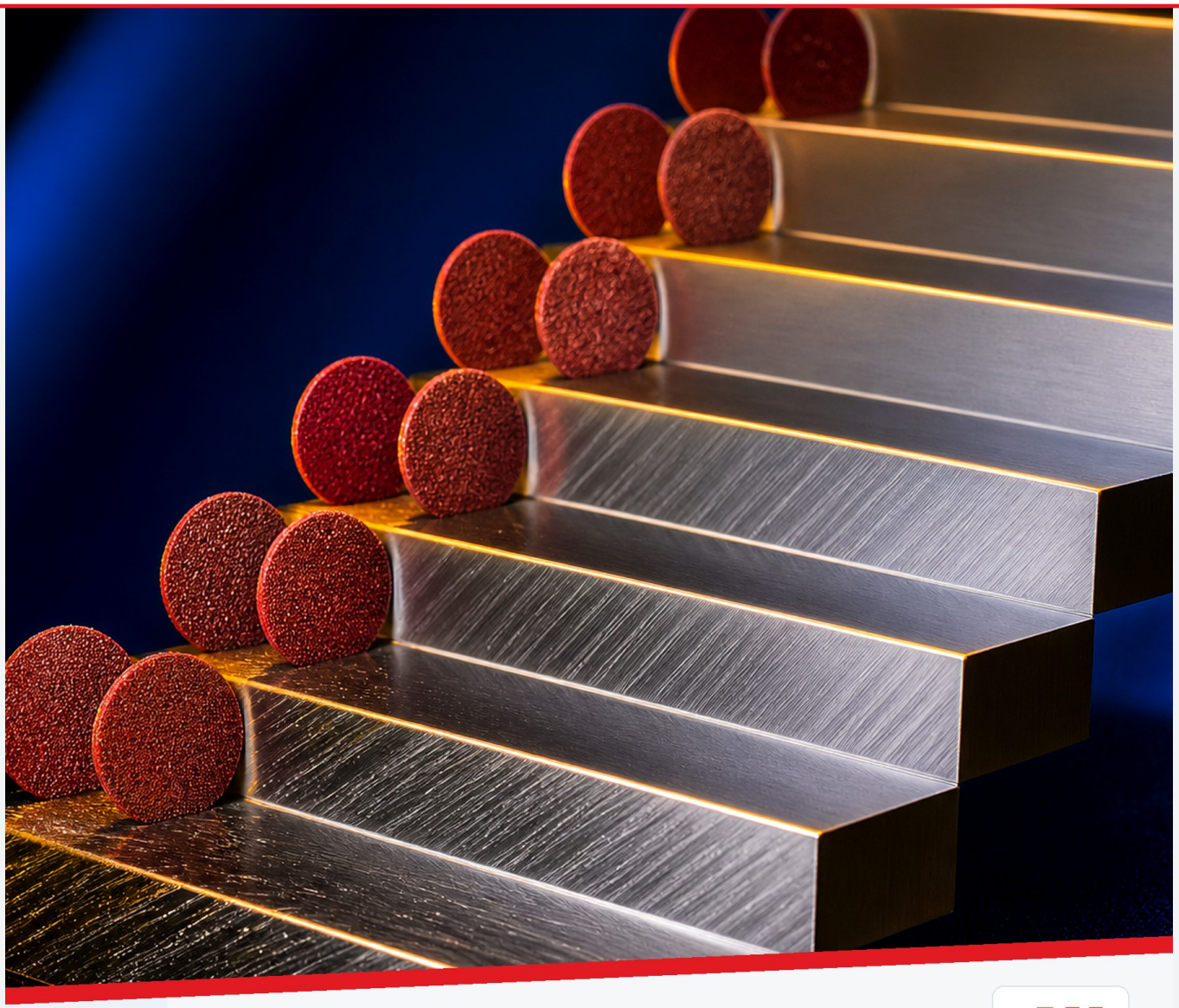
If the standard, measurement settings, trace direction, master panel or acceptance authority is unclear, place the work on hold until the requirement is defined. Do not reverse-engineer acceptance from a single historical reading or an internet finish photograph.

14. Applying the guidance

Use the following sequence when selecting and controlling a finishing process:

380. define the material, product form, starting condition and required function;
381. translate the requested appearance into a named standard or accepted physical sample;
382. identify the required lay, roughness parameter, defect limits and viewing conditions;
383. select an abrasive product and machine that are suitable for the material, geometry and finish stage;
384. verify maximum operating speed, intended use and accessories against the product label, current Technical Data Sheet and machine instructions;
385. establish the sequence on representative work using controlled technique and inspection;
386. compare measured texture, visual appearance and local defects with the specified acceptance criteria; and
387. record the process and inspection conditions needed for repeatable production.

When a drawing or customer requirement specifies Ra, Rz, Rt, No. 4, satin, bright or mirror, confirm the referenced standard, revision and acceptance method before production. For abrasive selection or product-specific application advice, consult the current product documentation or an MKTECH representative.



SURFACE FINISHING & POLISHING

CHAPTER 024

Scratch Refinement and Grit Progression

24

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: Practical scratch identification, abrasive-stage selection, cross-sanding, directional refinement, inspection lighting, contrast-marker methods, edge protection and final finish matching for industrial metalwork.

Core principle — A refinement stage is complete only when the unwanted scratches from the previous stage have been removed across the controlled area. A brighter surface is not proof that the deepest scratch has gone.

Chapter objectives

After this chapter, the reader should be able to:

- find and classify the deepest unacceptable scratch before selecting an abrasive;
- choose a practical next stage without relying on a universal grit-jump rule;
- use changed sanding direction, controlled lighting and suitable contrast methods to expose residual scratches;
- protect edges, features, thin sections and adjacent finished faces during refinement;
- re-establish a straight, consistent final lay where a directional finish is required;
- distinguish incomplete refinement from contamination, loading, smearing and local overworking; and
- confirm the finished surface against the specified visual, dimensional and measured requirements.

1. Refinement is controlled scratch replacement

Every abrasive stage creates a new surface while removing part of the old one. The practical objective is to replace the unwanted pattern with a more uniform pattern that the next stage can remove efficiently. This continues until the required functional or visual finish is achieved.

Grit designation alone cannot predict the delivered scratch. The result also depends on abrasive mineral and shape, grading system, coating or bond, backing, contact support, machine motion, speed, pressure, feed, overlap, wear, loading, lubrication, workpiece material, geometry and contamination. FEPA identifies P-grades for coated abrasives and explains that abrasive particle size is controlled as a distribution rather than a single diameter. The complete abrasive product and process therefore matter as much as the number on the backing. [S039–S041]

The central production rule is simple:

388. define the unacceptable scratch or starting texture;
389. select the least aggressive suitable stage that can remove it without unnecessary damage;
390. create a uniform new pattern;
391. clean and inspect the whole controlled area; and
392. advance only when the previous pattern is no longer present above the acceptance criterion.

Struers applies the same principle in systematic materialographic preparation: each successive stage removes damage from the preceding stage, the surface is examined between stages, and contamination is controlled. Its setting is laboratory preparation, but the scratch-removal logic transfers directly to industrial refinement. [S123]

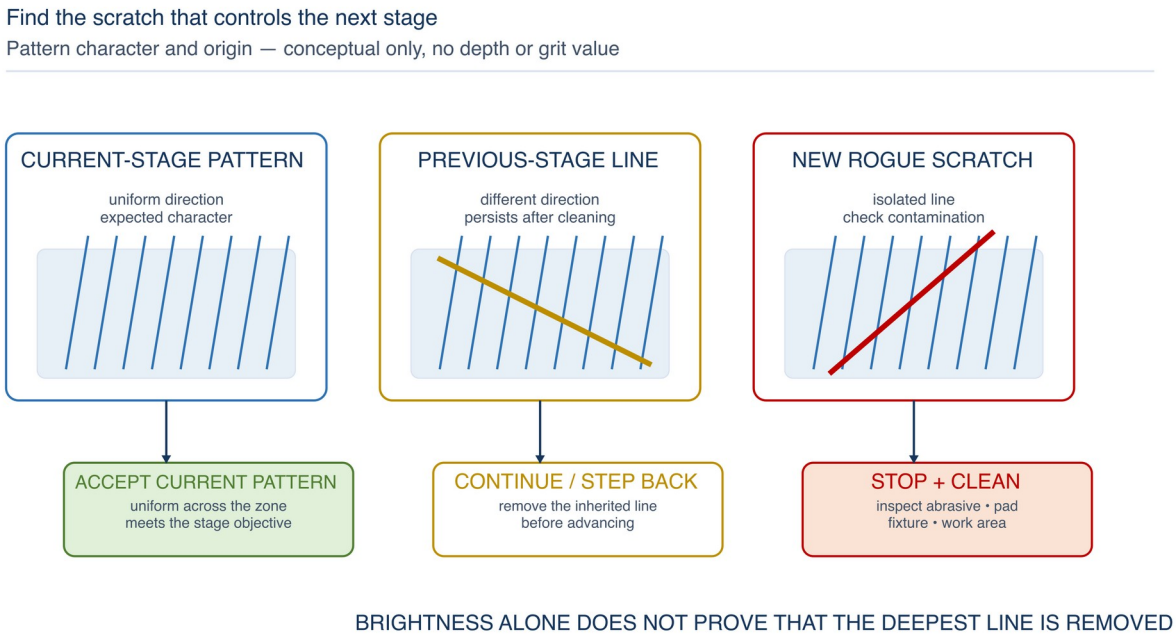


Figure 1. Scratch ancestry and deepest-scratch identification. A uniform current-stage pattern is separated from a persistent previous-stage line and a newly introduced contamination scratch.

2. Define the target before touching the surface

Start with the finish requirement, not the abrasive shelf. Confirm:

- material and product form;
- visible face, functional face and non-critical zones;
- starting condition, coating, oxide, weld transition or damage;
- required lay direction or non-directional appearance;
- accepted reference panel, drawing note, roughness requirement or coating specification;
- local defect limits and dimensional allowance;
- edge, radius, corner, hole, thread and adjoining-surface protection;
- contamination controls, especially for stainless steel and non-ferrous work; and
- the required cleaning and inspection method.

A final finish name such as brushed, satin, No. 4 or mirror does not by itself define a universal grit sequence. Material condition, product construction and process route influence the appearance, while a physical master panel or declared measurement method provides the acceptance reference. [S028; S119–S120]

3. Identify the deepest unacceptable scratch

The deepest visible line governs the early refinement work. If it remains, finer stages may brighten the surrounding peaks while leaving the valley untouched. The defect can then reappear under final lighting, polishing or coating.

Use a disciplined inspection sequence:

393. Stop the machine and make the work area safe.
394. Clean the surface using a method suitable for the material and downstream process.
395. Inspect the dry surface under broad diffuse light to see overall uniformity.
396. Add a low-angle line or point light and move it across the surface.
397. Rotate either the part, the light or the viewing position so scratches are viewed both across and along their direction.
398. Use suitable magnification for small defects, while retaining a normal viewing check for overall appearance.
399. Mark the defect beside the controlled area or use an approved contrasting aid that will not damage or contaminate the surface.
400. Check edges, low spots, curves, weld toes, corners and transitions separately.

Classify what you see:

- **Previous-stage scratch:** direction or character differs from the current uniform pattern and persists after cleaning.

- **Current-stage scratch:** matches the intended new pattern and is reasonably uniform across the worked area.
- **Rogue scratch:** isolated line introduced by loose grit, swarf, a damaged abrasive, contaminated support or debris trapped at the interface.
- **Smear or bright patch:** displaced or rubbed material that can hide a valley rather than remove it.
- **Geometric defect:** groove, undercut, flat spot, rolled edge or low area that cannot be corrected by surface refinement alone without checking dimensions.

Visual appearance and measured profile reveal different aspects of a surface. Use visual inspection to locate and classify the defect; use the specified measurement method where depth, roughness or function is controlled. [S042; S105; S117]

4. Choose the starting stage and the next stage

Begin with the least aggressive abrasive stage that removes the identified defect efficiently while protecting material allowance, edges and heat-sensitive geometry. Starting too fine can waste time and consumables; starting too coarse creates deeper damage that must later be removed.

Select the next stage by capability, not by a memorised number:

- identify the grading system and full product construction;
- consider the work material, hardness, ductility and tendency to load or smear;
- match the product form and support to the surface geometry;
- assess whether the next stage can reach the bottom of the deepest remaining scratch;
- consider the permitted heat, dimensional change and edge condition; and
- confirm that the stage can be inspected clearly before moving on.

Manufacturer sequences can provide a useful starting point when they apply to the same material, product family and machine system. They are not universal conversion charts. A change from coated abrasive to structured abrasive, non-woven product, film or polishing compound can alter the grading language and cutting behaviour even when the labels appear numerically related. [S039–S041; S046; S060]

Starting condition	Practical first decision	Checks before advancing	Avoid
Isolated deep scratch on an otherwise acceptable face	Localise the defect, protect surrounding finish and use the least aggressive suitable corrective stage	Deep line removed without a hollow, halo or edge change	Chasing the line with a tipped disc or prolonged local dwell
Uniform coarse pattern	Use a complete intermediate stage across the full controlled zone	Old-direction or coarse-character scratches are absent under changed lighting	Polishing only the peaks until the surface looks bright
Random deep lines after an otherwise uniform pass	Stop, clean, inspect abrasive, pad, support and work area for contamination or damage	New test pass produces a uniform pattern without rogue lines	Continuing with the same contaminated or loaded interface
Soft or ductile material showing shine and drag marks	Restore cutting action with a suitable product and controlled contact	Cleanly generated, uniform texture replaces smear	Adding pressure to a loaded or blunt abrasive
Thin sheet, edge or formed feature	Use controlled support and short, distributed contact	Scratch is removed while shape, edge and temperature remain acceptable	Concentrated force, unsupported work or repeated dwell at the edge
Directional finish repair	Plan a blend zone and final lay from a fixed datum	Direction, spacing, sheen and transition match the approved reference	A small bright patch with hooks, cross-lines or abrupt boundaries

5. Cross-sanding makes old scratches easier to see

Where geometry, product instructions and the required final finish permit, change the working direction between stages. When the new stage crosses the previous lay, residual old scratches remain visually distinct. The surface is ready to advance only when the old-direction lines have disappeared across the full controlled zone.

The direction change need not be exactly the same for every job. A clear angular separation is useful, but access, curvature, machine motion, final lay and safe tool control govern the actual path. On random-orbital or non-directional processes, the old and new patterns may not separate cleanly; use cleaning, controlled lighting, contrast aids and close inspection instead.

Cross-sanding is an inspection method, not the required final appearance. When the specification calls for a directional finish, the final stage must re-establish the specified lay from the defined part datum. Do not leave cross-lines hidden beneath temporary shine.

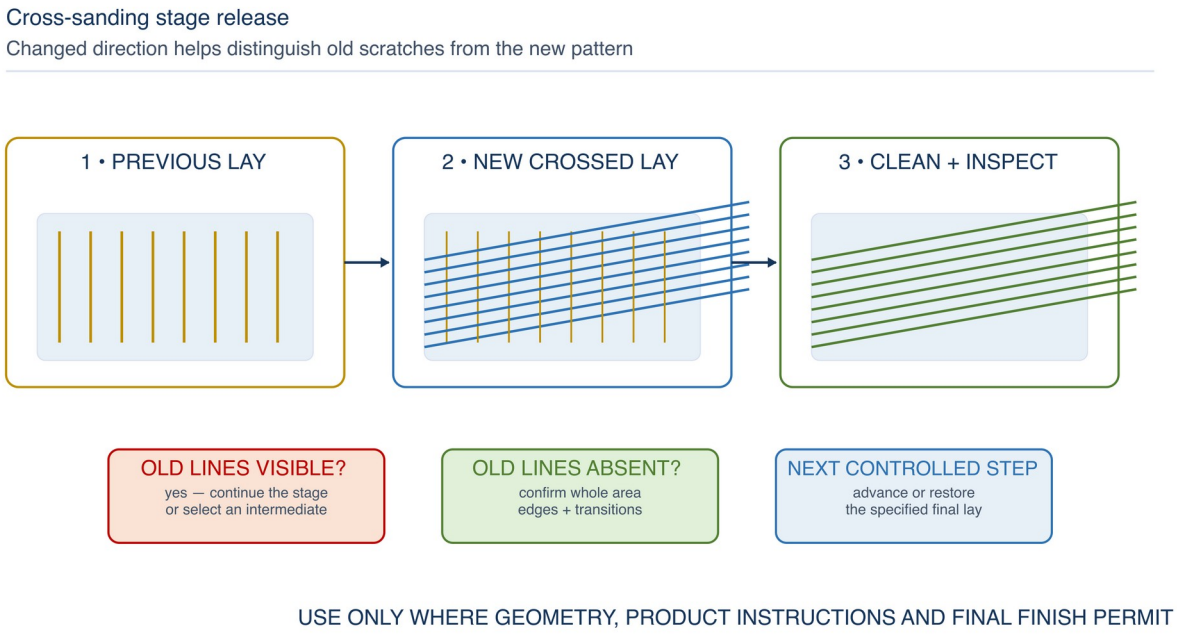


Figure 2. Cross-sanding and stage-release sequence. A changed working direction exposes the old pattern; cleaning and inspection release the stage only after the previous scratches are removed.

6. Directional sanding and final lay

A directional finish should read as one continuous surface. Establish the direction from a feature that operators and inspectors can repeat: longitudinal, transverse, circumferential, radial or another drawing-controlled datum.

Practical controls include:

- align the tool or belt before contact;
- use stable support and maintain the intended contact footprint;
- travel in a consistent path with controlled overlap;
- avoid stopping, reversing or pivoting while the abrasive is cutting in the visible zone;
- feather into and out of a repair so the transition is gradual;
- work with the grain during final matching;
- carry the lay consistently across weld blends and adjoining panels; and
- inspect line straightness, hooks, swirls, start/stop marks and local sheen from several angles.

Directional stainless finishing is normally separated into weld levelling, grain setting and final finishing. Straight-line tools can help restore a directional pattern; inspect a small area from several angles and ease contact at the ends of strokes when feathering a repair. Apply staged refinement, grain control and gradual blending without transferring product-specific settings. [S122]

7. Clean between every stage

Loose abrasive particles, swarf and loaded debris can create a scratch deeper than the nominal stage. Clean the workpiece, abrasive interface, support pad, fixture and nearby work area before changing grade or product family.

Use a cleaning method compatible with the material and next process. A clean, dedicated brush, suitable vacuum extraction or approved wipe may be appropriate. Avoid sweeping a contaminated cloth across the acceptance face. Compressed air can introduce oil or water and can project particles; use it only where the workplace method, air quality and exposure controls permit.

Keep abrasive products segregated by grade and material service. Do not place a clean fine abrasive on a contaminated bench or reuse a pad carrying coarse particles. For stainless steel, maintain dedicated tools and consumables where cross-contamination from carbon steel would impair corrosion performance or appearance.

8. Marker and guide-coat methods

A contrast aid can make scratches, low spots and incomplete coverage easier to see. Use it as an inspection aid, not as the acceptance standard.

Suitable methods include:

- a temporary mark placed beside an isolated defect rather than across the acceptance face;
- a light, compatible contrasting medium applied to a sacrificial or subsequently removed surface layer;
- a manufacturer-approved dry guide coat on the fillers or primers listed in its Technical Data Sheet; and
- removable witness marks on masking or adjacent non-finish areas to show the planned blend boundary.

A compatible contrast guide coat can reveal scratches and pinholes in declared filler and primer applications during wet or dry sanding. That use does not automatically authorise the same material on bare metal, hygienic surfaces, corrosion-sensitive alloys or a surface going directly to coating. Confirm substrate compatibility, residue removal and downstream-process acceptance before use. [S124]

Do not use an unidentified permanent marker, dye, aerosol, chalk, adhesive or solvent on a controlled finish. A marker can stain porous material, introduce residue, affect coating adhesion or create false contrast. Remove the aid as required, clean the surface and perform the final inspection without relying on residual colour.

9. Inspection lighting and viewing discipline

One light angle can hide a defect that another angle reveals. Use a repeatable combination:

- **diffuse overhead light** for overall patchiness, colour and sheen;
- **low-angle line light** for grooves, waviness, hooks and local high or low areas;
- **changed viewing direction** to expose scratches parallel to the first line of sight; and
- **normal-use viewing** for the customer-facing appearance of the finished part.

Keep the surface clean and dry unless the acceptance method specifies another condition. Reflections from windows, clothing and nearby equipment can alter apparent sheen. Compare the workpiece and the approved reference under the same light, angle, distance, orientation and cleanliness condition. Photographs support traceability but do not replace the physical comparison where appearance is critical. [S108; S119–S120]

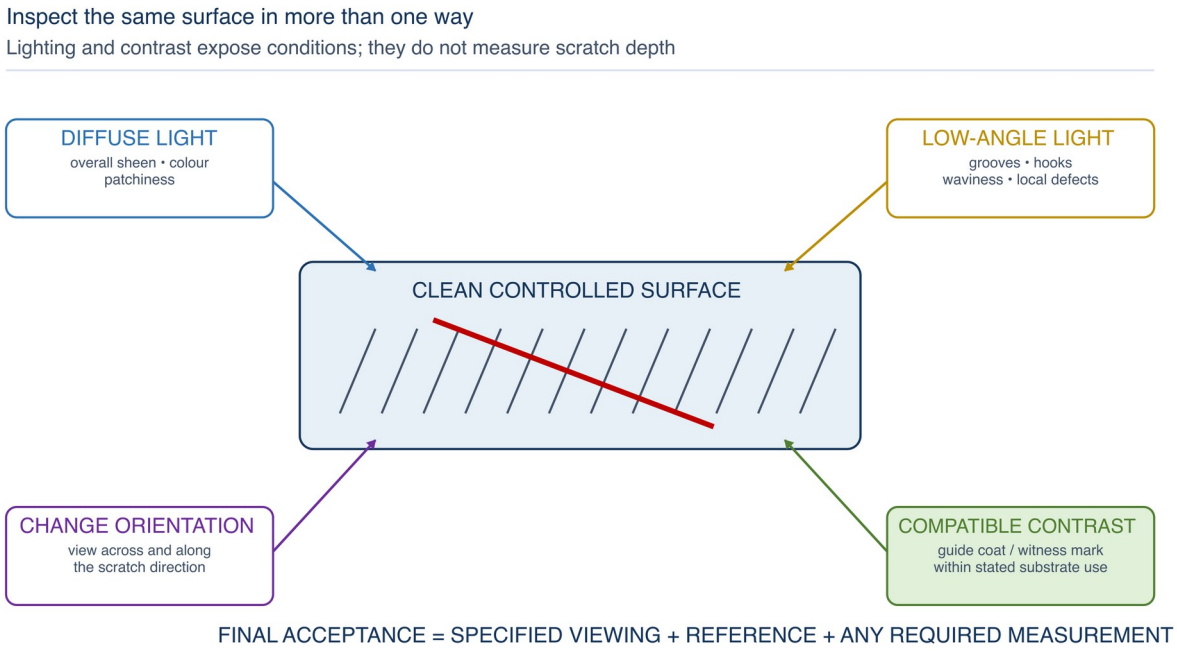


Figure 3. Lighting and contrast inspection map. Diffuse light, low-angle light, changed orientation and a compatible contrast aid reveal different aspects of the surface.

10. Protect edges, corners and adjacent faces

Edges concentrate contact pressure and are easy to round, thin, notch or over-brighten. Flexible or resilient products may wrap over an edge and remove material from both the face and side. Struers identifies resilient polishing surfaces, excessive time and force as contributors to edge rounding in materialographic preparation. The industrial response is to control support, contact, dwell and inspection rather than repeatedly chasing the edge. [S123]

Use these practical controls:

- mask or shield an adjacent finished face with a material suitable for the process;
- use a stable backing or contact support appropriate to the abrasive and geometry;
- keep the tool flat and avoid tipping the abrasive onto a small contact point;
- reduce repeated dwell at an edge and distribute corrective work over a planned blend zone;
- finish faces and edges in a deliberate order so one operation does not damage the other;
- inspect radius, chamfer, wall thickness, flatness and edge line where function requires it; and
- stop when scratch removal would exceed the permitted dimensional or geometric allowance.

On thin sheet and formed sections, also control heat and support. Surface appearance does not justify distortion, loss of section or a changed functional edge.

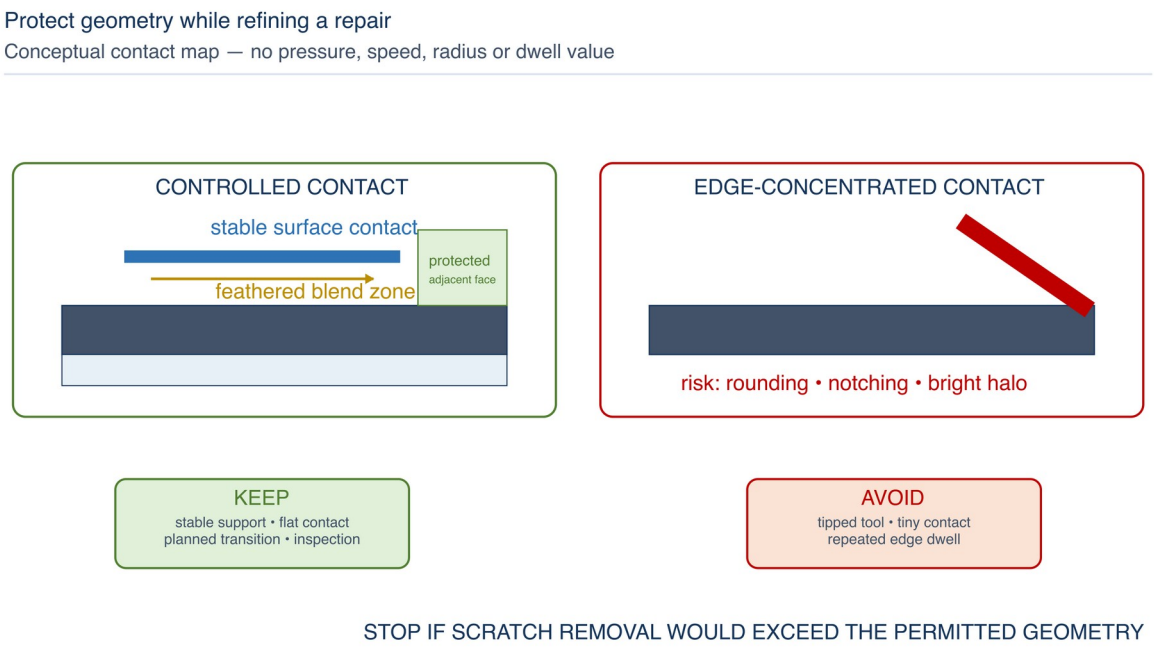


Figure 4. Edge protection and controlled blend zone. Stable support, a planned transition and reduced edge concentration protect geometry while the scratch is refined.

11. Match the final finish

Final matching requires more than reaching the same last grit. Match the attributes the customer actually sees or the component function requires:

- lay direction and straightness;
- scratch spacing and uniformity;
- sheen, reflectivity and colour;
- transition into the surrounding surface;
- local defects, halos, swirls and repair boundaries;
- edge and feature condition; and
- specified roughness or other measured requirement.

Whenever possible, refine a repair over a planned blend zone rather than polishing a tiny isolated patch. Extend the transition gradually while protecting unaffected areas. Use the same material condition, abrasive construction, machine motion, contact support and controlled technique that produced the accepted reference. A final grit label alone does not reproduce the result.

Compare the part with an approved master panel or accepted production reference under controlled viewing. If the specification includes Ra, Rz, Rt, coating readiness, cleanability or another function, perform that check separately; visual agreement cannot replace it. [S105; S117; S119–S120]

12. Troubleshooting scratch-refinement defects

Symptom	Likely process cause	Practical correction
Deep line remains after a finer stage	Previous stage incomplete; grit jump too ambitious; valley deeper than surrounding pattern	Return to the last effective stage or add a suitable intermediate stage, then re-refine the full controlled zone
New isolated deep lines appear	Loose grit, swarf, loaded abrasive, damaged pad, contaminated bench or wrong consumable segregation	Stop, clean, inspect and replace contaminated or damaged interface components before repeating
Surface becomes bright but old lines remain	Peaks are being rubbed or polished while deep valleys remain	Restore effective cutting with a suitable stage; do not add force to a blunt or loaded product
Hooks, swirls or stop marks	Tool pivots, stops or reverses while cutting; unstable contact or poor entry/exit control	Re-establish stable motion and finish with the required lay outside or through the affected zone
Patch or halo around a repair	Repair area too small; abrupt pressure change; product or wear state differs from surrounding process	Widen the blend zone gradually and match contact, product condition and final direction
Edge becomes rounded or over-bright	Abrasive wraps over edge; contact area too small; repeated dwell or excessive force	Improve support, protect adjacent faces, shorten edge exposure and inspect geometry more frequently
Finish varies from panel to panel	Direction, overlap, abrasive wear, support, cleaning, lighting or starting surface is inconsistent	Standardise the complete process and compare each panel under the same viewing conditions
Fine stage loads or smears	Material is ductile; abrasive is worn or unsuitable; debris is trapped; lubrication or extraction is unsuitable	Clean the interface, replace worn product and select a construction intended for the material and process

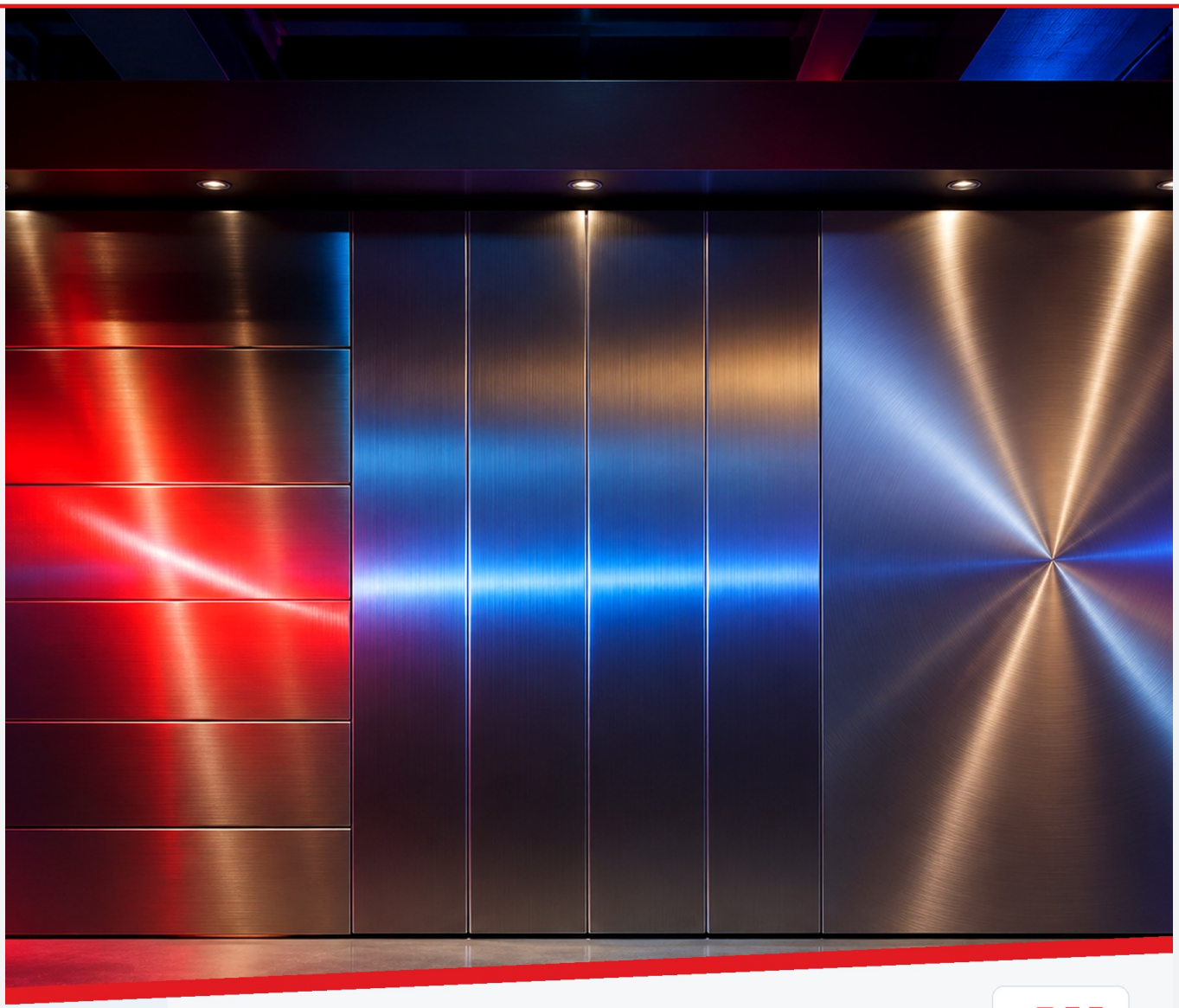
13. Concise safety reminders

- Use only abrasive products intended for the material, machine, mounting and task.
- Confirm that the abrasive and every accessory are compatible with the machine speed and dimensions.
- Keep guards, handles, extraction and other protective systems in place as required.
- Secure the workpiece and maintain a stable stance and controlled line of fire.
- Wear eye and face, hearing, respiratory, hand, body and foot protection selected from the workplace risk assessment.
- Control sparks, hot particles, combustible materials and mixed-metal dust. Aluminium and other combustible metal dusts require specific collection and fire/explosion controls.
- Stop for vibration, damaged backing, torn belts, abnormal sound, loading that creates rogue scratches, excessive heat or unstable support.
- Keep hands, clothing, hair and cables away from abrasive contact and in-running nip points.

Refer to the product label, Technical Data Sheet, or MKTECH representative.

14. Application sequence

401. Define the finish, controlled zone, lay, dimensional allowance and acceptance method.
402. Clean and inspect under diffuse and low-angle light.
403. Identify and mark the deepest unacceptable scratch without contaminating the finish.
404. Select the least aggressive suitable corrective stage.
405. Create a uniform new pattern using stable contact and controlled movement.
406. Clean the surface, abrasive interface and work area.
407. Inspect from more than one light and viewing direction.
408. Change sanding direction between stages where safe and compatible with the required finish.
409. Protect edges and adjacent faces, and monitor geometry and heat.
410. Re-establish the specified final lay and feather the blend zone.
411. Compare with the accepted reference and complete any specified measurement.
412. Release the finish only when pattern, appearance, geometry, cleanliness and functional checks all pass.



SURFACE FINISHING & POLISHING

CHAPTER 025

Directional and Brushed Finishes

25

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: Practical control of grain direction, entry and exit, pass overlap, line straightness, tool speed, contact pressure, hand-held and machine finishing, repair blending and visual acceptance for industrial metalwork.

Core principle — A directional finish is a controlled surface pattern, not simply a final grit. The accepted result depends on repeatable lay direction, scratch character, spacing, sheen, transitions and viewing conditions.

Chapter objectives

After this chapter, the reader should be able to:

- translate a finish requirement into a visible lay direction and repeatable datum;
- plan entry, exit, overlap and stroke sequence before contacting the workpiece;
- control line straightness without hooks, arcs, swirls or stop marks;
- understand how speed, pressure, contact support, abrasive wear and feed interact;
- select between hand-held, fixed-machine and automated finishing routes;
- blend a local repair without leaving a halo or abrupt boundary; and
- assess a directional finish against an approved reference under controlled viewing.

1. A directional finish is an engineered scratch pattern

Grinding, brushing and polishing create directional marks whose appearance depends on the complete finishing system. Abrasive construction, support, machine motion, contact shape, tool speed, travel speed, pressure, overlap, wear, material condition, cleanliness and lighting all influence the final pattern.

The words *brushed*, *satin*, *dull polished* and *No. 4* do not define one universal appearance. British Stainless Steel Association guidance explains that a final grit alone does not fully define a mechanically finished stainless surface, while EN finish families distinguish ground, brushed or dull-polished, satin and bright-polished routes by broader surface characteristics. Agreed samples or clearly stated surface requirements remain essential where appearance matters. [S028; S119–S120]

For production control, describe the target through observable attributes:

- lay direction and datum;
- line straightness and continuity;
- scratch spacing, width and uniformity;
- sheen, reflectivity and colour;
- permitted transition or blend zone;
- edge, corner and feature condition;
- local-defect acceptance; and
- any separately specified roughness or functional requirement.

2. Establish the datum and controlled zone

Define the lay from a part feature that different operators can recognise: longitudinal along a panel, transverse across a sheet, circumferential around a tube, axial along a shaft, radial from a centre or another drawing-controlled direction.

Before finishing, identify:

413. the visible face and the controlled zone;
414. the datum from which lay direction is judged;
415. the start and exit zones;
416. protected edges, holes, corners, weld toes and adjacent faces;
417. the intended blend boundary;
418. the accepted reference panel or production standard; and
419. the lighting and viewing method for final assessment.

On assemblies, plan how the grain will continue across joints and adjacent panels. Two individually uniform panels can still look mismatched when their lay direction, sheen or line spacing changes at the joint.

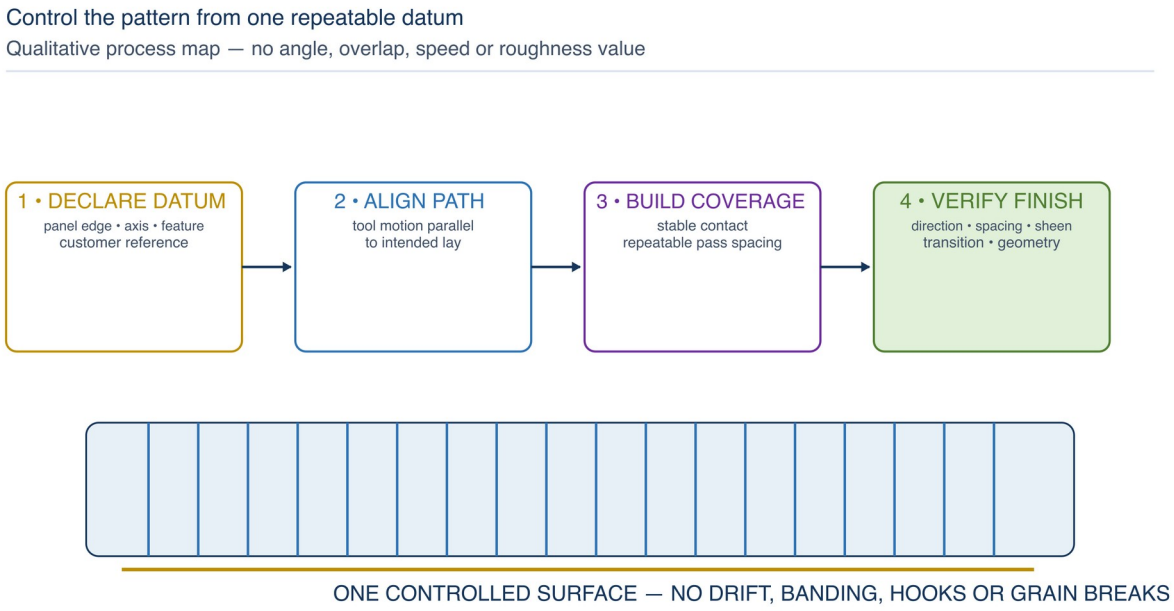

Figure 1. Directional-finish control map. A repeatable datum governs path direction, pass spacing, transitions and the final comparison with the accepted reference.

3. Select the process by the required pattern

Choose the product form and machine motion that can produce the required lay on the actual geometry. Straight-line belts and wheels can support a linear grain; rotary discs naturally create arcs unless the process and subsequent steps remove them; hand pads can follow small or complex areas but depend strongly on operator control; fixed machines and automation can improve repeatability when their path, force and abrasive condition are controlled.

Stainless finishing commonly separates weld levelling, grain setting and final finishing. Straight-line tools can restore directional finishes, while rotary discs create a different motion signature. Match machine motion to the required surface pattern and do not transfer product-specific settings between systems. [S122; S128]

Required outcome or geometry	Practical process direction	Control emphasis	Avoid
Long straight grain on flat sheet	Straight-line belt, wheel or guided linear hand process	Fixed datum, stable support, consistent path and wear state	Using a rotary arc as the final visible lay
Circumferential grain on tube	Tube-finishing belt or controlled wrap-around process	Even contact around the circumference and consistent axial position	Pausing at one quadrant or twisting the line
Axial grain on tube or profile	Linear belt, wheel or guided hand stroke along the axis	Support, straight entry and continuous exit	Helical drift or repeated short patches
Small repair in an existing finish	Compatible hand-held or small-machine route within a planned blend zone	Match the original direction, scratch character and sheen	Polishing only the defect into a bright island
Repeated production panels	Fixed-machine or automated route where practical	Controlled path, contact, feed, product condition and inspection	Assuming automation compensates for worn abrasives or variable parts
Complex formed feature	Conformable product with stable manual or programmed support	Protect edges and follow the declared local datum	Allowing the product to wrap uncontrolled over corners

4. Control entry, contact and exit

Start and stop marks occur when the abrasive contacts the visible zone without stable motion, dwells while cutting, pivots during a stroke or leaves the surface abruptly.

Use a deliberate sequence:

420. align the tool, belt or workpiece with the intended lay;
421. establish stable movement and support before full cutting contact where the equipment permits;
422. enter through a planned lead-in or non-critical zone;
423. maintain the intended contact footprint through the visible area;
424. avoid stopping, reversing or pivoting while the abrasive is cutting;
425. feather the pressure or contact gradually near the exit; and
426. leave through a planned run-out zone without hooking the path.

Where the part has no sacrificial lead-in or run-out, reduce the visible effect by using controlled feathering, masking or a process specifically suited to the geometry. Do not create a dimensional step merely to hide a cosmetic mark.

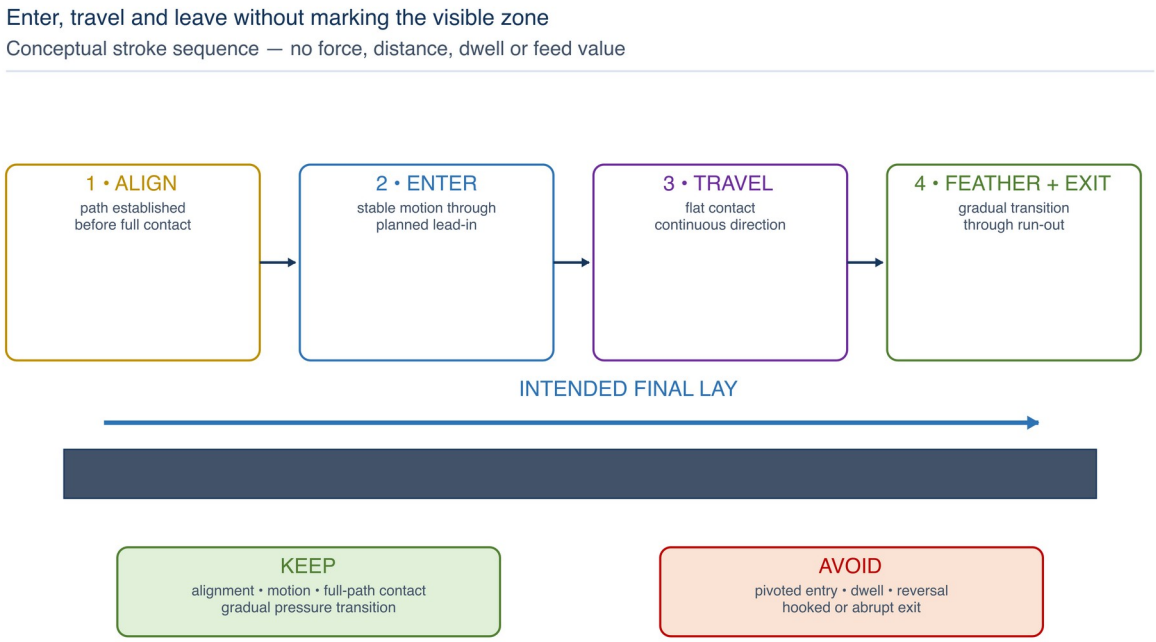

Figure 2. Entry, stroke and exit sequence. Stable alignment, full-path motion and gradual feathering reduce hooks, dwell marks and abrupt transitions.

5. Use overlap to build one continuous surface

Adjacent passes should read as one finish rather than separate stripes. Too little effective overlap can leave unworked bands or alternating sheen. Excessive repeated overlap can over-brighten a strip, change texture, generate heat or remove more material than intended.

Control overlap through visible reference points, guides, fixture position, programmed path spacing or other repeatable means appropriate to the job. The correct amount is not a universal percentage: it depends on the effective contact width, abrasive construction, wear state, support, geometry and required appearance.

Practical controls include:

- keep each pass parallel to the declared datum;
- maintain a consistent contact width and tool attitude;
- step across the surface in one planned sequence;
- avoid returning repeatedly to an isolated dull or bright stripe;
- inspect the whole panel under diffuse and low-angle light; and
- correct the process before adding more passes when banding persists.

6. Keep the grain straight and continuous

Line straightness is affected by the operator’s body position, tool balance, hose or cable drag, fixture alignment, workpiece movement, belt tracking, contact-wheel condition and the shape of the visible zone.

Use the longest practical reference for the job. A guide edge, fixture datum, machine axis, marked non-finish area or accepted reference panel can help operators recognise drift before it becomes a visible curve.

Watch for these pattern signatures:

- **hook:** the path curves at entry or exit;
- **arc:** a rotary tool leaves a visible circular segment;
- **wander:** successive lines drift away from the datum;
- **cross-line:** a corrective pass cuts across the intended final lay;
- **banding:** neighbouring passes have different sheen or scratch density;
- **stop mark:** a local bright, dark or coarse patch shows dwell; and
- **grain break:** direction or spacing changes at a weld, joint or panel boundary.

7. Balance speed, pressure, feed and contact support

Tool speed, travel speed, pressure and contact area work as a system. Changing one can alter cut rate, scratch depth, heat, sheen and abrasive wear. A faster tool is not automatically a finer finish, and additional pressure is not a reliable correction for loading, glazing, poor support or a worn product.

Use these qualitative controls:

- maintain the machine within the abrasive and accessory limits;
- use the product in the pressure range for which its construction is intended;
- keep travel smooth enough to avoid dwell and stable enough to maintain the lay;
- support the abrasive so the contact footprint matches the geometry;
- replace or condition products whose wear state changes the delivered finish;
- stop and investigate chatter, smearing, heat, bounce, streaking or tool stall; and
- confirm a setting change on a representative surface before applying it to the acceptance face.

Manufacturer troubleshooting guidance links heat, chatter, bounce, smearing and streaking to interacting speed, pressure, support and abrasive-condition variables. Exact corrective settings remain product-, machine- and material-specific. [S122]

8. Hand-held, fixed-machine and automated finishing

The best route depends on geometry, production volume, finish tolerance, access and the ability to control the complete process.

Route	Strengths	Main variability	Practical control
Hand-held finishing	Flexible access, local repair, low setup burden and adaptability to complex features	Operator path, attitude, pressure, dwell, fatigue and consumable condition	Guides, stable stance, supported work, declared stroke sequence, training and frequent visual comparison
Fixed or guided machine	Repeatable machine axis, support and feed for suitable part families	Setup alignment, belt tracking, contact-wheel condition, fixture variation and abrasive wear	Verified setup, controlled work support, repeatable feed, planned abrasive-change point and reference-panel checks
Automated or robotic finishing	Repeatable path and the potential for controlled force and production traceability	Part variation, programming, compliance, sensor condition, tool wear and cell maintenance	Qualified path and force strategy, part location control, wear compensation, guarded cell and scheduled inspection

Compliant robotic sanding can apply controlled force and support consistent surface results. Automation does not eliminate process engineering: workpiece location, path, compliance, abrasive wear, dust control and inspection still govern the delivered finish. [S127]

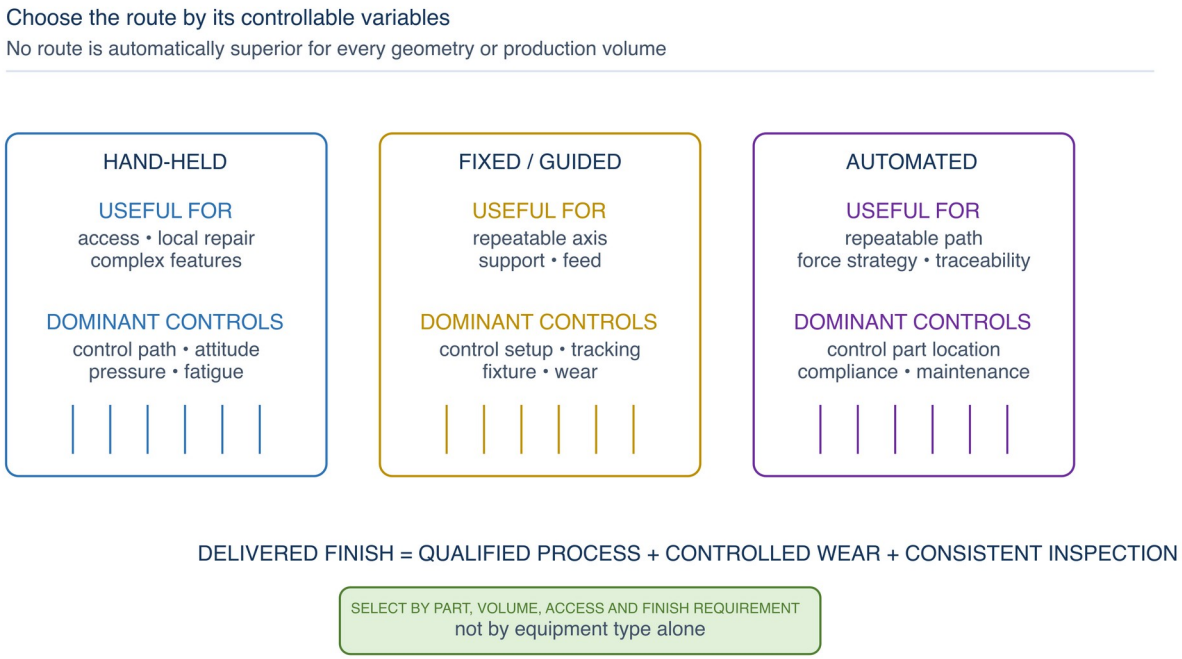

Figure 3. Hand-held and machine control comparison. Each route can produce useful finishes when its dominant sources of variation are controlled.

9. Curves, tubes and formed features

Directional finishing on curved work requires a local datum that remains understandable around the geometry. Decide whether the required lay is axial, circumferential or follows another feature before selecting the tool path.

Flexible products may conform well but can wrap over an edge, thin a corner or widen the contact area. Rigid support can improve line definition but may bridge low areas or create local flats. Match conformability and support to the shape, then inspect transitions, radii, wall thickness and edge condition.

On tubes, keep the work securely supported and control the in-running nip area created by belts or wheels. Do not allow clothing, gloves, hair, hoses or cables to enter the rotating or belt path.

10. Blend repairs into the surrounding finish

A local repair must reproduce the surrounding process character, not simply make the defect disappear. First remove the defect through an appropriate refinement sequence, then restore the final lay over a planned blend zone.

For directional stainless finishes, BSSA guidance recommends aligning and blending the new scratch pattern with the original and checking the resulting appearance. Work along the grain, use the finest suitable corrective stage, and avoid contaminating stainless work with tools previously used on carbon steel. [S125–S126]

Use this repair logic:

427. define the defect, original lay and permitted blend boundary;
428. protect unaffected faces and geometry;
429. refine the defect without creating a hollow or bright island;
430. widen the transition gradually rather than chasing a tiny spot;
431. re-establish the final grain from the declared datum;
432. clean away residue and inspect from several directions; and
433. compare the repaired area with the accepted reference and surrounding panel.

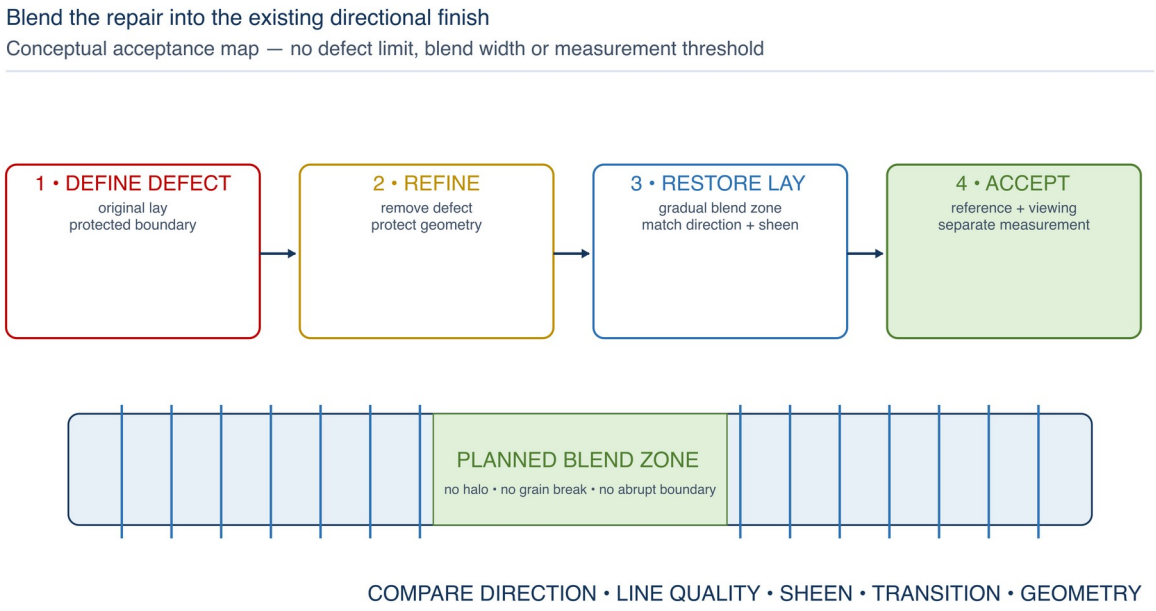

Figure 4. Repair blending and acceptance map. A repair progresses from defect removal through a gradual blend zone to controlled comparison with the surrounding directional finish.

11. Visual acceptance of directional finishes

Inspect the clean, dry surface under repeatable conditions unless the specification states otherwise. Use broad diffuse light for overall uniformity, low-angle light for hooks, grooves and waviness, and normal-use viewing for the customer-facing appearance.

Compare the workpiece and accepted reference under the same:

- light type and direction;
- viewing angle and distance;
- part orientation;
- cleanliness and dryness;
- protective-film condition, where relevant; and
- visible-area boundary.

Assess lay direction, line straightness, spacing, sheen, colour, transitions, local defects, edge condition and consistency across adjoining components. Photographs can support traceability but do not automatically replace a physical reference panel where appearance is critical. Any specified roughness, gloss, coating-readiness or functional measurement remains a separate acceptance check. [S105; S108; S117; S119–S120]

12. Troubleshooting directional-finish defects

Symptom	Likely process cause	Practical correction
Grain wanders or curves	Weak datum, tool drift, hose drag, workpiece movement or belt-tracking error	Re-establish the datum, support the work, remove external drag and verify machine alignment
Hooks at the ends of strokes	Tool pivots during entry or exit; contact begins or ends abruptly	Use a planned lead-in and run-out, keep the path aligned and feather contact gradually
Bright or dark overlap bands	Pass spacing, contact width, wear state or pressure varies	Standardise the path step, contact attitude and product condition; reblend the full controlled zone
Rotary arcs remain in a linear finish	Disc pattern was not removed before the final lay	Return to the last effective refinement stage and restore the directional grain with a suitable linear process

Symptom	Likely process cause	Practical correction
Repair halo or bright island	Blend zone is too small or the local process differs from the surrounding finish	Widen the transition gradually and match product construction, support, wear state and final direction
Finish changes at a weld or joint	Grain datum, support or process sequence changes across the transition	Plan one continuous final-lay sequence and inspect the joint under low-angle light
Streaks appear as the abrasive wears	Loading, damage, uneven wear, contamination or changed contact footprint	Stop, clean and inspect the interface; replace or condition the product as instructed
Surface smears or overheats	Excessive dwell or pressure, unsuitable speed, loaded abrasive or poor extraction	Restore effective cutting, reduce dwell and review the complete product-machine-material setup
Panels differ from each other	Starting surface, setup, path, consumable condition or viewing conditions vary	Standardise the full process and compare each panel with the same accepted reference

13. Concise safety reminders

- Use only abrasive products and accessories intended for the material, machine, mounting and finishing task.
- Confirm compatibility between the abrasive dimensions and speed rating, accessory, machine and guarding arrangement.
- Secure the workpiece and maintain stable support, stance and line of fire.
- Keep guards, handles, extraction, interlocks and other protective systems in place as required.
- Control sparks, hot particles, combustible materials and metal dust through the workplace risk assessment.
- Wear eye and face, hearing, respiratory, hand, body and foot protection selected for the task.
- Stop for abnormal vibration, chatter, belt-tracking error, damaged backing, torn belts, heat, smearing, tool stall or unstable support.
- Keep hands, clothing, hair and cables away from abrasive contact, rotating parts and in-running nip points.
- Isolate energy before changing, cleaning, adjusting or inspecting abrasive products and machine components.

Refer to the product label, Technical Data Sheet, or MKTECH representative.

14. Application sequence

434. Define the finish attributes, controlled zone, datum and accepted reference.
435. Select a machine motion and abrasive form capable of producing the required lay.
436. Protect edges, features and adjacent finished faces.
437. Establish the planned entry, full-contact path, overlap sequence and exit.
438. Confirm stable work support, tool condition, guarding and extraction.
439. Set the process within the product and machine instructions.
440. Make a representative pass and inspect direction, scratch character and sheen.
441. Complete the surface in one planned progression without isolated reworking.
442. Clean the surface and inspect under diffuse, low-angle and normal-use viewing.
443. Blend transitions and repairs gradually while preserving geometry.
444. Compare with the accepted reference and complete any specified measurement.
445. Release the finish only when the pattern, transitions, appearance, geometry and functional checks pass.

SURFACE FINISHING & POLISHING

CHAPTER 026

Non-Woven Surface Conditioning

26

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: Practical selection and use of non-woven abrasive products for cleaning, blending, light oxide removal, satin finishing and surface preparation on industrial metalwork.

Core principle — A non-woven abrasive is a finishing system, not merely a colour or a “grit.” Its behaviour comes from the web, abrasive mineral, grade, density, bond, product form, backing, contact support and operating method working together.

Chapter objectives

After this chapter, the reader should be able to:

- identify the main elements of non-woven abrasive construction;
- distinguish abrasive grade from web or wheel density;
- select conformability and support for the workpiece geometry;
- choose an appropriate product family for cleaning, blending, oxide removal, satin finishing or coating preparation;
- recognise loading, smearing, glazing, over-finishing and geometry loss;
- control a repeatable hand-held or machine-finishing sequence; and
- apply concise safety and compatibility checks before use.

1. How non-woven abrasives work

Non-woven abrasive products commonly use a three-dimensional network of synthetic fibres carrying abrasive mineral in a resin system. The spaces in the web allow removed material to escape, while the resilient fibres follow surface features and expose new abrasive as the product wears. The result can be a controlled combination of cut, blending and surface conformity. [S060; S129–S132]

The construction varies widely. A flexible hand pad, a scrim-backed surface-conditioning disc, a flap wheel, a dense unitized wheel and a coarse clean-and-strip product may all be described as non-woven, yet they differ greatly in aggressiveness, support, edge behaviour and intended machine.

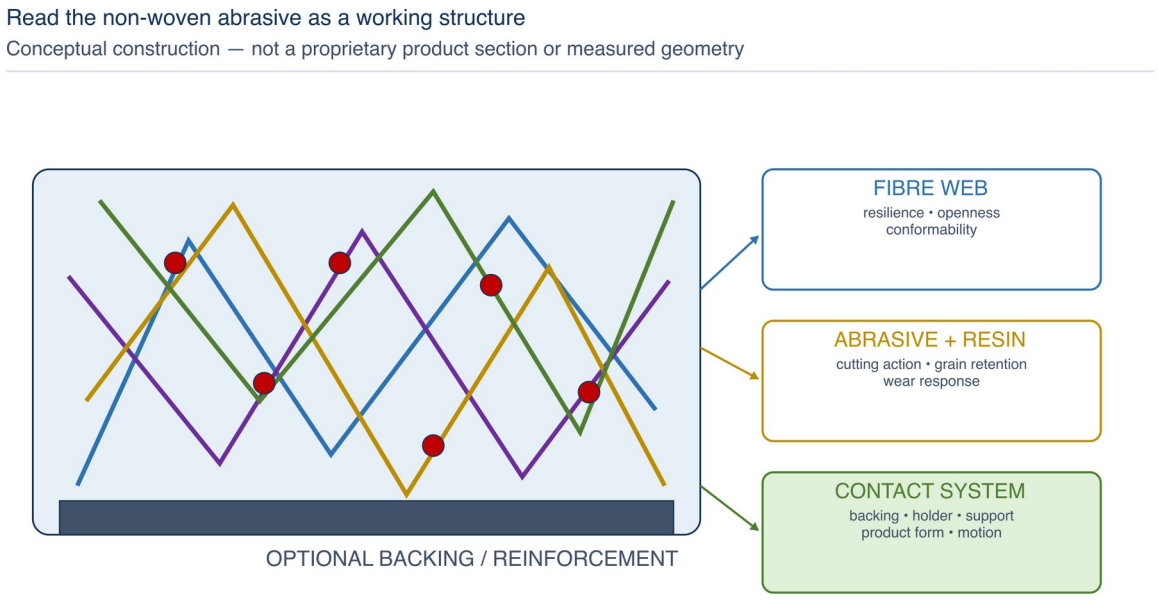

Figure 1. Non-woven construction and contact. Fibres, resin and abrasive form an open three-dimensional working structure; backing and contact support modify how it reaches the surface.

2. Read the complete construction

Treat the product marking and technical information as a system:

Construction element	What it influences	Practical selection question
Fibre and web structure	Openness, resilience, conformability, debris clearance and wear behaviour	Must the product follow a contour, reach a recess or hold a defined face?
Abrasive mineral	Cutting character, fracture behaviour and finish response	Is the mineral suitable for the substrate and required finish?
Abrasive grade	Relative cutting and finishing level within that product family	Is the task cleaning, blending, refinement or final satin finishing?
Density or compression	Support, durability, edge retention, cut and conformity	Does the job need a soft following action or a firmer, more defined contact?
Resin and treatment	Grain retention, resilience and wet/dry suitability	Is the product intended for the chosen coolant, cleaner or dry process?
Backing or reinforcement	Strength, stretch, attachment and contact control	Does the backing match the machine, holder and geometry?
Product form	Access, contact footprint, edge action and permissible mounting	Is a pad, roll, disc, belt, flap wheel, unitized wheel or stripping product appropriate?

A familiar colour is not a reliable universal specification. Colours, grade names, density numbers and shorthand codes can differ between manufacturers and product families. Likewise, a non-woven grade should not be assumed to equal a coated-abrasive P-grade or a bonded-wheel grit. Use the actual product designation and its technical information when matching a process.

3. Grade and density are separate controls

Abrasive grade describes the relative cutting or finishing level within a defined product range. **Density** describes how compact, supported or firm the non-woven structure is. They interact, but they are not interchangeable.

As a general selection tendency:

- a more open or softer construction usually follows contours more readily and produces a broader, more forgiving contact;
- a firmer or denser construction usually holds shape and edges more strongly and can deliver a more defined action;
- a coarser grade generally cuts or blends more aggressively within the same family; and
- a finer grade generally refines the scratch and appearance within the same family.

These are tendencies, not cross-brand conversions. Mineral, fibre size, resin, compression, backing, speed, pressure and wear state can change the result. [S129–S132]

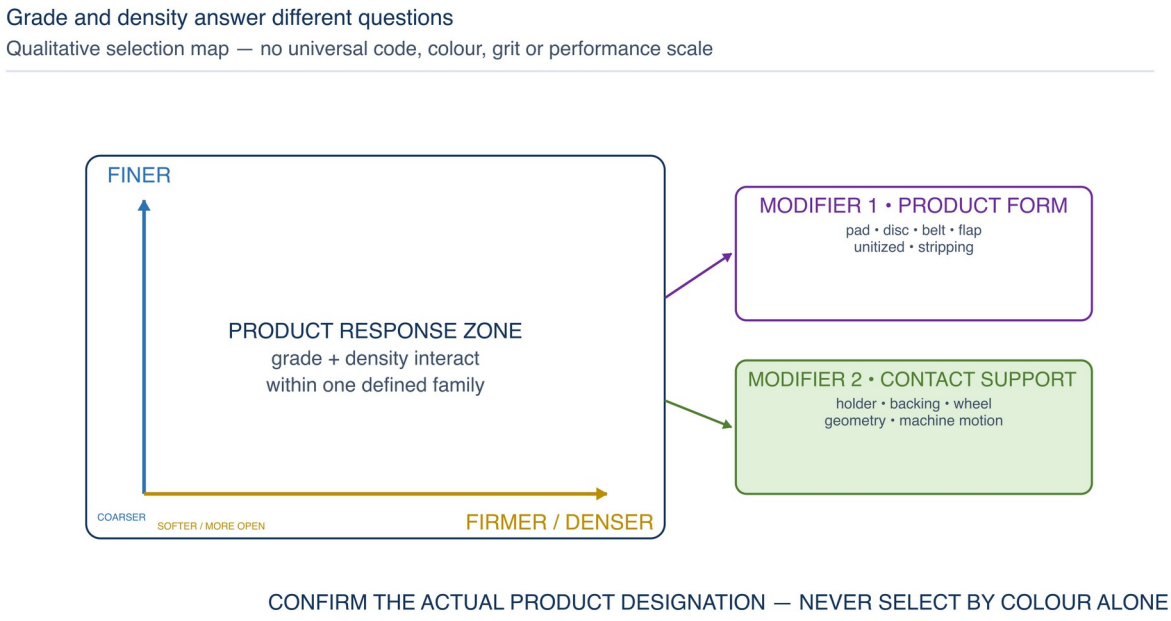

Figure 2. Grade, density and conformability control map. Grade and density are independent selection axes; product form and support determine how their behaviour reaches the workpiece.

Need	Starting selection tendency	Check on the workpiece	Typical error to avoid
Follow a radius or irregular profile	More conformable construction with suitable support	Contact reaches the intended zone without thinning edges	Choosing a firm product that bridges low areas
Hold a straight edge or narrow face	Firmer, shape-holding construction	Edge remains controlled without digging or rounding	Using an unsupported soft web over a critical edge
Remove light oxidation or blend a transition	Grade and family with sufficient cut but controlled base-metal action	Contaminant is removed without deep isolated scratches	Increasing pressure on a product that is too fine or loaded
Produce a uniform satin appearance	Finishing grade and motion matched to the required lay	Direction, sheen and line character match the reference	Selecting by colour alone
Prepare for a subsequent coating or bonding step	Product specifically suitable for the substrate and preparation objective	Surface is clean, dry and meets the separately specified profile or condition	Treating visual dullness as proof of readiness

4. Select the correct non-woven product family

Non-woven families are not interchangeable merely because they share a fibre-web construction.

Product family	Typical strengths	Main controls	Do not assume
Hand pad or roll	Manual cleaning, scuffing, light blending and access to complex forms	Hand support, stroke direction, cleanliness and even coverage	The colour defines one universal grade
Surface-conditioning disc or belt	Controlled blending, deburring, finishing and surface preparation	Backing, attachment, contact support, machine motion and wear	Every disc or belt has the same reinforcement or permissible duty
Flap or interleaf wheel	Contour following, tube/profile finishing and blending	Flap construction, exposure, rotation direction and access	It behaves like either all-coated or all-non-woven material
Unitized or convolute wheel	Shape-holding finishing, light deburring, edge work and controlled contact	Density, wheel construction, dressing, guarding and machine compatibility	It is a flexible hand pad in wheel form

Product family	Typical strengths	Main controls	Do not assume
Open stripping or clean-and-strip product	Removal of rust, paint, sealant or adherent contamination where the product is intended for it	Substrate protection, debris, heat, edge action and dust control	A general finishing web can perform heavy stripping, or that all stripping products preserve every substrate

Non-woven abrasive families include open stripping products, surface-preparation products and denser wheel constructions. Surface-conditioning products may also be supplied as pads, discs, belts and other forms with different support and use cases. Select the intended product family first, then the required grade and density within that family. [S060; S129–S132]

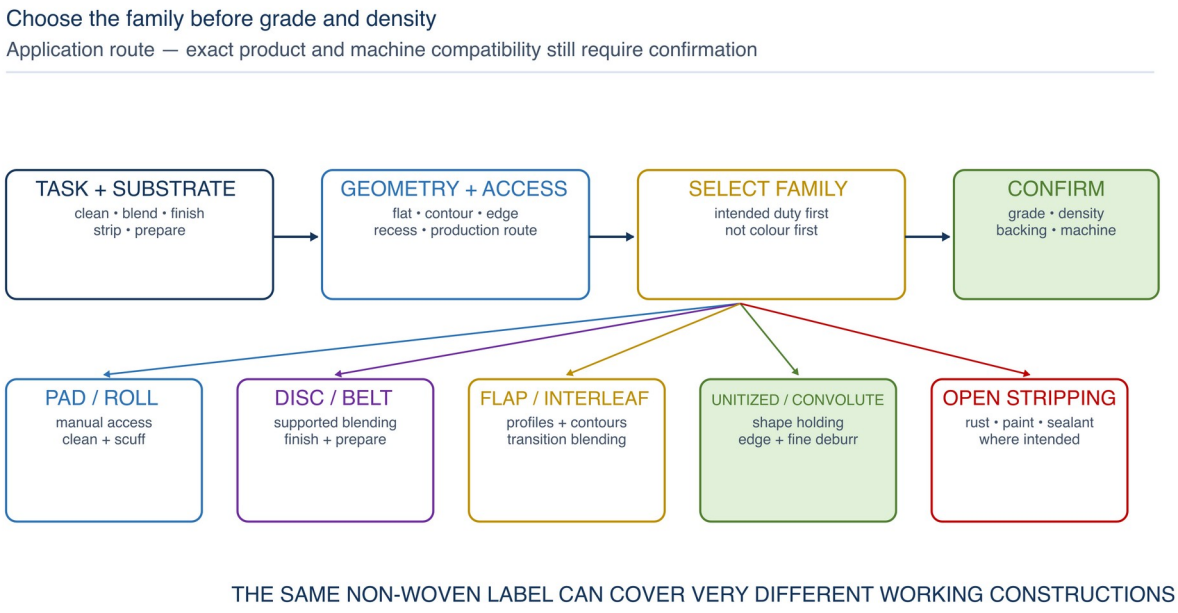

Figure 3. Non-woven product-family route map. The application objective and geometry lead to a suitable family; the exact grade, density, backing and machine are then confirmed from the product information.

5. Conformability must preserve geometry

Conformability helps the abrasive follow radii, moulded features, weld transitions and irregular surfaces. It can also widen the contact footprint, wrap over an edge or reach an adjacent face. A highly conformable product is therefore not automatically safest for every geometry.

Use a contact method that supports the intended surface:

- use a suitable holder or backing pad where the product requires one;
- keep the contact footprint on the controlled zone;
- approach edges and corners deliberately rather than allowing the web to wrap uncontrolled;
- use lighter, progressive contact around thin sheet and heat-sensitive areas;
- inspect dimensional and edge-critical features separately from visual finish; and
- stop when the product no longer holds the required shape or contact pattern.

6. Cleaning is not the same as abrasive finishing

Non-woven products can remove loose contamination, light deposits and surface films when the selected family is intended for that task. Abrasive action does not replace appropriate degreasing or chemical cleaning. Oils, salts, polishing compounds, adhesive residue and process chemicals may be spread, embedded or concealed if the surface is simply abraded.

Use a controlled sequence:

446. identify the contaminant and substrate;
447. remove gross soil using a compatible cleaning method;

448. use a clean, dedicated abrasive where contamination transfer matters;
449. abrade in the required direction with even coverage;
450. remove residue using the specified cleaning method; and
451. inspect the clean, dry surface before the next operation.

For stainless steel, avoid tools that have been used on carbon steel and work with the existing grain where appearance matters. BSSA guidance supports dedicated cleaning tools and alignment with the surface grain. [S125–S126]

7. Blending welds, scratches and surface transitions

Surface conditioning is effective when the heavy defect or weld profile has already been reduced to a level the selected web can refine. A finishing web should not be forced to perform stock removal beyond its intended duty.

For a controlled blend:

452. define the remaining defect, required geometry and final lay;
453. remove deep damage through an appropriate preceding abrasive stage;
454. select a non-woven family with enough cut to remove the previous scratch pattern;
455. blend over a planned transition rather than polishing one small spot;
456. keep direction, overlap, pressure and abrasive wear consistent;
457. clean and inspect under broad and low-angle light; and
458. finish to the accepted visual reference or specified functional condition.

If the previous scratch remains visible, adding pressure or dwell can burnish the surrounding peaks without removing the deeper line. Return to the last stage capable of removing the defect efficiently.

8. Oxide, rust and scale removal

Match the product family to the oxide and substrate. Light surface oxidation may respond to a surface-conditioning product; heavier rust, scale, heat oxide, paint or sealant may require a purpose-designed open stripping product or another approved method. Do not confuse an open finishing web with an aggressive stripping construction.

Control oxide removal by:

- identifying whether the layer is loose, adherent, local or widespread;
- checking the base metal, coating, plating, edge and dimensional sensitivity;
- using the least aggressive effective route;
- keeping the tool moving to limit local heat and grooving;
- inspecting for residual oxide in pits, corners and weld features;
- removing abrasive and contaminant residue; and
- completing any required stainless-steel cleaning, pickling, passivation or coating-preparation step separately.

Mechanical removal can change appearance without proving that a corrosion-sensitive surface is chemically clean or fully restored. The subsequent specification controls any chemical treatment and acceptance requirement. [S001; S125]

9. Producing a satin finish

A satin finish depends on the combined scratch character, lay, sheen and uniformity. It cannot be specified reliably by pad colour or non-woven grade alone.

Establish:

- the intended direction of lay;
- an approved reference or clearly stated appearance;
- the starting surface and preceding scratch stage;
- the product family, grade, density, backing and wear condition;
- the machine or hand motion and contact support;
- the pass sequence and transition boundary; and
- the inspection lighting and viewing conditions.

Complete the visible face in one planned progression. Avoid isolated reworking, repeated dwell or mixing new and heavily worn products across one panel. Where adjacent parts must match, prepare them with the same controlled process and compare them in their assembled orientation. Chapter 025 gives detailed guidance on directional and brushed finishes.

10. Surface preparation for painting, coating or bonding

Non-woven abrasion can help clean, scuff or refine a surface, but visual dullness alone does not prove coating readiness. Coating and bonding systems may separately require removal of oil, salts, corrosion products, weak existing coatings, dust and moisture, together with a specified surface profile or chemical treatment.

Before releasing a prepared surface, confirm:

- substrate and existing coating compatibility;
- the preparation method required by the coating or adhesive supplier;
- cleanliness after abrasive work;
- complete removal of loose or weakly bonded material;
- profile or texture where it is specified;
- absence of embedded residue or cross-contamination;
- permitted time between preparation and application; and
- environmental conditions required by the next process.

Chapter 027 addresses coating-preparation requirements in detail. The non-woven selection must remain subordinate to the coating, adhesive or customer specification.

11. Loading resistance is a process advantage, not immunity

The open web provides spaces through which swarf and debris can escape, so many non-woven products resist loading better than a closed abrasive surface in comparable finishing work. Loading can still occur when the contaminant is soft or adhesive, the product is too fine or too dense for the task, pressure and heat are excessive, extraction is poor, or the web becomes packed with residue. [S060; S129–S132]

Signs include streaking, smearing, increasing heat, reduced cut, a changed contact sound, deposits on the workpiece and a glazed or packed web. Stop and inspect rather than compensating with more pressure.

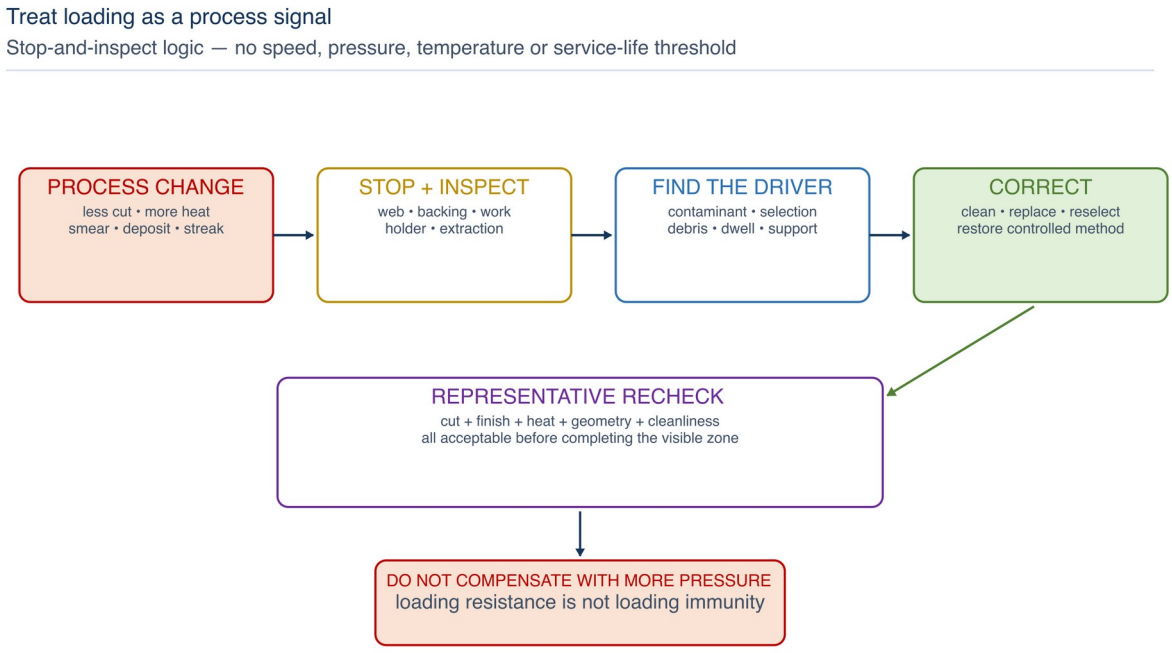

Figure 4. Loading and corrective-action flow. A change in cut, heat or finish triggers inspection of contamination, web condition, selection and operating method before work resumes.

12. Hand, machine, wet and dry use

Use each product only in the form and mode for which it is designed. A hand pad is not automatically suitable for mounting on a power tool. A machine disc or wheel requires the specified attachment, support, guarding and compatible machine. Products described as washable or wet-capable must still be compatible with the chosen liquid, substrate, machine and workplace controls.

For machine use:

- confirm product dimensions, attachment and direction of rotation;
- use the required backing pad, arbor, flange or holder;
- keep the machine and product within all marked limits;
- inspect the web, backing and attachment before use;
- secure the work and control the line of fire;
- provide extraction or wet collection appropriate to the generated residue; and
- isolate the machine before changing, cleaning or adjusting the abrasive.

Refer to the product label, Technical Data Sheet, or MKTECH representative.

13. Troubleshooting non-woven surface conditioning

Symptom	Likely process cause	Practical correction
Product loads or smears	Oil, adhesive or soft coating remains; web is too fine or closed; pressure or heat is excessive	Clean appropriately, review the product family and grade, restore debris clearance and reduce dwell
Cut falls rapidly	Web is loaded, glazed, damaged or unsuitable; contact is too light or poorly supported	Inspect the interface, replace the product if required and confirm grade, density and support
Surface becomes too bright or polished	Grade is too fine, dwell is excessive or repeated overlap burnishes the same zone	Return to the required finishing stage and use a planned full-surface sequence
Finish is too coarse	Product family or grade is too aggressive; previous scratches remain; contamination creates random lines	Verify the construction, refine progressively and clean the work and abrasive interface
Patchy satin appearance	Uneven pressure, overlap, direction, backing support or wear state	Standardise the pass sequence, contact footprint and product-change point
Edges round or dimensions change	Product wraps over an edge, contact is too concentrated or finishing continues too long	Protect critical edges, change support or density and inspect geometry during the process
Oxide remains in pits or corners	Contact cannot reach the feature or the selected family lacks effective action	Change access, form or preceding removal method without overworking adjacent metal
Deep isolated scratches appear	Trapped swarf, contamination, damaged web, exposed backing or debris on the surface	Stop, clean and inspect the product, holder and work area before reworking
Surface heats or discolours	Dwell, pressure, loading, poor cutting or unsuitable operating conditions	Stop, inspect the complete setup, restore effective cutting and reduce local heat input
Coating adhesion concern remains	Surface looks uniform but cleanliness, profile, residue or environmental condition is uncontrolled	Re-clean, measure or verify against the coating or bonding specification before application

14. Concise safety reminders

- Use only products intended for the material, application, machine and mounting system.
- Inspect the web, backing, attachment, wheel or belt before use; discard damaged products.
- Keep guards, handles, extraction, interlocks and required machine controls in place.
- Secure the workpiece and maintain stable support, stance and line of fire.
- Control sparks, hot particles, combustible dust, metal dust and contaminated residue through the workplace risk assessment.
- Wear eye and face, hearing, respiratory, hand, body and foot protection selected for the task.
- Keep hands, clothing, hair, cables and hoses clear of abrasive contact and in-running nip points.
- Stop for abnormal vibration, tearing, tracking error, tool stall, heavy loading, smearing, heat or unstable contact.
- Isolate energy before changing, cleaning, dressing, adjusting or inspecting machine-mounted products.
- Consult the label and applicable product information, including VPI or SDS where supplied, and follow Malaysian workplace requirements. [S032; S133]

15. Application sequence

459. Define the substrate, contaminant or defect, geometry and required final condition.
460. Select the intended non-woven product family before choosing grade or density.

461. Confirm mineral, grade, density, backing, attachment and wet/dry suitability from the product information.
462. Clean gross oil, dirt or incompatible residue using an appropriate method.
463. Protect critical edges, dimensions, adjacent faces and completed finishes.
464. Confirm machine compatibility, guarding, work support, extraction and PPE.
465. Establish the required direction, contact footprint and pass sequence.
466. Make a representative pass and inspect cut, finish, heat, loading and geometry.
467. Complete the work with consistent motion, coverage, pressure and abrasive condition.
468. Stop and correct any loading, smearing, streaking, deep line, heat or edge change.
469. Remove residue and inspect the clean, dry surface under suitable lighting.
470. Confirm the appearance and any separately specified cleanliness, profile, dimensional or coating-readiness requirement.

SURFACE FINISHING & POLISHING

CHAPTER 027

Surface Preparation for Painting and Coating

27

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, coating applicators, safety personnel, procurement staff and technical sales personnel

Scope: Practical surface preparation for industrial painting and coating on new work, maintenance work and repaired areas, with particular attention to Malaysian heat, humidity, condensation and contamination risks.

Core principle — A surface is ready for coating only when its substrate condition, cleanliness, profile, dryness and environmental condition all meet the selected coating system and project requirement.

This chapter is an educational and application-selection guide. It explains how the preparation controls fit together so that an appropriate abrasive product, cleaning route and inspection method can be selected for the work.

Chapter objectives

After this chapter, the reader should be able to:

- define coating preparation as more than rust removal;
- identify oil, grease, corrosion, oxide, dust, moisture and soluble contamination;
- choose between hand-tool, power-tool, abrasive-blast, waterjet and controlled scuffing routes;
- distinguish visible cleanliness from surface profile;
- protect galvanized, aluminium, stainless-steel and previously coated substrates;
- manage condensation, flash rust and time-to-coat;
- complete a practical final inspection; and
- troubleshoot common preparation and early coating problems.

1. Coating life begins at the substrate

Paint can bridge colour differences, but it cannot reliably correct a weak, oily, dusty, damp or unstable surface beneath it. Preparation must therefore create a sound interface for the complete coating system. The required result depends on the substrate, existing coating, corrosion condition, service exposure, coating chemistry, application method and project specification. [S113; S139]

Surface readiness has five linked controls:

471. **sound substrate** — defects, sharp features and weak material are treated as required;
472. **cleanliness** — oil, grease, dirt, corrosion products, weak coating and residues are removed;
473. **profile** — the texture is suitable for the selected coating system;
474. **dryness and environment** — condensation and recontamination are controlled; and
475. **inspection and timing** — the accepted surface is coated within the permitted condition and interval.

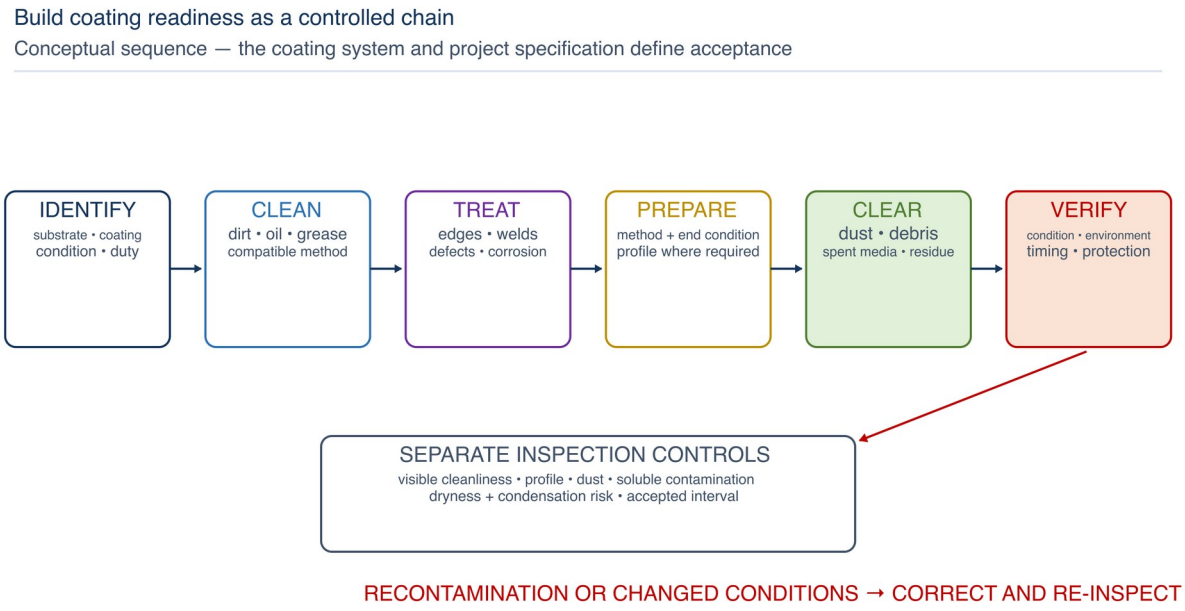

Figure 1. Coating-readiness control chain. Each stage protects the next; a visually bright surface is not automatically a coating-ready surface.

2. Define the complete preparation requirement

Before selecting an abrasive or machine, establish what the coating system requires. A preparation grade identifies a defined condition, not a complete product recommendation. Different steel surfaces and existing finishes can require different preparation routes, and non-carbon-steel substrates need their own controls. [S111; S136; S139]

Preparation input	Why it matters	Practical question
Substrate	Steel, galvanized steel, aluminium, stainless steel and previously coated surfaces respond differently	What material and surface treatment are actually present?
Existing condition	Mill scale, rust, oxide, old coating, repair edges and fabrication defects require different work	What must be removed, retained or repaired?
Coating system	Primer chemistry and total system determine acceptable cleanliness, texture and substrate condition	What preparation does the coating manufacturer specify?
Service environment	Immersion, chemical exposure, weathering, heat, hygiene or appearance can change the required control	What duty must the completed system withstand?
Inspection standard	Visual grade, profile method, dust test and soluble-salt assessment answer different questions	Which standard, revision and acceptance criterion apply?
Application window	Humidity, condensation, flash rust, dust and delay can change the prepared surface	How will the surface be protected and released for coating?

Where the exact product requirement is needed, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

3. Identify the substrate and existing coating

Begin with the actual surface rather than its apparent colour. Determine whether the work is bare carbon steel, alloy steel, galvanized or zinc-coated steel, aluminium, stainless steel, thermally sprayed metal, shop-primed steel or an existing paint system. ISO 12944-4 recognises that these surface types require distinct preparation considerations. [S139]

On maintenance work, identify the existing coating system and its condition before disturbing it. Old industrial coatings can contain hazardous metals or other substances that become airborne during sanding, grinding, needle-gunning or blasting.

Work planning must cover material identification, containment, extraction, waste handling, hygiene and suitable personal protective equipment. [S026; S145; S146]

Inspect edges, welds, spatter, laminations, pits, burrs and surface imperfections. Coating tends to pull thin over sharp features and can leave inaccessible contamination around weld details. ISO 8501-3 provides preparation grades for visible weld, edge and other steel-surface imperfections before coating. [S136]

4. Clean and degrease before mechanical preparation

Oil and grease can be driven into the surface, spread across a larger area or transferred to abrasive media if mechanical preparation starts first. The cleaning step should remove visible oil, grease and other specified contaminants without leaving an incompatible residue. AMPP SSPC-SP 1 defines solvent cleaning by its end condition rather than by one universal solvent. [S140]

Use this practical sequence:

476. remove loose dirt and gross deposits;
477. select a cleaner compatible with the substrate, existing coating and next process;
478. lift contamination away with clean materials rather than redistributing it;
479. rinse or remove cleaner residue where the method requires it;
480. allow the surface to dry; and
481. re-inspect before abrasive or mechanical work begins.

Replace contaminated wipes, brushes, pads and cleaning solution before they become transfer sources. Keep clean and dirty materials separate. Compressed air used for cleaning or blasting must not introduce oil or moisture. [S147]

5. Treat defects, corrosion and oxide deliberately

Preparation must remove the material specified by the coating system while preserving sound substrate. Loose rust, scale and failed coating are obvious targets, but pits, crevices, weld toes and edges require deliberate access and inspection. A broad clean appearance can hide residual corrosion deep in a pit.

For carbon steel, the specification may call for a visual preparation grade reached by abrasive blasting, hand or power tools, or another defined route. ISO 8501-1 provides written and photographic grades for relevant steel surfaces, while ISO 8504-3 describes hand- and power-tool cleaning methods. [S111; S138]

For stainless steel, aluminium and galvanized surfaces, avoid applying carbon-steel assumptions. Use dedicated, compatible tools and abrasives where contamination matters. Protect intact zinc and thin metal coatings from unnecessary removal. Brush-off blasting for non-ferrous metals, galvanized steel and stainless steel has distinct substrate considerations. [S021; S125; S144]

6. Select the preparation method by required outcome

Choose the method capable of achieving the specified cleanliness and profile without unacceptable substrate damage, contamination or environmental risk.

Method	Best suited to	Principal strengths	Main limitations and checks
Hand-tool cleaning	Local maintenance, light loose material and restricted access	Simple access and controlled local work	Limited production rate and ability to remove tightly adherent material; inspect crevices and pits
Power-tool cleaning	Local or general maintenance where blasting is impractical	Greater removal rate; varied brushes, discs and specialised tools	Can polish, smear, groove or leave an unsuitable profile if the tool and method are mismatched
Abrasive blast cleaning	Broad steel areas requiring defined cleanliness and profile	Removes corrosion and coating while generating a controllable blast profile	Requires compatible media, clean dry air, containment, dust control and profile verification
Waterjet cleaning	Coating and corrosion removal where waterjetting is specified	Can remove coatings and contamination without an abrasive-blast profile	Existing profile may remain; flash rust, water quality, runoff and coating compatibility require control
Controlled abrasion or scuffing	Sound existing coating, non-ferrous substrate or local preparation where specified	Creates a key, removes gloss and blends repair boundaries	Does not by itself prove removal of oil, salts, dust, moisture or weak underlying material

AMPP publishes distinct cleanliness standards for blast cleaning and waterjet cleaning, confirming that the method and specified end condition must be named together. [S141; S143]

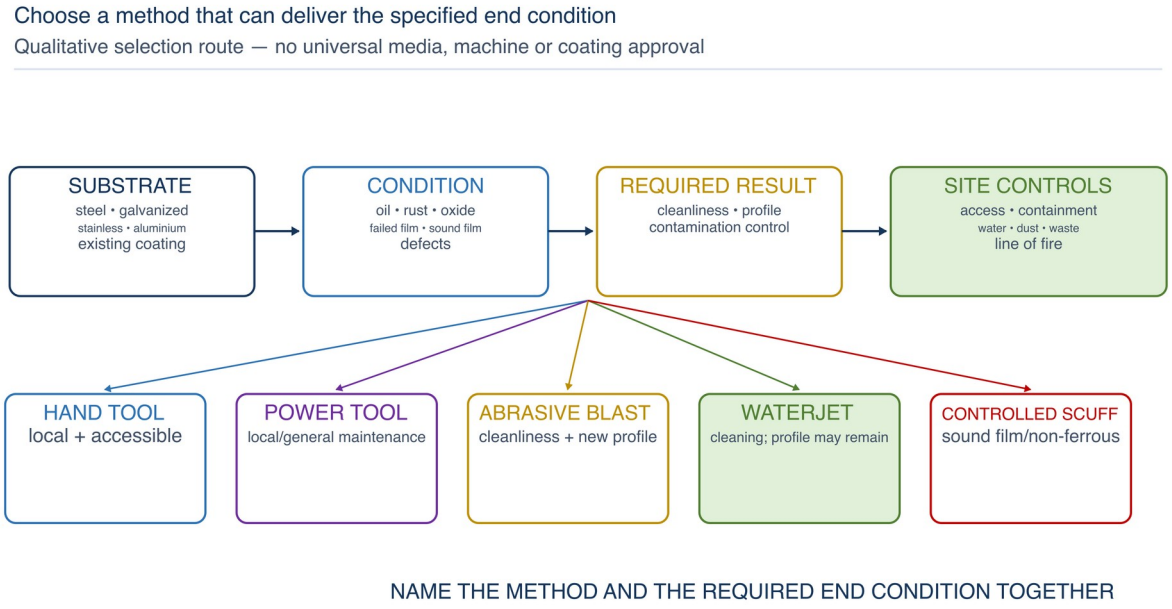

Figure 2. Mechanical preparation method route. Substrate, existing condition, required profile and site controls lead to an appropriate method; the selected coating system remains the governing reference.

7. Visible cleanliness and surface profile are different

Visible cleanliness describes the extent to which visible rust, mill scale, coating and foreign matter have been removed under the stated assessment method. **Surface profile** describes the texture produced on the substrate. One does not prove the other. [S111–S113]

A surface can be visibly clean yet too smooth for the coating, or it can have a pronounced profile while still carrying dust, oil or soluble salts. Likewise, ISO 8501 photographs are not profile comparators, and a roughness value from general machining metrology is not automatically the coating system's required blast-profile result.

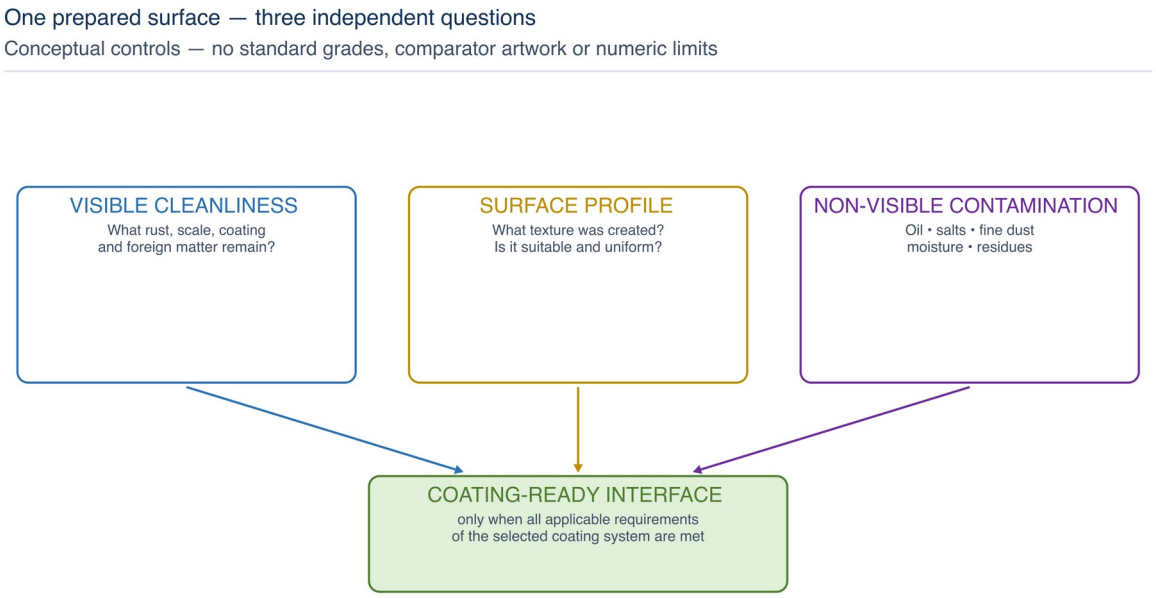

Figure 3. Cleanliness, profile and contamination controls. Coating readiness requires three independent questions to be answered: what remains visible, what texture was created, and what non-visible contamination remains.

8. Control the surface profile

The profile provides a textured interface for the coating, but deeper is not universally better. A profile that is too low may give inadequate mechanical key for the selected system. A profile that is too high may leave peaks insufficiently covered, increase coating demand or create local weak points. The acceptable range belongs to the coating system and project specification.

Profile is influenced by substrate hardness, preparation method, abrasive type and size, impact condition, tool geometry, wear state and technique. Do not attempt to control it by abrasive label alone.

Use the inspection method named in the specification. ISO 8503-1 addresses comparator assessment for abrasive blast-cleaned steel; AMPP SSPC-PA 17 describes procedures for assessing conformance to a specified steel profile range using several recognised measurement approaches. [S112; S142]

Refer to the product label, Technical Data Sheet, or MKTECH representative.

9. Remove dust and preparation debris

Dust can block intimate coating contact, absorb moisture and collect in pits, welds and horizontal ledges. Remove spent abrasive, corrosion residue, loose coating, swarf and cleaning debris after preparation. Work from clean areas toward collection points and prevent settled dust from returning to accepted surfaces.

Visual inspection alone may not reveal the amount or size of fine particulate. ISO 8502-3 describes a pressure-sensitive tape method for assessing dust remaining on cleaned steel surfaces prepared for painting. It provides ratings for dust quantity and descriptive classes for particle size. Use the method and acceptance level specified for the job. [S134]

10. Control soluble salts and other non-visible contamination

Chlorides and other water-soluble salts can remain after a surface looks clean. Under a coating, they can attract moisture and contribute to osmotic blistering, underfilm corrosion or early loss of adhesion. Their importance depends on the substrate, exposure and coating system.

Where the specification requires testing, use the stated extraction, measurement, locations and acceptance criteria. ISO 8502-9 describes field conductometric assessment of the surface density of various water-soluble salts on steel; it does not identify individual salt species. [S135]

Do not treat conductivity, chloride concentration or a single field result as interchangeable measures. Record the method, units, area, instrument and surface condition used by the governing inspection plan.

11. Manage moisture, condensation and flash rust

In Malaysian industrial conditions, a steel surface can be below the local dew point even when the air feels warm. Condensation may be visible, microscopic or intermittent as weather, ventilation and substrate temperature change. ISO 8502-4 provides guidance for estimating the probability of condensation before paint application. [S137]

Measure the conditions at the work surface, not at a distant office or weather station. Continue monitoring when conditions can change. Protect prepared work from rain, wash water, process vapour, compressor moisture, wet floors and overnight cooling.

Water-cleaned or waterjetted steel may develop flash rust. Its permitted condition depends on the waterjet cleanliness requirement and the coating system. Do not remove, accept or coat over flash rust solely by colour judgement. Confirm the permitted condition and time-to-coat from the governing coating information. [S141]

12. Respect coating compatibility and overcoating windows

A sound existing coating may be retained only when the new system permits it and the retained film is clean, dry, firmly adherent and suitably prepared. Feather repair edges to remove weak transitions without exposing or thinning adjacent protection unnecessarily. Check that cleaners, abrasive residues and dust-removal methods are compatible with both retained and new coatings.

On galvanized steel, aluminium, stainless steel and thermally sprayed metal, preparation must balance adhesion with preservation of the substrate or metallic layer. A method suitable for heavy carbon-steel rust removal can be too aggressive or contaminating for these surfaces. [S139; S144]

Observe the preparation-to-coating and intercoat windows stated for the coating system. Re-inspect any surface exposed to dust, moisture, handling, salts or delay. Coating manufacturer guidance commonly requires a sound, clean, dry and contaminant-free surface, with preparation and atmospheric controls read together with the relevant TDS and SDS. [S147]

13. Final inspection and coating-release gate

Release the surface only after all applicable checks are satisfactory.

Inspection point	Confirm	Typical instrument or method
Substrate and repair condition	Required defects, edges, welds and damaged areas have been treated	Visual and tactile inspection; drawing or repair specification
Visible cleanliness	Specified rust, scale, old coating and foreign matter have been removed	Named visual preparation standard and reference
Surface profile	Texture is within the specified range and uniformly produced where required	Named comparator or measurement method
Dust and loose residue	Prepared surface, pits, ledges and welds are acceptably free of particulate	Visual inspection and specified dust assessment
Oil and grease	No visible or otherwise specified contamination remains	Specified cleaning and inspection method
Soluble contamination	Required locations and results meet the stated criterion	Specified extraction and measurement method
Dryness and environment	Surface is dry and application conditions meet coating requirements	Surface temperature, air condition and dew-point assessment
Time and protection	Surface remains accepted at coating start	Time record, area identification and final re-inspection

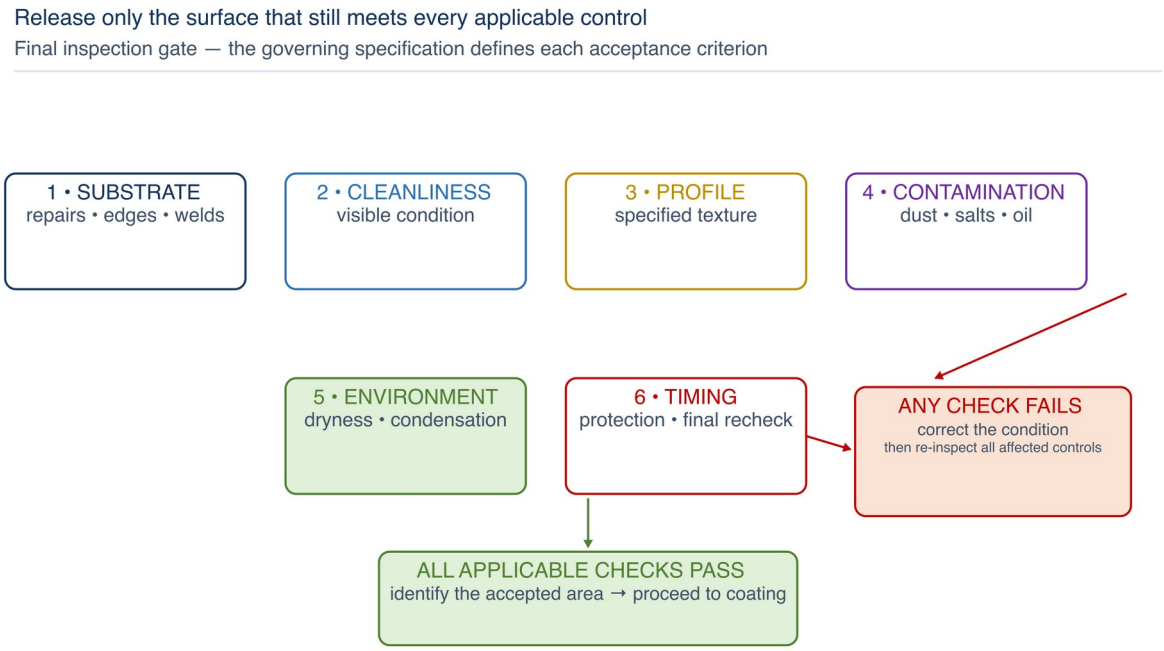

Figure 4. Final coating-release gate. A surface proceeds to coating only when substrate, cleanliness, profile, contamination, environment and timing are all acceptable.

14. Troubleshooting surface preparation

Symptom	Likely process cause	Practical correction
Oil smears or fisheyes appear during preparation	Degreasing was incomplete; contaminated wipes, air or abrasives redistributed oil	Stop, isolate the source, clean with compatible fresh materials and re-prepare the affected zone
Rust or coating remains in pits and weld details	Access or method is inadequate; broad-face appearance was accepted too early	Change the access tool or specified method and inspect recesses separately
Surface is bright but coating key is uncertain	Tool polished or burnished the surface; profile was not verified	Use the specified preparation route and measure or compare the resulting profile
Deep grooves or rounded edges develop	Tool contact is too concentrated, aggressive or poorly supported	Change product form or support, restore controlled motion and protect critical geometry
Dust returns after cleaning	Extraction, enclosure or cleaning sequence is ineffective	Clean from source to collection, improve containment and re-inspect immediately before coating
Soluble contamination remains high	Washing or extraction is ineffective; contaminated water or environment is reintroducing salts	Correct the source and repeat the specified cleaning and test sequence
Flash rust forms before coating	Water remains, humidity or condensation is uncontrolled, or delay is excessive	Restore dry controlled conditions and prepare to the coating system's permitted condition
Prepared steel darkens overnight	Condensation, airborne contamination or early corrosion has altered the surface	Re-inspect all acceptance points and restore the required condition before coating
New coating lifts from retained paint	Existing film was weak, incompatible, contaminated or inadequately keyed	Remove unsound material and prepare the retained boundary to the coating system requirement
Early blistering or underfilm corrosion occurs	Moisture, salts, dust, poor profile or hidden corrosion remained at application	Trace the failure by location and layer, then correct cleaning, testing, profile and environmental controls

15. Concise safety reminders

- Identify the substrate, old coating and contamination hazards before disturbing the surface.

- Contain and extract dust, spent abrasive, paint debris, rust and contaminated wash water.
- Treat unknown legacy coating as a potential hazardous-material source until properly assessed.
- Use only abrasive products, tools, machines, hoses, nozzles, guards and attachments intended for the task.
- Secure the work and control sparks, ricochet, high-pressure water, flying debris, noise and line of fire.
- Keep blasting air clean and dry; inspect hoses, couplings, deadman controls and containment before work.
- Select eye, face, hearing, respiratory, hand, body and foot protection for the complete exposure.
- Segregate stainless-steel and non-ferrous tools where cross-contamination matters.
- Control combustible dust, ignition sources and mixed-metal residues through the workplace risk assessment.
- Isolate energy and depressurise equipment before cleaning, changing, clearing or inspecting it.
- Follow current Malaysian workplace requirements, the machine instructions and the coating and abrasive product information. [S032; S145; S146]

16. Practical application sequence

482. Identify the substrate, existing coating, contamination, defects and service environment.
483. Confirm the coating system's required preparation grade, profile, tests, environment and application window.
484. Establish containment, access, work support, extraction, waste controls and PPE.
485. Remove dirt, oil and grease using a compatible cleaning method.
486. Treat welds, edges, burrs and other specified surface imperfections.
487. Select and confirm the preparation method, abrasive family, machine and attachment.
488. Prepare the surface without unacceptable grooving, polishing, contamination or geometry loss.
489. Remove dust, spent abrasive and all preparation debris.
490. Assess visible cleanliness and surface profile as separate controls.
491. Test dust and soluble contamination where specified.
492. Verify that the surface is dry and environmental conditions are suitable.
493. Protect the accepted area from handling, moisture, dust and delay.
494. Complete the final inspection and release the identified area for coating.
495. Re-inspect whenever conditions change or the permitted preparation-to-coating interval is exceeded.

SURFACE FINISHING & POLISHING

CHAPTER 028

Polishing Fundamentals

28

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, fabricators, safety personnel, procurement staff and technical sales personnel

Scope: Practical distinctions between grinding, sanding, finishing, polishing, buffing and lapping, with selection and process-control guidance for industrial metalwork.

Core principle — Polishing refines an already controlled surface. It cannot reliably conceal unresolved geometry, deep scratches, contamination or heat damage.

This chapter is an educational and application-selection guide. It establishes a consistent working vocabulary for the handbook and explains how successive abrasive stages create the intended appearance or functional surface.

Chapter objectives

After this chapter, the reader should be able to:

- distinguish grinding, sanding, finishing, polishing, buffing and lapping by purpose and abrasive action;
- decide whether the required result is geometric, visual, tactile or functional;
- plan a progressive scratch-refinement route;
- select a suitable abrasive form and contact support for the surface geometry;
- control contamination, heat, edge loss and compound carry-over;
- inspect a polished surface under repeatable conditions; and
- troubleshoot common polishing defects.

1. Use process names by purpose, not by appearance

Industrial terminology varies between metalworking, coating, automotive, toolmaking and precision-finishing trades. A flexible abrasive belt may be described as grinding in one plant and sanding in another; a cloth wheel may be called a polishing or buffing wheel. For this handbook, the process name follows the primary purpose, the abrasive system and the way the surface is controlled. [S148; S150; S151; S152]

Process	Primary purpose	Typical abrasive action	Usual result and control focus
Grinding	Remove stock, weld reinforcement, scale or defects; establish geometry	Bonded, coated or engineered abrasive cuts with comparatively high local removal	Shape, level, access and damage control come before appearance
Sanding	Refine a surface with coated abrasive sheets, discs or belts	Fixed abrasive grains create a controlled scratch pattern	Remove the previous pattern and prepare for finishing or coating
Finishing	Umbrella term for producing a specified surface condition	May include abrasive, brushing, polishing, chemical or other methods	Defined appearance, texture, cleanliness or functional condition
Polishing	Progressively reduce and regularise fine scratches	Fine fixed or loose abrasive acts through a supported tool, pad or cloth	Smoother, brighter or more reflective surface with controlled geometry
Buffing	Develop lustre and smooth very fine surface features after suitable preparation	Flexible wheel or mop, commonly with compound; relatively low intentional stock removal	Brightness, uniformity, cleanliness and avoidance of waves or drag marks
Lapping	Produce controlled precision geometry and fine finish	Loose abrasive slurry moves between the work and a prepared lap	Flatness, parallelism, thickness or finish verified by a specified method

The boundaries are practical rather than universal. Name the required result and process stage as well as the tool. A request for “mirror polish” is incomplete until substrate, geometry, directionality, defect limits, cleanliness and inspection conditions are defined.

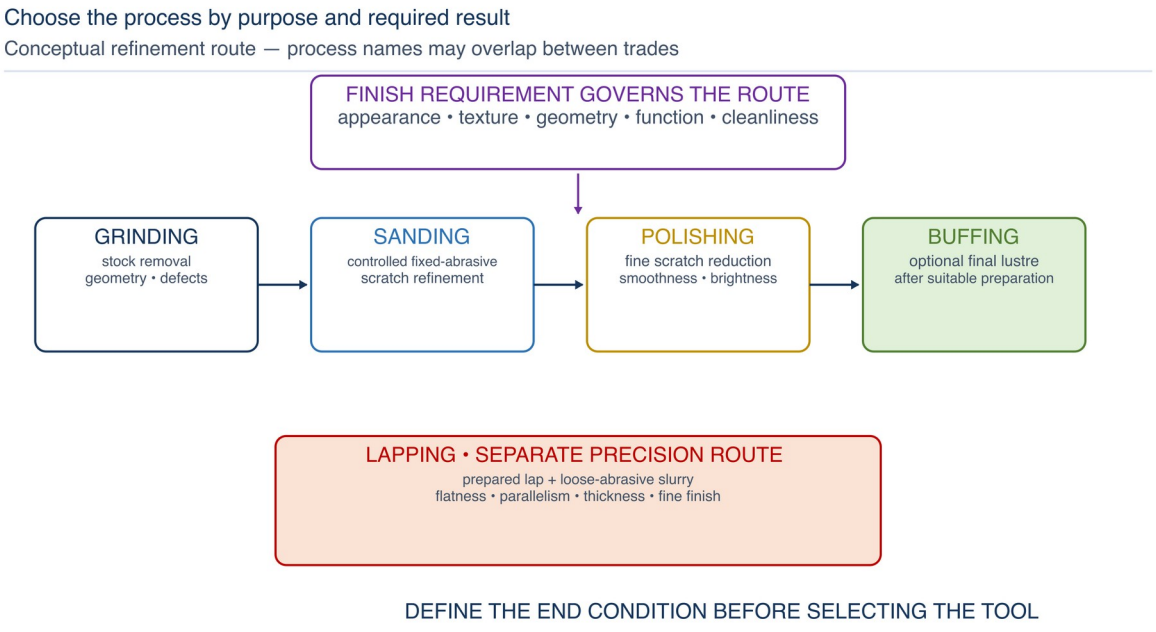

Figure 1. Surface-refinement process ladder. Grinding, sanding, polishing and optional buffing form one common refinement route; lapping is shown separately because it controls precision geometry through a lap-and-slurry system.

2. Grinding establishes; polishing reveals

Grinding is the appropriate starting process when the work still contains weld excess, heavy scale, casting skin, deep damage or substantial shape correction. It should leave enough material and a sufficiently uniform surface for the next stage without overheating, undercutting, gouging or rounding critical features.

Polishing removes far less material per stage and therefore tends to reveal rather than erase earlier errors. A deep grinding groove that survives the first refinement stage will remain visible after the surrounding surface becomes bright. Trying to remove it with an overly fine product usually increases time, heat and edge loss.

Use the coarsest stage only as coarse as the defect and geometry require. Move to refinement when the required shape is established and the remaining scratch pattern is uniform.

3. Sanding creates the controlled bridge

Sanding normally uses coated abrasive sheets, discs or belts to replace the grinding pattern with finer, more regular scratches. Its role is to bridge stock-removal work and the final finishing or polishing stages. The backing and contact support are as important as the abrasive grade: a firm support preserves flatness, while a more conformable support follows curves but can soften edges or amplify waves.

At every stage, remove the deepest scratches left by the previous stage rather than polishing only the surface peaks. Clean the work, tool and surrounding area before changing to a finer abrasive. Large particles carried forward can introduce isolated scratches that are deeper than the new stage can efficiently remove. Struers specifically emphasises successive finer removal and cleaning between preparation steps. [S123; S148]

4. Finishing is the required end condition

“Finishing” is the broadest term in this chapter. It can describe a directional grain, satin appearance, coating key, deburred edge, low-friction contact area, hygienic surface or decorative sheen. Polishing is therefore one finishing route, not a synonym for every finished surface.

Define the end condition in observable or measurable terms appropriate to the part:

- **appearance** — gloss, reflectivity, colour, directional lay and acceptable local marks;
- **geometry** — flatness, edge form, blend boundary and absence of waves;
- **texture** — specified roughness or texture parameter and measurement method;

- **function** — cleanability, sealing, friction, coating adhesion or product-contact duty; and
- **cleanliness** — absence of compound, debris, oil, embedded particles or cross-contamination.

A polished appearance does not by itself prove surface roughness, hygiene, passivation, coating readiness or corrosion performance. Inspect each required property separately. [S114; S120; S151]

5. Polishing is progressive scratch replacement

Mechanical polishing uses progressively finer abrasive action to reduce the depth and visibility of the preceding scratch pattern. The result depends on the starting surface, abrasive type and condition, carrier or backing, contact support, motion, pressure, time, temperature, cleanliness and material response. [S023; S060; S148; S149]

Each stage must perform two jobs:

496. remove the damage and deepest scratches from the previous stage; and
497. leave a uniform pattern that the next stage can remove economically.

Skipping a stage can be successful only when the next product has enough cutting ability and the earlier pattern is already controlled. A finer label does not guarantee that capability, and nominal grades from different abrasive systems are not automatically equivalent.

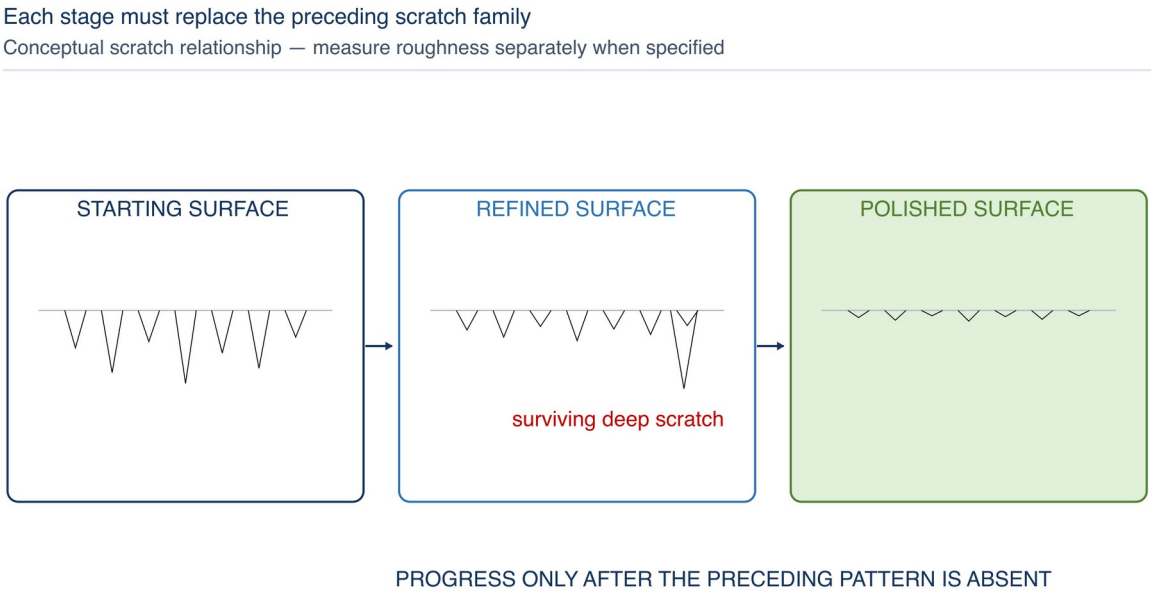

Figure 2. Conceptual scratch-scale transition. Each stage replaces the previous scratch family with a shallower, more uniform pattern; a surviving deep scratch remains visible through later brightening.

6. Buffing develops lustre after preparation

Buffing commonly uses a flexible textile or felt wheel or mop, often with a fine compound, to smooth very fine surface features and increase brightness. Worldstainless distinguishes buffing from grinding and polishing by its emphasis on smoothing and reflectivity rather than deliberate bulk removal, while noting that the pre-buff finish strongly influences the result. [S151]

Buffing is not a substitute for complete scratch refinement. Excessive buffing on an inadequately prepared surface can produce a shiny surface that still shows lines, ripples, edge rounding or smeared metal. Compound can also lodge in seams, pores and recesses, so cleaning compatibility must be considered before painting, plating, welding, bonding or product-contact service. [S151; S154]

For exact compound, wheel, attachment and machine compatibility, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

7. Lapping is a separate precision process

Lapping uses loose abrasive in a liquid carrier between the workpiece and a prepared lap. The grains roll and slide within the interface while material is removed. It is selected where controlled flatness, parallelism, thickness or fine finish is central to the requirement. [S150]

Unlike freehand polishing, lapping performance depends on the condition and geometry of the lap, slurry delivery, workpiece arrangement and a controlled measurement system. A bright lapped surface is not accepted by appearance alone. Conversely, a polished decorative surface does not imply lapped flatness or dimensional accuracy.

Keep lapping slurry, equipment and cleaning routes segregated where abrasive carry-over could damage precision work.

8. Select the route from the required result

Start with the defect and end condition, then select the least aggressive route capable of reaching them while protecting geometry.

Starting condition and objective	Appropriate starting family	Progression logic	Main verification
Weld excess, deep damage or major level correction	Grinding	Establish geometry, then remove the grinding pattern through controlled sanding	Shape, blend and absence of deep residual grooves
Uniform machined or previously ground surface requiring refinement	Sanding or fine grinding	Use successive stages until the pattern is suitable for finishing or polishing	Complete removal of the preceding pattern
Directional satin or brushed appearance	Finishing abrasive or non-woven system	Preserve lay direction and match the approved visual reference	Direction, sheen, blend and local defects
Bright or reflective appearance	Fine sanding or polishing, followed by buffing when appropriate	Refine scratches before developing final lustre	Scratch visibility under controlled lighting and viewing
Precision flatness, parallelism or thickness with fine finish	Lapping	Use a controlled lap, slurry and measurement plan	Specified geometry and surface measurement
Surface for coating, bonding, hygiene or corrosion service	Application-specific preparation	Prioritise cleanliness, texture and compatibility rather than gloss alone	The governing process or service requirement

Where a drawing or customer specification calls for an exact finish designation, parameter or appearance, use its stated method and revision. Do not convert a visual description into a roughness value, or a roughness value into a guaranteed appearance, without a validated correlation for that process.

9. Control the polishing interface

Polishing is governed by the complete contact interface, not by abrasive grade alone.

Control variable	Practical effect	Control question
Starting surface	Sets the deepest defect the stage must remove	Is the surface uniform enough for this stage?
Abrasive or compound	Governs cut, scratch character, loading and residue	Is the abrasive family compatible with the material and next process?
Backing, pad, wheel or lap	Controls support, conformability and local pressure	Will the carrier preserve the required flat, curve, edge or detail?
Motion and contact area	Influences lay, dwell, heat and visual uniformity	Is contact stable and moving through a repeatable path?
Pressure and exposure time	Affect removal, heat, smearing and geometry loss	Is the stage cutting cleanly without forcing or dwelling?
Lubrication or coolant	Can influence heat, loading, swarf transport and cleaning	Is it permitted and compatible with the work and downstream process?
Cleanliness and segregation	Prevent isolated scratches and material transfer	Are work, tools, hands and surroundings clean for the current stage?

Control variable	Practical effect	Control question
Inspection conditions	Determine which scratches, haze and waves can be seen	Are lighting, viewing, cleaning and reference conditions repeatable?

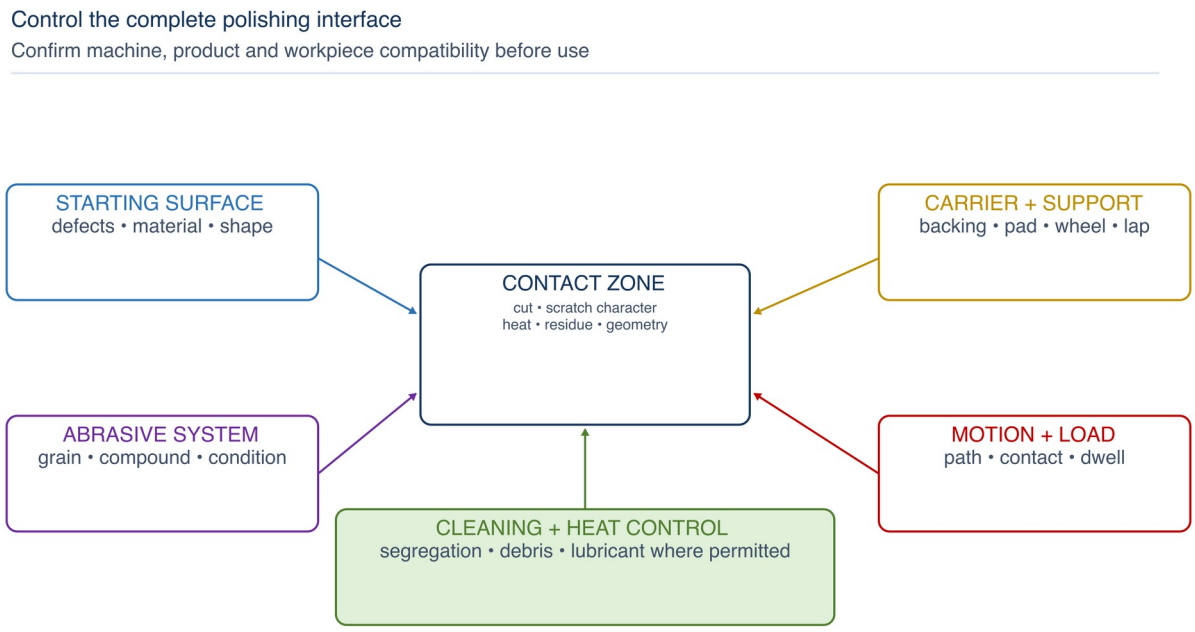

Figure 3. Polishing interface control map. Abrasive, carrier, workpiece, motion, support, heat control and cleanliness interact; changing one element can change cut, scratch character and appearance.

10. Protect flats, curves, edges and details

Use a firm, stable support when flatness and crisp transitions matter. Use conformable products deliberately on tubes, radii and contoured parts, recognising that conformability can increase contact around edges and high points. Match the tool width and contact footprint to the feature so that the operator can see and control the blend.

Approach edges with reduced local dwell and stable support. Do not allow a flexible wheel or pad to wrap unpredictably around a thin edge, opening or projection. Mask or physically protect adjacent finished faces where the process permits. On fabricated assemblies, plan access so that the polishing direction and overlap remain consistent across welds and adjoining surfaces.

11. Manage heat, loading and material response

Fine abrasive stages can generate damaging heat even when sparks are limited. Heat can soften coatings or polymers, promote smearing in ductile metals, discolour stainless steel, distort thin sections, load the abrasive and shorten wheel or compound life. [S023; S149; S154]

Maintain clean cutting action through appropriate product choice, adequate contact area, progressive movement and timely abrasive replacement. If cut falls while heat rises, stop and inspect for loading, glazing, contamination, insufficient support or an unsuitable stage. Increasing force is rarely the best first correction.

Use wet methods only when the machine, abrasive, workpiece and downstream process permit them. Control splash, electrical hazards, slurry, slip risks and drying. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

12. Prevent contamination between materials and stages

Separate abrasives, wheels, pads, compounds, brushes and cleaning materials where cross-contamination matters, especially between carbon steel and stainless steel or non-ferrous work. Identify tools by material family or process stage and store them so coarse debris cannot fall onto fine-stage products. [S125; S126]

Before every finer stage:

498. stop the machine and secure the work;
499. remove swarf, spent abrasive and compound from the part;
500. clean hands, fixtures, supports and the work area as required;
501. inspect the new abrasive or wheel for contamination and damage; and
502. confirm that the preceding scratch family has been removed.

Use a cleaner compatible with the substrate and next operation. A glossy film of compound or oil can conceal scratches and interfere with coating, bonding, plating, welding or hygiene requirements.

13. Inspect appearance and surface condition separately

Inspect a cleaned surface using consistent lighting, distance, angle and viewing direction. Use both diffuse illumination for overall uniformity and low-angle illumination to reveal scratches, waves and local drag marks. Change the viewing orientation because directional defects can disappear when aligned with the light.

Compare appearance with an approved physical reference when colour, sheen or directional character matters. If roughness, flatness or another parameter is specified, use the stated instrument, setup, locations and acceptance rule. Do not accept a part solely because it looks bright.

For compound-based work, make the final appearance judgement after compatible cleaning. Temporary filler or residue can mask scratches that reappear after washing or service.

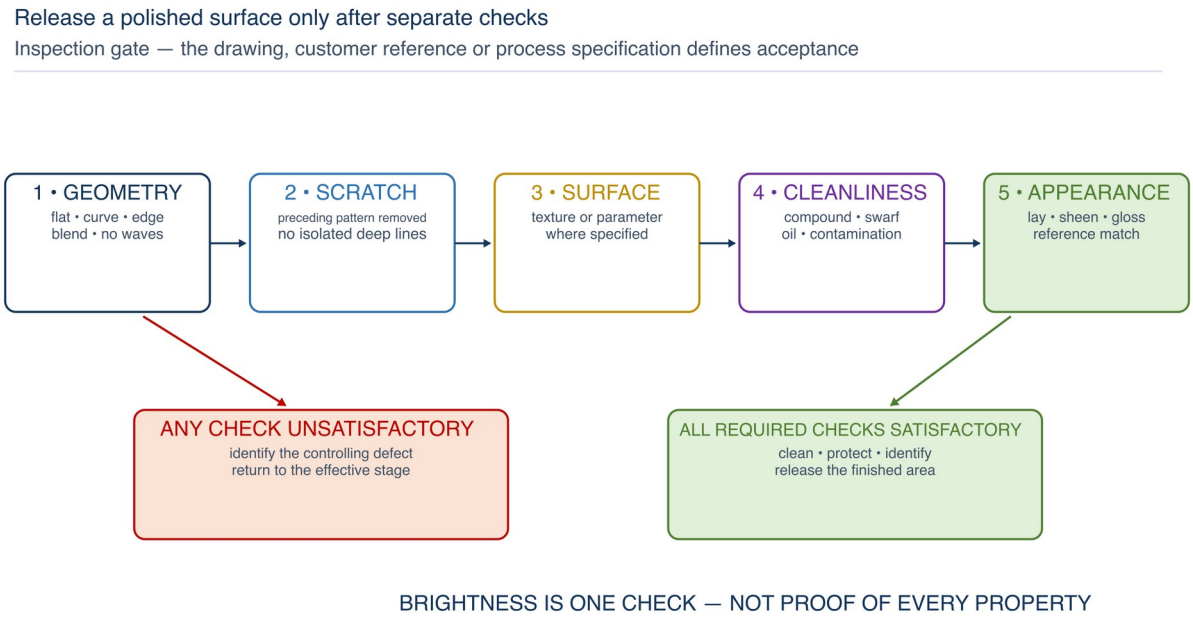

Figure 4. Polishing inspection and release gate. Geometry, scratch refinement, surface condition, cleanliness and appearance are checked separately before the finished area is protected and released.

14. Troubleshooting polishing defects

Symptom	Likely process cause	Practical correction
Deep lines remain after the surface brightens	Previous-stage scratches were not removed; stage jump was too large	Return to the stage that can remove the deepest line, restore a uniform pattern, clean and progress again
Random isolated scratches appear	Coarse-particle carry-over, dirty support, contaminated compound or damaged abrasive	Stop, clean and segregate; replace the contaminated item and rework from the required stage
Surface becomes hot while cut falls	Abrasive is loaded or glazed; contact is too concentrated; force or dwell is excessive	Stop and inspect; restore clean cutting action, support and movement before resuming

Symptom	Likely process cause	Practical correction
Haze or uneven gloss remains	Inconsistent scratch refinement, wheel condition, compound delivery, overlap or cleaning	Standardise the preceding finish and work path; clean and compare under controlled light
Ripples or waves appear on a broad face	Flexible contact, repeated local dwell or uneven support altered the surface	Return to a firmer supported stage and re-establish geometry before final polishing
Edges become rounded or lettering softens	The carrier wrapped around the feature or contact was concentrated at the edge	Protect the feature and use stable, reduced-area contact with controlled approach and exit
Metal smears instead of cutting cleanly	Heat, loading, soft material response or unsuitable abrasive/lubrication	Cool and clean the interface; select a compatible cutting system and reduce concentrated dwell
Compound remains in seams or pores	Excess compound, unsuitable carrier or inadequate cleaning access	Reduce application, improve containment and use a compatible cleaning method before release
Bright surface still fails functional inspection	Gloss was treated as proof of roughness, cleanliness, flatness or service condition	Test the specified property separately and correct the relevant process stage

15. Concise safety reminders

- Inspect the machine, guard, spindle, wheel, pad, belt, attachment and work support before use.
- Confirm that every rotating accessory is intended for the machine and task; never exceed its marked limit.
- Secure the work and keep hands, clothing, hair, jewellery, gloves and loose materials clear of rotating parts and nip points.
- Use extraction or other effective controls for polishing dust, swarf, fibres, mist and compound. Do not direct debris toward the breathing zone. [S152]
- Assess combustible metal dust and mixed-metal residues before collection or disposal.
- Select suitable eye, face, hearing, respiratory, hand, body and foot protection for the complete exposure.
- Control heat, sparks and ignition sources; isolate energy before changing, cleaning, clearing or inspecting equipment.
- Keep wet processes compatible with electrical protection, floor condition, wastewater and slurry controls.
- Follow current Malaysian workplace requirements, site procedures, machine instructions and abrasive-product safety information. [S153; S155]

16. Practical polishing sequence

503. Identify the substrate, starting condition, geometry, defects and downstream service.
504. Define the required appearance, lay, texture, geometry, cleanliness and inspection method.
505. Establish work support, guarding, extraction, access, segregation and personal protection.
506. Remove oil, dirt, scale and loose contamination before abrasive refinement.
507. Use grinding only where stock removal or geometry correction requires it.
508. Create a uniform supported sanding pattern that removes the grinding damage.
509. Clean the part, tool, fixture and work area before each finer stage.
510. Progress only after the preceding scratch family is absent under suitable inspection lighting.
511. Match backing or wheel conformability to the flat, curve, edge or detail being finished.
512. Maintain stable contact and movement; stop if heat, loading, smearing, vibration or loss of control develops.
513. Polish to the required scratch refinement; buff only when the specified lustre or final smoothing calls for it.
514. Remove compound and process residue with a compatible cleaning method.
515. Inspect appearance and specified functional properties as separate requirements.
516. Protect the accepted surface from handling marks, moisture, dust and cross-contamination.

SURFACE FINISHING & POLISHING

CHAPTER 029

Polishing Compounds and Buffing Wheels

29

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, maintenance teams, fabricators, safety personnel, procurement staff and technical sales personnel

Scope: Practical selection and use of cutting and colouring compounds with stitched, loose-leaf, sisal, cloth/sisal and felt polishing tools in manual and automated metal-finishing operations.

Core principle — The finish is produced by the compound–wheel–workpiece system. A compound or buff cannot be selected reliably in isolation.

This chapter explains how compound function, buff construction, contact behaviour and operating discipline combine to remove fine scratches, develop lustre and leave a clean surface ready for inspection or the next process.

Chapter objectives

After this chapter, the reader should be able to:

- distinguish cutting compounds from colouring compounds by process function;
- compare solid, paste and liquid delivery forms without relying on colour as a grade code;
- select a stitched, loose-leaf, sisal, cloth/sisal or felt tool for the required cut and geometry;
- apply enough compound to maintain effective action without overloading the wheel;
- control contact, speed, heat, residue and cross-contamination;
- clean and inspect the work between stages; and
- troubleshoot common compound-and-buff defects.

1. Treat compound and wheel as one abrasive system

Conventional buffing brings together a rotating wheel, an abrasive compound, a machine, a supported workpiece and a controlled contact path. The compound supplies abrasive particles and a carrier; the wheel holds, distributes and works that compound at the surface. The workpiece material, starting scratch pattern, geometry and required appearance determine how the pair should behave. [S154]

Changing only one component can alter cut, heat, residue and visual result. A firmer wheel can make the same compound act more aggressively on a flat surface. A softer, more conformable wheel may reach a contour but reduce geometric control. Too little active compound can allow heat and glazing to rise; excessive application can coat the wheel, create fling-off and leave difficult residue.

Select the pair from five questions:

517. What material and surface condition are entering the stage?
518. Must the stage remove scratches, develop lustre, or do both?
519. Which flats, edges, radii, recesses or details must be protected?
520. What cleaning and downstream process follow buffing?
521. How will appearance, cleanliness and any specified surface property be inspected?

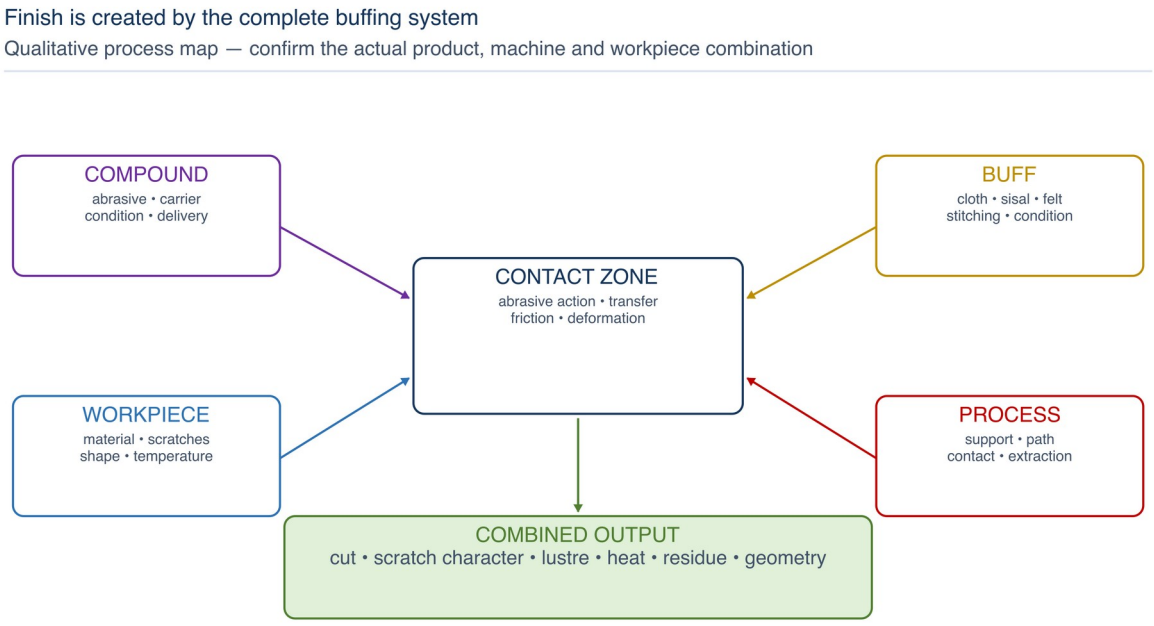

Figure 1. Compound–wheel–workpiece system map. Compound function, wheel construction and workpiece condition meet at the contact zone, where cut, scratch character, lustre, heat, residue and geometry are produced together.

2. Cutting and colouring are process functions

Most multi-stage buffing routes separate **cutting** from **colouring**. Cutting buffing removes the fine scratch pattern left by the preceding preparation stage and makes the surface smoother and more uniform. Colouring buffing uses a finer, gentler system to develop the final brightness or lustre. Some applications combine both functions, but the starting surface must still be suitable for the chosen system. [S154]

“Colouring” describes development of lustre; it does not mean applying a coloured coating. The visible colour of a compound bar is also not a universal grade system. Different manufacturers may use similar colours for different abrasive minerals, carriers or applications.

Compound function	Primary task	Suitable entering condition	Wheel tendency	Release check
Cutting	Remove fine preparation scratches and level small surface irregularities	Uniform, adequately refined surface with no deep grinding defects	Firmer or more cutting construction, selected for the geometry	Previous scratch family removed without waves, heat damage or edge loss
Cut-and-colour	Combine modest scratch refinement with brightness development	Consistent surface whose remaining marks are within the system’s cutting capability	Balanced cut and compliance	Uniform sheen with no persistent lines or local distortion
Colouring	Develop high lustre and reduce very fine haze	Clean, well-refined pre-buff surface	Softer, more conformable construction	Even colour and reflectivity after compatible cleaning
Precision polishing paste	Produce a fine controlled finish on a compatible felt or other carrier	Stable geometry and a prepared fine surface	Shape-retaining or application-specific support	Specified visual or measured result, checked separately

Do not ask a colouring stage to repair a deep scratch. The surrounding area may brighten while the line remains, encouraging excess pressure, heat and edge rounding.

3. Understand compound forms without assuming equivalence

Industrial compounds may be supplied as solid bars, pastes, liquids or specialised slurries. The form controls how the compound is stored, applied, metered and cleaned; it does not by itself define cutting strength or finish quality. Distinguish cutting or pre-polishing compounds from final high-gloss polishing compounds by their declared duty. [S151; S158]

Form	Typical production use	Main control points	Cleaning consideration
Solid bar	Manual application to a rotating cloth, sisal or felt tool	Brief, even presentation; avoid impact, prolonged loading and hand exposure to the contact zone	Waxy or greasy residue may collect in seams and recesses
Paste	Local manual work, felt tools, small features or precision polishing	Use a clean applicator; prevent drying, dilution or cross-mixing	Remove paste and spent abrasive before inspection or the next stage
Liquid compound	Metered manual, semi-automatic or automated delivery	Stable concentration, agitation where specified, clean lines/nozzles and even coverage	Overspray, mist, floor contamination and wastewater require control
Specialised slurry	Controlled polishing or lapping systems	Carrier compatibility, concentration, delivery, temperature and segregation	Slurry must not dry on the part or enter incompatible drains/processes

Compound labels such as “coarse”, “fine”, “cut”, “colour” or a particular bar colour are meaningful only within the supplier’s system. For exact compound identity, substrate compatibility, application method and storage condition, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

4. Compound chemistry affects cut, heat and cleaning

A buffing compound normally combines abrasive mineral with a carrier that helps transfer and retain it at the wheel face. Carrier behaviour influences adhesion, lubrication, cooling, fling-off and the residue left on the part. The abrasive influences cutting action and scratch character. Because these functions are coupled, adding more compound does not necessarily produce more useful cut.

Spent compound can contain carrier, metal fines, abrasive debris and material transferred from the wheel. Heat may make residue more tenacious, particularly in corners, seams, pores and textured regions. Control application carefully because conventional compound residue can be difficult to contain and remove. [S154]

Choose the compound with the entire route in mind: substrate, wheel, required finish, cleaning method, coating or plating compatibility, product-contact duty and waste controls.

5. Wheel construction controls contact behaviour

A buff is not simply a carrier for compound. Cloth grade, number and arrangement of plies, stitching, treatment, width, wheel condition and mounting all influence its effective firmness and ability to follow the work. Firmer stitched constructions resist deflection, while looser constructions conform more readily to shapes and contours. [S156; S157]

Wheel family	General behaviour	Useful application tendency	Main caution
Stitched cloth	Firmer face; sewing restrains the plies	Cutting, flat or gently curved work, controlled edges and repeatable contact	Excessive local dwell can create heat, lines or geometry change
Loose-leaf cloth	Soft, flexible face; individual plies follow contours	Colouring, recesses, complex contours and final lustre	Can wrap around edges, catch projections or soften detail if poorly controlled
Sisal	Firm, aggressive natural-fibre construction with good compound retention	Cutting after suitable abrasive preparation on compatible metals	Not a universal final-colour tool; protect edges and control heat
Cloth/sisal combination	Intermediate firmness and compound retention	Balanced cutting and contour response	Construction varies widely; do not infer behaviour from appearance alone
Felt wheel or bob	Dense, shape-retaining carrier available in different forms	Small areas, edges, profiles, bores and fine or precision polishing with compatible paste	Concentrated contact can raise heat quickly or alter local geometry

Wheel family	General behaviour	Useful application tendency	Main caution
Ventilated or pleated cloth	Folded construction with a compliant face and airflow between folds	Broad production work and contours where the construction suits the machine	Direction, mounting hardware and product instructions govern use

Wheel “hardness” is therefore a practical system property, not a single cross-brand scale. A wheel that feels soft at rest may behave firmer at operating speed or when assembled into a wider pack.

6. Use stitched wheels for controlled cut

Stitched buffs restrain the cloth layers and create a more stable face than a loose-leaf assembly. Closer or more extensive stitching generally increases firmness; cloth grade and any treatment also influence the result. Firmer contact can improve cutting action and help preserve flats, but it also concentrates energy when the operator dwells or presents an edge incorrectly. [S156; S157]

Use a stitched construction when the stage must remove a controlled fine scratch pattern, maintain a broad contact band or resist excessive wrap. Keep the work moving through a planned path. Inspect the face for glazing, hard compound deposits, frayed cloth, loose stitching, imbalance or embedded debris before and during production.

7. Use loose-leaf wheels for conformity and colour

Loose-leaf buffs are assembled from flexible cloth discs with minimal restraint away from the centre. Their soft face can conform to irregular shapes and enter narrower details, which makes them useful for final colouring and light smoothing. [S156; S157]

That compliance also requires careful presentation. A projecting edge, slot or thin lip can enter between the plies and be pulled by the wheel. Work below the safe contact zone defined by the machine arrangement, support small parts securely and present edges so the wheel moves off the edge rather than into it. Avoid loose clothing, jewellery and gloves that could be drawn into the rotating assembly.

8. Use sisal and cloth/sisal where more cut is needed

Sisal is a natural fibre used in comparatively aggressive cutting buffs and is recognised for retaining compound. Alternating cloth and sisal can soften the contact and improve conformity while retaining useful cutting action. [S157]

Select sisal only after confirming that the entering scratch pattern, substrate and geometry suit a cutting-buff stage. It should not be used to compensate for incomplete grinding or coarse sanding. If the surface heats, tears, ripples or develops deep directional lines, stop and restore the preceding preparation rather than forcing the buffing stage.

9. Use felt for shape-retaining fine contact

Felt wheels, points and bobs provide a denser, more shape-retaining carrier than loose cloth. They are useful where a controlled face must work a small flat, edge, bore, groove, tool feature or local detail. Select the felt form, density and compound for the intended polishing duty. [S151; S159]

Felt concentrates contact on a smaller area, so heat and local removal can rise quickly. Shape the tool only by an approved method, keep it dedicated to one compound and material family where contamination matters, and replace it when embedded debris, glazing, damage or loss of geometry prevents controlled action.

10. Match wheel firmness to geometry and result

Select the least aggressive compound–wheel pair that can remove the entering scratch pattern while protecting the part.

- **Broad flats:** favour stable support and a controlled contact band; excessive softness can create waves.
- **Outside curves and tubes:** use enough compliance to maintain contact without flattening the radius.
- **Inside radii and recesses:** choose a form that enters the feature without rubbing adjacent faces.
- **Edges, slots and projections:** reduce wrap and keep the direction of wheel travel from pulling the feature into the nip.
- **Fine details and tooling:** use a shape-retaining felt or small supported tool, with short controlled contact.
- **Final colour:** use a clean, softer system only after the cutting pattern is fully removed.

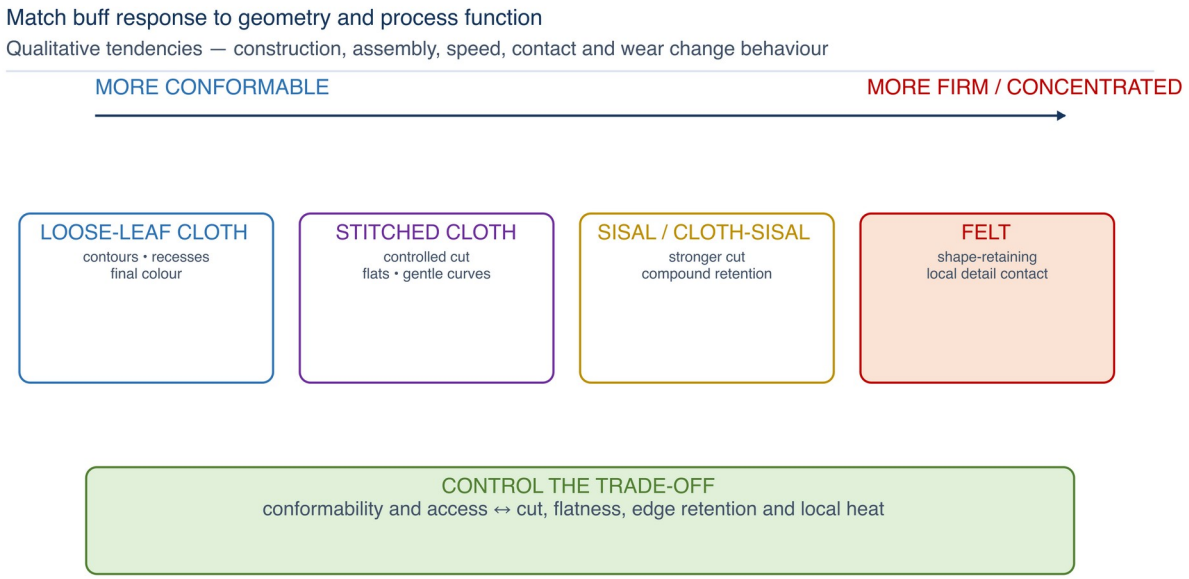

Figure 2. Buff firmness and conformability map. Firmer stitched or sisal-influenced contact favours cut and geometric control; loose cloth favours contour-following and final colour; felt concentrates shape-retaining contact on local features.

11. Apply compound to maintain an active face

Compound should form a useful, renewed working film at the wheel face—not a thick layer that masks the cloth. Apply small, controlled amounts and judge the need for reapplication from cut, heat, wheel sound, surface appearance and residue. In automated systems, stable delivery also depends on clean tanks, lines and nozzles and the specified compound condition. [S154]

Signs of under-application can include falling cut, dry drag, rising heat or glazing. Signs of over-application can include heavy fling-off, a greasy wheel face, smeared residue, obscured scratches and difficult cleaning. These symptoms can have other causes, so stop and inspect the complete interface before adjusting delivery.

Never force a solid bar into the wheel or hold it in contact for an extended period. Keep hands clear of the nip and use the application method intended for the compound and machine.

12. Control speed, contact and movement together

Wheel diameter and rotational speed combine to determine surface speed. The correct operating range depends on wheel construction, mounting, compound, material, machine and workpiece geometry. Never treat machine speed alone as the process setting.

Confirm the marked limits and instructions for the actual wheel, attachment and machine. **Refer to the product label, Technical Data Sheet, or MKTECH representative.** Never exceed the lowest applicable marked limit.

Use stable contact and progressive movement. Excess force can collapse a soft wheel, increase the contact area unpredictably, heat the work and pull the part from its support. Very light contact may fail to engage the compound and encourage prolonged dwell. Establish the process on a representative sample, then maintain the same presentation, overlap and work path.

13. Manage heat before it changes the surface

Heat is generated by friction, abrasive cutting and deformation at the contact zone. Excess heat can discolour metal, distort thin parts, smear ductile alloys, bake compound onto the surface, damage the wheel and contribute to fire risk. Temperature control is therefore central to safe, repeatable buffing. [S154]

Control heat by maintaining an effective cutting face, using appropriate wheel compliance, moving continuously, limiting local dwell, supporting thin work and allowing the part and tool to cool when required. If heat rises while useful cut falls, stop.

Inspect for loading, glazing, insufficient compound, excessive compound, contaminated material, poor support or a stage mismatch.

Do not cool a hot part by applying an unapproved liquid to a dry buffing operation. Liquid use must be compatible with the machine, wheel, compound, substrate, electrical controls and downstream cleaning route.

14. Prevent compound and metal cross-contamination

Dedicate wheels and applicators by compound function and material family where carry-over can affect finish, corrosion performance, plating, coating, hygiene or precision service. A colouring wheel contaminated with cutting compound can introduce random lines. A stainless-steel buff exposed to carbon-steel particles can transfer iron contamination. [S151]

Use clear identification and covered storage. Keep cutting and colouring bars separate; do not press one compound onto a wheel already charged with another. Clean the work, fixtures, hands and surrounding area before moving to the next stage. Where a compound or tool is changed, use a new or properly prepared carrier rather than relying on visual cleanliness alone.

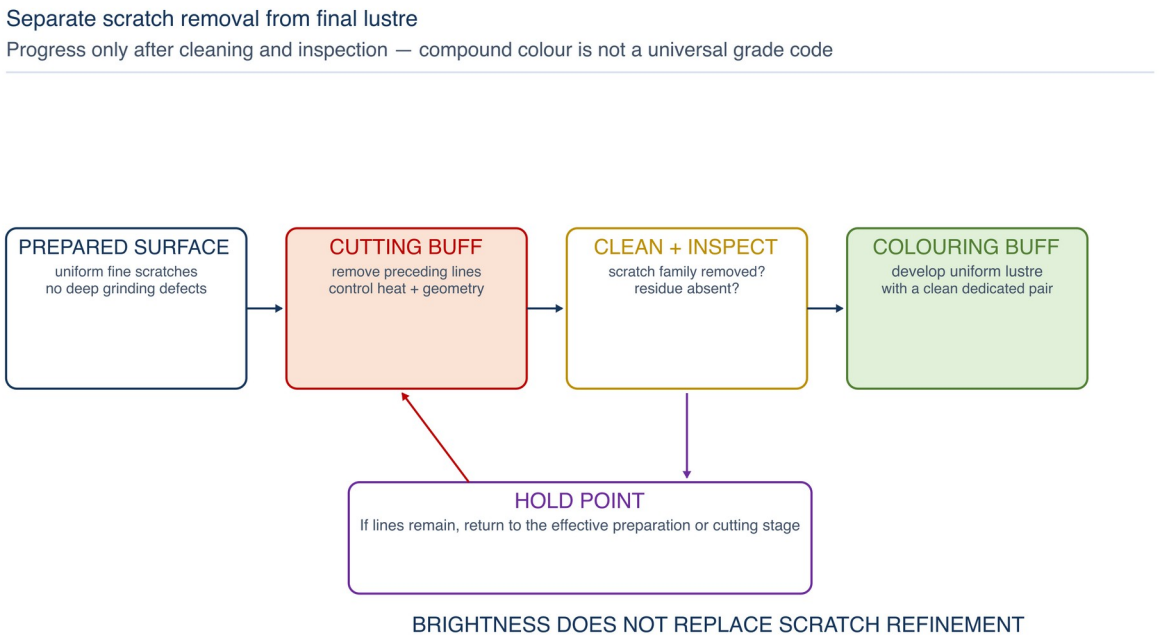

Figure 3. Cut-to-colour progression. A prepared surface enters cutting buffing, is cleaned and inspected at a hold point, then moves to colouring only when the preceding scratch family has been removed.

15. Clean before inspection and downstream work

Inspect the finish only after removing compound residue with a method compatible with the substrate and next operation. Residue can hide fine scratches, collect in joints and interfere with coating, plating, bonding, welding, passivation or product-contact service. [S154]

Begin with the least aggressive effective cleaning method. Use clean, non-scratching wipes or brushes, provide access to recesses and prevent dirty cleaning media from redistributing abrasive particles. If an aqueous, alkaline, solvent or specialised cleaner is required, confirm material compatibility, rinsing, drying, ventilation, storage and waste controls from its Safety Data Sheet and process requirements.

After cleaning, inspect under consistent diffuse and low-angle light. Check scratch removal, uniform lustre, local waves, edge form, residue and transferred contamination separately. A bright surface is not proof that every functional requirement has been met.

16. Troubleshooting compound-and-buff defects

Symptom	Likely system cause	Practical correction
Surface brightens but lines remain	Pre-buff preparation incomplete; colouring system has insufficient cut	Return to the effective preparation or cutting stage, restore a uniform scratch pattern, clean and progress again
Random deep scratches appear	Cutting compound or metal debris contaminated the wheel, work, fixture or cleaning media	Stop; segregate and replace contaminated items, clean the area and rework from the stage that removes the deepest line
Wheel face becomes greasy and cut falls	Compound over-application, loading or incompatible carrier/wheel pairing	Stop and inspect; remove excess by the approved wheel-maintenance method and resume with controlled application
Part becomes hot or discoloured	Excess dwell or force, concentrated contact, glazing, loading or unsuitable stage	Stop and cool safely; restore effective cut, support and movement before continuing
Uneven gloss or cloudy patches	Inconsistent pre-buff finish, wheel condition, compound delivery, overlap or cleaning	Standardise the entering surface and work path; clean fully and inspect under controlled light
Waves, hollows or softened edges	Wheel too compliant, contact too concentrated or repeated local dwell	Re-establish geometry with a firmer supported stage and protect critical transitions
Compound is flung around the station	Excess application, poor retention, incorrect presentation or unstable automated delivery	Reduce and stabilise delivery after checking the selected pair; improve containment and housekeeping
Residue remains in seams and recesses	Excess compound, heat-baked carrier or inadequate cleaning access	Reduce loading and heat; use a compatible cleaning method and appropriate non-damaging agitation
Wheel vibrates, frays or runs irregularly	Damage, contamination, incorrect assembly, uneven wear or incompatible mounting	Stop immediately, isolate the machine and inspect or replace the assembly before use
Finish changes between batches	Starting surface, compound condition, wheel wear, delivery or operator path has changed	Compare the complete process inputs and restore the approved combination and inspection conditions

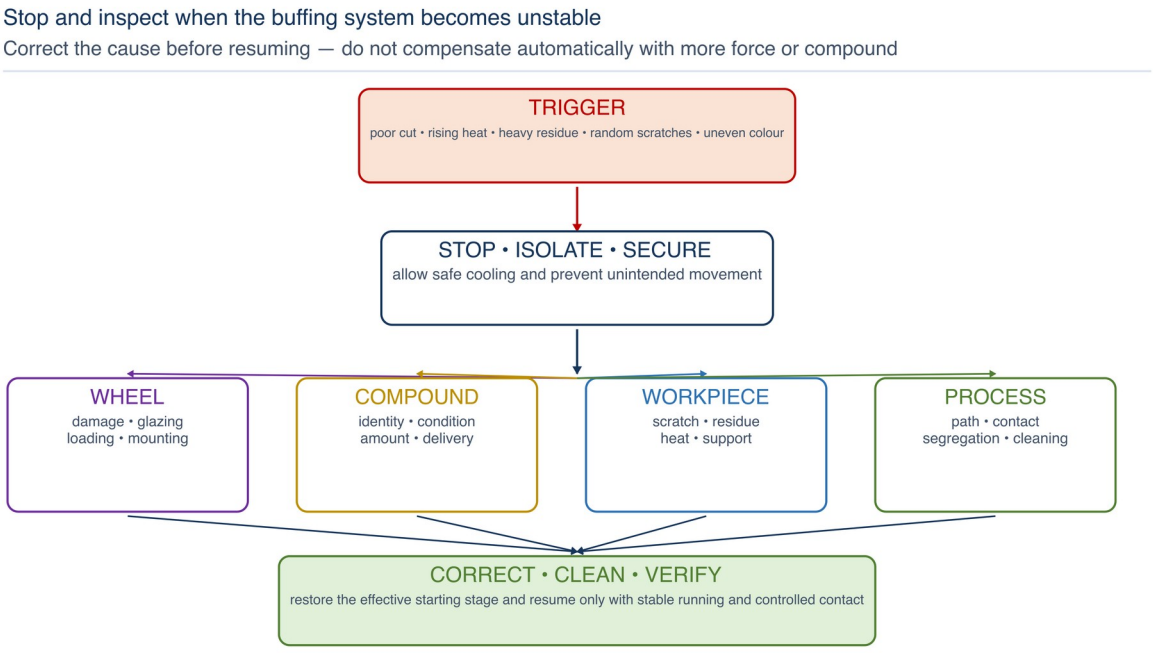

Figure 4. Loading, heat and contamination corrective flow. Poor cut, rising heat, heavy residue, random scratches or uneven colour trigger a stop-and-inspect route before the wheel, compound, starting surface and process path are corrected.

17. Concise safety reminders

- Inspect the wheel, stitching, centre, flanges, spindle, guard, machine and work support before use.
- Confirm wheel direction where marked and never exceed the lowest marked limit in the assembled system.
- Stand clear during start-up, allow the wheel to run without work contact, and stop immediately if vibration or irregular running develops.
- Secure the work and keep hair, clothing, jewellery, loose materials and hands away from rotating wheels and nip points.
- Use effective extraction or containment for compound dust, mist, fibres and metal particles; keep emissions away from the breathing zone. [S152]
- Review the compound and cleaner Safety Data Sheets and apply current Malaysian chemical-risk and exposure controls where relevant. [S153; S160]
- Assess combustible metal dust, lint and compound deposits; control ignition sources and clean the station using a method suitable for the collected material.
- Use suitable eye, face, hearing, respiratory, hand, body and foot protection for the complete task. Gloves must not introduce an entanglement hazard at rotating machinery.
- Isolate energy before mounting, dressing, cleaning, clearing, measuring or maintaining the equipment.
- Follow current site procedures, machine instructions and abrasive-product safety information. [S155]

18. Practical compound-and-buff sequence

522. Identify the substrate, starting scratch pattern, geometry, contamination sensitivity and downstream process.
523. Define whether the stage must cut, cut-and-colour, or colour, and establish the inspection reference.
524. Select the least aggressive compound–wheel pair capable of the required result.
525. Confirm wheel, mounting, machine, guard, marked limits, work support and extraction.
526. Dedicate and identify wheels, compounds and cleaning materials by stage and material family.
527. Clean the part and verify that the pre-buff surface is uniform and free of deep defects.
528. Start the machine from a safe position and confirm stable running before work contact.
529. Apply a small, controlled amount of compound using the intended method.
530. Present the work with stable support, planned wheel travel, progressive movement and controlled overlap.
531. Stop if heat, loading, vibration, heavy residue, grabbing or loss of cut develops; inspect before adjusting.
532. Clean the part fully and inspect the cutting result before changing to the colouring stage.
533. Use a clean dedicated colouring wheel and compound; do not carry cutting debris forward.
534. Remove all residue using a compatible cleaning route and dry as required.
535. Inspect appearance, cleanliness, geometry and any specified functional property separately; then protect the accepted surface and store the wheel and compound against damage or contamination.

SURFACE FINISHING & POLISHING

CHAPTER 030

Stainless-Steel Mirror Polishing

30

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, fabricators, polishers, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: A practical ten-stage route for producing and protecting a mirror-polished stainless-steel surface on accessible sheet, plate, tube, profile and fabricated components.

Core principle — Mirror polishing is an error-removal process. Every stage must remove the preceding scratch family while preserving the intended geometry; brightness alone does not prove completion.

This chapter integrates weld blending, abrasive refinement, compound polishing, final buffing, cleaning, inspection and protection into one controlled route. The exact combination depends on the starting surface, stainless-steel grade and condition, geometry, access, machine and required appearance.

Chapter objectives

After this chapter, the reader should be able to:

- define the required mirror appearance with an agreed reference and viewing conditions;
- plan the route from weld removal to protection without relying on a universal grit sequence;
- preserve flats, edges, radii and transitions while removing defects;
- recognise when a stage is complete before moving to a finer abrasive;
- use compound polishing and final buffing only after adequate preparation;
- clean, inspect and protect the finish without reintroducing scratches or contamination; and
- troubleshoot common mirror-polishing defects from the stage where they originated.

1. Define the mirror finish before starting

“Mirror” is a visual performance description, not a complete process specification. BSSA notes that nominally similar polished finishes can vary between suppliers and that grit designation alone does not fully define the result. ASSDA describes mirror finishes by high reflectivity, a substantially non-directional appearance and clear image formation, while recommending an agreed finished sample for critical work. [S161; S163]

Establish the acceptance basis before the first abrasive touches the part:

- the viewing side and all surfaces included in the finish;
- the required image clarity, uniformity and acceptable local variation;
- the agreed reference sample or first-off part;
- lighting type, intensity and direction;
- viewing distance, angle and part orientation;
- permitted edge softening, waviness, weld witness or local distortion;
- cleanliness and protection condition at final inspection; and
- any separate functional requirement for roughness, cleanability, corrosion service, coating, product contact or dimensional tolerance.

Do not use gloss, reflectivity or roughness as interchangeable terms. A surface may be bright yet retain rounded grinding furrows, waves, haze or isolated deep scratches.

2. Plan the complete ten-stage route

The most economical route begins with the finest stage capable of removing the actual defect without excessive dwell. It then advances only after the current scratch family has been removed. Mirror finishing is a progression from defect removal through increasingly fine preparation to final buffing. [S162; S163; S164]

Stage	Primary purpose	Completion signal	Main risk if rushed
1. Weld removal	Reduce proud weld metal without undercutting the parent surface	Weld crown removed to the planned level; no gouge or heat damage	Low spot, flat spot, blueing or deep coarse lines
2. Profile correction	Restore the intended flat, radius or transition	Reflected straightedge or contour appears continuous	Waves, edge roll-over or visible weld witness
3. Coarse scratch removal	Remove grinding damage and establish a uniform starting pattern	Deepest prior lines and pits are absent	Deep marks carried into every later stage

Stage	Primary purpose	Completion signal	Main risk if rushed
4. Progressive refinement	Replace each scratch family with a finer, uniform pattern	Previous-direction lines disappear under inspection	Mixed scratches, skipped-stage rework
5. Pre-polishing	Produce a fine, even surface suitable for compound	Uniform low-haze surface with protected geometry	Buffing used to chase preparation defects
6. Compound polishing	Remove the fine pre-polish pattern and begin image development	Fine lines removed; reflection becomes even	Heat, residue, waves or isolated compound scratches
7. Final buffing	Develop final colour, lustre and image clarity	Clean, uniform reflected image under agreed conditions	Brightness hides residual furrows or haze
8. Cleaning	Remove compound, abrasive and handling residue	Surface is residue-free without new scratches	False acceptance, staining or downstream interference
9. Inspection	Verify appearance, geometry, cleanliness and specified function	All agreed checks pass independently	Release based on one viewing angle or gloss alone
10. Protection	Prevent damage and contamination through handling and delivery	Suitable clean protection applied and identified	Scratches, adhesive residue, moisture entrapment or imprinting

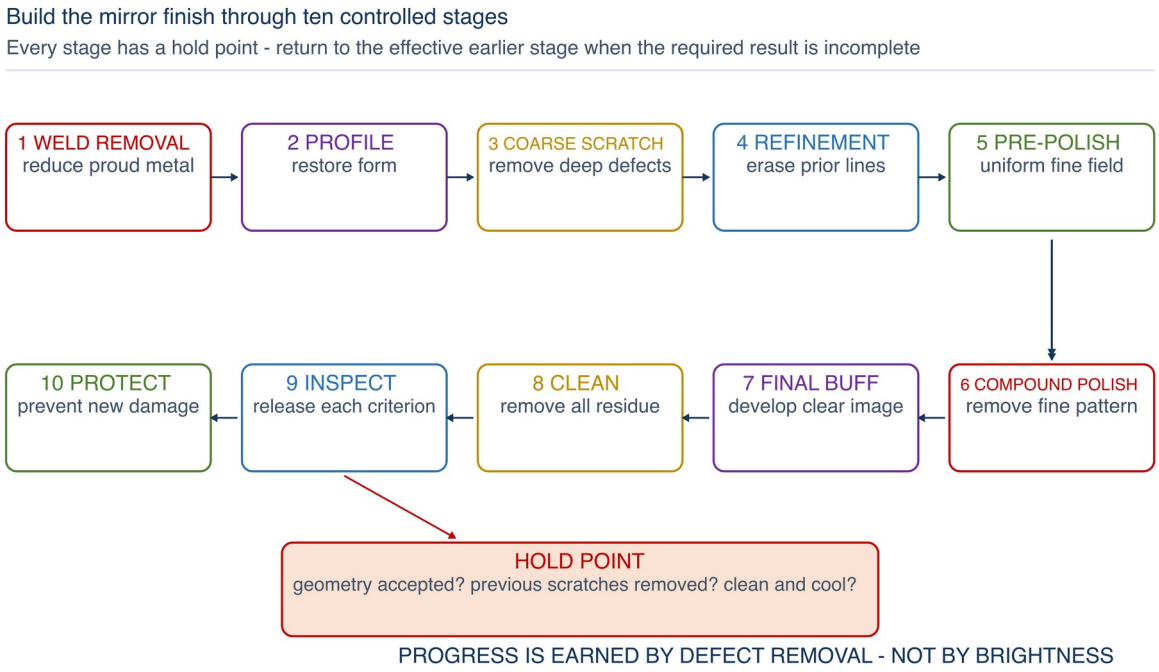


Figure 1. Complete mirror-polishing process flow. Each stage has a hold point. If the required defect or scratch family remains, the route returns to the effective earlier stage rather than applying more pressure at a finer stage.

3. Remove weld metal without creating a hollow

Weld removal is geometry control before it is surface finishing. Support thin fabrications, use stable access and keep the contact path broad enough to blend the weld without dwelling beside it. Work progressively along the joint instead of cutting one local area to final level while neighbouring weld remains proud.

Stop frequently and inspect across the weld. A smooth-looking strip can still be low relative to the parent surface. Use reflection from a straightedge, flexible contour reference or controlled low-angle light to reveal hollows and flats. Protect adjacent edges, corners and formed radii from accidental contact.

Visible weld heat tint and contamination require appropriate post-weld treatment for the service condition. Mechanical finishing may be one part of the restoration route; chemical or electrochemical treatment must follow the applicable process information and workplace controls. [S166]

4. Correct profile before chasing fine scratches

Mirror surfaces reveal small geometric errors because reflected lines bend across waves, flats and softened edges. Correct form while the abrasive still has enough cut to do so efficiently. A later polishing mop can brighten a low spot but cannot restore lost thickness or a crisp transition.

Control profile by separating three tasks:

- **Level:** remove proud material without cutting below the design surface.
- **Blend:** spread the transition so the change in slope is visually continuous.
- **Refine:** replace the correction pattern only after the shape is accepted.

For sheet and broad flats, use backing and a travel pattern that limits local dwell. For tubes and outside curves, follow the radius without creating flats. For inside corners, choose a tool that reaches the feature without rubbing an adjacent face. Inspect from more than one direction before releasing the profile stage.

5. Establish a uniform coarse scratch pattern

The first refinement stage must remove weld-grinding lines, pits, scale remnants, handling damage and other defects that would remain visible through the mirror finish. Begin with the least aggressive abrasive that can remove the deepest relevant defect at a controlled rate. A coarser starting stage may be necessary for severe damage, but it creates a deeper replacement pattern and increases later work.

Do not progress while isolated deep scratches remain. Marking the part with a removable inspection guide can help expose untouched areas, but the marking method must be compatible with stainless steel and the downstream process. Clean the surface before judging the scratch pattern so swarf or residue does not hide defects.

6. Refine scratches by making the previous pattern visible

Successive refinement works only when the new stage removes the preceding pattern. Where geometry allows, change the working direction between stages so residual scratches cross the new pattern and remain visible. ASSDA identifies this direction change as a practical way to monitor removal. [S162]

On tubes, bowls or fixed assemblies where a ninety-degree change is impossible, alter the travel angle, overlap, lighting or inspection orientation enough to distinguish old lines from new ones. Clean the work, tool contact area and fixture between stages. One coarse particle carried forward can create an isolated line that becomes more conspicuous as the surrounding surface brightens.

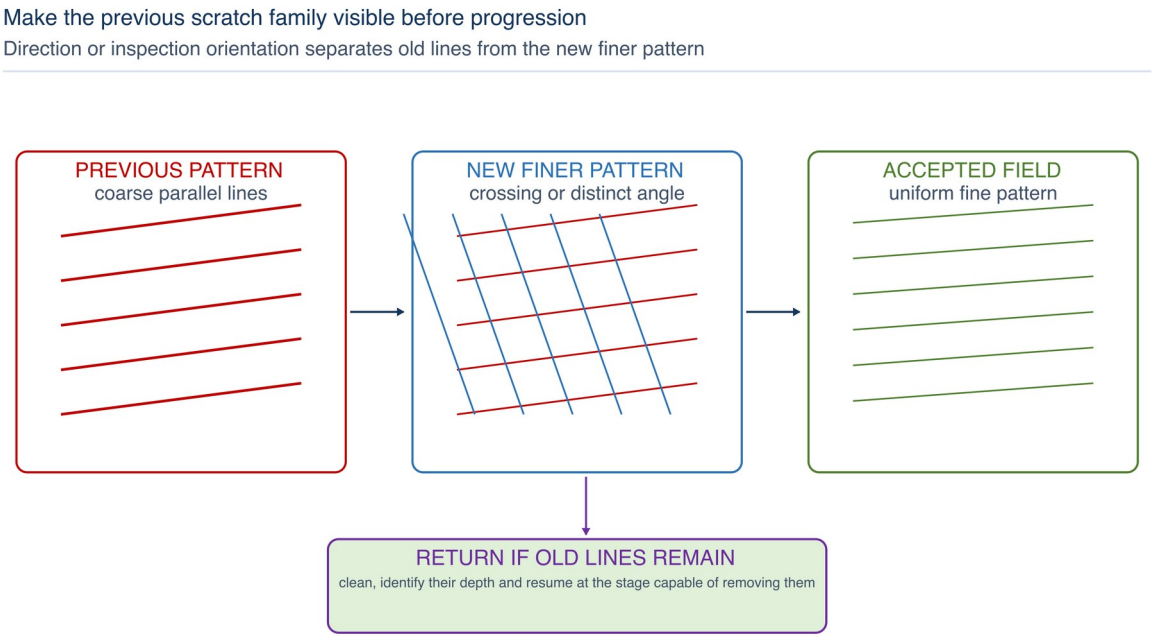


Figure 2. Scratch-erasure and direction logic. A new, finer pattern crosses or otherwise distinguishes the previous pattern. Progress occurs only when the earlier scratch family has disappeared across the complete inspection zone.

7. Control stage size without treating grit numbers as universal

Abrasive grade is only one part of the stage. Grain type, grading system, backing, product construction, contact wheel, wear, speed, pressure, lubricant and workpiece response all affect the scratch produced. Therefore, a numeric sequence from one product family must not be assumed equivalent to another.

Use practical progression rules:

- avoid jumps that leave the next stage unable to remove the previous scratches efficiently;
- replace a worn, contaminated or damaged abrasive rather than relying on unpredictable glazing;
- use stable backing to protect flats and enough conformity to follow curves;
- reduce force if heat rises while useful cut falls;
- keep stage direction, overlap and coverage consistent; and
- confirm the result on a representative area before extending a revised route across the part.

For exact abrasive grade, machine compatibility, marked operating limit and intended use, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

8. Pre-polish to create a buffable surface

Pre-polishing is the bridge between coated or structured abrasives and compound polishing. Its purpose is to leave a fine, uniform surface that the compound–wheel system can complete without excessive pressure or dwell. The surface should show no coarse directional lines, pits, weld witness, local haze bands or embedded debris.

Before release to compound polishing:

- clean the part and surrounding work area;
- inspect under diffuse light for overall uniformity;
- use low-angle light to reveal furrows and waves;
- check edges and transitions for rounding;
- verify the part is cool and dry as required; and
- segregate pre-polishing media from compound-polishing and final-buffing media.

9. Use compound polishing to remove fine preparation lines

Compound polishing is still a cutting stage. Pair the compound with a wheel construction that provides enough cut to remove the pre-polish pattern while protecting the geometry. A firmer stitched cloth or suitable cutting construction may support broad flats and controlled cut; more conformable systems may suit contours. The actual pair must be compatible with the material, machine and required finish. [S151; S154]

Apply a small, controlled amount of compound and maintain progressive movement. Too little active compound can allow glazing and heat to rise; too much can create heavy residue, fling-off and obscured scratches. Clean and inspect before changing to the final buff. Do not carry cutting compound or embedded metal debris into the colouring stage.

10. Final-buff for colour and image clarity

Final buffing develops lustre and image clarity; it removes little material compared with the preceding abrasive stages. ASSDA warns that scratches left from grinding can remain as rounded furrows after buffing. [S163]

Use a clean, dedicated colouring wheel and compatible compound. Maintain light, stable contact and a planned travel path. Watch the reflected image rather than the shine alone: straight reference lines should remain straight across flats and change smoothly across intended curves. If a dark line, furrow or wave remains, stop and return to the stage capable of removing it.

Before condition	Corrective route	Acceptable after condition	What a false improvement looks like
Proud weld with coarse grinding marks	Level weld, restore profile, then refine	Continuous profile with no visible weld crown or hollow	Bright strip beside a remaining low spot
Uniform fine preparation lines	Compound-polish with a controlled cutting pair	Lines removed and reflection beginning to resolve	Gloss rises but parallel furrows remain
Fine haze after cutting compound	Clean, inspect and final-buff with a dedicated colouring pair	Even colour and clear image under agreed light	Residue smears into temporary apparent gloss

Before condition	Corrective route	Acceptable after condition	What a false improvement looks like
Isolated deep scratch in a bright field	Return locally to the effective abrasive stage and re-progress a wide blend zone	Scratch removed without halo, dip or direction mismatch	Narrow over-polished patch around the scratch
Clear finish with handling marks	Compatible non-scratching clean and protected handling	Clean, dry, mark-free surface ready for protection	Cleaner residue or cloth marks visible at low angle

11. Clean without scratching the finished surface

Mirror-polished stainless steel makes dust, fingerprints, cloth marks and cleaner residue highly visible. Remove compound with a method compatible with the substrate, compound and next operation. Start with the least aggressive effective method; use clean, non-scratching wipes or brushes and prevent dirty cleaning media from returning abrasive particles to the surface.

Clean seams, holes, recesses and fixture-contact areas. If a chemical cleaner is needed, confirm its material compatibility, rinsing, drying, ventilation, storage and waste controls. Never use carbon-steel wool or a pad previously used on carbon steel. [S125; S161; S165]

12. Inspect reflection, surface and geometry separately

A reliable mirror-finish inspection uses more than one lighting condition and more than one viewing direction. A clear image can reveal waves, while low-angle light reveals furrows, haze and residue. Diffuse light helps judge overall uniformity. An agreed reference sample anchors the acceptance decision where appearance is critical. [S161; S163]

Inspection mode	Reveals	Practical method	Do not confuse with
Reflected straight line or grid	Waves, flats, hollows and abrupt transitions	View a stable high-contrast line at several positions and angles	Surface brightness
Low-angle directional light	Fine scratches, furrows, haze and wipe marks	Sweep light across and along the last working directions	Dirt or temporary compound film
Diffuse broad light	Overall colour, cloudiness and local patching	Compare the complete part with the agreed reference	One favourable viewing angle
Edge and contour check	Softened edges, changed radii and blend halos	Inspect silhouette and reflection across transitions	Acceptable deliberate rounding
Cleanliness check	Compound in recesses, fingerprints, dust and cleaner residue	Inspect after compatible cleaning with clean gloves and lighting	Base-metal inclusion or pit
Specified measurement	Roughness, dimensions or other functional criterion	Use the specified instrument, location and acceptance rule	Visual mirror quality alone

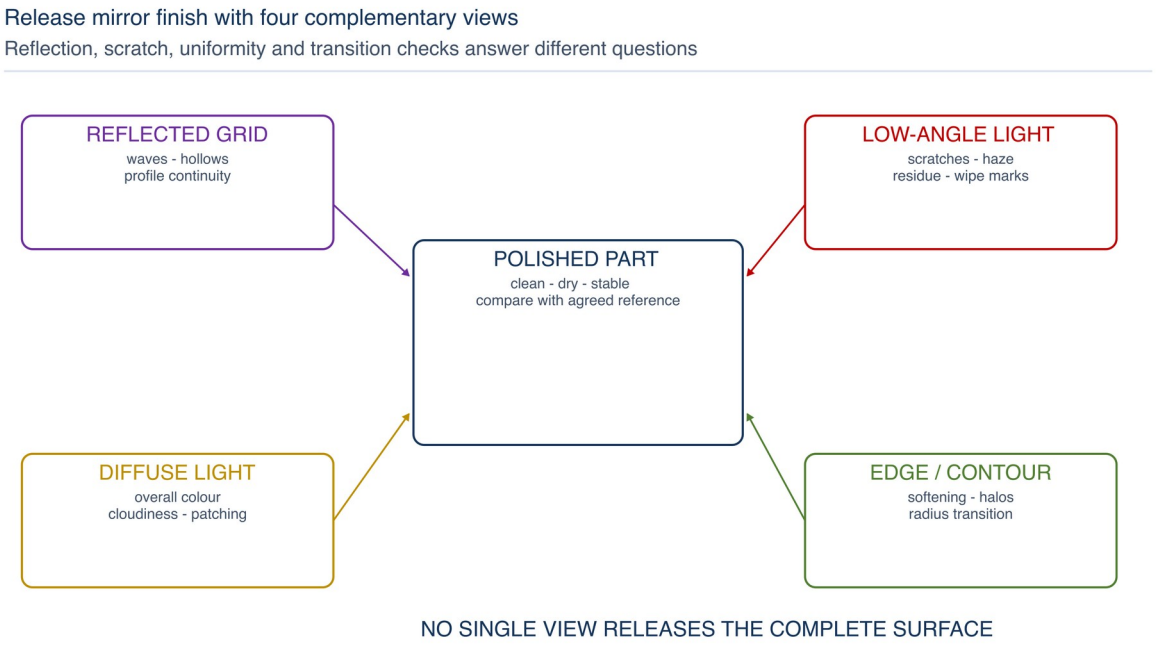


Figure 3. Mirror-finish inspection grid. Straight reflected lines expose geometry, low-angle light exposes scratches and residue, diffuse light exposes uniformity, and edge views confirm transitions. No single view releases the part.

13. Protect the accepted finish immediately

Highly polished stainless steel is susceptible to scratches, fingerprints, embedded particles and imprinting. Move the accepted part to a clean handling zone. Use clean gloves or non-marking handling aids, separate it from carbon-steel work and prevent finished faces from rubbing together.

Interleave parts with a clean, non-abrasive material that will not transfer a pattern. Where strippable film is suitable, confirm film compatibility, application cleanliness, storage conditions, service life, removal method and exposure limitations. IMOA notes that protective films can reduce scratching and contamination but can also deteriorate or leave adhesive if used outside their intended conditions. [S165]

Do not trap polishing residue, moisture or salts beneath protection. Identify the protected face and any removal instructions. Inspect again after packaging if the operation could have introduced pressure marks, trapped debris or edge damage.

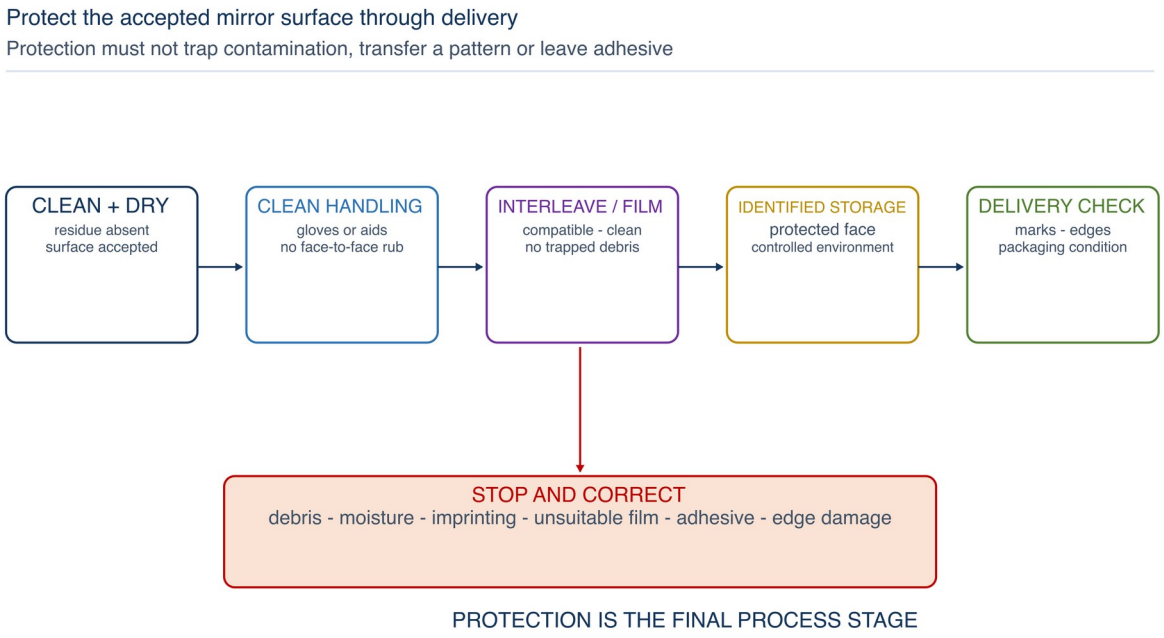


Figure 4. Protection flow after acceptance. A clean, dry and accepted surface moves through controlled handling, compatible interleaving or film, identified storage and a final delivery check.

14. Control contamination throughout the route

Use abrasives, wheels, compounds, fixtures, cleaning media and handling aids dedicated to stainless steel where iron contamination matters. Once an abrasive or wheel has contacted carbon steel, do not return it to stainless-steel mirror work. Keep grinding sparks and dust from nearby carbon-steel operations away from the polishing area. [S161; S165]

Segregate coarse and fine stages as well as material families. Store compounds covered and identified. Clean the machine, guards, rests and surrounding area before final polishing. Random deep lines in an otherwise refined surface often indicate contaminated media, embedded swarf or dirty cleaning materials rather than an insufficiently fine product.

15. Manage heat and distortion at every stage

Stainless steel can accumulate local heat during grinding and polishing. Thin sheet, edges and small contact zones are particularly sensitive. Heat can cause distortion, heat tint, smearing, compound baking and unpredictable scratch behaviour.

Control heat by keeping the abrasive cutting effectively, using appropriate contact support, moving progressively, limiting dwell and allowing the part and tool to cool when required. Stop if temperature rises while cut falls. Inspect for loading, glazing, excessive pressure, inadequate compound, contaminated media, poor support or an oversized contact zone before resuming.

16. Troubleshooting mirror-polishing defects

Symptom	Likely system cause	Practical correction
Deep line remains after several fine stages	Earlier scratch not removed; contaminated abrasive or cleaning media	Return to the effective earlier stage, clean the system and re-progress over a broad blend zone
Surface is bright but image is distorted	Profile error, local dwell, soft support or edge roll-over	Restore geometry with controlled support before repeating refinement
Parallel furrows remain after final buff	Pre-polish or cutting-compound stage incomplete	Stop buffing and return to the stage that can remove the furrows
Cloudy or patchy reflection	Inconsistent starting pattern, wheel condition, compound delivery, overlap or cleaning	Standardise the entering surface and path; clean fully and inspect under diffuse light
Random scratches appear late	Coarse particle, metal debris, contaminated wheel, fixture or wipe	Isolate and replace contaminated items; clean the area and rework from the scratch depth

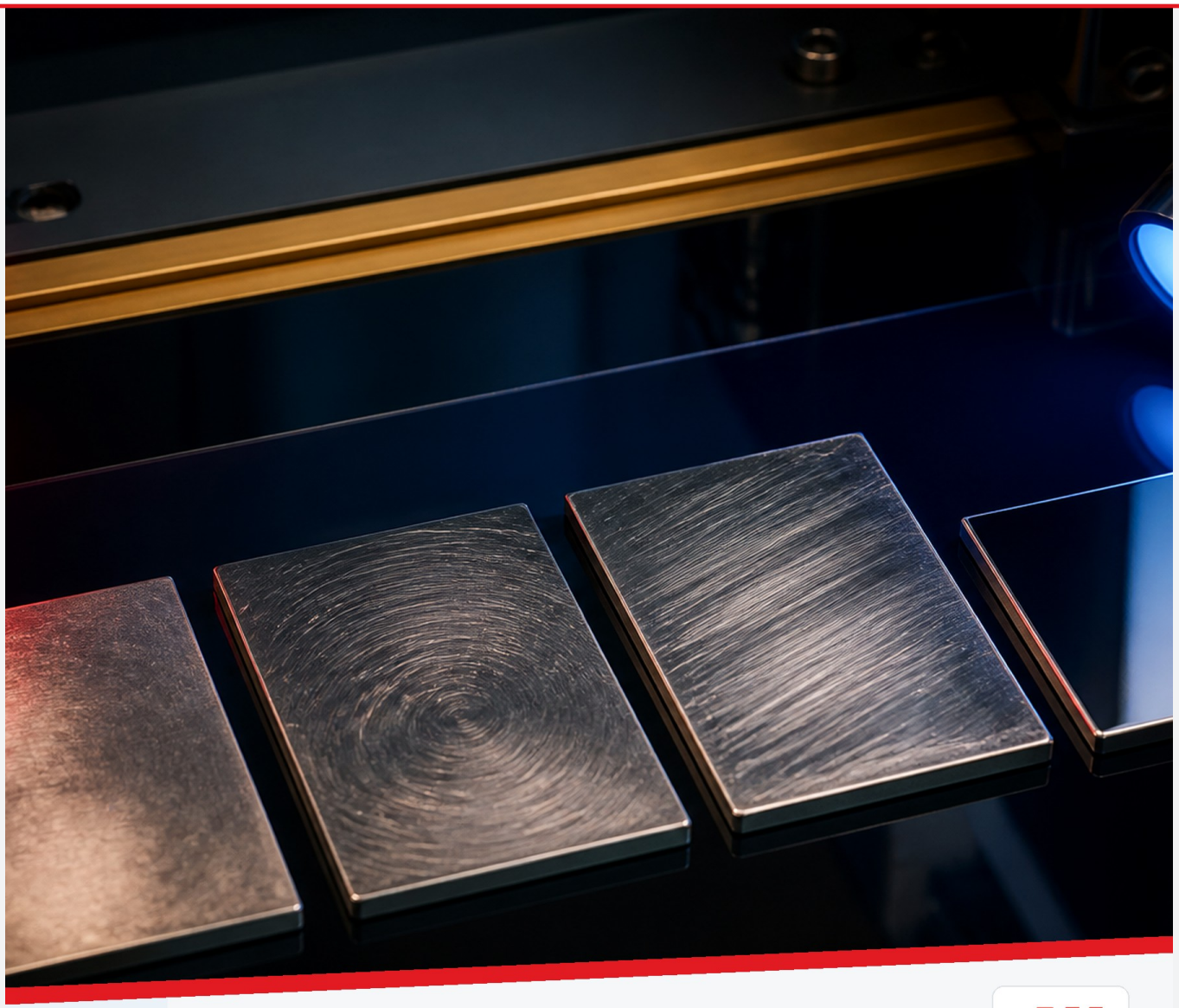
Symptom	Likely system cause	Practical correction
Part becomes hot or discoloured	Excess dwell or pressure, rubbing, loading, poor support or stage mismatch	Stop and cool safely; restore effective cut, support and movement
Edge becomes rounded	Excess wrap, soft support or repeated local contact	Use firmer support, protect the transition and widen the blend area
Compound smears or remains in seams	Over-application, heat-baked carrier or inadequate access	Reduce and stabilise application; use a compatible cleaning route with recess access
Finish changes between batches	Starting surface, abrasive condition, compound, wheel wear, path or inspection changed	Compare the complete process inputs with the approved reference and restore the controlled combination
Protection leaves marks or adhesive	Trapped debris, unsuitable interleaf or film used beyond its limits	Remove by the compatible method, re-clean and use validated protection conditions

17. Concise safety reminders

- Inspect abrasives, wheels, compounds, machine, guards, mounting, work support and extraction before use.
- Confirm compatibility and never exceed the lowest marked operating limit in the assembled system.
- Secure the work and keep hair, clothing, jewellery, loose material and hands away from rotating contact and nip points.
- Stand clear during start-up and stop immediately if vibration, irregular running or product damage develops.
- Control grinding dust, polishing debris, wheel fibres, compound particles and cleaning vapour at source. [S152; S153; S160]
- Review compound and cleaner Safety Data Sheets and apply current Malaysian chemical-risk controls.
- Control combustible lint, metal dust and compound deposits; keep ignition sources away and clean using a method suitable for the collected material.
- Use suitable eye, face, hearing, respiratory, hand, body and foot protection for the complete task. Gloves must not introduce an entanglement hazard at rotating machinery.
- Isolate energy before changing, mounting, dressing, cleaning, clearing or maintaining equipment.
- Follow current site procedures, machine instructions and abrasive-product safety information. [S155]

18. Practical mirror-polishing sequence

536. Confirm the material, component geometry, service condition and agreed mirror-finish reference.
537. Identify weld crown, heat tint, pits, coarse scratches, distortion and contamination before selecting the starting stage.
538. Secure and support the work; establish safe access, extraction and handling controls.
539. Remove proud weld metal without cutting below the parent surface.
540. Correct the profile and approve flats, radii, edges and transitions before fine refinement.
541. Establish a uniform scratch pattern that removes the deepest relevant defects.
542. Progress through finer stages, changing or distinguishing direction and cleaning between stages.
543. Release pre-polishing only when the surface is uniformly fine, cool, clean and free from coarse lines.
544. Compound-polish with a compatible cutting pair until the preparation pattern is removed.
545. Clean and inspect before changing to a dedicated final-buffing pair.
546. Final-buff for even colour and image clarity without chasing deep defects.
547. Remove all residue using a compatible non-scratching method and dry as required.
548. Inspect reflection, scratches, geometry, cleanliness and any specified measurement independently under agreed conditions.
549. Protect the accepted surface immediately with clean handling, compatible interleaving or film and identified storage.



SURFACE FINISHING & POLISHING

CHAPTER 031

Polishing Defects

31

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, QA/QC personnel, fabricators, polishers, maintenance teams, safety personnel, procurement staff and technical sales personnel

Scope: A practical method for diagnosing and correcting scratches, haze, swirl marks, compound marks, overheating, orange peel, uneven gloss, contamination, edge rounding and visible weld shadow on polished stainless-steel components.

Core principle — Do not polish a symptom blindly. Clean and inspect the surface, identify whether the defect is inherited, introduced, process-driven or limited by geometry or material condition, then return only to the stage capable of correcting it.

Polishing defects often become most visible at the end of the route, but many originate much earlier. Final buffing can brighten a surface without removing deep scratches, restoring lost geometry or eliminating inherent weld contrast. Effective correction therefore begins with diagnosis rather than additional dwell.

Chapter objectives

After this chapter, the reader should be able to:

- classify the ten common defect families by appearance and likely stage of origin;
- distinguish residue and temporary film from damage in the metal surface;
- select the earliest effective corrective stage without repeating the complete route unnecessarily;
- recognise when further polishing will worsen heat, orange peel, rounding or local distortion;
- diagnose visible weld shadow as geometry, texture, colour or material contrast;
- verify a correction under controlled viewing conditions; and
- prevent recurrence through clean media, stable technique and stage-by-stage inspection.

1. Diagnose before correcting

Start with a clean, dry and safely supported component. Remove loose dust and compatible compound residue without introducing new scratches. Inspect the same area under diffuse light, low-angle directional light and a reflected straight line or grid. Rotate the part or light so a true surface feature remains attached to the surface while temporary glare changes with the viewing direction. [S161; S163]

Mark the boundaries of the defect using a surface-compatible method away from the finished face. Observe its shape, direction, depth, width, repetition and relationship to the tool path, weld, edge, fixture or handling route. A defect that follows the previous abrasive direction is diagnosed differently from a circular swirl, isolated deep line, broad cloudy patch or reflected wave.

Establish the first process stage at which the feature appeared. If it was not observed earlier, inspect the media, compound, cleaning materials and work area used immediately before discovery. Struers emphasises that identifying when an artefact first occurs is central to correcting the method rather than repeating it. [S168]

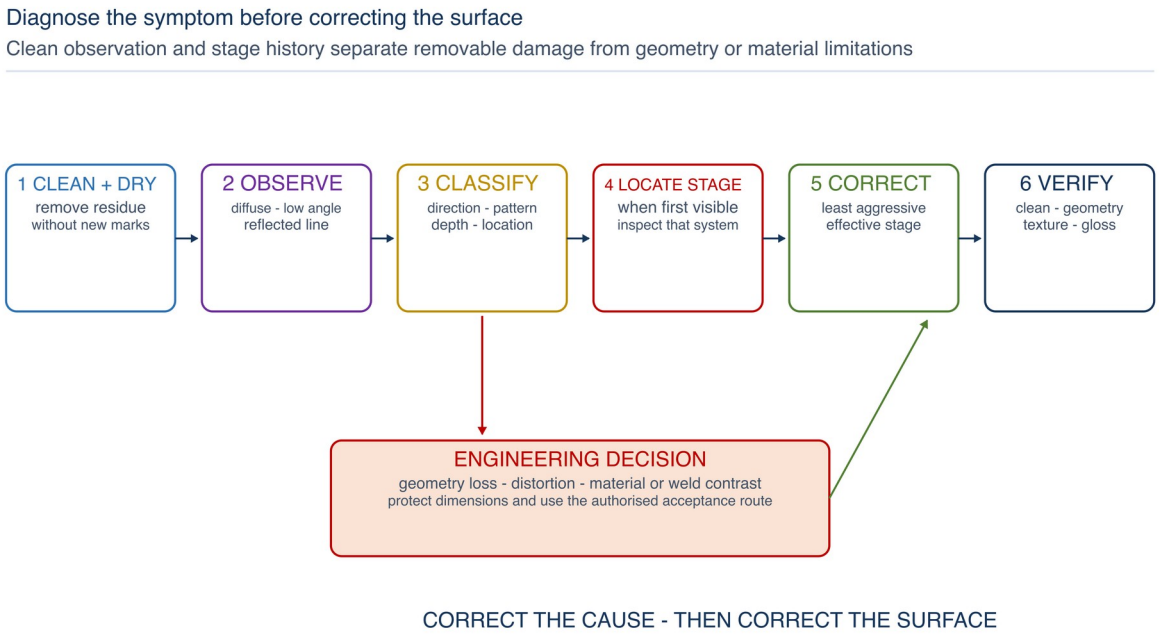

Figure 1. Diagnostic control chain. A polishing defect is cleaned, observed under complementary views, classified, located by depth and stage, corrected at the effective stage and independently verified. Geometry or material limitations move to an engineering decision rather than further polishing.

2. Classify the ten visible symptoms

Use the visible symptom as a starting point, not a verdict. Several causes can produce a similar appearance, and one cause can create more than one symptom. Cleanliness, defect direction, reflected geometry and the stage where the mark first appeared provide the strongest initial separation.

Visible symptom	Typical appearance	Confirming observation	First corrective direction
Remaining scratches	Straight or directional lines deeper than the final pattern	Persist after cleaning and align with an earlier stage	Return to the stage capable of removing their depth
Haze	Cloudy or frosted area with reduced image clarity	Remains under diffuse light after residue removal	Separate fine scratch field from film, heat or material texture
Swirl marks	Circular arcs, loops or hologram-like bands	Move in emphasis as the light angle changes and follow rotary travel	Correct the polishing pair, path and cleanliness
Compound marks	Smears, drag lines, patches or dark deposits	Change or lift during compatible cleaning	Stabilise compound delivery, heat and cleaning
Local overheating	Tint, smearing, baked residue, waviness or local dullness	Concentrated at dwell zones, edges or restricted access	Stop, cool and correct the complete contact system
Orange peel	Random smooth hills and valleys across a broad area	Shiny surface lacks smooth reflected geometry	Stop fine polishing and re-establish a controlled surface
Uneven gloss	Alternating bright and dull zones	Pattern follows coverage, wheel condition or starting finish	Standardise the entering surface and process path
Contamination	Isolated deep scratch, embedded speck, dark streak or rust bloom	Reappears after cleaning or traces to dirty media or fixtures	Isolate the source, clean and restore the affected surface
Edge rounding	Softened corner, changed radius or reflection roll-over	Silhouette and reflected line depart from the intended edge	Restore geometry only within dimensional allowance
Visible weld shadow	Halo, line, wave, colour or texture contrast at the weld	Remains centred on the weld after uniform polishing	Separate profile, texture, oxide and inherent weld contrast

3. Correct remaining scratches from their true depth

A remaining scratch is a groove that has not been removed by the later process. It may be an inherited grinding line, a skipped-stage line, an isolated contaminant scratch or a new handling mark. ASSDA notes that the next stage should not begin until scratches from the previous stage have been removed; final buffing removes little material and can round deep lines without eliminating them. [S162; S163]

Clean the area and inspect across the scratch. If a fingernail or stylus check is appropriate to the part and workplace method, use it only away from a critical accepted face and without creating another mark. More reliably, compare the line under low-angle light and magnification. A broad rounded furrow often indicates an old coarse line carried through later stages. A narrow sharp line appearing late often points to contamination or handling.

Return to the least aggressive earlier stage that can remove the scratch efficiently across a sufficiently broad blend zone. Do not polish only the line into a narrow bright trench. Re-establish one uniform scratch family, clean, inspect and then progress again through the controlled sequence.

4. Separate haze from temporary film

Haze is reduced image clarity over a patch or broad zone. It can arise from unresolved fine scratches, swirl marks, inconsistent pre-polish, local rubbing, dried compound, cleaner residue or a surface texture that polishing cannot level uniformly. Uddeholm describes haze as lower-gloss areas with a silvery frosted appearance; ASSDA warns that brilliant reflectance does not necessarily produce a sharp image. [S167; S163]

First remove residue using a compatible non-scratching method. Inspect the dry surface under diffuse and low-angle light. If the haze disappears, correct cleaning, compound quantity or residue control. If a fine directional pattern remains, return to the stage that can remove it. If the surface is bright but reflected lines remain blurred or wavy, examine profile, orange peel or material response rather than applying more final buff.

Do not judge haze while fresh compound is still filling fine lines. In polishing systems, film can temporarily mask scratches or swirls and allow cloudiness to reappear after cleaning. [S169]

5. Read swirl marks as a path signature

Swirl marks are fine arcs, loops or hologram-like bands created by the interaction of a rotating tool, polishing medium, travel path and surface. They differ from random contamination scratches because they repeat a recognisable movement pattern. Their visibility often changes strongly with light angle.

Check whether the swirl appeared after compound polishing or final buffing. Inspect the wheel or pad for embedded particles, dried compound, uneven wear, hard seams, damaged edges or cross-use between stages. Confirm the work was clean before the stage and that the tool remained stable rather than tilted onto a narrow contact zone.

Correct swirls with a clean, dedicated and compatible final-polishing system that has enough controlled cut to remove the mark rather than merely fill it. Standardise overlap and coverage; avoid repeated local chasing. Where the swirl is deeper than the final system can remove, return to the preceding cutting-compound or fine-abrasive stage. [S169; S164]

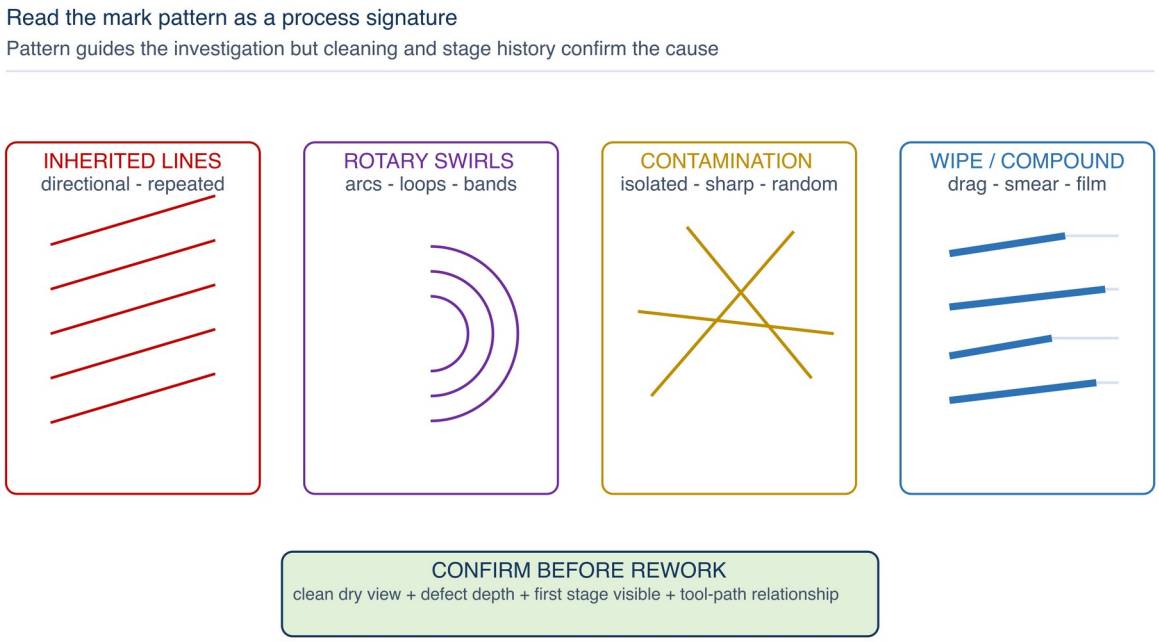

Figure 2. Mark-signature map. Directional inherited lines, rotary swirls, random contamination scratches and wipe or compound drag marks present different patterns. The pattern guides diagnosis but must be confirmed by cleaning and stage history.

6. Remove compound marks without creating cleaner marks

Compound marks include smears, dark streaks, drag lines, clumps in recesses and patchy carrier film. They can result from excessive application, poor distribution, rising heat, dried material, an overloaded wheel, inaccessible seams or unsuitable cleaning media. Compound colour alone does not identify its cutting function or compatibility.

Remove the residue with a method compatible with the stainless grade, compound, next operation and service condition. Use clean non-scratching wipes or brushes and change them before they redeposit abrasive particles. Clean seams, holes, fixture-contact areas and edges, then dry and inspect under low-angle light. [S125; S165]

Check after cleaning	If the mark changes	If the mark remains	Corrective meaning
Gentle compatible wipe	Smear transfers or lightens	Fixed line remains	Residue versus surface scratch
Diffuse-light inspection	Cloudiness clears	Broad haze remains	Film versus fine texture
Low-angle light	Wipe marks disappear	Furrows or swirls remain	Cleaning trace versus polishing defect
Clean-cloth repeat	Cloth stays clean	Residue continues to transfer	Surface ready versus trapped compound
Recess inspection	Deposit lifts from seam	Dark line remains in metal	Compound pocket versus contamination or pit
Dry-time recheck	Gloss remains stable	Haze returns	Stable finish versus filled scratch field

7. Stop local overheating before correction

Local overheating can show as heat tint, smearing, baked compound, rapid loading, a dull or bright patch, waviness or distortion. Thin sheet, edges, small contact zones and restricted areas are especially sensitive. Heat that rises while useful cut falls is a process warning, not a reason to press harder.

Stop and allow the part and tool to cool safely. Inspect abrasive or wheel loading, glaze, compound delivery, support firmness, contact width, pressure, travel, dwell, extraction and access. Replace damaged or contaminated consumables and restore effective cutting action before resuming. [S151; S154]

Visible weld heat tint is an oxide condition and may require restoration appropriate to the stainless grade and service. Mechanical brightening alone is not assumed to satisfy every post-weld corrosion requirement. [S166]

8. Treat orange peel as a stop condition

Orange peel is a broad irregular texture of smooth hills and valleys. The surface may be shiny yet fail to reflect straight lines cleanly. It is different from isolated pits and from large-scale distortion, although the three can coexist.

Process-induced orange peel is associated with over-polishing, particularly prolonged fine polishing, excessive local pressure and a change from a firmer cutting stage to a very soft conformable tool. Uddeholm advises stopping when orange peel appears because additional pressure and dwell can worsen the surface. The defective layer is re-established with the last effective pre-polishing or grinding stage and then repolished with a shorter, cleaner and more stable route. [S167]

Material hardness, grain structure, inclusions, casting condition, heavy cold work or weld microstructure can also limit the uniformity achievable. ASSDA notes that large or variable microstructures, including some welds, may not produce clear image formation or uniform lustre. [S163]

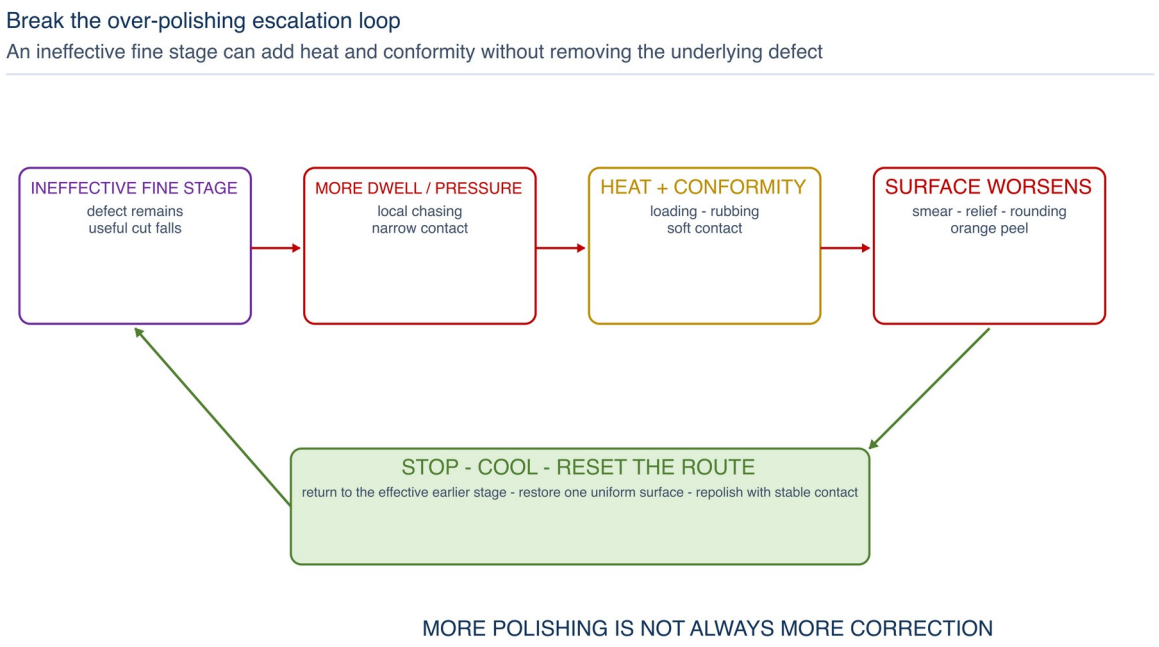

Figure 3. Over-polishing stop logic. More dwell or pressure on an ineffective fine stage raises heat and conformity, increasing smearing, relief, edge rounding and orange peel. The controlled response is to stop, restore the surface at an effective earlier stage and repolish with stable contact.

9. Restore uneven gloss from the entering surface

Uneven gloss appears as adjacent bright and dull zones, bands or patches. Common system causes include a non-uniform starting scratch pattern, inconsistent overlap, changing contact pressure, variable compound delivery, wheel wear, contamination, poor access, part temperature or inspection under changing light.

Clean and inspect the complete area rather than the brightest patch. Compare each zone with the same reference under the same lighting, distance and orientation. If the zones retain different scratch families, return to the earliest stage required to make the entering surface uniform. If the scratch field is uniform but gloss varies, inspect the compound–wheel pair, wheel condition, path and cleaning.

Blend across a controlled zone so the correction does not create a visible island. On large flats, support and travel must prevent local waviness that can appear as gloss variation even when the microtexture is similar.

10. Remove contamination at its source

Contamination may produce isolated scratches, embedded specks, black streaks, rust bloom, residue or recurring marks after cleaning. Coarse abrasive carried into a fine stage is a common source of deep late scratches. Carbon-steel contact can introduce iron contamination that later rusts and stains the stainless surface. [S161; S165]

Quarantine the suspect abrasive, wheel, compound, fixture, brush, wipe and handling aid. Clean the machine, guards, rests and surrounding area before introducing fresh fine-stage media. Keep stainless-steel tools and cleaning materials segregated where iron contamination matters.

If staining or embedded contamination is suspected, use a restoration method compatible with the finish and service condition. Do not repeatedly buff a rust bloom until its source is known. Chemical cleaning, pickling or passivation must follow the applicable product information, workplace controls and surface-finish requirements because some treatments can alter a mirror appearance. [S125; S166]

11. Protect edges from rounding and roll-over

Edge rounding occurs when a compliant abrasive or polishing wheel wraps around an edge and removes material from the face and side. Excess dwell, pressure, repeated local contact, a soft support and narrow blend zones accelerate the effect. Struers identifies resilient polishing surfaces and unnecessarily long polishing times as contributors to edge rounding in prepared metal specimens. [S168]

Inspect the silhouette and a reflected straight line across the edge. A glossy edge can still be dimensionally wrong. Once metal has been removed, further polishing cannot restore the original corner. Re-establish geometry only where the drawing, tolerance and remaining material allow it; otherwise route the component for the appropriate disposition.

Prevent recurrence with firmer support, protected transitions, planned travel off the edge, shorter contact and a blend width that does not concentrate work at the corner.

12. Diagnose visible weld shadow by layer

A visible weld shadow can be a reflected wave from distortion or a low blend, a texture halo from a different abrasive history, residual heat tint or oxide, contamination, or a colour and lustre contrast associated with the weld metal and heat-affected zone. These conditions require different responses.

Use a reflected grid first to check geometry. If the line bends across the weld, correct profile only within the dimensional and fabrication limits; polishing cannot remove distortion without changing shape. TWI explains that local weld heating and cooling create expansion, contraction and distortion, with stainless steel particularly sensitive to these effects. [S082; S083]

If geometry is continuous, compare scratch texture and cleanliness. Restore a uniform pattern across a broad blend zone if the weld area received a different abrasive route. Address heat tint and post-weld contamination using the applicable restoration process. If colour or lustre contrast remains after geometry, texture and cleanliness are controlled, recognise that the weld may remain visible. BSSA notes that a flushed and polished weld can retain slight colour or texture contrast, while ASSDA notes that weld microstructure may limit uniform mirror appearance. [S170; S163]

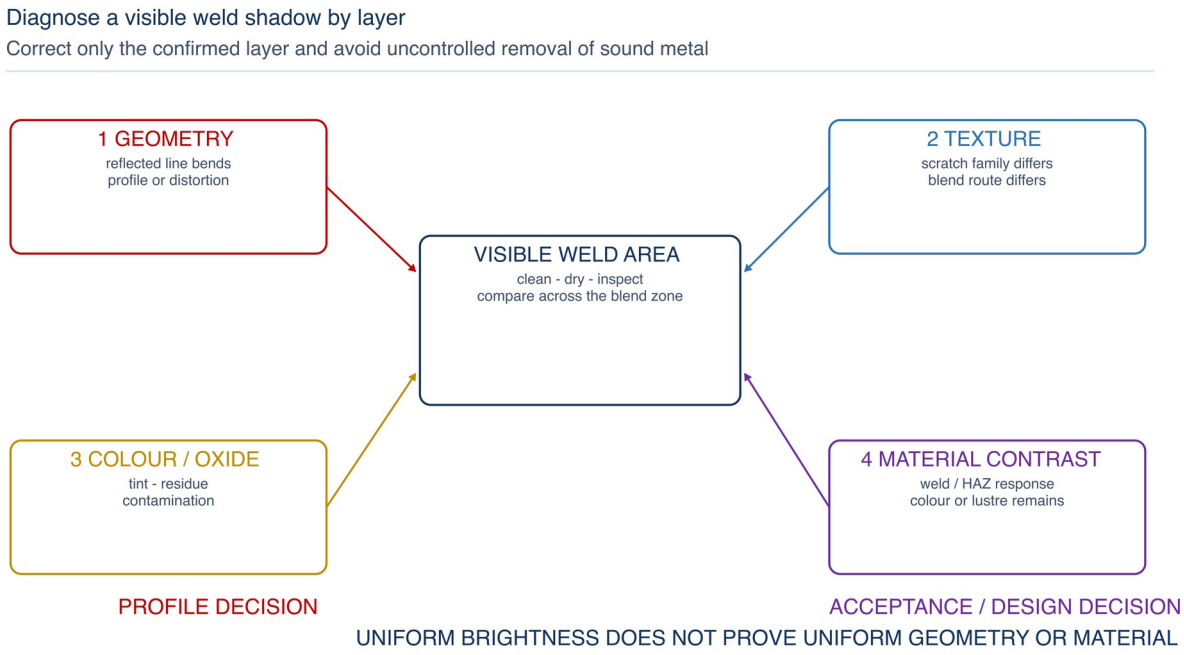

Figure 4. Weld-shadow layer diagnosis. Reflected geometry, scratch texture, colour or oxide and weld-material contrast are checked separately. Only the applicable layer is corrected; inherent contrast is not chased by uncontrolled grinding.

13. Select the corrective stage and blend width

The correction stage must have enough cut to remove the defect while preserving geometry. Starting too fine wastes time and adds heat; starting too coarse creates unnecessary rework. Test on a representative area or sample when the route changes.

Defect depth or condition	Effective starting level	Blend-zone principle	Release signal
Surface film or loose residue	Compatible cleaning	Clean beyond the visible boundary	Dry surface remains mark-free
Fine swirls or compound haze	Final polish or colouring stage with controlled cut	Cover the complete affected light pattern	Swirls absent under changing light
Fine preparation lines	Cutting compound or pre-polish stage	Rework a broad uniform zone	One fine field with no coarse lines
Deep scratch or weld-grinding furrow	Earlier abrasive refinement	Widen until no trench or halo remains	Defect removed and profile continuous
Geometry loss, distortion or inherent weld contrast	Engineering or fabrication decision	Do not expand removal without authority	Accepted disposition or revised part

For exact abrasive grade, compound, wheel construction, machine compatibility, marked operating limit and intended use, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

14. Inspect with complementary views

No single light or measurement releases every polishing defect. Use a clean reference surface or first-off part and keep viewing conditions stable for critical appearance work. [S161; S163]

Inspection mode	Best at revealing	Common false conclusion	Control point
Reflected straight line or grid	Waves, hollows, weld shadow and edge roll-over	Brightness proves flatness	Move the reflection across the complete area
Low-angle directional light	Scratches, swirls, haze, residue and wipe marks	One favourable angle is sufficient	Sweep along and across the process direction

Inspection mode	Best at revealing	Common false conclusion	Control point
Diffuse broad light	Uneven gloss, cloudiness and colour variation	Local shine represents the whole part	Compare complete zones under the same light
Magnified clean view	Embedded grit, pits, compound pockets and line depth	Every dark point is contamination	Clean first and compare at more than one angle
Profile or dimensional check	Edge loss, low weld blend and distortion	A smooth surface is within tolerance	Use the specified reference and acceptance rule
Time-delayed clean recheck	Returning haze, residue bleed and protection marks	Fresh compound film is final appearance	Reinspect dry before protection and delivery

15. Prevent recurrence through stage control

Prevention is faster than late correction. Begin each stage with a defined entering surface and a clean dedicated system. Record the abrasive or wheel family, compound function, stage order, work support, travel pattern and inspection method used for the accepted result. The record should identify the controlled combination without turning a process example into a universal setting.

Clean the work, tool contact area, fixture and surrounding zone between stages. Distinguish stage direction or inspection orientation so earlier lines remain visible until removed. Retire loaded, glazed, damaged or contaminated media rather than compensating with pressure. Separate coarse and fine work areas where practical.

Release each stage for geometry, scratch removal, cleanliness and temperature before moving finer. Final brightness is not a substitute for these hold points.

16. Troubleshoot corrections that do not hold

Symptom after correction	Likely reason	Next action
Scratch returns after final buff	Compound filled but did not remove the groove	Clean and return to the stage with adequate cut
Haze reappears after standing	Residue or film masked fine scratches	Re-clean, inspect dry and correct the scratch field
Swirls change but remain	Final pair or path is still introducing marks	Replace contaminated items and stabilise coverage
Compound smear persists in seams	Excess application, heat or inaccessible cleaning	Reduce delivery and use a compatible recess-cleaning method
Hot patch becomes brighter but larger	Extra dwell is increasing heat and local removal	Stop, cool and correct loading, support and movement
Orange peel worsens	Fine polishing continues after the stop condition	Re-establish the surface at the last effective earlier stage
Gloss remains patchy	Entering surface or contact system is inconsistent	Standardise the scratch field, wheel condition and path
New isolated scratches appear	Coarse particle or dirty handling item remains in the route	Quarantine, clean and replace the source before rework
Edge becomes progressively softer	Compliant media continues to wrap the transition	Use firmer support and shorter controlled contact
Weld halo remains after uniform texture	Geometry, oxide or inherent weld contrast was misclassified	Diagnose each weld layer and avoid uncontrolled removal

17. Concise safety reminders

- Inspect abrasives, wheels, compounds, machine, guards, mounting, work support and extraction before use.
- Confirm compatibility and never exceed the lowest marked operating limit in the assembled system.
- Secure the work and keep hair, clothing, jewellery, loose material and hands away from rotating contact and nip points.
- Stop immediately if vibration, irregular running, product damage, rapid heating, smoke or unexpected discolouration develops.
- Control grinding dust, polishing debris, wheel fibres, compound particles and cleaning vapour at source. [S152; S153; S160]
- Review compound and cleaner Safety Data Sheets and apply current Malaysian chemical-risk controls.

- Keep ignition sources away from combustible lint, metal dust and compound deposits; clean using a method suitable for the collected material.
- Use suitable eye, face, hearing, respiratory, hand, body and foot protection. Gloves must not introduce an entanglement hazard at rotating machinery.
- Isolate energy before changing, mounting, dressing, cleaning, clearing or maintaining equipment.
- Follow current site procedures, machine instructions and abrasive-product safety information. [S155]

18. Practical defect-correction sequence

550. Stop the process and secure the part when a defect is found.
551. Clean and dry the surface with a compatible non-scratching method.
552. Inspect under diffuse, low-angle and reflected-line views.
553. Mark the defect boundary without marking the accepted face.
554. Classify its signature: directional, rotary, random, film, thermal, geometric or weld-centred.
555. Review the stage history and identify when the feature first appeared.
556. Inspect the abrasive, wheel, compound, fixture, cleaning media and handling route used at that stage.
557. Decide whether the condition is removable surface damage, geometry loss, contamination or material or weld contrast.
558. Select the least aggressive stage with enough cut to remove the defect efficiently.
559. Establish a broad controlled blend zone and protect adjacent edges and transitions.
560. Correct the process cause before touching the part again.
561. Rework progressively, cleaning and inspecting between stages.
562. Verify geometry, scratch removal, gloss, cleanliness and any specified measurement independently.
563. Protect the accepted surface and confirm the defect does not return after final cleaning.

FILTRATION, CLEANING & PROCESS CONTROL

CHAPTER 032

Paint-Booth Airflow and Filtration Fundamentals

32

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, operators, painters, QA/QC personnel, maintenance teams, safety and environmental personnel, procurement staff and technical sales personnel

Scope: Practical guidance for understanding and controlling airflow direction, air velocity, pressure drop, overspray capture, intake and exhaust filtration, booth balance, fan load, coating quality, worker exposure and environmental discharge in industrial paint booths.

Core principle - A paint booth works as one connected air-handling system. Control the path from clean make-up air to safe discharge, and verify airflow, pressure and filter condition together. A filter cannot compensate for poor distribution, leakage, obstruction or an unsuitable fan duty point.

Spray atomisation creates a fast-moving cloud of coating droplets and vapour. The booth must contain that cloud, carry overspray away from the operator and workpiece, remove captured particulate before discharge, and maintain a clean, stable environment around the wet coating. These functions depend on the combined performance of the supply opening, intake filters, plenum, booth enclosure, exhaust filters, ductwork, fan and discharge point. [S171; S172; S174; S175]

This chapter explains the fundamentals that apply across dry-filter liquid-coating booths. Water-wash booths, powder systems, recirculation systems and specialised solvent controls require their own engineered arrangements and operating procedures.

Chapter objectives

After this chapter, the reader should be able to:

- trace the complete airflow path through a paint booth;
- distinguish crossdraft, semi-downdraft, side-downdraft and downdraft arrangements;
- explain why average velocity, distribution and direction must be considered together;
- interpret differential pressure without mistaking it for a direct airflow reading;
- separate the functions of intake filters and exhaust overspray arrestors;
- recognise how filter loading changes airflow, fan duty and coating quality;
- identify pressure-balance symptoms at doors, gaps and filter frames;
- apply practical checks for worker exposure and post-spray clearance;
- separate particulate capture from vapour and VOC control; and
- troubleshoot airflow and filtration as one connected system.

1. Treat the booth as a complete control system

The booth enclosure is the capture zone, but the enclosure alone does not create control. Air must enter through the intended clean path, travel through the work zone without harmful recirculation, pass through the correct exhaust treatment and discharge to a safe location. DOSH Malaysia describes an enclosure hood such as a spray-painting booth as a local exhaust ventilation control whose effectiveness depends on adequate, uniformly distributed flow and the performance of the complete system. [S171; S172]

System element	Primary function	Condition to verify	Typical consequence if uncontrolled
Make-up-air source	Replaces extracted air	Clean location, adequate supply and no exhaust re-entry	Starved booth, unwanted inward drafts or contaminated intake
Intake filter and plenum	Cleans and distributes supply air	Correct media, orientation, sealing and even loading	Dirt on wet coating or non-uniform airflow
Booth enclosure and openings	Define the pressure boundary and airflow route	Doors, panels, lights, joints and intentional openings intact	Bypass air, leakage and unstable capture
Work zone	Carries spray cloud away from people and accepted surfaces	Part and operator positioned for the designed flow	Recirculation, overspray escape and coating defects
Overspray arrestor	Captures coating mist and solids before the exhaust path	Correct media, full-bank sealing and controlled loading	Breakthrough, duct deposits and emissions
Exhaust plenum and duct	Collect and convey contaminated air	Cleanable, sealed and free from obstruction	Uneven suction, residue accumulation and leakage
Fan and drive	Overcome system resistance and deliver the duty airflow	Rotation, condition, control response and operating point	Low flow, instability, vibration or excess energy use
Discharge	Releases treated exhaust at the intended location	Clear outlet, suitable direction and separation from air intakes	Re-entry, nuisance deposition or uncontrolled exposure

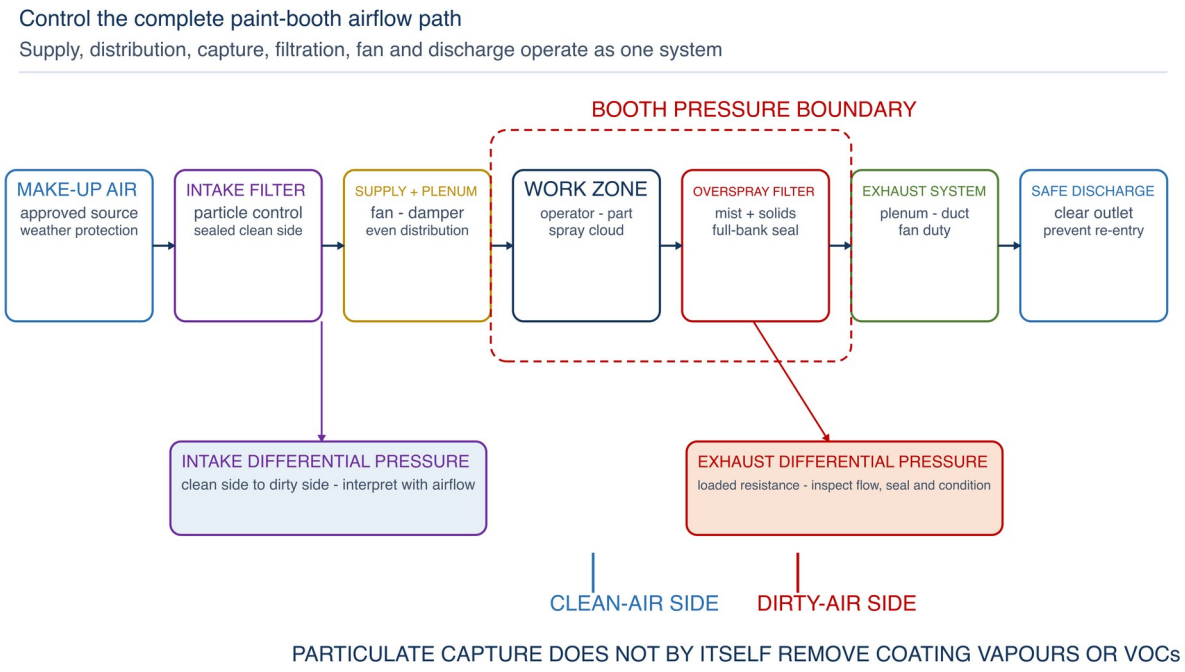

Figure 1. Complete paint-booth airflow system. Approved make-up air passes through intake filtration and distribution, sweeps the work zone, carries overspray to the arrestor, crosses the exhaust fan and leaves at the intended discharge. Differential-pressure points and the booth boundary are part of the same control system. Particulate capture does not by itself remove coating vapours or VOCs.

2. Select an airflow arrangement around the work

Airflow arrangement describes the main direction between the clean-air supply and the exhaust. Crossdraft booths move air broadly from one end to the other. Semi-downdraft systems introduce air overhead and move it diagonally to a low exhaust. Side-downdraft systems supply from above and extract low at the sides. Full downdraft systems move air from a ceiling plenum towards a floor or low-level exhaust. These are established families, but the best choice depends on work geometry, operator movement, process, building layout, contamination sensitivity and the engineered ventilation duty. [S184]

Arrangement	Main flow route	Practical strengths	Control considerations
Crossdraft	Horizontal, supply end to exhaust end	Simple path, clear upstream and downstream relationship, adaptable to long workpieces	Part and operator can obstruct the path; floor and door drafts can disturb distribution
Semi-downdraft	Overhead front supply to low rear exhaust	Directs air away from the clean entry zone without a full floor pit	Diagonal flow can create shadow zones behind large parts
Side-downdraft	Ceiling supply to low side exhausts	Removes overspray towards both sides and can avoid a central pit	Side banks must remain balanced; large work can shield one side
Full downdraft	Ceiling supply vertically to floor or low exhaust	Separates clean overhead supply from low exhaust and suits controlled production layouts	Floor grilles, pits and large horizontal surfaces can change local flow

The intended arrangement is only the starting geometry. A large product, fixture, platform, open door or operator can split the stream and create wake zones. Evaluate airflow with the normal part, support and work position in place, while preserving a safe test method.

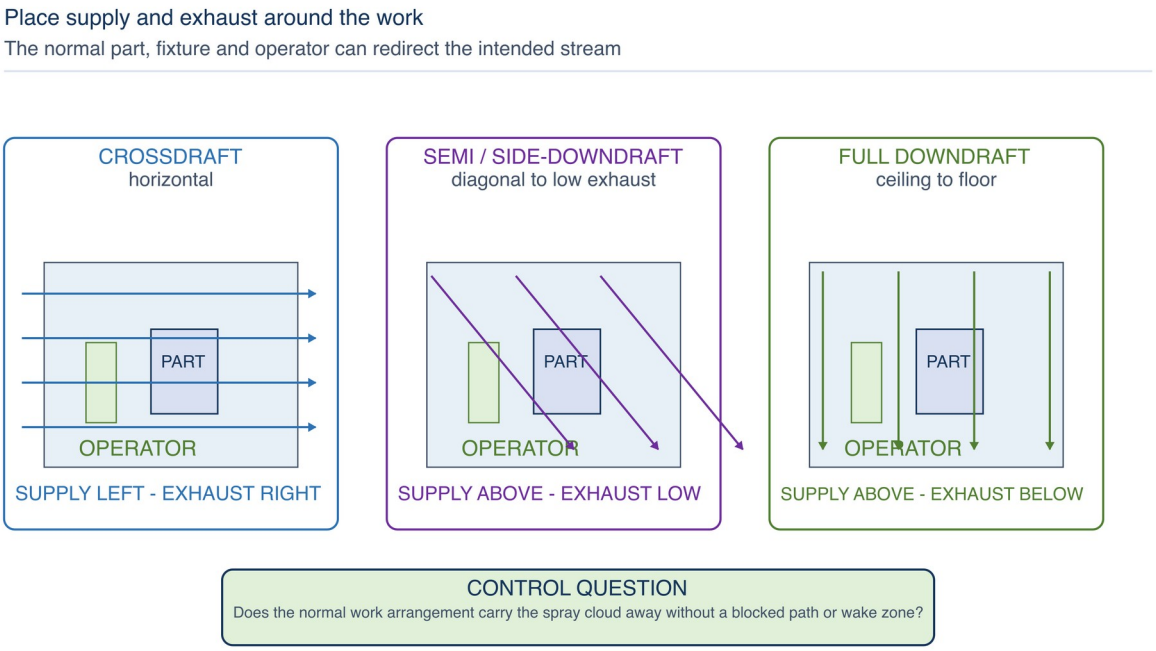

Figure 2. Common airflow arrangements. Crossdraft, semi- or side-downdraft and full downdraft systems place the clean-air supply and exhaust in different locations. In every case, the designed route should carry the spray cloud away from the operator and clean work without uncontrolled recirculation.

3. Control direction before increasing velocity

Direction determines where overspray and vapour travel. The spray gun ejects coating at much higher local speed than the general booth airflow, so extraction cannot simply pull every droplet backwards at the gun. The control objective is to contain and sweep the dispersed cloud after atomisation, keeping the operator out of the downstream plume where the designed process permits. [S172; S177]

Arrange the part and spraying sequence so the operator does not repeatedly spray into their own breathing zone or block the path to the exhaust. Use turntables, fixtures or planned access where appropriate so the work can be presented to the airflow rather than forcing the painter to stand downstream. Check that large surfaces do not form a wall across the booth or create a protected pocket behind the component.

Crosscurrents from doors, fans, compressed-air blow-off, nearby extraction, vehicle movement or building pressure can overcome the intended stream at an opening. Increasing fan speed may not correct a badly directed crosscurrent and can create more turbulence. First remove the disturbance, restore the intended openings and check distribution.

4. Measure air velocity as a distribution

Air velocity is the local speed of air at a stated plane and under stated operating conditions. Volume flow is related to average velocity and open area:

Volume flow = average velocity x effective open area

This relationship is useful only when the measurement plane and effective area are defined. A single centre reading cannot represent a large booth face, ceiling or filter bank. Use a planned traverse or the booth's specified verification method, compare readings across the intended plane, and record the operating condition of doors, fans, dampers, filters and production equipment.

Uniformity matters because two booths can have the same calculated average while one has strong jets and weak pockets. High local velocity can disturb the spray pattern, increase turbulence, dry the coating unevenly or draw contamination from gaps. Low local velocity can allow overspray to linger, escape or settle on the work. DOSH guidance therefore links effective enclosure control with both sufficient velocity and uniform distribution across the capture face. [S171]

Use smoke visualisation or another approved qualitative method only under safe non-spraying conditions and with materials suitable for the booth. Smoke can reveal reverse flow, dead zones, leakage and slow clearance, but it does not replace quantitative measurement or exposure assessment.

5. Read pressure drop correctly

Differential pressure is the pressure difference across a filter bank or another system section. It indicates resistance to airflow. Clean media has an initial resistance at a stated flow. As dust or overspray accumulates, resistance normally rises. The fan and controls then determine whether airflow falls, fan speed rises, power changes or the system reaches an alarm or control limit. [S174; S179; S180]

Pressure drop is not a direct measure of capture efficiency, remaining filter life or booth velocity. A low reading can mean a clean filter, low airflow, a missing panel, a split medium, an open bypass or incorrectly located pressure taps. A high reading can indicate loading, wet or collapsed media, excessive flow, a blocked downstream path or an unsuitable replacement. Always interpret pressure with airflow, physical condition and system configuration.

Pressure indication	Airflow observation	Likely interpretation	First check
Rising pressure drop	Airflow falling	Loading is increasing total resistance and the fan is not maintaining flow	Filter bank, fan duty and downstream obstruction
Rising pressure drop	Airflow stable	Controlled fan may be increasing speed or power to maintain duty	Fan control, motor load and remaining pressure capacity
Low pressure drop	Airflow low	Flow may be too low to develop the expected filter resistance	Fan, damper, drive, duct and measurement point
Low pressure drop	Dust or overspray downstream	Media, seal or frame may be bypassed or damaged	Full perimeter, joints, orientation and bank completeness
Sudden pressure change	Unstable or noisy flow	Filter movement, collapse, damper change, fan fault or instrument problem	Stop and inspect the complete air path
Uneven bank readings	Uneven face velocity	Plenum distribution, local loading, blockage or sealing differs across the bank	Traverse the bank and inspect upstream distribution

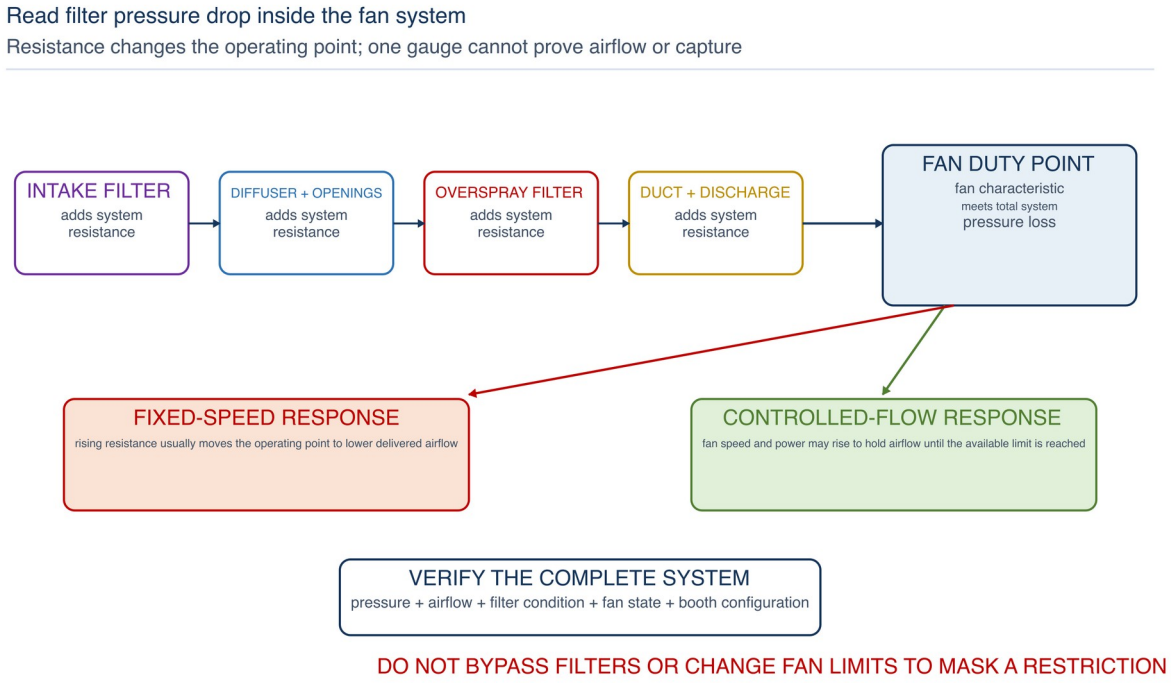

Figure 3. Filter pressure-drop and fan-duty chain. Intake filters, diffusers, booth openings, overspray arrestors, ductwork and discharge all add resistance. As filter loading changes the system curve, a fixed-speed fan may deliver less air, while a controlled fan may use more power to hold flow until its operating limit.

6. Use intake filtration to protect the process

Intake filtration reduces dust, fibres, insects and other particles entering with make-up air. Its main production purpose is a cleaner wet-film environment and more uniform air distribution. A staged intake may include coarse protection followed by a finer final supply filter, but the correct arrangement depends on the air source, finish requirement, booth design and fan capacity.

Filter efficiency cannot be selected independently of resistance. A finer or deeper filter may improve particle control but can also change pressure drop and fan duty. General-ventilation filters may be classified and tested under the ISO 16890 series, including airflow resistance and dust-loading behaviour, but laboratory classification does not by itself predict service life in a particular paint booth. [S181; S182; S183]

Install media in the stated airflow direction and provide full support. Seal the perimeter, panel joints and access doors so air cannot choose a lower-resistance route around the filter. Keep the clean side protected during replacement; contamination released downstream of the final intake stage can deposit directly on wet work.

Do not assume that a visually clean filter has low resistance or that a dark filter has failed. Use the specified differential-pressure and airflow checks with inspection. For exact media class, dimensions, orientation, initial and final resistance, rated airflow, compatibility and replacement limit, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

7. Capture overspray before the exhaust path

The exhaust filter or overspray arrestor captures coating droplets and solids carried from the work zone. It protects the downstream plenum, duct, fan and discharge path from excessive deposits and reduces particulate emissions. It is not the same product function as an intake filter, and the two should not be interchanged merely because they fit the same frame.

Overspray loading depends on coating solids, spray rate, transfer efficiency, part geometry, gun technique, production time and airflow distribution. A filter that performs well with one coating process may load rapidly, drain, soften, shed, react or permit breakthrough with another. Chapter 33 explains construction families; Chapter 34 develops the selection route.

Inspect the complete bank for uniform loading. A clean corner beside a heavily loaded centre can indicate poor distribution, a blocked part position or air bypass. Darkening or deposit alone is not a reliable end-of-life rule unless the filter instructions use it. Track differential pressure, airflow, loading pattern, downstream cleanliness and production condition together.

Never cut, compress, stretch, reverse or stack media unless the product and booth instructions permit that arrangement. Uncontrolled modification changes flow passages, support, resistance, holding behaviour and fire characteristics.

8. Control booth balance and leakage

Booth balance is the relationship between supplied and exhausted air, including every intentional opening and leakage path. The designed pressure condition may be negative, neutral or positive relative to the surrounding room depending on the booth type and process. The correct target is the engineered operating condition, not a universal pressure sign.

Too much exhaust relative to supply can pull dirty shop air through door gaps, panel joints and cable openings. This may increase dust defects, make doors difficult to operate and disturb temperature control. Too much supply relative to exhaust can drive vapour, odour or overspray out through openings. A nominal pressure indication can still hide local leakage if seals or distribution are poor.

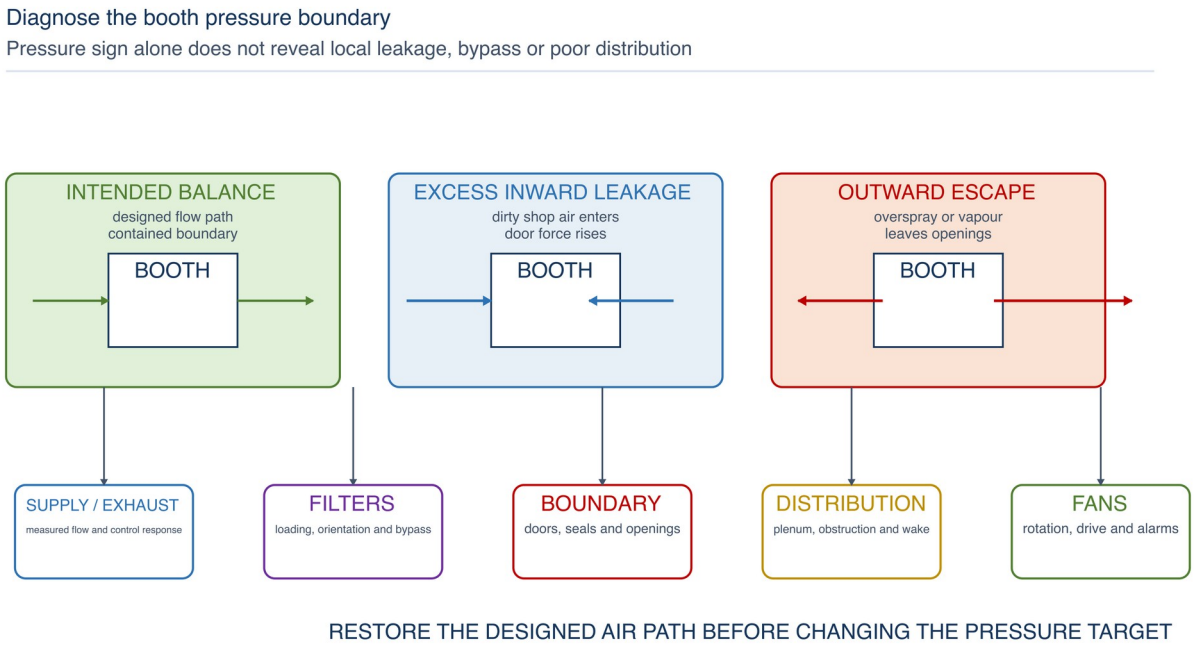

Figure 4. Booth-balance and leakage diagnosis. Intended balance is compared with excessive inward leakage and outward escape. The corrective route checks supply and exhaust flow, doors, openings, filter loading, seals, plenums and fan operation before changing the pressure setpoint.

Observed condition	Pressure-boundary meaning	Common contributors	Controlled response
Dust drawn through gaps	Excess inward leakage or poor intake sealing	Supply restriction, high exhaust, damaged panels or open penetrations	Restore supply path and seals; verify complete balance
Overspray or odour escapes at doors	Outward leakage, poor capture or disturbed direction	Excess supply, low exhaust, crossdraft, blocked bank or open door	Stop spraying, contain the area and verify exhaust and distribution
Door force changes during a shift	Balance is changing as resistance or fan control changes	Filter loading, damper movement, fan fault or building pressure	Check pressure, airflow, fans and adjacent systems
One filter bank loads much faster	Air distribution is not balanced across the exhaust face	Plenum restriction, work obstruction, leakage or uneven media	Inspect face velocity and the upstream flow path
Booth pressure appears stable but finish worsens	Average balance can hide local recirculation or dirty supply	Part wake, blocked diffuser, intake bypass or local turbulence	Traverse airflow and inspect the normal production arrangement

9. Understand fan load and the operating point

A fan delivers airflow at the pressure required by the system. The operating or duty point is where the fan characteristic and system resistance meet. Filters, plenums, diffusers, dampers, ducts, bends, stacks and deposits all contribute resistance. AMCA and US Department of Energy guidance treat fan performance as a system interaction rather than an isolated nameplate value. [S179; S180]

With a fixed-speed fan, rising resistance commonly reduces delivered airflow. With a variable-speed or pressure-controlled fan, the controller may increase speed and power to maintain a set condition. The booth can therefore appear to hold airflow while the motor approaches its limit or energy use rises. A control signal is not proof that the physical system is healthy.

Trend the indicators that matter to the installed design: filter-bank pressure drop, booth pressure, representative airflow, fan speed, motor current or power, damper position and alarms. Investigate a change in relationship, such as more fan effort for the same airflow, before the system loses control.

Do not compensate for a restricted filter by bypassing media, opening uncontrolled gaps or exceeding equipment limits. Restore the designed air path and use a compatible replacement.

10. Link airflow to coating quality

Coating quality depends on material preparation, atomisation, application technique, temperature, humidity, flash-off and curing as well as booth airflow. The airflow system cannot correct an unsuitable coating process, but it can introduce or amplify visible defects.

Finish symptom	Possible airflow or filtration contribution	Confirming check	Corrective direction
Dust nibs or fibres	Intake bypass, dirty clean side, shedding media or leakage from shop	Inspect particle pattern, intake seals and clean-side handling	Restore intake integrity and clean using an approved method
Dry spray or rough texture	Excess local velocity, turbulence, long spray distance or unsuitable application condition	Compare defect with airflow map and gun path	Correct distribution and application variables together
Uneven gloss or colour	Non-uniform flow, temperature or flash-off across the part	Compare zones with supply pattern and part shadowing	Stabilise distribution and environmental condition
Overspray settling on wet film	Weak capture, recirculation or workpiece wake	Use safe airflow visualisation and inspect exhaust-face uniformity	Reposition work or restore the designed route
Repeating dirt from one area	Damaged ceiling media, frame bypass or contaminated plenum	Trace the defect location to the upstream zone	Repair seal or media and clean the affected clean side
Edge or side remains hazy	Side bank imbalance or spray plume crossing accepted work	Compare both exhaust banks and operator route	Restore bank balance and revise work presentation

Release coating appearance only after the air system is stable under the normal production arrangement. An empty-booth test may not show wake zones created by the actual part, fixture or operator.

11. Protect workers during spraying and clearance

Ventilation is an engineering control, but it does not automatically reduce every hazardous substance below the applicable exposure requirement. Coating droplets, solvents, isocyanates, metals and other ingredients require assessment from the actual Safety Data Sheet, process and workplace exposure conditions. Fire-safe ventilation and flammability control do not by themselves prove toxic-exposure control. [S153; S160; S175; S177]

Keep the operator on the clean-air side of the spray cloud where the booth design and task allow. Avoid directing the gun towards another person, an exit or an uncontrolled opening. Maintain mechanical ventilation during spraying and for the required period afterwards. Respiratory, skin, eye and body protection must be selected through the current chemical-risk assessment and site programme.

Post-spray clearance is the time needed for airborne contamination to be removed after spraying stops. HSE guidance recommends establishing clearance under worst-case service conditions, including near the filter-change condition, and clearly communicating when entry or removal of respiratory protection is permitted. [S176; S177]

Do not use odour or visible mist alone as the clearance indicator. Some hazardous vapours are poorly detected by smell, and fine aerosol may remain after the obvious cloud disappears.

12. Separate particulate capture from vapour control

Dry overspray arrestors primarily capture coating droplets and solids. Ordinary particulate filters generally do not remove solvent vapours or VOCs. EPA guidance makes this distinction explicit: a booth can capture overspray particulate while vapour remains in the exhaust stream. [S178]

VOC, hazardous-air-pollutant and odour control may require coating reformulation, improved transfer efficiency, enclosure, dedicated adsorption, thermal or catalytic treatment, wet collection, or another engineered process. Selection depends on the actual coating chemistry, emission rate, regulatory requirement and control-system design.

Discharge treated air to the approved location away from doors, occupied zones and air intakes so contaminants are not drawn back into the building. Malaysia's Environmental Quality (Clean Air) Regulations 2014 establish the national environmental framework for air-pollution-control systems and emissions. Site design, notification, monitoring and limits must follow the current requirements applicable to the installation. [S173]

Captured filters and residues remain process waste. Store and dispose of them according to coating chemistry, fire risk, Safety Data Sheet information and Malaysian waste requirements. Do not treat a dry filter as harmless because the carrier frame is paper or synthetic fibre.

13. Verify the booth before production

Use a repeatable release check at start-up, after maintenance, after filter change and whenever airflow, coating quality, odour, fan load or booth pressure changes.

Verification point	What to observe or measure	Accept when	Escalate when
Air path	Supply opening to discharge, including doors and dampers	Intended path is open, complete and unobstructed	Temporary covers, closed dampers, deposits or blocked grilles are found
Filter installation	Identity, direction, support, joints and perimeter	Correct media is fully seated and sealed	Gaps, reverse installation, collapse, damage or improvised packing are present
Differential pressure	Each controlled filter bank and relevant system section	Reading is stable within the installed operating method	Sudden, unexplained, high, low or unequal readings occur
Airflow	Specified plane and representative traverse	Direction, average and distribution meet the booth method	Reverse flow, dead zones, strong jets or low capture are found
Booth balance	Door behaviour, boundary pressure and leakage	Pressure condition matches the engineered state	Overspray escapes or dirty air is drawn through uncontrolled gaps
Fan and drive	Rotation, noise, vibration, speed, load and alarms	Stable operation supports the required airflow	Fan effort rises, flow falls, vibration develops or an alarm is active
Cleanliness	Intake clean side, booth, exhaust face, plenum and discharge	No loose debris, residue release or downstream breakthrough	Dirt can enter the wet-film zone or deposits threaten the exhaust path
Clearance control	Ventilation run-on and communicated clearance status	Entry and protective-equipment rules are clear and functional	Timing, indicator or safe exit arrangement is uncertain

Record the booth identity, coating process, filter type, installed condition, pressure readings, airflow result, fan state, inspector and action taken. Trends are often more useful than isolated readings because they show how resistance and fan response change across filter life.

14. Troubleshoot the complete air path

Symptom	Likely system causes	Checks	Corrective direction
Overspray escapes from the opening	Low exhaust, excess supply, crossdraft, blocked arrestor or work obstruction	Direction at opening, filter pressure, fan state and normal part position	Stop spraying and restore containment before resuming
Airflow is reduced	Loaded filters, fan or drive fault, closed damper, blocked duct or discharge	Pressure profile, fan rotation, speed and system inspection	Correct the resistance or fan fault; do not bypass filters
Dust appears on painted parts	Intake bypass, dirty plenum, shedding media or excessive inward leakage	Clean side, seals, upstream air source and booth balance	Restore clean-air integrity and approved cleaning
Finish becomes uneven	Non-uniform velocity, temperature gradient, workpiece wake or side-bank imbalance	Traverse airflow around the production arrangement	Rebalance distribution and part presentation
Filter use rises sharply	More overspray, changed coating, poor transfer, higher spray rate or unsuitable media	Compare production, loading pattern and pressure trend	Correct application cause and confirm compatible media
Fan load increases	Rising resistance, fouled duct, control response or mechanical fault	Filter and system pressure, fan speed, motor condition	Restore the system before the operating limit is reached

Symptom	Likely system causes	Checks	Corrective direction
Filter bypass is visible	Poor fit, damaged seal, collapsed panel or incorrect support	Inspect full perimeter and downstream deposits	Replace and seal using the approved arrangement
Odour remains or returns	Vapour not controlled by particulate media, re-entry or poor clearance	Discharge location, ventilation run-on and coating chemistry	Apply the chemical-risk and environmental control route
Pressure drop is normal but capture is poor	Instrument fault, low-flow baseline, local dead zone or opening change	Verify gauge zero, airflow distribution and booth configuration	Correct measurement and restore the design condition
One area blocks prematurely	Uneven flow, spray aimed at the bank, part shielding or local media damage	Compare face loading and spray path	Correct distribution or work method before replacing the bank

15. Concise safety reminders

- Use the booth only for the coating processes, work sizes and operating modes covered by its current instructions and risk assessment.
- Confirm mechanical ventilation, airflow indication, interlocks and alarms before spraying.
- Keep doors and intentional openings in their stated operating position; do not defeat interlocks or pressure controls.
- Keep ignition sources, unsuitable electrical equipment, hot work and incompatible materials out of the spray area.
- Maintain ventilation during spraying and throughout the established post-spray clearance period. [S175; S176]
- Select respiratory, eye, face, skin and body protection from the coating Safety Data Sheet and current chemical-risk assessment.
- Isolate energy and follow the filter-change procedure before opening plenums, reaching into fans or servicing the air path.
- Treat used filters and deposits as coating-contaminated material; control ignition, exposure, storage and disposal.
- Never operate with missing, damaged, bypassed or improvised filter media.
- Follow the current authority, fire code, environmental approval, booth manual and site procedures. NFPA 33 is a recognised fire-safety reference where adopted by the authority having jurisdiction. [S173; S185]

16. Practical operating verification sequence

564. Confirm the booth, coating, part size and operating mode are authorised for the planned work.
565. Inspect the make-up-air intake and discharge location for blockage, contamination or re-entry risk.
566. Check intake and exhaust filters for correct identity, orientation, support, sealing and condition.
567. Inspect doors, panels, lights, floor grilles, plenums and intentional openings.
568. Start the ventilation system and confirm fan rotation, stable running, indicators, interlocks and alarms.
569. Record differential pressure across each controlled filter bank.
570. Verify airflow direction and distribution using the specified method and normal booth configuration.
571. Place the work and fixture so they do not block the designed path or force the operator downstream of the plume.
572. Confirm the booth pressure condition contains overspray without drawing dirty air through uncontrolled gaps.
573. Check the clean-air side, work zone and exhaust path for loose dust or residue.
574. Confirm protective equipment, safe entry, exit and post-spray clearance arrangements.
575. Spray only when the system is released and keep ventilation operating throughout the process.
576. Watch for changing door force, pressure, airflow, fan sound, visible escape, dust or finish quality during the run.
577. Stop if containment, ventilation, filter integrity, interlock or fire-safe operation is uncertain.
578. After spraying, maintain ventilation and access controls for the established clearance period.
579. Record readings, filter condition, abnormalities, corrective work and release decision.

FILTRATION, CLEANING & PROCESS CONTROL

CHAPTER 033

Paint-Stop and Overspray Filters

33

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, supervisors, painters, operators, maintenance teams, QA/QC personnel, safety and environmental personnel, procurement staff and technical sales personnel

Scope: Practical guidance for selecting, installing, inspecting, changing and disposing of paper labyrinth, expanded-paper, fibreglass, synthetic and multi-layer dry overspray filters used in industrial liquid-paint spray booths.

Core principle - Match the filter construction to the coating, spray load, booth airflow and downstream protection required. Install the full bank in the correct orientation, seal every edge, and base replacement on verified airflow, pressure trend and loading condition—not appearance or time alone.

An overspray arrestor is the dirty-air filter between the spray zone and the exhaust system. Its primary task is to capture paint droplets and solids before they deposit in the plenum, duct, fan or discharge path. It must perform this task without destabilising the designed booth airflow. A filter that captures well but is overloaded, incorrectly oriented, poorly supported or bypassed at the frame cannot provide reliable system control. [S171; S172; S175; S178]

This chapter addresses dry-filter liquid-coating booths. It does not treat ordinary intake filters as overspray arrestors, and it does not present particulate media as a control for solvent vapours or VOCs. Water-wash systems, powder-recovery systems and specialised emission controls require their own engineered arrangements.

Chapter objectives

After this chapter, the reader should be able to:

- distinguish paper labyrinth, expanded-paper, fibreglass, synthetic and composite overspray-filter constructions;
- explain inertial separation, surface loading and depth loading in practical terms;
- select a media family around droplet character, coating behaviour, spray load and downstream sensitivity;
- recognise when a single-stage or multi-stage system is appropriate;
- install media in the intended airflow direction with continuous sealing and support;
- interpret visible loading together with differential pressure and airflow condition;
- prevent unsafe mixing of incompatible coating residues;
- plan fire-safe filter handling and change-out;
- classify and route used media according to the coating residue and Malaysian waste requirements; and
- troubleshoot premature blocking, breakthrough, bypass, sagging and uneven loading.

1. Understand what an overspray arrestor controls

Spray application produces droplets with a broad size distribution. Some deposit on the workpiece; the remainder becomes overspray. Larger wet droplets, fine mist, partly dried particles, fibres and coating solids can reach the exhaust face. The filter must retain the intended fraction of that load while allowing the ventilation system to carry air through the booth.

The following four functions should be evaluated together:

Function	What the filter must do	What to verify in service	Failure symptom
Capture	Remove paint droplets and solids from the exhaust stream	Downstream cleanliness, loading pattern and correct media family	Paint deposits in plenum, duct, fan or discharge
Capacity	Store captured material without premature face sealing	Depth of loading, usable surface and change-out trend	Short life, rapid pressure rise or paint run-off
Airflow stability	Add predictable resistance within the booth fan duty	Pressure trend, airflow distribution and booth containment	Weak capture, turbulence or overspray escape
Mechanical integrity	Remain supported, sealed and correctly oriented	Frame fit, joints, backing, sag and wet strength	Bypass, collapse, tearing or media migration

Capture efficiency and loading capacity are different properties. A fine stage may capture small particles but block rapidly if it receives the full coarse wet load. A high-capacity first stage may store substantial overspray but still require a downstream polishing stage where the exhaust system or environmental control demands finer capture. Selection therefore starts with the complete filtration duty, not one percentage.

2. Paper labyrinth filters — separation by direction change

Paper labyrinth filters use punched, pleated or folded paper layers to force the contaminated air through repeated changes in direction. Paint droplets have more inertia than the carrying air. As the air turns through the internal path, droplets tend to continue towards a wall or retention pocket, where they deposit outside the main stream.

The Andreae/AEREM catalogue describes this principle in a two-layer punched and pleated kraft-paper construction. Catalogue variants add paper capacity strips, synthetic backing or glass-fibre backing for different loading and final-capture duties. Treat these as construction families rather than interchangeable grades. Refer to the product label, Technical Data Sheet, or MKTECH representative. [S186; S187]

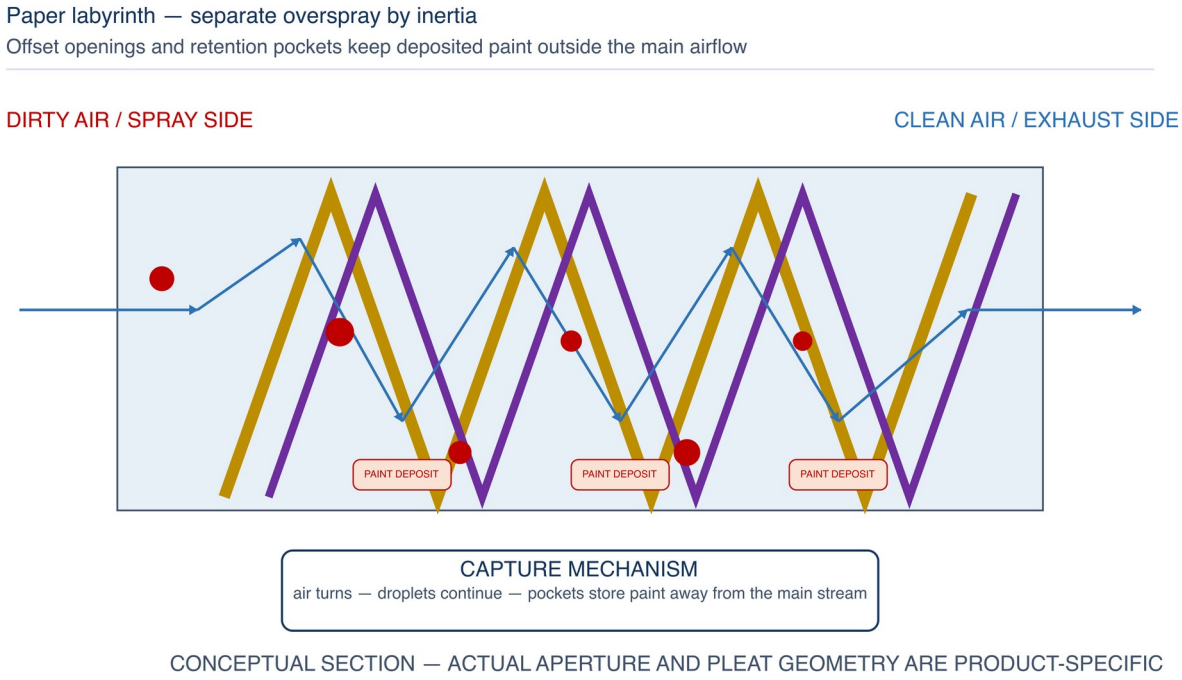

Figure 1. Paper labyrinth filter cross-section. Contaminated air follows a changing path through offset openings. Higher-inertia overspray leaves the air path and accumulates in retention pockets, while the filtered air continues towards the exhaust side. The drawing is conceptual and does not represent a specific product geometry.

Paper labyrinth media is well suited to applications where wet droplets and useful holding volume favour inertial separation. Its performance depends strongly on correct expansion, orientation and sealing. Under-expansion or over-expansion changes the internal geometry; a reversed filter presents the wrong apertures to the spray side; and a poorly clipped edge creates a bypass path with almost no filtration.

3. Expanded-paper filters — open area with multiple impaction surfaces

Expanded-paper filters are made by slitting and stretching paper into a three-dimensional mesh or stack. Multiple layers may be offset to create a tortuous route with many impaction surfaces. These filters are generally compact, easy to cut and useful for moderate overspray duties, prefiltration or applications that benefit from a disposable paper construction.

The term “expanded paper” covers different layer counts, paper weights, slit patterns and optional backing media. Two products that look similar may have very different airflow resistance, wet strength, fire behaviour and paint-holding performance. Confirm the intended spray-side orientation and the declared application before installation.

Paper construction	Capture behaviour	Practical strengths	Selection cautions
Pleated labyrinth	Repeated direction change and retention pockets	Good internal storage; self-supporting accordion form in suitable frames	Must be expanded and oriented as instructed; pocket geometry is product-specific
Multi-layer expanded paper	Impaction across offset open layers	Compact, cuttable and adaptable to pads or rolls	Face can seal with sticky paint; layer count alone does not define performance

Paper construction	Capture behaviour	Practical strengths	Selection cautions
Expanded paper with synthetic backing	Coarse paper stage plus finer fibrous stage	Combines paint storage with improved final capture	Backing adds resistance and must remain on the clean-air side
Expanded paper with glass-fibre backing	Coarse inertial stage plus glass-fibre depth stage	Useful where mixed droplet sizes require staged capture	Confirm coating compatibility, handling method and disposal route

Paper colour is not a universal grade code. Do not select a filter by colour, thickness or visual resemblance. Use the declared construction and application. Refer to the product label, Technical Data Sheet, or MKTECH representative.

4. Fibreglass paint-stop media — depth loading through an open fibre bed

Fibreglass paint-stop media consists of a resilient bed of glass fibres, commonly arranged from a more open spray side towards a denser clean-air side. Overspray collides with fibres and is retained within the depth of the media. The open upstream structure admits wet droplets; the denser downstream region provides progressively finer collection and support.

Fibreglass media is available as rolls or cut pads and can suit general refinishing and industrial liquid-coating duties. It must be handled without compressing the loft, tearing the backing or leaving exposed gaps. Compression reduces the usable depth and can increase resistance; stretching or sagging creates non-uniform flow.

5. Synthetic media — controlled fibre structure and mechanical stability

Synthetic overspray media commonly uses polyester or another engineered fibre in pads, rolls, pockets or shaped high-surface-area elements. The fibre structure may be progressive, multi-ply, thermally bonded or supported by a scrim. Synthetic media can provide stable handling, consistent thickness and resistance to fibre breakage, but these general characteristics do not establish compatibility with every coating or booth.

Fibreglass and synthetic filters are depth-loading media: particles are collected through a volume rather than only on the front face. Their useful life depends on preserving that volume and presenting the intended coarse-to-fine direction to the airflow.

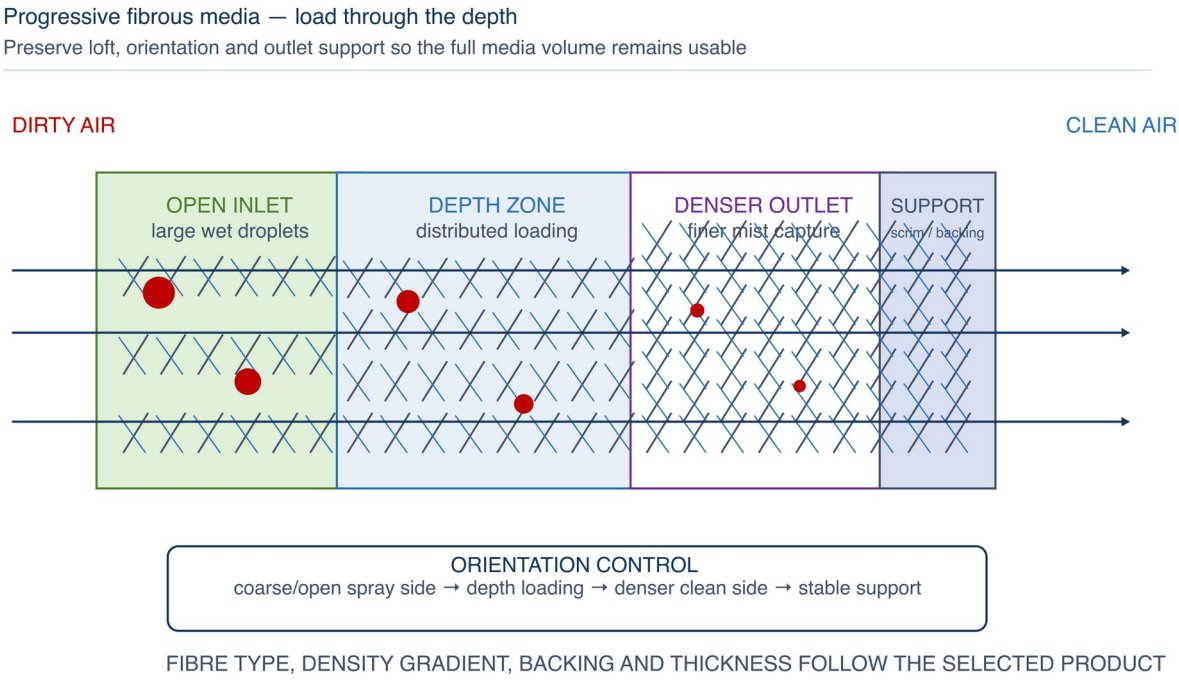

Figure 2. Progressive fibrous-media cross-section. A more open dirty-air side receives wet overspray, intermediate fibres distribute loading through the depth, and a denser clean-air side provides final capture and support. The actual fibre type, density gradient, backing and orientation are product-specific.

Media family	Typical strength	Watch for	Suitable selection question
Fibreglass pad or roll	Open depth and economical general overspray capture	Fibre handling, compression, sag, backing damage and run-off	Is the loft, backing and coating compatibility suitable for the spray load?
Synthetic pad or roll	Consistent structure, mechanical resilience and design flexibility	Surface skinning with sticky paint, incorrect orientation and unsupported spans	Does the declared media construction match wet, dry or mixed overspray?
Multi-ply synthetic panel	Staged fibre density in a supported format	Higher initial resistance, seal integrity and panel disposal volume	Is the panel intended as the first stage, final stage or both?
Pocket, cube or shaped synthetic element	Large effective area and internal storage	Frame depth, airflow distribution, collapse and full seating	Can the booth accommodate the required depth and support without bypass?

6. Multi-layer and high-loading systems

A multi-layer filter combines capture mechanisms or divides the load between separate stages. A coarse paper labyrinth, expanded-paper or deep-pocket stage can remove larger wet droplets and store bulk paint. A downstream fibrous stage then captures the finer mist that passes the first stage. Where required by the engineered exhaust system, a separate final stage protects downstream equipment or supports the specified discharge duty.

High-loading does not mean “leave the filter until airflow fails.” It means the construction is intended to store more paint at an acceptable resistance within its declared operating range. Uneven spraying, a blocked section, paint run-off, damaged media or a fan at its limit can require earlier replacement.

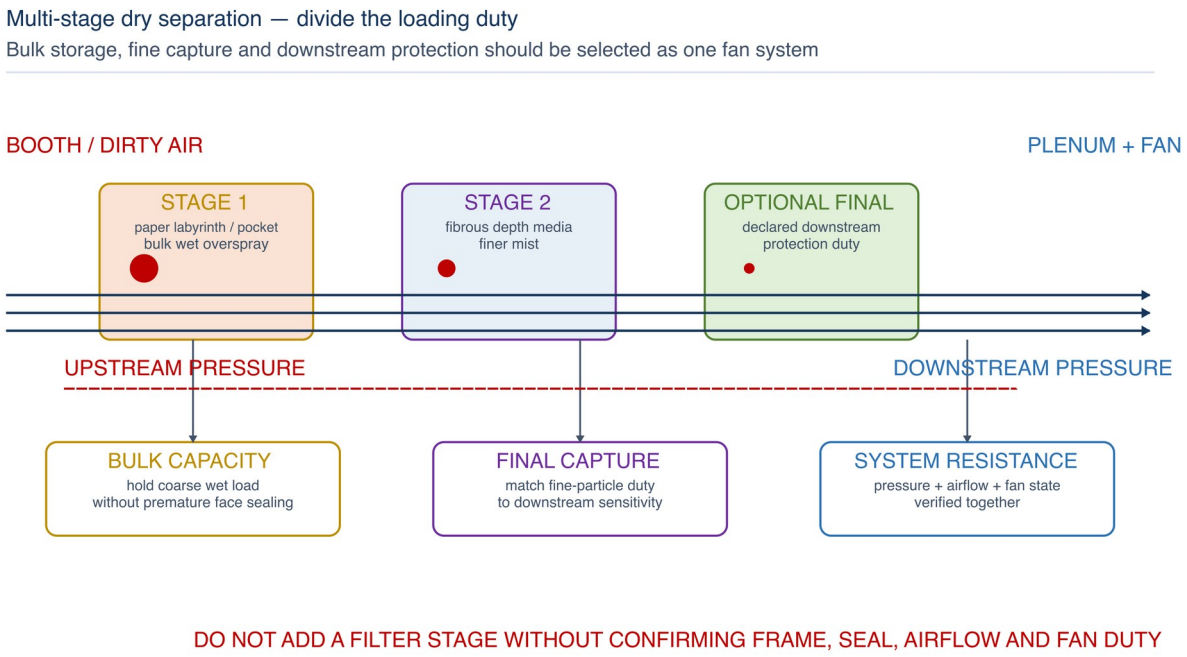

Figure 3. Multi-stage dry-separation cross-section. A coarse high-capacity stage removes and stores bulk wet overspray, a depth stage captures finer mist, and an optional final stage protects the downstream system where specified. Pressure and airflow are checked across the installed system; no universal stage count or sequence is implied.

Use multi-stage filtration when one or more of the following conditions apply:

- the spray process produces both heavy wet droplets and fine mist;
- the first-stage face blocks before its internal capacity is used;
- downstream duct, fan or discharge cleanliness requires improved final capture;
- high production loading justifies greater storage volume;
- coating changes cause widely different overspray behaviour; or
- the booth supplier specifies staged protection for the exhaust system.

Adding a stage increases system resistance and may change airflow distribution. Confirm the fan duty, frame depth, seal arrangement and pressure-monitoring method before changing the filtration configuration.

7. Match filter construction to coating behaviour

Overspray behaviour is influenced by solids content, viscosity, atomisation, transfer efficiency, solvent or water content, cure chemistry, tack time, spray rate and distance to the filter. The same filter may load differently when any of these variables changes.

Coating or overspray behaviour	Filtration implication	Practical direction
Large, wet, slow-drying droplets	Needs internal holding volume and resistance to run-off	Favour a high-capacity inertial or open-depth first stage with suitable wet strength
Fine atomised mist	Greater penetration through coarse media	Use a declared fine-capture or downstream depth stage where the system requires it
High-solids or heavy-build coating	Rapid mass loading and possible face bridging	Provide adequate storage volume and monitor distribution across the full bank
Fast-drying particulate	Can form a surface cake or release friable deposits	Select stable depth or staged media and control cleaning so deposits are not re-entrained
Water-reduced coating	Moisture can affect paper strength, adhesive or fibre behaviour	Use media specifically declared compatible with the coating and humidity condition
Two-component reactive coating	Residue may continue curing and generate heat	Keep identified waste streams controlled; follow coating SDS and site fire plan
Adhesive, gel coat or highly tacky material	Can seal the face and bridge openings	Use open, high-capacity construction and inspect for run-off or local blinding
Alternating coating chemistries	Residues may be incompatible when combined	Do not alternate a filter bank between materials that can react or self-heat

Compatibility is not proven by the carrier material alone. Check the complete filter construction, including paper treatment, fibre, binder, adhesive, backing, frame and any flame-retardant treatment. Check the coating Safety Data Sheet and the booth or filter supplier's declared application.

When changing from solvent-borne to water-reduced coating, or between resin systems, reassess overspray size, drying behaviour, residue compatibility, filter wet strength, pressure trend and waste classification. Refer to the product label, Technical Data Sheet, or MKTECH representative.

8. Select the media family systematically

Use the following matrix to form a technically useful shortlist. It does not replace the booth design, coating data or product documentation.

Application condition	First choice to evaluate	Possible supporting stage	Verification focus
Intermittent general liquid spraying	Paper labyrinth, expanded paper or open fibrous pad	Finer backing or downstream pad if specified	Correct direction, seal and stable booth flow
Continuous moderate production	High-capacity paper or progressive fibrous media	Separate depth stage	Loading uniformity and pressure trend
Heavy wet overspray	Deep labyrinth, pocket, cube or open high-loft first stage	Fine downstream stage	Run-off, storage volume and fan duty
Fine atomisation with sensitive downstream equipment	Coarse first stage	Declared fine-capture final stage	Downstream deposits and total resistance
Frequent colour or chemistry changes	Easily changed pad, roll or modular element	Dedicated stages or separated banks where required	Cross-contamination and residue compatibility
Limited frame depth	Compact paper or fibrous pad approved for the frame	Only if fan duty and space permit	Support, bypass and replacement frequency
High humidity or water-reduced process	Moisture-compatible declared construction	Compatible synthetic or composite stage	Wet strength, sagging and adhesive stability

Select by the normal production condition, not the clean-booth condition. Record the coating family, application equipment, transfer-efficiency condition, spray hours or output, exhaust-face area, current airflow, clean and loaded pressure trend, downstream cleanliness and waste route.

9. Install the filter bank as an air seal

Air follows the lowest-resistance path. A small gap at a frame, joint or corner can pass a concentrated stream of unfiltered overspray while the media itself remains lightly loaded. The complete bank must therefore be treated as a sealed, supported airflow boundary.

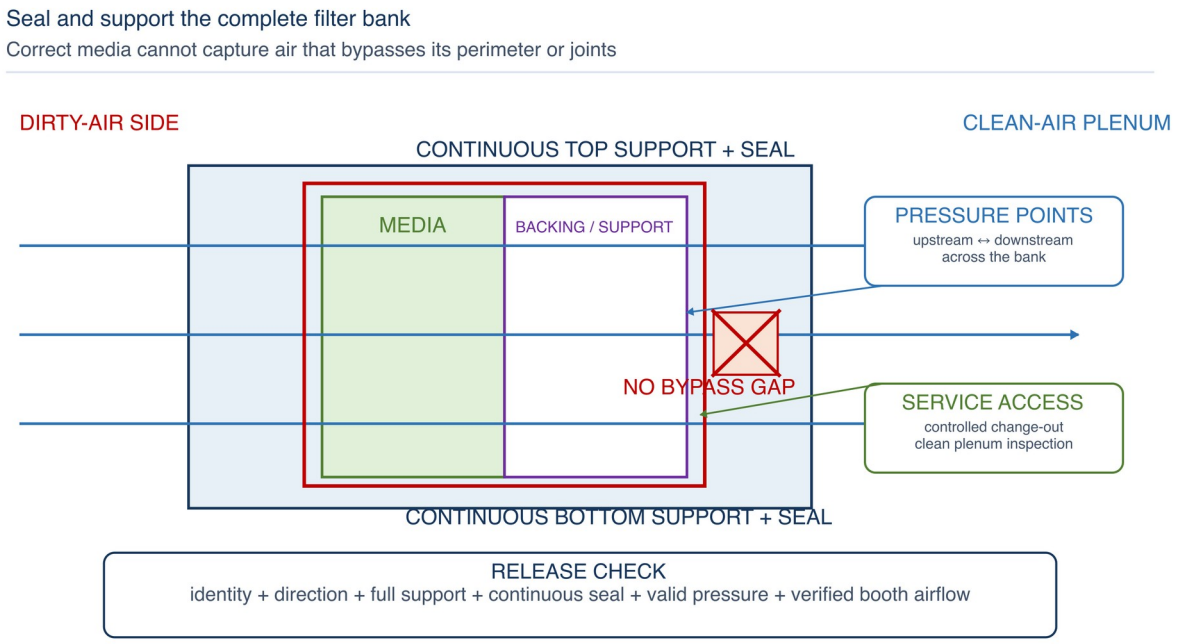

Figure 4. Sealed filter-bank installation cross-section. The filter is oriented from dirty-air side to clean-air side, fully supported, sealed at the perimeter and joints, and accessible from a controlled change-out area. Differential-pressure points span the bank, while the downstream plenum remains clear for inspection.

Before spraying:

580. Confirm the filter identity and airflow arrow or declared spray side.
581. Isolate and secure the booth according to the site procedure before entering the filter area.
582. Inspect the frame, clips, grids, channels and seals; remove old residue by an approved non-sparking method.
583. Cut or expand the media without damaging its layers, backing or designed pleat geometry.
584. Install from one edge in a controlled sequence so every joint and perimeter remains closed.
585. Support rolls and pads against sag, flutter or collapse without crushing the media depth.
586. Check the upstream face for reverse installation, gaps, folds, tears or exposed frame openings.
587. Check the downstream side for bypass paths and loose media before restoring ventilation.
588. Verify gauge condition, booth airflow and containment before production release.

For Andreae-type accordion media, the manufacturer identifies correct expansion, white or declared spray-side orientation, secured first and last pleats and continuous top and bottom support as important installation conditions. Use the current instructions for the selected grade. [S186; S187]

10. Monitor loading by pressure, airflow and pattern

No single observation proves filter condition. A dark or heavily coloured face may still have usable internal capacity; a clean-looking face may conceal deep loading, blocked pockets or a bypass path. Differential pressure shows resistance across the bank, but it does not directly prove airflow or capture.

Observation	What it may mean	Confirm with	Response
Pressure rises gradually and loading is even	Normal accumulation through the bank	Airflow distribution, fan state and downstream cleanliness	Continue within the established operating method

Observation	What it may mean	Confirm with	Response
Pressure rises rapidly after a process change	Finer mist, tackier coating, higher spray load or unsuitable media	Coating/application change and face-loading pattern	Correct the process cause and reassess media construction
Pressure remains unusually low	Torn media, reverse installation, gap, gauge fault or low system flow	Physical inspection, gauge zero and airflow measurement	Stop and restore the sealed bank and valid measurement
One zone loads much faster	Uneven airflow, gun aimed at the filter, part shielding or local damage	Booth traverse, spray path and frame condition	Correct distribution or work method before replacing the bank
Airflow falls as pressure rises	Fan cannot maintain duty against loaded resistance	Fan speed, drive, damper and system pressure profile	Replace the loaded media and correct system restrictions
Downstream paint appears	Penetration, bypass, failed joint or unsuitable final stage	Perimeter, media integrity and coating droplet character	Stop spraying; repair the bank and select the appropriate stages
Paint runs from the face	Excess wet load, unsuitable media, low airflow or local overspray concentration	Spray rate, transfer efficiency, airflow and filter orientation	Control the application and change to suitable capacity

Establish the clean-bank baseline after a correct installation. Trend pressure, airflow condition, fan state and loading pattern under comparable production conditions. The replacement point is the earliest applicable limit from the booth operating method, filter instructions, airflow verification, pressure trend, physical condition, fire control or downstream protection requirement.

11. Control spark, fire and self-heating hazards

Used overspray filters contain coating residue, not merely paper or fibre. The fire behaviour of the loaded filter depends on the coating ingredients, curing reaction, solvent content, deposited mass, airflow, heat sources and the filter construction.

OSHA's spray-finishing rule provides transferable safety principles: control combustible deposits, keep mechanical ventilation operating during spraying and clearance, prevent ignition sources, protect dry-filter areas with the required fire-protection system, remove discarded media to a safe controlled location, and do not alternate filters between coating materials where the combination can promote spontaneous ignition. The applicable Malaysian requirements and the authority having jurisdiction govern the installation. [S175; S185]

Apply these practical controls:

- keep grinding, welding, hot work, smoking, unapproved electrical equipment and other ignition sources out of the spray and filter areas;
- maintain bonding, grounding, fan clearances, interlocks and fire-protection equipment as designed;
- do not use a filter with a coating known to self-heat or react unless the complete system is specifically approved for that duty;
- segregate residues from incompatible coating systems, oxidisers, organic peroxides or reactive two-component materials;
- do not stack warm, wet or actively curing filters in an enclosed combustible pile;
- keep upstream and downstream filter spaces accessible and free from loose deposits;
- use non-sparking cleaning tools and the approved residue-removal method; and
- stop spraying if containment, ventilation, an interlock, a fire-control system or the filter bank is not in serviceable condition.

“Flame-retardant”, “self-extinguishing” or a filter classification applies only under the stated test and product condition. It is not a guarantee that paint-loaded media cannot burn. Refer to the product label, Technical Data Sheet, or MKTECH representative.

12. Change filters without spreading contamination

Plan change-out for the complete bank or controlled zone so clean and loaded media are not mixed. Keep ventilation and isolation states under the booth procedure, and allow the required post-spray clearance before entry.

589. Stop spraying and complete the specified ventilation run-on and isolation sequence.
590. Confirm the coating identity, required PPE, handling controls and waste container.
591. Protect the clean side and prevent dry deposits from being shaken into the booth or plenum.
592. Remove media in manageable sections without cutting through heavily loaded pockets where avoidable.
593. Place used filters directly into the compatible, labelled container; do not leave them beside the booth.
594. Clean the frame and accessible deposits using the approved method without compressed-air blow-off.
595. Inspect support, seals, gauge connections, fire-protection components and the downstream plenum.

596. Install the replacement bank, verify direction and sealing, then establish the operating condition before spraying.

Do not wash, burn, compact or solvent-clean used filters unless the waste and fire-management system specifically permits that method.

13. Classify and dispose of used media correctly

The disposal route follows the captured coating residue and process, not the appearance of the clean filter. In Malaysia, the waste generator is responsible for classifying the waste from its source and materials. DOE lists contaminated paper or filters and paint-related sludge within the scheduled-waste framework where the relevant criteria apply; scheduled waste must be managed through the prescribed system and licensed facilities. [S188; S189]

Use the following sequence:

Step	Practical action	Control point
Identify	Link the used filter to the coating, hardener, thinner, cleaning agent and process batch	Use current SDS and process information
Classify	Determine the applicable Malaysian waste classification	Waste generator applies DOE requirements; do not classify by carrier material alone
Segregate	Keep incompatible residues and separately classified streams apart	Prevent reaction, heat generation, fire or cross-contamination
Contain	Use a compatible, closed and labelled container in the designated area	Control leaks, vapour, ignition and unauthorised access
Record	Maintain the required inventory, date, quantity and movement information	Ensure traceability from booth to authorised destination
Transfer	Use the approved transporter and receiving facility where required	Verify licence and consignment controls before release

Do not assume that a paper or synthetic filter can enter general waste, landfill or incineration because the clean media may be combustible or marketed as disposable. The loaded filter must follow the classification and authorised route for its residue.

14. Troubleshoot overspray-filter performance

Symptom	Likely causes	Checks	Corrective direction
Filter blocks too quickly	Media too fine for first-stage load, tacky coating, low transfer efficiency, high spray rate or insufficient area	Coating change, gun setup, loading distribution and clean baseline	Correct application and evaluate a higher-capacity or staged arrangement
Paint passes downstream	Media too open, damaged backing, bypass, reverse installation or fine mist	Full perimeter, joints, downstream pattern and droplet character	Restore the bank and add the appropriate declared final stage
Paper filter sags or loses shape	Excess moisture, incorrect expansion, weak support or incompatible coating	Humidity, water-reduced process, clips and frame	Use the declared moisture-compatible construction and correct support
Fibrous pad collapses	Wrong airflow direction, compressed loft, inadequate grid or excessive resistance	Backing direction, support and pressure	Replace without compression and restore the support arrangement
Paint runs or drips from face	Excess wet loading, low airflow, poor atomisation or unsuitable storage volume	Spray path, transfer efficiency, airflow and face angle	Stop, clean safely and select higher wet-load capacity
One row remains clean	Bypass elsewhere, blocked upstream distribution or uneven exhaust	Airflow traverse, frame gaps and plenum condition	Restore balanced flow and continuous sealing
Pressure high immediately after change	Wrong grade, over-compressed media, excessive stages or obstructed frame	Identity, orientation, stage count and fan system	Install the correct construction and verify fan duty
Pressure low but capture poor	Torn media, open seam, gauge fault or insufficient airflow	Gauge zero, physical bank and measured flow	Repair measurement and filter integrity before spraying

Symptom	Likely causes	Checks	Corrective direction
Smouldering odour or heat	Reactive residue, hidden ignition, self-heating or hot deposit	Emergency response, coating chemistry and thermal condition	Stop work, isolate safely and activate the site emergency plan
Filter fibres or paper fragments appear downstream	Damaged media, poor support, unsuitable cleaning or excessive vibration	Backing, grid, fan vibration and handling	Replace damaged media and correct the mechanical cause

15. Practical selection and release sequence

Use this sequence for a new filter, coating change or persistent performance problem:

597. Define the coating family, spray method, normal output and overspray behaviour.
598. Confirm the booth airflow route, filter-face area, frame depth, support and fan duty.
599. Choose the required capture mechanism: inertial paper, expanded paper, fibrous depth media or a combination.
600. Decide whether a high-capacity first stage and finer downstream stage are needed.
601. Check moisture, chemical, mechanical and fire compatibility for the complete media construction.
602. Confirm the intended direction, installation method, clean resistance and replacement criteria.
603. Establish the waste classification, segregation and container before the first loaded filter is removed.
604. Install and seal the complete bank; record the filter identity and date.
605. Verify airflow, pressure, containment and downstream cleanliness under the normal production arrangement.
606. Trend performance and revise the selection only through the controlled booth-change process.

16. Concise safety reminders

- Never spray with missing, torn, reversed, collapsed or bypassed overspray filters.
- Keep the filter bank, plenum, duct and fan accessible and free from unsafe residue accumulation.
- Treat every used filter according to the captured coating, not the clean carrier material.
- Keep incompatible coating residues in separate controlled waste streams.
- Do not bypass filters or increase fan limits to hide a loaded or unsuitable bank.
- Keep ignition sources and hot work outside the controlled spray and filter areas.
- Maintain ventilation, interlocks, grounding and fire protection in their designed state.
- Use the coating SDS, current booth procedure and specified PPE during inspection and change-out.
- Stop work for smoke, heat, smouldering odour, sudden pressure change, overspray escape or downstream breakthrough.

FILTRATION, CLEANING & PROCESS CONTROL

CHAPTER 034

Filter Selection

34

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, paint-shop supervisors, process engineers, maintenance teams, QA/QC personnel, safety and environmental personnel, procurement staff and technical sales personnel

Scope: A practical method for selecting dry paint-booth overspray filters from verified process conditions, declared product data and whole-system constraints.

Core principle - Select the filter as part of the booth system. The correct option must capture the relevant overspray, hold the expected paint load, preserve the required airflow, fit the installed frame, remain compatible with the coating and follow an acceptable waste route at a sustainable total operating cost.

Filter selection is not a search for one highest percentage. Every dry arrestor represents a balance among droplet capture, paint-holding capacity, airflow resistance, physical integrity, service life and cost. A media that performs well in a low-rate intermittent booth may block prematurely in continuous high-solids production. A coarse high-capacity stage may control bulk wet overspray but require a downstream stage where fine mist or sensitive equipment must be protected. [S178; S192; S193]

This chapter develops the selection route introduced in Chapters 032 and 033. It is an educational and application-selection guide. The installed booth design, coating Safety Data Sheet, applicable Malaysian requirements and current product documentation remain controlling. Where an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- define the selection duty from paint type, solids content, spray rate and overspray volume;
- convert booth airflow and effective filter area into a meaningful face-velocity condition;
- distinguish overall arrestance, size-dependent capture, holding capacity, resistance and service life;
- establish the available resistance allowance without destabilising the booth;
- decide when a single-stage, backed or multi-stage arrangement should be evaluated;
- screen coating compatibility, fire behaviour, handling and Malaysian disposal requirements;
- compare operating cost on an accepted-production basis rather than purchase price alone;
- use a complete decision tree to produce a technically defensible shortlist; and
- recognise field symptoms that indicate the selected system is unsuitable or incorrectly applied.

1. Define the duty before choosing the media

Begin with the normal production condition, not an empty booth with clean filters. The filter must receive the actual coating cloud generated by the spray equipment, part geometry, painter or robot path, transfer efficiency, output and booth airflow. The selection record should describe the process in observable terms that another engineer can verify.

Selection factor	Define in practical terms	Why it changes the choice	Verification source
Paint type	Solvent-borne, water-reduced, two-component, adhesive, gel coat or other declared system	Changes droplet behaviour, wet strength, residue compatibility and fire/waste controls	Coating label, SDS and TDS
Solids content	Declared mixed or ready-to-spray condition	Influences deposited mass, tack, bridging and holding demand	Coating TDS and mix record
Spray rate	Normal and credible peak application rate	Establishes how quickly mass reaches the bank	Equipment setting and production observation
Overspray volume	Material not deposited on the workpiece that reaches the exhaust face	Determines bulk capture and storage demand	Material balance, transfer condition and booth inspection
Booth type	Crossdraft, semi-/side-downdraft, downdraft or engineered variant	Changes loading distribution, filter orientation and effective area	Booth drawing and physical survey
Airflow	Normal flow through the occupied booth and filter bank	Governs transport, face velocity and filter resistance	Commissioning or verified measurement
Required capture	Downstream cleanliness, permit, equipment or process duty	Determines whether coarse capture or staged fine capture is needed	Regulatory, booth and process requirement

Selection factor	Define in practical terms	Why it changes the choice	Verification source
Resistance allowance	Pressure available across clean and loaded filtration stages	Limits usable media and stage combinations	Fan/system information and pressure profile
Disposal route	Classification, segregation, storage and authorised destination	Affects material choice, handling and total cost	Coating/process information and DOE requirements
Operating cost	Media, labour, disposal, energy, cleaning and quality consequences	Prevents low unit price from hiding high process cost	Purchasing and production records

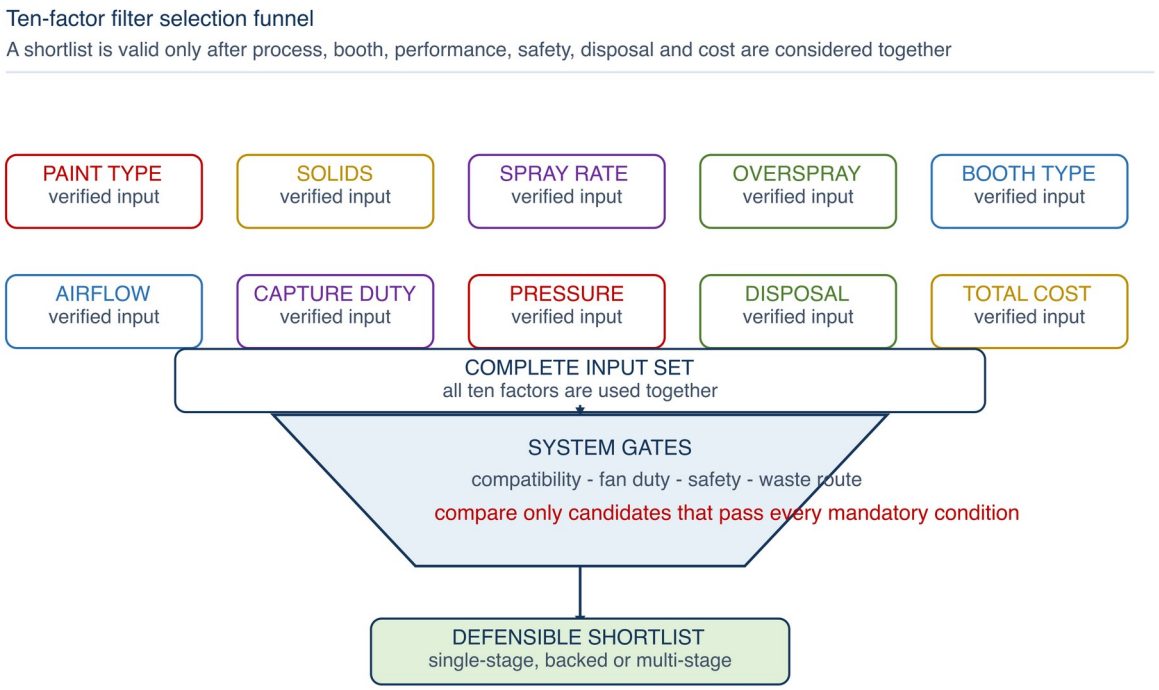

Figure 1. Ten-factor filter-selection funnel. Paint, production and booth conditions enter together, then pass through performance, safety, disposal and cost gates before a product family is shortlisted. No single input is allowed to bypass the complete system check.

2. Characterise the paint and overspray

Paint type is the first technical branch because the clean filter never operates alone; it becomes a paint-loaded composite. Check the mixed coating, hardener, thinner, cleaning materials and any alternation between products. The complete media construction includes paper or fibre, binder, adhesive, backing, frame and surface treatment.

Paint behaviour	Likely filtration demand	Media feature to evaluate	Do not assume
Large wet droplets	Internal storage and run-off control	Open labyrinth, pocket or high-loft first stage	A finer face automatically gives longer life
Fine atomised mist	Improved small-droplet capture	Declared fine stage or multi-stage system	Overall mass arrestance proves fine-particle capture
High-solids coating	High deposited mass and possible bridging	High holding volume and even full-bank loading	High solids always means large droplets
Water-reduced coating	Moisture exposure and different drying behaviour	Declared wet strength and compatible adhesive/backing	Paper colour or thickness proves moisture resistance
Two-component reactive material	Continued curing and possible heat generation in residue	Compatible media and segregated handling route	Loaded filters share the clean media's fire behaviour
Highly tacky adhesive or gel coat	Face skinning and blocked openings	Open first-stage geometry and adequate storage	A dense single pad will load through its full depth
Fast-drying or friable deposit	Surface cake, shedding or re-entrainment	Stable depth media and downstream protection	A filter suitable for wet mist suits dry particulate

Paint behaviour	Likely filtration demand	Media feature to evaluate	Do not assume
Frequent chemistry changes	Cross-contamination and incompatible residue	Dedicated banks, compatible construction or controlled change sequence	One bank can alternate safely among all coatings

Solids content is not a filter-efficiency value. It is one contributor to the mass that may reach the exhaust. Spray rate is also not overspray volume: a high-rate efficient application can place less material on the bank than a lower-rate application with poor transfer or difficult part geometry. Treat the three quantities separately.

3. Estimate the loading duty

The most useful loading description combines deposited mass, time and distribution. Exact paint capture may require a controlled material balance, but a sound first selection can be formed from normal consumption, transfer condition, production duration and filter inspection.

Use the relationship conceptually:

Overspray load reaching the bank = coating used - coating deposited on acceptable work - other controlled losses

Do not substitute a generic transfer-efficiency percentage. Part size, recesses, gun distance, fan pattern, robot path, painter technique, colour change and reclaim practices can materially change the result.

Classify the duty for selection:

- **Light/intermittent:** long non-spray periods, modest daily mass and limited local loading.
- **Moderate/repeating:** regular batches with predictable full-bank loading.
- **Heavy/continuous:** sustained application or high mass requiring substantial internal capacity.
- **Concentrated/local:** one zone receives a disproportionate load because of work position or spray direction.
- **Mixed droplet:** bulk wet overspray and fine mist reach the bank together.

The category is a communication aid, not a performance rating. Define it with actual production information and revise it when the coating, equipment, part family or work method changes.

4. Establish the booth and airflow constraint

The same filter can behave differently at different airflow conditions. Air must carry overspray from the work zone to the exhaust face, pass through the installed media and remain within the fan/system capability. Filter-face velocity depends on the flow through the bank and the effective open filter area.

Filter-face velocity = airflow through the bank / effective filter area

Use consistent units and exclude blocked frames, sealed-off zones and non-flow area from the denominator. Average velocity alone is not enough: a partially bypassed or uneven bank can contain high local velocity beside stagnant loading zones. [S171; S172; S194]

Booth/system condition	Selection consequence	Confirm before shortlisting
Crossdraft with full rear-wall bank	Loading may reflect part wake and gun direction	Effective bank area, perimeter seal and distribution
Downdraft with floor or pit filters	Gravity, floor geometry and local wet load affect distribution	Support, access, run-off control and plenum condition
Side- or semi-downdraft arrangement	Multiple paths can load asymmetrically	Flow balance and representative pressure points
Fixed-speed fan	Added resistance commonly reduces airflow	Fan curve, clean baseline and loaded operating limit
Controlled-flow fan	Control may increase fan effort as filters load	Available control range, motor capacity and alarm logic
Limited frame depth	Restricts pockets, cubes or added stages	Installed dimensions, support and service clearance
Small effective filter area	Raises face velocity for a given flow	Area calculation and local loading pattern
Existing dirty duct or blocked plenum	Consumes pressure allowance outside the filter	System pressure profile and cleaning condition

Do not correct an unsuitable filter by increasing fan speed beyond the booth's approved operating method. This may change containment, turbulence, motor load, noise, discharge behaviour and fire protection. Selection must fit the complete system.

5. Define capture performance correctly

Required efficiency should state what must be captured, under which test or service condition and for what downstream purpose. EPA research shows that overall mass arrestance and penetration by droplet size describe different aspects of overspray-arrestor behaviour. A high mass percentage can be dominated by large droplets while a small mass of finer droplets still penetrates. [S192; S193]

Ask five questions whenever a performance percentage appears:

607. What test method or verified service method produced it?
608. What challenge aerosol, coating or particle-size distribution was used?
609. At what airflow or face-velocity condition was the filter tested?
610. Was the result measured clean, loaded or across a defined loading sequence?
611. Does the figure apply to one layer, a complete composite or the installed multi-stage system?

Property	What it describes	Selection use	Common error
Overall mass arrestance	Fraction of challenge mass retained	Bulk paint control under stated test conditions	Treating it as fine-droplet efficiency
Fractional efficiency or penetration	Capture or passage by particle-size band	Downstream fine-mist sensitivity	Comparing values from different test methods
Paint-holding capacity	Mass retained before a stated endpoint	Change-out frequency and first-stage duty	Assuming more capacity always means lower resistance
Initial resistance	Pressure loss of clean media at a stated airflow	Clean-system pressure budget	Comparing products at different velocities
Final or recommended resistance	Declared endpoint under stated conditions	Change-out planning and fan-system fit	Using it as a universal booth limit
Service life	Operating period before the actual endpoint	Cost and maintenance planning	Treating supplier or another site's life as guaranteed

General-ventilation ratings are not automatically overspray-arrestor ratings. Compare only declared paint-arrestor data that match the intended coating and airflow condition. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

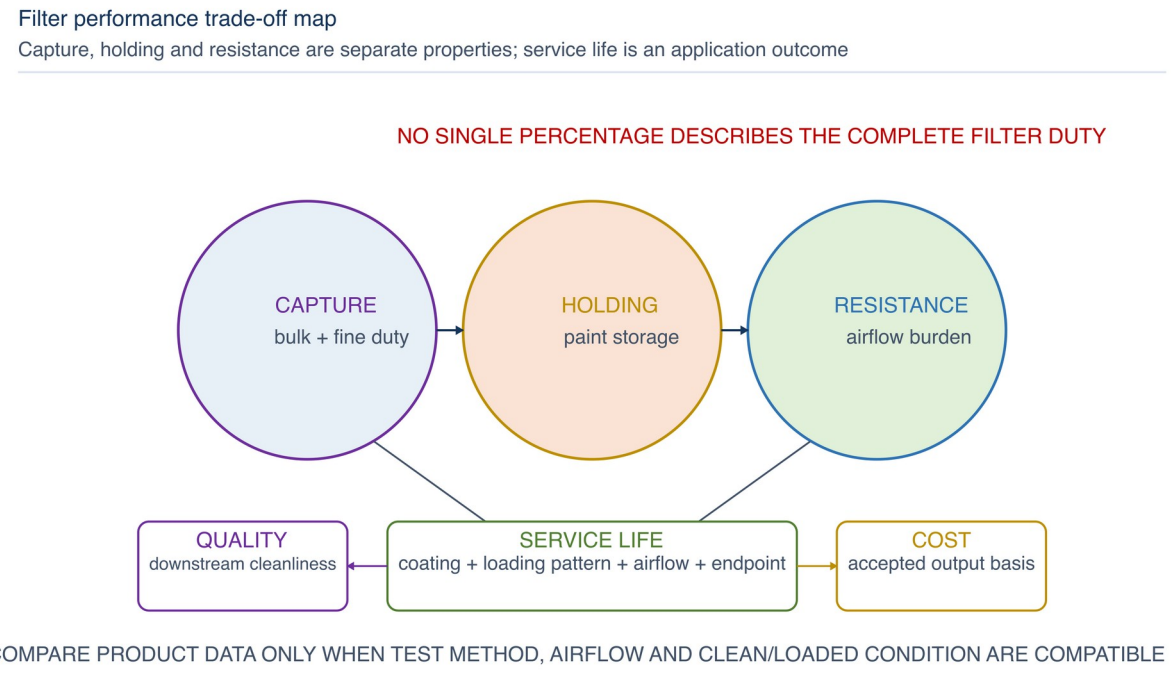

Figure 2. Filter performance trade-off map. Capture, holding capacity and airflow resistance interact, while service life and operating cost are outcomes of the complete application. The best balance depends on the actual overspray and booth duty.

6. Build the pressure-drop allowance

The filter receives only part of the fan's total pressure capability. Intake filters, diffusers, enclosure openings, exhaust filters, ducts, dampers, discharge fittings and dirty surfaces all contribute resistance. The available allowance must be established from the actual system pressure profile and acceptable airflow range. [S171; S179; S180]

Use this sequence:

612. Verify the normal production airflow and containment condition.
613. Confirm the current fan, drive, control mode, damper and motor state.
614. Measure or obtain the clean-system pressure profile at defined points.
615. Separate intake, booth, exhaust-filter and downstream-system losses where practical.
616. Determine the earliest allowed endpoint from airflow, containment, fan/motor, filter, physical and fire controls.
617. Reserve margin for realistic loading and measurement variation.
618. Evaluate the proposed first, intermediate and final stages as one combined system.

Adding pressure losses arithmetically is valid only when the values refer to the same airflow and compatible test conditions. Media resistance normally changes with airflow, loading and installation. Do not add a clean value at one velocity to a loaded value at another and present the result as a system prediction.

Pressure-budget question	Acceptable evidence	Selection decision
What is the clean baseline?	Verified installed pressure and airflow after a sealed change	Establish normal starting condition
What airflow must be maintained?	Booth method, commissioning basis or verified process requirement	Set the operational boundary
How does the fan respond to loading?	Fan/system information and observed trend	Determine whether flow falls or control effort rises
Which stage causes the resistance?	Pressure points across individual stages where provided	Select staged change-out instead of replacing everything
What is the physical endpoint?	Sag, collapse, tearing, run-off, bypass or downstream breakthrough	Replace before pressure alone reaches a limit
What exact product limit applies?	Current declared product information	Refer to the product label, Technical Data Sheet, or MKTECH representative.

7. Choose the system architecture

Use a single stage when one declared construction can provide the required bulk capacity and downstream protection within the available resistance and frame arrangement. Use a backed or multi-stage system when coarse wet load and fine-mist capture impose conflicting duties, or when downstream sensitivity justifies a separate final stage.

Duty pattern	Architecture to evaluate	Main benefit	Main risk to control
Light, broad droplet range and tolerant downstream	Single declared paper or depth-media stage	Simple installation and change-out	Insufficient fine capture or short life if duty increases
Heavy wet bulk load	High-capacity inertial or open-depth first stage	Stores paint away from the face	Run-off, local overloading and downstream penetration
Bulk load plus fine mist	Coarse/high-capacity stage followed by depth stage	Divides storage and final-capture duties	Added resistance and poor interstage sealing
Sensitive fan, heat exchanger or discharge duty	Staged system with declared final protection	Reduces downstream deposit	Final stage can block rapidly if first stage fails
Frequent product or colour changes	Modular easily changed first stage with compatible support	Controlled housekeeping and segregation	Excess waste volume or chemistry mixing
Limited frame depth or fan margin	Compact declared construction	Fits physical and pressure constraints	More frequent changes or reduced storage capacity

A downstream stage is not permission to leave a failed first stage in service. If bulk paint reaches the fine stage, resistance may rise quickly and the complete bank can lose airflow.

8. Screen compatibility, safety and disposal

No option proceeds to cost comparison until it passes the compatibility and safety screen.

Reject or escalate a candidate when:

- the supplier does not declare it suitable for the coating or moisture condition;
- the complete media construction can soften, shed, collapse or react in service;
- the coating residue is susceptible to self-heating and the arrangement is not specifically suitable;
- incompatible coatings would accumulate in the same bank or container;
- the booth's fire-protection, interlock or access arrangement cannot be maintained;
- the media cannot be installed in the intended direction with continuous support and sealing;
- used filters cannot be safely handled, classified, contained or sent to an authorised destination; or
- changing the filter system would compromise an applicable permit, booth approval or engineering control.

OSHA's dry-filter provisions are used here as transferable safety principles: airflow indication, filter inspection, control of discarded media, protection around the filter area and prevention of incompatible or self-heating residues. Malaysian requirements and the authority having jurisdiction govern the installation. [S175; S185]

In Malaysia, the waste producer classifies the used filter from the generating process and captured materials. Disposal cost and handling effort therefore depend on the residue, segregation plan, container and authorised route—not only the clean media mass. [S188; S189]

9. Compare total operating cost

Unit price is visible; process cost is distributed. Compare candidates over a common production basis such as accepted parts, coated area, production hours or coating throughput. Use the measure that best represents value at the site.

Total filter-system cost = media + change labour + disposal + energy + cleaning + filtration-related quality loss

Keep the comparison transparent. If a cost cannot be isolated reliably, record how it was estimated and avoid presenting it as a guaranteed saving.

Cost element	What to count	Frequent omission
Media	Complete first, intermediate and final stages	Support grids, clips or special frames
Change labour	Isolation, removal, cleaning, installation and verification	Lost production and post-change checks
Disposal	Containers, labels, storage, transport and authorised treatment	Residue-specific segregation
Energy	Fan input over the actual resistance profile	Comparing only clean-filter resistance
Booth cleaning	Plenum, duct, fan and surrounding overspray cleanup	Breakthrough caused by bypass or weak final capture
Quality	Dust nibs, dry spray, uneven finish, rework and rejected output linked to filtration	Blaming every coating defect on the filter
Inventory	Stockholding, storage life, roll offcuts and emergency supply	Obsolete or incompatible grades

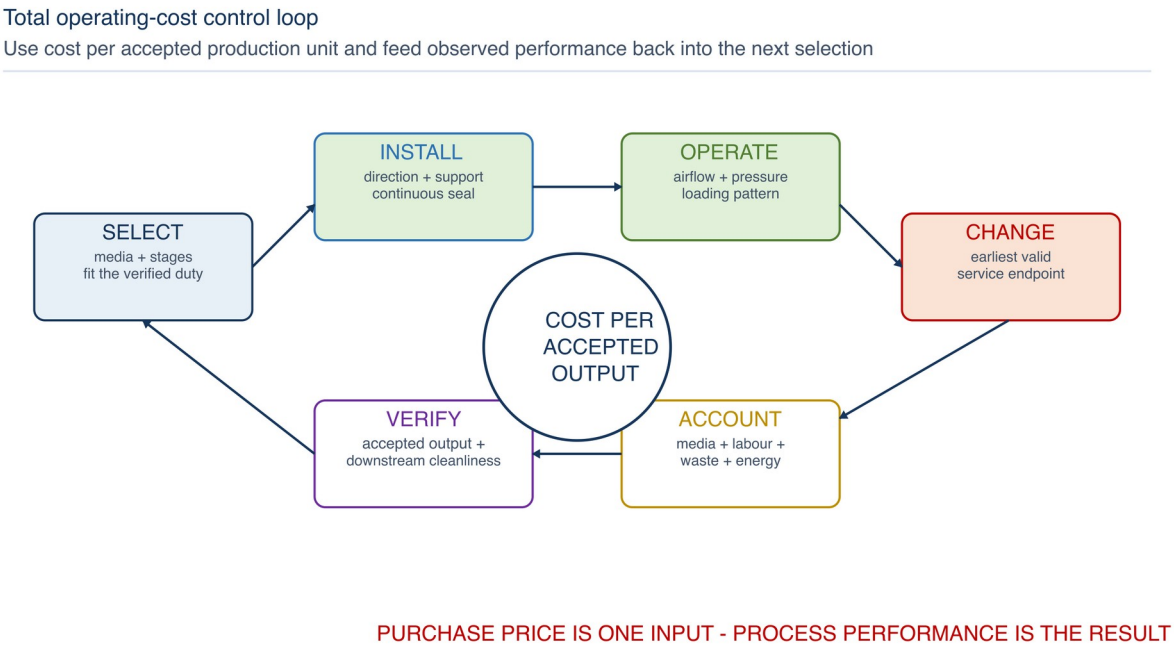

Figure 3. Total operating-cost control loop. Selection, installed operation, change-out evidence and accepted-production cost feed the next controlled decision. Purchase price is one input, not the result.

10. Use the complete selection decision tree

The following decision tree converts the ten required inputs into a shortlist and release path.

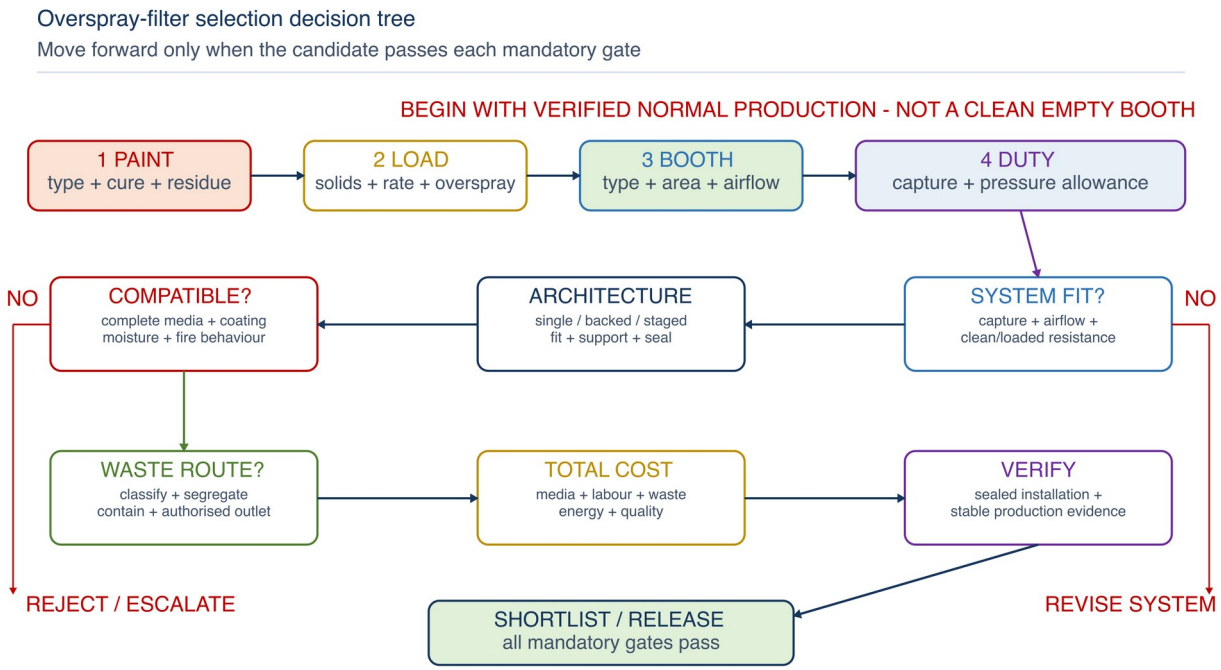

Figure 4. Complete overspray-filter selection decision tree. The route begins with paint compatibility and loading duty, then checks booth/airflow, capture, resistance, disposal and cost. A candidate proceeds only when all mandatory gates pass.

Apply the tree in this order:

619. **Identify the paint system.** Confirm mixed coating, carrier, cure chemistry, tack and residue hazards.
620. **Define solids and spray rate.** Use the normal condition and credible peak, not only nominal equipment capacity.

621. **Estimate overspray volume and pattern.** Distinguish total mass from local concentration and fine mist.
622. **Confirm booth type and effective filter area.** Establish frame depth, support, access and loading distribution.
623. **Verify airflow and fan response.** Use the occupied normal production arrangement.
624. **Define capture duty.** State downstream protection and the comparable test basis needed.
625. **Set the resistance allowance.** Evaluate clean and loaded stages within the complete fan/system condition.
626. **Choose architecture.** Shortlist single-stage, backed or staged media families.
627. **Pass safety and disposal gates.** Confirm compatibility, fire controls, segregation and Malaysian waste route.
628. **Compare operating cost.** Use accepted production and observed change-out evidence.
629. **Verify installation and production behaviour.** Release only after the sealed bank provides stable airflow, containment and downstream cleanliness.

11. Compare candidates on one basis

Use a structured shortlist so one attractive property cannot hide a system failure.

Comparison field	Candidate A	Candidate B	Candidate C
Declared coating/application	Record exact declared duty	Record exact declared duty	Record exact declared duty
Construction and stages	Media family and support	Media family and support	Media family and support
Test basis for capture	Method, challenge and airflow	Method, challenge and airflow	Method, challenge and airflow
Clean and change limits	Comparable declared conditions	Comparable declared conditions	Comparable declared conditions
Holding/load evidence	Test basis or controlled service trend	Test basis or controlled service trend	Test basis or controlled service trend
Installed fit and seal	Frame, direction and access	Frame, direction and access	Frame, direction and access
Safety/compatibility	Pass, reject or escalate	Pass, reject or escalate	Pass, reject or escalate
Waste route	Classification and container	Classification and container	Classification and container
Cost basis	Cost per accepted-output unit	Cost per accepted-output unit	Cost per accepted-output unit
Decision	Reasoned outcome	Reasoned outcome	Reasoned outcome

Do not score a mandatory safety, compatibility or legal requirement. It is a pass/reject gate. Weighted scoring is suitable only for remaining commercial and operational differences after all mandatory conditions pass.

12. Verify the shortlist in production

A controlled evaluation confirms system behaviour without claiming a universal product ranking. Keep the coating, booth, part family, application method and production basis comparable.

Record:

- exact filter identity, construction, stages, orientation and installed area;
- coating and mix condition, spray equipment and representative production output;
- clean pressure, airflow/containment condition and fan/control state;
- loading distribution, run-off, sag, damage, bypass and downstream deposits;
- change-out trigger and production achieved before that trigger;
- labour, waste container and disposal route;
- finish defects or cleaning work reasonably attributable to filtration; and
- deviations, stoppages and process changes that invalidate comparison.

The evaluation must not exceed the booth, filter, fan, fire-control or coating operating limits. It does not replace current product instructions. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

13. Diagnose a poor selection

Symptom	Selection-related possibilities	Verify first	Corrective direction
Very short life	Too-fine first stage, insufficient area, high wet load or face skinning	Process rate, loading pattern and stage duty	Increase appropriate capacity or divide the duty

Symptom	Selection-related possibilities	Verify first	Corrective direction
Downstream paint	Coarse-only media, fine-mist penetration, damaged backing or bypass	Seals, integrity and droplet character	Restore installation and evaluate declared final capture
High clean resistance	Excess stages, dense media, compression or high face velocity	Product identity, effective area and fan/system state	Select compatible lower-resistance architecture within capture duty
Uneven loading	Booth distribution, part wake, local spray path or bank obstruction	Airflow traverse and physical layout	Correct distribution before changing media grade
Run-off or dripping	Wet load exceeds storage behaviour	Coating rate, transfer, orientation and capacity	Evaluate open high-capacity first stage and process correction
Fine stage blocks first	Bulk first stage is ineffective, bypassed or absent	Interstage condition and downstream loading	Restore staged separation and seal every joint
High filter spend	Wrong cost denominator, unnecessary full-bank changes or unstable process	Accepted output, stage-specific condition and disposal	Use stage-level evidence and total-cost comparison
Fan overload or weak airflow	System resistance exceeds available duty	Pressure profile, fan state and obstructions	Restore system condition and select within the pressure allowance
Frequent chemistry disposal issues	One media stream receives incompatible residues	Coating schedule, segregation and waste classification	Dedicate or change banks under a controlled sequence

Correct the verified cause. Changing to a coarser filter to reduce pressure may increase downstream penetration; changing to a finer filter to improve capture may shorten life or reduce airflow. Re-run the complete selection tree after a significant change.

14. Prepare a useful purchasing description

A purchase request should describe the required duty without inventing a product result. Include:

- filter function and booth location;
- paint and coating-family compatibility;
- media family, stage role and physical format;
- installed dimensions, effective area, orientation, backing and support;
- declared test method and airflow condition for required capture data;
- clean resistance and declared change endpoint under comparable conditions;
- holding-capacity or service information with its test/service basis;
- fire, handling, storage and installation information;
- required TDS, SDS or disposal information;
- packaging, traceability and revision identification; and
- contact route for application confirmation.

Avoid descriptions such as “high efficiency”, “high capacity”, “low pressure drop” or “fire retardant” without the declared basis. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

15. Concise safety reminders

- Do not select an exhaust filter by price, colour, thickness or appearance alone.
- Do not compare percentages from different test methods as equivalent.
- Never add a stage without confirming fan duty, frame support, sealing and airflow.
- Do not use a loaded-filter fire classification inferred from the clean media.
- Keep coatings capable of reacting or self-heating in separate controlled filter and waste streams.
- Never bypass media or increase fan limits to hide excessive resistance.
- Stop spraying for loss of containment, abnormal pressure, collapse, run-off, breakthrough, heat, smoke or smouldering odour.
- Treat used filters according to the captured residue and Malaysian waste requirements.
- Maintain ventilation, interlocks, grounding and fire protection in their designed state.

FILTRATION, CLEANING & PROCESS CONTROL

CHAPTER 035

Filter Inspection and Replacement

35

SELECT • APPLY • FINISH • TROUBLESHOOT

MKTech Industry Sdn Bhd | www.mktechindustry.com

Audience: Paint-shop supervisors, booth operators, maintenance teams, production engineers, QA/QC personnel, safety and environmental personnel, procurement staff and technical sales personnel

Scope: A practical method for inspecting dry paint-booth intake and exhaust filters, interpreting pressure and airflow changes, diagnosing loading and failure patterns, setting condition-based replacement points, installing media correctly and maintaining useful disposal records.

Core principle — Replace a filter at the earliest applicable condition limit—not simply because it looks dirty or because a calendar date has arrived. A sound decision combines physical condition, differential pressure, airflow and containment, downstream cleanliness, production duty, coating compatibility and the declared limits of the booth and filter.

A paint-booth filter is a working component of the ventilation system. As it collects atmospheric dust or overspray, its resistance, loading distribution and mechanical condition change. These changes can reduce airflow, disturb booth balance, increase fan effort, promote bypass or allow paint to reach downstream surfaces. A clean-looking bank may still contain gaps or deep loading; a visibly coloured bank may still be stable. Inspection therefore needs a repeatable route and comparable operating information. [S171; S178; S195]

This chapter is an educational and application-selection guide. The installed booth method, coating Safety Data Sheet, applicable Malaysian requirements and current product information remain controlling. Where an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- conduct a structured visual inspection of intake, diffusion and exhaust-filter banks;
- establish a clean-bank pressure and airflow baseline after correct installation;
- distinguish normal loading from uneven loading, bypass, collapse and breakthrough;
- interpret pressure-drop and airflow trends together rather than as isolated readings;
- set replacement timing from the earliest relevant condition endpoint;
- confirm airflow direction, frame sealing, support and gauge condition during change-out;
- release a replaced bank only after physical and operational checks pass;
- maintain concise records that support maintenance, purchasing, safety and Malaysian waste control; and
- diagnose repeated short life without substituting an unsuitable filter or unsafe fan adjustment.

1. Inspect the complete filtration path

Inspection begins before touching the filter. Observe the booth while it is operating in its normal approved arrangement, then inspect the filter bank under the booth's isolation and access procedure. The useful inspection path follows the air:

630. room or make-up-air intake;
631. prefilter and supply-air stages;
632. ceiling or diffusion media;
633. booth work zone and openings;
634. exhaust paint-arrestor face;
635. supporting grid, frame and perimeter;
636. downstream plenum, duct and fan approach; and
637. pressure taps, gauge, alarms and control indication.

This route prevents a loaded exhaust filter from being blamed for a blocked intake, shut damper, dirty plenum, damaged fan or gauge fault. DOSH Malaysia treats local exhaust ventilation as a complete system of hood or enclosure, duct, air cleaner and fan, with regular inspection and maintenance of all components. [S171]

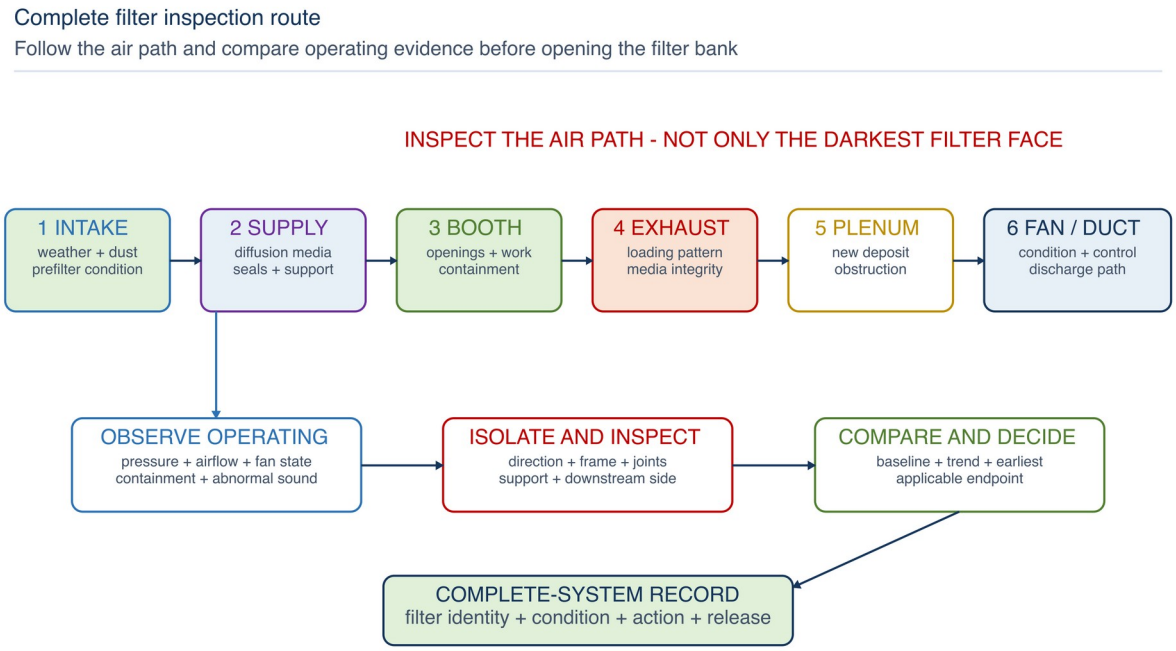

Figure 1. Complete filter inspection route. Follow the airflow from intake to discharge, checking operating condition before isolation and physical integrity after safe access. The route is qualitative and does not replace the booth's specified inspection method.

2. Use a repeatable visual inspection

Visual inspection is strongest when the same zones, lighting and observation order are used each time. Inspect with the bank operating where observation is safe and permitted; complete hands-on checks only after the required shutdown, run-on, clearance and isolation sequence.

Inspection zone	Acceptable condition	Warning signs	Immediate direction
Media face	Continuous coverage, stable shape and broadly explainable loading	Tears, holes, cuts, wet pooling, heavy crust, detached layers or exposed openings	Stop spraying for damage, exposed area or unstable media
Loading pattern	Even or consistent with the verified spray path and booth geometry	One saturated zone, clean streaks, edge-only loading or repeated high/low bands	Check airflow distribution, work position, spray aim and frame seal
Frame and perimeter	Media seated continuously with no visible gap	Missing clips, open corners, warped frame, compressed-off gasket or loose roll edge	Restore the mechanical seal before operation
Support	Grid or retainer supports the media without crushing it	Sag, flutter, bowing, pulled pleats or media moving toward the fan	Replace damaged media and correct support or direction
Upstream area	No excessive loose deposit or obstruction	Overspray mound, blocked open area, loose masking, paper or parts	Remove the obstruction by the approved cleaning method
Downstream plenum	Clean enough to identify new deposits; no wet paint trail	Fresh paint dots, streaks, puddles or growing deposit	Investigate bypass, damage or insufficient capture before restart
Pressure system	Gauge connected, legible and responsive	Broken tube, paint-blocked port, fluid loss, stuck pointer, abnormal zero	Restore valid measurement; do not infer condition from a faulty gauge
Fire and access controls	Required protection and access remain serviceable	Covered sprinkler, obstructed access, accumulated combustible residue or ignition source	Stop and restore the applicable safety control

Use photographs from fixed positions where practical. A close-up proves media condition; a full-bank photograph shows distribution. Record the booth state, filter stage, airflow direction and date so photographs remain meaningful.

3. Read loading patterns as system evidence

The shape of the deposit often reveals more than its colour. Compare the current pattern with earlier photographs and the physical layout of parts, guns, openings and plenums.

Pattern	Likely contributors	Verification check	Corrective direction
Broad, progressive loading	Normal accumulation under stable duty	Comparable pressure, airflow and production output	Continue to the established condition endpoint
Heavy centre, light edges	Concentrated spray path, part wake or central high flow	Observe normal work position and airflow distribution	Improve application path or distribution; do not patch the centre only unless the system method permits zoning
Heavy edges, light centre	Perimeter leakage path, centre obstruction or plenum distribution issue	Inspect seal, support, frame and downstream geometry	Restore seal and distribution before changing media grade
Alternating vertical or horizontal bands	Open joints, roll expansion error, support bars or local velocity variation	Trace bands to frame joints and pleat geometry	Reinstall with correct expansion, overlap and support
Clean streak through dirty bank	Gap, torn media, folded edge or bypass channel	Inspect both sides and downstream deposit trail	Stop spraying and close the bypass path
Wet pools or run-off	Excess local wet load, low airflow, unsuitable orientation or insufficient capacity	Check spray rate, transfer, airflow and media duty	Correct process and evaluate suitable holding construction
Sudden full-face skin	Fine/tacky mist, moisture, process change or dense first stage	Confirm coating, atomisation, ambient and filter identity	Correct the cause and reassess stage arrangement
Downstream paint with modest face loading	Bypass, reverse installation, damage or unsuitable capture duty	Check direction, seals, backing and fine-stage condition	Restore installation or select the declared capture duty

Uneven loading is a symptom, not a diagnosis. Replacing only the darkest section can move airflow toward the new low-resistance area and make distribution less stable. Zone replacement is appropriate only where the booth and filter arrangement are designed and controlled for it.

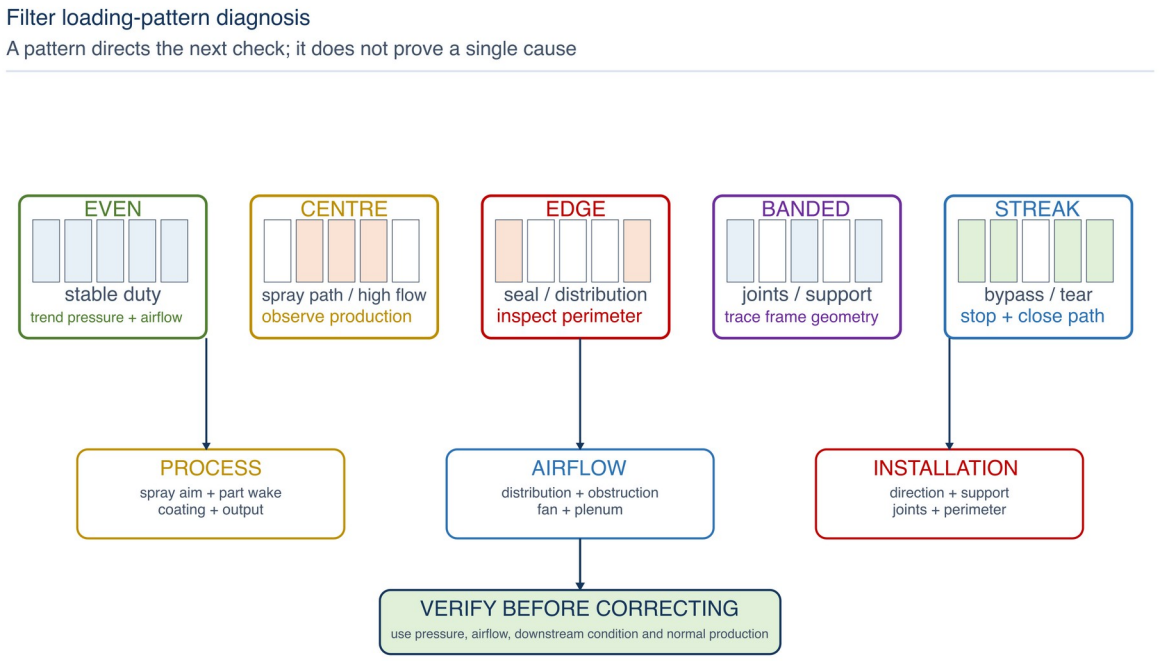

Figure 2. Loading-pattern diagnosis map. Full-bank, edge, banded, local and bypass patterns direct inspection toward process, airflow, installation or media-condition causes. The illustrated patterns are schematic rather than acceptance standards.

4. Monitor differential pressure correctly

Differential pressure is the resistance between two defined points. Across a filter bank, it normally increases as deposited material restricts the available flow paths. The reading is valuable only when the pressure taps, gauge, fan/control state, doors, dampers and airflow condition are comparable.

Before relying on a reading:

- confirm both pressure tubes are connected to the intended upstream and downstream points;
- inspect tubes for splits, kinks, condensation, paint blockage and reversed connections;
- check the instrument zero under its specified condition;
- confirm the gauge range and units are appropriate and legible;
- identify whether the reading covers one stage, several stages or the whole booth; and
- record fan speed or control state, door position and production condition.

Pressure behaviour	Possible meaning	What pressure alone cannot prove	Next check
Gradual rise from a stable clean baseline	Normal accumulation	That airflow and capture remain acceptable	Airflow/containment and physical condition
Rapid rise	Heavy loading, surface blinding, moisture, wrong media, compressed media or downstream restriction	Which cause is responsible	Loading pattern, coating/process change and stage-by-stage condition
Unusually low reading	Clean bank, low airflow, torn media, open bypass, disconnected gauge or blocked tap	That the bank is healthy	Gauge response, airflow and downstream deposit
Reading falls without a filter change	Flow reduction, media rupture, collapse, bypass opening or gauge fault	That resistance has improved	Fan state, physical integrity and gauge system
Oscillating reading	Fluttering media, unstable fan/control, opening doors or turbulent pressure taps	The time-averaged filter condition	Media support, operating sequence and instrument location
New clean bank reads higher than the previous clean baseline	Different media, excess layers, wrong direction, compression, obstruction or changed airflow	That the new media is defective	Identity, installation, effective area and fan state

Never convert a supplier's final-resistance value into a universal booth limit. The safe replacement point may be earlier because airflow, containment, motor load, physical stability, fire control or downstream cleanliness reaches its limit first. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

5. Link pressure to airflow and containment

Pressure drop and airflow are related through the complete fan system, but one is not a substitute for the other. With a fixed-speed fan, increasing system resistance commonly reduces flow. With a controlled-flow system, the drive may increase fan effort to hold flow until it reaches a control or motor limit. A stable pressure reading can therefore accompany different airflow conditions if the control state changes. [S171; S194; S195]

Use one or more verified operational indicators appropriate to the booth:

- face or cross-sectional airflow measurement under the approved method;
- fixed-position velocity checks used for trending;
- airflow indicator, alarm or interlock status;
- smoke or visual containment test performed by a competent person with suitable test material;
- booth pressure relationship to the surrounding area;
- fan speed, drive output or motor condition; and
- overspray behaviour at openings and workpiece position.

Combined observation	Interpretation	Action
Pressure rises; airflow falls	Loaded resistance is consuming fan capability	Replace at the established endpoint and check for other restrictions
Pressure rises; airflow remains stable; fan effort rises	Control is compensating for loading	Monitor available control/motor margin and change at the earliest limit
Pressure is low; airflow is low	Fan, damper, intake or gauge problem is possible	Inspect the complete system before blaming the exhaust filter
Pressure is low; airflow appears high; downstream paint increases	Bypass, torn media or insufficient capture may be present	Stop spraying and inspect seals, integrity and stage duty
Pressure is normal; containment is poor	Distribution, cross-draft, openings or work position may be defeating capture	Correct booth boundary and airflow distribution
Pressure and airflow are normal; finish dust increases	Intake leakage, ceiling-filter damage or housekeeping may be responsible	Inspect clean-air stages and booth surfaces

DOSH guidance uses baseline testing for comparison and calls for investigation where reduced flow or malfunction is indicated. Keep the site's statutory inspection and examination programme separate from routine operator checks, while making the two records support each other. [S171]

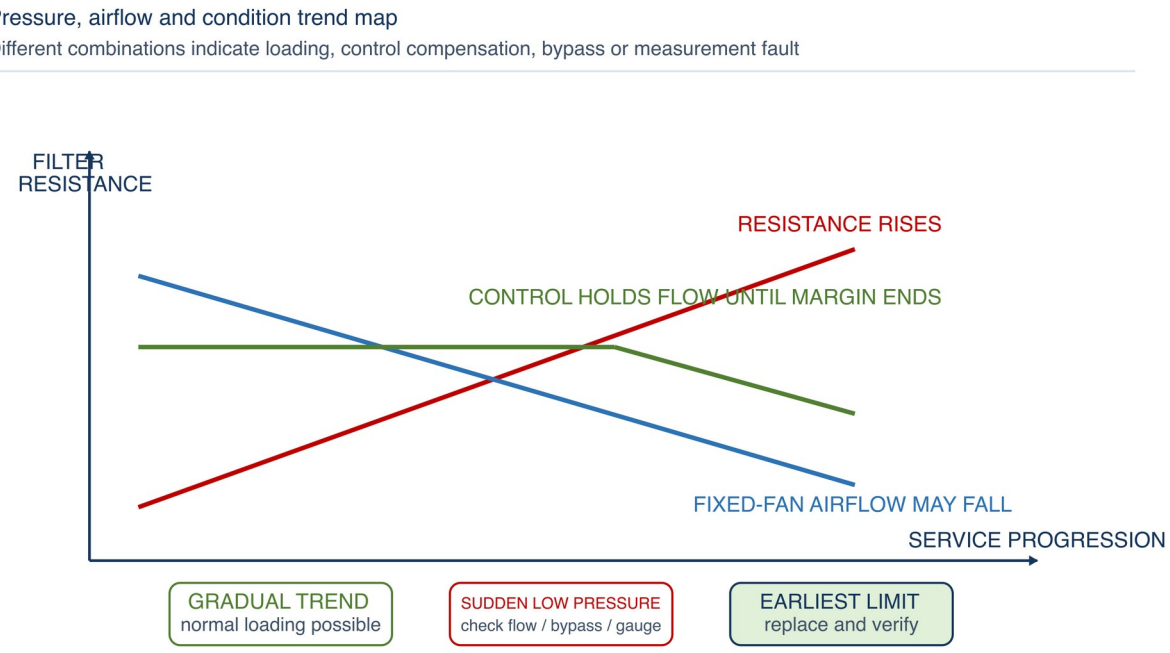

Figure 3. Pressure, airflow and condition trend map. The qualitative paths show why rising resistance, falling flow, control compensation and a sudden low-pressure fault require different responses. No numeric pressure or airflow limit is implied.

6. Recognise bypass, collapse and breakthrough

Bypass

Bypass is air passing around rather than through the intended media. It follows gaps at the perimeter, open joints, damaged gaskets, missing clips, poor roll overlap, unsealed frame connections or holes. Because the bypass path has lower resistance, it can remain deceptively clean while a downstream streak accumulates.

Typical indicators are:

- clean line or corner beside a loaded face;
- media lifting or fluttering at an edge;
- pressure lower than the established condition would suggest;
- paint trail on the clean side aligned with a joint; and
- local downstream deposit despite apparently suitable media.

Correct bypass mechanically. A finer filter cannot compensate for an open seal. Camfil's installation guidance for filter frames uses gasket compression and sealing between frame joints to prevent air bypass; the same transferable principle applies to a paint-booth bank while the booth and selected filter instructions govern the actual hardware. [S196]

Collapse

Collapse is loss of the media's intended shape or support under airflow, deposit weight, moisture or incorrect installation. It includes sagging, bowing, pleats pulling together, a pad being drawn through the grid, a pocket folding over, or a roll detaching from its anchorage.

Common contributors include reverse direction, insufficient support, excessive span, over-expansion or under-expansion, saturated deposit, media incompatible with the duty, abnormal pressure, damaged frame or missing retainers. Collapse can create both high local resistance and open bypass paths.

Stop spraying when the bank cannot retain its intended geometry. Replace the damaged section or bank, restore support and investigate the cause before restart.

Breakthrough

Breakthrough is paint or particulate appearing downstream of the installed filter system. It may be genuine penetration through intact media, but it can also result from bypass, tearing, poor joints, reverse installation, overloaded media, displaced backing or an unsuitable first/final-stage combination.

Confirm the route before selecting a finer grade:

638. identify whether the deposit is wet paint, dry residue, rust, old contamination or other dust;
639. trace its position back to the filter face, joints and frame;
640. inspect direction, backing and mechanical condition;
641. confirm the coating, atomisation and spray rate have not changed;
642. check the downstream stage and pressure/airflow trend; and
643. clean a defined downstream observation area so recurrence can be verified.

7. Set a condition-based replacement point

Replacement timing should be predictable but not arbitrary. A calendar schedule supports planning and inspection; it does not override an earlier physical or operational limit.

Replace at the earliest applicable endpoint:

644. **Declared filter endpoint:** the product's stated final resistance, loading or service condition.
645. **Booth airflow endpoint:** required airflow, containment or control range can no longer be maintained.
646. **Physical endpoint:** tear, hole, sag, collapse, loose backing, run-off, detachment or damaged seal.
647. **Downstream endpoint:** unacceptable breakthrough, deposit or protection loss.
648. **Fire/chemical endpoint:** residue compatibility, heat, smoke, odour, curing or housekeeping condition requires removal.
649. **Process-quality endpoint:** verified filtration condition is causing dust, dry spray, turbulence or finish defects.
650. **Maintenance endpoint:** the planned stoppage is the safe opportunity to replace a bank that would not reliably complete the next production period.

Replacement basis	Strength	Limitation	Best use
Differential-pressure endpoint	Direct trend of installed resistance	Depends on valid gauge and comparable airflow/control state	Primary condition indicator where correct pressure points exist
Airflow or containment endpoint	Directly relates to booth function	Requires a reliable measurement or indicator method	Confirms the booth remains effective as loading increases
Visual/physical endpoint	Detects damage, collapse, bypass and run-off	Appearance alone does not quantify remaining capacity	Mandatory inspection alongside pressure and airflow
Production-throughput trend	Supports stock and labour planning	Changes in coating, part or spray technique can invalidate comparison	Forecasting under stable production families
Calendar interval	Simple scheduling	Can replace too early or too late when duty changes	Maximum inspection/service prompt, not the only change trigger
Downstream-cleanliness endpoint	Reveals protection failure	May detect failure after contamination has occurred	Secondary confirmation and post-change verification

For an exact replacement value or interval, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

8. Plan the change safely

Loaded filters can contain wet coating, solvent, reactive hardener and combustible residue. Plan the change around the coating SDS, chemical assessment, booth procedure, fire controls and waste route.

Before starting:

- stop spraying and complete the specified ventilation run-on or clearance period;
- isolate equipment and energy sources under the site procedure;
- confirm that the filter area is safe to enter and that required fire protection remains available;
- identify the coating residues and select the specified PPE and handling controls;
- prepare compatible, labelled waste containers close enough to prevent uncontrolled carrying;
- protect the clean side, booth floor and nearby components from released deposits;
- prepare the correct replacement identity, quantity, direction and support hardware; and
- prohibit hot work, ignition sources and compressed-air blow-off of paint deposits.

Do not shake, tear or drag loaded media across clean surfaces. Do not cut into a wet or heavily loaded pocket unless the approved method specifically requires it. Do not stack warm, wet or actively curing filters in an enclosed combustible pile.

9. Remove and clean in a controlled sequence

651. Record the last comparable pressure, airflow/containment condition and observed loading pattern.
652. Photograph the bank before removal if failure pattern or service life is being investigated.
653. Remove media in manageable sections, supporting its weight and keeping the loaded face controlled.
654. Place each section directly into the prepared container; segregate incompatible residues.
655. Inspect the exposed frame, clips, grids, channels, gaskets and downstream side.
656. Remove accessible loose residue by the booth's approved non-sparking, low-dispersion method.
657. Check pressure taps and tubing without pushing contamination into the system.
658. Record damage that needs repair before new media is installed.

Replacing media over a dirty, warped or unsealed frame preserves the failure. Frame cleaning is complete only when the seating surface can make a continuous seal and the downstream side is suitable for detecting new breakthrough.

10. Install in the correct direction

Filter media can be directional. Direction may be identified by an airflow arrow, upstream/downstream label, colour, backing, graduated density, pocket orientation, pleat geometry or product instructions. Appearance is not a reliable substitute for declared installation information.

Use this installation sequence:

659. verify filter identity against the work order and installed location;
660. identify airflow direction and the declared spray or dust side;
661. inspect the replacement for moisture, crushing, tears, delamination or transport damage;
662. clean and repair the seating frame before placing media;
663. fit the media without compressing its designed depth or distorting pleats and pockets;
664. close every joint, overlap and perimeter in the specified sequence;
665. engage all clips, retainers, grids and anchors so deposit weight and airflow cannot displace the media;
666. inspect both upstream and downstream sides where accessible; and
667. confirm that no frame opening or unused area is exposed.

Roll and accordion media must be expanded or overlapped as specified. Under-expansion can reduce internal storage and leave open joints; over-expansion can flatten geometry and change resistance. Pocket and panel filters must be seated against the correct gasket face and supported in the intended airflow direction. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

11. Verify frame sealing and support

A sealed bank directs air through the media. Use a systematic perimeter-to-centre check:

- **Perimeter:** continuous contact with no visible daylight, folded edge or broken gasket.
- **Corners:** clips engaged and media not pulled away by tension.
- **Joints:** specified overlap, compression or sealing strip is continuous.
- **Centre:** no missing panel, crushed section or unsupported span.
- **Retainers:** installed without cutting, puncturing or excessively compressing media.
- **Frame:** square enough to seat the filter; no corrosion, dried paint ridge or damage holding an edge open.
- **Downstream:** no loose piece can be drawn into the fan or duct.

Where several frames form a bank, seal between the frames and between the bank and surrounding plenum as required. A perfect media-to-frame seal cannot correct leakage around the frame assembly itself. [S196]

12. Establish the clean-bank baseline and release

The first controlled operating condition after replacement becomes the reference for later trending. Record it only after the bank has passed physical checks.

Release sequence:

668. account for tools, offcuts and removed media;
669. close access panels and restore guards, fire protection, pressure tubing and interlocks;
670. remove isolation under the authorised procedure and start ventilation without spraying;
671. observe the bank for flutter, movement, abnormal noise or pulling at joints;
672. check the gauge zero/response and record the clean differential pressure;
673. verify airflow, containment and booth pressure by the established method;
674. inspect the downstream observation area and booth openings;

675. conduct the authorised production check using normal coating and operating conditions; and
676. record filter identity, installation date, baseline and release decision.

Stop and correct the installation if the clean reading, airflow or containment differs materially from the established condition, or if any gap, movement, unusual odour, smoke, heat or downstream deposit is observed.

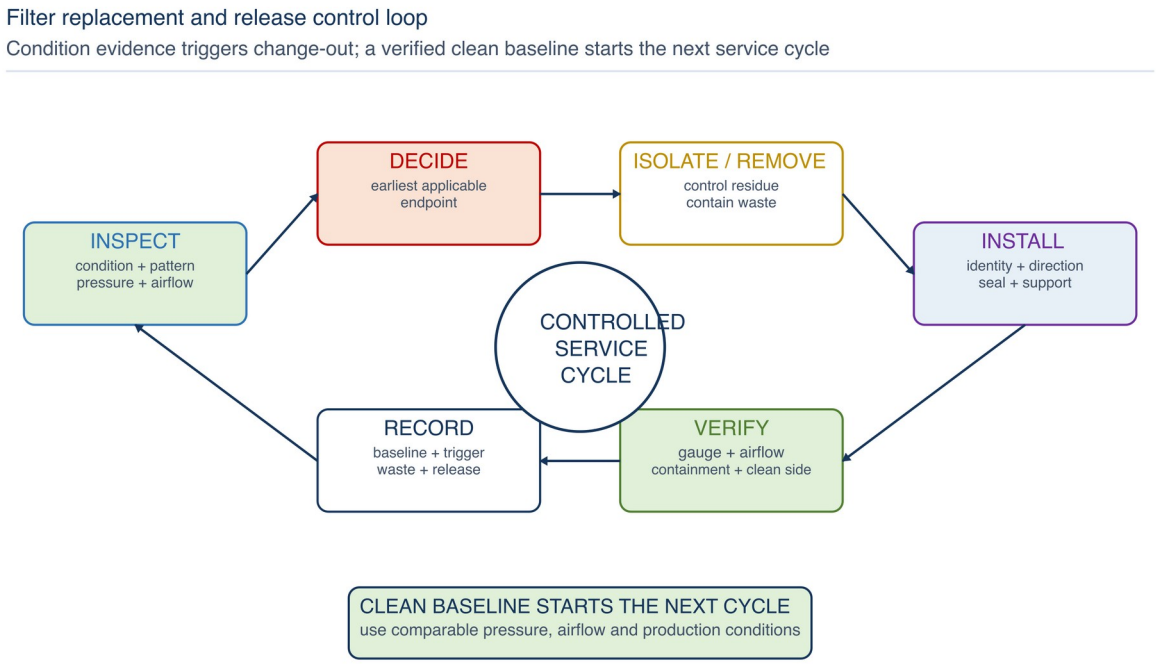

Figure 4. Filter replacement and release control loop. Inspection evidence triggers a controlled change, correct installation establishes a new baseline, and operating checks release the bank. Records feed stock planning and future diagnosis.

13. Keep useful inspection and replacement records

A concise record should support the next operator, maintenance planner, environmental coordinator and purchaser. It should explain what changed and why without relying on memory.

Record field	What to enter	Why it matters
Booth and filter location	Booth ID, supply/exhaust stage and bank/zone	Links the record to the correct pressure points and media
Filter identity	Manufacturer, product reference, format, size and batch where available	Supports traceability and repeat purchase
Installation details	Date, direction, quantity, expansion/overlap and sealing/support condition	Helps diagnose early failure or bypass
Clean baseline	Differential pressure, airflow/containment indicator and fan/control state	Establishes a comparable starting point
Inspection trend	Dates, readings, loading pattern, damage and downstream condition	Shows how the bank moved toward the endpoint
Production context	Coating family, major process changes and relevant production basis	Prevents false service-life comparisons
Change trigger	Pressure, airflow, physical, breakthrough, safety, quality or planned-maintenance endpoint	Makes replacement decisions auditable
Used-filter handling	Residue identity, classification, quantity, container and storage location	Supports safe segregation and Malaysian waste control
Transfer/disposal	Date, authorised route and required consignment or inventory reference	Completes traceability to the receiving route
Release result	Clean reading, airflow/containment check, downstream check and responsible person	Confirms the new bank returned to service correctly

Use trends to forecast stock, not to create an unqualified guarantee. Service life can change with coating solids, spray rate, transfer efficiency, part geometry, operator technique, ambient dust, humidity, airflow and media construction. [S178; S195]

14. Control disposal records in Malaysia

Used-filter classification follows the captured coating residue and the generating process. The waste generator identifies the applicable category using process and chemical information; the clean carrier material alone does not determine the route. DOE Malaysia requires scheduled waste, where applicable, to follow prescribed storage, labelling, inventory, transport and authorised-receiving controls. [S188; S189]

Use the following record chain:

677. link the removed filter to the coating, hardener, thinner and process period;
678. determine the applicable waste classification from the actual residue and generating process;
679. segregate incompatible waste streams;
680. record the date, quantity, container identity and designated storage location;
681. maintain the required current inventory and labels;
682. use authorised transport and receiving arrangements where required; and
683. retain the applicable inventory and movement records for the prescribed period.

Do not assign one universal waste code to all paint-booth filters. DOE Malaysia states that the waste producer is responsible for classification because it knows the raw materials and generating process. [S189]

15. Troubleshoot inspection and replacement problems

Symptom	Likely causes	Verify first	Corrective direction
Filters block much sooner than expected	Higher spray load, finer/tackier mist, reduced area, moisture, wrong media or compressed installation	Process change, face pattern, identity and airflow	Correct application/system cause and select capacity within the booth duty
New filter gives high pressure immediately	Wrong product, excess layers, reverse direction, over-compression, obstruction or changed flow	Identity, installation, gauge and fan state	Reinstall correctly or use the declared compatible configuration
Pressure stays low as filters load	Gauge fault, bypass, tear, low airflow or pressure taps across the wrong points	Gauge response, seals, media integrity and airflow	Restore valid measurement and sealed bank
Filter collapses	Wrong direction, missing support, excessive span, wet load, abnormal resistance or unsuitable construction	Support grid, frame, media duty and pressure trend	Replace damaged media and correct the cause before restart
Edge pulls away	Poor anchoring, incorrect roll tension/expansion, warped frame or deposit weight	Clips, perimeter and installation method	Repair frame and reinstall with continuous restraint
Downstream paint appears after change	Open joint, reversed backing, torn media, wrong stage or old downstream residue	Clean a defined area; inspect direction and seals	Correct installation and confirm capture duty
One zone repeatedly saturates	Local spray aim, part wake, uneven airflow, blocked plenum or inactive bank area	Observe normal production and perform distribution checks	Correct process/distribution; assess designed zoning only if appropriate
Finish dust rises after exhaust change	Intake leakage, disturbed booth dirt, damaged ceiling media or turbulence	Intake stages, housekeeping and airflow balance	Restore clean-air path and booth condition
Fan effort or noise increases	Loaded resistance, obstruction, control compensation or mechanical issue	Pressure profile, fan/control state and full system	Replace at endpoint and service the system cause
Filters are being changed too often without evidence	Calendar habit, inconsistent endpoint or poor records	Compare pressure, airflow, condition and production basis	Adopt condition-based records and a defined earliest endpoint

Repeated failure after correct installation is a system signal. Re-run the Chapter 034 selection method using the current coating, overspray volume, booth airflow, effective area, pressure allowance, capture duty and disposal route.

16. Concise safety reminders

- Keep ventilation, interlocks, grounding and fire protection in their designed operating state.
- Stop spraying for tears, open gaps, collapse, run-off, breakthrough, loss of containment, heat, smoke or smouldering odour.
- Do not use gauge pressure as the only proof of airflow or capture.
- Never increase fan limits to conceal a loaded or unsuitable filter.
- Do not mix filter residues from coatings that can react or self-heat together.
- Prevent ignition sources and uncontrolled compressed-air cleaning in paint and filter areas.
- Wear the PPE and use the handling method specified by the coating assessment and booth procedure.
- Place removed filters directly into the correct compatible container; do not leave them beside the booth.
- Treat used filters according to the captured residue and applicable Malaysian waste requirements.
- Verify direction, sealing, support, pressure indication, airflow and downstream condition before production release.

FILTRATION, CLEANING & PROCESS CONTROL

CHAPTER 036

Paint-Booth Troubleshooting

36

SELECT • APPLY • FINISH • TROUBLESHOOT

MKTech Industry Sdn Bhd | www.mktechindustry.com

Audience: Paint-shop supervisors, booth operators, maintenance teams, production engineers, QA/QC personnel, safety and environmental personnel and technical sales personnel

Scope: A practical, symptom-led method for diagnosing overspray escape, reduced airflow, dust contamination, uneven finish, excessive filter consumption, fan overload, filter bypass, odour, premature blockage and poor capture.

Core principle — Treat the booth as one connected air-handling and coating system. Confirm safety and containment first, then separate airflow, filtration, contamination, fan and application causes before changing a setting or component.

A paint-booth symptom rarely proves a single cause. Overspray at the opening may come from low exhaust flow, excessive make-up air, cross-draught, poor work position or spray aimed outside the capture path. Dust on a part may enter through intake leakage, fall from booth surfaces, come from clothing or be created by the coating process. A loaded filter may be the cause of reduced flow, but it may also be the result of excessive overspray. Effective troubleshooting therefore follows evidence through the complete intake–booth–filter–duct–fan path. [S171; S172; S178]

Chapter objectives

After this chapter, the reader should be able to:

- identify conditions that require spraying to stop before diagnosis continues;
- use a symptom-first troubleshooting flowchart;
- distinguish low-flow, poor-distribution and poor-balance faults;
- trace filter bypass separately from media penetration or mechanical damage;
- investigate dust and finish defects without assuming the filter is responsible;
- diagnose high filter usage and premature blockage from production and system evidence;
- recognise fan overload, noise and vibration as system faults requiring authorised maintenance;
- respond appropriately to odour without treating a particulate filter as a vapour filter;
- verify corrective action under a comparable operating condition; and
- record the cause, action and result so repeated failures can be prevented.

1. Make the booth safe before troubleshooting

Stop spraying and follow the site's emergency or isolation procedure when any of the following is observed:

- visible overspray or vapour is escaping into occupied work areas;
- smoke, fire, unusual heat, sparking or burning odour is present;
- a ventilation, fire-protection, access-door or spray-permissive interlock has operated;
- the exhaust or supply fan has stopped, stalled or developed severe noise or vibration;
- a filter has collapsed, detached or opened a direct bypass path;
- a significant liquid spill, wet paint accumulation or combustible deposit is present; or
- personnel report acute irritation, dizziness, breathing difficulty or other exposure symptoms.

Keep mechanical ventilation operating for the required post-spray clearance period unless the emergency procedure or responsible safety authority directs otherwise. Do not enter or open hazardous areas merely to investigate a fault. Isolation, atmospheric control, personal protective equipment and access arrangements follow the coating Safety Data Sheet, booth procedure and site risk controls. [S153; S160; S172; S175; S177]

2. Start with the symptom, then split the system

Record what changed before touching the booth. Identify the affected product, coating, shift, operator, spray gun, filter stage and time. Note whether the symptom appeared suddenly, developed gradually or followed maintenance, a coating change, a production increase or unusual weather.

Use five diagnostic branches:

684. **Airflow and pressure** — restriction, insufficient make-up air, open doors, cross-draught, damper position or changed control state.
685. **Filtration and sealing** — loaded media, wrong direction, poor expansion, damaged support, frame gap, breakthrough or unsuitable duty.
686. **Contamination and housekeeping** — dirty intake, booth deposits, clothing, compressed air, sanding dust, part contamination or disturbed floor material.
687. **Fan and mechanical condition** — belt, bearing, impeller deposits, rotation, obstruction, electrical load, vibration or system effect.

688. **Coating and application** — viscosity, temperature, atomisation, spray distance, overlap, gun condition, flash-off, part geometry or excessive overspray generation.

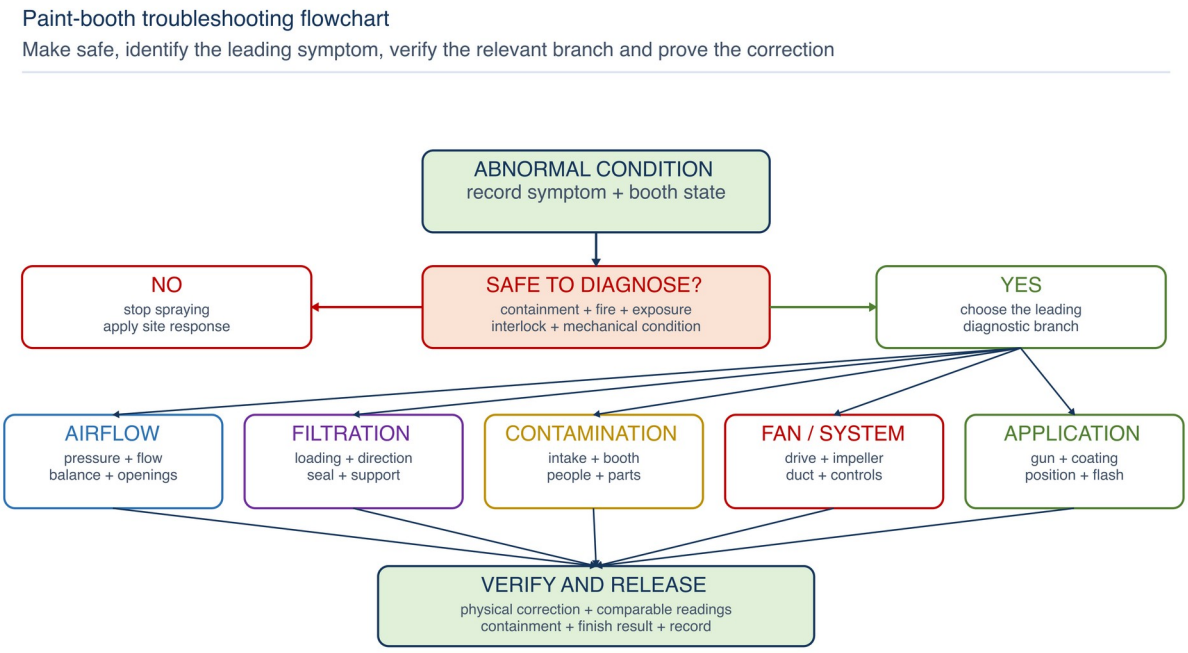

Figure 1. Paint-booth troubleshooting flowchart. Begin with safety and containment, identify the principal symptom, verify the relevant branch and prove the correction before release. The sequence does not authorise bypassing interlocks or changing engineered settings.

3. Overspray escaping the booth

Escaping overspray is a containment failure. Stop spraying when mist is visibly moving into occupied space or depositing outside the controlled area. Do not compensate by moving the operator, opening another door or increasing fan speed without understanding booth balance.

Observation	Likely contributors	Verification	Corrective direction
Mist rolls out across the full opening	Low exhaust flow, excessive supply, restricted exhaust bank or open boundary	Compare airflow, pressure and fan/control state with the accepted operating baseline	Restore the verified airflow path and booth balance
Escape occurs at one edge	Cross-draught, local supply jet, open door, blocked section or poor work position	Map direction at the opening and inspect local filter loading	Remove the disturbance or correct distribution
Escape follows the spray gun movement	Gun aimed outside capture path, excessive distance, rebound or poor part positioning	Observe the normal application route from a safe position	Reposition work and refine technique within the approved process
Escape begins after filter loading	Rising resistance and falling flow	Review pressure and airflow trend with physical filter condition	Replace at the established condition endpoint and verify the clean-bank baseline
Escape begins after filter change	Wrong medium, excess layers, reverse direction, compression, gap or control change	Confirm identity, direction, fit, support and fan state	Reinstall correctly or restore the selected system configuration

DOSH guidance treats enclosure performance, capture and the complete exhaust system as connected. A useful correction must restore both containment and the operating indications used for the booth baseline. [S171; S172]

4. Reduced airflow and poor capture efficiency

Reduced airflow is a measured or observable loss of air movement. Poor capture is failure to collect mist and residue at the source. They often occur together, but not always: total airflow may be adequate while distribution, part location or a cross-draught defeats capture.

Check the air path in order:

689. room and make-up-air openings;
690. intake and ceiling-filter stages;
691. booth openings, doors and temporary screens;
692. workpiece position and blockage;
693. exhaust filter bank and support;
694. downstream plenum and duct;
695. damper and control state; and
696. fan, drive and discharge condition.

Pressure/airflow pattern	Most useful interpretation	Next action
Pressure rising, airflow falling	Filter or downstream resistance is consuming available fan capability	Inspect each stage and remove the verified restriction
Pressure rising, airflow stable, fan effort rising	A control system may be compensating	Confirm motor/control margin and replacement endpoint through authorised maintenance
Pressure low, airflow low	Fan output, damper, supply restriction or measurement fault is likely	Verify fan/control state and measuring system
Pressure normal, capture poor	Distribution, cross-draught, work position or excessive mist generation may dominate	Check local air direction and application path
Pressure falls suddenly, downstream deposit rises	Rupture, bypass or media displacement is possible	Stop spraying and inspect integrity and sealing

Use fixed, repeatable measurement positions and a comparable booth state. A handheld spot reading taken at a different location, door arrangement or fan mode may suggest a change that is not real. Exact operating values must match the installed booth and selected filter system. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

5. Dust on painted parts

Dust contamination may reach the wet film before spraying, during application, during flash-off or while the coating cures. First determine whether the particles are loose, embedded, fibrous, metallic, paint-like or cratered around a liquid contaminant.

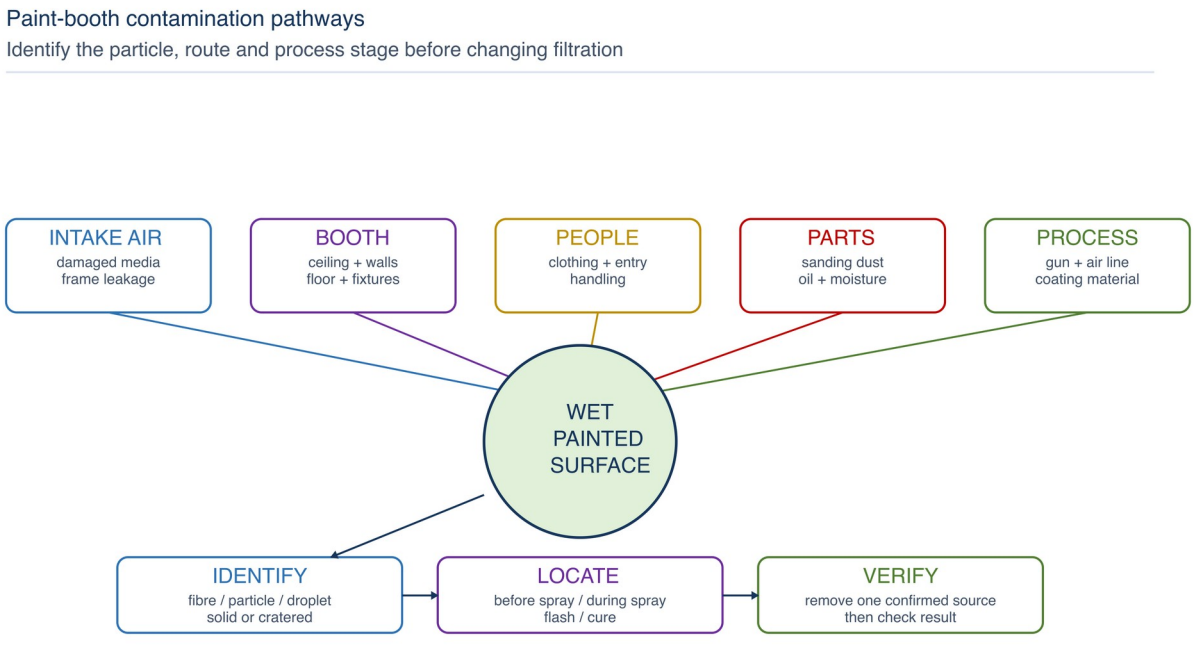

Figure 2. Contamination pathway map. Trace contamination from intake air, booth surfaces, people, parts, process equipment and coating material to the stage where the defect first appears.

Evidence	Likely source	Verification	Corrective direction
Fibres match intake or ceiling media	Damaged media, poor support, reverse installation or disturbed surface	Compare particle appearance and inspect the clean-air stages	Correct installation and replace damaged media
Dust concentrated on upper faces	Falling deposit from ceiling, fixtures, clothing or poor cleaning	Inspect overhead surfaces and observe entry/handling	Clean by the approved method and improve contamination discipline
Dirt increases near doors	Uncontrolled entry, pressure imbalance or cross-draught	Compare defect location with opening behaviour	Restore booth boundary and entry control
Metallic or abrasive particles	Inadequate part cleaning or adjacent grinding/sanding	Examine preparation and transfer route	Separate dirty work and clean parts before coating
Defect appears after flash-off	Contaminated flash area, disturbed floor deposit or airflow reversal	Track part movement and airflow state after spraying	Control the post-spray environment and clearance sequence
Craters or fisheyes rather than solid particles	Oil, silicone, water, compressed-air contamination or substrate residue	Inspect air quality, cleaning materials and part-preparation history	Remove the verified contaminant source and requalify the process

Do not increase intake-filter grade automatically. A finer filter cannot correct an open frame, dirty booth, contaminated part or unsuitable compressed air, and added resistance may reduce airflow if the fan system cannot support it.

6. Uneven finish

Uneven colour, gloss, texture or film build can arise from airflow, but application and coating variables remain equally important. Diagnose the spatial pattern.

- A repeated defect on the same booth side suggests airflow distribution, local temperature, supply jet or opening effects.
- A defect that follows the operator or gun suggests spray distance, angle, overlap, atomisation or gun condition.
- A defect tied to part geometry suggests shielding, rebound, edge build or difficult access.
- A defect that begins after a filter change suggests changed airflow distribution, media orientation, excess resistance or disturbed contamination.
- A defect that follows a coating batch or environmental change suggests viscosity, mixing, temperature, humidity, flash or cure conditions.

Finish symptom	Booth-related checks	Process-related checks
Dry spray or roughness	Excess local air velocity, turbulent jet, long travel to exhaust	Gun distance, atomisation, solvent balance, coating temperature
Sags or heavy area	Low or uneven air movement, local dead zone	Film build, overlap, viscosity, gun output
Uneven metallic orientation	Cross-flow disturbance or inconsistent booth balance	Gun path, overlap, flash and material preparation
Mottling or patchiness	Local airflow or temperature variation	Application sequence, wetness and coating-specific technique
Craters/fisheyes	Air or surface contamination	Cleaning chemistry, oil, silicone, water and compressed air
Dull or variable gloss	Contamination, airflow or cure uniformity	Mix ratio, flash, film build, substrate and cure conditions

Keep acceptance against the approved finish sample or job specification. When coating-specific values are required, refer to the coating Technical Data Sheet and Safety Data Sheet.

7. High filter usage and premature blockage

Short service life is an outcome, not a sufficient reason to fit a more open medium. Determine whether the filters are collecting an unusually high load, presenting insufficient effective area, blinding at the surface or being replaced before the true endpoint.

Common causes include:

- increased production hours, spray rate or coating solids;
- lower transfer efficiency, poor gun condition or excessive test spraying;

- work positioned too close to one filter zone;
- filter media compressed, under-expanded, layered incorrectly or installed backwards;
- moisture, tacky mist or incompatible residue closing the surface;
- one stage carrying load intended for a staged system;
- restricted intake or downstream path forcing an abnormal operating point;
- replacement triggered by appearance alone rather than combined condition evidence; and
- poor sealing that overloads a downstream stage.

Use a common basis such as accepted coated components or controlled spray hours when comparing service life. Record the coating family, production mix, filter identity, pressure/airflow trend, reason for removal and observed loading pattern. Do not claim improved life from a substitute until the complete system has been evaluated under comparable duty.

8. Fan overload, abnormal noise and vibration

Fan overload may appear as high motor current, protection trips, overheating, reduced speed, control alarms or repeated starter operation. Noise and vibration may point to impeller deposit, imbalance, bearing condition, belt or coupling fault, loose mounting, contact, foreign material, flow instability or adverse inlet/outlet conditions. [S175; S179; S197]

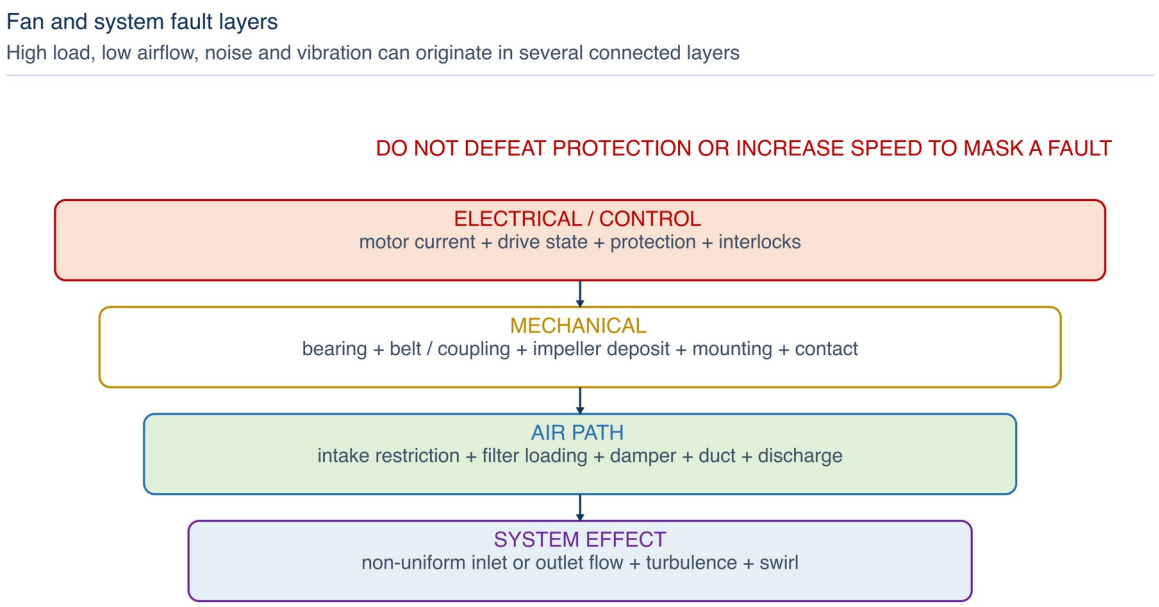

Figure 3. Fan and system fault layers. Inspect electrical/control, mechanical, air-path and system-effect causes as connected layers. Any intrusive fan work follows isolation and authorised maintenance.

Symptom	Possible causes	Safe diagnostic direction
Motor current or drive load rises with filter loading	Control compensation, changed duty point or added resistance	Compare fan mode, airflow and pressure trend; use authorised electrical measurement
Fan trips after maintenance	Wrong rotation, damper state, belt tension, obstruction, wiring/control issue or changed filter resistance	Isolate and verify the maintenance scope before restart
Vibration builds gradually	Impeller deposit, bearing wear, loose mounting or imbalance	Stop within the site's vibration/escalation rule and inspect under isolation
Sudden impact or scraping noise	Foreign object, loose component or rotating-element contact	Stop immediately and isolate
Airflow is low despite high fan effort	Excess system resistance, system effect, blockage or fan degradation	Inspect complete intake, duct and discharge path
Pulsing or hunting	Unstable control, damper interaction, stalled flow or rapidly changing booth pressure	Review control signals and air-path stability with competent maintenance

Do not defeat overload protection, bypass an interlock or increase speed merely to recover a lost airflow reading. The fan, motor, drive, duct and filters are selected as a system. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

9. Filter bypass and downstream paint

Bypass is flow around rather than through the intended filter area. It can occur at the perimeter, between panels, through an under-expanded roll, around a warped frame, at a missing clip or across a damaged gasket. Penetration is passage through the media; breakthrough may describe unacceptable downstream carry-over from penetration, overload, damage or bypass. These mechanisms need different corrections. [S178; S195; S196]

Trace a fresh downstream deposit upstream to its route:

697. isolate the booth and inspect the deposit shape;
698. look for a matching clean streak, open edge, joint or damaged zone on the filter face;
699. confirm airflow direction and required backing or support;
700. verify continuous frame contact and joint sealing;
701. inspect for collapse, cut, puncture or paint-softened structure;
702. confirm that the installed medium is intended for the coating and stage duty; and
703. clean the affected downstream area by the approved method before release so new carry-over can be identified.

A higher-efficiency medium cannot correct an open bypass path. Exact direction, expansion, overlap, support and sealing details are product specific. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

10. Odour inside or around the booth

Odour can indicate poor containment, inadequate clearance, exhaust re-entry, a spill, residue accumulation, coating-process change or a problem with a dedicated vapour-control system. Odour intensity is not a reliable measure of chemical concentration or safety.

Most dry intake and overspray filters are particulate-control devices; they do not remove solvent vapours merely because they capture paint mist. [S178] If odour is unusual, strong, persistent or accompanied by symptoms, stop work and apply the site's chemical-exposure response.

Check:

- exhaust fan and spray-permissive status;
- containment at openings and doors;
- post-spray clearance and drying/flash mode;
- exhaust discharge relative to make-up-air and building intakes;
- spills, wet deposits, waste containers and contaminated filter storage;
- coating identity, mix, application rate and Safety Data Sheet;
- make-up-air path and adjacent work; and
- the condition and declared service endpoint of any dedicated vapour-treatment stage.

Do not add an improvised carbon layer or recirculate exhaust air as a quick odour remedy. Vapour control, fire protection and discharge arrangements require competent system review.

11. Diagnose the system with comparable evidence

The strongest fault record combines four evidence groups.

Evidence group	Record	Why it matters
Symptom	Location, time, severity, photograph and affected product	Defines the problem without assuming the cause
Operating state	Booth mode, doors, fan/control indication, dampers and concurrent work	Makes readings comparable
Air and filter condition	Pressure, airflow/containment observation, filter identity, loading and seals	Separates restriction, distribution and bypass
Process context	Coating, gun, part, spray route, production load and recent changes	Tests whether the booth fault is actually generated by application

Compare with an accepted clean-bank and normal-production baseline. Check the measuring instrument before concluding that the system changed. DOSH guidance supports periodic inspection and testing of the complete local exhaust system, with investigation and maintenance when performance deteriorates. [S171]

12. Correct one verified cause at a time

Changing several variables together may restore production but destroys the evidence needed to prevent recurrence. Where safe and practical:

704. identify the most likely verified cause;
705. select a corrective action within the authorised operating method;
706. restore the system to a known configuration;
707. repeat the same observation or measurement;
708. coat an appropriate confirmation piece where production quality must be proven; and
709. record the result before introducing another change.

Possible corrections include replacing a condition-ended filter, reseating and sealing the bank, restoring the intended make-up-air path, removing an obstruction, cleaning a plenum, repairing a damaged support, correcting part position, servicing a spray gun or escalating fan/control work to competent maintenance.

13. Verify return to service

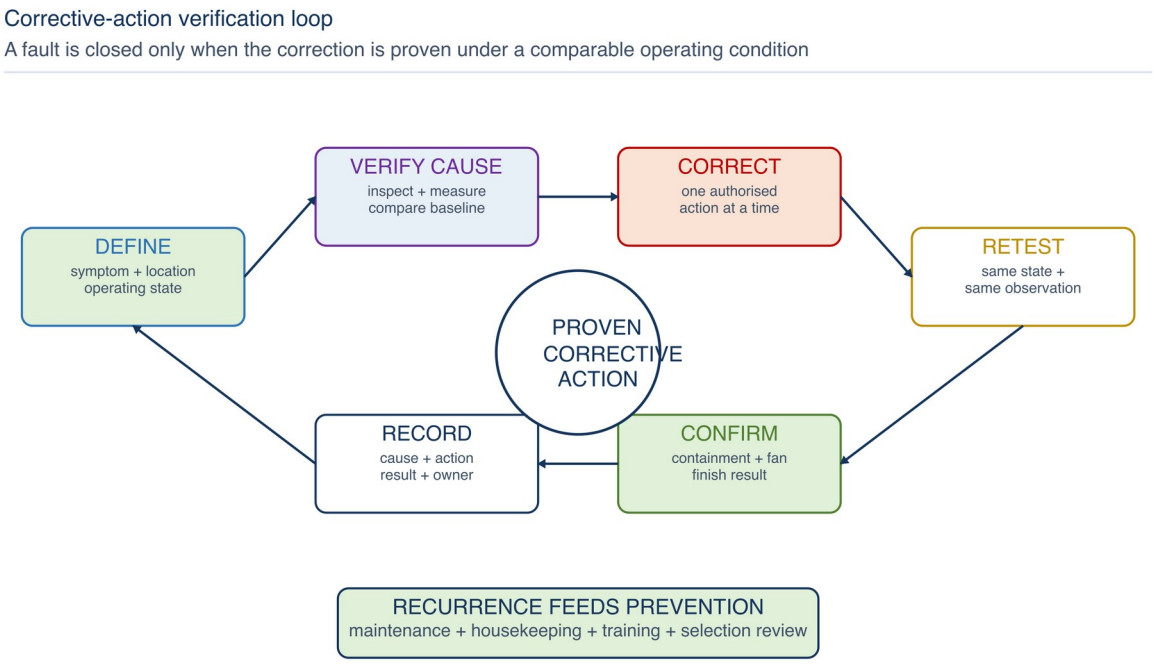

Figure 4. Corrective-action verification loop. A correction is complete only when the physical condition, operating evidence, containment and finish result have been rechecked and recorded.

Before normal spraying resumes, confirm:

- the fault area is physically corrected and all temporary materials are removed;
- filter identity, direction, coverage, support and perimeter sealing are correct;
- pressure instruments and control indications respond normally;
- fans operate without abnormal heat, noise, vibration or alarm;
- airflow and containment match the accepted operating method;
- doors, access panels, dampers, guards and interlocks are restored;
- the booth and downstream area are clean enough to identify recurrence;
- a verification spray or first-off part meets the applicable finish criteria; and
- the action, verification result and responsible person are recorded.

Where an exact pressure, airflow, electrical, clearance or product limit is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

14. Quick troubleshooting matrix

Symptom	Check first	Common root causes	Avoid
Overspray escaping	Fan/interlock, containment and opening airflow	Loaded bank, imbalance, cross-draught, poor work position, excessive mist	Continuing production or opening more doors
Reduced airflow	Complete intake-to-discharge path	Loaded stages, obstruction, fan/damper fault, restricted make-up air	Increasing speed without system review
Dust on parts	Particle type and point of appearance	Intake leak, booth deposits, clothing, part or compressed-air contamination	Assuming finer media is the only answer
Uneven finish	Spatial pattern and recent changes	Distribution, gun path, viscosity, temperature, part geometry	Changing booth and coating variables together
High filter usage	Production load and removal trigger	Excess overspray, compressed media, moisture, poor staging, early change	Comparing by calendar days alone
Fan overload	Alarm, current/load trend and mechanical condition	Compensation, blockage, deposit, imbalance, bearing or control fault	Defeating protection or repeated resets
Filter bypass	Perimeter, joints, support and downstream trail	Gap, reverse direction, damage, under-expansion, warped frame	Selecting finer media before sealing
Odour	Ventilation, containment, clearance and spill/residue	Exhaust re-entry, process change, spill, wet waste, vapour-control issue	Treating particulate media as vapour control
Premature blockage	Loading pattern and coating/process change	High solids load, tacky mist, local spray path, insufficient area	Substituting media without system-fit review
Poor capture	Local air direction and work position	Low flow, cross-draught, obstruction, distribution or excessive generation	Relying on pressure alone

15. Prevent repeated faults

A stable booth is maintained through short, regular checks rather than emergency changes alone:

- inspect visible filter condition, sealing and loading distribution;
- trend pressure, airflow indication and fan/control state together;
- keep booth surfaces, plenums and access areas clean by the approved method;
- maintain spray guns and compressed-air quality;
- protect clean parts and control dirty work around booth entrances;
- review filter consumption against accepted production, not calendar time only;
- examine repeated defect location on a simple booth map;
- investigate sudden changes after maintenance or material substitution; and
- feed recurring causes into preventive maintenance and operator training.

16. Practical decision summary

710. Stop and make safe when containment, fire, exposure, interlock or severe mechanical conditions are abnormal.
711. Record the symptom and operating state before changing anything.
712. Trace the complete air path from make-up air to discharge.
713. Interpret pressure, airflow, fan state and physical filter condition together.
714. Separate bypass, penetration, loading and mechanical failure.
715. Check contamination and coating-process causes alongside booth causes.
716. Correct the verified cause within authorised system limits.
717. Prove the correction through comparable operating evidence and finish quality.
718. Record the result and use recurrence patterns to improve maintenance and training.

FILTRATION, CLEANING & PROCESS CONTROL

CHAPTER 037

Industrial Cleaning and Degreasing

37

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production supervisors, maintenance teams, fabricators, finishing operators, coating and bonding personnel, QA/QC teams, safety and environmental personnel and technical sales personnel

Scope: Practical selection and control of water-based, solvent, alkaline, acidic and neutral cleaning systems for industrial metalwork, equipment and fabricated components.

Core principle - Cleaning is a complete process: identify the soil, select compatible chemistry and action, remove the released contamination, rinse where required, dry promptly and verify the surface against its next operation.

A surface can look clean yet retain oil film, surfactant, dissolved salt, polishing compound or moisture that later causes coating failure, corrosion, staining, poor bonding or unreliable inspection. Conversely, aggressive cleaning can attack the base metal, existing coating, seal, adhesive or precision feature. Effective degreasing therefore starts with the contaminant and downstream requirement, not with the strongest available chemical. [S198; S200]

Chapter objectives

After this chapter, the reader should be able to:

- classify common industrial soils before selecting a cleaner;
- distinguish water-based, solvent, alkaline, acidic and neutral cleaner families;
- match chemistry, delivery method and mechanical action to the work;
- screen the complete assembly for material compatibility;
- control concentration, temperature, contact, agitation and bath loading without guessing product values;
- prevent cleaner residue, rinse carry-over, water spotting and flash rust;
- select practical cleanliness checks for coating, bonding, inspection or service;
- recognise inhalation, skin, eye, fire and reaction hazards;
- manage spent solution, rinsate, sludge and contaminated wipes according to their actual composition; and
- troubleshoot common cleaning defects through a disciplined cause-and-correction method.

1. Identify the soil before choosing the chemistry

“Dirt” is not one material. A cleaner that dissolves lubricating oil may leave polishing compound, metal fines or salt behind. An acid that removes oxide may spread oil across the surface and prevent uniform contact with the metal. Begin by identifying the dominant soil and any hidden second layer.

Soil family	Typical examples	Useful first observations	Cleaning implication
Oils and greases	Machining oil, hydraulic oil, rust preventive, bearing grease	Smear, gloss, water beading, oily transfer to a clean wipe	Needs solvency, emulsification or alkaline detergency plus removal of released oil
Waxes and compounds	Buffing bar residue, lapping compound, protective wax	Firm or sticky film, often concentrated at seams and cool zones	May need heat, compatible solvent action and brushing or spray force
Particulate soils	Abrasive dust, metal fines, carbon, shop dust	Loose deposit, dark wipe, particles in corners and threads	Needs displacement, suspension, filtration and effective rinse or vacuum removal
Water-soluble soils	Salts, coolant residue, fingerprints, some process chemicals	May be invisible; can leave crystals, stains or conductive residue	Needs suitable water quality, access to crevices and complete rinse and drying
Oxides and scale	Light rust, heat tint, mill scale, corrosion products	Coloured or rough adherent layer; may remain after degreasing	Degrease first, then use a compatible oxide-removal process where appropriate
Mixed soils	Oily metal fines, burnt lubricant, compound plus oxide	Layered, tenacious or variable across the part	Usually requires staged cleaning rather than one increasingly aggressive bath

Use process history as evidence. Ask what machining fluid, polishing compound, handling material, protective coating or previous cleaner contacted the part. A clean white wipe, magnified examination and water-break observation can help locate contamination, but each test has limits and should be related to the next process.

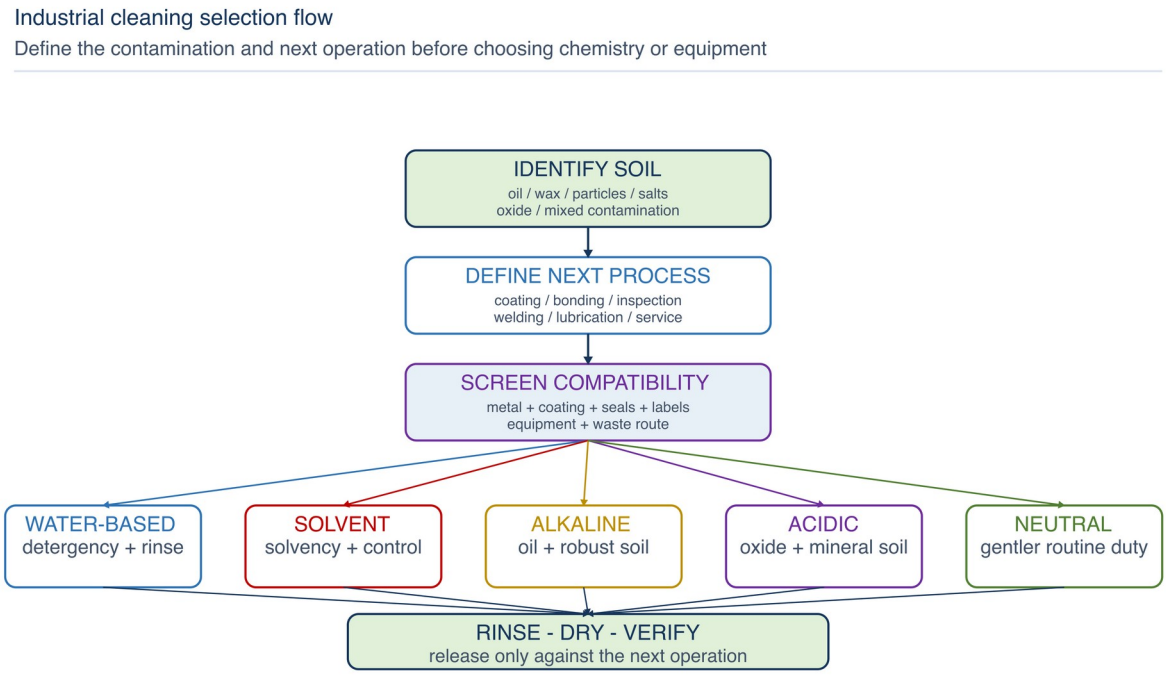

Figure 1. Cleaning selection flow. Move from soil and downstream requirement through compatibility, chemistry and delivery method to rinse, dry and verification. A failed check returns to diagnosis rather than automatically increasing chemical strength.

2. Choose a cleaner family by mechanism and duty

Cleaner names alone do not define performance. Water-based products may contain alkalis, acids, surfactants, corrosion inhibitors, chelants or solvent components. Solvent products vary widely in toxicity, evaporation, flammability and compatibility. Selection must use the current product information and the actual process.

Cleaner family	Best suited to	Principal strengths	Main cautions
Water-based detergent	General oils, shop soil, particulate contamination and many production parts	Combines wetting, emulsification, dispersion and rinsing; compatible with spray, immersion and ultrasonic systems	Bath loading, foam, residue, water quality, drying and corrosion control need attention
Solvent cleaner	Localised oil, grease, wax or adhesive residue where the solvent is compatible and controlled	Rapid solvency; useful for precision or spot cleaning when water is unsuitable	Vapour exposure, skin contact, fire, static, confined-space accumulation, material attack and contaminated-wipe handling
Alkaline cleaner	Oils, greases, carbonaceous soil and robust ferrous components, depending on formulation	Strong detergency; can combine wetting, emulsification and chemical action	May attack aluminium, zinc, coatings, skin and eyes; inadequate rinsing can leave alkaline residue
Acidic cleaner	Oxides, rust, mineral deposit or scale after oil has been removed	Chemical removal of inorganic contamination and surface conditioning	Can attack metal, generate fumes or hydrogen, damage coatings and accelerate corrosion if poorly rinsed or overexposed
Neutral or near-neutral cleaner	Routine cleaning, mixed-material assemblies and applications needing gentler chemistry	Often easier compatibility and handling profile; useful for light-to-moderate soils	“Neutral” does not mean harmless or universally residue-free; cleaning power and corrosion protection remain formulation specific

Select the least hazardous effective option that can reach the soil and deliver the required surface. Where the product concentration, temperature, immersion time, spray pressure, compatibility or rinse method is exact and product dependent, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

3. Water-based cleaning systems

Water-based cleaning uses water as the main carrier and relies on a combination of wetting, detergency, emulsification, dispersion, chemical reaction and mechanical or thermal energy. Spray cabinets, agitated tanks, ultrasonic systems, flow-through washers and manual stations apply these mechanisms differently. [S200]

Water-based systems are often effective when the complete process is designed around them:

719. expose the soil to fresh solution;
720. provide appropriate temperature, contact and movement;
721. separate displaced oil and solids from the active bath where the equipment permits;
722. prevent dirty solution from redepositing on the part;
723. rinse to remove cleaner and carried soil; and
724. dry the complete geometry before corrosion or water spotting develops.

The bath changes in service. Oil can consume or overload its cleaning capacity; fines can lodge in recesses; evaporation can concentrate dissolved material; incoming water can affect foam, spotting and rinse behaviour. A bath that remains visually clear is not necessarily effective, and a dark bath is not automatically exhausted. Monitor the condition indicators appropriate to the selected chemistry and equipment. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Avoid adding concentrate merely because cleaning has slowed. First check soil loading, bath circulation, heater or ultrasonic condition, nozzle alignment, filtration, foam, part orientation, contact time and rinse quality. Uncontrolled additions can increase residue, chemical exposure, cost and effluent load without correcting the true cause.

4. Solvent cleaning

Solvent cleaning removes compatible organic soils by dissolution and displacement. It may be useful for local repair, precision items, water-sensitive assemblies or tenacious wax and grease. It is not automatically the correct choice simply because it dries quickly.

Use a closed or otherwise controlled delivery method where practicable. Minimise exposed liquid area, avoid open soaking containers and keep lids closed when the equipment is idle. Provide the ventilation and other exposure controls established for the chemical and task. OSHA guidance on toxic cleaning solvents illustrates the enduring principles of enclosure, source ventilation, skin and eye protection and additional precautions for flammable solvents; Malaysian workplace controls follow the applicable DOSH chemical-risk framework. [S198; S201]

Never assume that evaporation removes the soil. A dirty wipe or bath can spread dissolved oil into a thin film that becomes difficult to see. Use clean-to-dirty wipe sequencing, turn or replace wipes before they are saturated, and verify the final surface. Do not use compressed air to accelerate evaporation where it could disperse vapour, spray liquid, drive contamination into openings or create an ignition hazard.

Before using solvent on an assembly, screen plastics, elastomers, painted surfaces, labels, sealants, electrical insulation and adhesives. Swelling, softening, crazing, colour transfer or loss of bond may appear after contact rather than immediately. “Non-flammable”, “low odour” and “fast drying” are not sufficient selection criteria; the Safety Data Sheet and the product’s declared application govern.

5. Alkaline cleaning

Alkaline cleaners range from mild detergent systems to strongly caustic formulations. Depending on composition, they can wet the surface, emulsify or displace oil, disperse particulate, react with fatty soil and support high-throughput spray or immersion cleaning.

Use alkaline cleaning when the formulation is compatible with every exposed material. Aluminium, zinc, galvanised surfaces, some coatings, glass, certain seal materials and sensitive alloys can be attacked or stained by unsuitable alkalinity, temperature or contact. Hidden pockets may retain concentrate and continue reacting after the visible surface is rinsed.

A successful alkaline process needs:

- correct solution make-up using the specified order of addition;
- controlled contact and mechanical action rather than excessive dwell;
- bath maintenance that removes oil and solids where possible;
- thorough rinsing, especially at folds, threads, tubes and blind holes;
- prompt inspection for etching, darkening or residue; and
- drying or subsequent treatment before corrosion develops.

Concentrated alkalis can cause serious skin and eye injury. Avoid splashing during mixing and part handling, and never improvise a neutralisation step on the workpiece or on a spill. Chemical addition, spill response and personal protective equipment follow the current Safety Data Sheet and site procedure. [S198]

6. Acidic cleaning and oxide removal

Acidic cleaners are principally selected for inorganic contamination such as rust, oxide, mineral scale or some heat-formed surface products. Oil and grease inhibit uniform acid contact, so effective degreasing normally precedes oxide removal. [S200]

Acid strength alone does not determine cleaning quality. Formulation, inhibitor system, alloy, temperature, contact, agitation, soil thickness and geometry all influence the result. Excessive exposure can etch the base metal, enlarge pits, change appearance, damage dimensions or leave a reactive surface. Contact with some metals can generate hydrogen; incompatible chemical mixing can produce heat, splashing or hazardous gas.

Keep acid cleaners separate from alkaline products, hypochlorite-containing materials and other incompatible chemicals. Use dedicated labelled tools and containers where cross-contamination could occur. Rinse the part thoroughly, remove trapped solution and proceed promptly to the specified drying, neutralisation or downstream treatment. Do not prescribe an improvised neutraliser: the correct sequence depends on the cleaner, substrate and process. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

7. Neutral and speciality cleaners

Neutral or near-neutral cleaners are useful for routine maintenance, light-to-moderate oils, mixed-material assemblies and situations where aggressive chemistry is unnecessary. Speciality products may be formulated for electronics, food-contact equipment, precision components, aluminium, stainless steel or low-residue duties.

The pH description does not prove low toxicity, non-flammability, corrosion protection, rinse-free use or universal material compatibility. Surfactants, builders, solvents, chelants and inhibitors still influence performance and hazard. Treat every formulation according to its label and Safety Data Sheet.

Neutral chemistry may need greater reliance on temperature, spray force, agitation, ultrasonics, brushing or longer contact. That is often preferable to stronger chemistry, provided the equipment and workpiece tolerate the added mechanical or thermal input. Compare the complete cleaning result, not only the wash step.

8. Screen the whole assembly for compatibility

Compatibility checks must include more than the principal metal. A steel housing may contain aluminium nameplates, copper conductors, polymer bearings, elastomer seals, adhesive labels and trapped lubricant. A cleaner acceptable for one material can damage another or carry contamination into a joint.

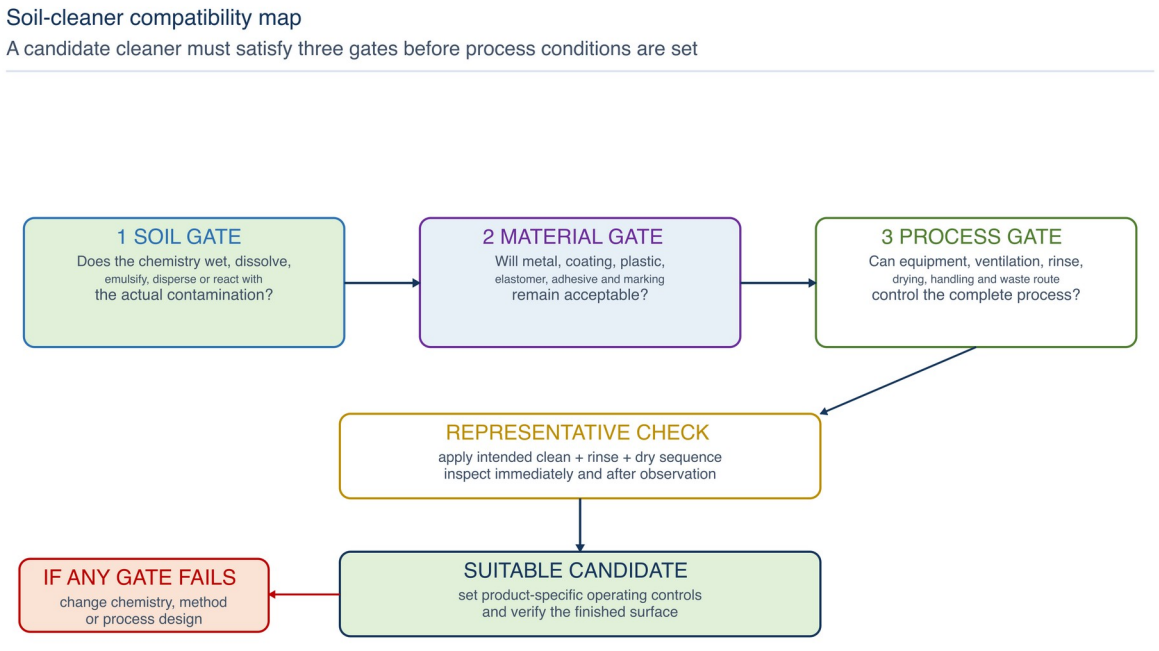

Figure 2. Soil-cleaner compatibility map. Cleaner-family suitability is screened against the soil, substrate and complete assembly before process conditions are set. The map is qualitative and does not replace product compatibility data.

Compatibility area	What to examine	Unacceptable signs
Base metal	Colour, gloss, roughness, mass-sensitive or dimensional features	Etching, darkening, pitting, staining or measurable change
Coating and plating	Paint, powder coat, conversion layer, anodising, zinc or decorative finish	Softening, lifting, blistering, chalking, colour transfer or loss of adhesion
Elastomers and plastics	Seals, hoses, grommets, glazing, housings and liners	Swelling, shrinkage, tackiness, cracking, crazing or hardness change
Adhesives and markings	Bonded joints, threadlock, tapes, labels, inks and identification marks	Edge lift, weakened bond, bleeding, loss of print or traceability
Equipment materials	Tank, pump, heater, nozzle, filter, basket and drain system	Corrosion, embrittlement, seal failure, blocked filters or incompatible waste route
Downstream process	Coating, welding, bonding, metrology, electrical service or lubrication	Residue, moisture, altered surface, poor wetting or contamination transfer

When compatibility is not established, use a representative test piece or a non-critical area and reproduce the intended exposure, rinse and drying sequence. Examine immediately and again after a suitable observation period. A small-area check reduces risk but does not prove long-term service compatibility.

9. Control the five process variables

Cleaning performance depends on five linked inputs: chemistry, concentration, temperature, time and mechanical action. Increasing one may allow another to decrease, but only within the product and material limits.

Variable	Too low or insufficient	Too high or excessive	Control approach
Chemistry or concentration	Incomplete wetting, slow oil removal, redeposition	Residue, attack, foam, exposure and waste load	Make up and maintain by the specified method
Temperature	Poor solvency or detergency, slow drying	Evaporation, attack, vapour, energy use and worker exposure	Verify heater and solution condition; do not exceed declared limit
Contact time	Soil remains in recesses or heavy deposits	Base-metal or coating attack, drying-on, swelling or staining	Time the actual wet contact, including delays before rinse

Variable	Too low or insufficient	Too high or excessive	Control approach
Mechanical action	Boundary layers and trapped soil remain	Damage to precision features, coatings or soft materials	Select spray, brushing, agitation or ultrasonics to suit geometry
Bath loading	Fresh solution cleans effectively	Oil, fines and dissolved material cause slow cleaning or redeposition	Monitor, separate contaminants and replace by condition

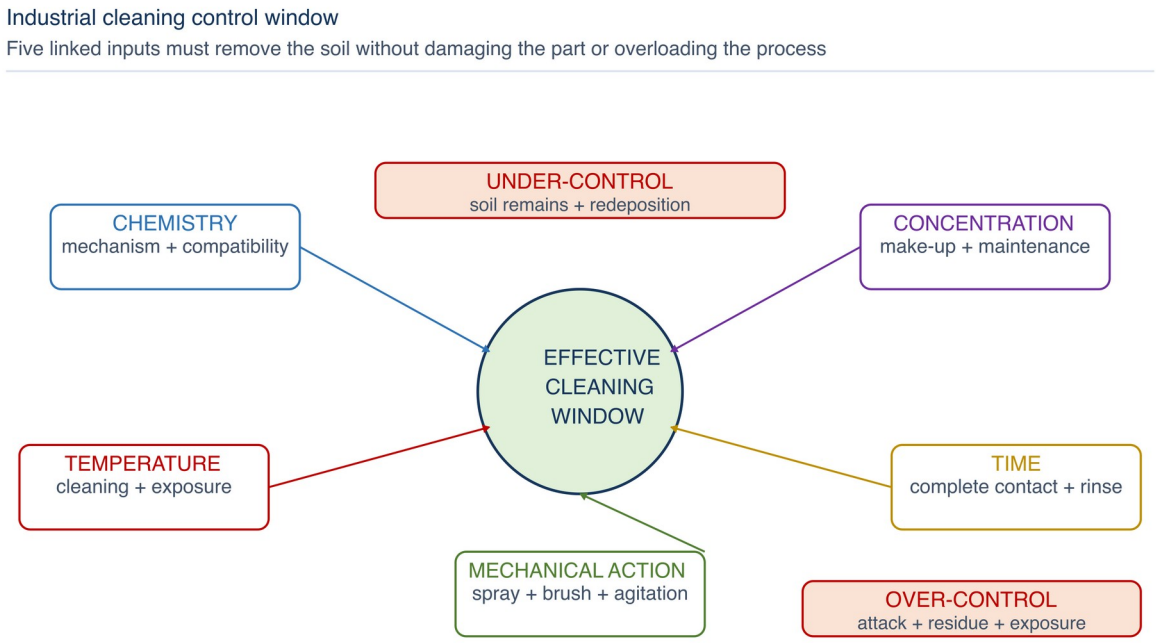

Figure 3. Cleaning control window. Chemistry, concentration, temperature, time and mechanical action operate together. The usable window is bounded by incomplete cleaning on one side and material damage, exposure or residue on the other.

Load parts so solution reaches all surfaces and drains freely. Avoid nesting, air locks and large horizontal pockets. Point blind openings to fill and drain where practical. In spray systems, check nozzle pattern and obstruction; in immersion systems, prevent baskets from shielding parts; in ultrasonic systems, confirm that the item and attachments are suitable for cavitation.

10. Rinsing is part of cleaning

Rinsing removes cleaner, released soil and dissolved contaminants. It is not simply dilution at the end of the process. Poor rinsing can turn a successful wash into a coating or corrosion failure.

Use enough rinse stages and movement to prevent carry-over from returning to the part. Arrange cleanest water at the final stage where the process permits, and control overflow or counterflow through the designed treatment system rather than discharging uncontrolled rinsate. Inspect spray nozzles, tank agitation, part orientation and drainage. Replace or treat rinse water by its relevant condition indicators.

Rinse-water quality matters when spots, conductivity, ionic residue or high-value finishes are important. Hardness minerals can remain after evaporation; contaminated water can reintroduce oil, salt or metal. Exact water-quality and cleanliness limits are application specific. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Avoid allowing concentrated cleaner to dry on the part before rinsing. On large fabrications, work in manageable zones and maintain a wet edge only where the product instructions allow. Do not use a high-pressure jet where it can aerosolise corrosive liquid, force water into sealed equipment or damage a prepared surface.

11. Dry promptly and prevent flash rust

After aqueous cleaning, water can remain in seams, threads, lap joints, tubes, porous deposits and under fasteners. Evaporation from the visible face does not prove the assembly is dry.

Drying methods include clean heated air, controlled oven drying, vacuum, centrifugal action, compatible water-displacing treatment or immediate transfer to the next controlled stage. The method must suit part mass, geometry, cleanliness requirement, coating schedule and heat-sensitive components.

Flash rust is favoured by a reactive steel surface, retained water, dissolved salts, slow drying and humid exposure. Reduce the wet hold time, improve final-rinse quality, expose pockets to drainage and keep cleaned parts away from grinding dust, fingerprints, rain and condensation. If an inhibitor or temporary protection is used, confirm that it is compatible with coating, bonding, welding or service.

Do not wipe a clean surface with a contaminated cloth to make it “look dry”. Use clean, low-lint materials only where wiping is part of the specified process. Compressed air must be suitable for the cleanliness duty; oil, water or particles from the air system can undo the entire wash.

12. Verify cleanliness for the next operation

There is no single universal cleanliness test. Select checks that can detect the contamination most likely to harm the next operation.

Verification method	Useful for	Limitation
Visual and magnified inspection	Gross soil, stains, corrosion, particles and damage	Thin oil, surfactant or soluble salt may remain invisible
Clean-wipe check	Loose particulate, oil transfer and inaccessible edges	Wipe material and pressure affect result; can miss uniform films
Water-break observation	Discontinuous wetting associated with some hydrophobic contamination	Surface texture, chemistry and water quality affect interpretation; not a universal pass test
Rinse-water or extract check	Ionic or soluble residue when a defined method exists	Requires controlled water, area, time and acceptance basis
Surface-energy or dyne method	Comparative wetting for selected coating or bonding processes	Material, roughness and method affect reading; not interchangeable across processes
Coating or bond process check	Direct confirmation through a representative downstream result	Slower and may combine several variables; use a defined acceptance plan

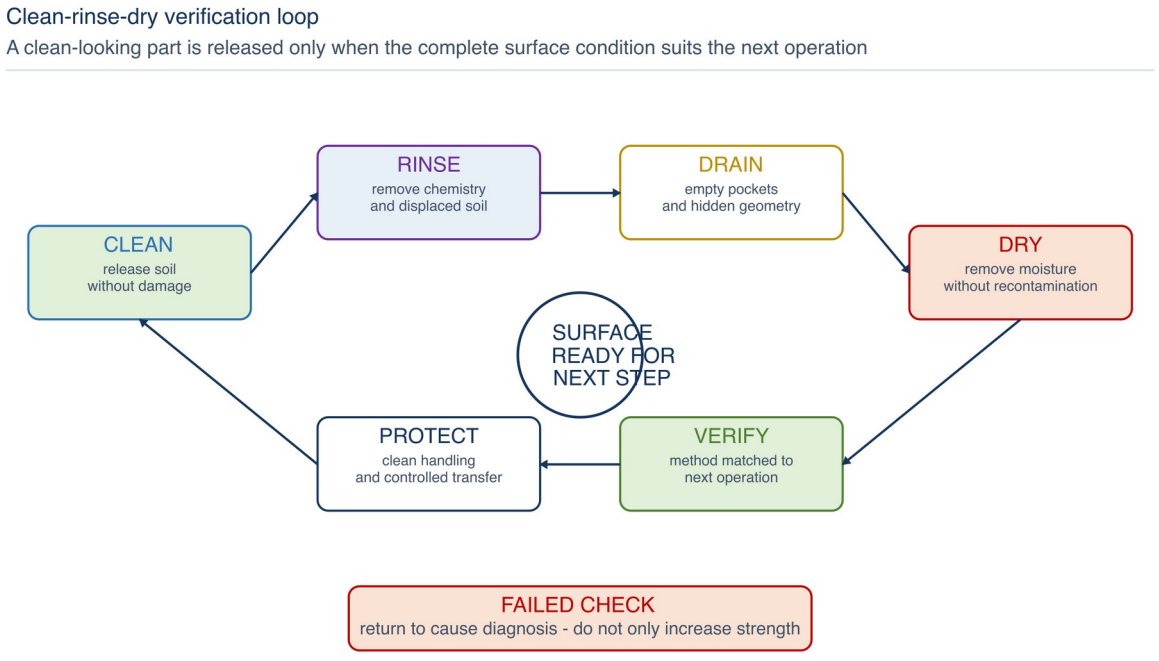

Figure 4. Clean-rinse-dry verification loop. A released surface has passed compatible cleaning, complete rinsing, drainage and drying, and a verification method matched to the next process.

Inspect for chemical attack as well as soil removal. Record the part family, soil, cleaner identity, equipment, significant process controls, rinse and drying route, check method and result. For exact product or acceptance values, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

13. Protect workers and control chemical reactions

The chemical risk depends on the ingredients, quantity, physical form, temperature, delivery method, frequency, duration and route of exposure. Heated tanks, spraying, brushing, compressed-air agitation and confined geometries can increase inhalation or contact risk. DOSH chemical-risk guidance uses hazard and exposure information to determine suitable controls within a hierarchy. [S160; S198]

Apply these practical principles:

- substitute a less hazardous effective chemistry or delivery method where practicable;
- enclose or automate the process where this materially reduces exposure;
- capture mist or vapour at source and maintain the ventilation system;
- prevent skin and eye contact through equipment design, tools, splash control and suitable PPE;
- keep containers labelled and closed, and make Safety Data Sheets accessible;
- segregate incompatible chemicals and use dedicated transfer equipment;
- provide suitable eyewash, spill response and emergency arrangements; and
- train operators in mixing, loading, draining, waste handling and abnormal-condition response.

Never mix cleaners unless the manufacturer explicitly specifies the combination. Acid with hypochlorite can release toxic gas; acid with alkali can generate violent heat and splashing; incompatible solvents can attack equipment or create unexpected fire and exposure hazards. Stop and apply the site emergency response if there is uncontrolled reaction, strong unexpected odour, heat, gas, pressure, fire, significant spill or acute worker symptoms.

14. Manage effluent, spent baths and contaminated materials

Cleaning moves contamination; it does not make it disappear. Oil, metal fines, dissolved metals, acid, alkali, surfactant, solvent and coating residue can transfer into the bath, rinsate, sludge, filters, absorbents and wipes.

Keep waste streams segregated where this supports safe treatment and accurate classification. Do not discharge concentrated cleaner, solvent, oily water, sludge or uncontrolled rinsate to a drain. Characterise the actual stream and route it through the site's authorised environmental system. Malaysia's industrial-effluent framework governs treatment, discharge, monitoring and related controls; spent chemical and contaminated material may also require classification under the applicable scheduled-waste framework. [S188; S189; S199]

Practical controls include:

725. minimise drag-out by allowing parts to drain back into the process where suitable;
726. remove free oil and solids to extend bath usefulness where the equipment and chemistry permit;
727. prevent leaks, evaporation and cross-contamination through closed, labelled storage;
728. keep incompatible waste streams separate;
729. retain the information needed to identify the generating process and contaminants; and
730. send waste only through the site's authorised route.

Waste classification follows the actual composition and process. It should not be inferred from the cleaner's unused form or from the carrier material alone.

15. Troubleshooting cleaning defects

Symptom	Likely contributors	Verification	Corrective direction
Oily film remains	Wrong cleaner family, low mechanical action, overloaded bath, poor access or dirty wipe	Compare soil type, fresh-solution response, bath condition and recesses	Restore effective chemistry/action and prevent redeposition
White haze or powder	Cleaner dried on part, hard-water deposit, inadequate rinse or excessive concentration	Inspect rinse coverage, water quality, drainage and solution control	Correct wash control and improve final rinse and drainage
Water spots	Mineral-laden rinse, slow drying, droplets trapped on horizontal faces	Compare spot pattern with drainage and water condition	Improve final-rinse quality and dry promptly

Symptom	Likely contributors	Verification	Corrective direction
Flash rust	Retained water, salt residue, reactive surface, long wet hold or contaminated air	Inspect pockets, drying route, rinse condition and exposure delay	Improve rinse, drainage, drying and clean storage
Darkening or etching	Chemistry, temperature or contact incompatible with substrate	Compare exposed and shielded areas; check representative sample	Stop use, confirm compatibility and select gentler conditions or chemistry
Paint fisheyes or poor wetting	Oil, silicone, surfactant, compressed-air contamination or handling	Trace materials and perform process-relevant wetting checks	Remove the verified source and repeat complete clean-rinse-dry cycle
Adhesive bond inconsistency	Residue, moisture, surface ageing, roughness variation or handling	Compare preparation-to-bond time and representative bond process	Stabilise surface preparation, protection and transfer
Foaming or overflow	Wrong product, contamination, excess concentration, air entrainment or spray return	Observe foam timing and check solution make-up and circulation	Correct source; do not add an incompatible defoamer
Short bath life	Excess soil input, poor oil/solid separation, evaporation or cross-contamination	Trend load, bath condition, incoming parts and make-up	Reduce soil load, improve separation and maintain by condition
Staining in seams	Trapped cleaner or rinse, mixed metals, slow drainage or continued reaction	Open or orient representative geometry and inspect retained liquid	Improve access, rinse, drainage and drying; reassess chemistry

Correct one verified cause at a time where safe and practical. Retest using comparable parts, soil load and downstream checks. A cleaner change that removes visible oil but introduces residue, corrosion or worker exposure is not an improvement.

16. Practical selection and release checklist

Before cleaning:

- identify the soil and next process;
- confirm cleaner compatibility with the complete assembly and equipment;
- review the label, Technical Data Sheet and Safety Data Sheet;
- prepare ventilation, PPE, spill control and segregated waste route; and
- set up clean handling, rinse and drying capacity before the first part enters the wash.

During cleaning:

- maintain solution and equipment by the specified method;
- expose every surface without trapping air or shielding the spray;
- control contact, agitation and drainage;
- watch for attack, unusual heat, gas, odour, excessive foam or redeposition; and
- keep clean and dirty tools, baskets and areas separated.

Before release:

- confirm soil removal using a method suited to the next operation;
- confirm cleaner and rinse residue have been removed;
- verify the part is dry, including concealed geometry;
- inspect for staining, etching, swelling, corrosion or lost identification;
- protect the cleaned surface from handling and shop contamination; and
- record the process and result at the level needed for repeatability.

Industrial cleaning succeeds when the soil is removed without damaging the part, exposing the worker or transferring an uncontrolled burden to the next process or the environment. The best system is not the most aggressive one; it is the compatible, controllable and verifiable system that consistently produces the required surface.

FILTRATION, CLEANING & PROCESS CONTROL

CHAPTER 038

Rust, Oxide and Scale Removal

38

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Fabricators, maintenance teams, production supervisors, coating personnel, inspectors, safety and environmental personnel and technical sales personnel

Scope: Practical selection and control of mechanical, abrasive-blast, water-jet and chemical methods for removing rust, oxide and scale from industrial metal surfaces.

Core principle - Remove the unwanted layer without creating a new surface problem. The correct result is not simply “bright metal”; it is a clean, compatible and suitably profiled surface ready for its next operation.

Rust, mill scale, weld oxide, heat tint and flash rust differ in composition, adhesion and effect on the substrate. A method that quickly removes loose rust may leave adherent scale, soluble contamination or an unsuitable profile. A chemical that dissolves oxide may attack the base metal, trapped joints, coatings or dissimilar materials. Selection therefore begins with the actual layer and downstream requirement, not with the most aggressive available tool or chemical. [S202; S205; S212]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish common rust, oxide and scale conditions;
- define the required end condition before selecting a method;
- compare hand-tool, power-tool, blast, water-jet and chemical removal routes;
- recognise when surface appearance, dust, salts and profile need separate checks;
- avoid cross-contamination and unnecessary base-metal removal;
- manage rinsing, drying, flash rust and temporary protection;
- recognise dust, noise, impact, toxic-coating and corrosive-chemical hazards;
- route blasting residue, spent chemical, sludge and rinsate appropriately; and
- troubleshoot incomplete removal, rapid re-rusting, staining, smearing and coating-readiness defects.

1. Identify the unwanted layer

Do not treat every brown, black, blue or grey surface as the same “rust.” Identify what is present, how strongly it adheres and what may lie beneath it.

Surface condition	Typical appearance and location	Removal implication	Important check
Loose atmospheric rust	Flaking, powdery or weakly attached corrosion product	Hand or power tools may remove loose material; pits and salts can remain	Inspect recesses and the pit base after cleaning
Adherent rust	Firm corrosion layer that resists scraping	May require a more capable mechanical, blast, water-jet or chemical route	Confirm required preparation grade and remaining section
Mill scale	Dark, hard oxide formed during hot rolling	Can be strongly adherent but may crack or detach in service	Do not assume smooth dark scale is a sound coating substrate
Weld oxide and heat tint	Coloured oxide around welds and heat-affected zones	Mechanical or chemical treatment depends on alloy and service duty	Preserve geometry and prevent embedded contamination
Flash rust	Fine new rust after wet preparation or humid exposure	Control water quality, drying, environment and time to the next step	Use the defined flash-rust acceptance for the coating system
Non-ferrous corrosion product	White zinc salts, aluminium oxide, copper compounds or mixed deposits	Ferrous-steel methods can damage the substrate or protective coating	Identify the alloy or coating before removal

The first inspection should include the visible condition, process history, previous coating, possible chemical exposure and any evidence of section loss. Thick corrosion can conceal pits, laminations, cracks, perforation or sharp remaining edges. Removal does not restore lost metal; structural or pressure-containing items require the appropriate engineering assessment.

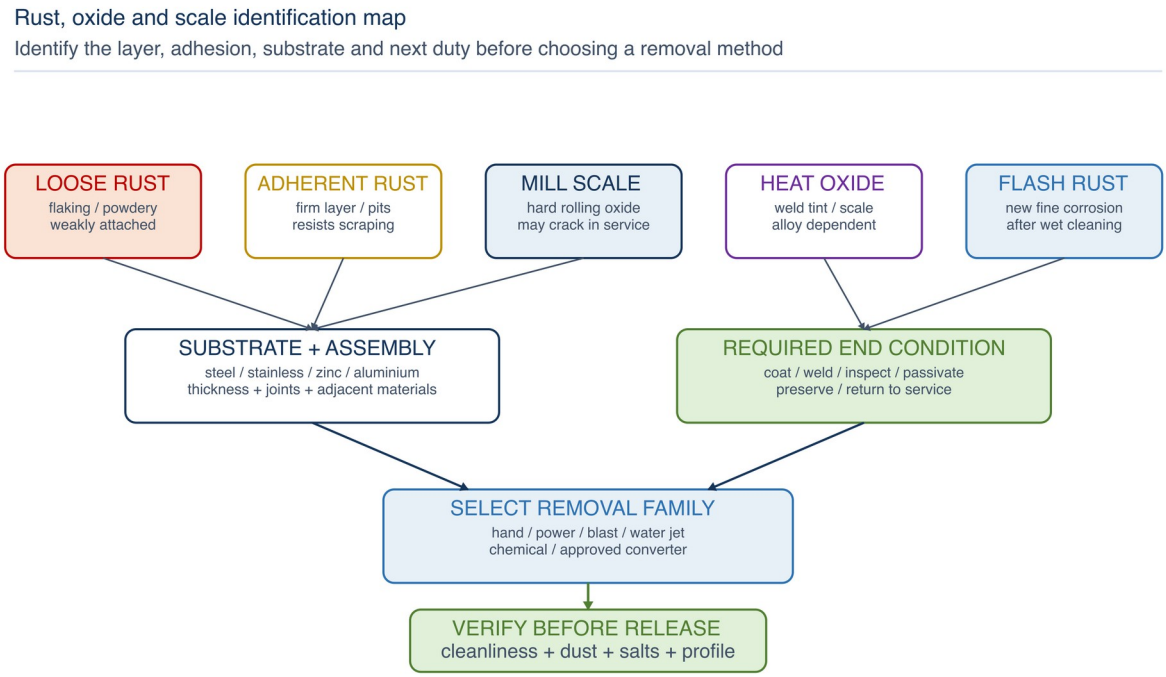

Figure 1. Rust, oxide and scale identification map. The visible layer, adhesion, substrate and downstream duty are identified before a removal family is selected.

2. Define the required end condition

State what the surface must be ready for: painting, thermal spraying, welding, inspection, assembly, passivation, preservation or return to service. These outcomes can require different levels of oxide removal, roughness and chemical cleanliness.

For coating work, the governing specification can separately define:

- the visual preparation grade;
- permitted remaining coating or staining;
- dust condition;
- soluble-contaminant limit and test method;
- surface-profile range and measurement method;
- treatment of welds, edges and imperfections;
- environmental condition and flash-rust limit; and
- maximum time before coating.

ISO 8501-1 provides visual rust and preparation grades for steel, while ISO 8501-3 addresses welds, edges and visible imperfections. ISO 8501-4 covers visual conditions and flash-rust grades associated with water jetting. These visual references do not by themselves establish soluble-salt content or surface profile. [S202-S204]

Where the exact preparation grade, profile, salt limit, flash-rust grade or time-to-coat is product or specification dependent, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

3. Remove oil, grease and interfering contamination first

Oil and grease can shield oxide from chemical action, contaminate abrasive media and smear across mechanically cleaned steel. Remove them using the suitable cleaning process before oxide removal where they would interfere with the selected method. Chapter 037 explains industrial cleaning and degreasing in detail.

Also identify old coatings and deposits that may contain hazardous metals or other toxic constituents. Surface preparation can convert an intact material into airborne dust, spent abrasive, sludge or contaminated wash water. The hazard assessment must consider both the removal medium and the material being removed. [S198; S215]

Use clean, dedicated tools where material transfer matters. Carbon-steel brushes, grinding debris or contaminated blasting media can deposit iron on stainless steel. Abrasive previously used on another surface can also transfer coating residue, salts or metals.

4. Select the removal family

Choose the least aggressive effective route that can reach the surface and deliver the required condition.

Method family	Suitable starting applications	Main strengths	Main limitations and controls
Hand-tool cleaning	Local loose rust, light scale, edges, small repairs and access-limited work	Portable, selective and easy to observe	Slow; may leave adherent material; wire brushing can polish or smear
Power-tool cleaning	Local-to-medium areas, maintenance repairs, welds and controlled mechanical removal	Higher productivity and range of abrasive actions	Heat, dust, noise, vibration, geometry loss and polished surfaces require control
Abrasive blast-cleaning	Large areas, strongly adherent scale, coating removal and profile generation	Efficient cleaning and deliberate surface profiling	Containment, dust, media condition, rebound, profile and substrate thickness are critical
High-pressure water jetting	Removal of rust, weak coating and water-soluble contamination where the system is suitable	Can remove salts and avoid adding dry abrasive	Does not normally create a new abrasive profile; flash rust, water collection and injection hazards matter
Chemical descaling or pickling	Complex geometry, internal surfaces or oxide that responds to compatible chemistry	Can reach detailed surfaces and dissolve oxide rather than mechanically cut it	Alloy attack, hydrogen effects, fumes, trapped acid, rinsing and waste require engineered control
Rust converter	Compatible residual rust in a specifically approved coating system	May stabilise a defined residual condition where full removal is impractical	Not a substitute for removing loose scale, oil, salt or failed coating; system compatibility is essential

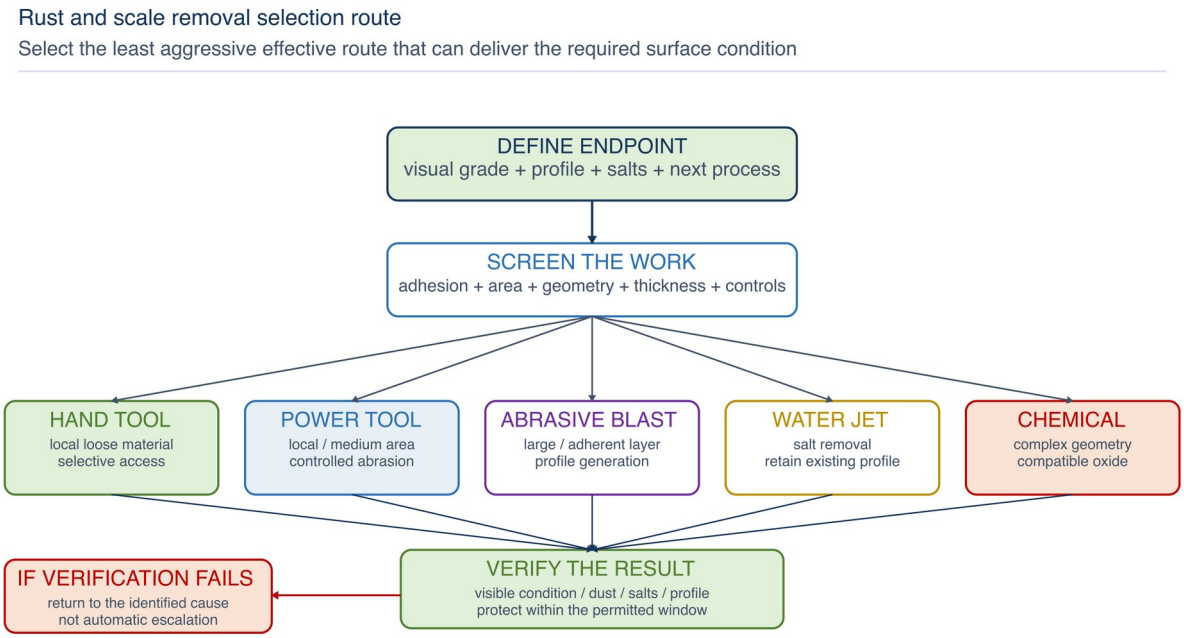

Figure 2. Rust and scale removal selection route. The required endpoint, layer adhesion, substrate, geometry and available controls guide selection; failed verification returns to cause diagnosis rather than automatic escalation.

5. Hand-tool removal

Scrapers, chipping tools, hand wire brushes and abrasive sheets can remove loose rust, scale and coating from small or irregular areas. ISO 8504-3 describes hand- and power-tool cleaning as recognised preparation methods for new and maintenance-coated steelwork. [S207]

Use hand tools when access, selectivity or local control is more important than production rate. Work from sound boundaries into the affected area and pay particular attention to edges, pits, weld toes, fasteners and corners. Keep scraping edges in usable condition and choose brush material compatible with the substrate.

Hand-tool cleaning has a defined limit: it can leave tightly adherent rust, scale and coating. Repeated wire brushing may burnish the surface, spread contamination or produce a polished appearance without achieving the required cleanliness or profile. If the selected endpoint cannot be reached, change the method rather than increasing effort indefinitely.

6. Power-tool removal

Power wire brushes, abrasive discs, non-woven stripping products, flap products, needle scalers and specialised impact or rotary tools provide different contact actions. Select the product form for the layer, geometry and required finish rather than treating all power-tool cleaning as equivalent.

Control the process by:

- securing the work and controlling the line of fire;
- selecting the correct accessory, attachment and guard;
- keeping the tool within all marked limits;
- using controlled passes instead of prolonged local dwell;
- preventing edge rounding, gouging, thinning and heat tint;
- removing dust and checking the surface under good lighting; and
- replacing damaged, loaded or ineffective consumables.

A shiny surface can be a warning sign when brushing or fine abrasion has polished rust or scale rather than removed it. Deep pits may remain contaminated even when the surrounding peaks are bright. Inspect both the overall appearance and the lowest accessible features.

Refer to the product label, Technical Data Sheet, or MKTECH representative.

7. Abrasive blast-cleaning

Abrasive blasting combines media, velocity, angle, distance, dwell, equipment condition and operator technique. It can remove strongly adherent oxide and create a surface profile suitable for many coating systems. ISO 8504-2 describes blast-cleaning methods and their fields of application. [S206]

Before blasting, confirm:

731. the substrate is thick and stable enough for the process;
732. oil, grease and incompatible contamination have been removed;
733. the old coating and corrosion residue have been assessed for hazardous constituents;
734. the abrasive type, cleanliness and size distribution suit the required surface;
735. air supply, hoses, nozzle, recovery, ventilation and containment are in suitable condition;
736. adjacent equipment, threads, bearings, seals and openings are protected; and
737. the coating specification defines the required cleanliness and profile.

Do not use abrasive appearance as the only acceptance check. Worn or contaminated media can change the profile and leave embedded residue. Excessive blasting can distort thin sheet, round edges, enlarge pits or remove sound metal. Incomplete coverage often remains around welds, corners, stiffeners and shadowed geometry.

Blasting creates dust from both the abrasive and the surface material. Enclosure, local extraction, exclusion zones, respiratory protection, hearing protection, protective clothing and cleanup methods must follow the assessed hazards. Dry sweeping and compressed-air dispersal can re-suspend fine contamination and should not replace controlled collection. [S198; S215]

8. High-pressure water jetting

Water jetting can remove loose rust, coating and water-soluble contamination without introducing dry abrasive. It is especially useful where salt removal and dust reduction are important. The existing steel profile normally remains rather than a new abrasive profile being created, so the exposed condition must suit the coating system. [S204]

Control water quality, pressure-rated equipment, nozzle condition, hose restraint, drainage, collection and the exclusion zone. Water jets can penetrate skin and cause severe injury; leaks and damaged hoses require immediate isolation under the equipment procedure.

After cleaning, inspect for retained coating, oxide, salts and flash rust. Drying begins with geometry: drain pockets, tubes, laps and blind holes before treating the visible face as dry. ISO 8501-4 distinguishes visual preparation and flash-rust grades, while ISO 8502 methods address invisible contamination separately. [S204; S209; S210]

9. Chemical scale removers, descaling and pickling

Chemical oxide removal uses a formulation that reacts with or dissolves the unwanted layer. The correct chemistry depends on the oxide, alloy, temperature, geometry and downstream requirement. Degreasing normally precedes chemical descaling because oil can prevent uniform contact. [S212]

Do not formulate or mix an improvised pickling solution. Use the supplied product in the specified equipment with the required ventilation, handling, first-aid and emergency controls. Acids can attack the base metal, release hazardous fumes, react with incompatible products and remain trapped in joints or cavities. Contact with some metals can generate hydrogen, with implications for fire, pressure and material integrity.

Stainless-steel pickling removes scale and a thin affected surface layer; passivation is a distinct treatment applied to a chemically clean surface. They are not interchangeable terms. Chapter 039 covers stainless-steel cleaning and passivation in depth. [S212; S213; S217]

Where exact chemistry, dilution, temperature, contact time, neutralisation sequence or compatibility is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

10. Rust converters and conversion treatments

A rust converter is used only where the selected coating system permits a defined residual rust condition. It does not make loose scale, grease, salt, dust or weak coating acceptable. Remove non-adherent material, clean the surface and achieve the preparation condition required by the converter and coating manufacturer.

Check compatibility across the complete system:

- base metal and remaining rust;
- previous coating and repair boundary;
- converter chemistry and film thickness;
- primer or topcoat family;
- cure condition and recoat window;
- service temperature and exposure; and
- inspection and acceptance method.

Do not use a converter to conceal uncertain corrosion depth, active contamination or an inaccessible structural defect. A dark colour change is not by itself proof of complete reaction, adhesion or coating readiness.

11. Protect the substrate and adjacent materials

The removal method must be compatible with the full assembly, not only the principal metal.

Material or feature	Main risk during oxide removal	Practical control
Thin carbon-steel sheet	Distortion, thinning, gouging and excessive profile	Use controlled energy and inspect geometry and remaining thickness
Stainless steel	Embedded carbon steel, smearing, heat tint and incompatible chemistry	Use dedicated compatible tools and follow the specified cleaning or passivation route
Galvanized or zinc-coated steel	Removal of protective zinc and attack by unsuitable chemistry	Confirm whether the objective is cleaning the zinc or exposing the steel beneath
Aluminium and soft alloys	Rapid abrasion, chemical attack, staining and dimensional loss	Use alloy-compatible media, chemistry and representative-area checks
Plated, painted or conversion-coated surfaces	Unplanned stripping, undercutting or loss of repair boundary	Define what must remain and protect sound adjacent areas
Seals, bearings, threads and electrical parts	Grit, water or chemical entry and loss of function	Mask, isolate, dismantle or select a process that prevents ingress

Heat-sensitive, hardened, high-strength or fatigue-critical components may have restrictions on aggressive grinding, blasting, acid treatment or hydrogen-producing processes. The drawing, repair specification or responsible engineer controls the permitted route.

12. Rinse, neutralise where specified and dry completely

Rinsing removes reacted oxide, dissolved metal, cleaner and process chemistry. Inadequate rinsing can leave corrosive residue or interfere with coating, welding, bonding and passivation. Use a sequence that reaches the same crevices and internal surfaces as the chemical treatment.

Neutralisation is product and process specific. It should not be improvised by adding an opposite chemical to the workpiece, bath or spill. Uncontrolled neutralisation can generate heat, gas and splashing, and can precipitate material that remains on the surface. Follow the defined treatment sequence and verify the rinse result.

Drain and dry the entire geometry promptly. Use clean handling and protected transfer after preparation; bare steel can re-rust rapidly and stainless steel can be recontaminated by dirty tools, racks or contact surfaces.

13. Control flash rust and the time to the next process

Flash rust is new corrosion that forms after wet preparation as water evaporates or the surface remains exposed. Its development depends on steel condition, soluble contamination, water quality, humidity, temperature, air movement and elapsed time. [S204]

Reduce the risk by:

- removing soluble contamination as required;
- using suitable process and rinse water;
- draining pockets and hidden geometry;
- drying with clean controlled air or another compatible method;
- preventing condensation and dirty handling;
- monitoring the environment required by the coating system; and
- applying the next treatment within its defined window.

Do not automatically coat over flash rust or repeat aggressive preparation without diagnosis. Determine whether the observed grade is acceptable to the coating system and whether salts, retained moisture or environmental conditions caused the recurrence.

14. Verify four separate surface dimensions

A reliable release decision separates visual cleanliness, dust, soluble contamination and profile. Passing one does not prove the others.

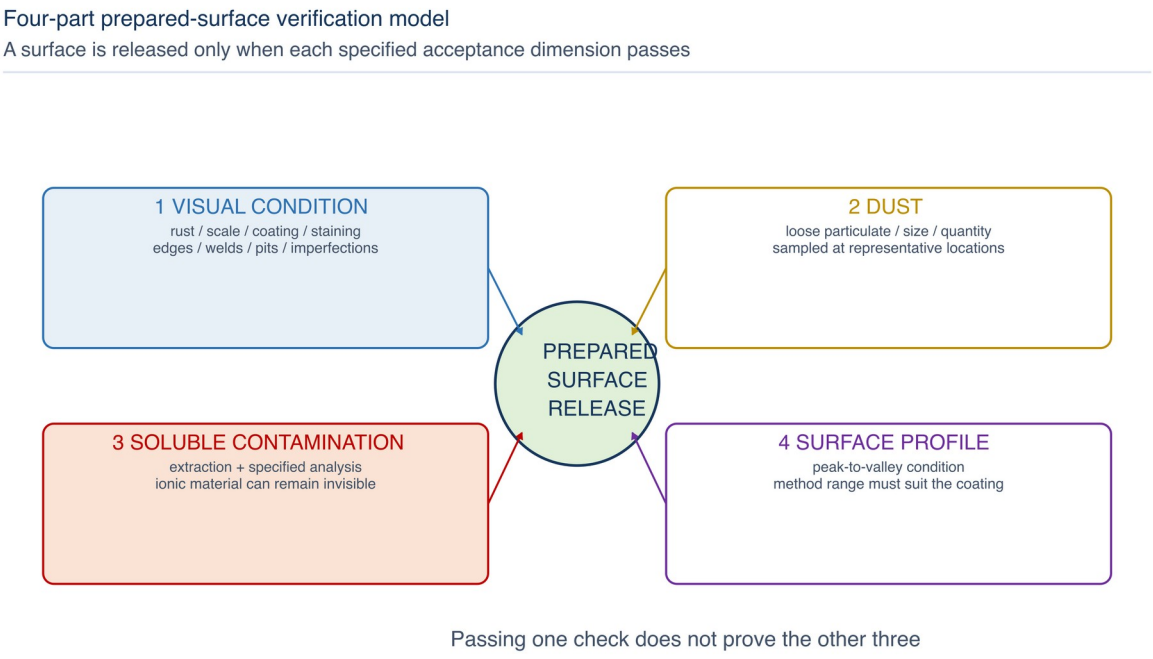

Figure 3. Four-part prepared-surface verification model. Visual grade, dust, soluble contamination and profile are checked independently before the surface is released to its next process.

Verification dimension	What it addresses	Example approach	Limitation
Visual condition	Remaining rust, scale, coating and visible defects	Comparison with the specified visual grade and inspection of edges, welds and pits	Does not quantify invisible salts or profile
Dust	Loose particulate remaining after preparation	Pressure-sensitive tape or another specified dust method	Sampling location and roughness affect interpretation
Water-soluble contamination	Ionic material that can promote coating failure or corrosion	Specified extraction and analysis method	Conductometry does not identify each ion and extraction may not reach concealed material
Surface profile	Peak-to-valley texture created or retained by preparation	Comparator, replica tape, stylus or specified instrument	Method range and coating requirement must be compatible

ISO 8502-3 addresses qualitative dust assessment. ISO 8502-6 describes extraction of water-soluble contamination, including limitations where material is hidden under films or in crevices. ISO 8502-9 uses conductometry to assess ionic contamination but does not identify the individual salt species. [S208-S210]

Record the method, location, condition and result needed by the job specification. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

15. Safety and waste controls

Surface preparation can combine high-energy equipment with dust, sharp debris, noise, vibration, corrosive chemicals, pressurised water and hazardous old coatings. Establish the controls before work starts.

Key safety checks include:

- isolate and secure equipment and workpieces;
- identify hazardous coating, scale and process residues;
- use enclosure, extraction, wet control or containment appropriate to the method;
- control flying particles, rebound and the line of fire;
- protect hearing, eyes, face, skin, body and respiratory system as required by the assessment;
- keep incompatible chemicals segregated and in labelled compatible containers;
- provide the specified spill, eyewash, shower and first-aid arrangements;
- treat confined-space work as a separate controlled activity; and
- stop for damaged hoses, guards, ventilation, respiratory equipment or containment.

Pickling products can contain highly corrosive acids, including formulations that require urgent specialist first aid after contact. HSE guidance emphasises substitution where practicable, effective ventilation, contamination control, suitable PPE and immediate first-aid readiness. [S214]

The removal process transfers material into dust, spent abrasive, filters, sludge, pickling solution, rinsate, wipes and protective sheeting. Characterise and segregate these streams by their actual composition and generating process. Malaysian DOE guidance governs scheduled-waste classification, compatible packaging, labelling, storage and authorised routing; industrial effluent requires the applicable treatment and discharge controls. [S199; S216]

16. Troubleshooting and release checklist

Symptom	Likely causes	Practical correction
Rust or scale remains	Method lacks effective action; coverage is incomplete; layer is shielded by oil; pits or shadow zones were missed	Re-identify the layer, clean interfering soil, improve access or select a suitable removal family
Surface is bright but coating preparation fails	Burnishing or smearing; salts, dust or oil remain; profile is unsuitable	Separate visual, dust, salt and profile checks; repeat only the deficient stage
Rapid flash rust	Soluble contamination, poor water quality, retained moisture, high humidity or delay	Correct rinse, drainage, drying, environment and time-to-coat controls
Deep random scratches or gouges	Tool or media too aggressive; debris trapped at the interface; local dwell or poor support	Clean the interface, change product or support, and use controlled progressive passes
Uneven blast profile	Media mix or flow varies; angle, distance, dwell or access is inconsistent	Restore equipment and media control, standardise technique and remeasure representative areas
Dark staining after chemical treatment	Incomplete oxide removal, base-metal attack, retained chemistry or poor rinsing	Stop, identify the stain mechanism and correct the specified clean-rinse-dry sequence

Symptom	Likely causes	Practical correction
Rust returns beneath coating	Residual salts, dust, moisture, weak material or delay before coating	Review preparation records and coating conditions; correct the verified cause before repair
Stainless surface develops rust spots	Embedded iron, carbon-steel tool transfer or recontamination after cleaning	Isolate the source, use dedicated tools and complete the specified stainless-cleaning route

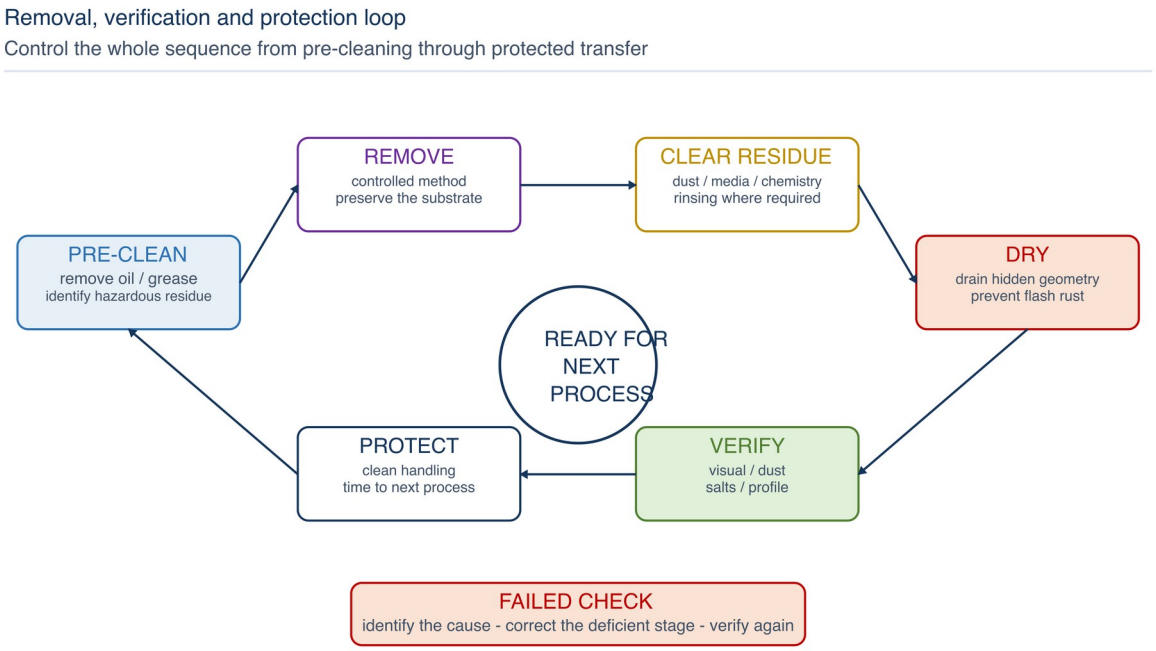

Figure 4. Removal, verification and protection loop. Preparation proceeds through cleaning, controlled removal, residue clearance, four-part verification and prompt protection; a failed check returns to the identified cause.

Before release, confirm:

- the substrate, unwanted layer and required end condition were identified;
- oil, grease and hazardous previous material were addressed;
- the selected method preserved required dimensions, edges, coatings and adjacent components;
- remaining rust, scale and coating meet the specified visual condition;
- dust, soluble contamination and profile were checked where required;
- chemical residue and rinse water were removed from hidden geometry;
- the surface is dry, protected and within the permitted time window;
- waste and effluent streams are contained and routed correctly; and
- the next coating, joining, passivation, inspection or service step accepts the prepared surface.

FILTRATION, CLEANING & PROCESS CONTROL

CHAPTER 039

Stainless-Steel Cleaning and Passivation

39

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Fabricators, welders, maintenance teams, production supervisors, quality personnel, safety and environmental personnel and technical sales personnel

Scope: Practical selection and control of stainless-steel cleaning, decontamination, pickling, passivation, electrochemical cleaning and electropolishing.

Core principle - A bright surface is not automatically clean, passive or corrosion-ready. Identify the contamination and fabrication history, preserve the specified finish, select the correct treatment family and verify the property that matters.

Stainless steel depends on a thin chromium-rich passive surface for corrosion resistance. This film can reform naturally on a clean surface exposed to oxygen, but fabrication can leave oil, heat tint, oxide scale, embedded iron, abrasive residue or smeared metal that obstructs or undermines the intended condition. Cleaning, pickling and passivation have different purposes and must not be treated as interchangeable workshop terms. [S212; S213; S217]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish soil, free-iron contamination, rust staining, heat tint, scale and finish damage;
- prevent carbon-steel transfer during fabrication, handling and storage;
- separate cleaning, decontamination, pickling, passivation and electropolishing;
- select a treatment family from alloy, geometry, finish and service duty;
- preserve brushed, satin, polished and functional surfaces;
- control rinsing, drainage, drying and protected handling;
- select verification methods for visible condition, soil, free iron, staining and finish;
- recognise corrosive-chemical, electrical, fume, splash and confined-space hazards;
- route spent treatment solution, rinsate, sludge and contaminated materials correctly; and
- troubleshoot rust bloom, uneven colour, etching, residue and recurring contamination.

1. Understand the stainless surface

Stainless steel is corrosion resistant because sufficient chromium in the alloy supports formation of a thin passive oxide film. The film is not a thick coating and cannot be judged reliably by brightness or colour alone. A clean stainless surface can self-passivate in air or aerated water, while chemical passivation is a controlled treatment used where the governing specification requires it. [S213; S217]

The base alloy still controls the attainable corrosion resistance. Cleaning cannot upgrade an unsuitable grade, restore metal lost to pitting or compensate for damaging service conditions. Surface treatment can remove contamination and affected surface material; it does not change the bulk alloy.

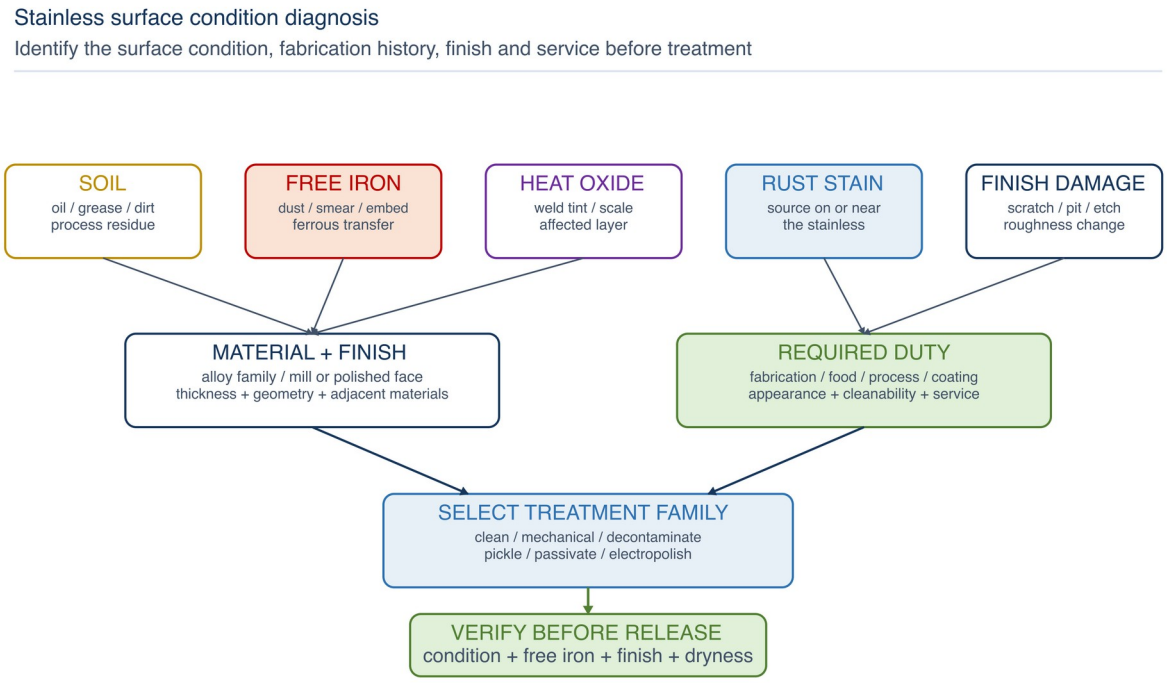

Figure 1. Stainless surface condition diagnosis. Soil, free iron, heat oxide, corrosion product and finish damage are separated before a treatment family is selected.

2. Identify the actual surface condition

Start with the visible condition, fabrication history, alloy family, finish and intended service.

Surface condition	Typical origin	Treatment implication	Important distinction
Oil, grease or shop soil	Forming, machining, handling, maintenance or storage	Preclean with a compatible cleaner and rinse or wipe as specified	Acid treatment is not a substitute for degreasing
Loose iron or grinding dust	Nearby carbon-steel work, dirty tables, lifting gear or poor housekeeping	Remove without spreading; inspect for embedded particles and rust marks	Loose dirt and embedded iron are different conditions
Embedded or smeared iron	Shared tools, steel brushes, contaminated abrasives, clamps or rollers	Decontaminate using a finish-compatible route	Mechanical brightness does not prove iron removal
Heat tint and weld oxide	Welding, heat treatment or inadequate shielding	Remove oxide and the affected surface layer where required	Passivation alone is not a descaling process
Rust staining	Corroding transferred iron, external run-off or service deposit	Identify the source before cleaning the stain	Staining can originate above or beside the observed area
Surface damage or pitting	Aggressive abrasion, chemical attack, chloride exposure or service corrosion	Assess geometry and remaining condition before restoration	Cleaning does not replace an integrity assessment

Examine welds, heat-affected zones, crevices, drain points, tube interiors, fastener interfaces and shadowed faces. Rust colour on stainless steel may come from transferred carbon steel, external run-off, contaminated water or corrosion of the stainless itself. Treating the colour without finding the source often produces recurrence.

3. Prevent contamination before it requires removal

Prevention is usually more controllable than restoration. Segregate stainless work from carbon-steel grinding and cutting where practical. Use clean dedicated brushes, abrasives, blasting media, racks, slings, clamps and handling surfaces. Protect sheet and finished parts from floors, traffic, ferrous strapping and dirty storage supports. [S214; S220; S221]

Good fabrication controls include:

- identifying stainless-only tools and storage positions;
- cleaning worktables, rolls, clamps and lifting contact points;
- removing carbon-steel grinding dust before it settles on stainless work;
- keeping abrasive products dry, clean and separated by material family;
- protecting finished faces during transport and assembly;
- using compatible markers, tapes, lubricants and temporary coverings; and
- preventing dirty gloves, rags or racks from recontaminating a cleaned part.

Dedicated does not mean permanently clean. A stainless-only tool can still carry oil, chloride, abrasive residue or damaged bristles and must be inspected before use.

4. Preclean before chemical or electrochemical treatment

Oil and grease can shield metal and oxide from uniform treatment. Remove interfering soil before pickling, passivation or electropolishing using a cleaner compatible with the alloy, finish, seals and downstream process. Chapter 037 explains cleaner-family selection in detail. ASTM A380/A380M treats cleaning and precleaning as integral to controlled stainless surface treatment. [S212]

Control the whole clean-rinse-dry sequence. Avoid merely moving soil from an open face into a lap, tube, threaded hole or crevice. Where exact cleaner chemistry, dilution, temperature, contact time or compatibility is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

After precleaning, use clean handling. Fingerprints, dirty rinse fixtures or a contaminated workbench can defeat the next operation.

5. Control free-iron contamination

Free iron can rust on the stainless surface and create local staining. Common pathways include shared carbon-steel brushes, previously used abrasive media, steel shot, dirty handling equipment, ferrous grinding dust and contact with corroding supports. [S220; S221]

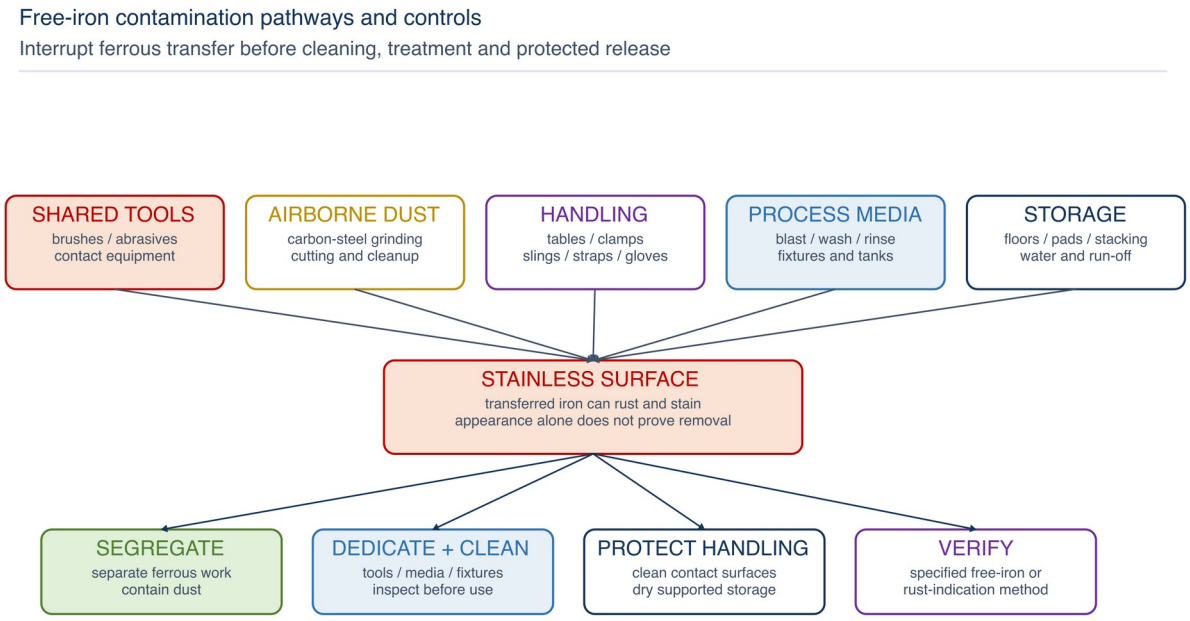

Figure 2. Free-iron contamination pathways and controls. Segregation, dedicated clean tooling, protected handling and verification interrupt the main transfer routes.

Transfer pathway	Warning sign	Practical control
Shared wire brush or abrasive	Rust specks follow tool marks or local dressing	Use a clean compatible tool reserved for stainless work

Transfer pathway	Warning sign	Practical control
Carbon-steel grinding nearby	Fine orange bloom appears over broad exposed faces	Separate work or contain and remove ferrous dust at source
Tables, rolls, clamps or slings	Marks repeat at contact points	Clean, cover or change the contact material
Reused blast media	Widespread embedded residue or unexpected staining	Use clean media and equipment controlled for the stainless duty
Wash or rinse system	Marks follow drainage paths or water spots	Verify water, fixtures, tanks, nozzles and drying arrangement
Storage and transport	Stains form beneath bands, pads or stacked contact areas	Use clean compatible supports and keep surfaces dry and protected

Do not repeatedly polish rust spots until the transfer source is known. Polishing can smear contamination, change the finish and remove sound metal while leaving the cause in place.

6. Select the treatment family

Choose the treatment from the surface condition and required endpoint, not from a general instruction to “passivate stainless.”

Treatment family	Primary purpose	Suitable starting condition	Main limitations and controls
Detergent or compatible cleaner	Remove oil, grease, dirt and process soil	Soiled but otherwise sound stainless surface	Must reach hidden geometry and leave a compatible residue condition
Mechanical cleaning	Remove local oxide, staining or damage and restore a defined finish	Accessible local areas where geometry and texture can be controlled	Can smear metal, embed particles, round edges or alter roughness
Chemical decontamination	Remove free iron or compatible surface contamination	Chemically clean surface with suspected ferrous transfer	Does not replace descaling where heat oxide remains
Pickling	Remove oxide scale, heat tint and a thin affected metal layer	Welded or heat-affected stainless requiring oxide removal	Etches the surface; alloy, finish, access, fumes, rinsing and waste are critical
Chemical passivation	Treat a clean stainless surface under a specified system	Clean, oxide-free surface where passivation is required	Not a degreaser or scale remover; exact treatment and verification are specification dependent
Electrochemical cleaning	Local controlled removal of weld discolouration using suitable equipment	Accessible weld zones suited to the equipment and finish requirement	Electrical, electrolyte, fume, contact-pad, rinse and appearance controls apply
Electropolishing	Smooth, brighten, deburr and passivate by controlled anodic removal	Clean components requiring a specified functional or visual finish	Removes metal and can affect dimensions, edges, appearance and part-to-part uniformity

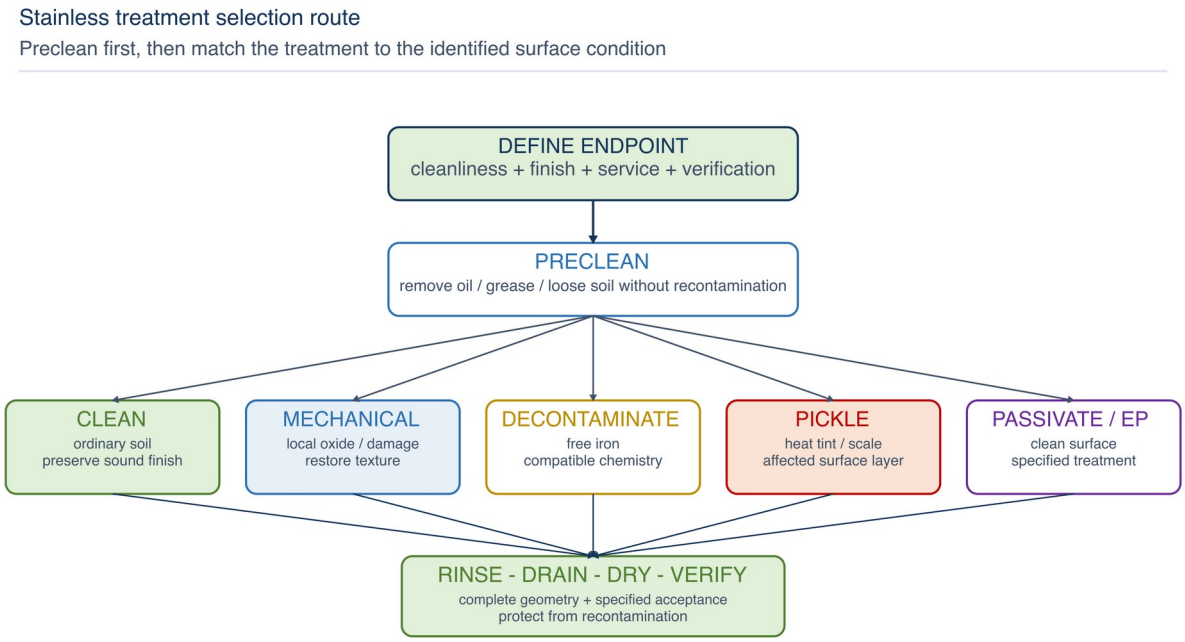

Figure 3. Stainless treatment selection route. Precleaning precedes condition-specific treatment, followed by complete rinsing, drying and verification.

7. Use mechanical cleaning without damaging the finish

Mechanical cleaning may use stainless-compatible brushes, non-woven products, abrasive sheets, flap products, grinding products, blasting media or polishing systems. Select the action for the defect, alloy, existing texture and required appearance. A tool suitable for removing heavy heat tint may be too aggressive for a fine satin finish or thin component.

Key controls are:

- use clean products compatible with stainless steel;
- match the direction of an existing directional finish;
- use controlled progressive passes and avoid local dwell;
- prevent heat tint, gouging, undercut, edge rounding and dimensional loss;
- remove abrasive debris before inspection;
- compare texture and colour across representative lighting angles; and
- complete any required decontamination or passivation step separately.

Wire brushing can remove loose surface material but may burnish oxide or smear metal rather than remove the affected layer. HSE guidance recognises mechanical alternatives to pickling paste but also notes that the resulting surface quality depends on the selected method and duty. [S214]

Refer to the product label, Technical Data Sheet, or MKTECH representative.

8. Use pickling for oxide and affected-layer removal

Pickling is a controlled chemical removal process for heat tint, oxide scale and a thin surface layer beneath the oxide. It differs from ordinary cleaning and from passivation. The method may be an immersion, local gel or paste, spray under engineered controls, or another specified system. [S212; S217; S223]

Do not formulate or mix a pickling product in the workshop. Use the supplied system only on compatible alloys and surfaces, with the specified application equipment, ventilation, exposure controls, first-aid readiness, rinsing and waste arrangements. Pickling can dull or etch the finish, attack the base metal, remain trapped in joints and generate hazardous fumes or acidic rinsate.

Before treatment, confirm:

738. the alloy and finish are compatible with the selected product;
739. the surface is free from oil and interfering soil;
740. all treated faces, crevices and internal surfaces can be rinsed completely;

741. adjacent metals, coatings, seals and equipment are protected;
742. the work area controls splashes, fumes and unauthorised access;
743. emergency and first-aid arrangements match the current safety information; and
744. rinsate and residues have a contained route.

Where exact chemistry, application amount, temperature, contact time, neutralisation sequence or rinse endpoint is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

9. Apply passivation only to a clean surface

Chemical passivation treats a clean stainless surface under defined conditions. It can remove compatible surface contamination and support formation of the passive condition, but it does not replace degreasing or removal of adherent weld oxide and scale. ASTM A967/A967M provides a treatment and verification framework for stainless-steel parts. [S213]

Passivation selection depends on the alloy family, metallurgical condition, surface finish, previous treatment, geometry, service environment and governing specification. Some grades or hardened components can be sensitive to unsuitable chemistry or hydrogen-producing conditions. The specified system controls treatment, rinsing and verification.

Do not describe a part as “passivated” solely because it is bright, has been exposed to acid or has dried without visible staining. Record the specified treatment and the applicable verification result.

10. Distinguish electrochemical cleaning and electropolishing

Electrochemical weld cleaning uses an electrical circuit and electrolyte at a local contact tool to remove weld discolouration. Electropolishing treats the component as the anode in a controlled process that removes surface metal, reduces micro-roughness and can passivate the stainless surface. They are not interchangeable processes. [S214; S218; S219; S222]

ISO 15730:2023 and ASTM B912-26 address electropolishing as a specified process with preparatory cleaning, controlled treatment, post-treatment, rinsing and verification. The alloy, component geometry, dimensional tolerance, rack contact, electrical conditions, bath condition and required finish all affect the outcome. [S218; S219]

Electropolishing can change edges, dimensions, reflectivity and texture even when its purpose is functional. Use representative components or agreed inspection areas where appearance and dimensional control are important.

11. Treat the complete geometry

The visible face is only part of the cleaning problem. Tubes, vessels, manifolds, threads, blind holes, crevices, lap joints, weld roots and drain points can retain soil, treatment chemistry or rinse water. Design the sequence so every treated surface can be contacted, rinsed, drained, dried and inspected.

For assemblies with dissimilar metals, coatings, elastomers, bearings or electrical components, assess the complete assembly before exposure. Where practical, dismantle sensitive items or select a local method that prevents ingress. Protect downstream product-contact, high-purity or coating surfaces from transfer during handling.

Do not introduce a chemical into a closed or poorly drained assembly unless the defined process provides controlled access, ventilation, circulation, recovery, rinse and verification.

12. Rinse, drain, dry and protect

Rinsing removes cleaner, dissolved metal, reacted oxide and treatment chemistry. Use the water quality and sequence required by the selected system and service. Rinse with enough access and movement to reach the same hidden features as the treatment. [S212; S213; S219]

Drain before drying. Rotate or position parts so tubes, pockets, threads and crevices empty. Dry with clean compatible air or another specified method, then handle with clean gloves, racks and packaging. Water marks, retained chemistry and dirty fixtures can create defects after an otherwise satisfactory treatment.

Neutralisation is product and process specific. Do not improvise by combining opposing chemicals on the workpiece, in a tank or in a spill. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

13. Verify the property that matters

No single observation proves every required property. Select verification from the governing specification and the actual risk.

Verification focus	What it can indicate	Example method family	Limitation
Visible condition	Remaining soil, tint, oxide, staining, etching and finish mismatch	Controlled lighting and representative visual comparison	Cannot prove absence of invisible free iron or chemical residue
Residual oil or soil	Interfering organic or particulate contamination	Specified wipe, water-break or service-specific cleanliness method	Method sensitivity and interpretation depend on the surface and process
Free iron	Ferrous contamination capable of producing rust indications	Specified water, humidity, copper-sulfate or ferroxyl-type method	Test suitability varies by alloy, finish, product-contact duty and acceptance rule
Corrosion indication	Tendency to develop visible rust under a defined exposure	Specified immersion, humidity or salt-spray method	A pass does not certify every service environment or corrosion mechanism
Finish and geometry	Texture, roughness, gloss, direction, edge and dimension	Visual comparator or specified instrument	Appearance and roughness do not by themselves prove chemical cleanliness
Rinse and drying result	Retained water, streaking, residue or inaccessible pockets	Drainage inspection and specified rinse-quality check	Visible dryness does not prove hidden cavities are dry

ASTM A967/A967M and ASTM B912 identify several verification-method families. The governing drawing, purchase specification or quality plan selects the applicable method and acceptance criterion; do not substitute a convenient test without confirming its suitability. [S213; S219]

14. Control safety, effluent and waste

Stainless surface treatment can combine corrosive chemicals, hydrofluoric-acid hazards in some pickling products, fumes, splashes, electrical energy, heated surfaces, pressurised rinsing and confined geometry. Establish the controls before work starts. [S198; S214]

Practical controls include:

- eliminate or substitute the hazardous method where the required result permits;
- use the current safety data and workplace chemical-risk assessment;
- segregate incompatible chemicals and retain them in labelled compatible containers;
- provide containment, ventilation and restricted access appropriate to the application;
- protect eyes, face, skin, respiratory system and body as required by the assessment;
- provide the specified eyewash, shower, spill and first-aid arrangements;
- isolate electrical equipment before cleaning, inspection or maintenance;
- prevent uncontrolled spray, pressure-wash splash and contaminated mist; and
- stop work if ventilation, containment, PPE, emergency equipment or rinse recovery is not ready.

Spent cleaner, pickling or passivation solution, electropolishing bath residue, sludge, wipes, absorbents and rinsate must be characterised by actual composition and generating process. Malaysian DOE controls govern industrial effluent and scheduled-waste classification, compatible packaging, labelling, storage and authorised routing. [S199; S216]

15. Troubleshoot from the source

Symptom	Likely causes	Practical correction
Rust spots return after cleaning	Ferrous source remains; contamination is embedded; rinse fixture or handling reintroduced iron	Trace the transfer pathway, isolate it, restore the surface and repeat the specified verification
Heat tint remains	Treatment cannot reach the oxide; contact is incomplete; mechanical action only burnished the surface	Reassess access, oxide severity and the selected oxide-removal route
Uneven colour or dull patches	Non-uniform cleaning, local over-treatment, mixed finish or retained residue	Stop, identify whether the change is soil, etching or texture and correct the deficient stage
Surface is bright but test fails	Polishing improved appearance without removing contamination	Use the specified free-iron or cleanliness route instead of further cosmetic polishing
Water marks or streaks	Poor rinse quality, dirty fixtures, slow drainage or incomplete drying	Correct water, rinse access, drainage, drying and protected handling

Symptom	Likely causes	Practical correction
Pitting or dark attack appears	Incompatible chemistry, excessive exposure, retained chemical or unsuitable alloy condition	Stop treatment, rinse as specified, assess damage and correct the selected process
Finish becomes too rough or glossy	Abrasive or electropolishing action does not match the required texture	Re-establish the finish specification and use a controlled representative-area method
Staining follows joints or holes	Soil, chemistry or water remains in hidden geometry	Improve access, circulation, rinsing, drainage and inspection of internal features

Repeating a stronger or longer treatment without diagnosis can deepen etching, change dimensions and create more waste. Correct the verified cause and repeat only the deficient stage.

16. Release the cleaned stainless surface

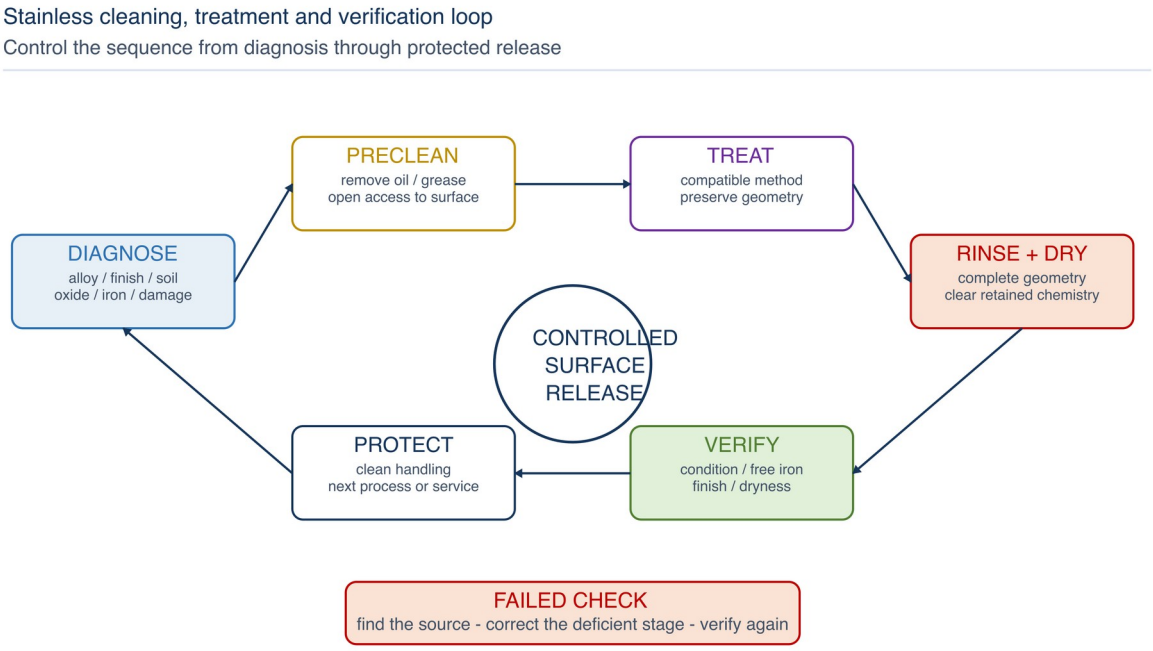

Figure 4. Stainless cleaning, treatment and verification loop. The surface proceeds from condition identification through precleaning, compatible treatment, complete rinsing and specified verification before protected release.

Before release, confirm:

- the alloy family, finish, fabrication history and service duty were considered;
- oil, grease and interfering soil were removed;
- carbon-steel transfer pathways were controlled;
- heat tint and scale were removed by a suitable route where required;
- cleaning, pickling, passivation and electropolishing were not treated as interchangeable;
- the complete geometry was rinsed, drained and dried;
- appearance, free iron, residue, finish or corrosion indication was checked as specified;
- adjacent materials, dimensions, edges and functional surfaces remain acceptable;
- waste and effluent streams are contained and routed correctly; and
- the part is protected from recontamination until its next process or service condition.

FILTRATION, CLEANING & PROCESS CONTROL

CHAPTER 040

Chemical Storage and Handling

40

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Storekeepers, production teams, maintenance personnel, supervisors, safety and environmental personnel, quality personnel and technical sales personnel

Scope: Practical control of packaged industrial chemicals from receipt and segregation through point-of-use storage, inspection, stock rotation, spill readiness and controlled disposition.

Core principle - Store chemicals by hazard compatibility and consequence, not by alphabet, convenience or container colour. A leak must remain contained without reaching an incompatible chemical, drain, work area or ignition source.

Chemical storage is an active control system. The label and Safety Data Sheet identify the product and its hazards; the storage arrangement separates incompatible groups, protects containers, limits release pathways and keeps emergency information accessible. Good storage also prevents aged, damaged or unidentified stock from entering production. [S224; S225; S226]

Chapter objectives

After this chapter, the reader should be able to:

- read the label and Safety Data Sheet before assigning a storage location;
- inspect deliveries and reject or isolate damaged packages;
- segregate incompatible chemical groups and their leak paths;
- select compatible cabinets, racks, trays, bunds and secondary containers;
- control ignition, heat, sunlight, moisture and ventilation according to the stored hazard;
- maintain positive identification of every primary, secondary and working container;
- minimise point-of-use quantity and keep containers closed when not in use;
- rotate stock by expiry priority and then first-in-first-out where appropriate;
- inspect storage conditions, containment and emergency arrangements systematically;
- select spill equipment and first-response actions from the actual hazard information; and
- route damaged stock, residues and contaminated materials correctly.

1. Define the storage duty

Begin with the current inventory, not with the empty shelves. For each chemical, establish its identity, physical form, package type, quantity, location, storage conditions, incompatibilities and emergency information. The same product can present different consequences in a small sealed bottle, a drum, a pressurised package or an open working container.

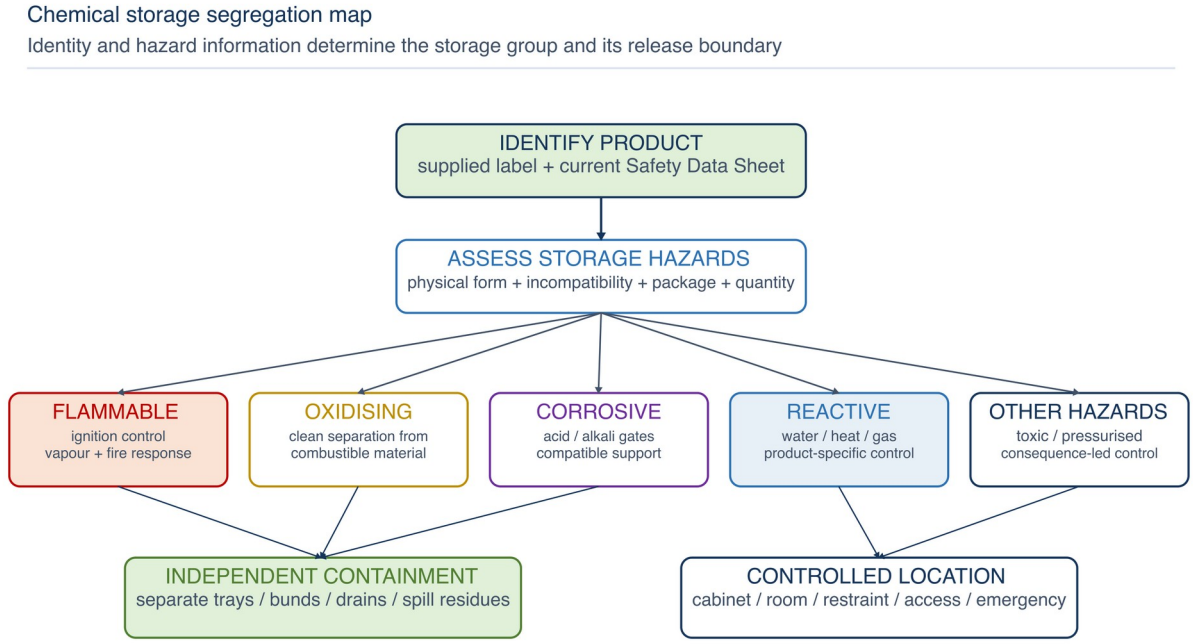

Figure 1. Chemical storage segregation map. Product identity and Safety Data Sheet information lead to compatible storage groups with separate containment and release pathways.

Storage decision input	Question to answer	Control produced
Product identity	Is the container positively identified by its supplied label?	Correct SDS, inventory entry and storage group
Hazard classification	Is it flammable, oxidising, corrosive, toxic, water-reactive, pressurised or otherwise hazardous?	Cabinet, room, ventilation, ignition and emergency controls
Incompatibility	What materials, products and conditions must be avoided?	Physical segregation and separate spill pathways
Physical form	Is it a liquid, solid, aerosol, compressed gas or temperature-sensitive material?	Suitable support, restraint and release control
Package and quantity	Can the closure, shelf and containment carry the package safely?	Storage height, load control, tray or bund arrangement
Product condition	Is the package intact, in date and free from swelling, corrosion or leakage?	Acceptance, quarantine or controlled disposition
Use location	How much is needed at the workstation and how will it remain protected?	Minimum point-of-use stock and return-to-store discipline

Keep the chemical register and Safety Data Sheets current and accessible to workers and emergency responders. Critical information should be obtainable without entering the affected storage area. [S160; S198; S224]

2. Read the label and Safety Data Sheet

Use the supplied label to confirm identity, hazard information and precautionary statements. Use the current Safety Data Sheet to review handling, storage, incompatibilities, fire response, accidental-release measures, exposure controls, first aid and disposal considerations. Do not assign compatibility from trade name, colour, odour or previous familiarity.

The storage section of the Safety Data Sheet is the starting point, not the entire decision. Cross-check fire, stability and reactivity, physical properties, transport information and the site chemical-risk assessment. Where exact storage temperature, ventilation, package compatibility or shelf-life information is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

If the label is unreadable or the product identity is uncertain, do not smell, taste, mix or open the container to identify it. Secure it against use and arrange controlled identification or disposition.

3. Receive and inspect deliveries

Inspect chemical deliveries before they enter general storage. Confirm the ordered identity and quantity, readable labels, intact closures, sound packaging and any required handling orientation. Look for wet patches, crystalline deposits, staining, corrosion, dents, bulging, pressure damage, odour or temperature abnormality.

Do not accept a leaking package into ordinary stock. Keep people clear, protect drains and ignition controls, and apply the site response plan using the product's current emergency information. Do not place an unidentified leaking package beside a known chemical merely because both containers look similar.

Record the receipt date and manufacturer expiry or retest date where provided. Place newly received stock so that older suitable stock remains accessible and is not hidden behind it.

4. Segregate incompatible chemicals

Compatibility is chemical-specific. Common storage families include flammable liquids, oxidisers, acids, alkalis, toxic materials, water-reactive materials and compressed gases, but these are decision groups rather than a complete universal matrix. Products within one broad family may still be incompatible. [S224; S225; S226]

Broad storage group	Keep separate from	Storage focus	Decision gate
Flammable liquids	Oxidisers, ignition sources and incompatible reactives	Approved storage arrangement, closed containers and vapour control	SDS fire and storage information
Oxidising materials	Flammables, organic materials, reducing agents and incompatible contaminants	Clean dedicated area and prevention of combustible contamination	SDS reactivity information

Broad storage group	Keep separate from	Storage focus	Decision gate
Acids	Alkalis and any product that can produce hazardous gas or heat on contact	Corrosion-resistant support and independent containment	Product-specific incompatibility list
Alkalis	Acids and incompatible metals or reactives	Compatible packaging, low stable storage and independent containment	Product-specific incompatibility list
Water-reactive materials	Water, moisture, aqueous chemicals and unsuitable fire media	Dry protected storage and response plan matched to the product	SDS handling, storage and fire sections
Toxic or highly hazardous materials	General access, food and personal items; incompatible reactives	Restricted access, clear identity and consequence-led containment	Workplace risk assessment and SDS
Aerosols and gases	Heat, impact, damaged valves and incompatible gas groups	Upright restraint, ventilation and temperature control as specified	Cylinder/package label and SDS

Do not store chemicals alphabetically until compatibility groups have already been established. Never place an oxidiser over a flammable liquid, an acid over an alkali, or any leaking container above another chemical.

5. Separate containment and leak paths

Segregation must continue below the shelf. Separate trays, bunds, floors, drains, sumps and spill-residue containers so that an escaped chemical cannot combine with an incompatible product. A cabinet divider does not control a release if both sides drain into one common tray. [S224; S225]

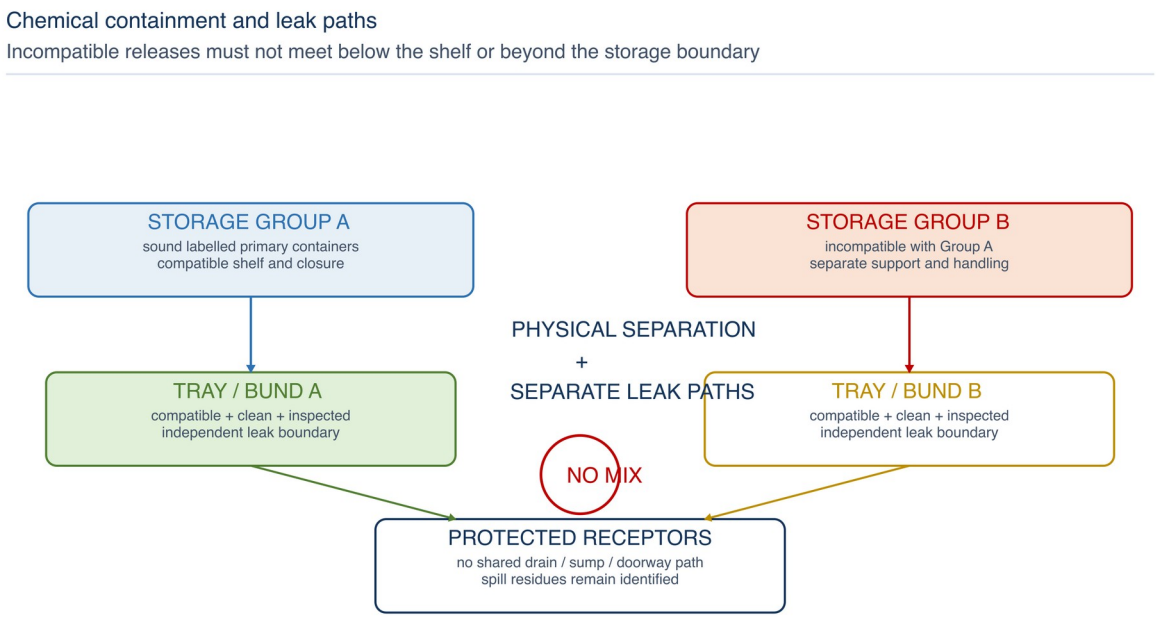

Figure 2. Chemical containment and leak paths. Primary containers, compatible secondary containment and independent leak routes prevent incompatible releases from meeting.

Keep containment clean, dry where required and available for its intended capacity. Do not use a bund as general storage space, allow rainwater or washwater to occupy it, or route it to an open drain. Where a release could spread under shelving or through a doorway, consider the whole floor and threshold arrangement, not only the individual tray.

6. Choose the storage room, cabinet and rack

The storage location must support the hazard, quantity, package and emergency access. Use stable, chemically compatible shelves with load ratings suited to the stored packages. Restrain cylinders and other tall packages. Keep heavy or corrosive containers low enough for controlled handling, but not directly on a floor where damage, water or unnoticed leakage is likely.

Protect packages from vehicle impact, falling objects, vibration, sharp edges and unauthorised access. Maintain clear aisles and keep exits, fire equipment, eyewash points, electrical panels and ventilation openings unobstructed. Labels should face outward where practical so identity and condition can be checked without moving every package. [S225; S229]

Do not use ordinary domestic cupboards, timber shelves or improvised racks where the hazard requires a purpose-designed chemical-storage arrangement.

7. Control ventilation, heat and ignition

Ventilation must control the actual vapour, gas, dust or heat load and must not transfer hazardous emissions into occupied areas, ignition zones or neighbouring processes. An open door or portable fan is not automatically an adequate control. Air intake, discharge, low or high vapour behaviour, package breathing and spill conditions all matter.

Keep flammable materials away from ignition sources, hot work, unsuitable electrical equipment and hot surfaces. Protect temperature-sensitive, pressurised and light-sensitive packages from conditions that can degrade the product or package. Where exact temperature, ventilation duty, hazardous-area equipment or fire-protection requirements are needed, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Ventilation systems, alarms and fire-protection equipment require competent design, inspection and maintenance. Do not defeat interlocks or block vents to reduce odour.

8. Protect primary containers and secondary containment

Keep chemicals in the original supplied package whenever practical. The closure, liner, vent and container material form a compatible system. Do not transfer a chemical into a food, beverage or unverified household container. Do not reuse an apparently empty chemical container for another product.

Container or containment layer	Selection requirements	Routine checks
Supplied primary package	Product-compatible material, closure and venting arrangement	Label, corrosion, swelling, cracks, cap, seal and residue
Secondary or working container	Positive identity and verified compatibility with contents and use	Label, closure, cleanliness, condition and return date where relevant
Shelf tray	Compatible with the stored group and large enough for credible leakage	Cracks, contamination, available capacity and drainage route
Bunded floor or cabinet sump	Independent from incompatible groups and resistant to expected contents	Integrity, penetrations, valves, rainwater, waste and obstruction
Rack or shelf	Stable, load-rated and resistant or protected against likely exposure	Corrosion, fasteners, deformation, anchoring and load distribution
Cylinder restraint	Compatible chain, strap or frame that protects the valve and prevents falling	Upright condition, restraint, cap where applicable and impact protection

Secondary containment is not a substitute for sound primary packaging. Replace or manage a deteriorated container through an approved route before it fails; do not depend on a tray to make damaged stock acceptable.

9. Label secondary and working containers

Every secondary and working container must remain positively identified throughout use. Apply the workplace label immediately after an authorised transfer. Include the product identity and hazard information required by the applicable system; keep the label legible and resistant to the working environment. [S227]

Do not identify chemicals by cap colour, bottle shape, shelf position or memory. Keep containers closed when not actively in use and return them to the correct storage group promptly. Where exact label content, package markings or supplied-container requirements apply, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Funnels, pumps and dispensing tools can carry residue between containers. Dedicate or clean them under a defined compatible procedure and keep them protected from dust and mistaken use.

10. Control point-of-use storage

Keep only the minimum practical quantity at the workstation. Reserve stock belongs in the controlled store, while point-of-use stock needs the same identity, compatibility, containment, ignition and housekeeping discipline as the main store. [S228]

Separate storage from dispensing and from chemical mixing. Use only the authorised closed-transfer or dispensing arrangement for the product and task. Do not decant over a sink, floor drain, unprotected bench or incompatible tray. Do not leave open containers, soaked rags or residue-bearing tools at the workstation after the task.

Return suitable stock to its assigned location after use. If contamination, wrong-product contact or package damage is suspected, isolate the container rather than returning it to clean stock.

11. Rotate stock and control expiry

Use earliest-expiry-first-out when packages have different expiry or retest dates. Where no date takes priority, first-in-first-out helps prevent new deliveries from burying older stock. Stock rotation must never override product condition, storage-history concerns or manufacturer instructions. [S228]

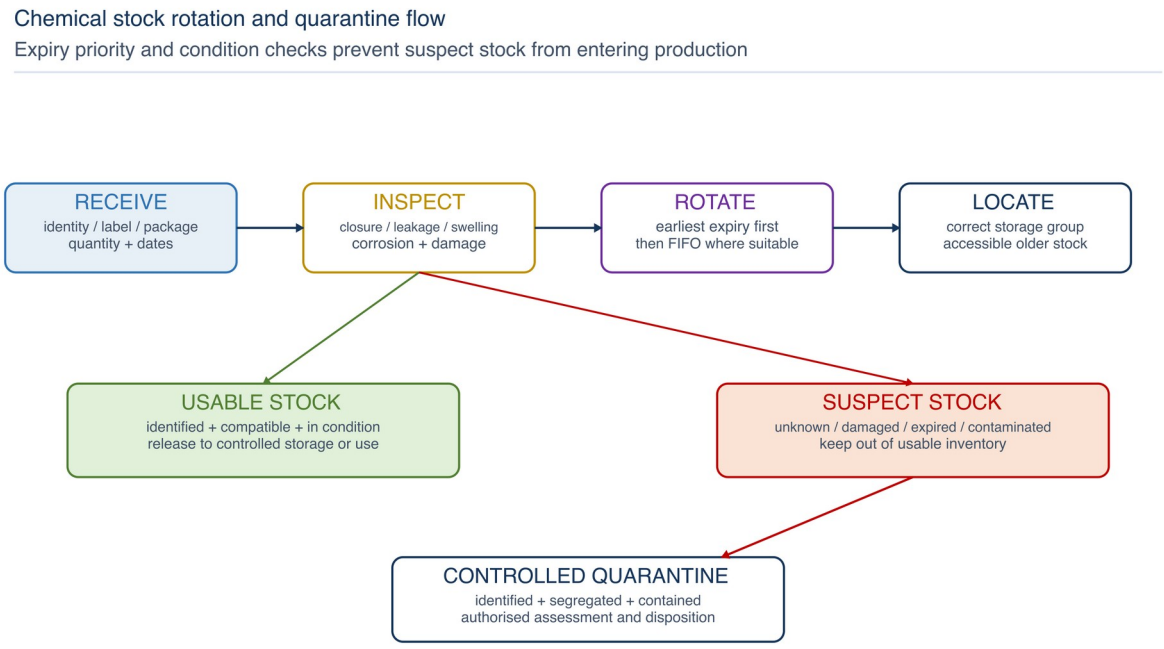

Figure 3. Chemical stock rotation and quarantine flow. Receiving checks, expiry priority, condition checks and controlled quarantine keep suspect stock out of production.

Track product identity, location, quantity, receipt date, opening date where relevant, expiry or retest date and responsible area. Review slow-moving and excess stock so it can be reduced before it deteriorates. Do not combine partial containers to simplify inventory unless the product system and authorised procedure specifically permit it.

Expired does not automatically mean safe, inert or suitable for disposal as ordinary waste. Keep it identified and segregated while the correct disposition route is arranged.

12. Inspect storage systematically

Inspection frequency should reflect hazard, inventory turnover, package condition, environment and previous findings. High-consequence or frequently handled areas need closer attention than stable reserve stock.

Inspection level	Typical focus	Corrective response
Before use or handling	Identity, label, closure, obvious leak, swelling, corrosion and correct location	Stop use and isolate any suspect package
Routine area check	Housekeeping, segregation, containment capacity, aisle access and ignition control	Correct safe defects promptly; restrict the area when consequence is significant
Scheduled detailed inspection	Inventory, expiry, racks, bunds, ventilation, emergency equipment and SDS access	Assign and verify corrective actions to completion
After delivery or stock movement	Package damage, overload, wrong location and blocked labels or access	Restore the approved arrangement before release

Inspection level	Typical focus	Corrective response
After spill, fire alarm or abnormal event	Contamination, package exposure, hidden damage and control-system condition	Keep the area controlled until competent assessment and recovery are complete

Document significant findings and completed actions. Repeated leaks, label damage or wrong-location events indicate a system problem in purchasing, handling, shelving, training or supervision—not merely poor housekeeping.

13. Prepare spill kits and first response

Spill equipment must match the chemicals present. A universal absorbent or neutralising agent is not safe for every release. Select compatible absorbents, drain covers, non-sparking or corrosion-resistant tools, waste containers and protective equipment from the current hazard assessment and emergency information. [S224; S225; S229]

Keep spill kits visible, identified, inspected and accessible without crossing the likely release zone. Where exact PPE, absorbent compatibility, first-aid treatment or fire-extinguishing media are required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

For a release: raise the alarm, keep people away, identify the product from a safe position, remove ignition only when this can be done safely, protect drains without entering the hazard, and use trained responders under the site plan. Do not touch, smell, walk through, neutralise or wash away an unknown spill.

14. Maintain emergency readiness

Emergency arrangements should cover alarm, isolation, evacuation, fire response, first aid, eyewash and shower access, spill control, environmental protection and external assistance. Display emergency contacts and a storage plan where responders can reach them even when the store itself is inaccessible.

Inspect eyewash and shower arrangements, alarms, ventilation status, fire equipment and escape routes on the defined schedule. Keep doors, access panels and emergency equipment clear. Consider after-hours access, lone work, power failure, flooding and loss of ventilation in the response plan.

Drills should test communication and decision-making as well as equipment. A responder must know when a spill exceeds the site's safe capability and requires evacuation or specialist assistance.

15. Control damaged, unknown and waste stock

Isolate damaged, leaking, swollen, corroded, expired, contaminated or unknown stock from usable inventory. The quarantine location must maintain compatibility, containment, identification and restricted access. Do not casually overpack, open, vent, transfer or combine suspect chemicals.

Spill residues, absorbents, contaminated PPE, rinsate and damaged packaging can have different hazards from the original product. Characterise and segregate them by actual composition and generating process. Malaysian DOE requirements govern classification, compatible packaging, labelling, storage and authorised routing of scheduled waste. [S216]

Do not pour chemical waste into sinks, drains, soil or general refuse. Empty packaging may retain hazardous residue or vapour and must follow the applicable product and waste controls.

16. Troubleshoot and release the storage system

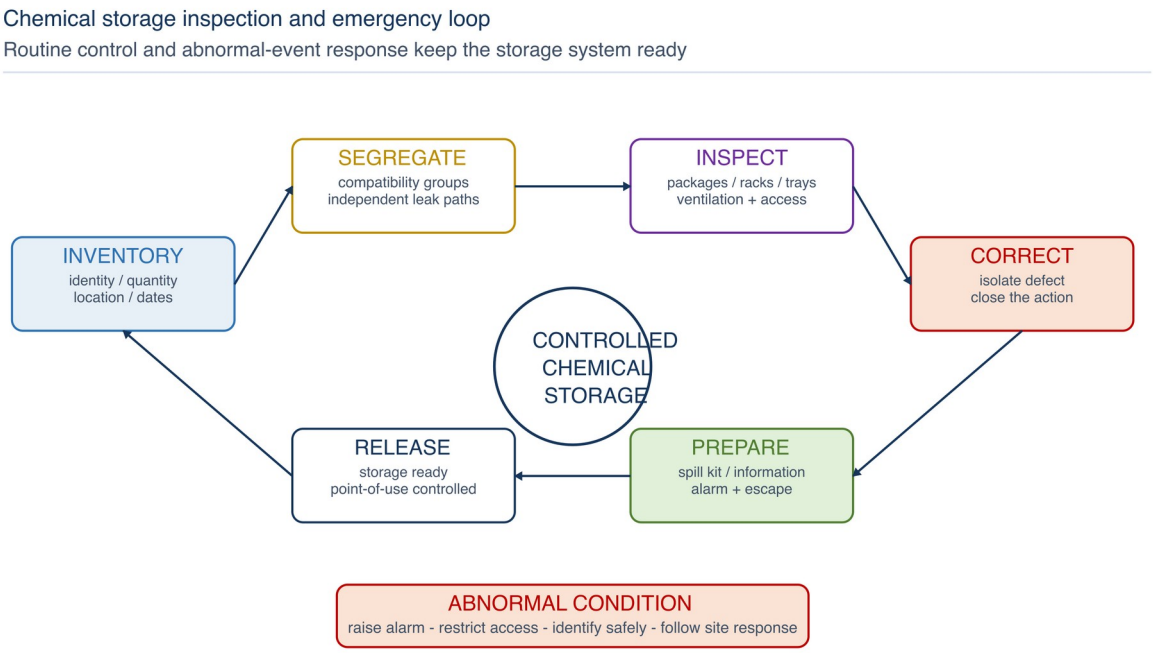

Figure 4. Chemical storage inspection and emergency loop. Routine control links inventory, inspection, correction and emergency readiness; abnormal conditions move directly to isolation and response.

Observation	Likely causes	Practical correction
Containers are in alphabetical order but incompatible	Shelving was organised for convenience rather than hazard	Reassign compatibility groups from the SDS and separate their leak paths
Tray contains mixed residues or standing liquid	Shared containment, poor housekeeping or an unnoticed leak	Control the area, identify contents safely, recover correctly and restore independent clean containment
Labels repeatedly become unreadable	Unsuitable label material, splash exposure or handling damage	Improve label durability and placement; verify identity before release
Strong odour appears near the store	Open or damaged package, inadequate ventilation or unsuitable storage condition	Restrict access, identify from a safe position and apply the site response plan
Expired stock accumulates	Over-purchasing, hidden inventory or weak rotation	Reduce purchase quantity, use FEFO/FIFO and review slow-moving stock
Containers deform or corrode	Incompatible package, heat, sunlight, moisture, age or external contamination	Isolate the package and correct the storage condition and supply route
Spill kit is incomplete or unsuitable	No ownership, use without replenishment or generic kit selection	Assign inspection ownership and match contents to the stored hazards
Chemical appears at a drain or doorway	Containment breach, shared leak path or unsuitable floor gradient	Activate response, protect receptors and redesign the containment boundary

Before the storage system is released for routine use, confirm:

- every container is positively identified and linked to a current Safety Data Sheet;
- compatibility groups and incompatible leak paths are separated;
- shelves, cabinets, restraints, trays and bunds are compatible and serviceable;
- ventilation, temperature, sunlight and ignition controls match the stored hazards;
- containers are closed, labels face outward where practical and aisles remain clear;
- point-of-use quantities are minimised and stored under equivalent controls;
- expiry priority, FIFO, inventory and quarantine controls are active;
- spill kits, alarms, emergency information, eyewash and fire equipment are accessible;
- damaged stock and chemical waste have identified controlled routes; and

- inspection findings are closed and the storage arrangement remains ready for abnormal events.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 041

Basic Dimensional Measurement

41

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production operators, fabricators, grinding and finishing teams, inspectors, supervisors, quality personnel, maintenance personnel and technical sales personnel

Scope: Practical workshop measurement of size, depth, height, gap, radius, thread and simple geometric variation, from drawing interpretation and instrument selection through setup, repeat checks, recording and conformity decisions.

Core principle - Measure the specified characteristic, at the specified location and orientation, with an instrument and method capable of supporting the decision. A clear display is not proof that the correct feature has been measured correctly.

Dimensional measurement connects manufacturing intent to an observed result. The drawing defines what matters; the workpiece, instrument, environment and operator determine how reliably it can be assessed. Good practice begins before the instrument touches the part: define the measurand, select the contact method, prepare the surfaces, control alignment and force, repeat at meaningful positions, and record enough information for another competent person to understand the result. [S230; S231; S237; S238]

Chapter objectives

After this chapter, the reader should be able to:

- identify the actual characteristic required by a drawing, inspection plan or work instruction;
- distinguish size from form, orientation, location, surface texture and comparative gauging;
- select a suitable basic instrument by feature access, tolerance, contact geometry and required decision;
- distinguish display resolution from accuracy, precision, calibration status and measurement uncertainty;
- prepare the workpiece, reference surfaces and measuring faces before measurement;
- control support, alignment, seating, contact position and measurement force;
- recognise temperature, dirt, burrs, coating, roughness, compliance and hand heat as possible influences;
- repeat measurements at positions that can reveal taper, ovality, bow and local variation;
- use zero and known-reference checks without confusing them with calibration;
- record the characteristic, location, unit, instrument identity and result clearly;
- treat results close to a specification limit through the applicable decision rule; and
- stop when the setup, instrument condition or result is not trustworthy.

1. Begin with the requirement, not the instrument

Read the complete drawing callout, note or inspection instruction before choosing a tool. A nominal dimension by itself is incomplete: the tolerance, datum or reference surface, feature boundaries, units, modifier, sampling requirement and acceptance rule may change the measurement method.

Ask four questions:

745. What characteristic is specified: outside size, inside size, depth, step, height, gap, radius, thread, form, orientation, location or surface texture?
746. Which exact surfaces, points or feature boundaries define it?
747. In which direction and at which location must it be measured?
748. What decision must the result support: setup, process adjustment, comparative sorting, in-process control or final acceptance?

The same two surfaces can produce different results when measured at different heights, angular positions or distances from an edge. A diameter can vary along its length and around its circumference; a plate can have acceptable local thickness but excessive bow; a hole can have a displayed diameter while its axis location remains unverified. Do not substitute an easy measurement for the specified characteristic. [S230; S235]

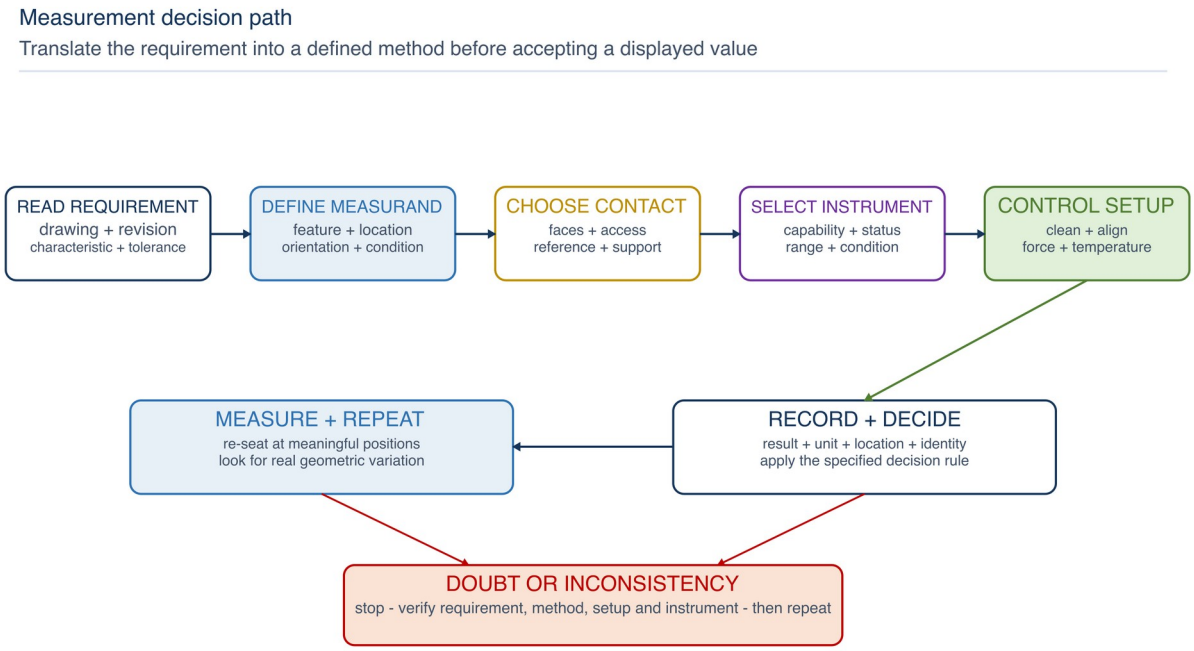

Figure 1. Measurement decision path. The requirement is translated into a defined measurand, suitable contact method, capable instrument, controlled setup and documented decision.

2. Define the measurand clearly

The measurand is the quantity intended to be measured. In workshop language, it is the precise answer to: “What dimension, at what place, in what direction, under what condition?” [S230; S238]

Compare these descriptions:

- “shaft diameter” is broad;
- “outside diameter at the bearing seat” is better;
- “outside diameter at three axial stations, measured in two angular orientations after temperature stabilisation” defines a repeatable measurement task.

A complete definition avoids accidental changes between operators, shifts or suppliers. It also makes variation meaningful: different readings may represent real workpiece geometry rather than instrument inconsistency.

Requirement family	What it describes	Basic workshop approach	Important boundary
Linear size	Distance associated with opposed surfaces, a cylinder or another specified feature of size	Rule, calliper, micrometer or dedicated size gauge	A size reading does not automatically establish form, position or orientation
Depth or step	Distance from a defined reference surface to a lower or higher feature	Depth gauge, depth micrometer, calliper depth rod or height-based method	The base must seat on the intended datum without rocking or bridging
Height	Distance from a reference plane to a feature	Height gauge on a suitable surface plate or controlled reference	Reference-plane condition and probe geometry affect the result
Gap or clearance	Separation between assembled or adjacent surfaces	Feeler gauges or another suitable contact method	Access force and surface damage can change the apparent gap
Radius or profile	Comparison of a contour with a specified form	Radius gauge, profile template or optical/profile method	A light-gap comparison is not a complete numeric radius measurement
Thread	Pitch, form, major/minor/pitch diameter or functional fit as specified	Pitch gauge, thread plug/ring gauge or dimensional method	Pitch identification alone does not prove functional thread acceptance

Requirement family	What it describes	Basic workshop approach	Important boundary
Form, orientation or location	Straightness, flatness, roundness, perpendicularity, position or related geometry	Indicator, comparator, surface plate, dedicated fixture or suitable measuring system	A calliper or micrometer reading alone normally cannot establish the full requirement
Surface texture	Roughness, waviness, lay or another specified texture characteristic	Suitable surface-texture instrument and method	Visual smoothness and dimensional size are different properties

3. Use measurement terms correctly

Clear terminology prevents false confidence. A digital display may show many digits, but the number of digits is not the same as the quality of the result. [S231; S238]

Term	Practical meaning	What it does not mean
Indication	The value shown or indicated by the instrument	Automatically the final measurement result
Resolution	The smallest change the display or scale can distinguish	Accuracy, capability or uncertainty
Accuracy	Qualitative closeness between a measured value and the value of the measurand	A numerical specification that can be read directly from display resolution
Precision	Closeness of agreement among repeated indications under specified conditions	Freedom from systematic error
Repeatability	Precision under defined repeat conditions such as same method, operator, instrument and location	Agreement between different methods or laboratories
Measurement uncertainty	A parameter describing the dispersion of values attributed to the measurand from the information used	A mistake allowance or automatic reason to reject a result
Calibration	Establishing the relation between standards and instrument indications, with associated uncertainties, so results can be obtained from indications	Cleaning, zeroing, adjustment or a quick shop-floor check
Verification	Confirmation that specified requirements have been fulfilled	A substitute for a suitable measurement method

Do not say that an instrument is “accurate to its last digit” merely because the display is stable. For the exact instrument range, resolution, permissible error, environmental rating or metrological characteristics, **Refer to the product label, Technical Data Sheet, or MKTECH representative.** [S231; S232; S233; S234]

4. Select the instrument by feature, access and decision

Choose the contact geometry first, then the instrument. The measuring faces must reach the intended feature, contact it in a controlled way and avoid bridging, rocking or touching adjacent geometry. The instrument's documented characteristics must support the required tolerance and decision. [S231; S237]

Instrument or gauge	Best suited to	Strengths	Common limitations or misuse
Steel rule	Approximate length, layout confirmation and generous-tolerance checks	Fast, robust and easy to apply	Parallax, end wear, line width and poor edge definition limit close decisions
Calliper	General outside, inside, step and depth measurements where its capability is suitable	Versatile and quick for workshop checks	Jaw wear, access, alignment and variable hand force can dominate the result
Outside micrometer	Controlled measurement of accessible outside sizes	Rigid frame, defined measuring faces and controlled-force features on suitable models	Narrower function; heat, alignment, anvil condition and overtightening still matter
Depth gauge or depth micrometer	Holes, slots, recesses and steps measured from a reference surface	Broad base can establish a defined reference plane	Base rocking, burrs, edge chamfers and bottom geometry can create false readings

Instrument or gauge	Best suited to	Strengths	Common limitations or misuse
Height gauge	Heights, steps, scribed locations and comparative checks from a reference plane	Useful for repeated work on a controlled surface	Surface plate, base cleanliness, probe alignment and part support are critical
Bore gauge or internal comparator	Internal diameter and variation at selected depths and directions	Sensitive to taper and ovality when correctly set and rocked	Usually requires a suitable reference setting and disciplined technique
Feeler gauge	Accessible gaps and clearances	Direct, simple comparative assessment	Blade drag, stack condition, access angle and part compliance affect interpretation
Radius gauge	Quick comparison of convex or concave radii	Useful for profile identification and gross mismatch detection	Light-gap judgement is operator dependent and not a full numeric profile measurement
Thread pitch gauge	Identifying or comparing thread pitch and form	Rapid matching aid	Does not by itself verify thread diameter, lead, flank condition or functional fit
Thread plug or ring gauge	Functional limit assessment of specified internal or external threads	Fast pass/fail control when gauge and method are correct	Does not report the actual dimension and must match the thread system and requirement

Prefer an instrument that makes correct alignment and contact easy. A higher-resolution instrument is not automatically better if its faces cannot reach the feature, the workpiece deforms under contact, or the setup introduces a larger error. Detailed calliper and micrometer technique is covered in Chapter 043; calibration-system control is covered in Chapter 044.

5. Prepare the workpiece and instrument

Measurement begins with clean, serviceable contact surfaces. Loose dirt, abrasive grain, oil film, paint flakes, corrosion product or swarf can hold the instrument away from the true surface. Burrs, raised edges and impact marks may be part of the manufactured condition or may be unwanted damage; do not remove them casually before understanding the inspection requirement.

Before use:

749. Stop and isolate moving equipment as required by the safe system of work; never place a hand instrument against a rotating or moving workpiece.
750. Confirm the instrument identity, status, measuring range and suitability for the feature.
751. Inspect measuring faces, jaws, tips, base and slides for dirt, damage, wear or looseness.
752. Clean the workpiece and reference surfaces with a method that will not scratch, distort or heat them.
753. Check that the feature is accessible without forcing the instrument or contacting adjacent geometry.
754. Confirm zero or the appropriate reference condition, then check a suitable known reference where the task requires it.

If a measuring face is chipped, loose, visibly worn or contaminated, remove the instrument from use under the site's measurement-control process. Do not polish, stone, bend or adjust precision measuring faces unless the authorised procedure allows it.

6. Control temperature and the environment

Dimensional properties are specified with reference to a standard reference temperature, and real materials change size with temperature. Instrument and workpiece temperature, temperature gradients, hand heat, recent machining, sunlight and air movement can therefore influence the result. [S230; S237; S239]

The practical control depends on material, size, tolerance and required uncertainty. A rough fabrication check may tolerate conditions that are unsuitable for a close final inspection. Bring the workpiece, instrument and reference standard into a sufficiently stable condition for the required decision. Avoid measuring a hot component directly after grinding, welding, machining or washing when thermal change can be significant.

Use insulating pads, supports or gloves only where they do not contaminate, deform or destabilise the setup. Hold precision instruments by their intended insulating surfaces where provided and avoid prolonged contact with the frame or measuring faces. Do not apply an assumed thermal correction unless the material, temperatures, method and uncertainty treatment are controlled.

Where exact stabilisation time, reference correction or environmental limit is needed, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

7. Support the workpiece without changing it

A dimension can change when a thin, long, soft or flexible part is clamped, lifted or placed on an uneven surface. Support must make the feature accessible without bending, twisting or masking the condition being measured.

For long parts, choose support points that minimise sag for the characteristic of interest. For thin sheet, do not squeeze the measuring faces hard enough to flatten local waviness unless the specified method defines that condition. For soft coatings, plastics, elastomers and thin-wall sections, consider whether the contact force or support can compress the material.

Keep the datum or reference surface clean and fully seated. A chip under one corner can tilt the entire part. If a part rocks, determine whether the cause is dirt, burrs, unstable support or actual form variation before recording a result.

8. Align the measurement axis and contact faces

The instrument axis must follow the intended dimension. Angular misalignment creates cosine-type error; an offset between the measurement scale and the line of measurement can amplify angular effects; incomplete seating or contact on a radius can shift the apparent boundary. [S231; S237]

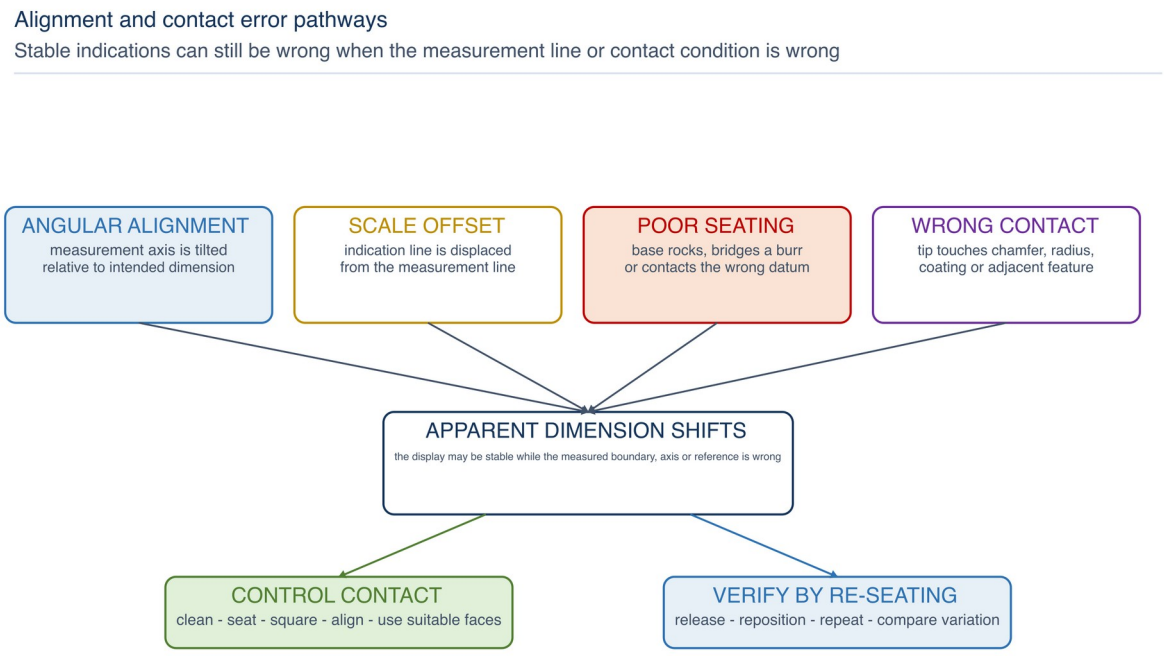

Figure 2. Alignment and contact error pathways. Angular alignment, scale offset, seating and contact position can shift a reading even when the display itself is stable.

Use these controls:

- keep measuring faces square to flat surfaces;
- seek the true diameter across a cylinder rather than a chord;
- use a gentle rocking or sweeping method only where appropriate to find the intended maximum or minimum contact condition;
- seat depth-gauge bases fully on the reference surface without bridging an edge or burr;
- keep long jaws or extensions aligned and avoid side loading;
- confirm that chamfers, radii, weld spatter, coating build-up or edge break are not being mistaken for the defined feature boundary; and
- repeat after releasing and re-seating the instrument rather than trusting one carefully “held” reading.

Do not force a stable number. If the reading changes with slight, legitimate repositioning, investigate geometry, support, access and technique.

9. Apply consistent and appropriate contact force

Contact force must be sufficient to establish repeatable contact but not so high that it deforms the part, bends the instrument, marks the surface or squeezes out a compliant layer. Force is especially important for soft materials, thin sections, coated surfaces, narrow contacts and hand-operated callipers. [S237]

Use the instrument's controlled-force device when provided and suitable for the method. With a micrometer, do not use the frame as a clamp or tighten past the controlled-contact action. With a calliper, use light, consistent thumb pressure and confirm that the slide is not being skewed. With feeler gauges, interpret drag consistently and avoid forcing a blade into a gap that damages the part or changes the clearance.

A repeated number obtained with excessive force is still a poor result. If different trained operators need substantially different force to obtain agreement, the method may require better fixturing, a more suitable instrument or a defined force-control approach.

10. Measure outside size correctly

For an outside width, thickness or diameter, contact the intended surfaces with clean, parallel measuring faces. Approach the part without impact. Align the instrument, establish contact using consistent force and observe whether slight repositioning changes the reading.

For a shaft or round feature, measure at more than one angular orientation and at suitable axial positions. This can reveal ovality, taper, barrel shape, local wear or surface damage. For sheet or plate, select positions that represent the requirement and avoid assuming an edge reading represents the full part.

Do not measure over loose scale, weld spatter or a burr unless the requirement intentionally includes it. If a coating is present, establish whether the drawing dimension applies before coating, after coating or to the substrate. The answer changes both the measurand and the instrument contact condition.

11. Measure inside size, depth and height correctly

Internal measurement is sensitive to access and contact geometry. Calliper inside jaws may contact a chord instead of the true diameter; worn knife edges can bias small internal measurements; bore gauges require correct setting and alignment. Use a method suited to the feature depth, diameter, surface condition and tolerance. [S232; S237]

For a hole or bore:

- measure at specified or meaningful depths;
- check at more than one angular orientation;
- keep the measuring axis perpendicular to the bore axis unless another condition is specified;
- avoid contacting chamfers, damaged edges, grooves or debris; and
- use a suitable comparative or direct-reading internal instrument when the calliper contact geometry is inadequate.

For depth, the base must sit flat on the specified reference surface. Keep the rod or spindle aligned with the depth direction and ensure the tip contacts the intended bottom—not a radius, chip, angled surface or accumulated debris. For height, keep the reference plane, instrument base and workpiece support clean and stable; approach the feature without side loading the probe.

12. Use comparative gauges within their purpose

Comparative gauges answer a defined comparison question. They may confirm fit, pitch, gap or profile without reporting the actual dimension.

Use a feeler gauge only when the selected blade or stack can enter along the intended path without forcing the assembly apart. Keep blades clean, flat and free from kinks or raised damage. Record the assessment method when “light drag” or a similar tactile condition is part of the procedure.

Use a radius gauge by comparing both the centre and edge light gaps at a clean profile. A good visual fit at one location does not establish the complete three-dimensional form. Use thread pitch gauges for pitch/form identification and plug or ring gauges for their defined functional limit decision. Do not use a thread gauge as a tap, die, scraper or alignment tool.

When the gauge identity, wear status, temperature or application is uncertain, stop and verify it through the site's measurement-control system.

13. Repeat at positions that reveal real variation

Repeating the same contact at the same place mainly tests immediate repeatability. To understand the part, move to positions and orientations that can reveal its likely geometric variation. [S237; S238]

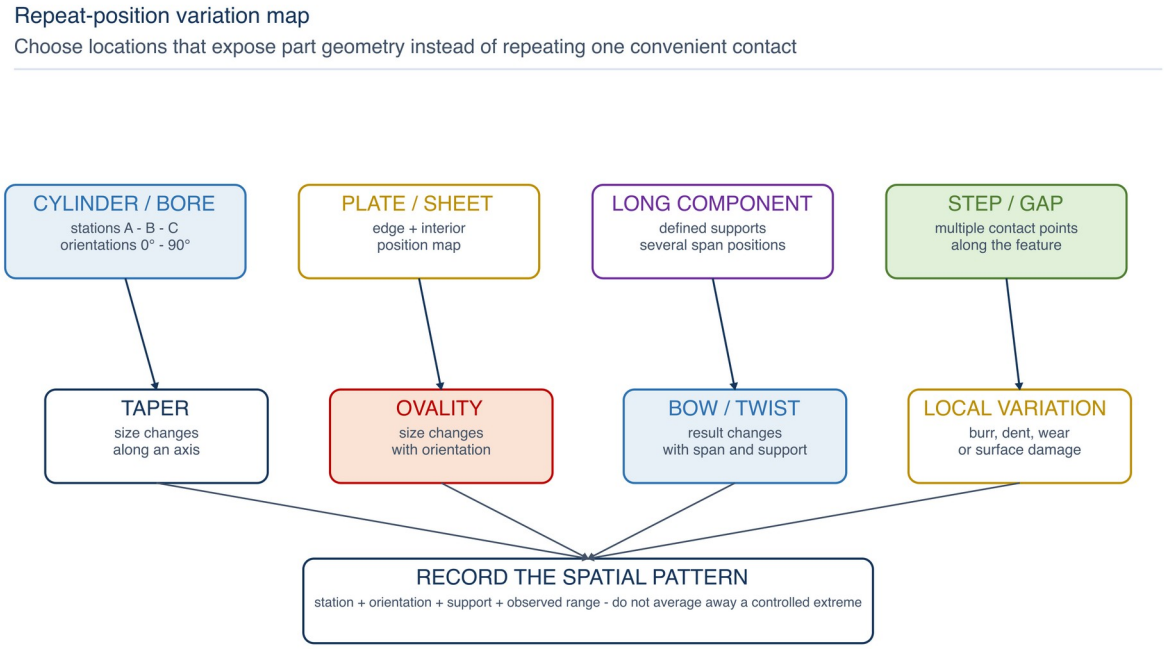

Figure 3. Repeat-position variation map. Axial stations, angular orientations and supported spans are selected to expose taper, ovality, bow and local damage rather than merely repeating one setup.

Feature	Useful repeat pattern	Variation that may appear	Recording cue
Shaft or pin	Several axial stations and at least two angular orientations	Taper, ovality, barrel shape, wear or local damage	Record station and orientation with each result
Hole or bore	More than one depth and angular orientation	Taper, bell-mouth, ovality, tool marks or local damage	Identify depth from the selected face and measurement direction
Plate thickness	Edge and representative interior locations as specified	Thickness variation, edge roll, coating build-up or local dents	Use a position map or coordinates for important parts
Long straight component	Defined support condition and several positions	Bow, twist, sag or local deformation	Record support arrangement and measurement direction
Step or recess	Several points across the base or face	Tilt, uneven bottom, burr or seating error	Record the reference surface and contact positions
Gap or clearance	Defined positions around or along the assembly	Misalignment, taper, distortion or local interference	Record assembly condition and gauge orientation

If variation is greater than expected, do not average it away automatically. The drawing may control maximum local size, least size, form or another characteristic for which the extreme or spatial pattern matters. Escalate unclear interpretation before making a conformity decision.

14. Check zero and a suitable known reference

A zero check confirms one condition at or near zero. It can reveal dirt, incomplete closure, obvious damage or an incorrect reference setting, but it does not demonstrate performance throughout the measuring range. A suitable known-reference check can provide stronger evidence near the working size, provided the reference is identified, in status and used correctly. [S237; S238]

Clean the reference and measuring faces before the check. Use a reference type and size appropriate to the instrument and measurement. Record significant check failures and remove the instrument from use when required. Do not adjust an instrument merely to make one reference agree if the cause may be wear, damage, temperature or an incorrect technique.

Calibration establishes a documented relation using measurement standards and uncertainties. A shop-floor comparison, zero setting or button labelled “cal” is not automatically calibration. [S238]

15. Record a result another person can understand

A useful record identifies what was measured and how. Do not record unsupported decimal places simply because the display provides them.

Include, as appropriate:

- part, job, drawing and revision identity;
- characteristic and nominal/tolerance requirement;
- measurement location, depth, station, orientation and datum or reference surface;
- result and unit;
- instrument or gauge identity;
- method or fixture identity where it affects interpretation;
- environmental or temperature condition where significant;
- operator and date/time where required;
- repeated values or observed range where variation matters; and
- decision rule, acceptance status or escalation reference where required.

Use a position sketch for complex parts. “Diameter 25.00” is not enough when the part has several diameters or the value varies along its length. Keep the original observed values available when a calculated average, correction or summary is reported.

16. Make conformity decisions with the applicable rule

A displayed value inside the nominal tolerance is not always sufficient for acceptance. The result, method capability, measurement uncertainty and applicable decision rule matter, especially close to a specification limit. ISO 14253-1 addresses uncertainty-aware rules for verifying conformity and nonconformity of workpiece characteristics and measuring equipment. [S236]

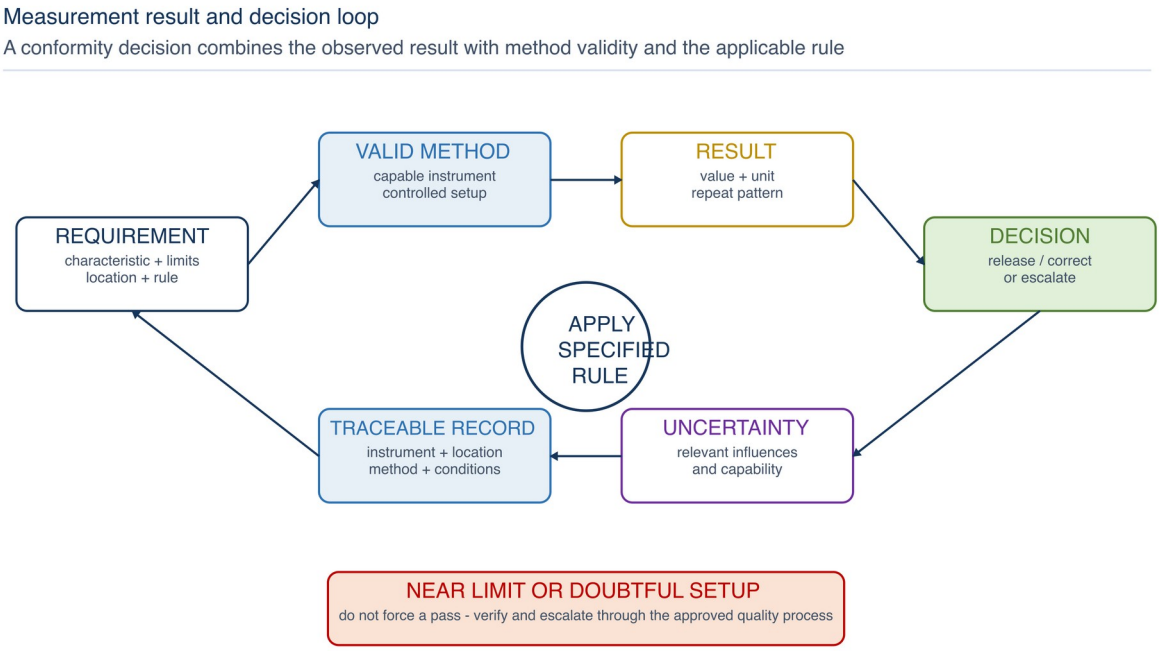

Figure 4. Measurement result and decision loop. The measured value is combined with method validity, uncertainty information and the applicable decision rule before release, correction or escalation.

Use this practical logic:

755. Confirm the requirement and measurement method are valid for the characteristic.
756. Confirm instrument status, setup and reference checks are acceptable.
757. Review repeated readings and spatial variation for evidence of setup or part-condition problems.

758. Compare the measurement result with the specification using the stated decision rule.
759. Escalate a result near a limit when uncertainty can affect the decision.
760. Record the decision and retain the supporting measurement information.

Do not invent a guard band, subtract uncertainty informally or round a value to create acceptance. Do not change instrument or operator repeatedly until one reading passes. If the required decision rule is not stated, use the organisation's approved inspection and quality procedure.

17. Troubleshoot doubtful measurements

Observation	Likely causes	Practical correction
Reading changes when the instrument is tilted	Angular misalignment, chord measurement or off-axis contact	Re-establish the intended measurement axis and use contact geometry suited to the feature
Reading changes with hand pressure	Variable force, part compliance, loose slide or instrument flex	Use consistent controlled force, improve support and select a more suitable instrument if needed
Zero is unstable or does not repeat	Dirt, damaged faces, temperature change, loose mechanism or low power on an electronic instrument	Clean and inspect; verify condition and remove from use if the fault remains
Different operators obtain different results	Measurand, location, alignment, force or tactile criterion is not sufficiently defined	Clarify the method, mark locations, standardise technique and verify with a suitable reference
Bore reading differs by direction	Ovality, alignment error, worn contacts or surface damage	Repeat at defined angular positions and depths with a suitable internal method
Depth reading varies across the opening	Base rocking, burr, debris, angled bottom or real form variation	Clean and seat the base; map positions and identify the actual bottom condition
Measurement drifts after handling	Hand heat, workpiece cooling, instrument warming or electronic instability	Stabilise conditions, reduce handling and repeat after a controlled interval
Result is close to the tolerance limit	Normal variation, uncertainty, rounding or inadequate method capability	Apply the specified decision rule and escalate rather than forcing a pass/fail conclusion
Surface is rough and readings scatter	Contact tips bridge peaks and valleys or touch different local points	Define the contact method and locations; use a method appropriate to the specified characteristic
Gauge passes in one location but fails elsewhere	Taper, bow, ovality, burr, distortion or local damage	Map the feature and compare the spatial pattern with the actual drawing requirement

18. Practical measurement and release checklist

Before releasing the result, confirm:

- the current drawing, revision and complete characteristic requirement were used;
- the measurand, location, orientation and reference surface are clear;
- the selected instrument can contact the feature correctly and supports the required decision;
- instrument identity, status, range and condition were checked;
- measuring faces, reference surfaces and the workpiece were clean and serviceable;
- the workpiece and instrument were sufficiently temperature stable;
- the part was supported without bending, twisting, heating or masking the characteristic;
- alignment, seating, contact position and measurement force were controlled;
- zero and any required known-reference check were satisfactory;
- measurements were repeated at positions that can reveal relevant variation;
- the unit, location, instrument identity and observed result were recorded without false precision;
- any result near a limit was handled through the applicable uncertainty-aware decision rule; and
- doubtful setups, damaged instruments and inconsistent results were escalated rather than accepted by convenience.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 042

Surface and Weld Inspection

42

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Fabricators, welders, grinding and finishing teams, production operators, inspectors, supervisors, quality personnel, maintenance personnel and technical sales personnel

Scope: Practical visual and dimensional inspection of fabricated surfaces and welded joints, including inspection planning, surface preparation, weld-zone coverage, indication mapping, measurement, repair control and selection boundaries for specialist non-destructive testing.

Core principle - Identification, classification, measurement, testing and acceptance are different steps. Observe the complete required area, describe the condition accurately, and make the decision only against the applicable drawing, fabrication specification, inspection plan and acceptance criteria.

Inspection protects the connection between design intent, fabrication quality and service performance. A quick glance at the weld face is not enough. The inspector needs a defined item and revision, a safe and representative surface, adequate access and visibility, a repeatable coverage path, suitable measuring tools, an acceptance basis and a record that locates every relevant observation. Visual testing is valuable before, during and after welding, but it cannot establish every internal, subsurface or metallurgical condition. [S240; S241]

Chapter objectives

After this chapter, the reader should be able to:

- identify the weld, surface, drawing revision, inspection stage, extent and acceptance basis;
- distinguish an observation, indication, imperfection, measured result and acceptance decision;
- make the area safe and establish representative access, cleanliness and visibility;
- inspect the weld face, toes, starts, stops, craters, transitions, adjacent base metal and accessible reverse side systematically;
- recognise common visible condition families without claiming hidden depth or cause;
- measure specified profile, alignment and local surface characteristics with suitable gauges;
- map an indication by station, side, orientation, length and relationship to the weld zone;
- select the correct boundary between visual inspection and penetrant, magnetic, ultrasonic or radiographic testing;
- prevent grinding and repair from hiding the original condition or reducing required section;
- record inspection method, extent, result, disposition and re-inspection status clearly; and
- stop when access, surface condition, acceptance basis or inspection competence is inadequate.

1. Begin with the inspection requirement

Before examining the surface, confirm:

761. part, assembly, weld and joint identity;
762. drawing, weld symbol, fabrication specification and revision;
763. material and joint type;
764. inspection stage: before welding, during production, after welding, after finishing, after repair or in service;
765. required inspection extent and accessible sides;
766. specified method, testing level and personnel requirement;
767. dimensional and surface characteristics to be assessed; and
768. applicable acceptance criteria and disposition route.

Weld symbols can convey geometry, manufacture, quality, testing and surface-finish information. Read the complete symbol system and associated notes; do not interpret one isolated symbol from memory. Where a symbol, finish requirement, testing extent or quality level is unclear, use the controlled drawing and inspection process before proceeding. [S244]

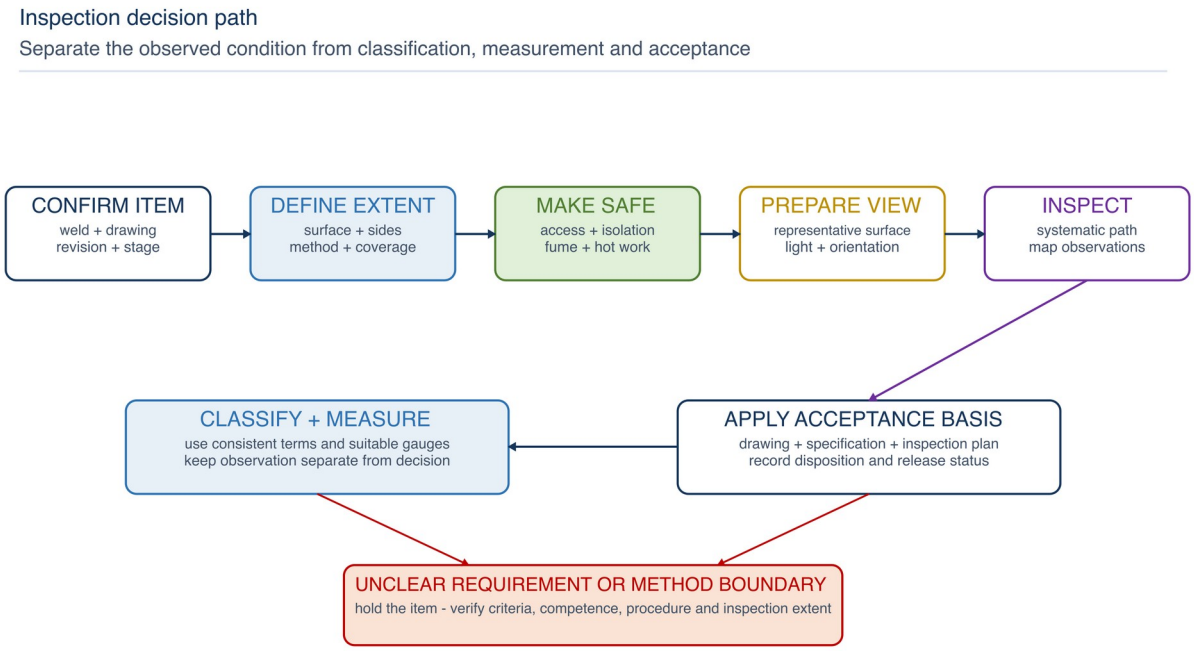


Figure 1. Inspection decision path. The item and requirement are confirmed before the surface is prepared, the inspection extent is covered, observations are measured and the specified acceptance rule is applied.

2. Keep five inspection functions separate

Confusion between description and acceptance creates inconsistent decisions. Use the following sequence:

Function	Practical question	Output	Important boundary
Observation	What is visible or measurable at this location?	Factual note, image, sketch or value	Avoid assigning cause or acceptability too early
Indication	What response or visible feature requires evaluation?	Located indication with method and extent	An indication is not automatically a defect
Classification	Which recognised condition or imperfection family best describes it?	Consistent name or classification	Classification does not itself select an acceptance limit
Measurement or testing	What size, extent or method response has been established?	Traceable result with unit or technique	A surface result does not prove internal depth
Acceptance	Does the result meet the applicable requirement?	Accept, repair, investigate, hold or reject	Use the specified criteria and authorised decision route

ISO 6520-1 provides a classification basis for geometrical imperfections in fusion welding. ISO 5817 provides quality levels for covered fusion-welded joints, while ISO 17635 links method selection, testing levels and acceptance levels on a general basis. These documents serve different functions; a classification code or quality-level label must not be converted informally into a universal pass/fail rule. [S241; S242; S243]

3. Make the inspection area safe

Inspection can expose personnel to residual hot-work hazards even when welding has stopped. Confirm the safe system of work before approaching, touching, cleaning, gauging or marking the item.

Control, as applicable:

- movement, stored energy, suspended loads and unstable components;
- hot metal, sharp edges, slag, spatter and recently ground surfaces;
- welding fume, metal dust and residues from coatings or cleaning chemicals;
- sparks, fragments, noise and kickback when preparation or repair grinding is authorised;
- electrical and magnetic equipment;

- penetrant materials, cleaners, developers and ultraviolet sources;
- confined-space entry, atmosphere, access, rescue and communication; and
- radiography exclusion zones and specialist access control.

Do not enter an industrial-radiography controlled area or disturb radiography equipment. Radiography is performed only through the authorised radiation-protection programme, trained personnel and controlled-area arrangements. [S251] Welding and grinding can involve fumes, UV radiation, fire, sparks, flying fragments and confined-space hazards; use the site's Malaysian risk assessment, permits and control measures. [S252; S253]

4. Establish a representative surface and clear view

The surface must show the condition being inspected without preparation that destroys evidence. Remove loose slag, dust, oil, marker residue or spatter only to the extent authorised by the inspection plan. Do not grind, peen, polish, pickle, wire-brush or blast an area merely to make it look acceptable.

Before inspection:

- confirm the surface state required by the procedure;
- identify coatings, oxides, heat tint, scale, contamination and previous repairs;
- clean using a compatible method that will not smear metal across a crack, fill a recess or round an edge;
- allow wet surfaces and cleaning residues to reach the required condition;
- use suitable direct or aided viewing access;
- position lighting to reveal profile and surface-breaking features without glare or deep shadow; and
- verify mirrors, borescopes, magnifiers, cameras and measuring aids when the method depends on them.

A photograph is useful evidence but not a substitute for controlled inspection. Include scale, orientation and location, avoid perspective distortion, and retain an unmarked original when annotated copies are used.

5. Cover the complete specified weld zone

Use a repeatable path rather than looking only at visually prominent areas. Start from a defined end or datum and move along the weld in overlapping inspection fields.

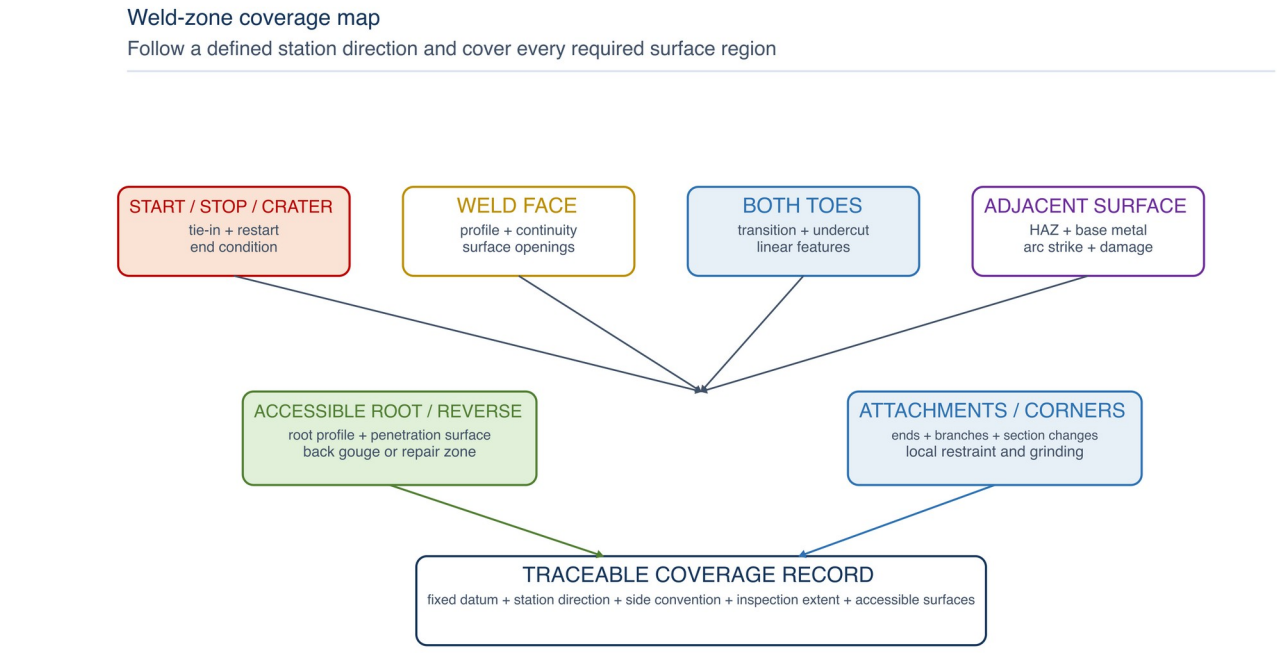


Figure 2. Weld-zone coverage map. Inspection follows the weld face, both toes, starts and stops, adjacent heat-affected zones, nearby base metal and any accessible reverse side with a traceable station direction.

Cover, as required:

- weld face and full length;
- both weld toes and transitions;

- starts, stops, craters, restarts and tie-ins;
- attachment ends, corners, branches and changes in section;
- adjacent heat-affected zones and base metal;
- arc strikes, temporary-attachment locations and ground areas;
- accessible root, penetration surface or reverse side; and
- surrounding surface affected by distortion, handling or finishing.

Mark the station direction and side convention before recording. On circular welds, define a clock position or angular datum. On long welds, use station distances from a fixed reference. Avoid descriptions such as “near the left end” when the item can be rotated or installed differently.

6. Recognise visible condition families

Describe what can be supported by the visible surface. Do not infer internal penetration, fusion, toughness, hardness or crack depth from surface appearance alone.

Visible condition family	What to observe	Useful record	What visual inspection cannot establish alone
Crack-like or linear feature	Sharp linear path, branching, crater or toe origin, direction and continuity	Exact start/end, orientation, image and surface condition	True depth, internal extent or cause
Weld profile	Face shape, reinforcement, concavity, convexity, transition and symmetry	Cross-section location and specified gauge result	Internal fusion or root condition when inaccessible
Undercut or groove	Position at toe or root, continuity and local depth where measurable	Side, station, length and measured characteristic	Hidden continuation beneath the surface
Overlap or poor transition	Rolled edge, abrupt toe, lack of smooth fusion appearance	Location, direction and profile image	Bond condition below the visible edge
Porosity or cavity	Number, grouping, distribution and open surface size	Mapped area and individual/group description	Subsurface population or internal volume
Incomplete fill or crater	Depression, unfilled end, local contour and tie-in	Station, measured profile and adjacent features	Internal soundness
Misalignment or distortion	Offset, angular change, bow, twist or local shrinkage	Datum, direction, span and dimensional method	Residual stress or service fitness
Arc strike, spatter or surface damage	Location, density, gouge, indentation or thermal mark	Surface map and relationship to required finish	Metallurgical effect without further evaluation
Grinding or blending mark	Direction, depth appearance, edge radius and remaining profile	Before/after images and local thickness where required	Remaining section or crack removal without measurement/testing

Use neutral wording: “linear surface indication at the upper toe from station 420 to 437 mm” is more useful than “bad crack near the end.” If an authorised classification is required, apply it after the observation is located and described. [S243]

7. Select the inspection method by the question

No single NDT method answers every question. ISO 17635 selects methods in relation to quality requirements, material, weld thickness, welding process and testing extent. [S241]

Method	Primary application	Material/surface boundary	Typical output boundary
Direct visual and dimensional inspection	Accessible surface condition, profile, dimensions and visible discontinuities	Requires representative access and visibility	Cannot establish hidden depth or internal soundness
Penetrant testing	Discontinuities open to a suitable non-porous surface	Test material must be compatible with the penetrant system; surface openings must remain accessible	Indication reveals surface opening, not depth or automatic acceptability
Magnetic particle testing	Surface-breaking and some shallow subsurface discontinuities	Ferromagnetic material only; orientation and magnetisation matter	Sensitivity reduces rapidly with depth; acceptance is separate

Method	Primary application	Material/surface boundary	Typical output boundary
Ultrasonic testing	Internal reflectors and thickness-related questions through an applicable weld technique	Material, thickness, geometry, surface and procedure suitability matter	Specialist interpretation; not a simple picture of defect shape
Radiographic testing	Internal volumetric and profile-related information through controlled X-ray or gamma techniques	Joint geometry, thickness, access and radiation controls matter	Specialist regulated activity with exclusion zones

The exact method, equipment, consumables, sensitivity, technique, testing level and acceptance level are controlled by the applicable procedure. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

8. Inspect before and during welding where required

Pre-weld inspection can prevent later conditions that are difficult to correct. ISO 17637 may be applied to visual testing of the joint before welding. [S240]

Check, as specified:

- correct material and joint identity;
- joint preparation, root face, root gap and included angle;
- alignment, mismatch, fit-up and restraint;
- cleanliness, moisture, coatings and contamination;
- tack weld location, condition and integration plan;
- backing, inserts, purge arrangements or consumable supports;
- accessibility for welding and later inspection;
- weld sequence, distortion controls and temporary attachments; and
- traceability marks that must remain visible.

During production, inspect hold points defined by the fabrication plan. Do not disturb hot work or enter the welder's controlled area merely to observe. Record the stage at which an observation was made because later passes can cover earlier surfaces.

9. Inspect the weld face, toes and transitions

View the weld from more than one angle. Low-angle lighting can reveal profile changes; more direct lighting can reveal surface texture and colour differences. Change position rather than relying on glare.

Follow this sequence:

769. survey overall continuity, alignment and distortion;
770. examine the full face for profile, cavities, inclusions open to the surface and irregular stops;
771. trace each toe continuously;
772. examine starts, stops, craters, restarts and tie-ins;
773. inspect adjacent base metal for arc strikes, gouges, spatter, damage and grinding;
774. inspect the accessible reverse side or root condition; and
775. revisit mapped indications with the specified gauge or follow-up method.

Do not accept a smooth face as proof of sound fusion. Conversely, do not reject an irregular but permitted profile without comparing it with the actual requirement.

10. Measure only the specified characteristic

Use a suitable verified gauge and a defined reference. Chapter 041 covers basic dimensional principles; this chapter applies them to weld inspection.

Characteristic	Practical method	Setup control	Common error
Fillet weld size or throat-related feature	Specified weld gauge or dimensional construction appropriate to the drawing	Confirm weld type, symbol convention and reference surfaces	Treating leg length and throat as interchangeable
Reinforcement or face height	Bridge or profile gauge from sound adjacent surfaces	Avoid rocking on spatter, scale or distorted base metal	Using a damaged local surface as the datum

Characteristic	Practical method	Setup control	Common error
Undercut depth	Suitable gauge across a representative reference surface	Measure the actual groove normal to the intended surface	Confusing shadow or oxide boundary with depth
Root gap or fit-up	Feeler, taper or dedicated gap gauge before welding as specified	Avoid forcing the joint apart or measuring over tack distortion	Reporting one accessible point as the complete joint
Misalignment or offset	Straightedge, bridge gauge, calliper or dimensional system	Define the two surfaces, direction and station	Mixing angular distortion with local offset
Angular distortion or bow	Straightedge, level, fixture or coordinate method over a defined span	Support the item consistently and record datum/span	Flattening the part during measurement
Local thickness after grinding	Suitable thickness method at mapped locations	Establish original/nominal requirement and surface access	Assuming visual blending preserved section

Record the gauge identity, location, orientation, unit and observed value. Do not use an unverified multipurpose gauge merely because it produces a number.

11. Map indications so they can be found again

An inspection record must allow another competent person to return to the same feature. Use:

- weld or joint identifier;
- station measured from a fixed datum;
- arrow side/other side, face/root or a documented side convention;
- clock position for circumferential joints;
- distance from weld centreline or toe;
- indication length, direction and distribution;
- relationship to start, stop, crater, attachment or repair;
- surface condition and inspection method; and
- image or sketch reference.

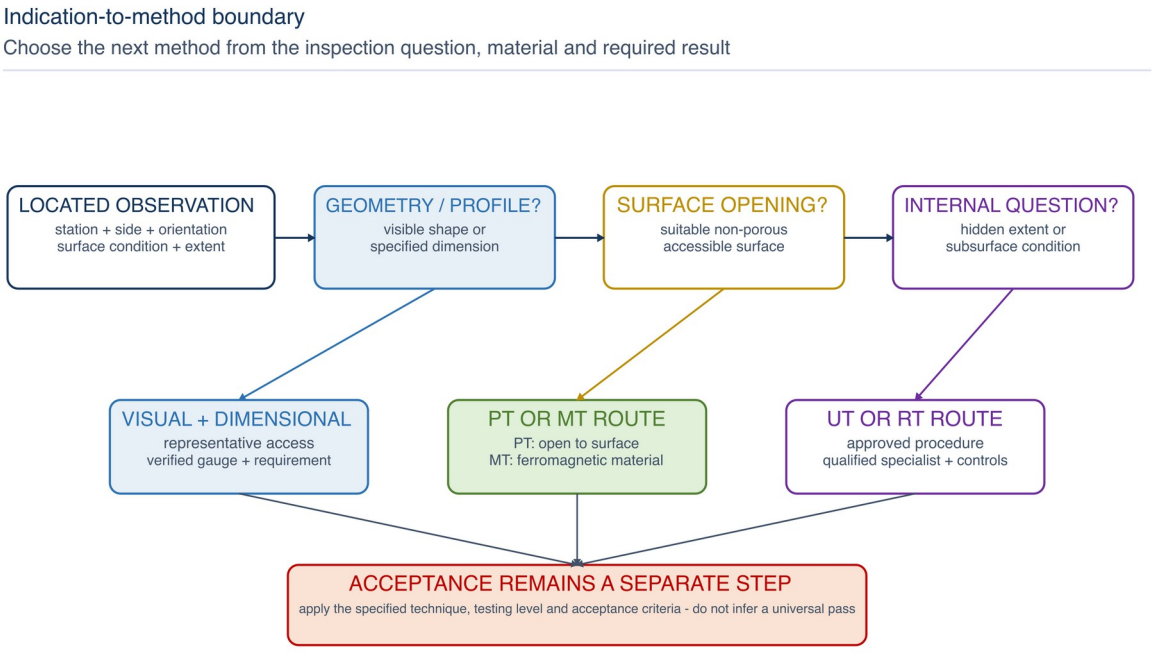


Figure 3. Indication-to-method boundary. A located visual observation is evaluated by the question it raises: accessible geometry, an opening at the surface, a ferromagnetic surface/near-surface condition, or a possible internal condition.

Marking paint, chalk or metal stamps can interfere with later NDT or damage the part. Use the authorised marking method and preserve traceability through cleaning, repair and finishing.

12. Control grinding, blending and repair

Grinding can expose a condition, remove it, smear metal across it, reduce section, change toe geometry or erase the original location. Treat repair preparation as a controlled manufacturing step, not as cosmetic tidying.

Before grinding:

- record and map the original condition;
- confirm repair authorisation and permitted extent;
- identify minimum thickness, profile and transition requirements;
- control sparks, fragments, dust, heat and contamination;
- select an abrasive and tool suitable for the material and access; and
- define the re-inspection method and extent.

During grinding, use light progressive removal and inspect frequently. Avoid deep grooves, sharp notches, overheating, excessive pressure and uncontrolled widening. After grinding, clean the area, verify remaining profile or thickness as required, and re-inspect the repaired zone plus affected transitions. A visually smooth repair is not evidence that a crack or internal condition has been removed.

13. Use penetrant testing within its boundary

Penetrant testing detects discontinuities open to the surface on suitable materials using visible or fluorescent systems. It can reveal cracks, laps, folds, porosity and lack-of-fusion conditions only where they communicate with the surface. The term discontinuity does not by itself state acceptability. [S245]

The controlled procedure governs:

- material and product compatibility;
- cleaning and drying;
- penetrant family and sensitivity;
- application, dwell, removal and development;
- viewing conditions and timing;
- control checks and reference materials;
- interpretation and acceptance criteria;
- post-cleaning and corrosion/contamination control; and
- operator qualification.

Do not mix products from different systems casually, substitute household cleaners, guess dwell times or apply penetrant to an excessively rough, porous, contaminated or hot surface outside the procedure. Penetrant acceptance levels for welds are addressed separately from the general method principles. [S248]

14. Use magnetic particle testing within its boundary

Magnetic particle testing is for ferromagnetic materials. It is primarily used for surface-breaking discontinuities, particularly cracks, and may detect some shallow subsurface discontinuities; sensitivity reduces rapidly with depth. [S246]

Weld testing can cover the weld and heat-affected zones using techniques suited to the joint and likely discontinuity orientation. Magnetisation direction, field strength, surface condition, detection medium, lighting, demagnetisation and recording are controlled by the procedure. ISO 17638 does not itself specify acceptance levels; those are addressed separately or by the product/application standard. [S247; S249]

Do not apply magnetic testing to non-ferromagnetic alloys, infer depth from indication intensity, or accept one field direction when the procedure requires coverage of different orientations. Keep sensitive equipment, electronic devices and magnetically affected parts within site controls.

15. Route internal-condition questions to specialist NDT

Visual, penetrant and magnetic methods do not provide universal assurance of internal weld soundness. Possible internal lack of fusion, incomplete penetration, inclusions, volumetric porosity or cracking may require ultrasonic or radiographic testing selected through the applicable code, material, thickness, geometry and quality requirement. [S241]

Specialist NDT requires an approved written procedure, suitable equipment and calibration/reference arrangements, defined testing and acceptance levels, and competent personnel. ISO 9712 provides a qualification and certification framework for industrial NDT personnel but the required scheme and authorisation remain contract and jurisdiction dependent. [S250]

Do not:

- request “an X-ray” as a universal answer;
- enter radiography barriers or rely on warning signs alone;
- interpret an ultrasonic screen or radiograph without the required competence;
- convert an NDT indication into a fabrication cause without evaluation; or
- assume a result from one method closes questions outside that method's capability.

16. Record a reconstructable inspection result

Include, as applicable:

- job, part, assembly and weld identity;
- drawing, specification, inspection-plan revision and acceptance basis;
- material, joint type and welding/repair stage;
- inspection date, operator and competence/authorisation reference;
- method, technique, extent and accessible sides;
- surface condition, access and viewing aids;
- measuring or NDT equipment identity and status;
- station convention and indication map;
- observation, classification and measured result with units;
- image, sketch or report references;
- decision and authorised disposition;
- repair reference and re-inspection method/extent; and
- final release, hold or escalation status.

Keep the original observation separate from later annotations and disposition. If an indication changes after cleaning or grinding, retain the before-and-after record rather than replacing the original description.

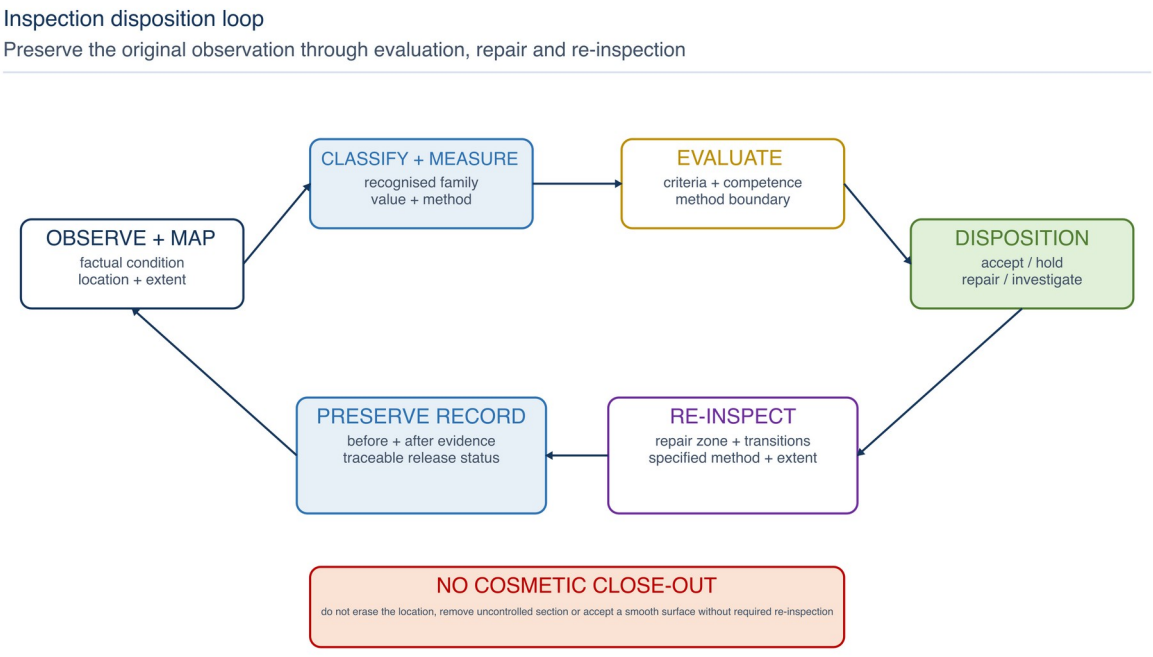


Figure 4. Inspection disposition loop. The original observation and location remain traceable as the condition is classified, measured, evaluated, dispositioned, repaired where authorised and re-inspected before release.

17. Troubleshoot inconsistent inspection results

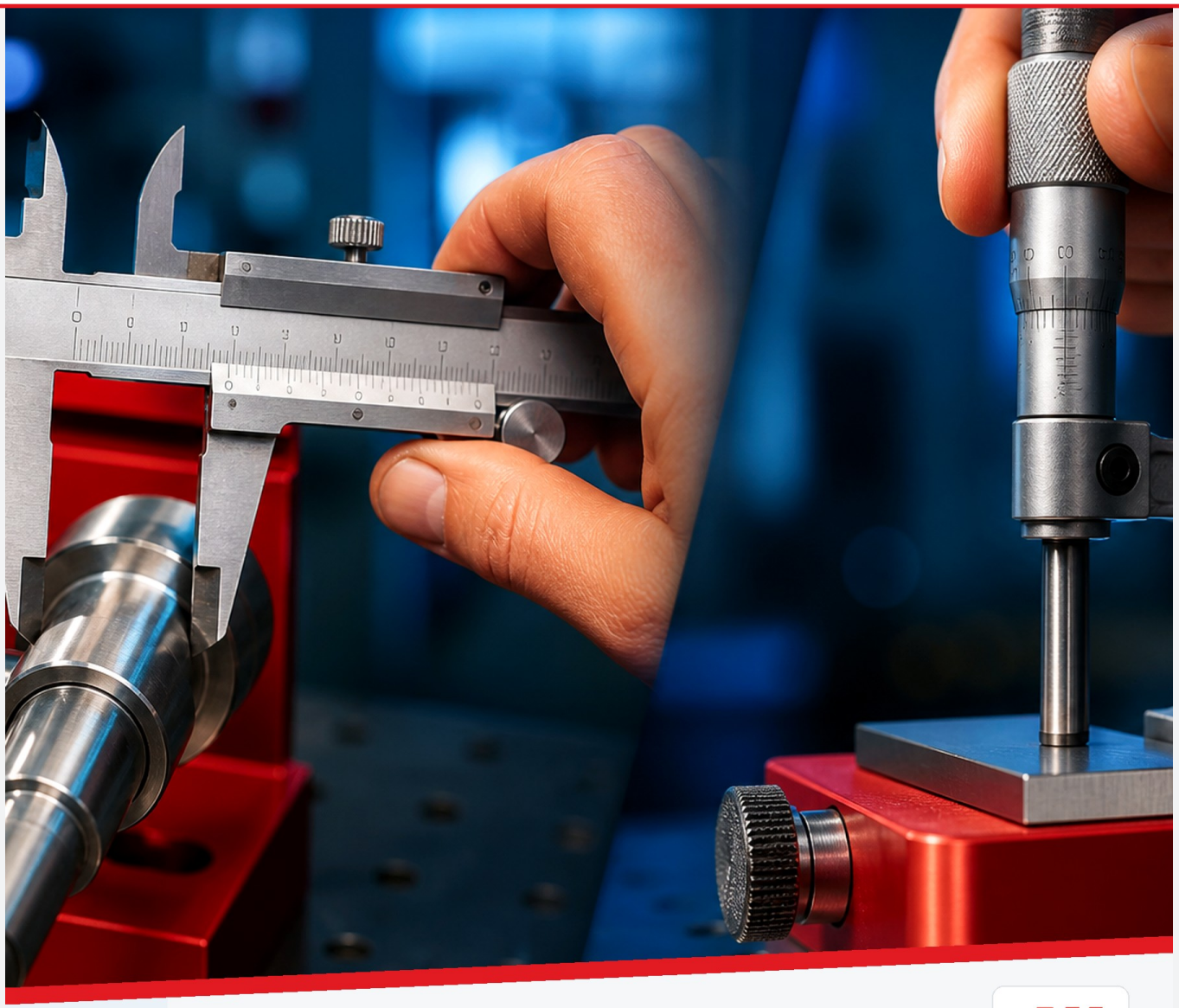
Observation	Likely causes	Practical correction
Feature appears only from one viewing angle	Glare, shadow, surface texture or very shallow geometry	Change lighting and viewing direction; clean only as authorised and map the feature

Observation	Likely causes	Practical correction
Different inspectors locate different extents	Undefined datum, inconsistent surface preparation or overlapping fields	Establish station/side convention and a repeatable coverage path
Gauge result changes with position	Real profile variation, rocking, spatter or poor datum contact	Map several stations; clean reference contacts and verify gauge seating
Linear feature disappears after brushing	Loose residue, smeared metal or insufficiently controlled preparation	Preserve the original record and route to the specified follow-up method
Penetrant background obscures indications	Rough/porous surface, poor cleaning/removal or unsuitable system/application	Stop and repeat only under the approved procedure with suitable surface and controls
Magnetic indication appears in one direction only	Discontinuity orientation relative to the magnetic field	Apply the required multi-direction technique through qualified personnel
Ground repair looks smooth but thickness is uncertain	Uncontrolled removal or distorted reference surface	Measure remaining section with a suitable method and compare with the requirement
Repaired area cannot be relocated	Marking removed and no station record	Re-establish traceability from fixed datums before further work
Visual result conflicts with specialist NDT	Different method capability, location error or interpretation boundary	Reconcile item, extent, coordinate system, procedure and acceptance basis
Acceptance decision varies by person	Criteria, quality level or authority not defined	Use the controlled inspection plan and authorised disposition route

18. Practical inspection and release checklist

Before releasing the inspection result, confirm:

- the correct item, weld, drawing and revision were used;
- the inspection stage, required extent, accessible sides and acceptance basis were clear;
- the area was safe to access and specialist exclusion zones were respected;
- the surface condition and visibility were suitable for the method;
- the complete weld face, toes, starts, stops, transitions and required adjacent areas were covered;
- the accessible root or reverse side was inspected where required;
- observations were factual, located and kept separate from acceptance decisions;
- specified dimensions were measured with suitable verified tools and recorded with units;
- indication station, side, orientation, length and relationship to the weld zone were mapped;
- visual inspection was not used to claim hidden depth, internal soundness or metallurgy;
- penetrant, magnetic, ultrasonic or radiographic work followed the approved qualified-person route;
- original conditions were recorded before grinding or repair;
- remaining profile or thickness was checked where material was removed;
- repaired areas and affected transitions were re-inspected to the specified extent;
- the applicable acceptance criteria and authorised disposition were applied; and
- the final record supports traceability, review and release.



INSPECTION, SAFETY & MAINTENANCE

CHAPTER 043

Correct Use of Calipers and Micrometers

43

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Machinists, fabricators, grinding and finishing teams, production operators, inspectors, supervisors, maintenance personnel and technical sales personnel

Scope: Practical use of vernier, dial and digital calipers and outside micrometers for common industrial measurements, including instrument selection, pre-use checks, surface preparation, temperature control, alignment, contact force, outside, inside, depth and step measurement, repeat-position checks, result recording and troubleshooting.

Core principle - A displayed number is useful only when the correct feature has been contacted in the correct location and direction with a suitable instrument, controlled force and a traceable measurement process.

Calipers are versatile, fast and useful for many workshop measurements. Outside micrometers provide more controlled opposed-face measurement when the feature, access and required decision suit them. Neither instrument automatically measures form, location, orientation, surface texture or hidden geometry. Correct technique begins with the drawing requirement and ends with a result that another competent person can understand and reproduce. [S232; S234; S237]

Chapter objectives

After this chapter, the reader should be able to:

- identify the feature, characteristic, location, orientation, unit, tolerance and decision requirement;
- select between a caliper, outside micrometer or a more suitable dedicated method;
- recognise the functional measuring surfaces and controls on common instruments;
- check cleanliness, damage, smooth movement, zero behaviour and a suitable known reference;
- control burrs, coatings, roughness, support, temperature and hand heat;
- read vernier, dial and digital indications without parallax, unit or reference-mode errors;
- measure outside features with the jaws square to the part and the measuring axis;
- measure accessible inside diameters by finding the true diameter in the required plane;
- seat depth and step references fully without bridging chamfers, radii or debris;
- use an outside micrometer with aligned faces and consistent constant-force operation;
- avoid deforming soft, thin, flexible or hot workpieces;
- repeat at meaningful positions to reveal taper, ovality, wear and local variation;
- record the instrument, location, orientation, unit, reference check and result; and
- recognise when uncertainty, access or contact geometry requires a different measurement route.

1. Begin with the feature and the decision

Read the complete drawing, work instruction or inspection plan before selecting the instrument. Confirm:

776. part and feature identity;
777. characteristic to be measured;
778. location, section and orientation;
779. whether the requirement concerns an outside size, inside size, depth, step, thickness, gap or another property;
780. unit, nominal value and limits;
781. surface condition and manufacturing stage;
782. required number and distribution of measurement positions;
783. applicable decision rule and reporting precision; and
784. instrument or method restrictions.

A two-point size reading does not automatically establish roundness, cylindricity, parallelism, flatness, position or the complete form of a feature. If the requirement is geometrical rather than a simple accessible size, use the measurement process specified for that characteristic. [S236; S237]

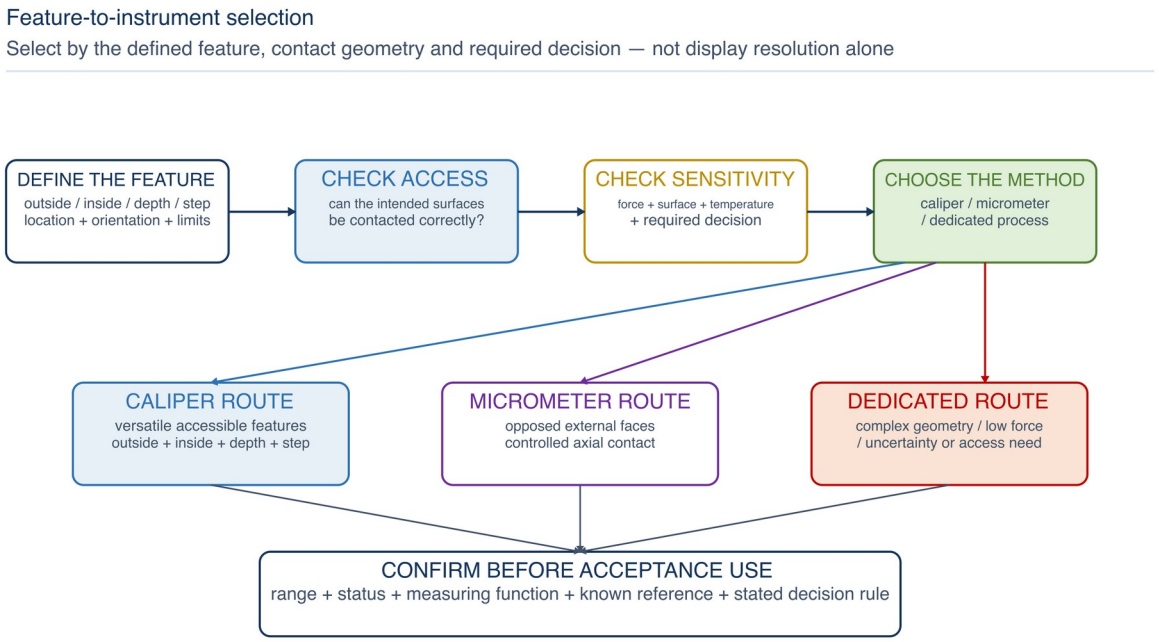

Figure 1. Feature-to-instrument selection. Begin with the feature and required decision, then confirm access, contact geometry and instrument capability before choosing a caliper, micrometer or dedicated method.

2. Choose the instrument by contact geometry

Use the simplest instrument that can contact the required feature correctly and support the decision. Do not select by display resolution alone.

Measurement task	Usually suitable starting point	Key contact requirement	Route elsewhere when
Accessible outside width or diameter	Outside jaws of a suitable caliper	Jaws square to feature with clean face contact	Tolerance, force sensitivity or access requires greater control
Opposed external faces or diameter	Outside micrometer	Anvil and spindle aligned with the measuring axis	Contact shape, part form or accessibility is unsuitable
Accessible internal diameter	Caliper inside jaws	Correct plane and true-diameter search	Hole is small, deep, short, tapered or accuracy need exceeds the method
Depth from a defined reference surface	Caliper depth rod or a dedicated depth instrument	Reference surface fully seated and rod aligned	Base is narrow, curved, obstructed or unstable
Step or shoulder difference	Caliper step faces where designed for the task	Both reference faces seat on the intended surfaces	Chamfer, radius or access prevents representative contact
Thin, soft or compliant material	Task-specific low-force or non-contact method where needed	Controlled force without deformation	Ordinary jaws or micrometer force changes the measurand
Groove, wall, blade, thread or complex form	Dedicated instrument and contacts	Contact geometry matches the defined feature	General-purpose faces cannot reach the specified surface

The exact range, resolution, maximum permissible error, measuring force, environmental protection and approved accessories are instrument specific. **Refer to the product label, Technical Data Sheet, or MKTECH representative.** [S232; S234; S255]

3. Know which surfaces perform the measurement

On a typical caliper, distinguish:

- beam and main scale;
- slider, gib and thumb control;
- outside jaws and outside measuring faces;

- inside jaws and inside measuring faces;
- depth rod or blade and depth reference surface;
- step measuring faces where provided;
- lock and fine-control features where provided; and
- vernier, dial or electronic indication and unit/reference controls.

On a typical outside micrometer, distinguish:

- rigid frame and insulating grip area where provided;
- fixed anvil and moving spindle measuring faces;
- sleeve or barrel, thimble and analogue graduations;
- electronic display and controls where provided;
- spindle lock;
- ratchet stop, friction thimble or other constant-force device; and
- setting standard supplied for ranges that do not close to zero.

Do not use non-measuring surfaces as datums. Jaw backs, beam edges, frame surfaces and protective tips may not represent the intended measuring geometry.

Instrument or indication	Confirm before use	Common error to prevent
Vernier caliper	Main and vernier scales are legible; zero lines and jaw condition are checked	Choosing the wrong coincident line or viewing at an angle
Dial caliper	Pointer returns consistently; rack and pinion travel smoothly; revolution is understood	Combining the dial value with the wrong beam interval
Digital caliper	Unit, sign, zero/reference mode and battery condition are confirmed	Treating a relative reference as an absolute zero
Analogue micrometer	Sleeve, thimble and any vernier graduation are read in the correct order	Missing a sleeve graduation or reading with parallax
Digital micrometer	Unit, origin/preset state, display stability and constant-force action are confirmed	Trusting the display while alignment or force remains uncontrolled

4. Perform a disciplined pre-use check

Before measuring:

785. confirm the instrument identity, range, status and intended unit;
786. inspect jaws, anvil, spindle, depth surfaces and reference faces for damage, wear, corrosion or embedded debris;
787. wipe measuring faces with a clean compatible material;
788. move the slider or spindle through the required region and feel for sticking, looseness, shock or abnormal drag;
789. check analogue scales for legibility and dial pointers for stable return;
790. check electronic display, battery indication, unit and reference mode;
791. close or set the instrument gently using its normal measuring action;
792. perform the required zero check; and
793. check a suitable known reference when the measurement plan requires it.

A zero indication demonstrates only one condition at one position. It does not prove jaw parallelism, internal-jaw condition, depth performance, scale behaviour through the range or suitability for the task. [S237; S254]

5. Prepare the workpiece without changing the feature

The measured surfaces must represent the intended manufacturing condition. Remove loose dirt, oil film, chips and permitted burrs using the controlled process. Do not file, scrape, grind or polish a feature merely to obtain a favourable reading.

Check for:

- burrs at machined edges and hole mouths;
- weld spatter, abrasive particles and embedded swarf;
- coatings, plating, oxide, corrosion or contamination included in or excluded from the requirement;
- chamfers and radii that prevent full measuring-face contact;
- roughness peaks that make a single reading unstable;
- dents, local damage or previous measurement marks; and
- hot surfaces or recent machining, welding, grinding, washing or cooling.

Support the part so it is stable but not bent, flattened, clamped out of shape or heated by handling.

6. Control temperature and handling

Dimensional properties are specified with a reference-temperature context, and temperature differences can change the workpiece, instrument and reference differently. The practical importance depends on material, size, tolerance and the required decision. [S230; S237]

Good practice includes:

- avoiding measurement immediately after heat-generating work when the tolerance is sensitive;
- keeping the instrument, part and reference in a sufficiently stable environment;
- minimising bare-hand contact with the frame, beam, setting standard and precision workpiece;
- avoiding direct sunlight, hot air, cold airflow and contact with hot machinery;
- recording relevant temperature conditions when required; and
- using an approved correction or controlled-room method only where the measurement process defines it.

Do not apply a universal waiting time. Stabilisation depends on mass, material, geometry, temperature difference, airflow and required uncertainty.

7. Read the indication correctly

For a vernier caliper:

794. read the main scale value immediately before the vernier zero;
795. identify the vernier line that aligns correctly with a main-scale line;
796. add the vernier contribution using the instrument graduation; and
797. confirm the unit and avoid estimating beyond justified readability.

For a dial caliper:

798. read the beam interval passed by the slider;
799. read the dial within the correct revolution and direction;
800. add the two contributions; and
801. check that the pointer returned and the rack was not disturbed by debris or shock.

For an analogue micrometer, read the sleeve and thimble in the correct sequence and view the graduation squarely to avoid parallax. For digital instruments, confirm unit, zero/reference mode, sign and a stable display. A digital display reduces reading ambiguity; it does not eliminate alignment, force, temperature, contact or instrument error. [S237; S255]

8. Measure outside features with a caliper

Use this sequence:

802. open the jaws wider than the feature;
803. place the broad measuring faces on clean representative surfaces;
804. align the beam and jaws square to the required dimension;
805. close gently until both faces contact without visible gap or part deformation;
806. make a small controlled alignment search where needed;
807. stabilise the contact without using the lock to force the jaws tighter;
808. read without twisting the caliper; and
809. repeat at the specified positions.

For an outside diameter, a reading that is too high may result from angular misalignment; a reading that is too low can result from missing the true diameter or contacting local damage. Search deliberately in the required plane and retain meaningful variation rather than selecting the preferred number.

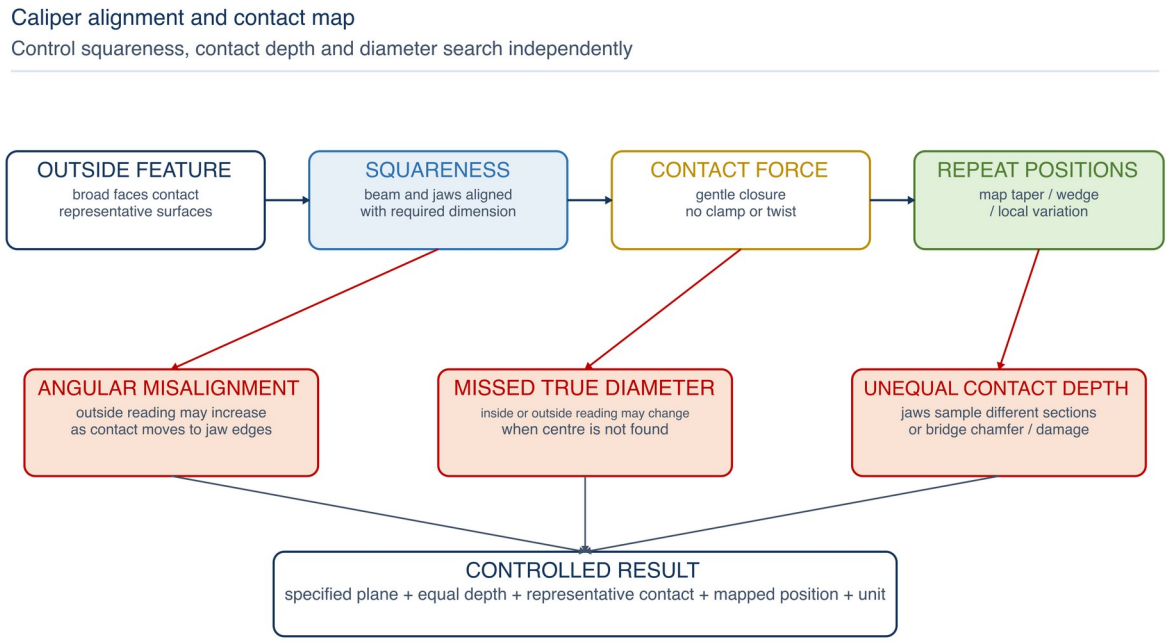

Figure 2. Caliper alignment and contact map. Squareness, true-diameter search, jaw depth and representative face contact are controlled separately; a stable display does not prove correct alignment.

9. Measure inside features with a caliper

Inside-jaw measurements are sensitive to jaw-tip geometry, jaw depth, alignment, hole size, wear and operator feel.

For an accessible bore:

810. insert the inside jaws without striking the edge;
811. keep both contacts at the same required depth;
812. orient the caliper in the specified measurement plane;
813. open gently until both faces contact;
814. rock through the diameter in one direction and sweep through the centre in the perpendicular sense as appropriate;
815. identify the true-diameter position rather than the first stable reading;
816. avoid tilting one jaw deeper than the other; and
817. repeat in required planes and depths to reveal taper or ovality.

Small, shallow, chamfered, rough, interrupted or deep holes may not provide representative contact for ordinary inside jaws. Use a bore gauge, inside micrometer, plug or ring system, coordinate method or other specified process when required.

10. Measure depth and steps from the intended datum

For depth measurement:

- clean the reference surface and feature bottom;
- place the caliper end or designated reference surface fully on the datum;
- avoid rocking across a narrow edge, radius, chamfer or burr;
- extend the depth rod along the intended axis;
- contact the bottom gently without bending the rod or lifting the reference; and
- repeat across the feature if the requirement concerns variation rather than one local point.

For step measurement, use only the step faces designed for the instrument. Confirm that both faces contact the intended shoulders and are not held apart by corner radii, coatings or damage.

11. Use an outside micrometer correctly

An outside micrometer is suited to opposed external faces when the contact geometry and documented instrument characteristics support the task. Use this sequence:

818. confirm the correct range and setting reference;
819. clean the anvil, spindle and workpiece surfaces;
820. open the spindle beyond the feature;
821. place the part between the faces without striking or scraping it;
822. align the spindle axis with the required dimension;
823. advance using the thimble until near contact;
824. complete contact with the constant-force device in the instrument's specified manner;
825. maintain alignment while the force stabilises;
826. lock only when the method requires it and without shifting the reading;
827. read in position where practical; and
828. withdraw before sliding the faces across the part.

Do not spin the thimble rapidly into the work, use the micrometer as a clamp, force the spindle with the frame, or drag precision faces across an abrasive surface.

12. Control alignment and measuring force together

Alignment error and force error can interact. Excessive force may flatten contamination, deform the part, flex the frame or make a misaligned contact appear stable. Insufficient or inconsistent force may leave incomplete contact.

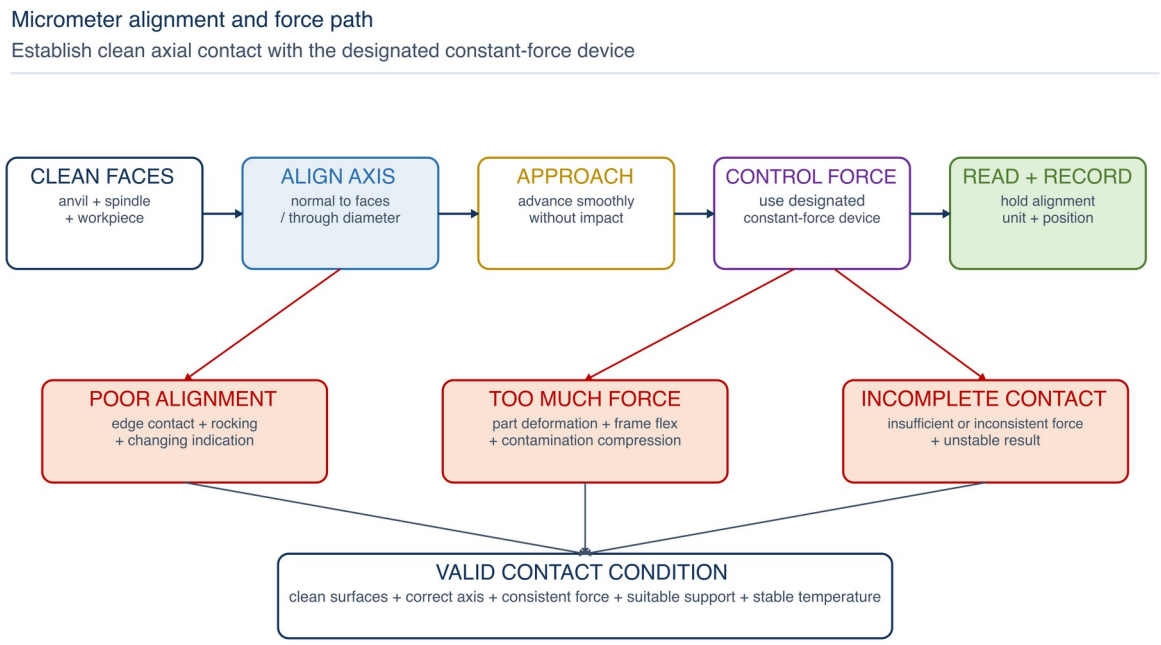

Figure 3. Micrometer alignment and force path. Clean faces, axial alignment, controlled approach and consistent constant-force operation establish contact before the result is read and recorded.

Control the following:

Influence	Practical control	Warning sign
Axial alignment	Keep anvil and spindle normal to parallel surfaces or through the true diameter	Reading changes as the frame is rocked
Measuring force	Use the designated constant-force device consistently	Reading changes with operator grip or repeated clicks
Face condition	Keep faces clean, undamaged and appropriate to the feature	Unstable contact or light visible at one side
Part support	Hold or fixture without heating or deforming the feature	Reading changes when grip or support changes
Surface geometry	Avoid bridging radii, burrs, rough peaks or local dents	Repeated values differ by contact position

13. Protect soft, thin, flexible and sensitive workpieces

Contact measurement can change the dimension being measured. Take particular care with:

- thin sheet, foil, tubing and soft polymers;
- rubber, coatings, seal materials and laminated products;
- hot parts and materials with high thermal expansion;
- flexible shafts, long bars and lightly supported components;
- very rough, porous or compressible surfaces; and
- finished surfaces susceptible to scratching or indentation.

Use the specified force-controlled contact, support and method. If the ordinary caliper or micrometer changes the part, contacts only roughness peaks or cannot represent the specified material condition, route the task to a suitable low-force, dedicated-contact or non-contact process.

14. Repeat at positions that answer the requirement

Repeated readings are useful only when their positions are defined. For a cylindrical feature, measure in specified angular planes and at meaningful axial stations. For parallel faces, compare positions that can reveal taper, wedge or local wear. For sheet or plate, define edge distance and support.

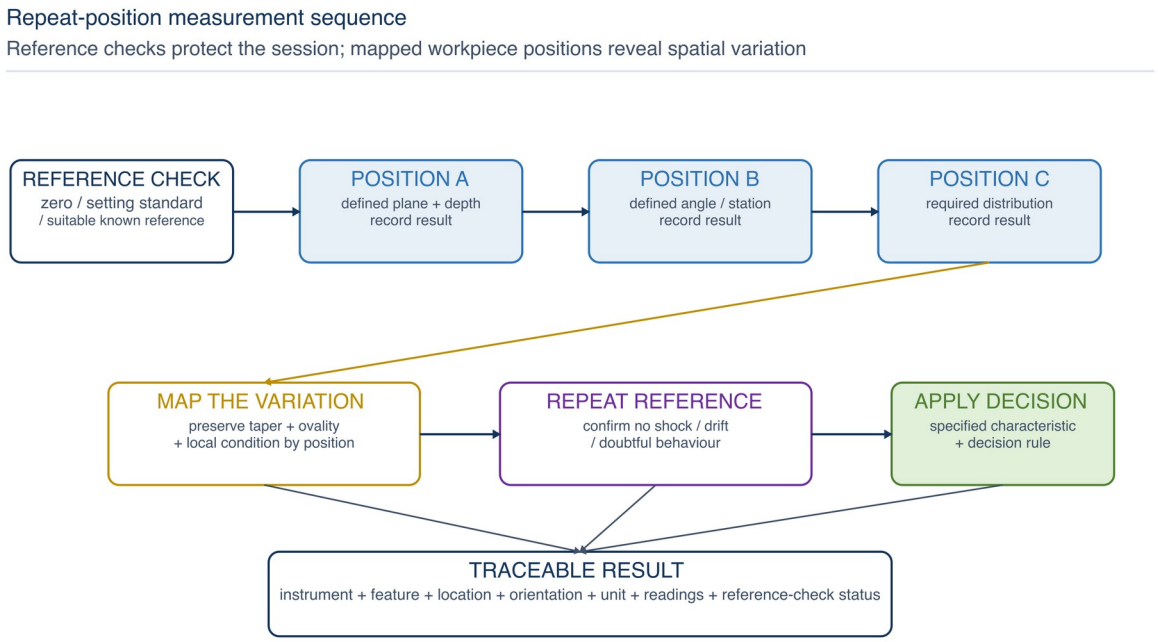

Figure 4. Repeat-position measurement sequence. Reference checks establish instrument condition, while mapped workpiece positions reveal genuine spatial variation and a repeated reference check confirms the measurement session remained controlled.

Do not average away taper, ovality or local variation when the drawing controls an extreme or geometrical characteristic. Record the mapped results or the required derived value using the approved inspection method.

15. Use zero and known-reference checks correctly

Apply checks appropriate to the instrument and task:

- clean-face zero or setting check;
- supplied setting standard for the relevant micrometer range;
- suitable calibrated gauge block, ring, setting master or other reference;
- checks near the measurement region when required;
- internal, depth or step checks that exercise the relevant contact function; and
- repeat checks after shock, temperature change, doubtful behaviour or a measurement session.

Gauge blocks are controlled length standards with their own grade, condition, calibration status and uncertainty. Select references through the measurement system; do not treat any convenient object as a calibration standard. [S254; S256]

Check	What it establishes	What it does not establish by itself
Clean-face zero or setting check	Indication at the closing or defined setting condition	Performance through the range or every measuring function
Supplied micrometer setting standard	Setting response for the applicable range and reference	Workpiece suitability, alignment or measuring uncertainty
Suitable calibrated length reference	Response at a controlled value and stated condition	Complete calibration unless the authorised process defines it so
Internal, depth or step reference	Behaviour of the specific contact function being used	Capability for a different jaw, rod, range or feature geometry
End-of-session repeat reference	Evidence that the checked condition remained stable during the session	Proof that every workpiece contact and recorded position was correct

If the instrument fails a required check, isolate it from acceptance work and follow the authorised verification, adjustment, calibration or repair route. Do not adjust repeatedly until one reading agrees.

16. Clean, store and transport the instrument correctly

After use:

- remove chips, dust, coolant and fingerprints with an approved method;
- leave precision faces clean, dry and protected as specified;
- do not store a micrometer tightly closed unless its instructions require it;
- release locks and avoid loading the slider, depth rod, spindle or frame;
- place the instrument in its protective case or controlled cabinet;
- separate it from grinding dust, welding spatter, corrosive chemicals, moisture, impact and magnetic or electrical hazards as applicable;
- do not mark measuring faces with scribers, stamps or abrasive cleaners; and
- report shock, dropping, sticking, corrosion, unstable indication, battery leakage or damaged contacts before reuse.

Measurement-management controls should keep equipment fit for its intended process and provide confidence in the validity and reliability of results. [S254]

17. Troubleshoot inconsistent readings

Observation	Likely causes	Practical correction
Outside caliper reading increases when tilted	Jaws not square or contact on an edge	Re-establish the specified plane and square broad-face contact
Bore reading changes widely with position	Missed true diameter, unequal jaw depth, taper or ovality	Define plane and depth; search through the centre and map positions
Depth reading changes when hand pressure changes	Reference surface rocking or depth rod not axial	Clean and fully seat the reference; support squarely
Micrometer reading falls with greater force	Soft material, contamination or frame/part deformation	Use the specified force method and suitable support or alternative process
Micrometer reading changes while rocking	Measuring faces not aligned with the feature	Search for correct axial alignment without excessive force
Zero passes but known reference fails	Wear, damage, scale error, temperature difference or incorrect reference use	Isolate the instrument and follow the controlled verification route
Digital value jumps or changes unit	Contamination, low battery, reference-mode or control error	Stop, clean, confirm power, unit and reference setting, then re-check
Vernier or dial readings differ by operator	Parallax, reading sequence, dial revolution or alignment variation	Standardise viewing, reading and contact technique; use a known reference
Repeated readings differ only at mapped positions	Genuine taper, ovality, roughness or local damage	Preserve the positional results and evaluate the specified characteristic
Near-limit result cannot support a clear decision	Instrument/process uncertainty is significant	Apply the controlled decision rule or route to a more capable process

18. Practical measurement and release checklist

Before releasing the result, confirm:

- the correct part, feature, drawing and revision were used;
- the characteristic, location, orientation, unit and limits were clear;
- the selected instrument and contact geometry suited the task;
- instrument identity, status, range and indication mode were confirmed;
- measuring faces and workpiece contacts were clean and undamaged;
- burrs, chamfers, radii, coatings, roughness and local damage were considered;
- the instrument, workpiece and reference were sufficiently temperature stable;
- the workpiece was supported without deformation;
- the required zero and known-reference checks passed;
- outside caliper jaws were square and used with controlled force;
- inside caliper jaws found the true diameter at the specified plane and depth;
- depth and step references were fully seated on the intended datum;
- micrometer faces were aligned and the constant-force device was used consistently;
- the indication was read in the correct unit and mode without unsupported digits;
- mapped repeat positions answered the drawing requirement;
- genuine taper, ovality or local variation was not averaged away;
- instrument, location, orientation, unit, result and relevant conditions were recorded;
- near-limit or doubtful results followed the applicable decision route; and
- the instrument was cleaned, protected and returned to controlled storage.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 044

Calibration and Measurement Control

44

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, quality personnel, machinists, fabricators, grinding and finishing teams, inspectors, supervisors, maintenance personnel, calibration coordinators and technical sales personnel

Scope: Practical control of measuring and test equipment used in industrial grinding, finishing, fabrication and inspection, including equipment registration, terminology, acceptance requirements, calibration-provider selection, transport, certificate review, uncertainty, risk-based intervals, intermediate checks, status identification, environmental control, out-of-tolerance response, decision rules, records and troubleshooting.

Core principle - Calibration control is not a sticker exercise. It is a managed chain from the measurement requirement through equipment suitability, traceability and uncertainty to a defensible product decision.

A calibration certificate reports what was found for an identified item under stated conditions. It does not automatically prove that the item is suitable for every workshop measurement, that every function was covered, or that every result obtained since the previous calibration is acceptable. Effective control begins with the measurement process and the consequence of an incorrect decision, then applies suitable equipment, competent calibration, defined acceptance, controlled intervals and prompt containment when confidence is lost. [S238; S254; S257; S258]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish calibration, adjustment, verification, intermediate checking, maintenance and repair;
- identify which equipment requires measurement control and assign clear ownership;
- maintain an equipment register that connects each item to its intended measurement process;
- define calibration range, points, method, uncertainty and acceptance requirements before service;
- select a calibration provider by current accredited scope rather than by accreditation logo alone;
- prepare, protect and transport instruments without changing their condition;
- review a calibration certificate for identity, coverage, results, uncertainty, traceability and decision rule;
- interpret error, correction and uncertainty without treating them as interchangeable;
- establish and revise calibration intervals using risk, history and operating conditions;
- apply intermediate checks that detect change between calibrations;
- control equipment status, access, storage, handling and environmental exposure;
- contain overdue, damaged, failed or doubtful equipment and assess affected work;
- separate the measurement result, conformity statement and product-release authority;
- retain records that reconstruct the equipment life cycle; and
- troubleshoot common calibration and measurement-control failures.

1. Begin with the measurement process

The first control question is not “When is the instrument due?” It is “Which decision depends on this measurement, and what could happen if the result is wrong?”

Define:

829. the product, process or safety decision;
830. the characteristic and unit;
831. nominal value, tolerance or control limit;
832. required measurement range and resolution;
833. contact geometry, access and environmental conditions;
834. expected use frequency and severity;
835. required uncertainty or decision confidence;
836. applicable method, standard or customer requirement;
837. record and traceability needs; and
838. consequence of false acceptance or false rejection.

Equipment used only for indication may need a different control level from equipment used to accept product, set a critical process, verify a safety function or establish a reference. Identify that role explicitly. Do not allow an uncontrolled indicator to become an acceptance instrument through convenience. [S254]

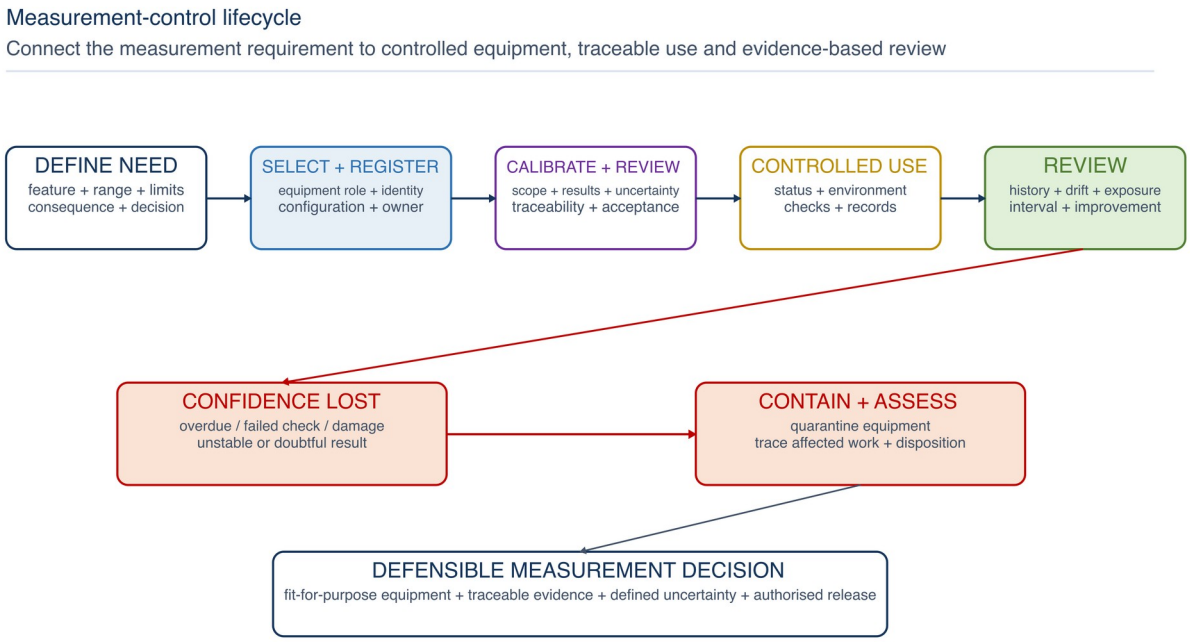

Figure 1. Measurement-control lifecycle. The measurement requirement drives equipment selection, calibration and verification, controlled use, review and improvement; loss of confidence routes the item to containment and impact assessment.

2. Use measurement-control terms correctly

Similar words describe different actions. Using them precisely prevents a certificate, workshop check or repair from being given more authority than it has. [S238]

Term	Practical meaning	Important boundary
Calibration	Establishes the relationship between reference values and the instrument indications, including relevant uncertainty	Calibration does not necessarily include adjustment, repair or a conformity decision
Adjustment	Changes the instrument so its indication or response is brought closer to the required condition	Record before-adjustment results where needed; adjustment can affect the evidence available for earlier measurements
Verification	Provides objective evidence that specified requirements have been fulfilled	The requirement and method must be defined before the verification
Intermediate check	Confirms selected behaviour between formal calibrations using a suitable reference or comparison	It is not automatically a replacement for calibration and may cover only part of the range or function
Functional check	Confirms basic operation such as movement, display, alarm or zero response	Functional operation alone does not establish metrological performance
Maintenance	Preserves or restores service condition through cleaning, lubrication, battery replacement or other controlled work	Maintenance may require follow-up verification or calibration if measurement performance could change
Repair	Corrects a fault or damage	Repaired equipment requires defined post-repair evaluation before acceptance use

Use the action actually performed in the record. Do not label a zero check as calibration, a calibration as repair, or an accredited certificate as product approval.

3. Decide which equipment enters the control system

Include equipment when its result can influence product acceptance, process setting, inspection, safety, environmental monitoring, customer reporting or a reference used to check other equipment. This may include:

- calipers, micrometers, height and depth instruments;

- dial indicators, bore gauges and thickness gauges;
- surface-roughness instruments and comparison references;
- tachometers, pressure gauges, flowmeters and temperature instruments;
- electrical test instruments;
- weighing equipment and force instruments;
- timers where process duration is controlled;
- coating-thickness, gloss or colour instruments;
- master gauges, gauge blocks, reference artefacts and setting standards; and
- software or data-acquisition channels that calculate, transform or store measurement results.

Classify each item by intended role: reference, acceptance, process control, monitoring, indication only, training or out of service. Apply a clear visual and record distinction where similar-looking items have different roles.

4. Build an equipment register that supports decisions

Assign every controlled item a unique identity that remains with it through calibration, repair, storage and retirement. Where a removable accessory or interchangeable probe affects performance, control the combination or clearly record the configuration.

Register field	Purpose	Good control practice
Unique equipment ID	Links the physical item, certificate and use record	Mark durably without damaging a measuring surface
Description, maker, model and serial number	Prevents mistaken identity	Record identifiers exactly as shown on the item
Owner, location and custodian	Establishes responsibility and retrieval	Update transfers promptly
Intended use and measurement role	Connects the item to a process and decision	Avoid unrestricted “general use” where capability differs by task
Range, functions and accessories	Defines required coverage	Identify probes, leads, anvils, software or masters that affect results
Required acceptance and uncertainty	Supports service specification and certificate review	Define before calibration, not after an unfavourable result
Calibration and check interval	Controls planned activity	Record basis and review history
Status and due date	Controls access to acceptance work	Use system controls in addition to a physical label
Certificate, check, repair and damage history	Reconstructs the equipment life cycle	Retain superseded records according to the quality system
Disposition	Records active, restricted, quarantined, retired or scrapped state	Prevent accidental return to service

The register should be searchable and protected from unauthorised change. A spreadsheet can be suitable for a small system if identity, revision, access, backup and change control are maintained.

5. Define the calibration requirement before sending the instrument

A purchase order that says only “calibrate and certify” leaves important decisions unresolved. Prepare a service specification that states, as applicable:

- equipment identity and complete configuration;
- measurement functions, ranges and units to be covered;
- calibration points or distribution through the working range;
- required method or applicable standard;
- as-found results before adjustment or repair;
- as-left results after authorised adjustment;
- required measurement uncertainty or capability;
- acceptance limits or manufacturer specification to be applied;
- whether a statement of conformity is required;
- the agreed decision rule for that statement;
- required environmental conditions;
- traceability and accreditation requirements;

- certificate content and electronic file format;
- treatment of seals, firmware, software, accessories and batteries;
- notification before adjustment, repair or work beyond the agreed scope; and
- handling, packaging and return requirements.

When the correct point, tolerance, function or accessory is instrument-specific, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

6. Select a competent calibration provider

In Malaysia, accredited calibration laboratories operate within the Skim Akreditasi Makmal Malaysia framework. Accreditation supports confidence only for activities within the laboratory's current scope and status. Check the scope document itself. [S257; S262; S263]

Confirm that the current scope covers:

839. the measurement parameter;
840. the required range;
841. the calibration method or service type;
842. the relevant site or laboratory location;
843. the required calibration and measurement capability;
844. any field-calibration activity;
845. the equipment configuration and accessories; and
846. the accreditation status on the service date.

An accreditation symbol on a quotation, website or unrelated certificate is not enough. If a result must be covered by accreditation, ensure the requested activity appears within the current scope and that the issued certificate identifies the accredited status appropriately. For cross-border work, check the applicable accreditation body and ILAC Mutual Recognition Arrangement context through the organisation's approved supplier process. [S258]

7. Protect the item before, during and after service

Calibration results describe the item's condition at the time and under the stated conditions. Poor transport can change that condition.

Before dispatch:

- photograph or record the item's external condition where useful;
- confirm identity, accessories, leads, probes, standards and cases;
- clean only by the approved method;
- secure moving parts without loading precision mechanisms;
- protect measuring faces, connectors, displays and adjustment controls;
- isolate batteries or hazardous contents where transport rules require it;
- include the service specification without exposing it to oils or damage;
- use a rigid, cushioned, moisture-appropriate container; and
- apply chain-of-custody or tamper control where the risk requires it.

On return, inspect the packaging and item before release. Check for impact, corrosion, loose parts, changed seals, missing accessories, unit or software changes and abnormal operation. Do not place an instrument directly into service merely because a certificate arrived with it.

8. Review the calibration certificate systematically

Certificate review should be performed by a person who understands both the measurement requirement and the equipment. File receipt is not technical acceptance. [S257; S260; S263]

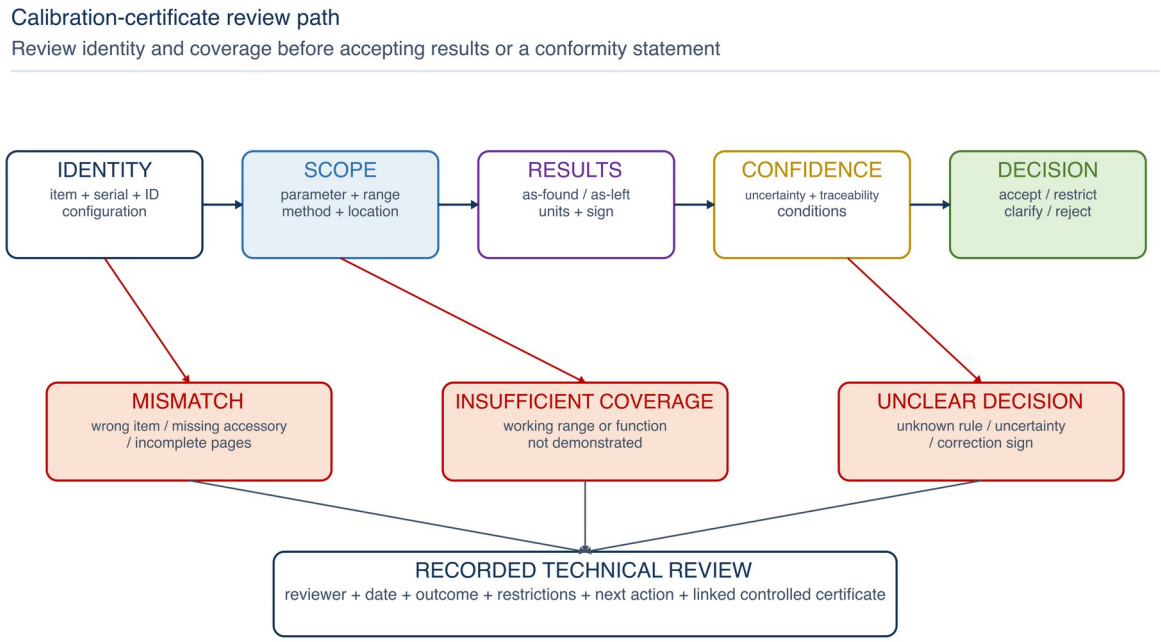

Figure 2. Calibration-certificate review path. Identity and service coverage are checked before results, uncertainty, traceability and conformity information are evaluated against the defined use requirement.

Certificate check	Question to answer	Typical action if unclear
Laboratory and accreditation	Is the issuing laboratory identified, and is the relevant work within its current accredited scope?	Confirm scope and status with the laboratory or accreditation body
Certificate identity	Are certificate number, issue date and page controls complete?	Obtain a corrected or complete controlled copy
Equipment identity	Do equipment ID, maker, model, serial number and configuration match the item?	Quarantine until identity is reconciled
Method and conditions	Are the method, relevant conditions and service location stated?	Confirm suitability for the intended process
Coverage	Were the required functions, ranges, points and accessories covered?	Restrict use or arrange additional work
As-found and as-left state	Are results before and after adjustment distinguishable?	Assess previous work before accepting the adjusted item
Results and units	Are indication, reference value, error or correction and units clear?	Ask for clarification; do not infer sign conventions
Measurement uncertainty	Is uncertainty reported with the required supporting information?	Compare with the measurement need and decision process
Traceability	Is the traceability route adequately established?	Resolve through the provider and quality system
Conformity statement	If provided, are specification and decision rule identified?	Do not rely on an unexplained pass/fail statement
Authorisation and amendments	Is the report authorised and are changes controlled?	Retain the complete authorised version and amendment trail

Record who reviewed the certificate, the date, the outcome, restrictions and next action. Acceptance may be full, restricted to certain ranges or functions, conditional on another check, or rejected pending correction.

9. Interpret error, correction and uncertainty correctly

These quantities answer different questions:

- **Indication** is the value shown or provided by the instrument.
- **Reference value** is the value assigned through the calibration reference system.
- **Error** is the indication minus the reference value under the reported conditions.
- **Correction** is the value applied to compensate for an estimated systematic effect and normally has the opposite sign to the corresponding error.
- **Measurement uncertainty** describes the dispersion associated with the reported quantity; it is not simply the error and is not proof that the result is wrong.

Never assume the sign of a correction from an unfamiliar table. Confirm the certificate convention. Do not subtract the uncertainty from the error, use uncertainty as an automatic tolerance, or ignore it because the indicated error is small. The working measurement process may contain additional uncertainty contributions from resolution, repeatability, temperature, fixturing, reference condition, sampling, operator technique and the workpiece itself. [S238; S260; S261]

10. Establish an initial calibration interval by risk

There is no universal annual interval that is correct for all equipment. Establish the initial interval from a documented assessment, then revise it as history develops. [S259]

Consider:

- consequence of an incorrect result;
- equipment type and stability;
- manufacturer's information;
- use frequency and operating hours;
- severity of vibration, shock, contamination, heat, humidity and transport;
- amount of adjustment or drift expected;
- required uncertainty and tolerance relationship;
- availability and effectiveness of intermediate checks;
- repair, overload and damage history;
- calibration provider recommendations supported by results;
- regulatory, customer or contract requirements; and
- ability to identify and reassess affected product if the item is later found outside control.

Use a conservative initial interval for unfamiliar or high-consequence applications, then extend or shorten only through an authorised, evidence-based review.

11. Review intervals using performance history

An interval is a controlled decision, not a date copied permanently from the first certificate.

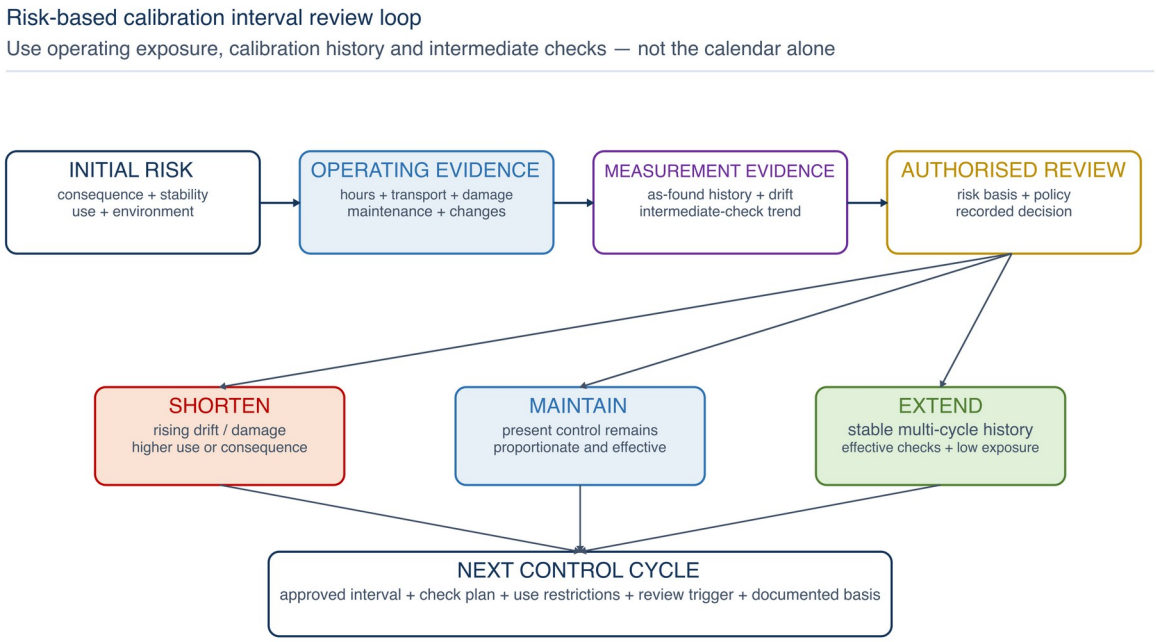

Figure 3. Risk-based calibration interval review loop. Initial risk, operating exposure, calibration history and intermediate checks are reviewed together; the authorised outcome may maintain, shorten or extend the interval with a recorded basis.

Evidence observed	Possible interpretation	Typical controlled response
Stable results over several cycles with effective checks and low exposure	Present interval may be conservative	Consider a controlled extension within policy
Drift increasing toward an acceptance boundary	Risk is rising before the due date	Shorten interval and investigate use, environment and equipment condition
Frequent adjustment or repair	Item or application may be unsuitable	Shorten interval, restrict use or replace with a more robust method
Damage, overload, drop or abnormal operation	Calendar interval no longer represents condition	Quarantine immediately and verify or calibrate before reuse
Check result shifts but calibration remains acceptable	Early change or check-method variation may exist	Investigate both instrument and check process; increase monitoring where justified
Calibration repeatedly covers unused ranges	Service may not match the real process	Refine calibration points while preserving required coverage
Use frequency or consequence increases	Previous risk basis has changed	Reassess and normally strengthen control
Item remains unused in protected storage	Operating exposure may be low, but ageing and storage effects remain possible	Apply the documented inactive-storage and return-to-service rule

Avoid changing intervals merely to reduce service cost or workload. The objective is confidence at the time of use, with efficient control supported by evidence.

12. Use intermediate checks to detect change

Intermediate checks provide timely evidence between calibrations. Design each check around the instrument's working range, function and dominant failure modes.

A controlled check defines:

847. instrument and reference identity;
848. check point, range and function;
849. environmental and preparation conditions;
850. method and number of repetitions;
851. acceptance or warning criteria;

852. person or role authorised to perform it;
853. frequency or event trigger;
854. result and trend record; and
855. action for warning, failure or doubtful behaviour.

Suitable references may include calibrated gauge blocks, setting masters, reference artefacts, electrical sources, mass standards or stable comparison items selected through the measurement system. Protect and control the reference itself. A workshop check is only as useful as its method, reference condition, resolution and decision criteria. [S254; S256]

Checks may be triggered before use, at shift start, at defined production intervals, after transport, after suspected overload, after battery replacement, after environmental change or at the end of a measurement session. Use trends to detect gradual drift; do not wait for a result to cross the rejection limit before investigating.

13. Control status, access and use

Every user should be able to determine whether an item is authorised for the intended task. Status may be communicated by a durable label, electronic register, issue-control system or a combination.

Status	Meaning	Use control
In calibration / authorised	Required review is complete and due date has not passed	Use only within approved range, function and conditions
Restricted	Approved only for stated functions, ranges, locations or indication	Restriction must be visible at issue and in the register
Reference only	Reserved to establish or check other measurement results	Protect from routine production use
Indication only	Not authorised for product acceptance	Mark clearly and segregate where confusion is likely
Quarantined	Overdue, damaged, failed, doubtful or awaiting assessment	Prevent issue and acceptance use
Under repair or calibration	Not available for production decisions	Control custody and temporary replacement
Retired or scrapped	Permanently removed from service	Deface status, disable or dispose to prevent reuse

Labels should not cover serial numbers, ventilation, adjustment points, displays or measuring surfaces. If a label is lost or illegible, confirm status from the controlled register before use.

14. Control environment, storage and handling

Measurement equipment can change through heat, humidity, condensation, dust, abrasive particles, coolant, corrosion, magnetic fields, electrical interference, shock and poor storage.

Apply controls suitable to the equipment:

- stabilise the instrument, workpiece and reference where temperature matters;
- keep precision faces and reference artefacts clean, protected and corrosion free;
- separate instruments from grinding dust, welding spatter, chemicals and vibration;
- use cases, cabinets and transport fixtures that do not load sensitive mechanisms;
- avoid leaving equipment on hot machines, vehicles or exposed benches;
- manage batteries, leads, probes, chargers and software configurations;
- prevent unauthorised adjustment and protect calibration seals where used;
- inspect after transport or environmental excursion; and
- record relevant conditions when they affect interpretation.

Environmental control at the calibration laboratory does not remove the need to control the workshop measurement process.

15. Respond to overdue, failed, damaged or doubtful equipment

Stop acceptance use when an item is overdue, fails a check, is dropped, overloaded, damaged, repaired, adjusted without authorisation, exposed to a severe environment, produces unstable results or otherwise loses its known status.

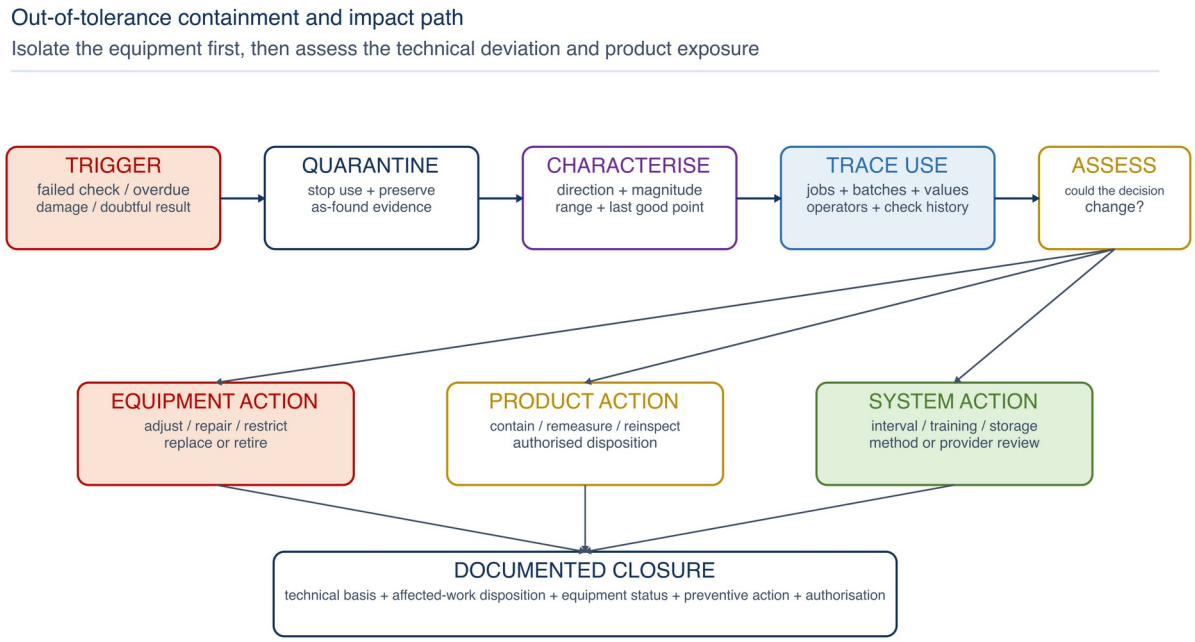

Figure 4. Out-of-tolerance containment and impact path. The item is isolated first, then the technical deviation, use history and product exposure are assessed before equipment disposition and product action are authorised.

Use this response sequence:

856. stop use and identify the instrument;
857. physically and electronically quarantine it;
858. preserve the as-found condition and available evidence;
859. record the event, date, user, location and suspected cause;
860. verify or calibrate the relevant range and function without premature adjustment;
861. determine the magnitude, direction and range of any deviation;
862. identify the last known acceptable point;
863. trace measurements, batches, jobs and product decisions made since that point;
864. assess whether the deviation could change conformity or process-control decisions;
865. contain, remeasure, reinspect or otherwise disposition affected work through authorised quality personnel;
866. repair, adjust, restrict, replace or retire the equipment; and
867. document closure and any interval, training or process change.

Do not assume all product is defective merely because an instrument failed. Equally, do not assume earlier product is acceptable because the deviation appears small. Evaluate the direction of error, actual measured values, specification margins, uncertainty, range of use, check history and process evidence.

16. Apply decision rules and conformity statements deliberately

A measurement result is not the same as a conformity statement. A laboratory may report values without declaring pass or fail, or it may provide a conformity statement using an agreed decision rule. The rule describes how measurement uncertainty is considered when deciding conformity. [S257; S264]

Before requesting or using a statement of conformity, define:

- the specification and acceptance limits;
- the measurand and units;
- whether uncertainty is considered and how;
- the consequence of false acceptance and false rejection;
- the decision rule agreed with the laboratory or customer;
- any guard band or acceptance zone;
- the reporting language for indeterminate or conditional cases; and
- who retains product-release authority.

Do not create an unexplained internal “pass” by comparing only the displayed calibration error with a tolerance. Review the reported uncertainty, coverage, decision rule and intended measurement process. Product acceptance remains a separate decision under the applicable inspection plan.

17. Retain complete life-cycle records

Records should allow a competent reviewer to reconstruct what the item was, how it was controlled, what was found and why the next decision was made.

Retain, as applicable:

- equipment identity, owner, location, role and configuration;
- purchase, receipt and initial-acceptance information;
- calibration service specification and purchase order;
- quotations and current provider-scope evidence;
- complete certificates and controlled amendments;
- certificate-review outcome, restrictions and authorisation;
- intermediate-check results and trends;
- maintenance, repair, adjustment, damage and transport events;
- interval calculations, reviews and approvals;
- overdue or failed-equipment investigations;
- affected-product trace and disposition;
- software, firmware, probe and accessory changes;
- status changes, issue history and return-to-service evidence; and
- retirement, scrapping or transfer record.

Protect records against loss, unauthorised editing and mistaken replacement. Preserve original issued certificates and link corrections or amendments rather than silently overwriting earlier evidence.

18. Troubleshoot calibration-control problems

Observation	Likely causes	Practical correction
Certificate covers only part of the working range	Service request was vague or provider scope was not checked	Restrict use and obtain the required coverage; revise the service specification
Serial number or configuration does not match	Misidentification, accessory omission or clerical error	Quarantine and reconcile the physical item with the provider
Certificate states pass but no decision rule is clear	Conformity requirement was not agreed or reporting is incomplete	Obtain clarification and review against the defined decision process
As-found result is absent after adjustment	Provider was authorised to adjust before recording or request was unclear	Seek available evidence and strengthen future as-found requirements
Instrument repeatedly drifts before due date	Harsh use, instability, overload, poor storage or unsuitable interval	Investigate cause, shorten interval and consider a more suitable instrument
Intermediate check fails but zero passes	Range-dependent change, damaged contact, reference problem or check-method variation	Quarantine; verify the reference and relevant range before reuse
Calibration passes but workshop results disagree	Different environment, method, fixturing, contact force or workpiece variation	Study the complete measurement process, not the certificate alone
Due label is valid but register shows quarantine	Label was not updated or item was recalled after labelling	Follow the controlled register and prevent issue until status is resolved
Overdue instrument was used	Issue control failed or status was not visible	Contain the item, trace affected results and strengthen access controls
Unused equipment has no recent history	Long storage, ageing or unknown condition	Apply the return-to-service inspection, check and calibration rule
Calibration cost rises without reducing risk	Unnecessary range/points, poor interval strategy or repeated repair	Review the measurement requirement and history without weakening essential control
Near-limit result gives conflicting decisions	Unclear uncertainty treatment or decision rule	Apply the agreed rule and route product release to authorised quality personnel

19. Practical release checklist

Before releasing equipment to acceptance use, confirm:

- the physical item, serial number, asset ID and configuration match the record;
- the intended measurement process, range and function are defined;
- the calibration provider's current scope covers the required activity;
- the certificate is complete, authorised and technically reviewed;
- required points, range, functions and accessories were covered;
- as-found and as-left conditions are understood;
- results, units, error or correction sign and uncertainty are clear;
- traceability information is adequate for the intended use;
- any conformity statement uses the agreed specification and decision rule;
- the equipment meets the defined acceptance requirement;
- restrictions are visible in the register and at the point of issue;
- calibration and intermediate-check intervals have a recorded basis;
- returned equipment passed condition and functional checks;
- due date and status identification are correct;
- storage, transport and environmental controls are available;
- overdue, damaged or doubtful conditions trigger immediate quarantine;
- records can trace product measured since the last known acceptable point; and
- release is authorised by the responsible role.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 045

Inspection Photography

45

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, quality personnel, inspectors, fabricators, grinding and finishing teams, supervisors, maintenance personnel, technical sales personnel and personnel who prepare industrial reports

Scope: Practical photography for documenting abrasive applications, surface condition, welds, components, equipment and inspection findings, including planning, site safety, camera position, image sequence, focus, lighting, reflections, scale references, colour limitations, file control, repeat photography, reporting and troubleshooting.

Core principle — An inspection photograph is useful when a reviewer can identify the item, locate the feature, see the relevant detail and understand the capture conditions without being misled by glare, perspective, processing or an incomplete view.

Photography can preserve condition, support communication and make comparisons easier. It does not replace the applicable inspection method, acceptance criteria or competent judgement. A sharp close-up without context may be impossible to locate; a ruler placed at a different depth may suggest a false size; and an attractive image may hide the very feature being inspected. A controlled sequence is therefore more valuable than a single dramatic photograph. [S265; S267; S274]

Chapter objectives

After this chapter, the reader should be able to:

- define the purpose and required views before capture;
- perform photography without entering a danger zone or disturbing the condition being documented;
- capture location, context, item, feature and close-detail views in a logical sequence;
- identify the item, orientation and feature without obscuring relevant evidence;
- select suitable field of view, working distance, camera support, focus and depth of field;
- choose lighting geometry for shape, texture, scratches, contamination and reflective surfaces;
- use a clean scale as a size reference while recognising perspective and calibration limits;
- control colour appearance and avoid treating uncontrolled images as absolute colour measurements;
- preserve original files, metadata and an understandable file relationship;
- annotate controlled copies while retaining an unchanged original;
- repeat photographs in a way that supports meaningful comparison; and
- troubleshoot common failures before releasing an inspection report.

1. Start with the inspection question

Before selecting a camera, define what the image must help a reviewer decide. Typical purposes include:

- locating a defect or process area;
- documenting pre-work and post-work condition;
- showing an abrasive product in use without implying a performance test;
- recording surface contamination, heat tint, scratches, gouges, coating failure or weld profile;
- supporting a maintenance, warranty or technical-service discussion;
- comparing condition at two controlled stages; or
- showing an installation, access or guarding issue.

Write a short image requirement: item identity, feature, orientation, required detail, scale context, lighting condition and intended use. If a dimension, colour difference or acceptance decision is critical, specify the separate controlled measurement or inspection method that will provide it. Photography then documents the condition and the measurement location rather than carrying more authority than the imaging process can support. [S265; S266; S268]

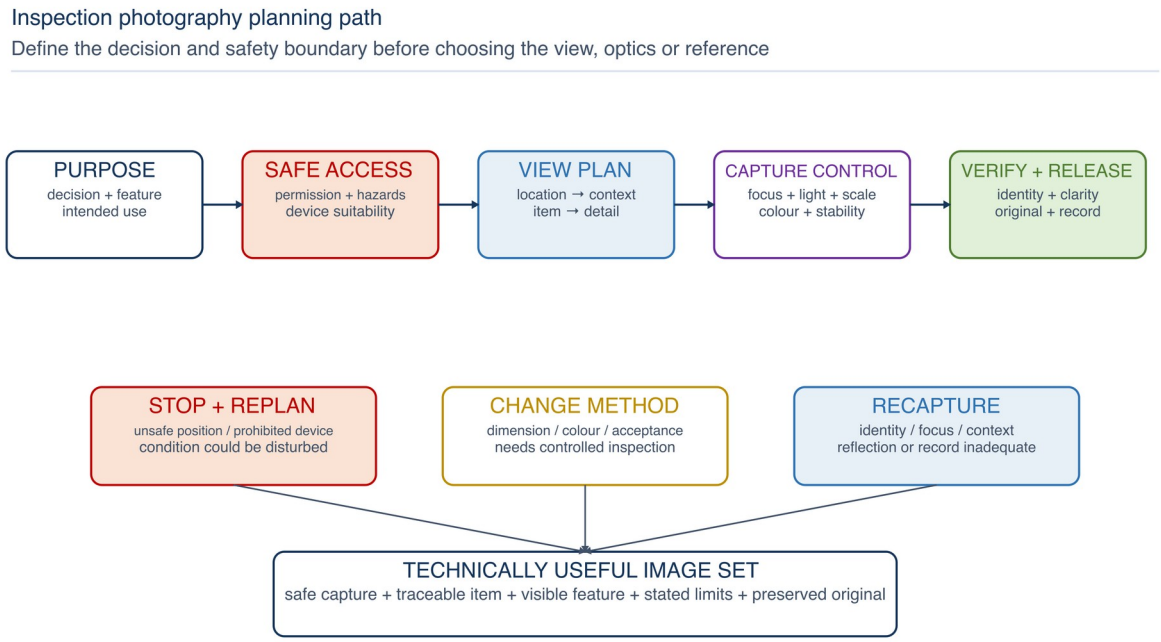

Figure 1. Inspection photography planning path. The decision purpose controls safety, view sequence, optical setup, references and file records before the image is released.

2. Make safety the first camera setting

Do not step into a danger zone, remove a guard, lean over rotating equipment or defeat an interlock to obtain a better angle. Use a safe viewpoint, zoom or suitable remote support when the required view can be obtained without approaching the hazard. If access requires isolation, follow the site's authorised energy-control and verification procedure. Photography never creates an exception to machine guarding, work-at-height, confined-space, hot-work, chemical, electrical or traffic controls. [S272]

Before capture, confirm:

868. site permission and the responsible contact;
869. area hazards and required PPE;
870. whether equipment must be stopped, isolated, cooled or cleaned;
871. whether the photographer can remain outside guarded or restricted zones;
872. whether flash, lamps, tripods, cables or magnetic mounts create a new hazard;
873. whether the camera could contaminate a clean process or be contaminated by the process;
874. whether people, screens, labels or drawings contain confidential or personal information; and
875. whether the device is permitted in the area.

In an explosive atmosphere or classified hazardous area, do not assume that a phone, camera, battery, lamp or accessory is acceptable. Equipment selection must match the area classification, protection requirements and site authorisation. [S273]

3. Protect the condition being documented

Photograph the as-found condition before cleaning, repositioning, marking, measuring or repair where that condition matters. Avoid touching deposits, smearing contamination, dislodging fragments or placing a dirty scale on a sensitive surface. Use clean barriers and handling controls appropriate to the item.

If cleaning is required to reveal a feature, record the sequence clearly:

- overall condition before cleaning;
- close view before cleaning;
- cleaning method or prepared state, where relevant;
- the revealed feature after cleaning; and
- any measurement or inspection location.

Keep “before” and “after” descriptions factual. Do not use the photograph alone to claim that a process removed all contamination, restored corrosion resistance or met a surface specification.

4. Use an overview-to-detail sequence

A complete image set normally moves from where the item is to what the feature looks like. [S267; S274]

View	What it establishes	Typical content
Location	Where the condition exists	Machine, bay, line, structure or installation area
Context	How the item sits within the assembly	Adjacent components, access, orientation and process direction
Item	Which component is being discussed	Whole part, item ID, drawing reference or unique geometry
Feature	Where the relevant area lies on the item	Pointer beside the feature, weld segment, edge or surface zone
Close detail	What the feature looks like	Texture, indication, damage, deposit, finish or marking
Alternate-light view	How appearance changes with controlled illumination	Low-angle, diffuse, cross-light or backlit view
Post-action repeat	What changed after authorised work	Same orientation, scale, lighting and framing where practical

Do not begin and end with a macro image. A reviewer should be able to travel from the location view to the close detail without guessing.

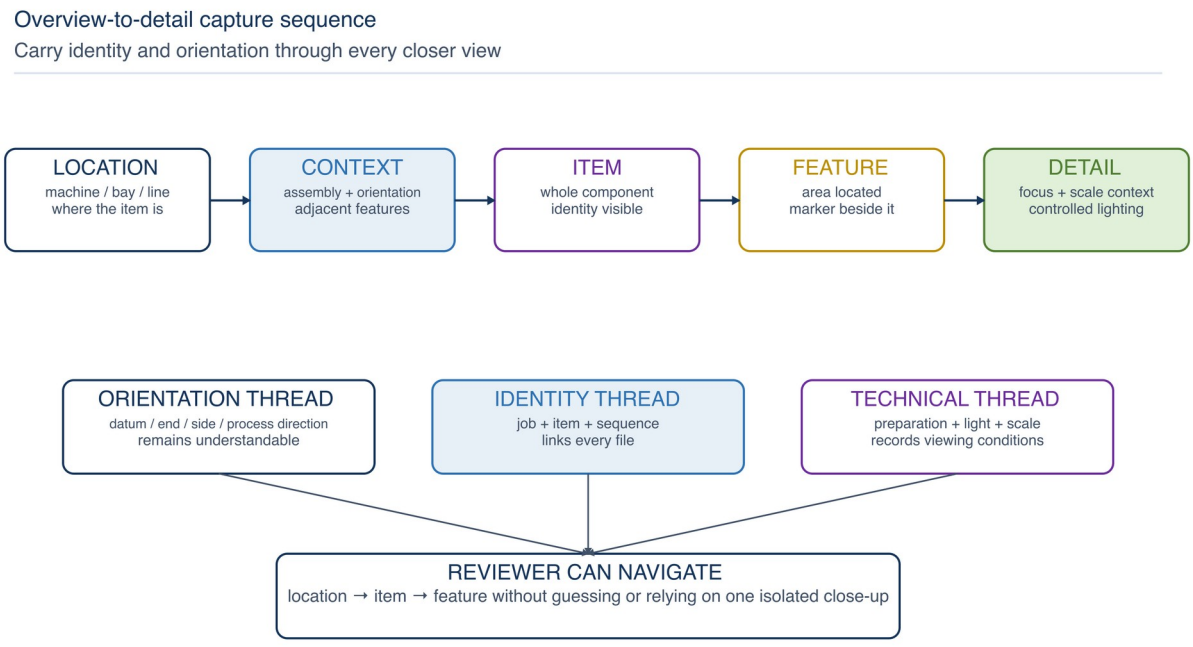

Figure 2. Overview-to-detail capture sequence. Each closer view retains enough orientation to connect the feature to the item and the item to its operating context.

5. Identify the item and orientation

Use an identification card, job number, part label, drawing reference or other controlled identifier that can be linked to the report. Position it beside the item, not over the feature. Avoid including customer-sensitive information beyond what the report needs.

Record orientation with plain terms that fit the item: drive end, operator side, top, inlet, outlet, clockwise direction, weld start, datum face or another unambiguous reference. If a removable arrow or marker is used, photograph one view without it when the marker could hide surface condition.

Number and describe photographs carefully. A useful caption identifies the item, view, location of the feature, capture condition and purpose. [S274]

6. Choose field of view and working distance

Fill enough of the frame with the subject to preserve detail, but retain the context needed for interpretation. Moving extremely close with a wide-angle phone lens can exaggerate near features, curve straight edges and change apparent proportions. When space allows, step back and use an appropriate focal length or optical magnification.

Select working distance so that:

- the camera can be held or mounted safely;
- the feature fills the intended part of the frame;
- the lens can focus reliably;
- lighting can reach the surface without blocking the camera;
- perspective is controlled; and
- the camera, scale and hands do not touch the feature.

Digital zoom usually crops and enlarges the existing pixels. It may help framing on screen but does not create missing detail. Capture the highest useful native quality available and confirm the feature is resolved in the saved file, not only in the live preview. [S267]

7. Stabilise before increasing magnification

Close photography amplifies small movements. Use a tripod, copy stand, rigid arm, beanbag, stable platform or another suitable support where practical. Prevent the support from becoming a trip hazard or contacting moving, hot or energised equipment.

For handheld capture:

- brace elbows or the camera against a stable safe surface;
- use two hands;
- avoid reaching at full extension;
- use a short timer or remote release when pressing the shutter causes movement;
- take more than one frame; and
- review at high magnification for motion blur.

Adding light can support a faster exposure and reduce motion blur. Raising electronic sensitivity may make capture easier but can add noise and reduce fine detail. Select settings according to the inspection purpose rather than a universal formula.

8. Control focus and depth of field

Place focus on the feature of interest, not on a bright reflection, scale edge or nearby label. At close distance, only a shallow depth may appear sharp. A curved surface, deep gouge or raised weld may therefore require:

- a more square camera position;
- a smaller aperture where the camera permits and sufficient light is available;
- greater working distance with suitable focal length;
- separate frames focused at different depths; or
- a controlled optical system designed for extended-depth imaging.

Do not rely on the small screen. Enlarge the saved image and inspect the relevant edges and texture. If software combines multiple focus planes, keep the source images and identify the combined result as processed.

9. Select lighting by feature, not convenience

Lighting determines which surface information becomes visible. The same scratch can disappear under broad frontal light and become prominent under low-angle light. Specular, diffuse and transmitted arrangements are useful starting points, and the best direction depends on surface shape and inspection purpose. [S270]

Inspection purpose	Useful starting light	Watch for
General surface condition	Broad diffuse light from above or beside the camera	Flat contrast that hides shallow texture
Fine scratches and raised edges	Low-angle light across the surface	Directional shadows that exaggerate height
Reflective flat metal	Large diffuse source or controlled off-axis light	Hot spots, reflected people and dark camera silhouette
Engraving, stamping or shallow relief	Oblique light from one or more directions	A single direction hiding features aligned with the light
Through-hole, profile or edge shape	Backlight where safe and physically possible	Silhouette loses surface information
Contamination or colour variation	Stable neutral illumination with controlled white balance	Mixed daylight and artificial light changing colour appearance
Deep recess	Small directed light supplemented by a context view	Bright rim with an unreadable dark interior
Curved polished surface	Diffuse enclosure, flags or cross-polarisation where suitable	Uneven brightness and reflections being mistaken for defects

Move the light, not the safety boundary. Take paired views under different controlled directions when a feature is directional. Record unusual lighting arrangements so a repeat image can be made.

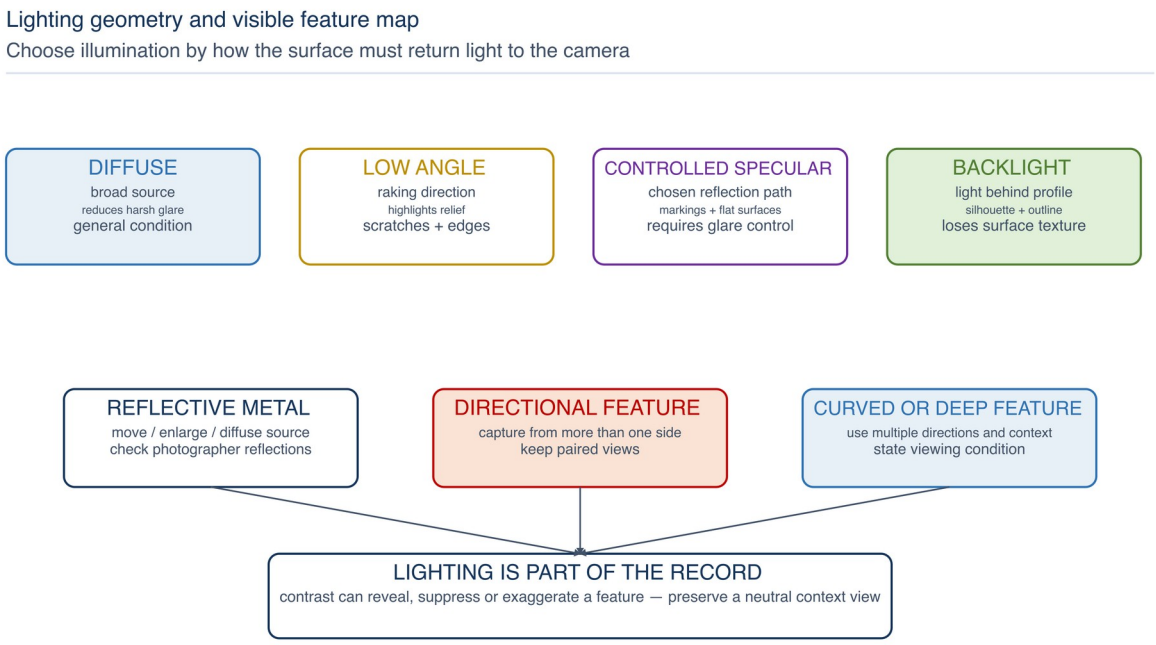

Figure 3. Lighting geometry and visible feature map. Diffuse, low-angle, backlit and controlled specular arrangements reveal different properties; no single arrangement is best for every surface.

10. Manage glare and reflections deliberately

Polished metal acts like a mirror. A bright patch may be the lamp, and a dark patch may be the camera or photographer. Change one variable at a time:

876. move the light farther off axis;
877. enlarge or diffuse the source;
878. change the camera angle slightly while preserving the required geometry;
879. use white or black cards outside the frame to control reflected surroundings;
880. use a polarising arrangement where it is effective and does not suppress relevant evidence; and
881. capture a second angle to show whether a mark follows the surface or the reflection.

Do not retouch reflections out of a released inspection image. If an alternate-light view improves visibility, keep both the neutral context view and the feature-enhancing view.

11. Use scale references correctly

A scale gives size context only when its geometry and quality are suitable. Place a clean, legible scale close to the feature and in the same plane where practical. Keep it parallel to the surface direction being compared and avoid covering the indication. Capture a view without the scale if placement could disturb or obscure the condition. [S267; S268]

Scale-control question	Good practice	Limitation to state or manage
Is the scale suitable?	Use a stable, legible reference with appropriate graduations and known identity	Printed or worn scales may not have verified dimensional quality
Is it in the feature plane?	Place it at the same depth and orientation as the nominally flat feature	A different plane creates perspective error
Is the camera square?	Keep the optical axis as perpendicular as practical for flat features	Oblique capture changes apparent length and shape
Is distortion controlled?	Avoid extreme close-range wide-angle views; keep the feature near the central field	Lens distortion varies across the frame
Is the scale readable?	Preserve the complete relevant graduations and unit	A cropped or blurred scale cannot support reliable comparison
Is measurement intended?	Use a validated calibrated imaging or photogrammetry method	An ordinary image with a ruler is not automatically a dimensional result

When a photograph is used to indicate a measurement location, record the actual value from the controlled measuring instrument separately. Refer to the product label, Technical Data Sheet, or MKTECH representative.

12. Control perspective and shape

For nominally flat features, position the image sensor as parallel to the feature plane as practical. Use visible parallel edges or a small level aid where safe. Keep the area of interest near the centre of the frame and capture an oblique context view separately if it helps show depth.

For curved surfaces, no single view represents all points without distortion. Use multiple overlapping views and state the orientation. A scale laid across a curve may not share the same plane as the entire feature. If profile, flatness, angle or area is decision-critical, use the applicable controlled measurement method.

Perspective can also change apparent abrasive contact angle, guard clearance, weld shape and scratch length. Avoid making geometric claims from an uncontrolled viewpoint.

13. Treat colour as conditional information

Colour in a photograph depends on the light spectrum, reflections, exposure, white balance, camera processing, file profile, display and viewing environment. International camera colour characterisation uses controlled stimuli and metrology; an ordinary workshop photograph does not provide that control. [S266]

For colour-sensitive documentation:

- avoid mixed light sources;
- use a stable, suitable neutral light;
- set and record a repeatable white-balance method;
- include a suitable neutral or colour reference when the workflow calls for one;
- avoid clipping bright channels on reflective surfaces;
- preserve the original file and colour profile;
- compare images on a controlled display where the decision warrants it; and
- confirm critical colour or appearance using the applicable instrument or agreed visual method.

Heat tint, coating shade and contamination may be documented photographically, but image colour alone should not be converted into temperature, oxide thickness, chemical identity or acceptance unless a validated method supports that conclusion.

14. Use a repeatable capture record

Record enough information to recreate an important view. The level of detail should match the consequence and comparison need.

Record field	Why it matters	Example content
Job and item ID	Connects image to report and component	Work order, part ID, batch or location
Photographer and date/time	Establishes capture responsibility and sequence	Name or controlled user ID plus timestamp
View and orientation	Allows the feature to be relocated	Operator side, inlet end, weld clock position
Camera and lens mode	Supports repeat setup and file interpretation	Device ID, lens or magnification mode
Working distance and support	Controls framing, perspective and stability	Marked stand position or approximate distance
Lighting arrangement	Explains contrast and reflection	Diffuse overhead, low-angle from left, backlight
Scale or reference ID	Links the visible reference to its control	Reference identity and unit
Preparation state	Distinguishes as-found, cleaned and post-repair views	Dry as found, solvent cleaned, after dressing
Original filename	Preserves traceability to the native file	Camera filename retained in the image register
Processing history	Identifies crops, exposure changes, composites or annotations	Working copy only; original preserved

Where exact device capability, operating condition or approved accessory is required, use the applicable controlled information for that device.

15. Preserve originals and control working copies

Transfer files promptly to the controlled project location. Preserve the original image in its native captured form, including available metadata. Perform cropping, tonal adjustment, redaction, arrows, labels and other processing on a copy. [S269]

A practical file relationship is:

- JOB-ITEM-VIEW-SEQUENCE_ORIGINAL.ext
- JOB-ITEM-VIEW-SEQUENCE_WORKING-v01.ext
- JOB-ITEM-VIEW-SEQUENCE_ANNOTATED-v01.ext

Do not overwrite the original with an annotated version. Keep processing proportionate and reversible where practical. Adjustments may improve visibility but must not add, remove or relocate a feature. Record material processing, especially stitching, focus stacking, noise reduction, perspective correction or generative editing. Do not use generative fill or content-aware replacement on technical inspection content.

Verify the transferred file opens correctly, retains sufficient detail and matches the item and sequence record before clearing removable media.

16. Annotate without changing meaning

Annotations should direct attention, not create a conclusion. Use an arrow, circle, box or short label on a controlled copy and keep it outside the feature where possible. State whether the annotation identifies a location, an observed indication or an accepted defect classification.

Avoid:

- drawing over the feature boundary;
- using a thick arrow that suggests a size;
- increasing contrast until texture disappears;
- presenting a cropped image without its linked context view;
- removing background items that affect interpretation;
- placing an unverified dimension on the image; or
- using colour-coded pass/fail labels without the applicable decision record.

Captions should distinguish observation from interpretation. “Linear dark indication at the 3 o'clock edge” is an observation; “crack caused by grinding” is a technical conclusion that needs supporting inspection and analysis.

17. Repeat photographs for comparison

A before-and-after pair is useful only if changes in imaging are controlled. Match, as practical:

- item orientation and camera viewpoint;
- working distance and focal length;
- field of view and crop;
- focus plane and depth of field;
- light position, size, direction and colour;
- scale position and identity;
- surface preparation state; and
- exposure and colour workflow.

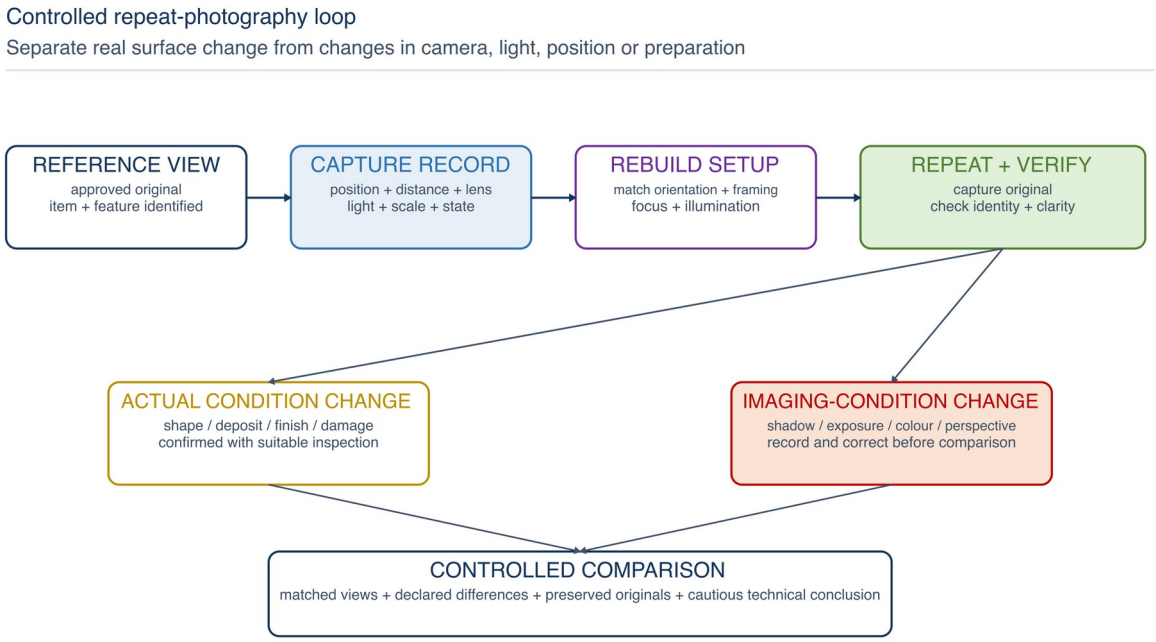

Figure 4. Controlled repeat-photography loop. A reference view and capture record guide repeat setup; differences are reviewed for both actual surface change and imaging-condition change.

When an exact match is impossible, record the difference. Do not attribute a darker image, stronger highlight or changed shadow automatically to surface deterioration or improvement.

18. Troubleshoot the image before release

Symptom	Likely cause	Practical correction
Feature is sharp on screen but soft in the file	Camera movement, wrong focus target or insufficient depth of field	Stabilise, refocus on the feature, add light and review at full size
Bright patch hides the surface	Direct specular reflection	Move or diffuse the light, alter view slightly and capture an alternate-light pair
Fine scratch disappears	Light aligned poorly with the scratch or contrast is too flat	Apply low-angle light across the feature from more than one direction
Surface looks rougher than it is	Strong raking light exaggerates relief	Add a diffuse context view and label the raking-light view
Scale looks readable but feature size is inconsistent	Scale and feature are in different planes or camera is oblique	Reposition scale, square the camera and avoid dimensional conclusions from the image
Colour changes between frames	Mixed lighting, auto white balance or exposure shift	Use one stable source and a controlled repeatable colour workflow
Close-up cannot be located	Context and orientation views are absent	Add linked location, item and feature views

Symptom	Likely cause	Practical correction
Repeated view does not match	Position, focal length, light or preparation changed	Rebuild from the capture record and document unavoidable differences
Annotation hides the indication	Mark-up applied over technical content	Return to the original and annotate a clean copy outside the feature
Image cannot be traced to the job	Filename, item ID or sequence record is incomplete	Reconcile before release; do not rely on memory

If a feature remains ambiguous, change the lighting or use the appropriate inspection method. Repeatedly sharpening or enlarging a weak file cannot recover detail that was never captured.

19. Inspection-photography release checklist

Before including an image in a customer report, technical recommendation or handbook asset, confirm:

- [ ] photography was authorised and performed from a safe position;
- [ ] the device was permitted for the area and conditions;
- [ ] the as-found state was preserved or the preparation state is clear;
- [ ] the image set includes enough location, context, item and detail views;
- [ ] item identity and orientation are unambiguous;
- [ ] the feature is in focus and resolved in the saved file;
- [ ] lighting reveals the intended feature without an unrecognised reflection;
- [ ] any scale is clean, legible, suitably placed and not overstated as calibrated measurement;
- [ ] colour language reflects the limits of the capture workflow;
- [ ] the original file and metadata are preserved;
- [ ] processing and annotation were performed on controlled copies;
- [ ] captions distinguish observation from interpretation;
- [ ] repeat images control or declare changed conditions;
- [ ] confidential, personal and customer-sensitive content is handled appropriately; and
- [ ] the released image is linked to the correct report, item and sequence record.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 046

Abrasive Safety Fundamentals

46

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, workshop supervisors, safety and health personnel, operators, maintenance teams, technical buyers, trainers and application personnel involved in grinding, cutting, sanding or polishing

Scope: Fundamental controls for abrasive products and powered tools, including risk assessment, competence, product marking, compatibility, receiving and storage, pre-use inspection, mounting, guarding, workpiece support, safe start-up, operating behaviour, spark control, stop-work conditions, post-use isolation and troubleshooting.

Core principle — Safe abrasive work depends on the complete system: a suitable abrasive, a compatible tool, correct mounting and guarding, a stable workpiece, a controlled environment and a trained operator using the product only for its marked purpose.

Abrasive products remove material by operating at high speed and concentrating force at a small contact area. The useful cutting action is therefore accompanied by stored rotational energy, fragments, sparks, hot metal, dust, noise, vibration and reaction forces. Safety is achieved by controlling these hazards before start-up and maintaining that control until the tool has stopped and the work has cooled. [S275; S280; S283; S284]

Chapter objectives

After this chapter, the reader should be able to:

- identify the principal hazards of grinding, cutting, sanding and polishing;
- apply the hierarchy of control to the task, work area, tool and abrasive product;
- define the competence required for selection, mounting, operation and supervision;
- interpret the product label and recognise when exact technical information is required;
- verify tool–accessory compatibility before mounting;
- receive, handle and store abrasive products without avoidable damage;
- inspect tools, guards, mounting parts and abrasive products before use;
- mount common abrasive products without improvisation;
- secure the workpiece and control the fragment, spark and reaction-force zones;
- use controlled start-up and operating techniques for grinding and cutting;
- recognise stop-work conditions and respond safely; and
- troubleshoot unsafe symptoms without attempting to work through them.

1. Treat abrasive work as a complete safety system

Do not assess an abrasive product in isolation. A suitable product can become unsafe when fitted to the wrong tool, mounted with incorrect parts, used without the specified guard, applied to an unstable workpiece or operated in an uncontrolled area.

Review seven connected elements before work begins:

882. **Task:** material, operation, access, required finish and cut or grinding path.
883. **Abrasive:** product family, dimensions, intended use, marking, condition and attachment.
884. **Tool:** power source, spindle or drive, speed, capacity, guard, handle, controls and maintenance condition.
885. **Mounting system:** flange, backing pad, nut, adaptor, collet or other manufacturer-specified parts.
886. **Workpiece:** mass, support, restraint, residual stress, movement and behaviour as material is removed.
887. **Environment:** people, combustible material, cylinders, cables, ventilation, wet conditions, confined areas and hazardous atmospheres.
888. **Operator:** training, authorisation, physical control, body position, PPE and readiness to stop.

If one element changes, review the system again. A different wheel diameter, material grade, power tool, access position or support arrangement can change the hazard and the correct control.

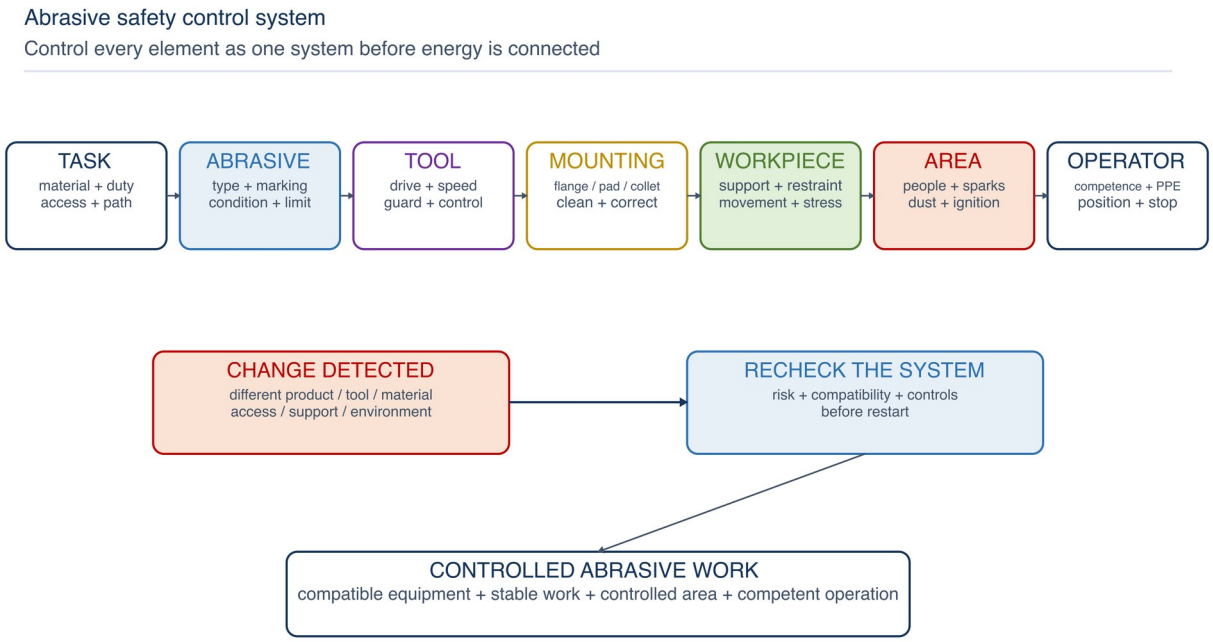

Figure 1. Abrasive safety control system. The task, product, tool, mounting, workpiece, environment and operator form one interdependent system; a change in any element requires a fresh compatibility and risk check.

2. Apply the hierarchy of control

Personal protective equipment is important, but it is the final layer rather than the starting point. Use the hierarchy of control to reduce exposure at source. Malaysian workplace duties place emphasis on safe plant, safe systems of work, information, instruction, training, supervision and risk assessment. [S275]

Control level	Abrasive-work application	Practical example
Eliminate	Remove the abrasive task or hazardous access	Order a profile nearer to final size; redesign access so finishing is unnecessary
Substitute	Use a less hazardous process, product or material	Use a lower-dust method or a product intended for the required operation
Engineering	Separate people from energy, fragments, dust and sparks	Machine guard, enclosure, local extraction, screen, fixture or remote handling
Administrative	Control competence, sequence, area and duration	Authorisation, safe-work procedure, hot-work permit, inspection and exclusion zone
PPE	Protect against remaining exposure	Suitable eye, face, hearing, respiratory, hand, body and foot protection selected through risk assessment

Choose controls for the actual process. A screen may protect nearby personnel from sparks but will not control airborne dust unless airflow and capture are designed for that purpose. A face shield supplements the selected eye protection; it is not a substitute for guarding or a reason to stand in the likely fragment path.

3. Recognise the principal hazards

Hazard	How it develops	Primary controls
Abrasive breakage or accessory release	Damage, incompatible speed or mounting, side loading, impact, excessive force or incorrect support	Correct selection, inspection, mounting, guard, controlled start-up and stable technique
Contact with moving product	Exposed abrasive, loss of balance, uncontrolled run-down or reaching across the tool	Guard, two-handed control where designed, body position, isolation and complete stop

Hazard	How it develops	Primary controls
Kickback or reaction force	Binding, pinching, edge impact, twisting in a cut or sudden contact	Secure workpiece, planned path, correct product, stable grip and avoidance of jamming
Sparks, hot particles and hot workpiece	Material removal and friction	Direct discharge, clear combustibles, hot-work controls, fire watch where required and cooling time
Dust, fume and mist	Workpiece, coating, abrasive and process fluid are fragmented or heated	Material identification, source capture, ventilation, process selection and suitable respiratory protection where required
Noise and vibration	Tool, abrasive, workpiece resonance and contact conditions	Suitable equipment, maintenance, exposure control, technique and health-protection programme
Entanglement	Loose clothing, hair, jewellery, gloves or cables enter rotating parts	Clothing and work-area control; keep hands and loose items clear
Electrical, pneumatic or hydraulic energy	Damaged supply, wet conditions, hose failure, unintended start or stored pressure	Inspection, suitable supply, isolation, controlled connection and maintenance
Workpiece movement or collapse	Poor restraint, cut closure, released stress or unsupported offcut	Fixture and support both sides of the operation; plan the final separation

Chapters 047 to 050 develop PPE, dust, noise, vibration, spark, fire and explosion control in greater depth. The fundamental rule remains: control the hazard at source and use the appropriate specialist controls before starting.

4. Define competence and authorisation

Selection, mounting and operation require practical competence, not familiarity alone. Training should cover the product families used at the site, label interpretation, correct mounting systems, tool inspection, guarding, operating technique, abnormal conditions and emergency response. FEPA identifies training as a foundation of professional abrasive safety practice. [S285; S286]

Supervisors should authorise personnel according to the tasks they can perform. Useful categories include:

- select a product for a defined application;
- inspect and issue abrasive products;
- mount products on portable tools;
- mount wheels on stationary machines;
- operate specific tool or machine types;
- adjust work rests, guards or extraction systems;
- isolate and maintain equipment; and
- train or assess other personnel.

Competence should be refreshed when equipment, product families, materials, work methods or site conditions change, and after an incident or unsafe observation. New personnel should work under direct supervision until they demonstrate correct selection, mounting, start-up, control and stop-work decisions.

5. Read the abrasive product before selecting it

The label and product marking are part of the safety system. Bonded-abrasive marking is addressed internationally by ISO 525, while product standards define shapes, dimensions and intended-use context for common wheel types. [S277; S278; S279]

Verify, as applicable:

- manufacturer and product identification;
- abrasive product family and shape or type;
- dimensions and bore or attachment;
- material or application marking;
- intended operation, including grinding, cutting, sanding or polishing;
- maximum permitted speed or other operating limit;
- direction of rotation where marked;
- required guard, flange, backing pad or support;
- restriction symbols and required PPE symbols;
- traceability or date information; and

- damage-free, legible condition.

Do not use colour alone to identify a product. Similar-looking products may have different construction, intended use or limits. Do not copy a speed, mounting arrangement or application from another diameter or product family.

When an exact product value is required: **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

6. Pass every tool–accessory compatibility gate

Compatibility must be confirmed before the product is fitted. Electric grinders, pneumatic grinders, sanders, polishers and die grinders have different safety scopes and mounting systems; an attachment that physically fits is not automatically suitable. [S280; S281; S282; S283]

Gate	Confirm	Reject when
Operation	Product is marked or documented for the intended grinding, cutting, sanding or polishing duty	Intended use is unknown or conflicts with the task
Material	Product is suitable for the workpiece and any coating or contamination	Material compatibility is uncertain or could create a reactive or contaminated process
Dimensions	Diameter, thickness, bore, thread, shank or belt size matches the tool and mounting system	Product requires forcing, alteration or an improvised adaptor
Speed	Tool maximum no-load speed does not exceed the product's marked maximum permitted speed	Either value is unreadable, unavailable or incompatible
Guard	Correct guard type and capacity can be fitted and positioned	Guard must be removed, opened beyond its design or substituted
Support	Specified flange, backing pad, blotter, nut, collet or other support is available and undamaged	Mounting parts are mixed, worn, distorted or improvised
Direction	Rotation and directional marking agree where direction is specified	Direction cannot be verified
Tool condition	Spindle, controls, handle, bearings, supply and safety devices are serviceable	Abnormal play, damage, unreliable control or overdue maintenance is present

Do not alter a bore, reduce a product diameter by striking it, stack products, add packing or use makeshift washers to make an incompatible product fit. Use only the tool and mounting parts intended for the accessory system.

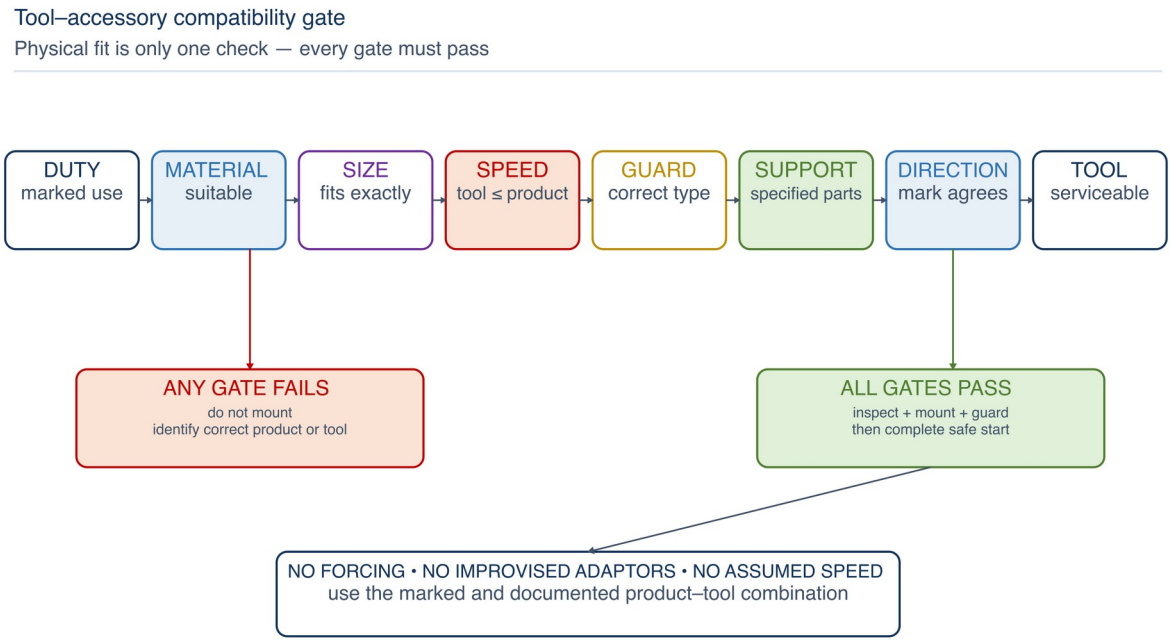

Figure 2. Tool–accessory compatibility gate. The product proceeds to mounting only after operation, material, dimensions, speed, guard, support, direction and tool condition have all been verified.

7. Receive and store abrasive products carefully

Abrasive products can be damaged without obvious packaging damage. Handle cartons and individual products without dropping, throwing, bending or allowing impact against hard edges. Check deliveries for correct identity, quantity, visible damage, moisture, deformation and legible labels before acceptance into controlled storage.

Store products:

- in the original packaging where practical;
- in a dry, stable environment away from water, excessive heat and direct sunlight;
- on suitable shelves or racks that support the product without distortion;
- away from traffic, vibration and falling-object exposure;
- so heavy items cannot crush lighter products;
- with product identity and stock rotation visible; and
- separately when quarantined, damaged or returned.

Store thin cutting wheels upright in a suitable compartment or supported as recommended by the manufacturer. Keep coated-abrasive belts and discs free from folds, kinks, edge damage and contamination. Do not hang heavy products from points that distort them. Allow products moved from a markedly different environment to stabilise in accordance with supplier guidance before use.

8. Inspect the complete setup before mounting

Isolate the tool from its energy source and verify that it cannot start. Clean the area and inspect under adequate light.

Item	Check	Unsafe finding
Abrasive product	Identity, marking, cracks, chips, distortion, contamination, moisture damage and attachment condition	Damage, unreadable critical marking or uncertain history
Tool body	Housing, vents, fasteners, labels and general condition	Cracks, missing parts, severe contamination or unauthorised modification
Spindle or drive	Threads, shoulder, runout indicators, locking mechanism and cleanliness	Damage, excessive play, burrs or unreliable lock
Guard	Correct type, secure adjustment, adequate coverage and freedom from distortion	Missing, loose, cracked, modified or incompatible guard

Item	Check	Unsafe finding
Handle and controls	Side handle, trigger, lock-off, switch return and grip surfaces	Missing handle, sticking control or unintended-start risk
Mounting parts	Correct identity, matching set, flat contact, clean surfaces and sound condition	Mixed flanges, warped backing pad, damaged nut or improvised washer
Energy supply	Cable, plug, battery, hose, coupling, regulator and pressure condition	Cuts, exposed conductors, damaged pack, leaking hose or insecure coupling

A ring test applies only to appropriate wheel types and must be performed using the correct method by trained personnel. It is not suitable for every wheel construction, size or mounting condition and does not replace visual inspection or product instructions.

9. Mount without force or improvisation

Use the specified mounting sequence for the tool and product. Keep spindle, flange and support surfaces clean. The product should seat without hammering, forcing or uncontrolled clearance. Use the correct tightening tool and method; excessive tightening can damage the product or mounting system, while insufficient tightening can allow movement.

General mounting sequence:

889. isolate and verify zero energy;
890. confirm the compatibility gates again at the point of use;
891. inspect and clean all contact surfaces;
892. install the specified inner support, flange, backing pad or collet;
893. orient the abrasive product correctly;
894. install the specified outer flange, nut or retaining part;
895. tighten using the prescribed method without shock loading;
896. rotate by hand where the design permits and check for interference;
897. refit and position the guard and handle; and
898. remove mounting tools and loose items before reconnecting energy.

Blotters, flanges, backing pads, nuts, collets and adaptors are functional safety components. Do not substitute them by appearance. Stationary-wheel mounting and dressing require the machine-specific procedure and trained personnel. [S284; S286; S287]

10. Position and verify the guard

Use the correct guard for the tool, accessory and operation. Position it between the operator and the most likely fragment or spark path while preserving safe access to the work. Secure the adjustment before start-up.

Never remove a guard because the product is difficult to access. Change the tool, product, fixture or work sequence so the operation can be completed with the designed protection in place. Do not use a grinding guard as an assumed substitute for a cutting guard, or enlarge, trim or bend a guard to create clearance.

On stationary machines, verify the enclosure, tongue or opening controls, work support, spark control and extraction arrangement according to the machine design and current site procedure. Adjustments near the wheel require isolation. ISO 16089:2025 provides a current safety framework for specified stationary grinding machines. [S284]

11. Secure and support the workpiece

The workpiece must remain stable through contact, material removal and final separation. Use a suitable vice, clamp, fixture or machine support. Do not hold a small component in one hand while operating a grinder in the other.

For cutting operations:

- support the main workpiece and offcut so neither traps the wheel;
- anticipate residual stress, spring movement and gravity;
- plan where the offcut will fall;
- keep supports clear of the wheel path;
- maintain a straight cut path; and
- protect hoses and cables from the cut, sparks and falling material.

For grinding operations, place the work so the tool can be controlled with balanced footing and without excessive reach. Avoid positions where a loss of contact will carry the tool into the body, another person, a cable or an unprotected edge.

12. Control the work area and spark path

Establish a clear operating zone before start-up. Keep other people outside the likely fragment, spark and reaction-force areas. Use suitable screens without creating reflected hazards, blocked exits or poor ventilation.

Inspect the spark path to its full travel, including downward gaps and areas behind the work. Remove or protect combustible materials, flammable liquids, gas cylinders, hoses, cables, glass, painted surfaces, vehicles and sensitive equipment. Apply the site's hot-work controls where sparks or heat can create ignition. Confirm that extraction equipment is suitable for the material and fire or explosion hazard.

Grinding or cutting a coated, plated, contaminated or unknown material can create hazardous airborne products. Identify the substrate and surface system before work. Do not grind containers, pipework or equipment that may retain flammable, toxic or pressurised contents until the authorised preparation and verification process has made the work safe.

13. Prepare the operator

Before connecting energy, confirm:

- training and authorisation for the tool and task;
- suitable eye and face protection for the hazard;
- hearing, respiratory, hand, body and foot protection selected by risk assessment;
- close-fitting clothing, secured hair and removal of jewellery;
- clean, dry grip surfaces and stable footwear;
- a correctly fitted side handle where the tool is designed to use one;
- balanced footing and sufficient room for the expected reaction force;
- safe routing of cable or hose; and
- clear communication with nearby personnel.

Glove selection requires care. Gloves may protect against sharp edges, sparks and hot surfaces, but loose or unsuitable gloves can introduce entanglement or reduce control. Select and use them according to the task, rotating-equipment risk and site assessment.

14. Use a controlled start-up sequence

Reconnect energy only after mounting, guarding, workpiece and area checks are complete. Hold a portable tool firmly in the intended operating posture with the accessory clear of the work. Keep yourself and others out of the likely fragment plane or discharge path.

Start the tool and allow it to reach stable no-load operation. Observe sound, vibration, runout, guard security and control response. Stop and isolate immediately if anything is abnormal. Conduct the manufacturer-specified test run for the actual product and tool before applying work.

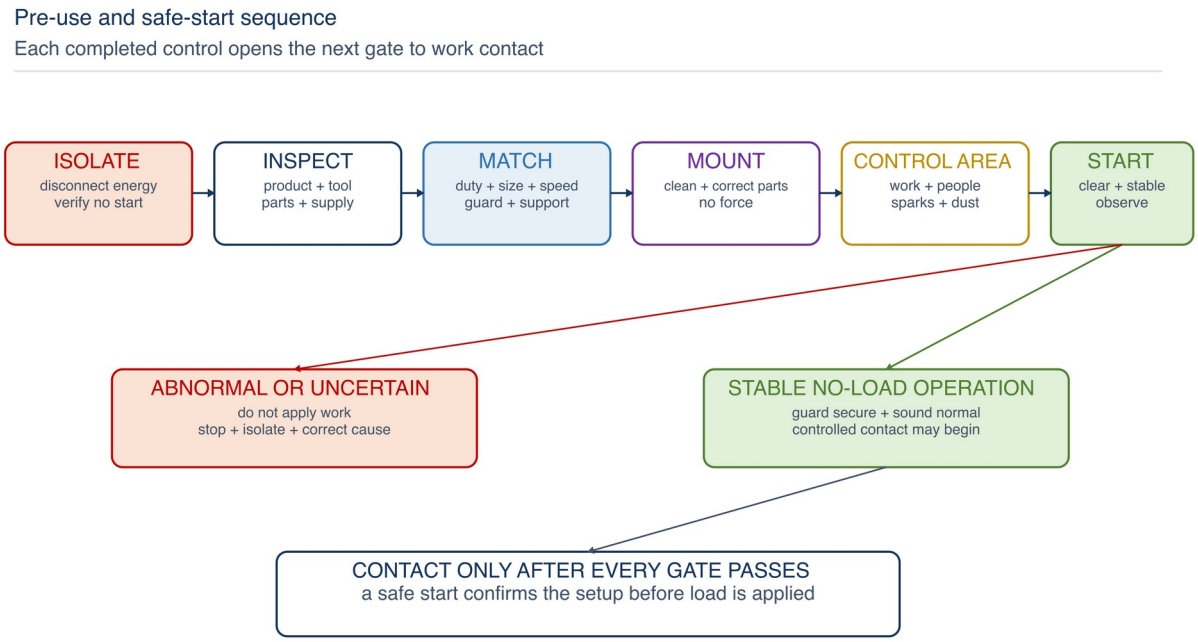

Figure 3. Pre-use and safe-start sequence. Isolation, inspection, compatibility, mounting, guarding, work-area control and stable no-load observation form a continuous gate before contact with the workpiece.

15. Grind with controlled contact

Bring the abrasive to the work smoothly after stable running is confirmed. Use a grip, body position and movement that keep the tool under control if the contact force changes. Let the abrasive cut; excessive force increases heat, loading, wear, reaction force and the likelihood of damage without guaranteeing faster work.

Maintain the contact angle and direction appropriate to the product. Avoid striking the edge, bouncing, levering, deep uncontrolled gouging or allowing the tool body and guard to collide with the work. Keep moving where the process requires it so heat and wear are not concentrated in one point.

If cutting performance declines, stop and determine why. A worn, loaded, glazed, damaged or unsuitable product should be addressed through selection and controlled replacement, not greater force.

16. Cut without side loading or binding

Use a cutting-off wheel only for the operation permitted by its marking. Keep it aligned with the cut and apply force in the radial cutting direction. Do not use the side of a cutting wheel for grinding unless the product is specifically marked and documented for that combined duty. ISO 603-16 identifies flat and depressed-centre cutting-off-wheel types intended for hand-held cutting applications; product marking remains decisive. [S279]

Avoid twisting the tool in the kerf, forcing a change of direction, striking the wheel against the work or allowing the cut to close onto the wheel. If the tool stops or the wheel binds:

899. release the control while maintaining a firm grip;
900. hold the tool still until the wheel has completely stopped;
901. remove energy and stabilise the workpiece;
902. determine and correct the cause of pinching or misalignment;
903. inspect the wheel, guard and mounting system; and
904. restart with the wheel clear of the cut, then re-enter only under the approved method.

Do not restart a portable cutting wheel while it is trapped inside the kerf.

17. Maintain control through run-down and post-use handling

After releasing the control, keep holding the tool until the abrasive has stopped completely. Do not place a running or coasting tool on a bench, floor or workpiece. Keep the accessory away from clothing, cables and people during run-down.

Isolate the energy before changing the product, clearing debris, adjusting the guard, inspecting damage or leaving the tool unattended. Treat the abrasive, workpiece, swarf and sparks landing area as hot until checked. Place tools and removed products in a stable, clean location where they cannot roll, fall, become wet or be damaged.

At task completion, inspect the tool and remaining product for abnormal wear or damage. Return reusable products to suitable controlled storage only when their identity and condition remain clear. Quarantine damaged or uncertain items so they cannot be issued accidentally.

18. Stop work when control is lost or uncertain

Stop, isolate and assess when any of the following occurs:

- unusual vibration, sound, smell, smoke or visible runout;
- cracked, chipped, torn, distorted, loaded or contaminated abrasive product;
- loose product, guard, handle, flange, backing pad or workpiece;
- binding, kickback, repeated stalling or speed instability;
- damaged cable, battery, hose, coupling, plug, switch or control;
- guard movement or contact between the product and guard;
- excessive heat, unexpected discolouration or sparks outside the controlled path;
- extraction failure or visible dust escaping the control zone;
- entry of another person, vehicle or obstruction into the work area;
- changing weather, water, ventilation or hazardous-area condition;
- loss of stable footing, visibility, grip or access; or
- uncertainty about product marking, speed, mounting or intended use.

Do not resume merely because the symptom disappears after stopping. Identify and correct the cause, replace damaged components, and repeat the full pre-use and safe-start sequence.

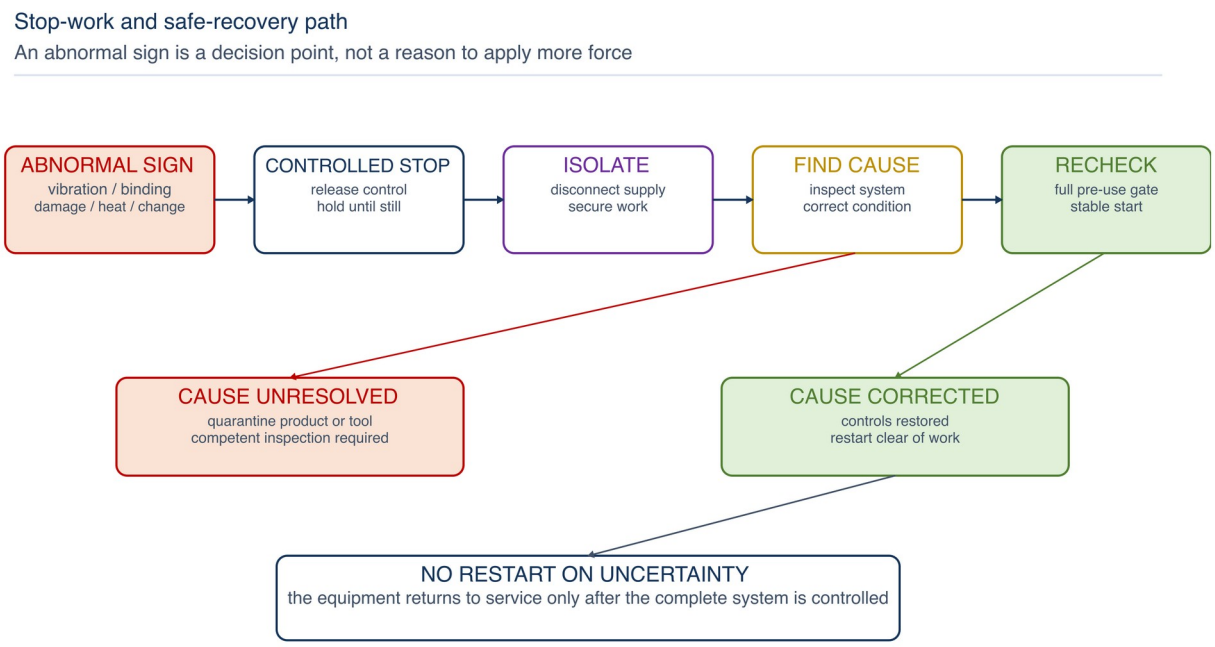

Figure 4. Stop-work and safe-recovery path. An abnormal sign leads to controlled stop, complete isolation, cause correction, inspection and a fresh start-up gate; unresolved uncertainty keeps the equipment out of service.

19. Troubleshoot unsafe symptoms

Symptom	Likely contributors	Safe response
Strong vibration immediately after start	Damaged product, dirty or mismatched flange, incorrect seating, spindle condition or incompatible mounting	Stop and isolate; remove and inspect the complete mounting system; do not test by applying work

Symptom	Likely contributors	Safe response
Wheel or disc repeatedly loosens	Incorrect mounting parts, direction, tightening method, worn spindle or incompatible product	Remove from service and verify the prescribed mounting system and tool condition
Cutting wheel binds	Workpiece closes the kerf, poor support, misalignment, twisting or excessive force	Stop, isolate and stabilise; correct support and alignment before inspecting and restarting clear of the cut
Tool kicks or climbs	Edge impact, wrong direction of approach, excessive depth, unsuitable product or unstable grip	Stop and reassess product, work support, direction, access and body position
Excessive heat or burning	Excessive pressure, poor movement, loaded or unsuitable abrasive, restricted airflow or incorrect process	Stop, allow safe cooling and correct selection, technique and ventilation
Guard cannot be positioned effectively	Incorrect tool, guard or product geometry; restricted access	Change the setup; do not remove or modify the guard
Dust escapes extraction	Poor capture position, blocked duct, insufficient airflow, unsuitable system or changed process	Stop and restore effective source control before resuming
Speed sounds unstable	Supply, regulator, battery, motor, control or tool-maintenance issue	Isolate and remove tool from service for competent inspection
Product marking is unreadable	Wear, contamination, poor storage or loss of label	Do not use until identity and all critical compatibility information are reliably established
Product performance falls suddenly	Damage, loading, glazing, contamination, material change or tool fault	Stop and inspect; do not compensate with greater force

Troubleshooting must preserve the safety boundary. Never diagnose a suspected mounting, guard, spindle or product fault while the tool is energised or coasting.

20. Abrasive safety release checklist

Before starting a grinding, cutting, sanding or polishing task, confirm:

- [ ] the task, material, coating and environment have been assessed;
- [ ] elimination, substitution and engineering controls have been considered;
- [ ] the operator is trained and authorised for the tool and task;
- [ ] product identity, intended use and marking are legible;
- [ ] operation, material, dimensions, attachment, direction and speed are compatible;
- [ ] the correct guard and mounting parts are installed and secure;
- [ ] the abrasive product, tool, spindle, handle, controls and supply are undamaged;
- [ ] mounting was completed with energy isolated and without force or improvisation;
- [ ] the workpiece and offcut are supported against movement and binding;
- [ ] the spark, fragment, dust and reaction-force zones are controlled;
- [ ] combustible material and vulnerable equipment are removed or protected;
- [ ] extraction and ventilation are operating as required;
- [ ] PPE is selected, fitted and in serviceable condition;
- [ ] cable or hose routing, footing, access and lighting are safe;
- [ ] nearby personnel are outside the controlled area;
- [ ] the no-load start is stable and free from unusual vibration or sound;
- [ ] the operator knows the stop-work conditions; and
- [ ] post-use isolation, cooling and storage arrangements are ready.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 047

Personal Protective Equipment

47

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, workshop supervisors, safety and health personnel, operators, maintenance teams, technical buyers, trainers and application personnel involved in grinding, cutting, sanding, polishing, weld preparation or chemical surface finishing

Scope: Risk-based selection, fitting, compatibility, inspection, use, care and replacement of eye, face, hearing, respiratory, hand, body and foot protection for industrial abrasive and surface-finishing work.

Core principle — PPE is a coordinated protection system for the residual hazard. Each item must suit the task, fit the wearer, remain compatible with the other items and retain its protective function throughout the work.

Personal protective equipment reduces the worker's exposure when hazards cannot be eliminated or adequately controlled by engineering and work-practice measures. It does not make an uncontrolled process acceptable. The correct sequence is to understand the task, control the source, define the remaining exposure, select documented protection, verify fit and compatibility, and supervise correct use. [S275; S288]

Chapter objectives

After this chapter, the reader should be able to:

- position PPE correctly within the hierarchy of control;
- translate abrasive-process hazards into protection requirements by body area;
- distinguish primary eye protection from supplementary face protection;
- select hearing protection using valid noise and attenuation information;
- recognise when a respiratory-protection programme is required;
- distinguish particulate filters from gas and vapour cartridges;
- select gloves for mechanical, chemical and thermal hazards without creating an entanglement risk;
- choose clothing and footwear for the actual spark, heat, chemical, impact and slip hazards;
- check that all items remain compatible when worn together;
- inspect, clean, store and replace PPE using controlled criteria; and
- troubleshoot common PPE failures before exposure occurs.

1. Begin with the residual hazard

PPE selection starts after the task and its controls have been reviewed. Identify the workpiece, coating, abrasive, process fluid, tool, work position, duration, nearby work and foreseeable upset conditions. Determine how harm could reach the worker: impact, inhalation, skin contact, eye splash, noise, heat, sharp edges or falling material.

Then apply the hierarchy:

905. eliminate unnecessary grinding, cutting or chemical handling;
906. substitute a lower-hazard material or process where practicable;
907. use guards, enclosure, local extraction, wet methods, screens, fixtures and noise control;
908. control access, competence, work sequence, exposure time and housekeeping; and
909. select PPE for the exposure that remains.

Malaysian USECHH requirements place chemical PPE after preferred control measures, or as an interim or supplementary measure where those controls do not adequately control exposure. Where chemical PPE is used, selection, issue, maintenance, inspection, training, suitability and fit must be managed as a system. [S288]

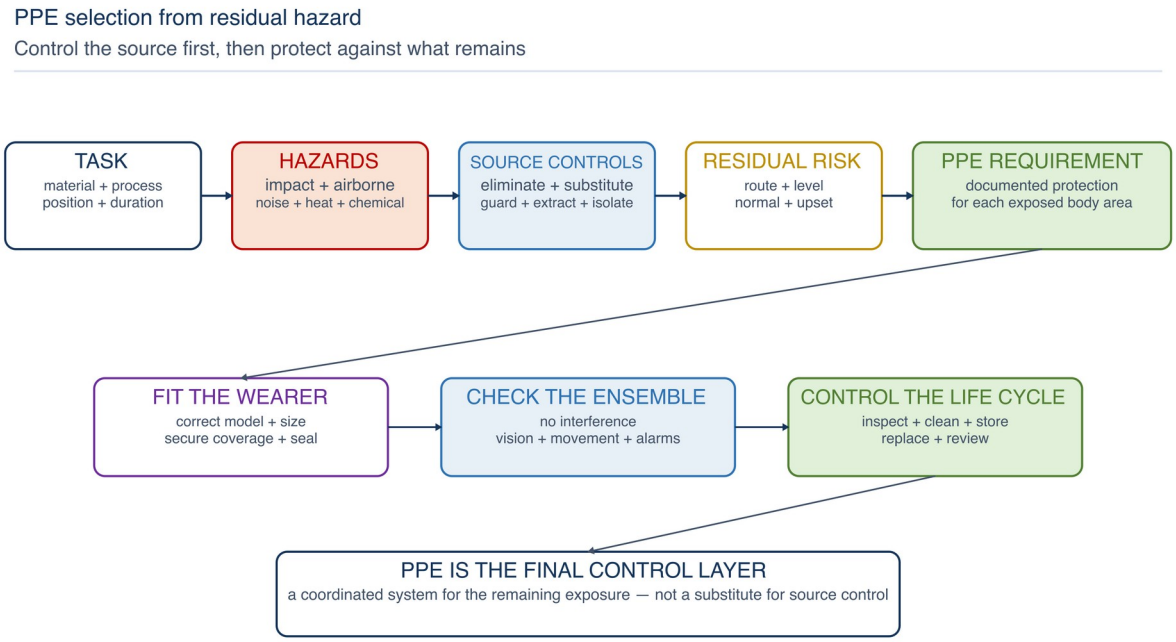

Figure 1. PPE selection from residual hazard. The task and source controls define the remaining exposure; the residual hazard then determines protection, fit, compatibility and care requirements.

2. Build the ensemble by hazard and body area

Avoid issuing one standard kit for every task. A worker may need several items, but each must answer a defined hazard.

Hazard from the task	Body area at risk	Typical protection decision
High-speed particles, fragments and swarf	Eyes and face	Suitable impact-rated primary eye protection; add appropriate face protection for broader exposure
Fine dust, fume, mist, gas or vapour	Respiratory tract	Source control first; suitable respiratory protection selected through the respiratory-protection programme
Grinding, cutting and compressed-air noise	Hearing	Suitable earplugs, earmuffs or a compatible combination selected from assessed exposure and attenuation data
Sharp edges, burrs and abrasive handling	Hands and forearms	Close-fitting mechanical-protection gloves or sleeves suited to cut, abrasion, puncture and grip needs
Chemicals and contaminated parts	Eyes, skin and respiratory tract	Chemical goggles or face protection, compatible gloves, clothing and respiratory protection as the assessment requires
Sparks, hot particles and hot surfaces	Face, torso, arms, legs and feet	Suitable face protection, clothing, gloves and footwear that resist the identified heat and particle exposure
Falling workpieces and sharp offcuts	Feet	Safety footwear with documented properties appropriate to impact, penetration, slip and other site hazards

The ensemble must protect during setup, operation, cleaning and waste handling. A worker who is protected during grinding may still be exposed while emptying a dust collector, changing a contaminated filter or handling a hot component.

3. Select eye protection for the exposure

Occupational eye protectors include spectacles, goggles and other designs with different coverage and performance. ISO 16321-1 addresses common hazards including impact, dust, splash, heat and optical radiation, together with product marking and information. [S291]

Select from the hazard outward:

- **Flying particles:** use primary eye protection with documented impact performance suitable for the task.
- **Fine airborne dust:** use a design that limits entry around the eyes; ordinary open-sided spectacles may not control dust from all directions.
- **Liquid splash:** use chemical-splash protection compatible with the liquid and exposure direction.
- **Hot particles or radiant heat:** select protection documented for the relevant thermal hazard.
- **Optical radiation:** use the correct filter and coverage for the source; clear impact lenses do not provide welding protection.
- **Prescription needs:** use compatible prescription safety eyewear or a protector designed to fit over prescription lenses without disturbing coverage.

Inspect lenses for cracks, deep scratches, chemical attack, heat damage, loose components and impaired vision. Clean them using a method that will not damage coatings or transfer abrasive grit across the lens.

4. Understand the face-shield relationship

A face shield provides broader face coverage, but it should not be treated as automatic primary eye protection. For grinding and cutting, use suitable primary eye protection beneath the selected face protection unless the documented protector system and workplace assessment specify otherwise.

Check that the shield:

- covers the foreseeable fragment and spark directions;
- is marked and documented for the hazard;
- remains down in the operating position;
- is not cracked, deeply scratched, warped or heat damaged;
- does not contact the respirator, eyewear or hearing protection;
- allows adequate peripheral vision and head movement; and
- stays secure when the operator bends or changes posture.

For welding and related processes, ISO 16321-2 adds requirements for optical radiation, impact, fragments and hot solids. Select the welding protector and filter for the actual process and exposure; do not infer suitability from lens colour alone. [S292]

5. Match the eye-and-face combination to the task

Task condition	Primary concern	Practical selection direction
Bench or angle grinding	High-speed particles, sparks and side exposure	Impact-rated primary eyewear plus suitable face protection and correctly positioned machine guard
Cutting-off	Wheel or workpiece fragments, sparks and hot offcut	Primary eyewear plus broad face coverage; maintain the controlled fragment plane and spark path
Power sanding	Dust and ejected debris	Eye protection with coverage suited to dust direction; coordinate with extraction and respirator
Wire-brush or non-woven finishing	Wire or fibre release and debris	Primary impact protection plus face coverage selected for the ejection hazard
Chemical cleaning or pickling support	Splash, mist and contaminated droplets	Chemical-splash eye protection with compatible face and skin protection as required
Weld preparation near active welding	Impact plus optical radiation	Separate the tasks or select documented combined protection for both hazards

Fogging is a control problem, not a reason to remove protection. Review ventilation, lens treatment, fit, work-rest cycles and compatibility with the respirator. Replace a protector that cannot provide clear vision without compromising coverage.

6. Select hearing protection from assessed noise

Grinding, cutting and finishing noise varies with the tool, abrasive, workpiece, enclosure, contact condition and neighbouring processes. Selection therefore requires workplace noise information rather than a generic protector rating. Malaysian Noise Exposure Regulations 2019 provide the current national framework for assessment, control, hearing protection, training and health surveillance. [S290]

ISO 4869-2 provides octave-band, HML and SNR methods for estimating protected A-weighted sound levels. The calculation method and input data must match the workplace assessment. [S294]

Consider:

- noise level, frequency character, duration and impulsive content;
- protector attenuation data and the method used to apply it;
- fit variation between workers;
- compatibility with eyewear, helmets, respirators and face shields;
- communication, alarms and situational awareness;
- heat, humidity, hygiene and the need for repeated fitting; and
- whether dual protection is required by the assessed exposure.

Avoid unnecessary over-protection that prevents communication or warning detection. Provide a suitable choice of protectors where several models meet the protection requirement; comfort and usability influence consistent wear. NIOSH also emphasises attenuation, fit, comfort, compatibility and communication rather than rating alone. [S301]

7. Fit and inspect hearing protectors

Earplugs must be inserted according to their design and training. Earmuff cushions must seal around the ear without gaps from eyewear temples, hair, headwear or respirator straps. Helmet-mounted muffs must be compatible with the helmet and attachment system.

Before use, check:

- plugs are clean, undamaged and within their intended service condition;
- reusable plugs retain their shape and flanges;
- earmuff cushions are soft, complete and sealing;
- cups, headband and attachment arms are not cracked or distorted;
- tension is adequate without unsafe modification; and
- the selected configuration matches the assessed work area.

Replace disposable products after their intended use. Replace reusable components when damaged, hardened, contaminated or no longer sealing. Store clean protectors away from dust, chemicals, heat and crushing.

8. Treat respiratory protection as a programme

A respirator is not selected by dust visibility or mask appearance. A complete programme identifies the contaminant, exposure level, physical form, oxygen condition, work rate, duration and other hazards; selects a suitable device; confirms medical suitability and fit; and controls training, inspection, cleaning, storage, filter or cartridge change, and programme review. ISO/TS 16975-1 establishes this programme approach. [S293]

The responsible person should determine:

910. what contaminants are present or can be generated;
911. whether they are particles, gases, vapours, mists or a mixture;
912. the concentration and exposure pattern;
913. whether oxygen deficiency or an immediately dangerous condition is possible;
914. the required level and duration of protection;
915. eye, skin, heat and impact hazards that affect device choice;
916. wearer medical and ergonomic factors; and
917. cleaning, storage, filter and cartridge controls.

Atmosphere-supplying equipment requires specialist selection where an air-purifying respirator is unsuitable, including oxygen-deficient or otherwise immediately dangerous environments. Do not enter such an environment on the basis of this chapter alone.

9. Distinguish particles from gases and vapours

Grinding and sanding commonly generate particles, but coatings, solvents, cleaning chemicals, heated contamination and some metals can create gases, vapours or complex fumes. A particulate filter does not protect against gases or vapours. A gas or vapour cartridge does not automatically protect against particles unless the documented configuration includes suitable particulate protection.

Airborne hazard	Selection question	Common error to prevent
Dust from metal, coating, abrasive or filler	What material is airborne, at what concentration and particle form?	Choosing a disposable mask from appearance alone
Welding or thermal fume near finishing work	What metals, coatings and process conditions contribute?	Treating all fume as ordinary nuisance dust
Solvent or coating vapour	Which chemical and concentration must the cartridge address?	Assuming a particulate filter removes vapour
Acid or alkaline mist	Is the hazard liquid aerosol, vapour or both?	Selecting only for splash and ignoring inhalation
Mixed contaminant	Which combined device and change control are documented?	Combining unapproved components or relying on odour
Unknown or oxygen-deficient atmosphere	Is air-purifying protection prohibited?	Entering before competent atmospheric assessment

Use the safety data sheet, workplace assessment and respirator manufacturer's selection information together. Refer to the product label, Technical Data Sheet, or MKTECH representative.

10. Control respirator fit and facial seal

Tight-fitting respirators depend on a continuous face seal. Fit testing must be specific to the make, model, style and size used. A user seal check is performed each time the respirator is donned, following the manufacturer's method; it does not replace fit testing. [S300]

Hair, stubble, jewellery, eyewear parts, headwear or facial features must not cross or disturb the sealing surface. Reassess fit after a model or size change and when facial, dental or body changes could affect the seal. Respirator straps should not be moved merely to accommodate other PPE if that changes the approved wearing position.

Stop and leave the exposure area safely if breathing resistance rises unexpectedly, the seal fails, contamination is tasted or smelled, the device is damaged, airflow alarms activate, or physical distress occurs. Investigate the cause before reuse.

11. Manage filters, cartridges, cleaning and storage

Filter and cartridge service life depends on the device, contaminant, concentration, humidity, temperature, breathing rate and use pattern. Establish the change method from the workplace programme and manufacturer information. Odour, taste or irritation is not an acceptable primary change schedule.

After use:

- remove PPE without transferring contamination to the face or clean clothing;
- dispose of single-use components through the applicable waste route;
- clean reusable parts with the specified method;
- inspect facepiece, valves, seals, straps, threads and connectors;
- dry fully without damaging heat or sunlight;
- record controlled maintenance where required; and
- store in a clean, sealed or protected container without deforming the facepiece.

Never wash a disposable filter, use compressed air to clean it, mix components from incompatible systems or repair a respirator with improvised parts.

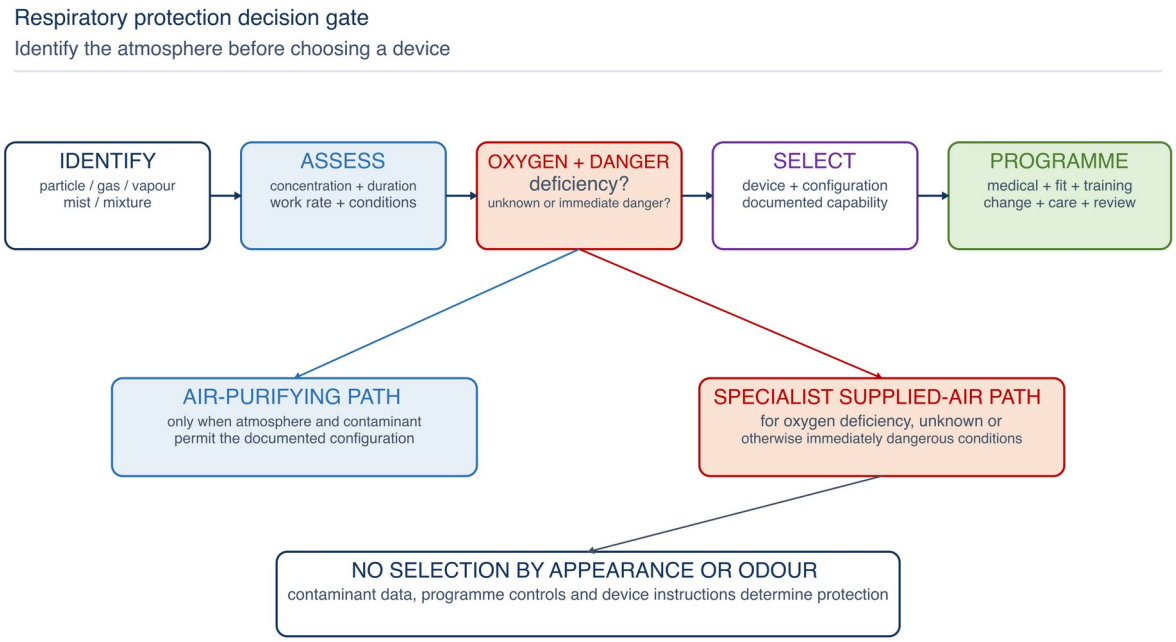

Figure 2. Respiratory protection decision gate. Contaminant identity, concentration, oxygen condition and work factors determine whether air-purifying protection can be considered and which programme controls must follow.

12. Select gloves by hazard—not material name

ISO 21420 covers general glove design, construction, comfort, marking and information, but it does not establish hazard-specific protection by itself. Use it with the relevant mechanical, chemical or thermal standard. [S295]

Mechanical-risk selection should consider abrasion, blade cut, tear, puncture, impact, grip and dexterity. ISO 23388 addresses these mechanical properties, but a single performance level does not describe every sharp-edge or puncture hazard. [S296]

Chemical-glove selection requires the actual chemical, mixture, concentration, temperature, contact type and expected duration. ISO 374-1 addresses chemical-risk terminology and performance requirements. Breakthrough, permeation and degradation information for one chemical must not be transferred automatically to another. [S297]

Glove duty	Key selection factors	Stop-use signs
Handling unused abrasive products	Grip, cleanliness, dexterity and avoidance of product contamination	Torn, oily or grit-embedded surface
Handling burrs and sharp sheet	Cut, puncture and abrasion needs balanced with secure grip	Cuts, holes, worn coating or exposed liner
Handling hot finished work	Documented contact-heat protection, cuff and dexterity	Charring, stiffening, shrinkage or heat felt through glove
Chemical preparation or cleanup	Chemical-specific compatibility, cuff length, splash direction and change time	Swelling, softening, cracking, colour change or contamination inside
Precision measurement after finishing	Cleanliness, tactile control and part protection	Glove interferes with safe instrument control or contaminates surface

13. Prevent glove-related entanglement

Gloves can protect against sharp edges and heat, yet they can also be caught by rotating spindles, chucks, drills, shafts or exposed moving parts. The machine and task assessment must decide whether gloves may be worn during operation. Never reach toward a moving abrasive product, rotating workpiece or drive system with a gloved or bare hand.

Use guards, fixtures, brushes, hooks or handling tools to keep hands out of danger. Isolate and verify complete stop before measuring, clearing swarf, adjusting, cleaning or changing the setup. Choose close-fitting gloves where gloves are permitted; loose cuffs, damaged fingers and excess material reduce control and increase snagging risk.

14. Choose clothing for sparks, heat and contamination

Work clothing should fit closely enough to avoid entanglement while covering exposed skin against the assessed sparks, hot particles, sharp edges and contamination. Secure sleeves and collars. Remove jewellery, secure long hair and avoid open pockets, cuffs or trouser turn-ups that can collect hot particles.

For welding and allied-process hazards, ISO 11611:2024 covers clothing such as hoods, aprons, sleeves and gaiters for specified spatter, flame, radiant-heat and optical-radiation risks. It does not replace eye, face, hand or foot protection. [S299]

Do not assume ordinary cotton, synthetic workwear or a leather apron has a defined protective performance. Select documented properties for the exposure. Keep clothing clean; oil, solvent, metal dust and other contamination can change fire behaviour or skin exposure. Remove contaminated clothing by a method that prevents transfer to the wearer, other workers, vehicles or homes.

15. Select footwear for the workplace and task

ISO 20345:2021 with Amendment 1:2024 specifies general-purpose safety-footwear requirements and optional properties, including mechanical, slip, thermal and ergonomic aspects. Special chemical, electrical, molten-metal and other risks require relevant additional protection. [S298]

Assess:

- falling workpieces, tools and abrasive products;
- sharp offcuts and floor debris;
- wet, oily, dusty or uneven walking surfaces;
- sparks, hot particles and hot metal;
- chemicals and contaminated liquids;
- electrical or electrostatic conditions;
- ladder, platform and driving duties; and
- fit, support and heat comfort during the full shift.

Keep trouser legs arranged so sparks and debris cannot enter the footwear. Inspect uppers, seams, fastenings, soles and protective components. Remove footwear from service when damage, contamination or excessive wear compromises the required property.

16. Verify ensemble compatibility

PPE items that pass individual inspection can fail when combined. Spectacle arms may break an earmuff seal; a face shield may push a respirator; helmet fittings may prevent muffs from closing; straps may cross and move each other; goggles may redirect exhaled air and fog.

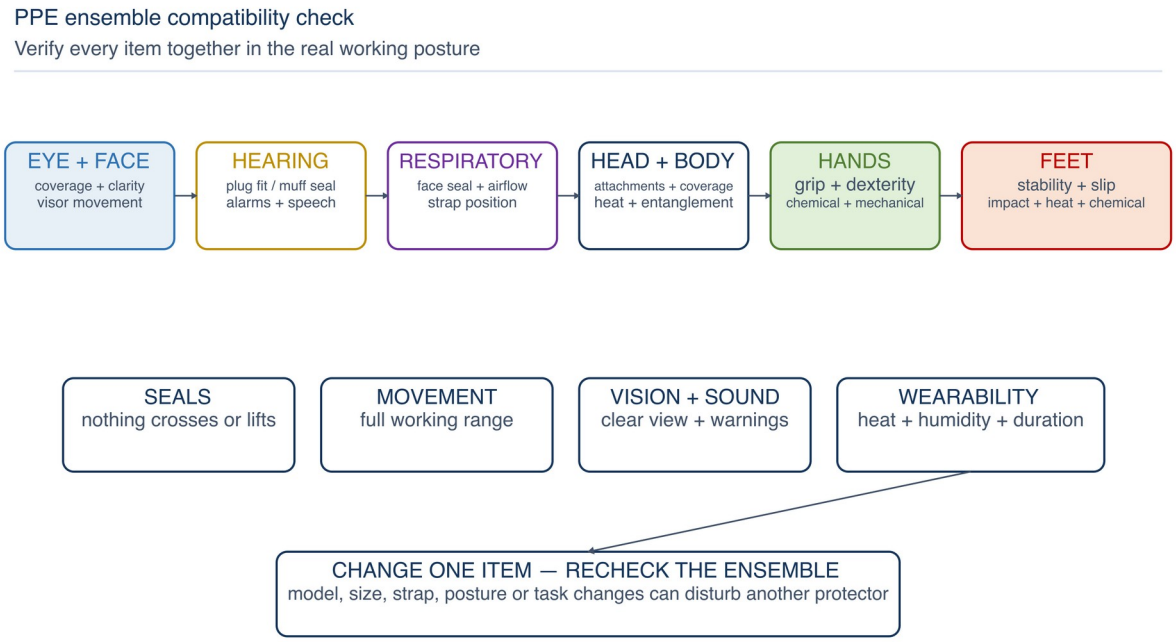

Figure 3. PPE ensemble compatibility check. Coverage, seals, movement, vision, hearing, communication and heat burden are verified with every required item worn in the working posture.

Conduct the compatibility check with the complete ensemble:

918. don each item in the trained sequence;
919. check eye, face, skin and respiratory coverage;
920. verify respirator and earmuff seals;
921. move the head, shoulders and arms through the working range;
922. adopt the actual bending, kneeling or overhead posture;
923. verify vision, communication and alarm recognition;
924. confirm that sweat and heat will not predictably defeat fit; and
925. repeat after any item, model, size or task changes.

Malaysian heat and humidity make comfort and moisture management operational issues. Provide clean replacement items, suitable rest and hygiene arrangements, and a selection that workers can wear correctly for the required period.

17. Inspect, clean, store and replace systematically

PPE category	Pre-use check	Care and replacement trigger
Eye and face	Lens or visor clarity, cracks, marking, frame, side coverage and adjustment	Clean without scratching; replace for damage, severe abrasion, chemical attack or insecure fit
Hearing	Plug condition, cushion seal, cup, band and attachment	Replace soiled disposables and hardened, cracked or non-sealing reusable parts
Respiratory	Correct identity, facepiece, valves, straps, filters, cartridges, battery and alarms	Follow programme cleaning and change control; replace damaged or contaminated parts
Gloves and sleeves	Correct type, holes, coating, seams, contamination and fit	Replace for wear, penetration, degradation, internal contamination or loss of grip
Clothing	Correct garment, closures, holes, burns, contamination and coverage	Repair only by an approved method; replace when protective integrity is uncertain
Footwear	Upper, toe area, sole, tread, penetration layer, seams and contamination	Replace when worn, cut, separated, contaminated or no longer stable and protective

Separate clean PPE from used or contaminated items. Store products away from sunlight, heat, moisture, chemicals, dust, crushing and distortion as applicable. Do not mark, drill, paint or modify PPE unless the manufacturer permits the method.

18. Troubleshoot PPE problems

Symptom	Likely contributors	Corrective action
Eyewear repeatedly fogs	Poor compatibility, high humidity, blocked airflow, worn treatment or incorrect fit	Stop safely; review fit, ventilation, lens condition and a documented anti-fog solution
Face shield rises or contacts tool	Loose adjustment, incompatible headgear or wrong working posture	Replace or adjust the compatible system; do not continue with reduced coverage
Earmuff seal gaps at spectacles	Thick temple arms, poor cup position or incompatible combination	Select compatible eyewear or hearing protection and verify fit on the wearer
Earplugs loosen during shift	Incorrect size, insertion, contamination or jaw movement	Retrain fitting and provide another suitable size or model
Respirator leaks at nose or cheeks	Incorrect size or model, facial hair, strap interference, damage or poor donning	Leave exposure safely; correct the cause and repeat the required checks before entry
Breathing resistance increases	Loaded filter, wet media, blocked component or high work rate	Leave exposure safely and follow the programme's inspection and change procedure
Chemical glove swells or softens	Incompatible material, concentration, temperature or excessive contact time	Stop contact, remove safely, decontaminate as directed and select documented compatibility
Glove reduces tool control	Excess bulk, poor fit, contamination or unsuitable grip	Stop and reassess glove and handling method; never trade control for nominal protection
Sparks enter clothing or footwear	Open cuff, pocket, damaged closure or wrong garment arrangement	Stop, extinguish and cool safely; correct coverage before restarting
PPE is removed in the work zone	Heat, discomfort, communication, fogging or poor supervision	Stop the task and redesign selection, compatibility, work–rest and control arrangements

Repeated discomfort is useful safety information. Investigate it; do not normalise partial wear, loosened straps or lifted visors.

19. PPE release checklist

Before exposure begins, confirm:

- [ ] the task, materials, airborne contaminants, noise, sparks, heat and chemicals are understood;
- [ ] source and engineering controls are operating;
- [ ] residual hazards have been mapped to each exposed body area;
- [ ] every PPE item has documented suitability for its assigned hazard;
- [ ] the correct make, model, size and configuration have been issued;
- [ ] primary eye protection and supplementary face protection are correctly combined;
- [ ] hearing protection is based on assessed noise and valid attenuation information;
- [ ] respiratory protection is controlled under the workplace programme;
- [ ] tight-fitting respirator fit and seal conditions are satisfied;
- [ ] filters and cartridges are correct, in service condition and within change control;
- [ ] gloves suit the mechanical, chemical or thermal hazard without unsafe entanglement;
- [ ] clothing covers exposed skin and cannot trap sparks or enter moving parts;
- [ ] footwear suits impact, penetration, slip, heat, chemical and site conditions;
- [ ] all items remain compatible through the full working posture;
- [ ] vision, communication, alarms and movement remain adequate;
- [ ] inspection, cleaning, storage and replacement arrangements are ready; and
- [ ] the wearer knows when to stop, leave the exposure area and report a problem.

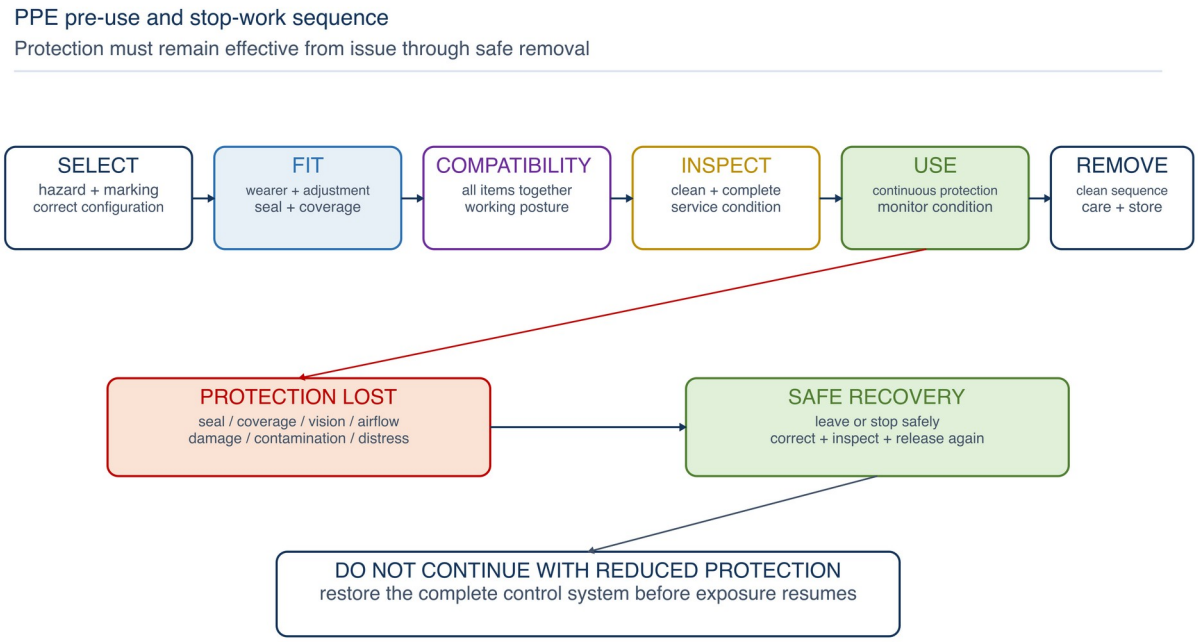

Figure 4. PPE pre-use and stop-work sequence. Selection and issue are followed by fit, ensemble compatibility and pre-use inspection; any loss of protection leads to safe exit, correction and a fresh release check.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 048

Dust, Fume and Ventilation

48

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, workshop supervisors, safety and health personnel, operators, maintenance teams, technical buyers and application personnel involved in grinding, cutting, sanding, polishing, weld preparation and industrial surface finishing

Scope: Identification and control of dust, fume, mist, gas and vapour; source capture; local exhaust ventilation; wet methods; general ventilation; daily checks; maintenance; housekeeping; waste handling and troubleshooting.

Core principle — Effective airborne-contaminant control begins at the point of generation. Capture or suppress the emission before it crosses the worker's breathing zone, then verify that the complete control system remains effective during the real task.

Grinding and surface finishing can release material from the workpiece, coating, abrasive and process residue. Adjacent welding, thermal cutting, cleaning and coating work may add fume, mist, gas or vapour. The appropriate control depends on what is released, how it moves and where people stand—not simply on whether a cloud can be seen. Malaysian chemical-health requirements place engineering control ahead of personal protective equipment and require the workplace to assess and control actual exposure. [S275; S288]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish dust, fume, mist, gas and vapour;
- identify the materials contributing to an airborne mixture;
- select elimination, substitution, enclosure, wet methods or local extraction in the correct order;
- distinguish source capture from general room ventilation;
- position an extraction hood relative to the source, emission direction and operator;
- explain the function of each component in an LEV system;
- recognise common causes of lost capture and poor transport;
- carry out practical pre-use checks without treating them as commissioning tests;
- coordinate extraction with make-up air, workpiece movement and neighbouring processes;
- control filter, collector and dust-disposal work;
- identify conditions that require the task to stop; and
- troubleshoot common ventilation failures systematically.

1. Identify what becomes airborne

Begin with every material that can enter the process. The airborne mixture may contain base metal, alloying elements, rust, scale, paint, plating, oil, adhesive, filler, abrasive grain, bond material, polishing compound or cleaning residue. Heating can change the form and chemistry of contamination. A coating that appears harmless while cold may release a different mixture when ground or heated.

Airborne form	How it is commonly generated	Practical control implication
Dust	Mechanical fracture, abrasion, sanding, grinding, cutting or dry handling	Capture particle momentum close to the tool; prevent deposits and re-suspension
Fume	Condensation of material vaporised by welding, thermal cutting or intense heat	Capture the rising or process-driven plume close to formation without disturbing the process
Mist	Atomised or mechanically dispersed liquid from sprays, coolants or wet processes	Control droplets at the source and prevent contaminated liquid accumulation
Gas	Process reaction, combustion, decomposition or shielding-gas displacement	Identify the gas and assess ventilation, accumulation and oxygen conditions
Vapour	Evaporation of solvent, cleaner, coating or other volatile liquid	Prefer containment and closed handling; assess ignition and chemical hazards

Particle size cannot be judged reliably by sight. A settling layer proves that material escaped, but the absence of visible dust does not prove acceptable air quality. Odour is equally unreliable because some hazardous substances have little warning property and sensory response varies between people.

2. Map the emission to the real task

Observe the complete work cycle: setup, initial contact, continuous operation, repositioning, abrasive change, cleaning and waste removal. Record where the emission starts, its direction and momentum, how the tool and workpiece move, where the operator breathes and what cross-draughts are present.

Ask:

926. Which materials can contribute to the airborne mixture?
927. Does the process fracture material, heat it, atomise liquid or evaporate chemicals?
928. Is generation continuous, intermittent or concentrated at entry and exit?
929. Does a rotating abrasive eject particles tangentially?
930. Does a hot plume rise, or is it driven sideways by the process?
931. Can the workpiece remain inside an enclosure or close to a hood?
932. Does the operator stand between the source and the hood?
933. Do doors, fans, vehicles or compressed air disturb capture?
934. What happens during cleaning, filter changes and waste disposal?

The workplace chemical-risk assessment and exposure-monitoring programme determine whether control is adequate. A generic tool description, room volume or visible-dust impression cannot replace that assessment. [S288; S303]

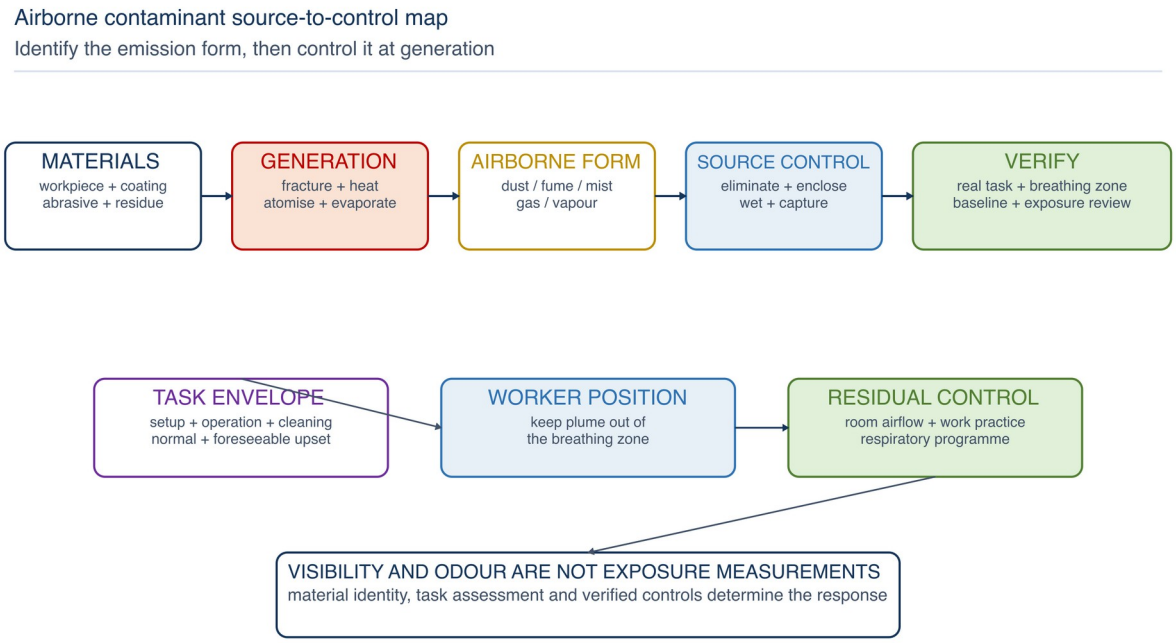

Figure 1. Airborne contaminant source-to-control map. Material identity and generation mechanism determine the airborne form; the source control is then verified through the complete task and worker position.

3. Apply the control hierarchy at the process

Control is most dependable when generation is prevented or the source is enclosed. Consider the following sequence:

935. eliminate unnecessary abrasive or chemical work;
936. remove hazardous coatings or residues by a safer controlled method before hot or abrasive work;
937. substitute a lower-emission material, process or product where technically suitable;
938. automate, isolate or fully enclose the operation;
939. use compatible wet methods or tool-integrated extraction;
940. capture remaining emissions with correctly designed LEV;
941. use general ventilation to manage background contamination and replacement air;
942. control access, work sequence, cleaning and maintenance; and
943. select respiratory protection for the residual exposure through the workplace programme.

Wet methods are not automatically suitable. Water or process fluid must be compatible with the electrical tool, abrasive product, workpiece, downstream finish, collected material and waste route. Avoid using a wet method where it creates

electrical, corrosion, reaction, slip or contamination hazards. Exact product compatibility must be confirmed. Refer to the product label, Technical Data Sheet, or MKTECH representative.

4. Distinguish local extraction from general ventilation

Local exhaust ventilation captures contamination close to its source and conveys it away for separation and safe discharge. General ventilation supplies and removes room air to dilute background contamination and control overall air movement.

Control	Best use	Limitation to recognise
Tool-integrated extraction	Mobile sanding or grinding where the extraction point follows the abrasive contact	Small passages and hoses block easily; connection and airflow must suit the complete system
Partial or full enclosure	Repetitive work that can remain within a controlled opening	Large openings, poor part positioning or open access reduce containment
Captor or receiving hood	A predictable plume or particle trajectory	Capture declines rapidly when distance increases or cross-draughts dominate
Downdraught or backdraught surface	Work that can be positioned over or in front of a distributed capture area	Covered or overloaded areas and poor workpiece position can short-circuit airflow
General room ventilation	Make-up air, background dilution and control of room airflow	Does not reliably capture concentrated emissions at the worker's breathing zone

Using a pedestal fan to blow a cloud away from one operator may move it toward another person, an ignition source or an unprotected work area. Air movement should form part of a designed path from clean air, past the operator where appropriate, toward the capture point and safe discharge.

5. Capture close to the point of generation

The hood is the interface between the process and the ventilation system. DOSH identifies it as the most important LEV component because it must collect the contaminant into the airflow. Hood position should account for emission direction, worker position and room airflow. [S302]

Practical positioning rules are:

- keep the capture point as close as the task safely permits;
- use the natural or process-driven movement of the contaminant;
- place the hood so contamination moves away from the breathing zone;
- minimise the open area that must be controlled;
- avoid placing large workpieces between the source and the hood;
- reposition a movable hood whenever the source moves;
- keep guards, fixtures and extraction working together; and
- do not allow a hose or hood to interfere with tool control, visibility or emergency movement.

An exterior hood must pull air across a distance and is therefore sensitive to separation and cross-draughts. Enclosing hoods use inward airflow at an opening and are generally less vulnerable when the process can be contained. A receiving hood can use the momentum of a plume or particle stream, but it must be large and correctly located for all expected directions.

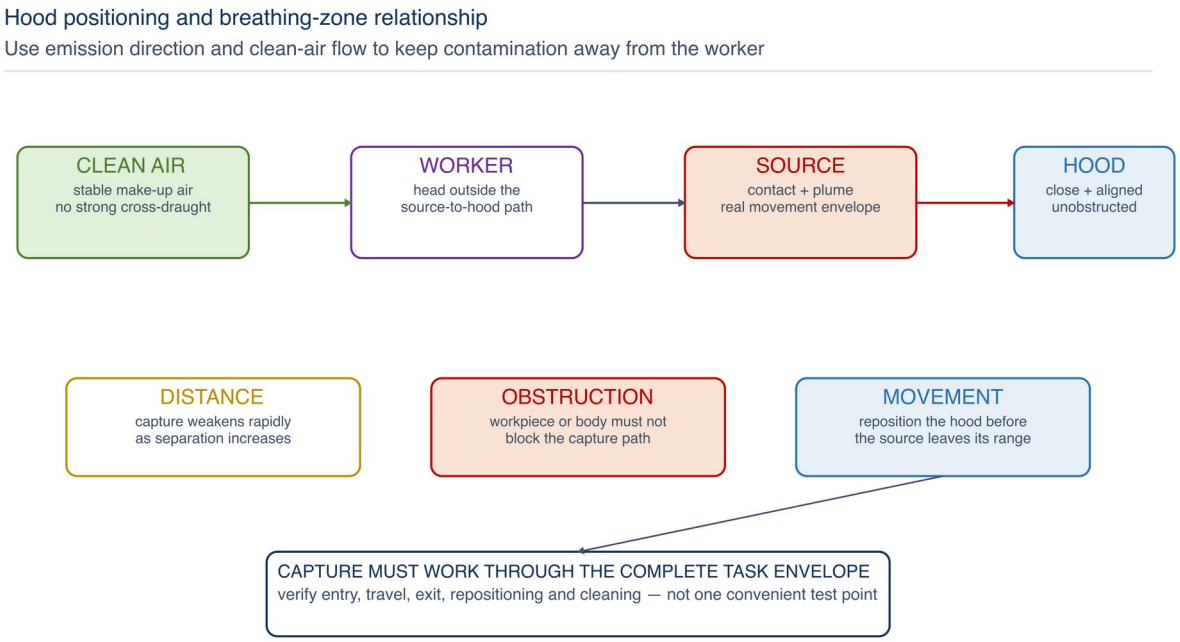

Figure 2. Hood positioning and breathing-zone relationship. Stable clean-air movement supports capture when the worker remains outside the contaminant path and the hood stays close, aligned and unobstructed.

6. Match capture to abrasive motion

Rotating tools eject material in a directional path. Extraction placed on the wrong side of the contact may collect settled debris while the airborne fraction passes the operator. Determine tool rotation, contact point, spark path, wheel or belt travel and workpiece obstruction before selecting hood position.

Application	Preferred control concept	Positioning focus
Bench or pedestal grinding	Close-fitting ventilated guard or enclosure integrated with the machine	Collect near the wheel periphery and work contact without weakening the safety guard
Belt sanding	Enclosure and extraction at the belt contact and carry-off direction	Control both primary ejection and material carried around the belt
Disc or orbital sanding	Tool-integrated extraction with suitable perforated abrasive and backing system	Maintain alignment of extraction holes and an unrestricted hose path
Portable grinding on large work	Movable capture or partial enclosure where practicable	Reposition capture as the contact point moves; keep the operator out of the source-to-hood path
Polishing or buffing	Receiving or enclosing hood arranged for the wheel's throw direction	Account for lint, compound, heat and combustible deposits
Abrasive cutting	Enclosure or local capture compatible with guard and cut path	Do not modify the guard or create binding to improve extraction

NIOSH work on ventilated sanders supports the principle that extraction integrated close to the sanding interface can materially reduce dust for the assessed application. That evidence does not establish performance for another tool, abrasive, material or extraction unit. [S306]

7. Control welding and thermal-process fume nearby

Surface preparation often occurs beside welding, gouging or thermal cutting. Treat these emissions as process-specific fume and gas hazards rather than ordinary grinding dust. ISO 21904-1 addresses equipment for capturing and separating welding fume, including hoods, ducting, filter units, air movers and unsafe-operation indication; it specifically does not establish requirements for general ventilation or grinding dust. [S307]

Position a welding-fume capture device close enough to intercept the plume without disturbing shielding gas, process stability or the welder's access. When the joint progresses, the capture point must progress with it unless an enclosing or

distributed system maintains effective capture. ISO 21904-4 provides methods for establishing minimum flow for specified captor hoods, nozzles and on-gun devices; it does not provide a universal setting for every extraction arrangement. [S309]

Grinding extraction and welding-fume extraction may share some engineering principles, but their contaminants, emission motion, equipment standards and fire-loading conditions differ. Confirm that the entire collection system is suitable for the connected processes.

8. Understand the complete LEV chain

An LEV system is only as effective as its connected components:

Component	Function	Typical loss-of-control condition
Hood or enclosure	Receives or captures contamination	Too far away, damaged, obstructed or poorly positioned
Branch connection	Carries air from one hood into the system	Loose joint, closed damper, crushed flexible section or material buildup
Ductwork	Transports contamination toward separation	Leakage, corrosion, dents, blockage, poor branch balance or deposition
Air cleaner or separator	Removes collected material from the airstream	Loaded, damaged, unsuitable, leaking or incorrectly serviced element
Air mover	Produces pressure and airflow	Wrong rotation, belt slip, wear, fouling, power loss or unstable operation
Discharge	Releases exhaust to a controlled location	Recirculation into air intakes, doors, neighbours or occupied areas
Make-up air	Replaces extracted air without harmful disturbance	Strong cross-draught, negative pressure, blocked inlet or contaminated supply
Indicators and controls	Show operating state or control condition	Alarm ignored, gauge unreadable, baseline absent or interlock defeated

Changing one branch, hood, damper, filter or fan can affect other parts of a multi-branch system. Do not add extraction points or alter duct geometry without competent review and rebalancing.

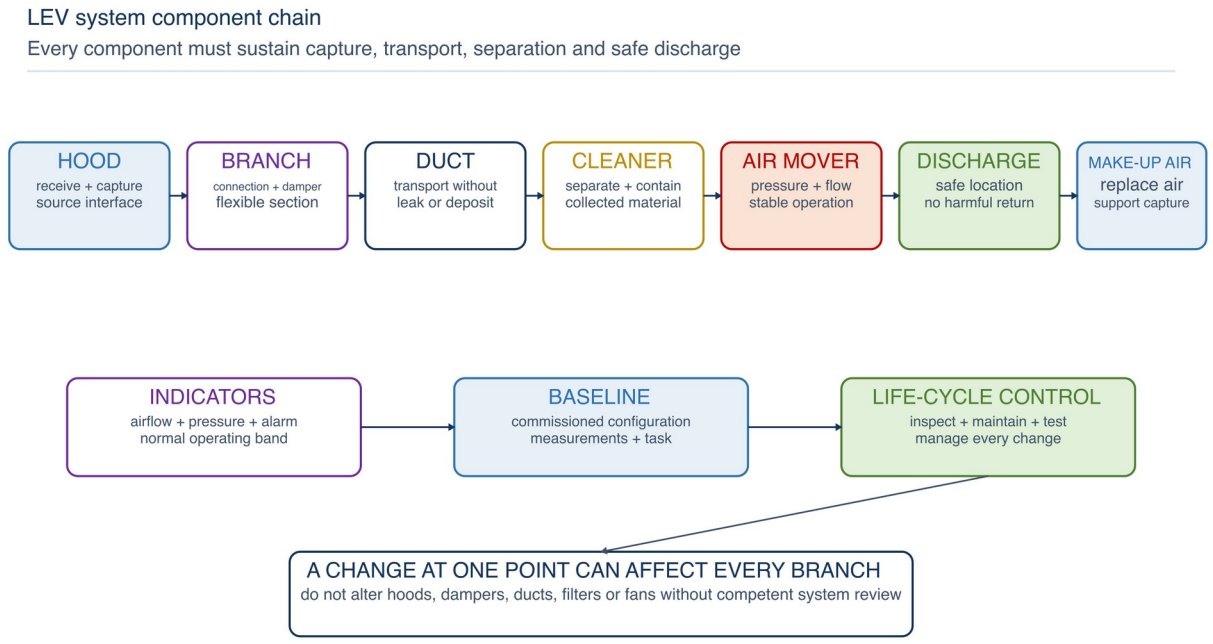

Figure 3. LEV system component chain. Capture, transport, separation, air movement, discharge and replacement air function as one system supported by indicators, baseline data and life-cycle control.

9. Manage make-up air and cross-draughts

Extracted air must be replaced. If make-up air is insufficient, doors may become difficult to open, unwanted air may enter through dirty areas, combustion equipment may be affected and capture may deteriorate. If replacement air arrives as a high-velocity draught across an open hood, it can push contamination out of the capture zone.

Check the effect of:

- open roller shutters and doors;
- pedestal or ceiling fans;
- compressed-air jets;
- vehicle movement;
- air-conditioning diffusers;
- neighbouring exhaust systems;
- large moving workpieces; and
- the operator's body and clothing.

Arrange replacement air so it supports the intended flow pattern without cooling, discomfort or process interference. Smoke visualisation or another suitable tracer may help a competent person evaluate direction, but tracer substances must be appropriate to the workplace and must not create an exposure or product-contamination hazard.

10. Use wet methods as an engineered control

Wet methods can reduce airborne dust by applying liquid at the generation point and keeping collected material from drying. They work best when delivery remains continuous at the active contact and slurry is removed before it dries or spreads.

Before use, verify:

- the tool and electrical installation permit the method;
- the abrasive product is intended for wet use;
- the liquid does not react with the workpiece or contaminant;
- corrosion and finish-quality consequences are acceptable;
- splash and mist are controlled;
- floors and access routes remain safe;
- slurry cannot enter unsuitable drains; and
- the waste route suits the collected material.

NIOSH silica guidance supports wet methods and local extraction for silica-containing work, while also discouraging practices that re-suspend deposited dust. Apply that material-specific guidance only when silica may be present. [S311]

11. Commission against the actual process

Commissioning proves that the installed system performs its intended function with the real process, hood positions, branch configuration, make-up air and work practices. It should establish baseline information that later checks and examinations can compare.

Commissioning should address:

944. process and contaminant description;
945. hood type, position and intended operating envelope;
946. operator and workpiece positions;
947. airflow and pressure measurements at defined points;
948. air-cleaner and air-mover performance;
949. make-up air and cross-draught effects;
950. discharge location and recirculation risk;
951. exposure-control verification;
952. alarms, indicators and interlocks;
953. cleaning, waste and maintenance arrangements; and
954. information, instruction and training for users.

DOSH guidance calls for a newly installed system to be tested and examined so design performance and adequate extraction can be verified, with the results retained as baseline data. [S302]

12. Perform a practical pre-use check

Operators should confirm that the control is available before generating contamination. A pre-use check does not replace competent inspection or testing.

Check point	Acceptable operating indication	Stop and correct when
Correct extraction point	Intended hood or tool connection is fitted and positioned	Wrong branch, missing adapter or capture cannot follow the work
Physical condition	Hood, hose, duct and connections are complete and secure	Split hose, crushed section, loose joint, damaged hood or visible leakage
Airflow indication	Indicator, gauge or alarm shows the normal released condition	Reading is abnormal, absent, unstable or outside the defined operating band
Capture behaviour	Emission moves into the hood throughout the task envelope	Cloud escapes, crosses the breathing zone or spreads into the room
Collector condition	Differential indication and service state are acceptable	Filter or collector alarm, damage, overflow or unsafe dust accumulation
Make-up air	Doors, fans and room airflow support capture	Cross-draught defeats the hood or room pressure changes unexpectedly
Waste arrangement	Closed, compatible container and safe change method are ready	Waste route is open, incompatible, full or likely to release dust

If extraction fails, stopping generation is normally the first safe response. Do not continue merely by opening a door, adding a fan or wearing an unselected respirator.

13. Keep the worker out of the contaminant path

Even a well-designed hood can be defeated by poor working position. The operator should not lean between the source and the capture point. Arrange fixtures, lighting and work height so the source remains visible without placing the face above a rising plume or in the tangential ejection path.

When a part must be rotated, plan the sequence so the capture point remains effective. For large work, divide the task into controlled zones and reposition movable extraction before restarting. Keep hoses supported so they do not pull a hand tool off line, snag the workpiece or encourage the operator to disconnect extraction.

14. Inspect, test and maintain systematically

DOSH guidance describes regular physical inspection, observation of use, airflow indication, air-cleaner condition and fan maintenance, together with competent testing and examination against baseline performance. [S302]

Maintenance should cover:

- hood damage, corrosion, coating loss and obstruction;
- hose wear, crushing, holes and insecure cuffs;
- duct leakage, deposits, dents, corrosion and loose access covers;
- damper position and branch balance;
- filter loading, seal integrity and cleaning mechanism;
- collector hopper or receptacle level;
- fan noise, vibration, rotation, drive and bearing condition;
- indicator, alarm and interlock operation;
- make-up air paths and discharge condition; and
- changes to process, material, tool, layout or work practice.

Isolate hazardous energy before opening, clearing or maintaining the system. Assess chemical, confined-space, fire, explosion, sharp-object, work-at-height and manual-handling hazards before internal access or collector servicing.

15. Control collected dust and filter changes

Capture transfers contamination from the air into hoses, ducts, filters, collectors and waste containers. It does not remove the need to control exposure during servicing.

Use a method that:

- stops and isolates the generating process and extraction equipment;
- prevents unexpected fan start or damper movement;
- avoids dropping, shaking or blowing dust from filters;
- contains contaminated elements during removal;
- uses compatible sealed waste containers;
- prevents mixing of reactive or incompatible materials;
- cleans external contamination before equipment leaves the controlled area;
- protects maintenance personnel for the assessed exposure; and
- returns the system to service only after inspection and functional checks.

Do not use ordinary domestic vacuum cleaners for hazardous industrial dust unless the complete unit and collection method are documented as suitable. Do not use compressed air or dry brushing where it can re-suspend hazardous dust.

16. Treat combustible or reactive dust separately

Some metal, organic, coating and polishing residues can burn, react or form an explosive atmosphere when finely divided. A collector that is appropriate for inert dust may be unsuitable for combustible metal dust, hot sparks or mixed residues.

Before connecting a process, determine:

955. whether the dust can burn, react with water or react with another collected material;
956. whether hot particles or sparks can reach the collector;
957. whether ducts can accumulate hazardous deposits;
958. whether the fan, filter, collector, bonding, grounding, discharge and protection systems suit the hazard;
959. whether recirculation is permitted; and
960. how collected material will be emptied, stored and disposed of.

Keep incompatible processes on separately assessed systems. Never connect a new metal, coating or polishing compound to an existing collector solely because a hose connection fits. Fire and explosion controls are developed further in Chapter 050.

17. Diagnose control loss from the source outward

Symptom	Likely contributors	Corrective direction
Dust escapes at the contact point	Hood too far away, wrong side of ejection, workpiece obstruction or cross-draught	Stop; reposition or redesign capture and repeat the release check
Extraction weak at one branch	Closed damper, crushed hose, blockage, leak or branch imbalance	Isolate as required; inspect the branch and restore the verified configuration
All branches are weak	Loaded collector, fan or drive fault, blocked main, lost make-up air or system alteration	Stop affected processes and arrange competent system diagnosis
Filter loads unusually quickly	Excess generation, wrong separator, wet or sticky material, poor pre-separation or process change	Identify the changed contaminant and review collector suitability
Dust deposits inside duct	Transport is inadequate, duct is damaged or material is unsuitable for the system	Stop and assess fire, exposure and cleaning hazards before controlled removal
Hood capture changes when a door opens	Make-up air or cross-draught is uncontrolled	Stabilise room airflow and verify capture under normal operating conditions
Operator disconnects the hose	Poor ergonomics, excessive hose drag, blockage, noise or incompatible adapter	Correct the system and handling arrangement; do not normalise bypassing the control
Fume passes the breathing zone	Capture is behind the operator, too distant or not moved with the joint	Stop and place capture so the plume travels away from the breathing zone
Visible discharge near the building	Separator fault, leak, unsuitable discharge or recirculation	Stop affected work and prevent exposure until competent correction and verification

Troubleshooting should compare the present condition with commissioning data and the normal operating indication. Random damper adjustment can shift the problem to another branch.

18. Know when to stop work

Stop airborne-contaminant generation when:

- the required extraction is unavailable or not connected;
- the airflow indicator or alarm is abnormal;
- visible emission escapes the defined capture zone;
- dust or fume crosses the breathing zone;
- a hose, duct, hood, filter, collector, fan or discharge is damaged;
- abnormal noise, vibration, heat or odour suggests system failure;
- a collector is full, leaking or receiving incompatible material;
- sparks or hot particles enter a system not assessed for them;
- a changed material, coating or process has not been assessed;
- cross-draughts or room pressure defeat capture;
- dust deposits indicate uncontrolled release or poor transport; or
- workers experience irritation, breathing difficulty, dizziness or other distress.

Move to a safe area, isolate as required, control access and report the condition. Restart only after the cause has been corrected and the complete control arrangement has passed its release checks.

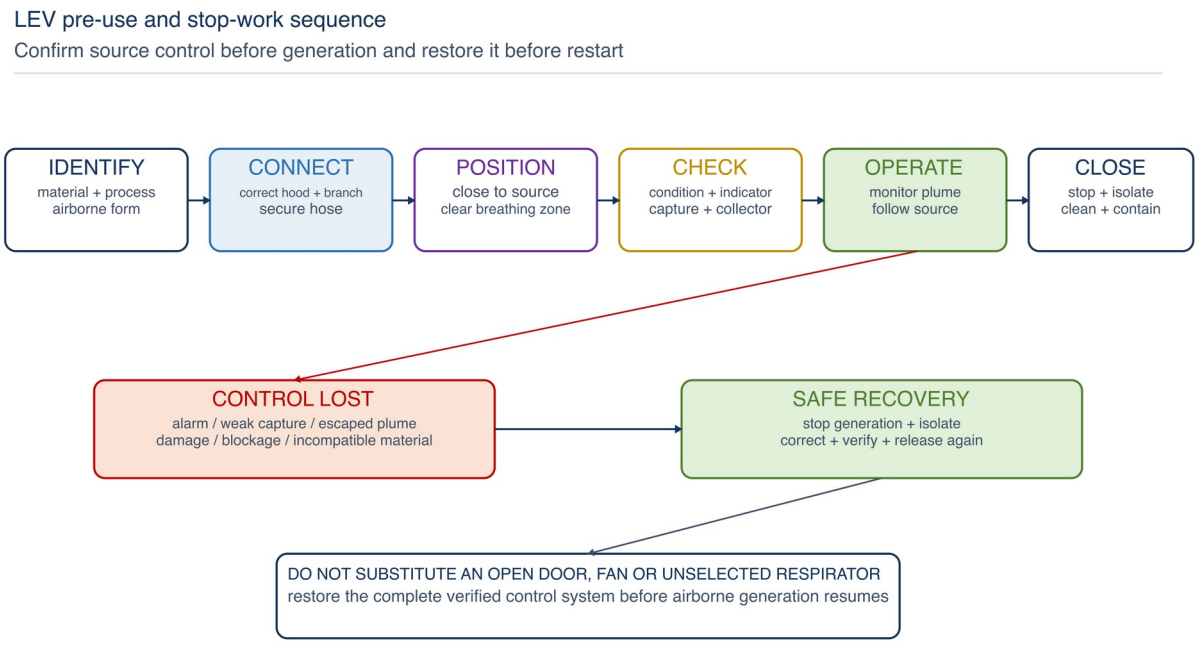

Figure 4. LEV pre-use and stop-work sequence. Identification, connection, positioning and checks precede operation; loss of control leads to stopped generation, safe isolation, correction and renewed release.

19. Ventilation release checklist

Before the task begins, confirm:

- [ ] the workpiece, coating, abrasive, residue and adjacent processes are understood;
- [ ] airborne forms and exposure routes have been assessed;
- [ ] elimination, substitution, enclosure and wet methods have been considered;
- [ ] the correct extraction system is connected and released for the process;
- [ ] hood position follows the source and keeps contamination out of the breathing zone;
- [ ] guards, fixtures, hoses and extraction remain compatible with safe tool control;
- [ ] hoses, ducts, joints, dampers and access covers are intact;
- [ ] indicators, alarms and interlocks show the normal operating condition;
- [ ] make-up air and neighbouring activities do not defeat capture;
- [ ] filters, collectors and waste containers are in service condition;
- [ ] combustible, reactive and mixed-dust hazards are controlled;
- [ ] housekeeping will not re-suspend deposited dust;
- [ ] maintenance and filter-change work use isolation and containment;
- [ ] respiratory protection addresses the assessed residual exposure; and

- [ ] the operator knows the stop-work conditions and reporting route.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 049

Noise and Vibration

49

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, workshop supervisors, safety and health personnel, operators, maintenance teams, technical buyers and application personnel involved in grinding, cutting, sanding, polishing and industrial surface finishing

Scope: Occupational noise; hand-arm vibration; task assessment; engineering and administrative controls; tool, abrasive and workstation selection; hearing protection; symptom reporting; inspection, maintenance and troubleshooting.

Core principle — Noise and vibration are process outputs. Control them by selecting an efficient method, keeping the machine–abrasive–workpiece system stable and reducing transmission to people before relying on exposure time limits or personal protection.

Grinding and surface finishing combine high-speed motion, abrasive contact, airflow, impacts and vibrating structures. The same task may expose the operator to airborne sound and hand-transmitted vibration while also affecting nearby workers. A smooth-sounding tool is not automatically low-risk, and a short task is not automatically acceptable. Actual exposure depends on the source, operating condition, task duration, work pattern and position of each person. Malaysia's Noise Exposure Regulations 2019 and the supporting DOSH industry code provide the national framework for identification, assessment, control, hearing conservation and audiometric management. [S290; S312]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish noise level, daily noise exposure and impulsive noise;
- recognise how hand-arm vibration enters the operator through a tool or workpiece;
- map noisy and vibrating stages across the complete work cycle;
- apply elimination, substitution and engineering controls before personal protection;
- select suitable, efficient equipment using comparable application information;
- recognise abrasive, mounting, machine and work-support conditions that increase vibration;
- control airborne, structure-borne and reflected sound;
- distinguish equipment emission information from worker exposure;
- organise representative noise and vibration assessment;
- select, fit and verify hearing protection for residual noise;
- recognise early hearing and hand-arm symptoms;
- identify conditions requiring a controlled stop; and
- troubleshoot abnormal noise and vibration systematically.

1. Understand the two exposure pathways

Noise reaches the ear through the air and, in some circumstances, through structures that radiate sound. Hand-arm vibration enters through contact with a powered tool, a hand-guided machine or a workpiece held against a powered machine. Grinding, sanding, cutting and polishing can create both at the same time.

Hazard	Main pathway	Typical abrasive-work source	Principal health concern
Continuous or varying noise	Airborne sound to the ear	Motor, abrasive contact, extraction, compressed air, rattling guards	Permanent hearing damage, tinnitus, fatigue and reduced warning-signal awareness
Impulsive or impact noise	Short-duration pressure peaks	Workpiece impact, hammering, dropped stock, explosive release	High short-term hearing risk and startle response
Hand-arm vibration	Tool handle or vibrating workpiece into hands and arms	Portable grinder, sander, cut-off tool, polisher or hand-fed pedestal machine	Vascular, neurological and musculoskeletal injury, including hand-arm vibration syndrome
Whole-body vibration	Seat, feet or supporting surface into the body	Mobile plant, vibrating platform or vehicle	Discomfort and musculoskeletal risk, commonly involving the lower back

This chapter concentrates on occupational noise and hand-arm vibration because these are directly associated with handheld and hand-fed abrasive work. Where vehicles, mobile plant or vibrating platforms are involved, assess whole-body vibration separately.

2. Identify noise before it becomes routine

Noise often becomes accepted because it is familiar. Treat the following as prompts for formal evaluation:

- conversation at normal voice becomes difficult at close working distance;
- workers raise their voices or remove hearing protection to communicate;
- ringing, buzzing or dulled hearing follows a shift or task;
- powered tools, compressed air, impact work or multiple machines operate together;
- alarms or verbal warnings are difficult to recognise;
- sound changes sharply with contact force, workpiece position or abrasive condition;
- a quiet task is performed beside a louder uncontrolled process; or
- maintenance work exposes a person closer to a source than normal production.

The DOSH excessive-noise identification checklist uses practical observations such as raised-voice communication, powered machinery and impact sources to decide whether a noise-risk assessment is needed. These observations are screening prompts. They do not quantify exposure. [S312]

3. Map the complete work cycle

Observe the entire shift, not only the moment when abrasive contact looks most intense. Include:

961. tool startup and free running;
962. first contact, steady cutting and exit;
963. repositioning and repeated short contacts;
964. abrasive dressing, cleaning or changing;
965. compressed-air use and dust extraction;
966. workpiece loading, unloading and impact;
967. maintenance, fault finding and test running;
968. nearby machines and simultaneous tasks;
969. travel between noisy zones; and
970. actual trigger or contact time for each vibrating tool.

Group workers only where their tasks, sources, durations and positions are genuinely similar. A supervisor who enters several noisy areas, a maintenance technician working close to an open machine and an operator stationed at one guarded process may have different exposure patterns even in the same workshop.

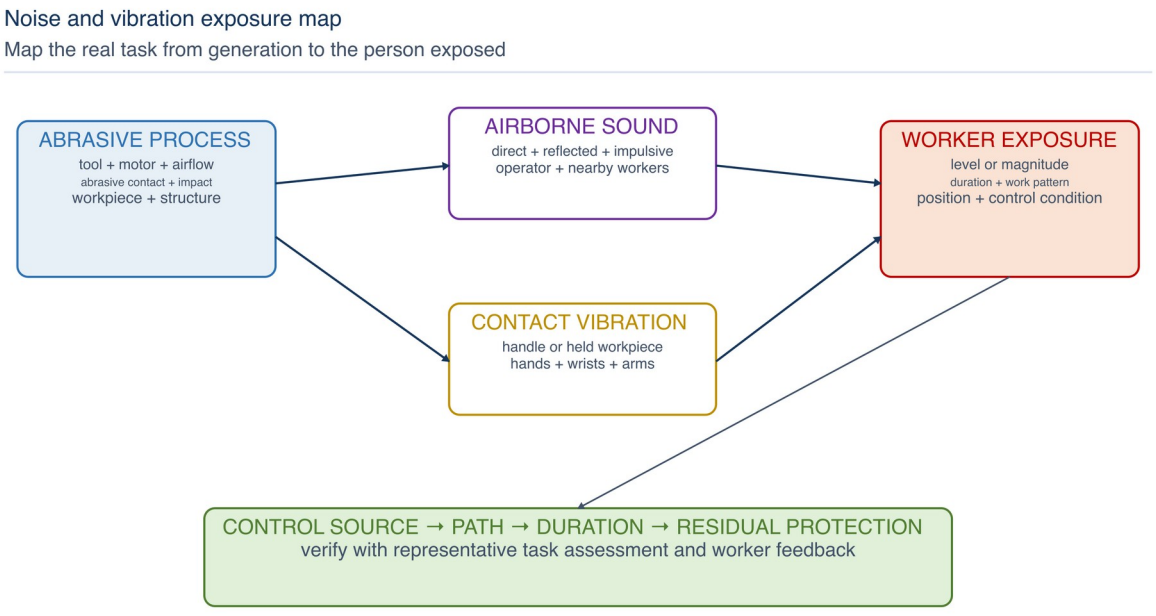


Figure 1. Noise and vibration exposure map. Follow sources through the real work cycle and identify how sound reaches each worker and how vibration enters the hands through the tool or workpiece.

4. Apply the control hierarchy

Use the strongest practicable control first:

971. remove unnecessary grinding, cutting, impact or compressed-air work;
972. change the design, preparation or production sequence so less finishing is required;
973. mechanise, automate or isolate repetitive high-exposure work;
974. substitute a quieter or lower-vibration method that still performs the task safely and efficiently;
975. reduce noise and vibration at the machine, abrasive contact and work support;
976. interrupt the transmission path with isolation, damping, enclosures, barriers or distance;
977. organise access and duration around the residual exposure;
978. use correctly selected and fitted hearing protection for residual noise; and
979. verify performance through assessment, inspection and worker feedback.

Do not extend a slow, unsuitable process merely because its declared emission appears lower. If it takes much longer, creates poor control or requires greater force, total exposure and other risks may increase. Select the method for safe, efficient removal and finish quality as well as noise and vibration.

5. Select suitable and efficient equipment

Compare tools that are capable of completing the same application. Consider:

Selection factor	Why it matters	Verification question
Task capacity	An underpowered or unsuitable tool may prolong exposure and encourage force	Can it complete the work efficiently within its intended use?
Declared noise information	Supports like-for-like procurement screening	Were values measured and reported using a comparable method?
Declared vibration information	Helps identify unusually high-emission options	Does the information represent the intended accessory and application?
Control features	Isolation, balancing, speed control or damping may reduce transmission	How must the feature be used and maintained to remain effective?
Ergonomics	Weight, handle position and trigger design affect grip and fatigue	Can the operator maintain a neutral posture without excessive grip?
Accessory system	Abrasive, backing, flange, guard and attachment affect stability	Is the complete combination approved and compatible?
Service support	Wear and faults can increase exposure	Are inspection criteria, spares and competent repair available?

Battery power does not by itself establish lower noise or vibration. HSE comparative research found that battery-powered tools can perform higher or lower than traditional equivalents depending on tool and task. Compare suitable models using application-relevant information and, where needed, representative in-use evaluation. [S318]

When an exact tool, abrasive or accessory value is required, Refer to the product label, Technical Data Sheet, or MKTECH representative.

6. Keep the machine–abrasive system stable

Abnormal vibration often indicates energy being wasted in movement that does not contribute to the cut or finish. Common contributors include:

- damaged, distorted, unsuitable or incorrectly stored abrasive products;
- incorrect mounting, flange condition or tightening method;
- contamination between mounting surfaces;
- imbalance, excessive runout or eccentric tracking;
- loaded, glazed or unevenly worn abrasive surfaces;
- damaged backing pads, belts, contact wheels or interface layers;
- worn bearings, loose fasteners, damaged guards or flexible couplings;
- unsuitable speed selection where speed adjustment is permitted;
- excessive force, unstable entry or interrupted contact;
- unsupported, resonant or thin workpieces; and
- poor workstation stiffness or machine anchorage.

Never continue operating merely to see whether severe vibration will settle. Stop, isolate as required and inspect the complete system. Do not dress, reshape, modify or remount an abrasive product except by an approved method for that product type.

7. Match the control to the abrasive process

Application	Main contributors	Practical control direction
Portable angle grinding	Abrasive contact, motor, cooling air, imbalance, force and workpiece resonance	Use a suitable efficient abrasive; support the work; maintain the tool; avoid side loading and excessive force
Abrasive cutting	High contact energy, binding, unstable work and thin resonant sections	Secure the work, keep the cut aligned, avoid twisting and use the correct guarded cutting arrangement
Random-orbital or disc sanding	Airflow, backing-pad condition, abrasive loading, surface discontinuity and hose drag	Match abrasive and backing; keep extraction paths clear; support hoses; replace damaged or loaded components
Belt grinding	Belt joint, tracking, platen/contact wheel, work support and enclosure radiation	Maintain tracking and tension by the machine procedure; inspect contact surfaces and isolate radiating panels
Pedestal grinding	Wheel condition, mounting, guard, work rest, motor and workpiece contact	Maintain wheel and machine; set work support correctly; isolate hand-fed support from avoidable machine vibration
Buffing and polishing	Flexible wheel condition, compound loading, spindle balance and grip	Maintain wheel build and balance; use suitable support; avoid catching edges and excessive pressure

Changing only the abrasive grit may not solve a noise or vibration problem. Confirm material, removal objective, contact area, tool power, speed range, backing, guard, support and technique as one application system.

8. Reduce noise at the source

Source control is normally more reliable than trying to protect every exposed person. Practical measures include:

- maintain bearings, drives, fasteners, guards and panels;
- eliminate rattles, looseness and unnecessary impacts;
- use low-noise compressed-air nozzles where air use is necessary and suitable;
- reduce material drop height and cushion impact surfaces where compatible;
- separate vibrating panels from the machine or add engineered damping;
- smooth turbulent airflow paths in ducts and pneumatic systems;
- reduce unnecessary free-running time;
- isolate or relocate secondary sources such as extraction fans; and
- procure quieter equipment before an old machine becomes locked into production.

Maintenance is a noise control, not only a reliability activity. A new rattle, tonal sound, bearing whine or contact squeal should trigger inspection because it may signal a developing fault, poor setup or unstable process.

9. Control the transmission path

When source control cannot complete the job, interrupt the path between source and people.

Path control	Suitable use	Important limitation
Full or partial enclosure	Stationary source that can operate behind closed panels	Openings, gaps and unsealed penetrations can dominate leakage; ventilation and fire hazards must remain controlled
Acoustic barrier or screen	Direct line-of-sight sound, especially at higher frequencies	Sound can pass around edges and reflect from ceilings or walls
Absorptive treatment	Reverberant rooms with hard reflective surfaces	It reduces reflections but does not replace source control or block direct sound
Vibration isolation	Structure-borne transmission from machine, duct or pipe	Incorrect isolator selection can increase movement or compromise stability

Path control	Suitable use	Important limitation
Damping	Thin panels, guards or chutes that radiate sound	Material and placement must suit temperature, cleaning, fire and process conditions
Distance or remote operation	Tasks not requiring continuous close attendance	Moving one person must not expose another or weaken supervision

An acoustic enclosure must preserve cooling, dust extraction, spark control, visibility, access, interlocking and emergency arrangements. A barrier should be close enough and large enough to interrupt the direct path without introducing collision, handling or line-of-sight hazards. [S317]

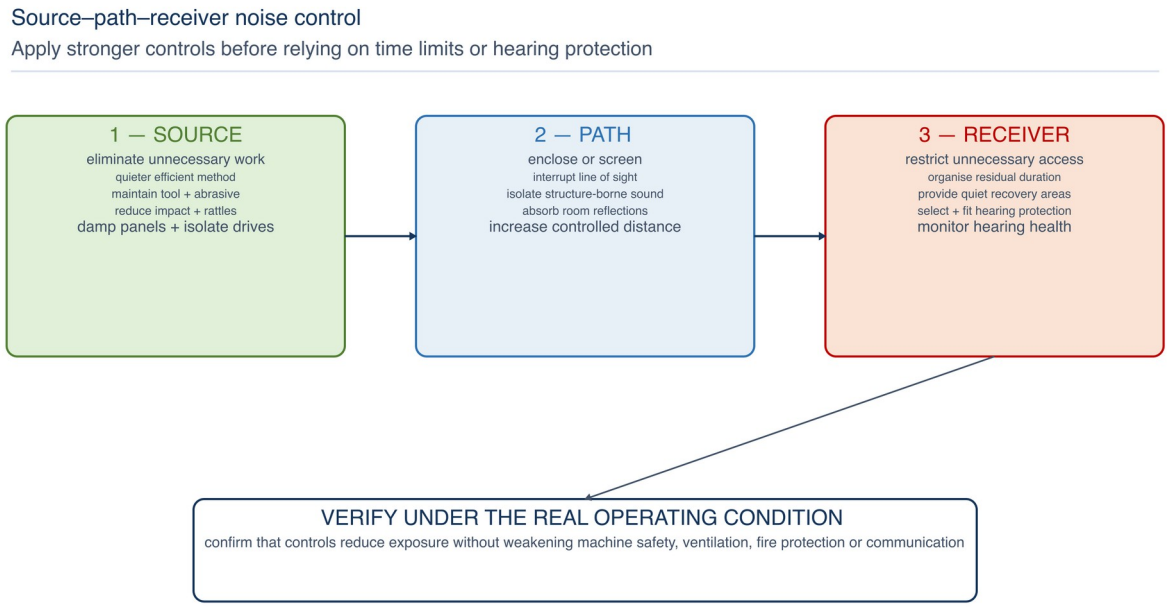


Figure 2. Source–path–receiver noise control. First reduce sound generation; then block or absorb its transmission; manage time and hearing protection only for the residual exposure.

10. Understand what measurements mean

A sound-level reading describes a location and time under stated conditions. A personal dosimeter follows a worker and integrates changing exposure. Frequency information supports control design and hearing-protector selection. Peak measurements address short impulsive events.

ISO 9612:2025 specifies methods for measuring workers' occupational noise exposure, calculating exposure level, observing work conditions and estimating uncertainty. It does not calculate the sound at the ear beneath a hearing protector. [S313]

Representative assessment should document:

- worker and task or similar exposure group;
- measurement strategy and instrument configuration;
- calibration and field checks;
- operating condition, material, tool and abrasive;
- duration, cycles, breaks and unusual events;
- nearby sources and room conditions;
- uncertainty and limitations; and
- priorities for control and follow-up.

A smartphone reading can be useful for awareness or finding a louder condition, but it should not be used as the sole basis for statutory exposure decisions, hearing-protector attenuation calculations or declaring a task safe.

11. Distinguish emission from exposure

Manufacturer emission data describe a defined test condition. Worker exposure describes the person's actual work pattern and environment. They are related but not interchangeable.

For hand-arm vibration, representative workplace evaluation considers frequency-weighted vibration in three axes together with the duration of exposure. ISO 5349-1 establishes the general evaluation framework, while ISO 5349-2 provides practical workplace measurement guidance, including the need to represent tool condition, task, grip, workpiece and operating mode. [S314; S315]

For procurement, declared data help compare candidate equipment when methods and tasks are comparable. For exposure control, use representative workplace information. Do not convert a catalogue value into a universal daily "safe time" without a competent assessment of the real task and all contributing exposures.

12. Reduce hand-arm vibration at the task

Use a combined technical and organisational approach:

- eliminate or automate high-vibration work where practicable;
- use a suitable lower-vibration method that completes the task efficiently;
- support heavy tools with balancers, jigs or suspension systems;
- fixture the workpiece to reduce gripping and unstable contact;
- maintain neutral wrist and arm posture;
- use only the grip force needed to control the tool safely;
- keep hands warm and dry where cold conditions aggravate symptoms;
- maintain tools, bearings, handles and vibration-reduction features;
- replace damaged, worn, unbalanced or inefficient abrasives promptly;
- organise work to avoid long uninterrupted periods of vibration; and
- account for all vibrating tools used during the day.

Anti-vibration gloves may help with warmth and some contact conditions, but they are not a substitute for reducing vibration at the source. Do not assume a glove produces a defined exposure reduction unless the complete assessment supports that conclusion.

13. Design the workstation for control

The workstation influences grip force, posture, contact stability and exposure time. Arrange work so that:

- the task is between comfortable elbow and shoulder levels where practicable;
- heavy workpieces are supported rather than held against the abrasive;
- jigs resist movement without forcing the hands close to the hazard;
- a suspended or balanced tool remains controllable through its full path;
- hoses and cables do not pull the tool off line;
- lighting reveals the contact point without requiring the operator to lean closer;
- work rests are stable and maintained to the machine procedure;
- the operator is not positioned between a noise source and a reflecting corner; and
- controls can be reached without releasing a secure working posture.

For repetitive fixed work, HSE guidance specifically supports jigs and suspension systems that reduce arm loading and tight grip, including counterbalancing a heavy grinder at a permanent workstation. [S316]

14. Organise residual exposure responsibly

Administrative controls support engineering controls but depend on consistent supervision. Use them to:

- restrict unnecessary entry to noisy work areas;
- schedule noisy work when fewer people are present;
- separate noisy and quiet tasks spatially;
- provide genuinely quiet recovery areas;
- limit individual trigger time and total time in noisy zones;
- rotate tasks only where this reduces individual exposure without spreading risk;
- coordinate contractors and neighbouring processes;
- keep doors to acoustic enclosures closed during operation; and

- record task changes that can invalidate an assessment.

Do not use job rotation as the only response where a practical source control is available. Do not transfer a noisy or vibrating task to another worker without accounting for that person's existing exposures and competence.

15. Select hearing protection for the residual noise

Hearing protection must suit the measured or competently assessed exposure, frequency content, work, wearer and other PPE. Selection should achieve sufficient protection while preserving necessary communication and alarm awareness.

Selection question	Practical consideration
Is attenuation sufficient?	Use valid exposure and protector data through the applicable method; do not assume the package number equals protection achieved by every wearer
Will it fit this worker?	Ear canal shape, head size, hair, jewellery and technique affect fit
Is it compatible?	Eyewear temples, respirator straps, helmets and face shields can disturb earmuff seals or placement
Can it be worn for the full exposure?	Heat, pressure, hygiene and communication affect consistent use
Are signals still usable?	Verify alarms, vehicles, radio and speech under actual conditions
Is double protection indicated?	Base the decision on the noise assessment and programme method, not assumption
Can fit be checked?	Individual fit testing provides a personal attenuation result and targeted coaching

ISO 4869-2 provides recognised methods using octave-band, HML or SNR information to estimate protected A-weighted level. Individual fit can differ materially from laboratory-labelled performance; NIOSH recommends fit testing where available. [S294; S301]

16. Fit, inspect and care for protectors

For earplugs:

- use clean hands and the taught insertion method;
- select the correct model and size;
- seat the plug consistently in both ears;
- replace disposable plugs after their intended use;
- clean reusable plugs by the documented method; and
- discard hardened, torn, contaminated or misshapen items.

For earmuffs:

- inspect cushions, cups, headband and attachment points;
- keep the seal free from hair, eyewear temples, clothing and respirator straps;
- replace worn cushions and hygiene components as specified;
- store them clean, dry and protected from deformation; and
- confirm helmet-mounted cups engage fully in the use position.

Never lift a protector for conversation while remaining in the noise. Move to a controlled quiet location or use an approved communication method that preserves protection.

17. Recognise and report early symptoms

Noise-related warning signs include ringing or buzzing in the ears, temporary dullness, difficulty understanding speech and a need to increase audio volume after work. Hearing damage can develop without pain and may become permanent.

Hand-arm warning signs include:

- tingling or numbness in fingers;
- reduced touch or temperature sensitivity;
- loss of grip strength or dexterity;
- fingers becoming pale in cold or wet conditions;
- pain or delayed recovery after tool use; and
- difficulty with fine tasks such as fastening buttons or handling small components.

Report symptoms promptly through the workplace health system. Early reporting supports exposure review, control improvement and appropriate occupational-health assessment. Do not wait until symptoms interfere with normal work.

18. Diagnose abnormal noise and vibration

Symptom	Likely contributors	Corrective direction
Tool vibrates before contact	Abrasive damage, mounting error, imbalance, worn bearing or loose component	Stop; isolate as required; inspect the abrasive, mounting and tool before release
Vibration rises only during contact	Excessive force, unstable work, wrong abrasive, loading, glazing or interrupted contact	Stabilise the work and verify application selection and technique
Thin workpiece “drums” loudly	Resonance, insufficient support or broad unsupported area	Add safe support or damping and review contact method
Sharp squeal during grinding	Glazing, rubbing, unstable contact, unsuitable specification or machine resonance	Stop and review abrasive condition, pressure, support and machine state
New rattle from guard or enclosure	Loose fastener, cracked panel, contact with rotating parts or worn mounting	Stop and correct before further operation
Noise increases after enclosure work	Open gap, failed seal, bypass path, removed absorption or restricted cooling	Restore enclosure integrity and verify temperature and control performance
Operator grips harder over time	Tool weight, poor balance, hose drag, awkward posture, blunt abrasive or fatigue	Improve support, workstation, abrasive efficiency and work organisation
Hearing protector repeatedly removed	Poor fit, discomfort, communication need, heat or incompatible PPE	Reassess selection and fit; provide suitable alternatives and communication control
Several tools contribute across shift	Exposure assessed one task at a time only	Combine all work-cycle contributions in the competent assessment

Troubleshoot from the source outward: tool and abrasive, mounting and bearings, workpiece and fixture, workstation and structure, enclosure and room, then duration and personal protection. Verify the correction under the real task.

19. Know when to stop work

Stop the task when:

- a tool or hand-fed workpiece shows sudden, severe or increasing vibration;
- the abrasive product is damaged, loose, incorrectly mounted or unstable;
- a new rattle, knock, squeal, bearing sound or structural movement appears;
- the workpiece, fixture, rest or support is unstable;
- a guard, enclosure, isolator, damper or acoustic control is damaged;
- required hearing protection is unavailable, damaged or cannot be fitted correctly;
- an alarm or warning signal cannot be detected by the approved method;
- a changed tool, abrasive, material, duration or layout is outside the assessed arrangement;
- the operator experiences ringing ears, sudden hearing change, tingling, numbness, loss of grip or finger colour change; or
- noise or vibration control has been bypassed.

Move to a controlled area, isolate equipment as required and report the condition. Restart only after the cause has been corrected, the equipment and application have passed their release checks, and any required health or exposure follow-up has been arranged.

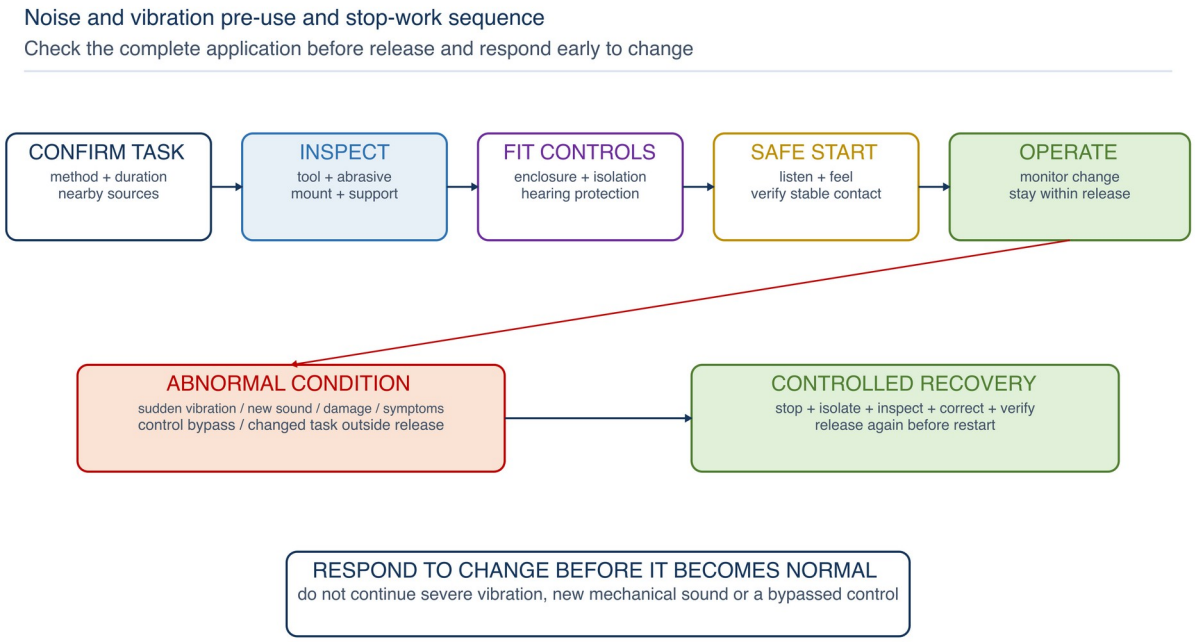


Figure 3. Noise and vibration pre-use and stop-work sequence. Confirm the task, equipment, abrasive, work support and controls before operation; abnormal sound, vibration or symptoms lead to a controlled stop, correction and renewed release.

20. Noise and vibration release checklist

Before work begins, confirm:

- [ ] the complete work cycle and all nearby sources have been considered;
- [ ] the tool and abrasive are suitable and efficient for the application;
- [ ] declared noise and vibration information has been used only within its stated conditions;
- [ ] the abrasive, backing, flanges, guard, bearings and machine are serviceable;
- [ ] the workpiece, fixture, rest and workstation are stable;
- [ ] hoses, cables and extraction do not increase grip force or instability;
- [ ] source controls, isolation, damping, enclosure and absorption are intact;
- [ ] noisy areas and access controls are clearly managed;
- [ ] actual exposure duration includes every noisy and vibrating task;
- [ ] hearing protection is selected from the assessment and fits the individual;
- [ ] eyewear, respirator, helmet and hearing protection remain compatible;
- [ ] alarms, communication and emergency arrangements remain effective;
- [ ] operators recognise early hearing and hand-arm symptoms;
- [ ] abnormal sound or vibration has a clear reporting and isolation route; and
- [ ] restart follows correction and a complete release check.

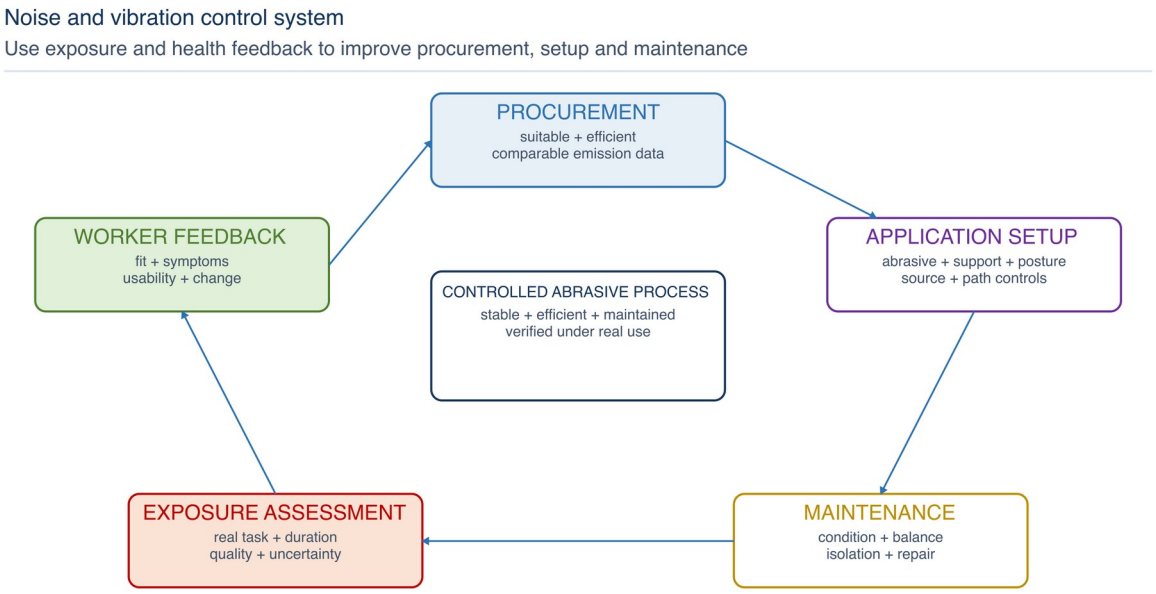
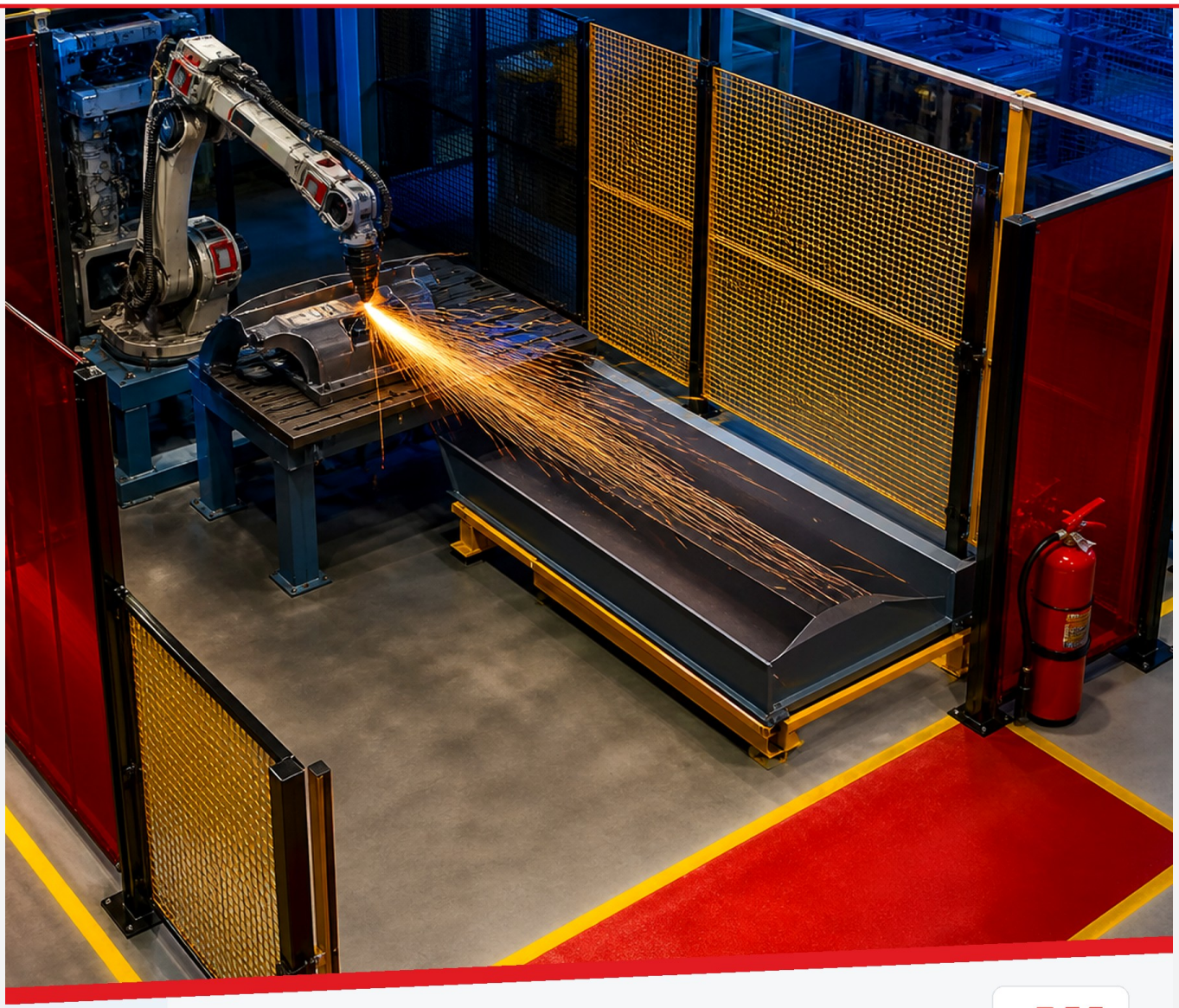


Figure 4. Noise and vibration control system. Procurement, application setup, maintenance, exposure assessment, worker protection and health feedback form a continuous improvement loop.



INSPECTION, SAFETY & MAINTENANCE

CHAPTER 050

Spark, Fire and Explosion Control

50

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, workshop supervisors, safety and health personnel, operators, maintenance teams, technical buyers and application personnel involved in grinding, cutting, sanding, polishing, weld preparation and industrial surface finishing

Scope: Spark and hot-particle control; hot surfaces; flammable liquids and vapours; used containers and pipework; combustible dust; collectors and ducting; housekeeping; hot-work release; fire watch; emergency response and troubleshooting.

Core principle — A spark is an ignition source, not a harmless sign that grinding is taking place. Control the fuel, ignition source, atmosphere, dust dispersion and confinement before work starts, then monitor the complete area until delayed ignition is no longer credible.

Grinding, cutting and polishing can produce sparks, incandescent particles, hot swarf, frictional heating and hot workpieces. These can ignite packaging, insulation, coatings, oil, solvent vapour, gas, residues inside equipment or accumulated dust well beyond the visible contact point. A fire can begin after the tool stops, while a combustible-dust event can spread through ducts, collectors, rooms or connected equipment. Malaysian DOSH incident alerts involving polishing operations and accumulated process dust demonstrate why ignition control, housekeeping and suitable engineered protection must function as one system. [S319; S320]

Chapter objectives

After this chapter, the reader should be able to:

- distinguish fire conditions from dust-explosion conditions;
- identify abrasive-process ignition sources and potential fuels;
- map the complete travel path of sparks, hot particles and heat;
- decide whether work should be eliminated, relocated or controlled as hot work;
- prepare an area and protect adjacent levels, cavities and equipment;
- control grinding and cutting on tanks, drums, pipes and enclosed sections;
- recognise when dust may be combustible or reactive;
- explain how accumulated layers can support a secondary explosion;
- separate incompatible dusts and processes;
- coordinate extraction, collectors and spark control;
- use suitable housekeeping without re-suspending dust;
- apply fire-watch, close-out and restart controls;
- recognise conditions requiring an immediate controlled stop; and
- troubleshoot fire and explosion hazards systematically.

1. Understand fire and explosion conditions

Fire requires fuel, oxygen and a sufficiently energetic ignition source. A dust explosion additionally requires combustible particles dispersed in air within a hazardous range and sufficient confinement for pressure to develop. Removing any required element interrupts the event.

Event condition	Required elements	Abrasive-work examples	Primary control direction
Surface or ordinary fire	Fuel, oxygen and ignition	Spark enters cardboard, oily waste, insulation or coating	Remove or protect fuel; contain sparks; monitor for smouldering
Flammable-vapour fire or explosion	Flammable vapour, oxygen, ignition and hazardous concentration	Grinding near solvent use, fuel system or inadequately cleaned container	Eliminate ignition; isolate, clean, ventilate and verify atmosphere
Dust flash fire	Combustible dust cloud, oxygen and ignition	Fine dust released at a sander, polisher or during cleaning	Prevent release and dispersion; control ignition; capture safely
Dust explosion	Combustible dust cloud, oxygen, ignition, dispersion and confinement	Dust cloud in collector, duct, enclosure, ceiling void or room	Control dust and ignition; provide correctly engineered containment or protection
Reactive-material event	Incompatible materials, water, air or heat	Reactive metal dust mixed with another material or exposed to unsuitable wet control	Identify chemistry; segregate; use a compatible collection and emergency method

The absence of a visible cloud does not prove that dust deposits are harmless. A layer can burn, conceal hot material or become dispersed by an initial fire, pressure wave, cleaning jet or equipment failure.

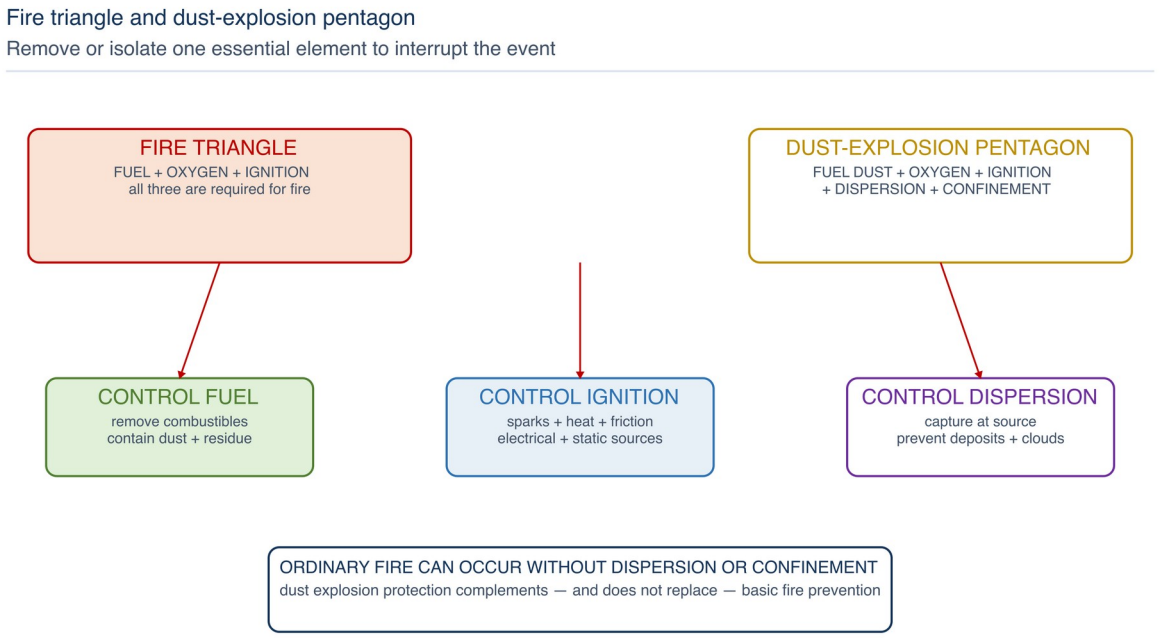

Figure 1. Fire triangle and dust-explosion pentagon. Fire needs fuel, oxygen and ignition; a dust explosion also needs dispersion and confinement. Control strategies remove or isolate one or more essential elements.

2. Identify ignition sources from the complete process

Visible grinding sparks are only one ignition source. Inspect the whole process for:

- incandescent particles, hot swarf and cut-off fragments;
- hot workpieces, sharp offcuts and recently ground edges;
- friction from binding, rubbing, poor tracking or seized components;
- overheated bearings, motors, brakes, drives and cables;
- damaged electrical equipment, loose connections and arcing;
- static discharge from powders, hoses, filters, containers or clothing;
- welding, gouging, flame cutting, brazing and soldering nearby;
- smoking, open flames, heaters and vehicle exhausts;
- chemical reaction, self-heating or contaminated waste; and
- hot particles transported through extraction ducting.

Abnormal heat, odour, smoke, colour change, noise or vibration is a warning condition. Stop and investigate rather than increasing airflow, contact force or production speed to continue the task.

3. Map spark and heat travel

Sparks rarely stop where they first land. They can bounce from floors, pass through grating, enter cable trenches, settle behind machines, lodge in insulation, travel inside hollow sections or be pulled into extraction.

Observe the process from first contact to shutdown and ask:

980. What direction does the wheel or belt throw particles?
981. How does the direction change as the tool or workpiece moves?
982. Can sparks fall through openings or reach another floor?
983. Are there hidden cavities, wall penetrations, roof spaces or combustible linings?
984. Can extraction carry hot particles to ducts, filters or collectors?
985. Can wind, fans or vehicle movement extend the travel path?
986. Where will hot offcuts and spent abrasives be placed?
987. What could smoulder after visible work ends?

Inspect the opposite side of partitions, floors and workpieces where heat may conduct through. Spark screens should contain and direct particles toward a controlled landing area without trapping heat, blocking ventilation, obstructing escape or creating rebound toward the operator.

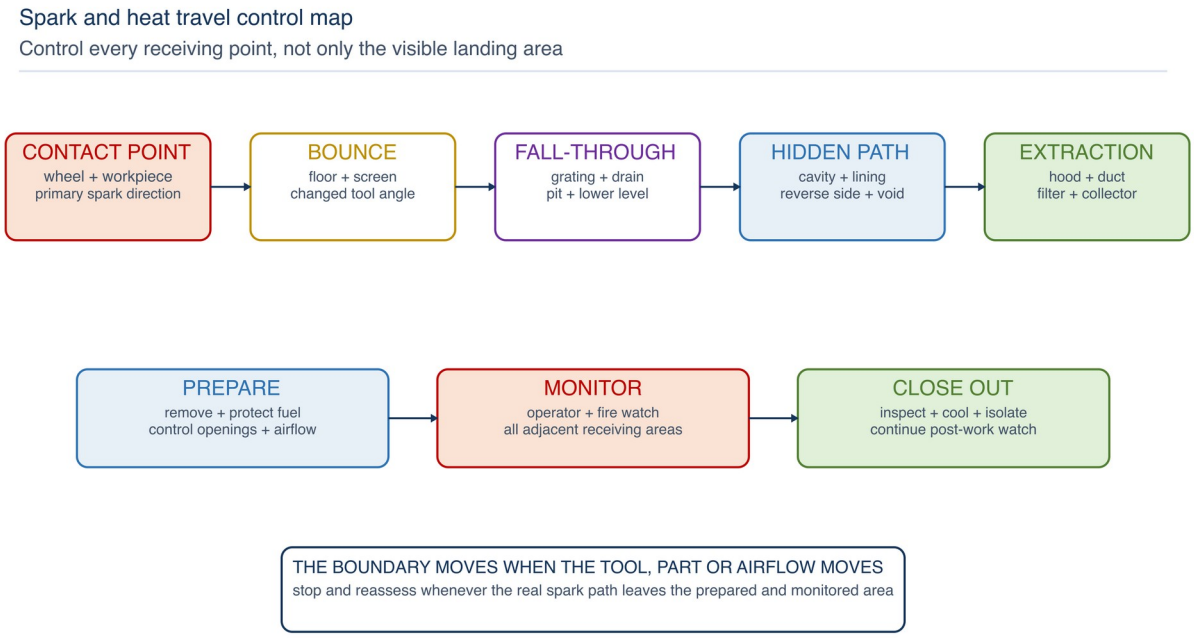

Figure 2. Spark and heat travel control map. Control the primary trajectory, bounce, fall-through openings, hidden cavities and extraction path, then inspect all receiving areas during close-out.

4. Decide whether the task is hot work

Treat grinding, abrasive cutting and any other process that produces sparks or significant heat as hot work wherever combustible, flammable or explosive material may be affected. A designated grinding bay can simplify control, but designation alone does not make it safe when fuel, dust or process conditions change.

Use this decision sequence:

988. **Eliminate:** Can the part be replaced, unbolted, mechanically separated or repaired without ignition-producing work?
989. **Relocate:** Can the item be moved to a prepared hot-work area away from fuel and occupied operations?
990. **Isolate:** Can connected equipment, lines, energy, material flow and hazardous atmosphere be positively controlled?
991. **Prepare:** Can combustibles, residues and dust be removed or protected and receiving areas inspected?
992. **Authorise:** Does the site hot-work system release the defined task, location, time, personnel and precautions?
993. **Monitor:** Are fire watch, communication, alarm, extinguishing readiness and post-work inspection established?

If the task changes location, material, tool, duration, atmosphere, collector connection or spark direction, return to the decision point. Do not extend an authorisation by assumption.

5. Prepare the work area

Area element	Preparation action	Release check
Loose combustibles	Remove packaging, paper, timber, textiles, plastic, waste and portable flammable material	Work and spark-receiving zones are clear
Fixed combustibles	Protect with a suitable non-combustible system and prevent particles passing behind it	Covers are secure, complete and compatible with heat
Floors and openings	Clean deposits; cover or control grating, drains, pits and penetrations where appropriate	No path leads sparks to hidden fuel or another level
Adjacent equipment	Stop, isolate or protect processes that release dust, vapour, gas or combustible material	Simultaneous operations cannot create a hazardous combination
Walls and reverse side	Check for insulation, concealed voids, coatings, cables and heat conduction	Both sides can be monitored and remain accessible
Extraction	Confirm system suitability for hot particles and collected material	Spark path and collector compatibility are controlled

Area element	Preparation action	Release check
Emergency arrangements	Establish alarm, access, escape, communication and suitable response equipment	Assigned personnel understand actions and boundaries

Keep the work zone orderly. Hoses, leads, screens and extinguishing equipment should remain accessible without crossing escape routes or creating trip hazards.

6. Control flammable liquids, gases and vapours

Flammable material may be present in containers, process equipment, drains, pits, coatings, cleaning stations, fuel systems, aerosols or nearby storage. Vapours can travel away from a leak or open container and ignite at the hot-work location.

Before work:

- identify products, residues and decomposition hazards;
- stop transfer, spraying, cleaning and dispensing that can release vapour;
- close, remove or isolate portable containers;
- prevent leakage from connected pipes, valves and equipment;
- control low points, drains and enclosed spaces where vapour may collect;
- use suitable atmospheric testing where the assessment requires it;
- maintain ventilation without spreading vapour toward ignition; and
- prevent reintroduction while hot work and close-out remain active.

Oxygen enrichment increases the ease and intensity of combustion. Keep oxygen equipment, hoses and fittings clean and suitable for oxygen service, protect them from sparks and oil contamination, and never use oxygen for ventilation, cooling or blowing dust from clothing or equipment.

7. Never assume an empty container is safe

Drums, tanks, vessels, pipes, ducts and hollow sections can retain flammable vapour, combustible residue or pressure after appearing empty. Rinsing, leaving a lid open or waiting several days does not by itself establish safe conditions.

Container condition	Hazard	Required direction
Unknown history or label	Unidentified residue, coating, pressure or atmosphere	Do not grind or cut; identify and route through competent preparation
Previously held flammable or combustible material	Vapour or residue can ignite when heated or disturbed	Prefer cold dismantling or replacement; use a controlled cleaning and gas-freeing system where hot work is unavoidable
Connected to pipework or process	Material can re-enter through valves, drains, vents or trapped sections	Positively isolate and control every connection under the site procedure
Closed or partly closed section	Heat and pressure can build rapidly	Establish an engineered method; do not rely on a small opening or puncture
Lined, coated or insulated item	Hidden fuel and hazardous decomposition products	Identify construction and remove or control affected material before release
Documented prepared item	Condition can change before or during work	Maintain isolation, ventilation, monitoring and time-limited release conditions

HSE identifies grinding and disc cutting as hot work capable of igniting residues in drums and containers, including materials such as oils, solvents and fuels. [S323] Use cold cutting or dismantling methods wherever they remove the ignition hazard.

8. Recognise combustible dust

Many finely divided materials can burn even when the bulk material appears difficult to ignite. Relevant materials may include aluminium, magnesium, titanium and other metals; polymer, paint and coating dust; wood, textile or organic material; polishing lint and compound; and mixed process residues.

Combustibility cannot be decided reliably from:

- whether the parent metal normally burns;
- spark colour or quantity;
- particle colour or visible fineness;

- a previous job that did not ignite;
- the absence of a warning on an unrelated product; or
- an ordinary dust-extraction rating.

ISO/IEC 80079-20-2 specifies test methods for identifying combustible dust and dust-layer characteristics used in hazardous-area and equipment decisions. [S321] Material identity, process history, representative testing and competent engineering determine the required controls.

9. Understand primary and secondary dust events

A primary event may begin inside a machine, enclosure, duct or collector. The pressure wave can disturb deposits on beams, lights, cable trays, roofs and equipment, creating a larger secondary cloud. Ignition of that cloud can produce a more destructive secondary explosion.

DOSH's motorcycle-rim manufacturing alert describes a polishing-machine fire followed by a chain of dust explosions and highlights dust control, ignition-source control and explosion-damage control. [S319]

Prevent escalation by:

- containing dust release at the process;
- preventing deposits on horizontal and elevated surfaces;
- inspecting concealed and difficult-to-reach areas;
- keeping collectors and ducts suitable and maintained;
- avoiding work that disperses accumulated dust;
- controlling ignition throughout the connected system; and
- providing engineered fire and explosion protection where the assessment requires it.

Do not wait for a thick visible layer. The significance of a deposit depends on the material, area, process and potential for dispersion.

10. Separate incompatible and reactive dusts

Mixing dusts can change combustibility, reactivity, waste classification and extinguishing strategy. Keep collection routes separately assessed where processes involve:

- different combustible metals;
- metal and organic or polymer dust;
- reactive metal and water or aqueous slurry;
- iron or steel sparks entering a light-metal dust system;
- oil-, solvent- or compound-contaminated dust;
- oxidising materials; or
- residues with unknown composition.

Use dedicated tools, extraction, containers and cleaning equipment where cross-contamination would create a hazard. Label waste by source and prevent hot material entering the receptacle. A container suitable for ordinary steel swarf may be unsuitable for fine reactive metal dust.

When an exact abrasive, collector, filter, container or extinguishing-system value is required, Refer to the product label, Technical Data Sheet, or MKTECH representative.

11. Control sparks at the machine and workpiece

Good application control reduces unnecessary heat and erratic particle throw:

- select the correct tool and abrasive type for the material and operation;
- keep the guard installed and correctly positioned;
- mount the abrasive with clean, compatible components;
- secure the workpiece and support offcuts;
- maintain a stable contact angle and controlled entry;
- avoid binding, twisting, side loading and excessive force;
- replace damaged, loaded, glazed or inefficient abrasives;
- maintain bearings, belts, contact wheels and drives; and
- allow hot workpieces and offcuts to cool in a controlled non-combustible location.

A spark-reduction measure must not weaken guard coverage, cause tool overload, reduce visibility or direct fragments toward people. Wet methods require full compatibility with the abrasive, electrical tool, workpiece, reactive dust and waste system.

12. Integrate extraction and collector safety

Local extraction can control airborne dust while also transporting hot particles and combustible material into a confined system. Ordinary capture performance does not establish fire or explosion suitability.

System element	Fire or explosion concern	Control question
Hood or enclosure	Receives sparks, hot fragments and dust together	Can ignition be prevented or safely controlled before transport?
Duct	Accumulates deposits and transmits flame or pressure	Is the material, geometry, cleaning method and isolation arrangement suitable?
Fan	Can create heat, friction or ignition and spread burning material	Is its construction and location appropriate to the assessed hazard?
Filter or separator	Concentrates fine dust in a confined volume	Are fire, deflagration, isolation and discharge protections engineered for the material?
Waste container	Can retain hot material or incompatible mixtures	Is it compatible, closed, identified and emptied by a controlled method?
Recirculated air	Can return smoke, flame, contaminants or pressure effects	Is recirculation permitted and protected for the actual process?
Discharge location	Can expose people, buildings or air intakes	Does discharge remain controlled during normal and emergency conditions?

Do not connect a new polishing, sanding or metal-grinding process to an existing collector because the hose fits. Review material, spark loading, dust properties, branch balance, collector location, protection systems and waste route before change.

13. Keep housekeeping from creating a dust cloud

Housekeeping is an explosion-control measure when it removes deposits without dispersing them.

Use a planned method that:

- captures dust at the source before it settles;
- defines accessible and elevated inspection areas;
- uses equipment documented as suitable for the material and hazardous area;
- isolates production where cleaning can disturb deposits;
- avoids dry sweeping or uncontrolled compressed air;
- prevents dust falling from one level onto workers or ignition sources;
- keeps incompatible dusts and cleaning equipment separate;
- empties collectors and vacuums before overfilling;
- contains filters, bags and waste during change; and
- records recurring deposits as a control fault to correct.

Do not clean a large area by blowing dust toward extraction. The resulting cloud may reach ignition sources, penetrate inaccessible spaces and overload the collector. DOSH guidance on chemical-processing dust events specifically discourages compressed-air blowing and sweeping in favour of suitable industrial vacuum cleaning. [S320]

14. Use a controlled hot-work release

A hot-work permit or equivalent release coordinates the conditions that must remain true during the job. It should identify:

994. exact task, item and location;
995. authorised time window and shift handover;
996. materials, residues and connected processes;
997. isolation and atmosphere-control method;
998. combustible removal and protection;
999. spark, heat and extraction controls;
1000. fire watch and receiving-area coverage;

1001. alarm, communication and emergency actions;
1002. close-out inspection and monitoring period; and
1003. responsible persons for release, suspension and closure.

The release ends when conditions change, the time expires, the work moves or control is lost. Suspend the job and issue a fresh release after reassessment. A signature does not compensate for an unprepared area or an uncontrolled dust hazard.

15. Assign an effective fire watch

The fire watch monitors areas the operator cannot continuously observe, including adjacent rooms, reverse sides, lower levels, penetrations and extraction receiving points. The person must understand the task hazards and have authority to stop work.

The fire watch should:

- confirm the prepared boundary before ignition-producing work;
- maintain communication with the operator and permit controller;
- watch spark travel, hot surfaces, smoke, odour and changing conditions;
- keep access and escape routes clear;
- know how to raise the alarm and initiate evacuation;
- use available response equipment only within training and the emergency plan;
- continue post-work monitoring for the defined period; and
- record closure or escalate any abnormal condition.

DOSH confined-space guidance emphasises combustible removal, suitable protection and a trained fire watch for hot work within confined spaces. [S322] Apply the same disciplined observation principle wherever hidden or delayed ignition is credible.

16. Select emergency response by assessed material

Different fuels and reactive materials require different response methods. Water, foam, carbon dioxide, dry chemical or specialised media may be effective for some hazards and dangerous or ineffective for others. Selection must follow the identified material, equipment, atmosphere and facility emergency plan.

Before release, confirm:

- alarm method and who receives it;
- emergency isolation and shutdown points;
- evacuation route and assembly arrangements;
- suitable response equipment and trained users;
- restrictions for reactive metal, electrical or confined-space hazards;
- access for emergency services;
- control of smoke and contaminated run-off; and
- preservation of the scene after people are safe.

If fire enters a collector, duct, container or enclosed machine, do not open it casually. Opening can admit oxygen, release flame, disperse dust or expose the person to pressure and toxic products.

17. Close out the work completely

Stopping the tool does not close the fire risk. At completion:

- remove hot offcuts, spent abrasives and waste to controlled locations;
- inspect the immediate area and full spark-travel path;
- inspect reverse sides, cavities, lower levels and penetrations;
- check extraction, ducts, collectors and waste containers for abnormal heat or smoke;
- verify that temporary screens and covers did not conceal ignition;
- restore fire detection or suppression systems that were controlled for the task;
- maintain fire watch for the assessed post-work period;
- record findings and close the hot-work release; and
- hand over unresolved conditions to the next responsible person.

Thermal imaging can support inspection where suitable, but it does not replace physical access, material knowledge or continued observation. A surface temperature image may not reveal a concealed ember behind insulation or inside a duct.

18. Know when to stop work

Stop grinding, cutting, sanding or polishing when:

- unidentified combustible, flammable or reactive material is found;
- spark travel extends beyond the prepared and monitored boundary;
- a screen, cover, extraction control or isolation is displaced;
- smoke, flame, smouldering, unusual odour or abnormal heat appears;
- dust becomes visibly dispersed or deposits are disturbed;
- a collector, duct, filter or waste container becomes hot, damaged or abnormal;
- incompatible material enters the collection or waste route;
- atmosphere monitoring, ventilation or required fire watch is lost;
- a used container, pipe or enclosed section is not under a documented release;
- work conditions no longer match the hot-work authorisation;
- emergency equipment, alarm or escape route becomes unavailable; or
- the operator cannot identify where sparks and hot material are landing.

Isolate the task as required, raise the alarm when indicated, control access and follow the site emergency plan. Do not restart until the cause is understood, controls are restored and the complete area has been released again.

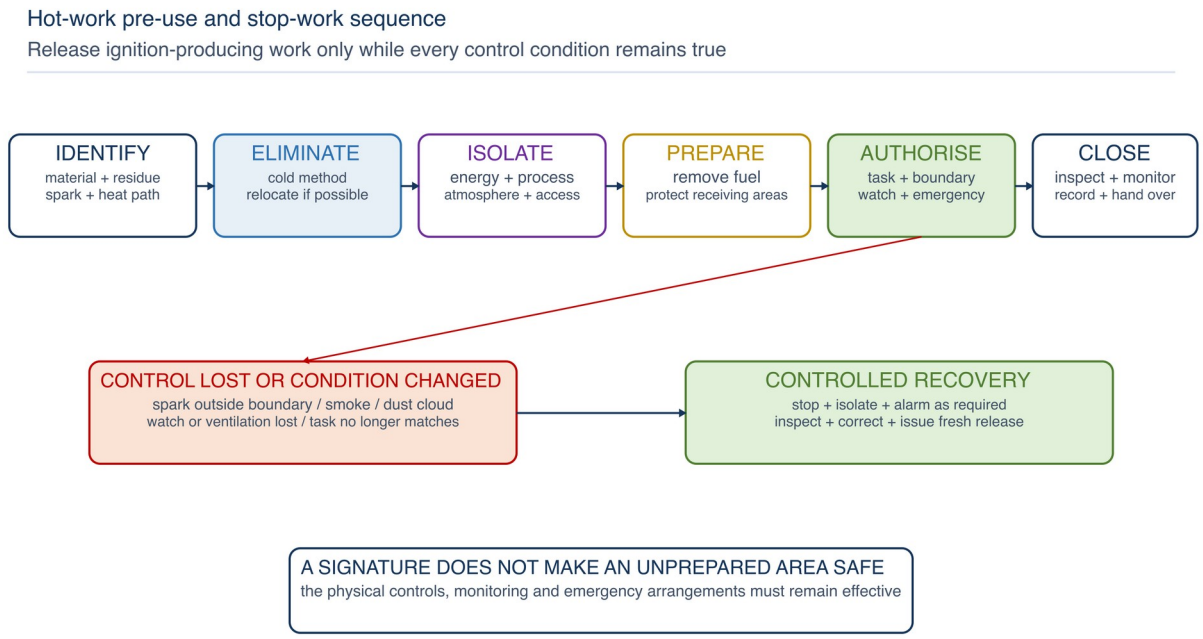

Figure 3. Hot-work pre-use and stop-work sequence. Identify materials and spark paths, eliminate or isolate hazards, prepare and authorise the area, monitor during work and close out; any change or sign of ignition triggers a controlled stop.

19. Troubleshoot fire and explosion controls

Observation	Likely contributors	Corrective direction
Sparks pass beyond the screen	Wrong screen position, rebound, changing tool angle or airflow	Stop; remap the full trajectory and reposition or redesign containment
Workpiece remains unusually hot	Excessive force, inefficient abrasive, poor support, rubbing or prolonged contact	Review selection, technique and cooling method; control the hot item after work
Burning odour but no visible flame	Concealed smouldering, hot coating, insulation, dust deposit or extraction event	Stop; isolate and inspect all receiving areas under the emergency plan
Dust repeatedly accumulates	Ineffective source capture, leakage, poor transport or unsuitable cleaning frequency	Correct the generating and collection system; do not normalise repeated cleanup
Collector temperature or sound changes	Hot material entry, filter event, bearing fault, friction or internal fire	Stop connected processes and follow the collector emergency procedure

Observation	Likely contributors	Corrective direction
Static shocks occur during dust handling	Inadequate bonding or grounding, unsuitable hose or dry powder transfer	Stop and obtain competent review of the complete electrostatic-control system
Fire watch loses sight of receiving area	Task movement, obstruction, staffing or communication failure	Suspend work until full coverage and communication are restored
Permit conditions change mid-task	New material, process, location, shift, ventilation or adjacent activity	Stop and reassess; issue a fresh controlled release
Hot waste is placed in ordinary bin	Poor close-out planning or unsuitable receptacle	Isolate the waste, control any ignition and establish a compatible cooling and disposal route

Investigate from fuel and ignition source through dispersion, confinement, extraction, work practice and emergency readiness. Correct the system cause rather than relying on a larger screen, more PPE or more frequent cleanup alone.

20. Spark, fire and explosion release checklist

Before ignition-producing work begins, confirm:

- [ ] the exact task, workpiece, material and location are identified;
- [ ] elimination, cold methods and relocation have been considered;
- [ ] ignition sources and fuels are mapped through the complete work cycle;
- [ ] the full spark, bounce, fall-through and extraction path is controlled;
- [ ] combustibles, flammable materials, residues and dust deposits are removed or protected;
- [ ] containers, pipes, ducts and enclosed sections are prepared and isolated through the site system;
- [ ] atmosphere and ventilation controls match the assessed hazard;
- [ ] the abrasive, tool, guard, support and technique minimise unnecessary heat and spark spread;
- [ ] extraction and collectors are suitable for the material and hot-particle exposure;
- [ ] incompatible or reactive dusts have separate collection and waste routes;
- [ ] housekeeping will remove dust without dispersing it;
- [ ] the hot-work release defines task, boundary, time and responsible persons;
- [ ] fire watch covers hidden, adjacent and lower receiving areas;
- [ ] alarm, isolation, evacuation and suitable response equipment are ready;
- [ ] post-work monitoring and handover are defined; and
- [ ] everyone understands the stop-work conditions.

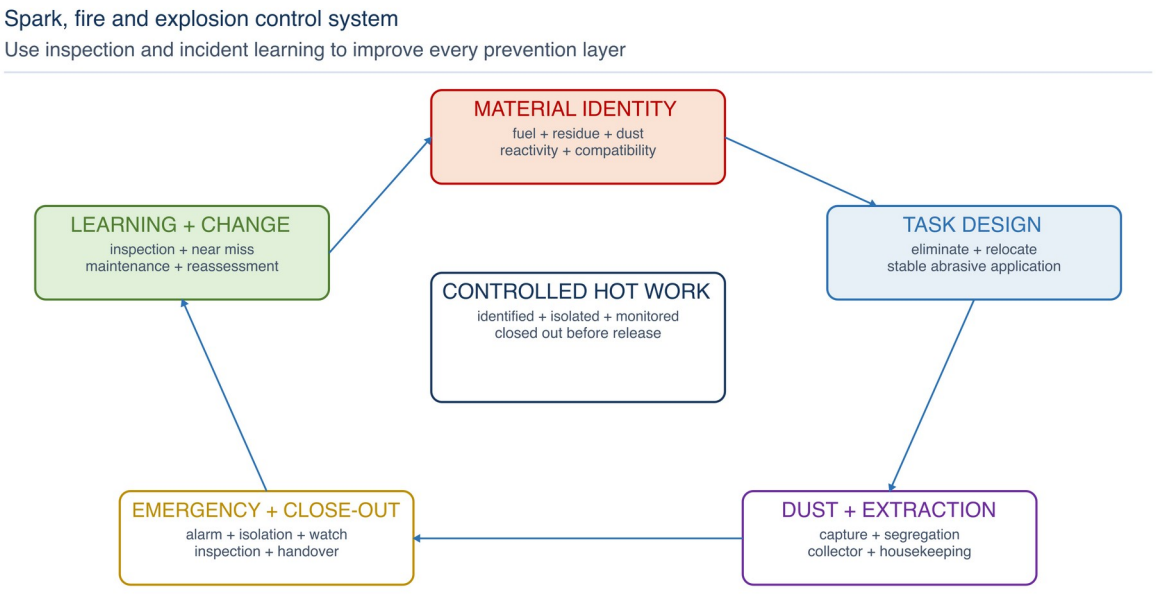

Figure 4. Spark, fire and explosion control system. Material identification, task design, source and path controls, dust management, hot-work release, emergency readiness and post-work learning form a continuous prevention system.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 051

Pre-Use Safety Decision Tree

51

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Operators, supervisors, tool issuers, maintenance personnel, safety and health teams, technical buyers and application personnel involved in industrial grinding, cutting, sanding, polishing and surface finishing

Scope: Task definition; abrasive identification and condition; tool–accessory compatibility; mounting; guards and controls; workpiece restraint; work-area conditions; dust, spark and atmosphere controls; PPE; safe start; stop-work decisions; quarantine and release.

Core principle — Do not energise the tool until the task, abrasive, machine, mounting system, guard, workpiece and work area form one compatible control system. A failed check leads to correction, quarantine or escalation—not a trial run.

A pre-use check is a decision process, not a quick glance. It prevents a correct product being used on the wrong tool, a sound tool being used with a damaged abrasive, or an apparently simple task being started in an unsafe area. The decision must follow the actual product marking, machine information, material and work arrangement. [S275; S285; S286; S326]

Chapter objectives

After this chapter, the reader should be able to:

- apply four consistent outcomes: proceed, correct, quarantine or escalate;
- define the task and intended abrasive operation before product selection;
- verify product identity, marking, dimensions, attachment and permitted speed;
- recognise product conditions requiring quarantine;
- check the tool, mounting system, guard, handle and controls while isolated;
- confirm workpiece restraint, cut closure, offcut movement and operator position;
- assess sparks, dust, atmosphere, access, lighting and simultaneous work;
- select the correct product-family branch;
- conduct a controlled free-running start where applicable;
- stop safely when conditions change; and
- use a concise release checklist before work begins.

1. Use four decision outcomes

Every check should end in one of four unambiguous outcomes.

Outcome	Meaning	Typical action
Proceed	The condition is identified, compatible and controlled	Continue to the next gate; energise only after all gates pass
Correct	The issue can be restored safely before use	Isolate, correct, reinspect and repeat the affected gate
Quarantine	The abrasive, tool or component may be damaged, defective or unidentifiable	Remove from service, identify it and prevent accidental reissue
Escalate	Compatibility, hazard or required control cannot be confirmed at operator level	Refer to a competent supervisor, maintenance person, safety specialist or technical representative

“Proceed” applies only to the condition checked. The task is released only when every applicable gate passes. If the task, material, tool, abrasive, area or control changes, return to the first affected gate.

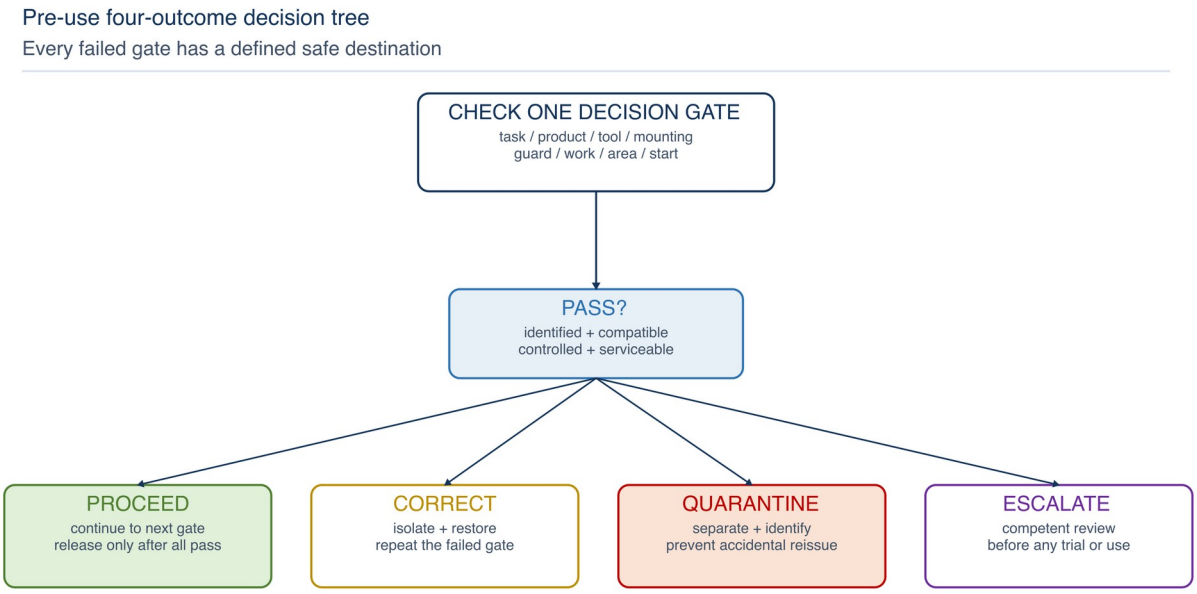

Figure 1. Pre-use four-outcome decision tree. Each gate either passes, is corrected and rechecked, sends an item to quarantine, or requires competent escalation. Energising is permitted only after the complete chain passes.

2. Gate 1 — Define the task and material

State the operation in practical terms before choosing an abrasive:

- material and coating to be contacted;
- cutting, stock removal, weld blending, deburring, cleaning, finishing or polishing;
- geometry, access and required finish;
- portable or stationary machine;
- dry or wet process, where the equipment and product permit it;
- expected spark, heat, dust and debris path;
- workpiece support, restraint and movement; and
- adjacent people, equipment and processes.

Do not substitute one operation for another because the product fits the spindle. A cutting-off wheel is intended for peripheral cutting and must not be used for side grinding. A grinding wheel is not automatically suitable for cutting. Select from the marked intended use and restrictions. [S278; S279; S326; S327]

Decision: If the material, operation or access condition is uncertain, escalate before selecting the abrasive. If the job can be completed by a lower-risk method that achieves the required result, use that method.

3. Gate 2 — Read the abrasive identity

Confirm that the product can be positively identified. Depending on product family, useful information may include:

- manufacturer or supplier identity;
- product name, type or code;
- dimensions;
- abrasive specification, grit or grade;
- intended operation or application symbol;
- maximum permitted rotational speed;
- direction of rotation;
- expiry or use-by information where applicable;
- restriction and PPE symbols; and
- traceability or batch information.

Do not guess from colour, shape, packaging resemblance or a handwritten description. Keep labels and packaging with the product until issue is complete. If essential identity or marking is illegible, quarantine the product.

When an exact product value is required, Refer to the product label, Technical Data Sheet, or MKTECH representative.

4. Gate 3 — Prove tool–accessory compatibility

Compatibility is a chain. All links must match:

1004. **Intended operation:** cutting, grinding, sanding, blending, cleaning or polishing.
1005. **Machine type:** the accessory is intended for the actual portable or stationary machine.
1006. **Dimensions:** diameter, width or thickness, bore, arbor and working clearance fit the machine and guard.
1007. **Attachment:** thread, flange, backing pad, chuck, collet, mandrel or hub is the intended system.
1008. **Speed:** the machine's maximum no-load speed does not exceed the abrasive's marked maximum permitted speed.
1009. **Direction:** directional products and machines run in the indicated direction.
1010. **Guarding:** the correct guard can be fitted and positioned without modification.
1011. **Material and environment:** the product is suitable for the work material and dry, wet, dusty or potentially hazardous conditions.

Never rely on nominal diameter alone. Two products of similar size may have different attachment systems, speed limits, intended uses or guard requirements. Do not reduce a wheel bore, enlarge a hole, force a thread, stack accessories or fit an improvised adaptor.

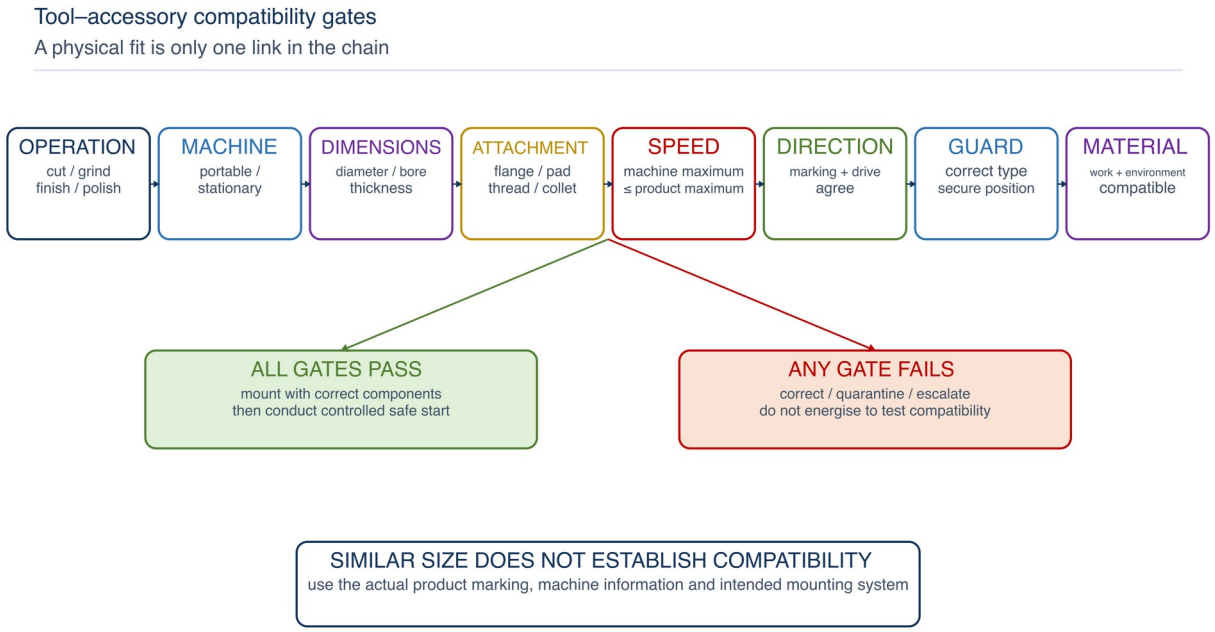

Figure 2. Tool–accessory compatibility gates. Intended use, machine type, dimensions, attachment, speed, direction, guarding and material conditions must all pass before mounting.

5. Gate 4 — Inspect the abrasive condition

Inspect in good light before fitting. Handle the product by its strong, intended support surfaces and avoid bending, dropping or striking it.

Product condition	Decision
Cracked, chipped, torn, delaminated, distorted, crushed or impact-damaged	Quarantine
Bore, thread, hub, backing, joint or attachment damaged	Quarantine
Wet, chemically contaminated, oil-soaked or affected by unsuitable storage	Quarantine pending competent assessment

Product condition	Decision
Marking needed for selection or speed verification is unreadable	Quarantine
Applicable expiry or use-by date has passed	Quarantine
Uncertain drop, impact, exposure or storage history	Quarantine pending assessment
Normal, identifiable and free from visible damage	Continue to the product-family check

For products and applications requiring an inspection test such as a ring test, use the correct method only on product types for which that test is applicable and only by a trained person. A test result does not override visible damage, unsuitable storage or incorrect mounting. [S285; S286]

6. Gate 5 — Isolate and inspect the machine

Disconnect the electrical supply, remove the battery, isolate pneumatic or hydraulic energy, or apply the machine's isolation method before fitting, adjustment, clearing or inspection. A released trigger is not isolation.

Check:

- model, rated capacity and maximum no-load speed information;
- spindle, arbor, chuck, collet, mandrel or drive condition;
- threads, keys, shoulders and contact surfaces;
- bearings, play, unusual resistance and run-out;
- power lead, plug, battery, charger, air hose and couplings;
- start, stop, dead-man or hold-to-run control as fitted;
- auxiliary handle and required machine supports;
- vents, extraction ports and cooling paths; and
- evidence of unauthorised modification or previous impact.

Quarantine a tool with a damaged guard, defective control, exposed conductor, cracked housing, loose spindle, abnormal run-out or uncertain safe condition. Maintenance release is required before reissue. [S280; S281; S282; S283; S284; S328]

7. Gate 6 — Confirm mounting components

Use the flange, nut, backing pad, adaptor, washer, blotter, chuck, collet, mandrel or hub specified for the abrasive and machine combination. Mounting surfaces should be clean, flat, undamaged and correctly seated.

Reject these practices:

- mixing unmatched flanges or nuts;
- omitting a required component;
- using a component that is bent, burred, worn or cracked;
- forcing the abrasive onto the spindle or into a collet;
- using packing, tape or makeshift washers to remove looseness;
- stacking discs to increase thickness;
- using excessive tightening force; or
- modifying the guard to accommodate an unsuitable accessory.

Tightening should secure the product without distorting it. Use only the intended tool and method. After mounting, rotate by hand where the machine design permits and confirm free clearance from the guard, work rest and machine structure.

8. Gate 7 — Verify guards, handles and controls

The guard is part of the machine–abrasive system. Confirm that it is the correct type for the operation, securely installed, undamaged and positioned to maximise protection while allowing controlled access to the work.

Check that:

- the guard covers the required portion of the abrasive;
- the opening is directed away from the operator and others as far as practicable;
- the guard cannot contact the accessory during run-up or use;

- the auxiliary handle is fitted where required and enables stable two-hand control;
- the switch operates freely and returns or latches only as designed;
- emergency stopping means are accessible on stationary equipment; and
- protective screens do not replace required eye and face protection.

Never tie, wedge or bypass a control. Do not remove a guard for visibility or access; change the task method, tool or work arrangement instead.

9. Gate 8 — Secure and support the workpiece

Restraint must control both the workpiece and any material that will be released.

Before starting, determine:

- how the part is clamped, located or supported;
- whether the contact force can rotate, lift or eject it;
- how a cut will close or open as residual stress is released;
- where the offcut will fall, swing or roll;
- whether the abrasive can be pinched or trapped;
- whether the operator’s hands or body enter the line of cut;
- whether hoses or cables can be caught; and
- whether hot or sharp material can strike people or ignite nearby fuel.

Support the work so the kerf remains controlled and the wheel is not twisted. Small parts should not be hand-held against a powered abrasive. On a stationary grinder, set and maintain the work support in accordance with the machine instructions and the actual wheel arrangement.

10. Gate 9 — Prepare the work area

Walk the entire operating and receiving area, including the opposite side, lower level and extraction path.

Area factor	Release question
People and access	Are bystanders excluded and is the escape route clear?
Lighting and footing	Can the operator see the contact point and maintain stable balance?
Sparks and hot particles	Are combustibles removed or protected along the complete travel path?
Flammable atmosphere	Are vapours, gases, residues, containers, drains and connected systems controlled?
Dust	Is dust captured without creating an incompatible fire or explosion path?
Water and moisture	Are electrical, abrasive, material and waste systems suitable for the method?
Noise and vibration	Are engineering controls and exposure arrangements in place?
Simultaneous work	Can nearby welding, spraying, cleaning, lifting or vehicle movement affect the task?
Housekeeping	Are trip hazards, loose debris and accumulated dust removed safely?

If sparks, dust, fragments or noise cross the prepared boundary, correct the area or relocate the task. Abrasive work on used containers, pipework or equipment that may retain hazardous residue requires a controlled site method before release.

11. Gate 10 — Confirm engineering controls and PPE

Engineering controls come first. Confirm required enclosure, local extraction, spark containment, screens, work supports, ventilation and noise controls are operating and compatible with the material.

Select PPE from the task assessment and product symbols. The ensemble may include:

- safety eyewear and face protection;
- suitable hearing protection;
- task-selected respiratory protection;
- protective clothing and footwear;
- gloves appropriate to material handling and entanglement risk; and
- head or body protection for the work environment.

Check fit and compatibility. Safety glasses must not prevent a face shield sitting correctly; eyewear must not break a respirator seal; hearing protection must remain correctly seated; loose clothing, jewellery and hair must not approach rotating equipment. PPE does not correct an incompatible abrasive, missing guard or uncontrolled atmosphere.

12. Select the product-family branch

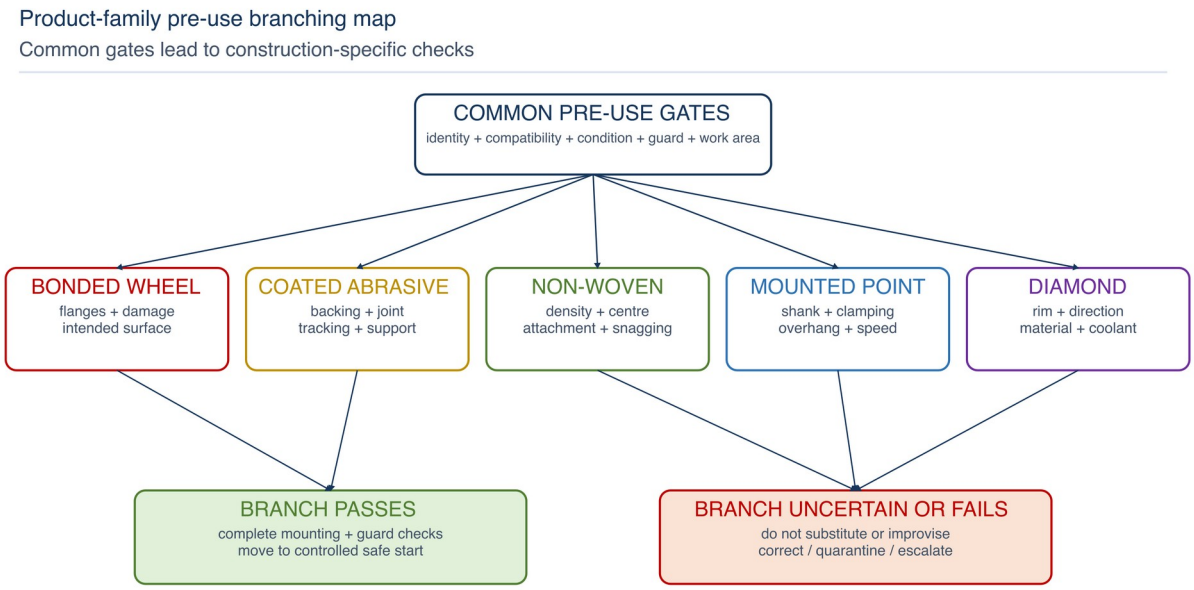

Figure 3. Product-family pre-use branching map. Common checks lead to additional branch checks for the actual abrasive construction and attachment system.

Product family	Additional pre-use focus
Bonded grinding wheel	Marking, dimensions, speed, flange contact, blotter where applicable, damage inspection, correct guard and intended grinding surface
Bonded cutting-off wheel	Cutting designation, correct cut-off guard, straight peripheral cut, work support and freedom from side load
Fibre or flap disc	Correct backing/support where required, disc condition, thread or flange seating, guard, direction and intended contact angle
Coated abrasive belt	Belt dimensions, joint and edge condition, tracking direction, tension, platen/contact wheel condition and enclosure
Non-woven product	Correct density or grade for the task, centre or backing integrity, attachment, speed and avoidance of snagging edges
Mounted point or small wheel	Correct shank/mandrel, insertion and clamping, overhang control, speed relationship and guard or enclosure arrangement
Diamond or superabrasive product	Intended material and method, direction, segment or rim condition, mounting, coolant requirements where applicable and machine suitability
Polishing mop or brush-type accessory	Hub and retention, speed, direction, loose sections, compound compatibility, enclosure and entanglement control

The branch check supplements the common gates; it does not replace them.

13. Portable angle-grinder branch

For a portable angle grinder, verify:

1012. the abrasive is intended for an angle grinder and the planned operation;
1013. the marked maximum permitted abrasive speed is not below the machine’s maximum no-load speed;

1014. diameter, bore or thread and thickness suit the machine and guard;
1015. the correct guard and auxiliary handle are fitted;
1016. flanges, nut or backing pad are the intended, undamaged set;
1017. the workpiece is clamped and the spark or fragment path is controlled;
1018. the lead, battery or air hose remains clear of the abrasive and hot work; and
1019. the operator can maintain stable two-hand control without overreaching.

For cutting, enter the work in line with the cut and avoid twisting or side pressure. For grinding, use only a wheel surface intended for grinding and maintain the product's recommended working angle. [S326; S327]

14. Stationary grinding branch

For a bench, pedestal or other stationary grinding machine, confirm:

- machine isolation during mounting and adjustment;
- wheel type, size and speed compatibility;
- wheel condition and applicable inspection method;
- correct flanges, blotters and mounting sequence where required;
- enclosure, guard and tongue or opening controls as designed;
- stable and correctly positioned work rest;
- screen condition and visibility;
- extraction and debris collection;
- emergency stop access; and
- a clear operator position outside the likely fragment path during start-up.

Do not adjust a work rest or guard while the wheel is moving. Numeric clearances and machine-specific settings must follow the applicable machine instructions and workplace procedure. [S284; S286; S287]

15. Conduct a controlled free-running start

After all pre-use gates pass:

1020. clear tools, keys, loose parts and packaging;
1021. confirm the abrasive rotates freely and the guard is secure;
1022. warn or exclude nearby personnel;
1023. establish a stable stance and two-hand control where applicable;
1024. position the body outside the likely fragment path;
1025. start without contact with the workpiece;
1026. allow the product to reach stable operating speed for the period required by its instructions; and
1027. listen and observe for abnormal vibration, noise, run-out, rubbing, movement, smell or control behaviour.

Stop immediately if the start is not smooth and stable. Isolate before inspection. Never test an uncertain abrasive by standing in line with it or bringing it into contact with the work.

16. Apply stop-work logic during operation

Pre-use release is not permanent. Stop in a controlled manner when:

- vibration, noise, run-out or heat changes unexpectedly;
- the abrasive chips, tears, loads, glazes, sheds or loses cutting efficiency abnormally;
- the guard, handle, work support or workpiece moves;
- the wheel binds, the cut closes or the tool kicks;
- sparks, dust or fragments leave the controlled area;
- extraction, ventilation, lighting or power quality is lost;
- a bystander enters the exclusion zone;
- flammable material, vapour or an unexpected coating is discovered;
- the task no longer matches the selected operation; or
- the operator loses stable posture or clear sight of the contact point.

Allow the abrasive to stop completely before setting down a portable tool or approaching a stationary wheel. Isolate, identify the cause and repeat the relevant decision gates before restart.

17. Quarantine and return-to-service control

A quarantined item should be physically separated from usable stock, clearly identified and protected from accidental reissue. Record enough information to support a competent disposition: item identity, observed condition, date, task, machine and person reporting.

Do not return an abrasive or tool to service because the defect is difficult to see on a second inspection. Abrasives are not repaired by adhesive, trimming, re-boring or re-labelling. Tools return only after the responsible maintenance or inspection process confirms safe condition.

After normal use, let the accessory stop fully, isolate the machine and inspect before storage or reissue. Store abrasives in their intended packaging and environmental conditions, protected from impact, moisture, contamination, distortion and uncontrolled temperature.

18. Troubleshoot a failed pre-use gate

Symptom or failed check	Likely control issue	Corrective direction
Product fits but speed cannot be confirmed	Incomplete marking or machine information	Do not energise; identify both ratings or escalate
Wheel does not seat flat	Dirty, damaged or incompatible flange/attachment	Isolate; clean and inspect; replace the incorrect or damaged component
Guard will not close around accessory	Wrong product size, thickness or guard type	Select the correct combination; never modify or remove the guard
Abrasive rubs during hand rotation	Incorrect seating, distortion, guard contact or spindle fault	Isolate, remove and inspect the complete mounting system
Excessive vibration at free run	Damage, imbalance, mounting error, run-out or machine defect	Stop, isolate and quarantine the suspected item
Cut begins to pinch	Inadequate support, residual stress or incorrect cutting path	Stop safely; redesign support and cut sequence before restarting
Dust escapes capture	Poor hood position, airflow, filter condition or unsuitable system	Stop; restore effective compatible control and reassess the area
Sparks reach outside the boundary	Tool direction, screen, airflow or task position has changed	Stop; extend or redesign containment and recheck receiving areas
Operator cannot hold stable posture	Access, tool size, handle position or work height is unsuitable	Reposition or select a more suitable method and support
Uncertain product application	Selection information is insufficient	Refer to the product label, Technical Data Sheet, or MKTECH representative.

19. Supervisor release questions

For higher-risk or non-routine work, the supervisor should be able to answer:

- Is the task defined and is this the preferred safe method?
- Are the material, coating and potential residues understood?
- Can the abrasive and machine be positively identified?
- Has the complete compatibility chain been checked?
- Are product and machine free from damage or modification?
- Are mounting, guard, handle and control arrangements correct?
- Is the workpiece restrained through the complete operation?
- Are sparks, dust, noise, heat and released material controlled?
- Are atmosphere, adjacent processes and people controlled?
- Are engineering controls and PPE available and effective?
- Does the operator understand start, stop and escalation actions?
- Will any change return the job to reassessment?

The release should be proportionate to the task. A documented permit may be required for hot work, confined spaces, hazardous atmospheres, isolation or other site-controlled activities.

20. Pre-use safety release checklist

- [ ] Task, material, operation and required finish are defined.
- [ ] Abrasive identity and essential marking are legible.
- [ ] Intended use, dimensions, attachment, direction and speed are compatible.
- [ ] Abrasive is within applicable date and free from damage, contamination and distortion.
- [ ] Tool is isolated and its spindle, drive, supply and controls are serviceable.
- [ ] Correct mounting components are clean, undamaged and properly seated.
- [ ] Correct guard, handle, work support and protective devices are installed.
- [ ] Workpiece and offcut are restrained; binding and released stress are controlled.
- [ ] Operator stance, access, visibility and cable or hose routing are stable.
- [ ] Bystanders and simultaneous operations are controlled.
- [ ] Spark, fragment, heat and dust paths remain inside the prepared boundary.
- [ ] Atmosphere, combustibles, residues and connected equipment are controlled.
- [ ] Compatible extraction, ventilation and engineering controls are operating.
- [ ] Task-selected PPE is fitted and compatible.
- [ ] Free-running start position and stop-work actions are understood.

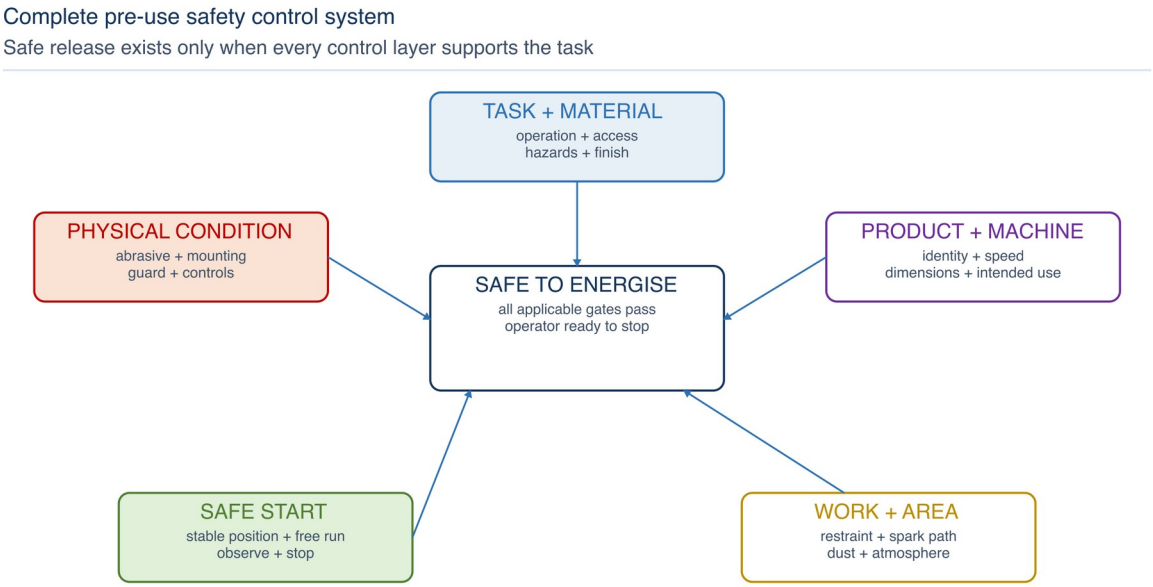

Figure 4. Complete pre-use safety control system. Safe release depends on the interaction of task definition, product identity, machine compatibility, physical condition, work control and safe start—not on any single check.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 052

Preventive Maintenance for Grinding Machines

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SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Factory owners, production managers, workshop supervisors, maintenance teams, operators, safety and health personnel, technical buyers and application personnel responsible for portable and stationary grinding equipment

Scope: Asset control; maintenance planning; competence; hazardous-energy isolation; cleaning; inspection; guards and controls; spindles, flanges, bearings and drives; electric, battery and pneumatic tools; stationary machines; extraction and coolant; condition monitoring; defect priority; repair release; records and troubleshooting.

Core principle — Preventive maintenance is complete only when the machine is safe to maintain, the required work is performed correctly, every protective function is restored, and the machine passes a controlled return-to-service check.

Grinding machines operate in a severe environment of abrasive dust, impact, vibration, heat and repeated load. Small deterioration can affect guarding, mounting accuracy, wheel life, surface finish, noise, vibration and productivity before a breakdown occurs. A strong maintenance system combines operator care, planned inspection, competent technical work, condition monitoring and disciplined defect closure. [S275; S284; S286; S329]

Chapter objectives

After this chapter, the reader should be able to:

- establish a controlled identity and maintenance basis for each machine;
- set task content and frequency from risk, duty and condition;
- separate operator checks, competent maintenance and specialist repair;
- isolate electrical, pneumatic, mechanical and stored energy safely;
- clean equipment without spreading hazardous dust or damaging components;
- inspect guards, controls, spindles, flanges, bearings, drives and supports;
- apply relevant branches for portable, pneumatic and stationary machines;
- recognise condition indicators before failure;
- classify defects and prevent unsafe reissue;
- control replacement parts and repair quality;
- complete a staged return-to-service check; and
- improve the maintenance plan from history and recurring faults.

1. Build one maintenance control system

Preventive maintenance has four connected layers:

Layer	Primary purpose	Typical output
Operator care	Detect visible deterioration and abnormal behaviour early	Pre-use check, cleaning within authority, defect report
Planned inspection	Examine defined safety and condition points at suitable intervals	Inspection result, measured condition, work request
Preventive task	Restore or preserve a defined function before failure	Adjustment, lubrication, replacement, cleaning, calibration or test
Condition-based action	Respond to a meaningful trend or abnormal event	Investigation, controlled shutdown, repair or interval change

These layers should share one defect and release process. A clean machine is not necessarily serviceable, and a completed work order is not a release if the guard, control, extraction or mounting system has not been verified.

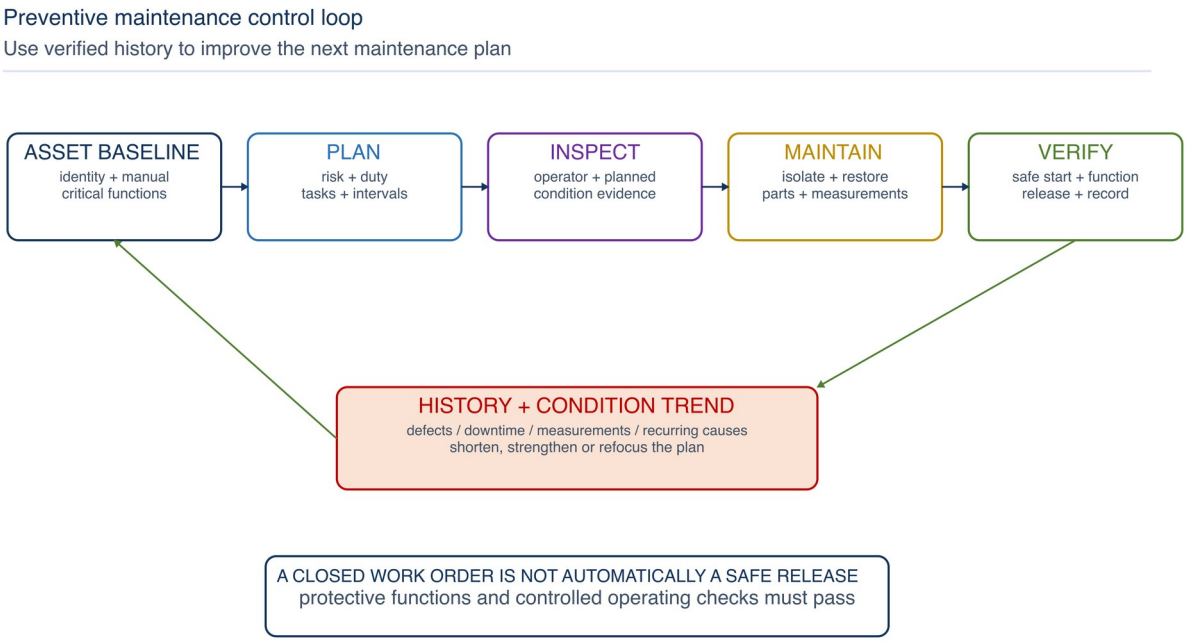

Figure 1. Preventive maintenance control loop. Asset information defines the plan; inspection and condition data trigger controlled work; verification releases the machine; history improves the next plan.

2. Establish the asset baseline

Create a reliable machine record before planning maintenance. Identify:

- asset number, location and responsible owner;
- manufacturer, model and serial number;
- machine type and intended operations;
- electrical, battery, pneumatic, hydraulic or other power source;
- rated capacity and maximum no-load speed information;
- spindle, arbor, flange, chuck, collet or mounting system;
- guard, handle, work-rest, interlock and emergency-control arrangement;
- extraction, coolant, filtration or lubrication system where fitted;
- applicable instruction, parts and service documents;
- authorised accessories and replacement components;
- commissioning, modification, repair and inspection history; and
- critical production and safety functions.

Keep markings legible. Do not create a new rating plate, guess a model from appearance or transfer a specification from a similar machine. Refer to the product label, Technical Data Sheet, or MKTECH representative.

3. Set priorities from risk and criticality

Maintenance attention should reflect the consequence and likelihood of failure, not only the purchase price of the machine.

Factor	Higher-priority examples	Planning effect
Safety consequence	Guard, spindle, wheel mounting, control or emergency-stop failure	Shorter review cycle and defined release authority
Duty severity	Multiple shifts, heavy contact, high dust, frequent starts or mobile use	More frequent cleaning and condition checks
Environment	Moisture, corrosive residue, outdoor work, heat or conductive dust	Environmental protection and targeted inspection
Process sensitivity	Tight finish, run-out or dimensional requirement	Baseline measurement and trend monitoring

Factor	Higher-priority examples	Planning effect
Failure history	Repeated bearing, switch, cable, hose or tracking defects	Root-cause action and revised task content
Production impact	Bottleneck machine or no ready backup	Planned access, critical spares and condition monitoring

Do not extend a maintenance interval simply because the machine has not failed. Review inspection findings, near misses, product changes, repair history and operating severity together. [S330; S332]

4. Define roles and competence

Match work authority to risk and technical complexity.

- **Operator:** pre-use checks, approved external cleaning, correct accessory change and prompt defect reporting.
- **Supervisor or issuer:** asset status, quarantine, work allocation, inspection confirmation and operating release within the site system.
- **Maintenance technician:** planned tasks, isolation, adjustment, component replacement, measurement and functional verification within competence.
- **Electrical or specialist technician:** internal electrical work, protective-device testing, controller work, major spindle or drive repair and calibrated acceptance tests.
- **Manufacturer or authorised service provider:** work reserved by the manual, warranty conditions, special tooling, firmware, safety electronics or proprietary assemblies.

Competence includes knowing when not to proceed. An operator who can change a wheel is not automatically authorised to dismantle a spindle, repair a guard, alter an interlock or adjust a speed controller. [S329; S333; S334]

5. Plan and isolate maintenance safely

Maintenance may expose rotating parts, stored pressure, gravity, springs, heat, sharp edges, electricity, automatic movement and hazardous deposits. Prepare the job before opening the machine.

1028. Define the work scope and affected equipment.
1029. Identify every energy source and possible reaccumulation.
1030. Shut down by the normal stopping method.
1031. Isolate energy using the workplace procedure.
1032. Release, block or restrain stored energy.
1033. Verify that isolation is effective before work begins.
1034. Control adjacent machines, connected extraction, automatic feeders and remote starts.
1035. Maintain isolation through shift, contractor and group changes.

Removing a battery, unplugging a cord or closing an air valve is effective only when it controls all relevant energy and remains under the required control. A switch, emergency stop or software command is not automatically an energy-isolating device. [S275; S331]

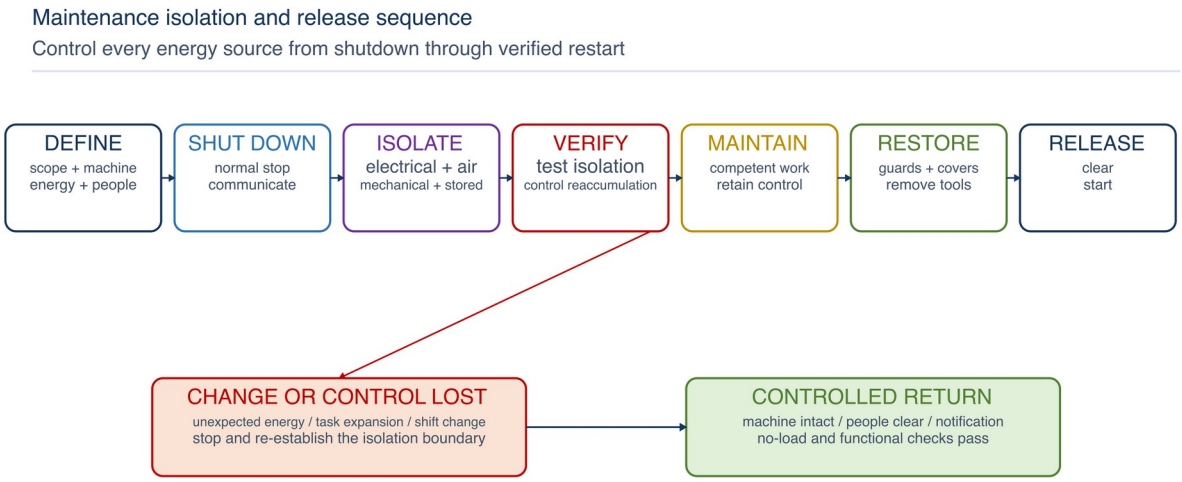

Figure 2. Maintenance isolation and release sequence. Define, shut down, isolate, dissipate, verify, maintain control, restore protections and release through a controlled start.

6. Clean without creating a second hazard

Cleaning protects cooling, movement, visibility and inspection, but poor methods can force dust into bearings, motors, switches or the breathing zone.

Use a method compatible with the machine and deposit:

- isolate before opening guards, covers, filters or collection points;
- capture dust with suitable extraction or vacuum equipment;
- avoid uncontrolled compressed-air blowing and dry sweeping;
- keep ventilation slots and cooling paths clear without pushing debris deeper;
- use only cleaning agents compatible with plastics, insulation, seals, coatings and lubricants;
- keep liquids away from electrical assemblies unless the procedure permits them;
- control metal, coating, compound and combustible-dust mixtures;
- inspect hidden ledges, enclosures, ducts and base cavities;
- dispose of collected material by its actual composition; and
- allow all parts to dry and restore covers before energising.

Clean enough to inspect. A polished exterior should not conceal blocked ventilation, loaded extraction, damaged wiring or contaminated mounting faces. [S320; S329; S333; S334]

7. Maintain guards, controls and protective devices

Treat these items as safety-critical:

- wheel and belt guards, covers and enclosures;
- auxiliary handles, handholds and tool rests;
- start, stop, hold-to-run and lock-off controls;
- emergency stops and braking functions;
- interlocks, presence sensing and access switches;
- spark, chip and transparent screens;
- overspeed, overload, anti-restart and other protective functions where fitted; and
- labels, direction arrows and warnings.

Inspect for cracks, distortion, looseness, missing fasteners, unauthorised holes, bypasses, slow return, sticking or unreliable operation. Replace a damaged guard with the correct component; do not weld, hammer, trim or drill it unless an approved repair procedure specifically permits the work.

After maintenance, test every affected protective function under controlled conditions before production release. A guard refitted without its fasteners, an interlock defeated for testing or a switch that works intermittently is not an acceptable temporary condition.

8. Protect spindle and mounting accuracy

The spindle–flange–abrasive interface transfers speed and load while controlling alignment.

Check, as applicable:

- spindle or arbor straightness and run-out;
- thread form, shoulder and locating diameter;
- flange flatness, matching, contact surfaces and retention;
- chuck, collet, mandrel or hub wear;
- key, taper and locking mechanism condition;
- axial and radial play;
- mounting-face contamination, burrs and impact damage; and
- free rotation and clearance after assembly.

Do not dress a damaged flange with an improvised hand method, force a nut over damaged threads or use packing to remove looseness. Quantitative checks require the correct instrument, setup and acceptance value. Refer to the product label, Technical Data Sheet, or MKTECH representative.

9. Inspect bearings, gears, belts and drives

Rotating components often signal deterioration through changing sound, vibration, heat, backlash, leakage or load behaviour.

Indicator	Possible system area	Maintenance direction
Rumbling or rough rotation	Bearing, contamination, lubrication or fit	Isolate and inspect; do not mask with additional lubricant
Gear noise or backlash change	Gear wear, lubrication, alignment or damage	Inspect drive and lubricant condition using the service method
Belt dust, slip or tracking drift	Tension, pulley alignment, contamination or wear	Correct cause; replace matched components where required
Hot housing	Load, bearing, cooling, lubrication or electrical condition	Stop and compare with baseline; investigate before restart
Repeated fastener loosening	Vibration, damaged thread, joint design or incorrect assembly	Identify cause; use the specified fastener and retention method
Oil or grease leakage	Seal, fill level, pressure, breathers or over-lubrication	Control contamination and restore the specified sealing system

Lubrication is product-specific. More grease or oil can increase heat, attract abrasive contamination, damage seals or affect braking. Use the specified lubricant, quantity, point and method.

10. Portable electric grinder branch

For corded tools, include:

- lead, plug, strain relief and external insulation;
- switch and anti-restart behaviour where fitted;
- vents, fan path and brush area;
- brush wear or automatic brush shut-off where the design uses brushes;
- spindle lock, guard clamp and side-handle threads;
- gearbox leakage, noise and play; and
- applicable electrical inspection and test.

For battery tools, also inspect:

- battery case, contacts, latch and contamination;
- charger, lead and ventilation;
- heat, swelling, impact or liquid exposure;
- battery seating and retention; and
- protective cut-out or brake behaviour described by the manual.

Do not open a battery pack, bypass protective electronics or clean electrical tools with flammable solvent. Internal repair and electrical testing should follow the actual tool instructions and competent service process. [S283; S334]

11. Pneumatic grinder branch

Pneumatic-tool maintenance should consider the complete air system:

- hose, coupling, whip restraint and inlet condition;
- pressure control, filter, regulator and lubricator where applicable;
- air quality, moisture and contamination;
- throttle, lock-off, governor and exhaust;
- spindle, collet and guard;
- free-speed verification after relevant work and at the specified interval;
- vibration, noise and leakage; and
- specified lubrication.

Turn off the supply, bleed pressure and disconnect before accessory change or maintenance. A speed controller or governor is a safety-relevant assembly and should not be improvised, altered or dismantled beyond authorised instructions. Use a calibrated tachometer and the specified no-accessory method when a free-speed check is required. [S280; S333]

12. Stationary grinding-machine branch

For bench, pedestal, cut-off and larger stationary grinding machines, include the installed system:

- foundation, anchorage and machine stability;
- wheel enclosure, guard, doors and fasteners;
- work rest, tongue or opening controls and adjustment locks;
- spindle, bearings, flanges and drive;
- brake, start, stop and emergency controls;
- screens, lighting and visibility;
- wheel-change lifting or handling arrangements;
- extraction, spark collection, coolant and filtration;
- workholding, tables, slides, feeds and limit devices; and
- automatic cycle, interlock and safe-access functions.

Adjustments made after wheel wear must preserve the required machine arrangement and clearance. Perform them only while safely stopped and isolated as required. Machine-specific numeric values follow the current instructions and workplace procedure. [S284; S286; S287]

13. Maintain extraction, coolant and collection systems

A grinding machine may be mechanically sound while its supporting controls are ineffective.

Check extraction hoods, dampers, ducts, flexible connections, filters, separators, waste containers and airflow indicators. Look for blocked branches, leaks, spark damage, deposits, incompatible material mixing and unauthorised changes. A stronger fan does not correct an unsuitable collector or hazardous dust combination.

Where coolant is used, control:

- concentration or condition by the approved method;
- flow, nozzle position and return path;
- filtration, tramp oil and solids loading;
- tank cleanliness and biological deterioration;
- leaks, hose damage and slip hazards;
- compatibility with the abrasive and work material; and
- mist control and enclosure condition.

Coordinate machine and extraction maintenance so one system is not released while the other remains unavailable.

14. Use condition monitoring intelligently

Condition monitoring compares repeatable indicators against an established baseline and decision process. It may include:

- vibration at defined locations and operating conditions;
- bearing or housing temperature;
- acoustic or ultrasonic behaviour;
- spindle run-out and wheelhead movement;
- motor current, power or cycle behaviour;
- pneumatic free speed and air consumption;
- lubricant or wear-debris condition;
- extraction airflow or pressure indication; and
- process signals such as finish drift, burn, chatter, loading or cycle-time change.

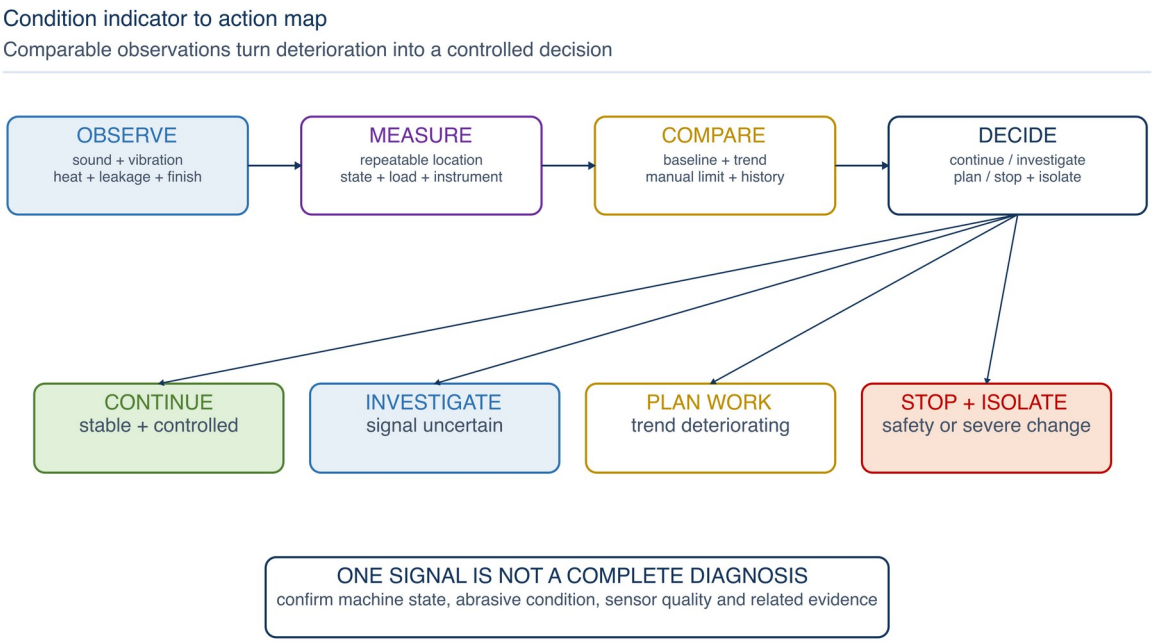

Figure 3. Condition indicator to action map. Repeatable observations and measurements are compared with baseline and limits, then routed to continue, investigate, plan work or stop and isolate.

Do not diagnose a bearing, wheel or motor from one signal alone. Confirm sensor location, machine state, load, abrasive condition and measurement quality. A trend is useful only when readings are comparable. [S332]

15. Set and improve maintenance intervals

Use the shortest applicable requirement from manufacturer instructions, workplace controls, statutory inspection, warranty or risk assessment. Then refine the programme with actual history.

Consider:

- operating hours, cycles, starts and shifts;
- abrasive dust quantity and type;
- contact load and thermal severity;
- portable, outdoor or corrosive exposure;
- operator reports and pre-use findings;
- measured condition trends;
- time since repair or modification;
- failure consequence and spare availability; and
- evidence of stable or accelerating deterioration.

Intervals may be shortened when defects recur or conditions become more severe. They may be reviewed when history consistently shows negligible deterioration, but only through a controlled risk-based decision. Avoid creating excessive low-value checks that encourage superficial completion. [S330]

16. Classify defects and control machine status

Defect class	Examples	Status action
Immediate safety defect	Guard missing, control unreliable, spindle loose, exposed conductor, severe air leak, abnormal free speed	Stop, isolate and quarantine
Degraded safety function	Intermittent brake, cracked screen, loose work rest, damaged extraction connection	Remove from production and arrange competent correction
Developing condition	Rising vibration, heat, leakage, belt dust, finish drift or repeated loading	Plan investigation promptly and define operating restrictions only through authorised assessment
Housekeeping or minor condition	External dirt, label beginning to fade, non-critical loose cover fastener	Correct within the assigned period and recheck
Recurring defect	Same component or symptom repeats after repair	Escalate to root-cause review; do not continue parts replacement alone

Status should be visible at the machine and in the maintenance system. Prevent an isolated or quarantined machine from being restarted, moved or reissued without formal release.

17. Control repairs and replacement parts

Before repair, confirm the exact machine identity, revision and parts basis. Use components that match the design and safety function. Check part number, material, rating, dimensions, firmware or configuration where relevant.

Do not:

- substitute a guard, flange, switch, cable, bearing or fastener by appearance;
- bypass an interlock because the correct part is delayed;
- re-machine a safety-critical component without an approved specification;
- mix unmatched bearing or flange components;
- alter cooling, speed or control settings to compensate for wear; or
- return an incomplete machine for “light duty only” without a controlled engineering decision.

Record the fault found, work performed, parts fitted, measurements, tests and person releasing the machine. Retain removed safety-critical parts where investigation or warranty review requires them.

18. Complete a staged return to service

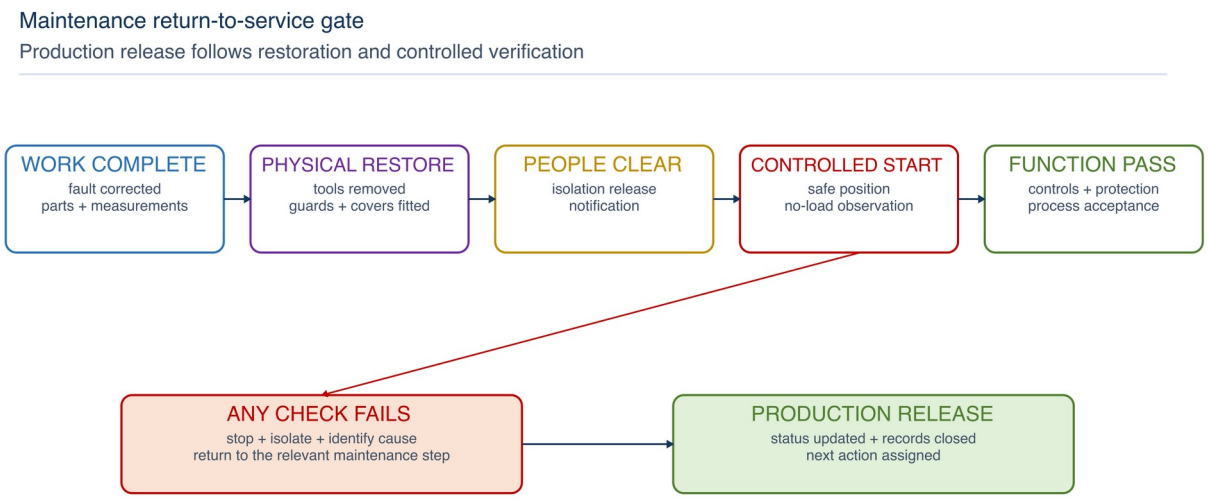

Figure 4. Maintenance return-to-service gate. Work completion, physical restoration, personnel clearance, controlled energisation and functional verification must all pass before production release.

Use this sequence:

1036. Confirm the planned work and defect corrections are complete.
1037. Remove tools, loose parts, temporary leads, cleaning materials and blocks.
1038. Check fluids, fasteners, covers, guards, handles and work supports.
1039. Restore interlocks, extraction, coolant and protective functions.
1040. Confirm the machine is operationally intact and the area is clear.
1041. Follow the workplace process for removing isolation and notifying affected people.
1042. Energise under controlled conditions from a safe position.
1043. Conduct required no-load, speed, direction, vibration, leakage and control checks.
1044. Test the affected function and stop arrangements.
1045. Release for production only when acceptance criteria pass and records are closed.

If a check fails, stop, isolate and return to maintenance. Production demand does not reduce the release criteria. [S331]

19. Troubleshoot maintenance-system failures

Symptom	Likely system issue	Corrective direction
Repeated emergency repairs	Plan ignores duty, failure history or early indicators	Review criticality, task content and interval
Machine clean but overheats	Internal blockage, load, bearing, fan or electrical condition	Compare with baseline and inspect the complete cooling/load path
New bearing fails early	Contamination, fit, alignment, lubrication or installation damage	Protect the work, verify method and investigate root cause
Wheel run-out after service	Spindle, flange, mounting face, assembly or wheel condition	Isolate and measure the complete mounting chain
Belt repeatedly tracks off	Pulley/contact wheel alignment, tension, wear or structure	Correct geometry and cause; do not guide by guard contact
Guard fasteners loosen	Vibration, thread damage, wrong fastener or incorrect assembly	Restore specified joint and investigate vibration

Symptom	Likely system issue	Corrective direction
Pneumatic speed changes	Governor, pressure, air quality, leakage or load	Remove accessory, use authorised checks and competent repair
Dust returns after cleaning	Capture, duct, filter, sealing or cleaning method is ineffective	Correct source and system; do not increase blowing
Defects appear soon after release	Incomplete verification, wrong part or hidden cause	Re-isolate, review repair scope and strengthen the release gate
Interval or part value is uncertain	Machine-specific information is required	Refer to the product label, Technical Data Sheet, or MKTECH representative.

20. Preventive-maintenance release checklist

- [ ] Correct machine, model, serial number and work scope are confirmed.
- [ ] Applicable instructions, parts basis and acceptance criteria are available.
- [ ] All energy sources and stored energy are isolated and verified.
- [ ] Dust, residues, sharp parts, heat and maintenance access are controlled.
- [ ] Guards, controls, handles, supports and protective functions are inspected.
- [ ] Spindle, flanges, threads, bearings, drives and mounting faces are serviceable.
- [ ] Electrical, battery, pneumatic or other power-system checks are complete.
- [ ] Extraction, coolant, filtration and collection systems are restored where fitted.
- [ ] Correct parts, lubricants, fasteners and assembly methods were used.
- [ ] Required quantitative checks used suitable calibrated equipment.
- [ ] Tools, loose parts, temporary controls and cleaning materials are removed.
- [ ] Covers, guards, interlocks and emergency controls are fully restored.
- [ ] People are clear and affected personnel are notified before energisation.
- [ ] Controlled no-load and functional checks pass without abnormal condition.
- [ ] Defects, work, parts, measurements, release and next due action are recorded.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 053

Pneumatic Tool Maintenance

53

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, workshop supervisors, operators, maintenance technicians, safety and health personnel, tool-room teams and technical buyers responsible for pneumatic grinders, die grinders, sanders and polishers

Scope: Air supply; isolation and pressure release; hoses and couplings; filters, regulators and lubricators; air quality; throttles and governors; exhaust; spindle, collet and guards; lubrication; free-speed verification; condition monitoring; cleaning; competent repair; release and troubleshooting.

Core principle — A pneumatic abrasive tool is only as reliable as the complete system supplying and controlling it. Maintain the tool, hose, coupling, air treatment, pressure control, mounting system and accessory as one compatible operating chain.

Pneumatic tools are compact and robust, but their speed and condition can be affected by air pressure, flow restriction, water, particles, lubrication, hose damage, leakage and internal wear. Abrasive dust can also enter controls and exhaust passages. Preventive maintenance must therefore follow the complete route from the compressed-air connection to the abrasive contact point. [S280; S281; S282; S333; S336]

Chapter objectives

After this chapter, the reader should be able to:

- map the complete pneumatic tool system;
- isolate, bleed and disconnect the tool safely;
- inspect hoses, couplings, retainers and routing;
- maintain filters, drains, regulators and lubricators;
- understand particles, water and oil contamination;
- distinguish lubricated and non-line-lubricated tool arrangements;
- inspect throttles, lock-offs, governors, exhausts and guards;
- check spindles, collets, mandrels and accessory mounting;
- recognise when calibrated free-speed verification is required;
- diagnose weak power, speed drift, leakage, noise and vibration systematically;
- control cleaning and internal repair; and
- complete a controlled return-to-service check.

1. Treat the air tool as a system

System element	Main function	Typical maintenance concern
Supply header or drop	Provides air volume and pressure	Contamination, drainage, isolation, capacity
Filter and separator	Removes particles and liquid	Loading, drainage, damage, bypass
Regulator	Controls delivered pressure	Drift, tampering, poor location, gauge condition
Lubricator where required	Introduces specified lubricant	Empty bowl, wrong oil, over-feed, poor placement
Hose and coupling	Carries air to the tool	Leakage, damage, restriction, whip, trip hazard
Tool inlet and motor	Converts air energy to rotation	Dirt, water, wear, lubrication, speed change
Governor or speed control	Limits or regulates speed where fitted	Wear, contamination, unauthorised adjustment
Spindle and mounting	Retains and drives the abrasive	Run-out, wear, damaged thread or collet
Guard and controls	Protect and stop the operator	Damage, bypass, slow return, incorrect position

Inspecting only the tool body can miss the real cause of poor performance. A blocked filter, undersized coupling, wet hose, excessive length or leaking joint can reduce power while an incorrect regulator setting or internal governor fault can create an unsafe condition.

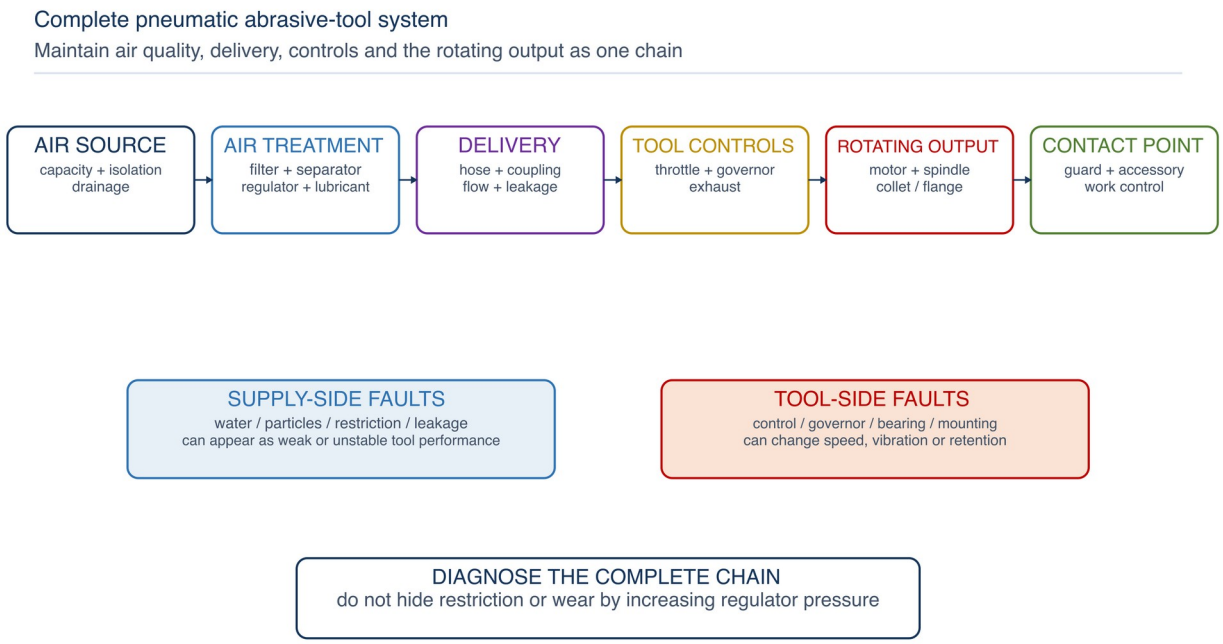

Figure 1. Complete pneumatic abrasive-tool system. Air quality, pressure control, delivery components, tool condition, mounting and guarding must operate together.

2. Establish tool identity and service basis

Before maintenance, confirm:

- manufacturer, model and serial number;
- intended tool family and operation;
- rated speed and accessory capacity information;
- inlet connection and approved supply arrangement;
- lubrication method;
- guard, handle, spindle, collet or chuck configuration;
- product, safety, parts and maintenance instructions;
- service history, previous repairs and modifications; and
- authorised replacement parts and responsible service level.

Keep the nameplate and warnings legible. Do not identify a tool by colour, general shape or a similar model. A replacement motor, governor, arbor housing or nameplate can change the controlled configuration and requires the correct parts basis.

When an exact tool, pressure, lubricant, part, speed or service value is required, Refer to the product label, Technical Data Sheet, or MKTECH representative.

3. Separate maintenance roles

- **Operator care:** external condition check, approved cleaning, hose inspection, accessory change and defect reporting.
- **Tool-room inspection:** controlled issue and return, identity check, guard and control inspection, leakage observation and scheduled status.
- **Competent maintenance:** isolation, dismantling within authority, cleaning, lubrication, parts replacement and specified tests.
- **Specialist or authorised service:** governor, rotor, safety control, spindle assembly or other work reserved by the manufacturer.

Do not allow production familiarity to substitute for repair competence. Internal air-tool parts can be spring-loaded, precisely fitted or safety-critical. Incorrect assembly may change free speed, braking, throttle return, vibration or accessory retention. [S329; S333]

4. Isolate, bleed and disconnect

Before accessory change, adjustment, clearing or maintenance:

1046. release the throttle and allow the accessory to stop;
1047. close the correct air isolation point;
1048. bleed trapped pressure from the hose and tool;
1049. disconnect the air supply using the intended method;
1050. secure or cap the hose where contamination or movement is possible;
1051. verify that the tool cannot start; and
1052. control any stored mechanical energy or hot components.

Do not rely on the throttle alone. A stuck valve, accidental contact, wrongly connected supply or trapped pressure can cause unexpected rotation. Group or fixed-installation work may require the workplace energy-control procedure rather than simple disconnection. [S275; S331; S333]

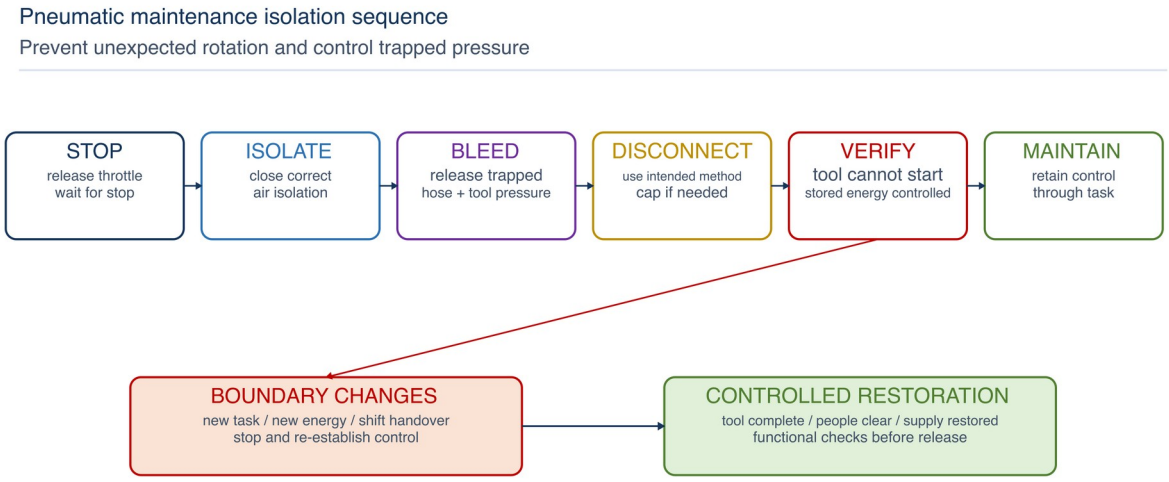

Figure 2. Pneumatic maintenance isolation sequence. Stop, isolate, bleed, disconnect, verify and maintain control before work begins; restore the supply only through a controlled release.

5. Inspect hoses, couplings and retainers

Inspect the complete hose length in good light. Look for:

- cuts, abrasion, blisters, hardening, softening or exposed reinforcement;
- crushed, kinked or heat-damaged areas;
- damaged threads, nipples, sockets or locking parts;
- loose clamps, makeshift repairs or incompatible fittings;
- leakage at joints, swivels and strain points;
- contamination inside disconnected ends;
- missing positive retention where required;
- hose weight or pull affecting tool control; and
- routing across sharp edges, traffic routes, hot work or liquids.

Quarantine visibly damaged or unsafe hose. Do not repair pressure hose with tape, wire, ordinary clamps or unapproved splices. Couplings should connect fully, lock correctly and remain suitable for the hose, pressure and flow duty. [S336]

6. Control pressure and flow at the tool

Pressure and flow are different. A gauge can show expected static pressure while restriction causes a large drop during operation. Conversely, an incorrect or bypassed regulator may expose the tool to excessive supply conditions.

For performance complaints, check:

- regulator identity, condition and tamper control;

- gauge condition and location;
- pressure under the specified operating test;
- filter loading and separator restriction;
- coupling and hose internal size;
- hose length, kinks and manifold demand;
- simultaneous users on the branch;
- leakage; and
- tool inlet screen or fitting restriction.

Never increase regulator pressure to compensate for a worn motor, blocked filter, undersized hose or overloaded abrasive. Correct the cause using the actual tool and system information.

7. Maintain filters, separators and drains

Air-treatment equipment should be accessible, correctly oriented and protected from impact.

Component	Check	Corrective direction
Filter element	Loading, damage, pressure indication where fitted	Replace by condition or specified interval
Bowl	Cracks, clouding, chemical attack, secure fit	Depressurise and replace damaged components
Drain	Water removal, blockage, automatic-drain function	Clean or repair without releasing pressure unsafely
Separator	Collection, differential condition, leakage	Restore effective separation and sealing
Regulator	Stable control, adjustment lock, gauge	Verify by the specified method; prevent tampering
Lubricator	Correct lubricant, level, feed and location	Service only where the tool system requires it

Drainage should not discharge onto walkways, electrical equipment or people. Treat condensate according to its actual oil and contaminant content.

8. Understand compressed-air contamination

ISO 8573-1 classifies compressed-air purity in relation to particles, water and oil and identifies other possible contaminants. [S335] For abrasive tools, contamination can:

- abrade motor vanes, bearings, valves and governors;
- cause corrosion, sticking or freezing;
- wash out or degrade lubricant;
- block small passages or exhaust silencers;
- contaminate the workpiece or finished surface;
- carry hazardous process material into maintenance work; and
- change tool speed or power.

Do not assign a purity class from appearance or install a finer filter without checking flow capacity and system design. Sample or measure at a location representative of the tool supply when quantitative air quality is required.

9. Apply the correct lubrication method

Pneumatic tools may use line lubrication, periodic inlet lubrication, sealed lubrication or a model-specific combination. One method cannot be assumed for every tool.

Use only the lubricant, quantity, location and interval specified for the actual tool. Too little lubrication can accelerate wear and sticking. Too much can contaminate the work, exhaust into the breathing zone, load silencers, attract dust or affect process finish.

Check that a line lubricator is close enough and adjusted appropriately for the intended branch. Do not feed lubricated air into tools or processes that require oil-free supply. Keep lubricant containers identified, clean and closed; do not mix oils by appearance.

10. Maintain throttle, lock-off and shut-off controls

The throttle should move freely, start only by deliberate action and return reliably when released. Check:

- lever, trigger or twist control condition;
- lock-off or safety latch operation;
- spring return and valve movement;
- dirt, sticky residue or damage around the control;
- unintended continuous running;
- air leakage when released; and
- unauthorised ties, wedges or modifications.

Remove from service any tool that starts unexpectedly, continues to run, responds intermittently or leaks severely through the control. Do not flush an assembled control with an unapproved solvent or lubricate it externally to hide a sticking fault.

11. Protect governors and speed-control assemblies

Where fitted, the governor is a safety-relevant speed-control device. Internal wear, contamination, incorrect springs, mismatched parts or unauthorised adjustment can change tool speed.

Do not:

- dismantle a sealed or unit-replacement governor beyond instructions;
- bend springs or modify weights;
- alter ports or exhaust restrictions to gain power;
- mix parts between tool models;
- infer safe speed from sound; or
- fit an abrasive until required free-speed checks pass.

After relevant repair, confirm the correct assembly and use the specified calibrated test method before release. [S280; S333]

12. Inspect exhaust and silencing

The exhaust affects noise, back pressure, contamination and operator exposure.

Check that:

- exhaust openings are clear;
- silencers or mufflers are present and serviceable;
- exhaust direction does not blow dust toward the face or workpiece;
- ice, oil mist or debris is not accumulating abnormally;
- deflectors and hoses are secure; and
- replacement components do not create excessive restriction.

A blocked silencer may reduce power or affect speed control. Removing it may increase noise, debris discharge and exposure. Replace or service it using the approved arrangement.

13. Maintain spindle, collet and accessory mounting

Inspect the rotating output system for:

- spindle, arbor or shaft straightness and play;
- thread, shoulder and flange condition;
- collet slots, taper, nut and seating surfaces;
- chuck or mandrel wear;
- spindle-lock condition where fitted;
- damage from overtightening, impact or abrasive contact;
- correct insertion and clamping of shanks; and
- free rotation and guard clearance.

Do not force a shank, pack a worn collet, dress damaged threads by trial or substitute a flange because it fits. Quantitative run-out, shank insertion and overhang limits follow the actual tool and accessory instructions.

14. Maintain guards, handles and tool body

Replace a guard that is bent, cracked, severely worn or affected by a wheel failure. Check the clamp, fastener and indexing system so the guard remains secure in the intended position. [S333]

Also inspect:

- side handle and mounting threads;
- housing cracks, loose screws and missing covers;
- label and direction marking;
- inlet fitting and exhaust deflector;
- suspension eye or balancer point where fitted;
- reaction bar or support for relevant tools; and
- evidence of grinding, drilling or unauthorised modification.

Never use the air hose to carry or suspend the tool.

15. Verify free speed correctly

Free-speed verification is required where specified by the tool instructions, after relevant repair and when speed-control condition is uncertain. The test should be performed by a competent person using a calibrated tachometer and the correct no-accessory arrangement. [S333]

Before testing:

1053. confirm exact tool identity and rated information;
1054. verify air supply and regulator test conditions;
1055. remove the abrasive product where the method requires it;
1056. inspect spindle, guard, control and tool body;
1057. secure the tool and control exhaust direction;
1058. keep people clear of the rotating output;
1059. record the stable result; and
1060. compare it with the specified acceptance basis.

If speed exceeds, fluctuates beyond, or cannot be confirmed against the specified basis, isolate and quarantine the tool. Do not fit a lower-speed abrasive as a workaround.

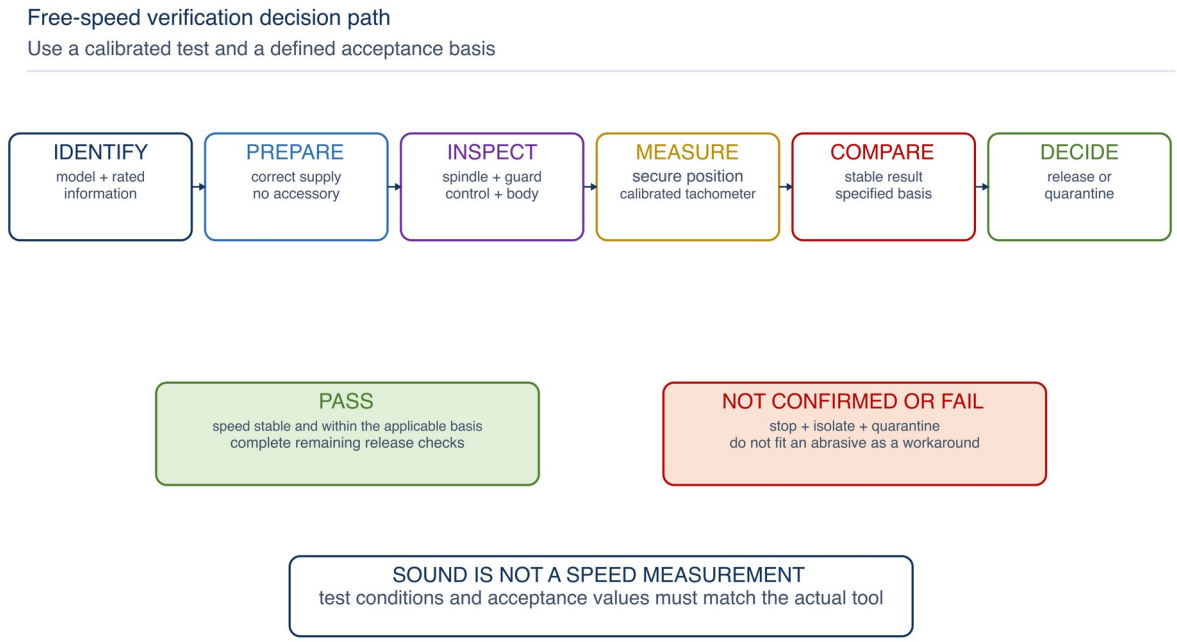

Figure 3. Free-speed verification decision path. Correct identity, supply condition, calibrated measurement and acceptance criteria are required before the tool is released for an abrasive accessory.

16. Use condition indicators before failure

Observe changes in:

- free speed and loaded speed behaviour;
- start response and stopping time;
- vibration, noise or roughness;

- housing temperature;
- air consumption and leakage;
- exhaust oil, water, debris or ice;
- spindle play and run-out;
- abrasive finish, chatter, loading or cycle time; and
- repeated hose, coupling or control defects.

Compare like with like: same tool configuration, supply condition, test method and measurement location. One signal is not a complete diagnosis. A power loss may come from the supply, delivery path, throttle, motor, exhaust, accessory or technique.

17. Clean and repair safely

Pneumatic tools can contain abrasive dust, coating residue, metal fines, oil and cleaning chemicals. Isolate and clean the exterior before opening. Use suitable ventilation, capture and PPE for the deposit.

During internal work:

- keep parts ordered and protected from contamination;
- use the correct disassembly and assembly tools;
- inspect rather than automatically replace every part;
- replace seals, bearings, vanes and safety components by the specified basis;
- use compatible cleaning solvent in a ventilated area;
- apply lubricant only to the required surfaces;
- observe orientation, clearances and tightening methods; and
- prevent dirt entering open air passages.

Repair should be performed by authorised trained personnel where the instructions require it. [S333]

18. Troubleshoot pneumatic-tool symptoms

Symptom	Possible system causes	Corrective direction
Weak power	Supply drop, blocked filter, restrictive hose, leakage, motor wear, loaded abrasive	Test supply under defined conditions; inspect complete chain
Speed high or unstable	Regulator, governor, wrong parts, contamination or test error	Stop, isolate and perform competent calibrated verification
Tool will not start	Isolation closed, coupling fault, throttle sticking, motor seizure or ice	Bleed and isolate before inspection; do not strike the tool
Excessive leakage	Hose, coupling, inlet, valve, seal or housing defect	Locate safely, depressurise and replace the correct component
Excessive vibration	Accessory, collet, spindle, bearing, motor or mounting fault	Remove accessory; inspect and measure from tool outward
Exhaust heavily oily	Over-lubrication, wrong method, internal condition	Correct lubrication basis and inspect exhaust system
Water or ice at exhaust	Drainage, dryer, temperature or air-quality problem	Correct the supply condition; do not rely on extra oil
Tool runs after release	Throttle contamination, spring, valve or modification	Quarantine immediately for competent repair
Abrasive repeatedly loosens	Mounting wear, incorrect component, vibration or technique	Inspect spindle, collet/flange and accessory compatibility
Exact value uncertain	Model-specific data are required	Refer to the product label, Technical Data Sheet, or MKTECH representative.

19. Complete a controlled return to service

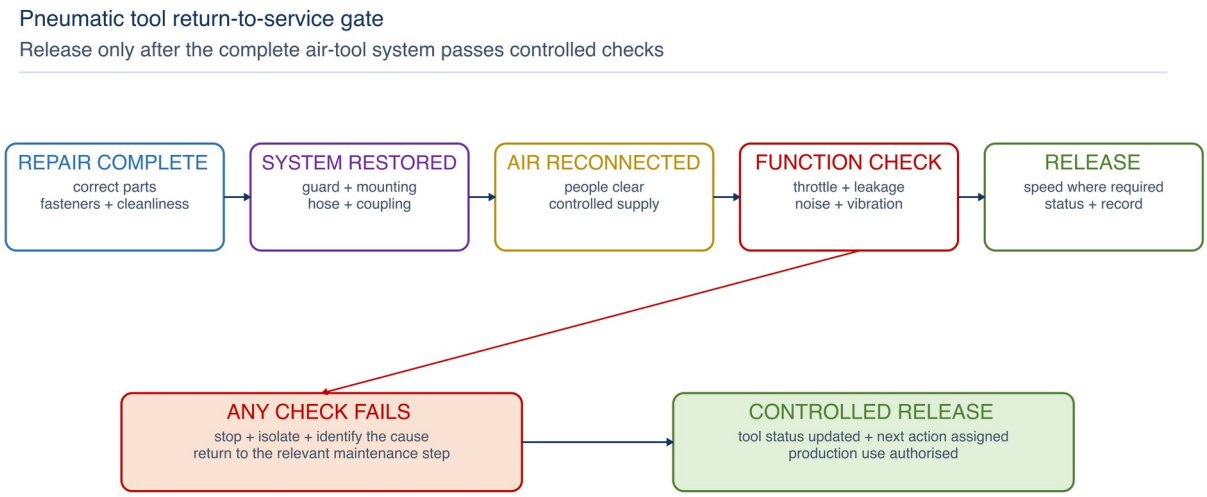

Figure 4. Pneumatic tool return-to-service gate. Assembly, protective devices, supply connection, no-accessory testing and accessory compatibility must pass before production release.

Use this release sequence:

1061. confirm work and parts are complete;
1062. remove loose items and restore covers, guard, handle and exhaust components;
1063. confirm throttle-off condition before connection;
1064. connect the correct hose and coupling with required retention;
1065. pressurise gradually from a stable, controlled position;
1066. check leakage and throttle return;
1067. verify free speed where required;
1068. observe noise, vibration, heat and exhaust condition;
1069. isolate again before fitting the abrasive;
1070. confirm tool–accessory compatibility; and
1071. record release and next maintenance action.

Any abnormal result returns the tool to isolation and investigation.

20. Pneumatic tool maintenance checklist

- [ ] Tool identity, rated information and service instructions are confirmed.
- [ ] Air supply is isolated, pressure is bled and disconnection is verified.
- [ ] Hose, coupling, retainer and routing are serviceable.
- [ ] Filter, separator, drain, regulator and gauge are functioning.
- [ ] Air contamination and treatment match the tool and process needs.
- [ ] Correct lubrication method, product, point and quantity are used.
- [ ] Throttle, lock-off and shut-off return reliably without leakage.
- [ ] Governor or speed-control assembly remains correct and unmodified.
- [ ] Exhaust and silencing components are clear, secure and correctly directed.
- [ ] Spindle, flange, chuck, collet or mandrel is serviceable.
- [ ] Guard, handle, housing, labels and fasteners are complete.
- [ ] Internal parts and passages are clean and correctly assembled.
- [ ] Required free-speed check uses a calibrated method and passes.
- [ ] Controlled connection and no-accessory functional test are satisfactory.
- [ ] Tool status, repair, parts, measurements and next action are recorded.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 054

Paint-Booth Maintenance

54

SELECT • APPLY • FINISH • TROUBLESHOOT

MKTech Industry Sdn Bhd | www.mktechindustry.com

Audience: Paint-shop managers, supervisors, booth operators, maintenance technicians, production engineers, safety and environmental personnel, QA/QC teams and technical buyers

Scope: Maintenance planning; isolation and clearance; residue control; booth enclosure; doors, seals and glazing; intake and exhaust filtration; gauges; fans and drives; plenums and ducts; make-up air; heating and curing; electrical equipment; grounding; interlocks; fire-protection interfaces; water-wash systems; compressed and breathing air; records; troubleshooting and return to service.

Core principle — A paint booth is a connected process-safety system. Maintain the enclosure, airflow path, filtration, fan, controls, fire protection and supporting utilities together; releasing one repaired component does not release the complete booth.

Maintenance protects coating quality, worker exposure control, fire safety, environmental control and production reliability at the same time. Overspray residue, loaded filters, air leakage, loose drives, blocked pressure taps, damaged seals or bypassed interlocks can interact. A useful programme therefore combines routine care, condition evidence, competent specialist work and a controlled functional release. [S171; S172; S175; S195]

Chapter objectives

After this chapter, the reader should be able to:

- map the complete booth and its supporting systems;
- plan maintenance around chemical, electrical, pressure, thermal and mechanical hazards;
- apply post-spray clearance, shutdown, isolation and verification;
- clean overspray residue without creating a new fire or exposure hazard;
- inspect the enclosure, doors, seals, glazing and access routes;
- maintain filters, gauges, fans, drives, plenums and ductwork;
- coordinate make-up-air, heating, electrical and fire-protection specialists;
- maintain water-wash equipment where fitted;
- distinguish compressed process air from breathing-air support;
- diagnose airflow, contamination, noise, leakage and control faults systematically; and
- complete a controlled return-to-service check.

1. Maintain the booth as one system

System zone	Main function	Maintenance focus
Make-up-air intake	Supplies replacement air	Screens, weather entry, dampers, filters, fan
Supply plenum and diffusion	Distributes clean air	Cleanliness, seals, uniform delivery, access
Booth enclosure	Contains spray and directs airflow	Panels, doors, seals, floor, glazing, openings
Exhaust filtration or wash stage	Captures overspray	Media or wash condition, bypass, pressure loss
Exhaust fan and drive	Moves contaminated air	Rotation, bearings, belts, vibration, guarding
Duct and discharge	Conveys and releases exhaust	Deposits, leakage, corrosion, supports, obstruction
Controls and instruments	Indicate and coordinate operation	Gauges, sensors, alarms, interlocks, timers
Fire and electrical systems	Control ignition and consequence	Integrity, classification, grounding, specialist service
Heating or curing equipment	Conditions air or coating	Burners/heaters, limits, airflow proof, shutdown

A fault in one zone can appear elsewhere. Low booth flow may come from a loaded intake, closed damper, exhaust-filter resistance, slipping belt, wrong fan rotation, duct obstruction or open access panel. Diagnose from the complete airflow route before changing settings or components.

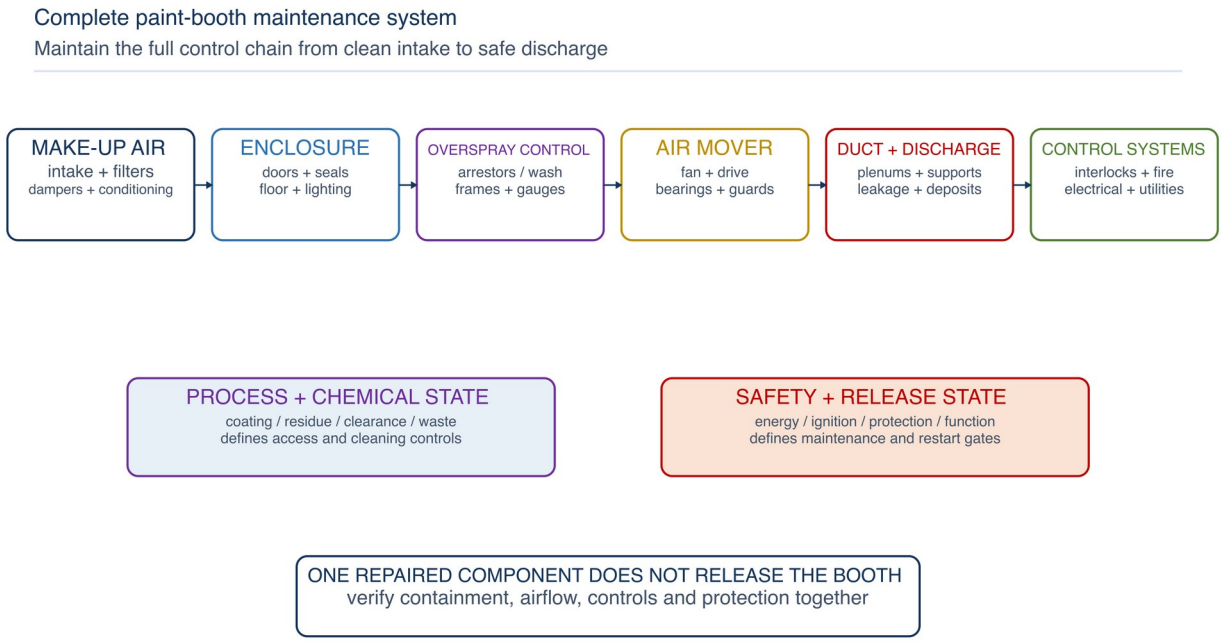

Figure 1. Complete paint-booth maintenance system. Asset, airflow, chemical, ignition, fire and control elements form one maintenance boundary.

2. Establish the maintenance basis

Confirm before planning work:

- booth identity, manufacturer, model and serial information;
- process type, coating families and normal operating modes;
- airflow arrangement and intended direction;
- drawings, schematics, manuals and previous modifications;
- filter stages and declared installation arrangement;
- fan, motor, drive, damper and make-up-air configuration;
- heating, curing, water-wash or recovery equipment where fitted;
- electrical classification, grounding and control philosophy;
- fire-detection, alarm, sprinkler or suppression interfaces;
- pressure, airflow, clearance-time and condition baselines; and
- maintenance history, recurring defects and responsible specialists.

Do not identify components from appearance alone or assume a similar booth uses the same sequence. When an exact part, filter, pressure, airflow, temperature, clearance time, lubricant, adjustment or test value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

3. Define maintenance roles and boundaries

- **Operator care:** approved housekeeping, visual checks, gauge observation and defect reporting.
- **Routine maintenance:** planned inspection, filter service, mechanical checks and cleaning within established authority.
- **Competent technical work:** fan, drive, instruments, controls, isolation, testing and system balancing.
- **Specialist work:** hazardous-area electrical equipment, burners, gas trains, fire protection, breathing air and statutory or authority-controlled examinations.

The person who can clean a booth safely may not be competent to adjust a burner, test an interlock or alter a fan. Define who may isolate, dismantle, test, override for diagnosis and authorise release.

4. Plan shutdown, clearance and isolation

Maintenance can expose electrical energy, fan inertia, compressed air, hot surfaces, fuel, automatic dampers, stored pressure, elevated work and hazardous coating residue. Review the actual job before shutdown.

Use this sequence:

1072. stop spraying and secure coating delivery;
1073. keep ventilation operating for the established post-spray clearance period;
1074. restrict access while airborne contamination may remain;
1075. shut down through the normal sequence;
1076. isolate all applicable energy and material sources;
1077. release or secure stored energy;
1078. verify isolation at the work location; and
1079. retain control until the task and restoration are complete.

Do not enter early because visible mist has disappeared. Clearance depends on the booth, airflow, loading and test basis; HSE guidance illustrates why verified clearance and leakage observation matter for hazardous spray processes. [S176; S177]

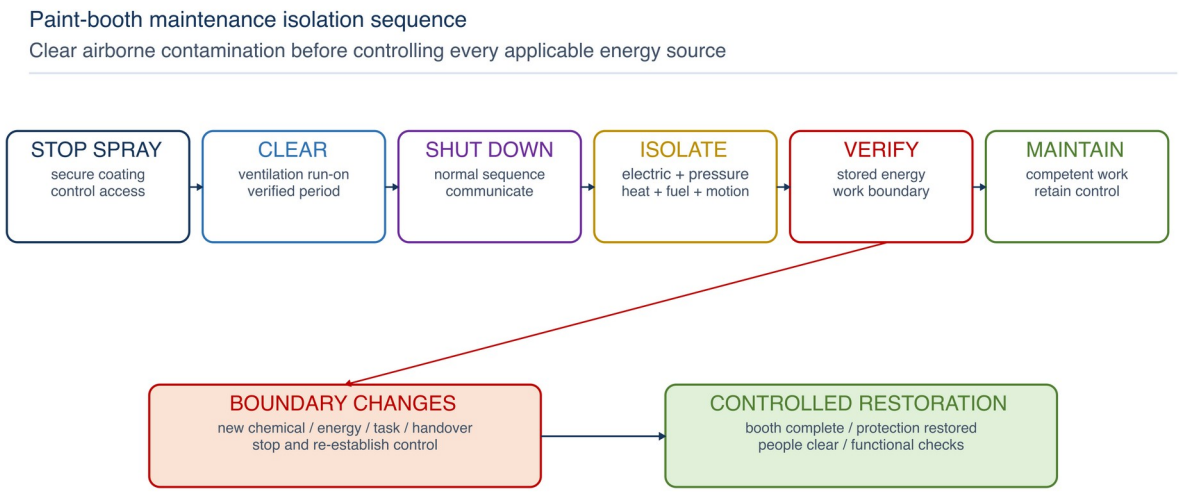

Figure 2. Paint-booth maintenance isolation sequence. Clearance precedes isolation; controlled restoration follows competent work.

5. Control residue before maintenance

Overspray deposits may be combustible, chemically hazardous, reactive with other coatings or easily dispersed during cleaning. Identify the coating and cleaner before disturbing residue.

Prefer methods that collect residue at source and minimise airborne dust or solvent vapour. Use approved scrapers, non-sparking or otherwise suitable tools where required, compatible cleaning materials and controlled waste containers. Never use compressed air to scatter dry deposit. Do not use an unapproved flammable cleaner, create sparks by grinding hardened residue, or mix wastes that may react or self-heat.

Maintain clear access around the booth and remove accumulated combustible residue before it affects filters, lights, sprinklers, fan parts or exits. [S175; S185]

6. Inspect enclosure panels, floors and openings

Check:

- panel joints, fasteners, corrosion and impact damage;
- floor condition, grating, pits and drainage;
- penetrations for pipes, cables, conveyors and hoses;
- loose masking, temporary sheet or combustible lining;
- overspray build-up on walls, ceilings and ledges;
- sharp edges and damaged internal finishes;

- pedestrian and product access routes; and
- evidence of spray escaping through unintended openings.

Restore cleanability and containment. Do not seal a required air path, drain or pressure-relief feature while closing an unintended gap.

7. Maintain doors, seals and glazing

Doors should close freely, latch correctly and preserve their intended airflow and emergency function. Inspect hinges, rollers, tracks, handles, vision panels, perimeter seals and door interlocks.

Clean glazing and light panels before heavy residue raises temperature, reduces visibility or encourages operators to open doors during spraying. Replace cracked or unsuitable transparent panels through the specified arrangement. Do not defeat a door switch to keep production running.

8. Maintain filters and pressure indication

Filter condition must be read with airflow, pressure, physical integrity and downstream cleanliness. Chapters 033–035 give detailed selection and change-out guidance.

During booth maintenance:

- confirm stage identity and airflow direction;
- inspect frames, clips, gaskets and supports;
- look for bypass, collapse, breakthrough and uneven loading;
- clean pressure taps and verify tubing condition;
- check gauge zero and response by the specified method;
- record comparable readings in the defined booth state; and
- control contaminated media and residue as process waste.

Do not substitute a filter only because it fits the opening. Capture duty, resistance, holding capacity, coating compatibility, installation and disposal basis all matter. [S178; S195]

9. Inspect fans, shafts and drives

Isolate and secure rotating equipment before access. Inspect:

- fan blades or wheel for deposits, damage and contact;
- shaft alignment, play and seal condition;
- bearings for noise, heat, lubrication and mounting;
- belts for wear, contamination, tension and matched condition;
- pulleys, keys, couplings and guards;
- motor mounts, flexible connectors and vibration isolators;
- rotation after electrical work; and
- inlet and outlet conditions that disturb flow.

Do not scrape a fan unevenly, add balance weights by trial, fit unmatched belts or increase fan speed to hide system resistance. Fan cleaning and repair should preserve clearances, alignment, balance and the applicable ignition-control arrangement. [S175; S179; S180; S197]

10. Inspect plenums, ducts and discharge

Follow the route from the booth to the final discharge. Check access doors, joints, flexible sections, supports, drains, corrosion, internal deposits, leakage marks and foreign objects. Confirm that maintenance has not left tools, rags or loose material inside.

Unexpected deposit downstream of a filter can indicate bypass, damage or unsuitable capture. A crushed flexible connection, closed damper or accumulated residue can raise system resistance. Repair the cause and verify the full path rather than adjusting only the fan.

11. Maintain make-up air and air balance

Inspect outdoor screens, weather louvres, dampers, filters, coils, fans, drives, plenums and controls. Water entry, blocked intakes or a stuck damper can disturb booth balance and carry contamination into the finish.

After relevant maintenance, compare pressure relationships, airflow direction and containment with the established operating basis. A closed door, open service panel or changed filter stage can alter the result. Do not balance the booth by permanently opening an unintended gap.

12. Control heating and curing equipment

Heating and curing equipment may include electric heaters, burners, fuel trains, heat exchangers, temperature limits, airflow-proving devices, purge sequences and high-temperature shutdowns. These are specialist systems.

Keep burners, heaters and heat-transfer surfaces free of incompatible residue. Inspect visible damage, leakage, wiring, sensors, fans and seals within authorised scope. Never bypass purge, airflow proof, flame supervision, high-limit or door-control functions. Test affected safety functions before heating or spraying is released.

13. Preserve electrical and grounding integrity

Electrical suitability depends on equipment location, enclosure, wiring method, coating process and hazardous-area design. Maintenance must preserve the installed classification and certification basis.

Check for damaged luminaires, cracked panels, loose glands, open covers, overspray on cooling surfaces, unauthorised sockets, portable equipment, degraded cables and altered control boxes. Verify grounding and bonding through the applicable competent test method. Do not replace a motor, light, switch, sensor or fan component with a general-purpose item simply because its voltage and size match. [S174; S175]

14. Test controls, alarms and interlocks

Controls may coordinate ventilation, spraying, heat, conveyors, doors, pressure, filter alarms, fire systems and emergency stops.

Control function	Maintenance question	Release evidence
Ventilation proof	Does spraying remain prevented when required airflow is unavailable?	Defined functional test passes
Post-spray run-on	Does extraction continue for the established sequence?	Timer or control sequence verified
Door or access interlock	Does the response match the booth design?	Switch and resulting action verified
Pressure or filter alarm	Are sensing line, setpoint control and indication serviceable?	Simulated or specified test passes
Emergency stop	Does it produce the intended safe state?	Stop and reset sequence verified
Heating permissive	Are airflow, purge and limit conditions satisfied?	Specialist functional test passes

Record temporary overrides used for diagnosis, control access to them and remove them before release.

15. Coordinate fire-protection maintenance

Sprinklers, suppression, detection, alarms, dampers and system shutdown interfaces should be inspected and serviced through the responsible fire-protection programme. Booth cleaning and repairs must not coat, paint over, obstruct, isolate or damage these devices.

Before taking protection out of service, use the site's impairment-control process. Control ignition sources and spraying status, notify responsible persons and restore protection promptly. Confirm that filter changes, new duct access, curtains or stored items do not obstruct the intended protection.

16. Maintain water-wash systems where fitted

Water-wash booths may include pumps, strainers, tanks, troughs, weirs, nozzles, eliminators, level controls, treatment chemicals and sludge removal.

Inspect circulation, leakage, blockage, corrosion, foam, odour, deposit and pump condition. Maintain the water curtain or wash pattern through the specified method. Control chemistry from measured system condition and coating compatibility; do not add treatment chemical by colour or habit. Isolate pumps and control chemical exposure before cleaning tanks or removing sludge.

Classify wastewater and sludge from the actual materials and process. [S188; S189]

17. Separate process air and breathing air

Spray-gun air, control air and supplied breathing air are different services. Trace each line, connection, filter and regulator so cross-connection is prevented.

Maintain process-air traps and filters to protect coating quality. Maintain breathing-air supply, alarms and hoses through the dedicated respiratory-protection programme and specified test method. Do not use an ordinary shop-air assumption as evidence that breathing air is suitable.

18. Troubleshoot maintenance symptoms

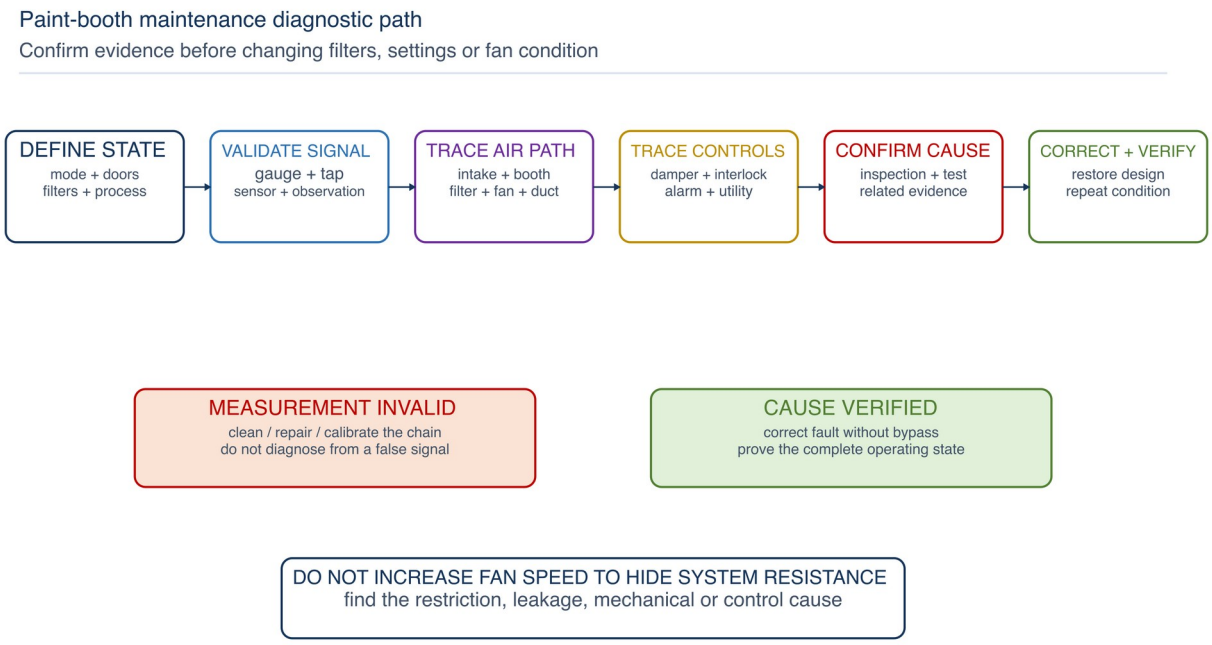

Figure 3. Paint-booth maintenance diagnostic path. Confirm booth state and measurement validity, then trace the complete air and control path before correcting the verified cause.

Symptom	Possible system causes	Corrective direction
Weak or reversed containment	Filter loading, damper, fan, door, duct or make-up-air fault	Trace intake to discharge in the defined operating state
Dust or debris on finish	Intake leakage, dirty plenum, damaged seal, clothing or internal deposit	Separate incoming, internal and process sources
Rising vibration or noise	Deposit, bearing, belt, alignment, loose panel or duct system effect	Isolate; inspect mechanical and airflow causes
Pressure reading unchanged	Blocked tap, failed tubing, gauge fault or stable resistance	Verify the measurement chain before interpreting filters
Overspray downstream	Bypass, damage, wrong installation or unsuitable capture stage	Stop spraying; inspect media, frame and downstream path
Door difficult to open	Pressure imbalance, seal, hinge or control fault	Verify booth state; correct airflow and mechanical cause
Heating fails to enable	Airflow proof, purge, limit, sensor, burner or control fault	Use competent sequence-based diagnosis; do not bypass
Repeated short filter life	Spray transfer, loading distribution, stage selection or fan condition	Review process and whole-system duty
Exact value uncertain	Component-specific information is required	Refer to the product label, Technical Data Sheet, or MKTECH representative.

19. Complete a controlled return to service

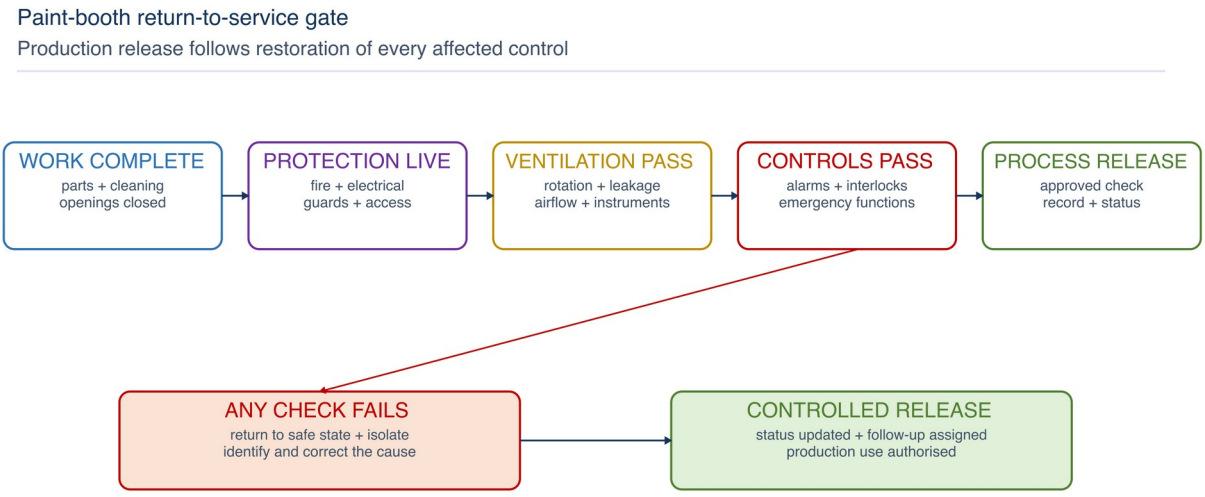

Figure 4. Paint-booth return-to-service gate. Physical restoration, protection, airflow, controls and process checks must all pass.

1080. confirm the work scope and parts are complete;
1081. remove tools, residue, temporary covers and waste;
1082. restore panels, doors, seals, filters, guards and access covers;
1083. confirm fire-protection systems are in service;
1084. clear people and remove maintenance isolation through the authorised process;
1085. start ventilation in the normal sequence;
1086. check rotation, leakage, noise, vibration and instruments;
1087. verify airflow direction, containment and alarms;
1088. test affected interlocks and emergency functions;
1089. test heating or wash systems separately where applicable;
1090. conduct the approved process check; and
1091. record release, readings and follow-up action.

Any abnormal result returns the booth to a safe state and investigation.

20. Paint-booth maintenance checklist

- [ ] Booth identity, process duty, drawings and maintenance instructions are confirmed.
- [ ] Spraying has stopped and the established clearance sequence is complete.
- [ ] Electrical, pressure, thermal, mechanical, fuel and material energy are controlled.
- [ ] Residue and cleaning chemicals are identified and handled safely.
- [ ] Enclosure, floor, doors, seals, glazing and access routes are serviceable.
- [ ] Intake, diffusion and exhaust filters are correctly installed and sealed.
- [ ] Pressure taps, tubing, gauges and airflow indicators are serviceable.
- [ ] Fan, shaft, bearings, drive, guards and flexible connections are serviceable.
- [ ] Plenums, ducts, supports, access doors and discharge are clear and intact.
- [ ] Make-up-air and booth balance checks are satisfactory.
- [ ] Heating, curing or water-wash equipment passes the applicable specialist checks.
- [ ] Electrical classification, grounding and enclosure integrity are preserved.
- [ ] Alarms, interlocks, emergency stops and run-on sequence pass.
- [ ] Fire-protection impairment is closed and protection is restored.

- [ ] Process air and breathing-air systems remain correctly separated and controlled.
- [ ] Functional and process verification pass before production release.
- [ ] Work, parts, readings, defects and next maintenance action are recorded.

INSPECTION, SAFETY & MAINTENANCE

CHAPTER 055

Maintenance Planning

55

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Maintenance managers, production managers, supervisors, planners, technicians, reliability engineers, safety personnel, QA/QC teams, storekeepers, contractors and technical buyers

Scope: Maintenance objectives; asset register; criticality; daily, weekly and monthly planning bands; task and interval selection; condition monitoring; planned shutdowns; job packs; hazardous-energy control; critical spares; backlog; work completion; return to service; failure history; maintenance KPIs; troubleshooting and programme review.

Core principle — Good maintenance planning connects the right task, competent people, safe access, correct parts, reliable evidence and a suitable production window. A calendar entry alone does not make work planned or effective.

Maintenance supports safe operation, product quality, environmental control, equipment availability and asset life. The most useful programme is neither purely calendar-based nor purely reactive. It combines routine operator care, planned preventive tasks, condition evidence, defect history, competent inspection, corrective work and improvement action. [S275; S329; S330; S332; S337]

Chapter objectives

After this chapter, the reader should be able to:

- define maintenance objectives for an industrial grinding and surface-finishing operation;
- build a usable asset register and rank equipment criticality;
- translate daily, weekly and monthly planning bands into equipment-specific tasks;
- select task triggers and intervals from manufacturer instructions, risk, duty and condition;
- prepare a complete maintenance job pack before scheduling downtime;
- coordinate isolation, contractors, parts, access equipment and production release;
- identify critical spares without creating uncontrolled stock;
- use condition trends and failure history to improve the programme;
- prioritise backlog by consequence and deterioration risk; and
- use balanced maintenance KPIs that support decisions rather than reward superficial compliance.

1. Define what maintenance must achieve

Set objectives that reflect the actual operation. Common objectives include:

- keeping guards, controls, interlocks, extraction and other safety functions effective;
- maintaining tool, machine and process capability;
- preventing contamination, heat damage, vibration, leakage and unplanned stoppage;
- preserving coating, grinding, sanding and polishing quality;
- controlling dust, fume, overspray, noise and waste;
- reducing repeat failures and emergency work;
- coordinating planned downtime with production needs; and
- protecting equipment condition without unnecessary intervention.

A maintenance decision normally balances performance, risk and expenditure across the asset life cycle. The cheapest immediate action is not always the lowest-cost or lowest-risk decision. Deferring a low-consequence cosmetic repair may be reasonable; deferring a deteriorating guard, isolation point, fan bearing, filter seal or pressure component may not be. [S337]

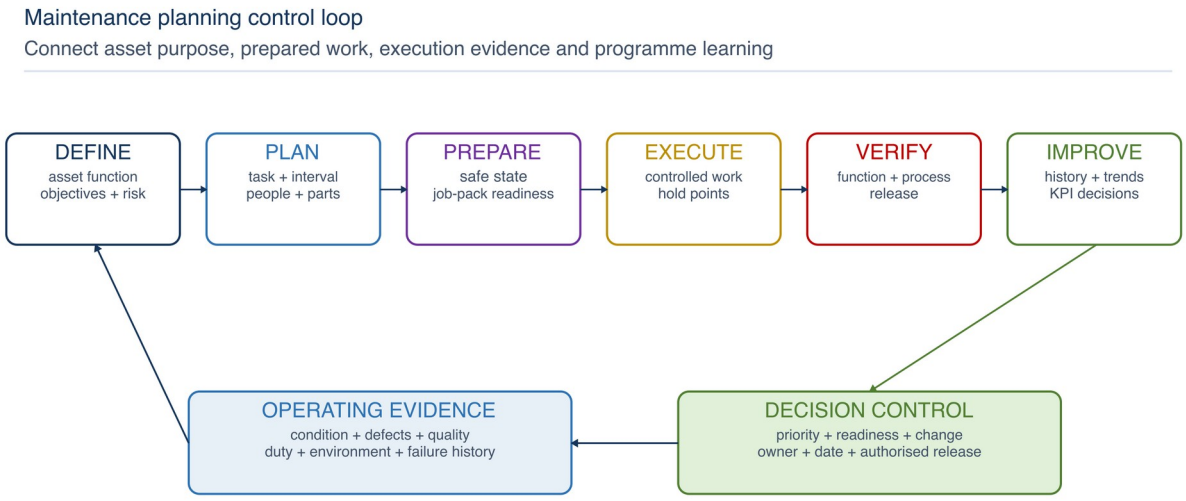


Figure 1. Maintenance planning control loop. Asset purpose and risk define the work basis; execution evidence and operating results feed the next planning cycle.

2. Build an asset register that technicians can use

The asset register is the planning foundation. It should identify equipment consistently across the workshop, maintenance system, drawings, spare-parts store and work permits.

Register field	Practical content	Why it matters
Asset identity	Unique number, equipment name, location	Prevents work on the wrong item
Manufacturer identity	Manufacturer, model, serial number	Links the asset to correct instructions and parts
Function and duty	Process served, material, operating pattern	Establishes consequence and maintenance demand
Energy sources	Electrical, pneumatic, hydraulic, thermal, gravity, stored energy	Supports isolation planning
Safety and environmental functions	Guard, interlock, extraction, filter, alarm, containment	Identifies safety-critical work
Configuration	Motor, drive, spindle, fan, control, filter or accessory arrangement	Preserves the approved equipment state
Technical information	Manual, drawing, parts list, inspection method, baseline	Provides the work basis
Responsible roles	Asset owner, operator group, maintainer, release authority	Clarifies decisions and handover
History	Defects, repairs, modifications, condition results	Supports learning and interval review

Use durable, readable asset identification. Record relocations, substitutions and modifications so the physical machine and the maintenance record remain aligned. Similar-looking grinders, fans, booths or extraction units may use different components and procedures.

When an exact part, lubricant, filter, setting, operating value, test method or acceptance limit is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

3. Rank criticality by credible consequence

Criticality helps decide where planning effort, condition monitoring, spares and shutdown protection are most valuable. Consider credible failure consequences rather than equipment price alone.

Criticality consideration	Questions for the planning team
People	Could failure expose a person to moving parts, hazardous energy, dust, fume, chemicals, fire or loss of protection?
Environment	Could failure release dust, overspray, contaminated liquid, oil, chemical or waste?
Quality	Could deterioration create scratches, dimensional error, contamination, coating defects or undetected nonconformance?
Production	Is there a standby asset, alternate route or recoverable buffer?
Deterioration	Will continued operation accelerate damage or turn a minor defect into a major repair?
Detectability	Is the developing fault visible to the operator, measurable, alarmed or hidden?
Recovery	Are competent people, parts, access equipment and specialist support available?

Do not convert the discussion into an arbitrary score that hides judgment. Record the reason for the ranking and the controls it drives. A small extraction fan or inexpensive pressure switch can be more critical than a high-cost machine if its failure removes an important control.

Review criticality after process changes, new materials, significant failures, repeated defects or changes in production dependency.

4. Separate maintenance work types

Work type	Trigger	Typical purpose
Operator care	Before, during or after use	Cleanliness, obvious condition, correct setup and early defect reporting
Planned inspection	Time, usage, event or risk basis	Find deterioration before loss of function
Preventive maintenance	Defined interval or usage trigger	Restore or preserve condition before expected deterioration
Condition-based maintenance	Trend, alarm or measured change	Act when evidence shows deterioration
Corrective maintenance	Confirmed defect	Restore the required function and configuration
Breakdown response	Functional failure	Make safe, diagnose, repair and recover control
Examination or specialist test	Applicable requirement or technical basis	Confirm integrity using competent methods
Improvement work	Recurrence, risk or performance opportunity	Remove causes, improve maintainability or strengthen control

Keep these categories distinct in planning and reporting. Calling emergency repair “preventive maintenance” hides programme weakness. Treating every inspection finding as a completed repair hides backlog.

5. Use daily, weekly and monthly planning bands correctly

Daily, weekly and monthly headings are useful organising bands, but they are not universal equipment intervals. Convert each band into tasks suited to the asset, duty, environment, manufacturer instructions, risk and observed deterioration.

Daily or shift-based attention

Use this band for conditions that can change quickly or should be observed by the people closest to the process:

- damage, unusual noise, vibration, heat, smell or leakage;
- guards, handles, switches, hoses, cables, plugs and couplings;
- cooling openings, extraction connections and visible airflow condition;
- tool, wheel, belt, pad, disc, filter or consumable condition;
- pressure, differential-pressure, temperature or status indications;
- cleanliness around intakes, machines, booths and work areas;

- safety devices, alarms or interlocks included in an approved check; and
- defects carried from the previous shift.

Operator checks should be short, observable and connected to clear action. A tick without looking has no maintenance value. Define when the asset must be removed from service, when a supervisor may assess it and when a work request is required.

Weekly planning band

Use this band for broader condition reviews and recurring care that needs more access or coordination:

- inspect fasteners, mounting, guards, supports and accessible drive components;
- review filter loading, seals, drains, collection points and dust or residue accumulation;
- inspect hoses, reels, couplings, electrical leads and strain relief;
- clean approved ventilation paths and equipment surfaces;
- check lubrication or service points where specified;
- compare condition indicators with the established baseline or recent trend;
- review open defects, temporary measures and repeated operator observations; and
- confirm that planned jobs, parts and specialist support remain ready.

Monthly planning band

Use this band for system-level review, deeper planned tasks and management control:

- perform equipment-specific preventive tasks due in the period;
- inspect extraction, booth, compressor, fan, drive and utility systems as complete systems;
- review vibration, temperature, pressure, airflow or other condition trends;
- inspect safety-critical functions using approved methods and competent personnel;
- reconcile critical-spares condition and stock status;
- review repeat failures, overdue work and long-standing defects;
- confirm upcoming shutdown scope and job-pack readiness; and
- review KPI signals and adjust plans where evidence supports a change.

These bands may be shortened, extended or supplemented by usage, event or condition triggers. Document the task basis so the next planner understands why it exists.

6. Select the task and interval from evidence

Start with the manufacturer’s instructions and the actual equipment configuration. Then consider risk, operating duty, environment, condition evidence, defect history and the consequence of late or intrusive maintenance. [S329; S330; S333; S334]

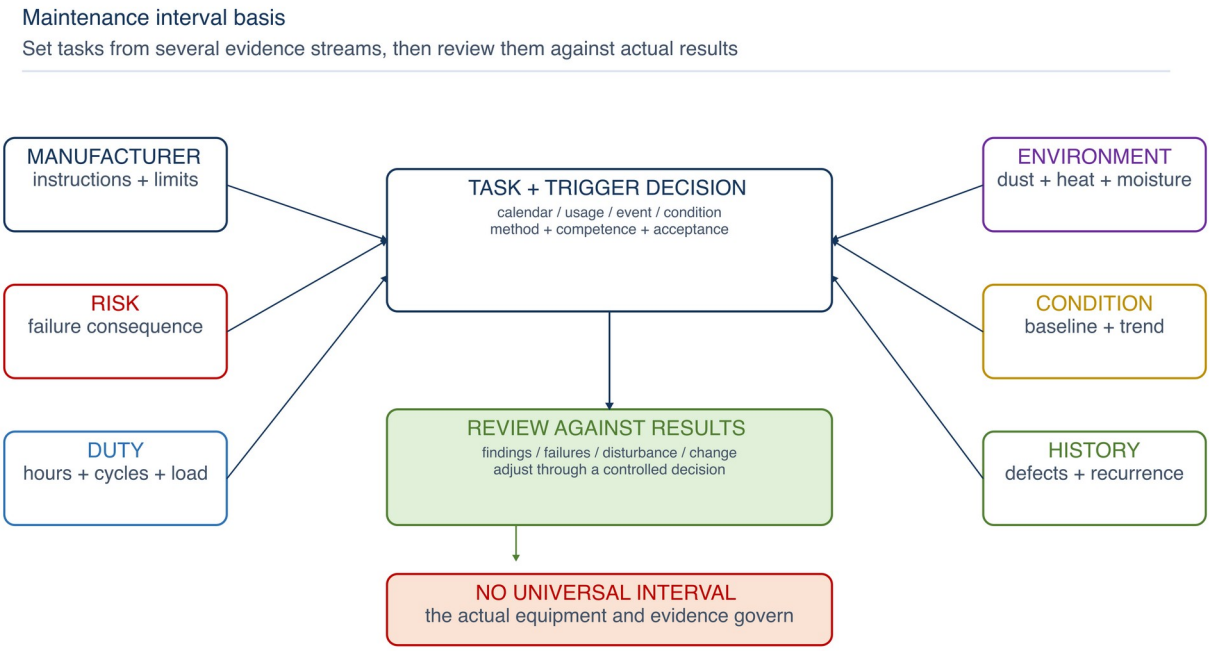


Figure 2. Maintenance interval basis. No single input sets a reliable interval; the task and trigger are reviewed against operating evidence.

Interval input	Planning implication
Manufacturer instructions	Establish specified tasks, parts, service limits and competent-work boundaries
Operating hours or cycles	Use where deterioration relates more closely to use than calendar time
Duty severity	Increase attention for high load, long duration, frequent starts or demanding process conditions
Environment	Consider dust, moisture, chemicals, heat, contamination and outdoor exposure
Failure consequence	Use greater planning assurance where loss of function has serious consequences
Condition trend	Advance, defer or investigate work only through a controlled decision
Defect history	Address recurring components, causes and weak task content
Post-maintenance disturbance	Avoid unnecessary intrusive work that can introduce error or contamination

Do not extend an interval merely because no failure occurred. Confirm that inspections were capable of detecting the relevant deterioration, results were credible and the consequence remains controlled. Likewise, shortening every interval after one failure may add cost without treating the cause.

Review the interval when duty changes, a new material is introduced, the asset is relocated, the environment changes, a significant failure occurs, condition results drift or maintenance repeatedly finds no deterioration.

7. Write tasks that produce a clear result

Weak instruction: “Check grinder.”

Useful instruction: identify the asset and safe state; inspect the specified cable, plug, switch, guard, spindle, flange, cooling path and abnormal-vibration indicators; record defects; complete the defined functional check; and apply the stated release route.

Each task should define:

- trigger and due basis;
- asset and component boundary;
- required safe state and isolation;
- competence and authorisation;
- tools, test equipment and access equipment;
- consumables, controlled parts and replacement criteria;

- inspection, cleaning, adjustment or replacement steps;
- measurements and recording method;
- acceptance criteria and escalation route;
- restoration, functional check and release authority; and
- waste, housekeeping and handover requirements.

Keep task detail proportional to risk and complexity. A simple cleaning task may need a short instruction; a fan overhaul, electrical intervention, booth service or extraction examination needs a controlled work pack.

8. Build a job pack before booking downtime

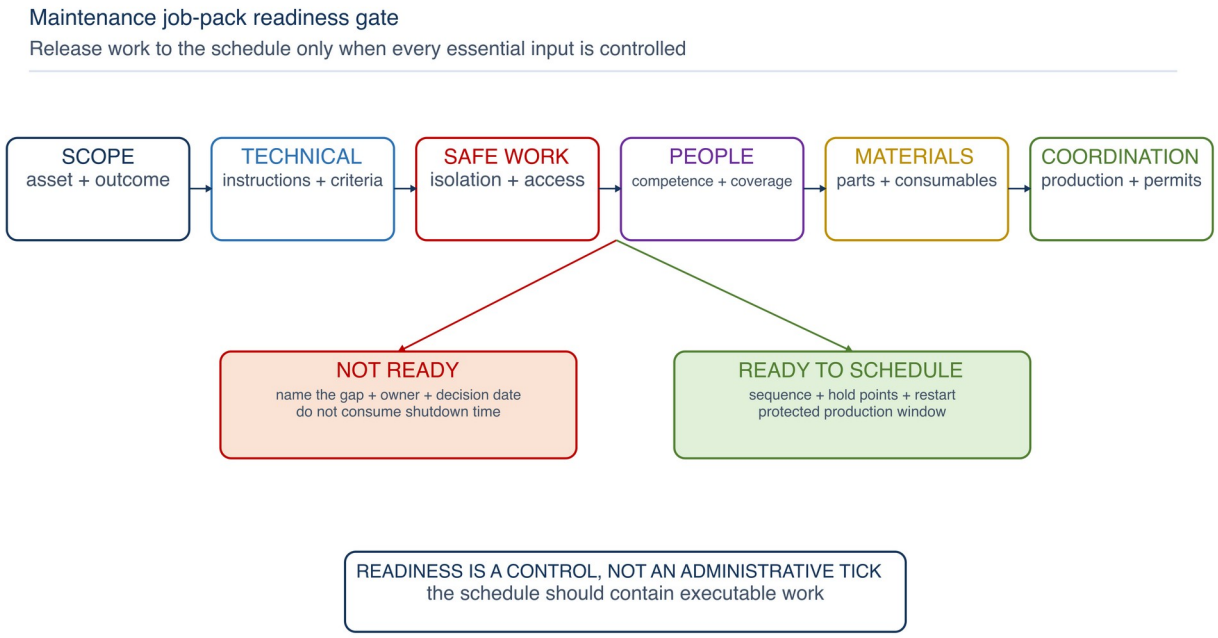


Figure 3. Maintenance job-pack readiness gate. A job becomes schedulable only when its technical, safety, resource and coordination needs are ready.

Job-pack element	Ready condition
Scope	Asset, fault or task boundary and required outcome are clear
Technical basis	Current instructions, drawings, parts and acceptance method are available
Safe work	Isolation, access, residue, pressure, temperature and adjacent-work controls are planned
Labour	Required competence, number of people and shift coverage are available
Materials	Correct parts, consumables, lubricants, filters and fasteners are verified
Tools and tests	Suitable tools, lifting/access equipment and valid measuring equipment are ready
Coordination	Production, permits, contractors, utilities and simultaneous work are aligned
Release	Functional test, process check, documentation and release authority are defined

Do not schedule an incomplete job merely to fill a shutdown plan. Flag the readiness gap, assign an owner and protect the decision date. Planned work that waits for a seal, permit, drawing or specialist after the machine stops is avoidable downtime.

9. Plan hazardous-energy control and safe access

Maintenance may expose electrical supply, battery energy, compressed air, hydraulic pressure, gravity, rotating inertia, springs, hot surfaces, fuel, automatic movement and chemical residue. Plan the complete boundary, including connected equipment and stored energy. [S331]

The work plan should address:

1092. normal shutdown and communication with affected people;
1093. identification of every relevant energy source;
1094. isolation and control under the workplace procedure;
1095. dissipation, restraint or blocking of stored energy;
1096. verification of the safe state before work;
1097. control of keys, locks, tags, permits and group work;
1098. boundary changes, shift transfer and contractor handover;
1099. inspection for completeness before restoration; and
1100. controlled re-energisation, functional check and release.

Temporary energisation for diagnosis or testing requires a specific controlled method. Do not normalise bypassed guards, defeated interlocks or informal “quick tests.”

10. Coordinate planned shutdown work

Build shutdown scope early enough to prepare it. Separate mandatory work, condition-driven work, opportunity work and optional improvements. Protect the jobs that control safety, environment, quality or the critical path.

Shutdown preparation sequence

1101. Freeze a preliminary scope and confirm asset boundaries.
1102. Review task dependencies and shared isolations.
1103. Validate job packs, drawings, parts, labour and specialist support.
1104. Confirm access, lifting, ventilation, cleaning, waste and permit needs.
1105. Sequence work to prevent congestion, contamination and conflicting activities.
1106. Define inspection hold points and who can accept them.
1107. Prepare restart and production-verification plans.
1108. Conduct a readiness review before the shutdown begins.
1109. Control emerging work through an authorised scope-change process.
1110. Close the shutdown with defects, lessons, parts usage and follow-up actions recorded.

Avoid overloading the shutdown with low-readiness work. Emergency additions can delay critical tasks and compress testing time. New findings should be assessed by consequence, required resources and effect on the restart path.

11. Identify and control critical spares

A critical spare is not simply an expensive part. It is a part whose absence could create unacceptable safety, environmental, quality or production consequences before a replacement can be obtained.

Spare decision factor	Planning question
Failure consequence	What happens while the part is unavailable?
Lead time	How long from verified order to usable receipt?
Failure predictability	Is deterioration detectable early enough to order?
Commonality	Can a verified part serve several assets?
Preservation	Does the part age, corrode, deform, absorb moisture or require rotation?
Configuration control	Could a similar-looking but incompatible part be selected?
Repair option	Is a safe, competent and timely repair route available?
Obsolescence	Is the part or supporting control becoming unavailable?

Control spare identity, storage condition, shelf life where applicable, inspection, preservation and issue history. Protect bearings, seals, belts, filters, electronic modules, motors and precision components from contamination, moisture, impact and distortion. Keep safety-critical parts linked to the correct asset and technical information.

When a precise spare identity or storage condition is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

12. Use condition monitoring as a decision system

Condition monitoring is more than collecting readings. A useful programme defines the failure mode, measurement point, method, operating state, baseline, trend, review responsibility and action route. [S332]

Common evidence may include:

- vibration, noise or bearing-condition indicators;
- temperature and thermal pattern;
- electrical current or power behaviour;
- pressure, differential pressure or airflow;
- speed, run-down behaviour or rotational stability;
- oil, moisture, particle or contamination condition;
- belt, seal, hose, cable, filter and surface condition;
- process quality, finish, dimensional drift or defect rate; and
- operator observations linked to a repeatable operating state.

Compare like with like. Record asset, location, instrument, operating mode, load, process condition and measurement point. A changed reading may reflect a changed process, sensor, mounting point or operating state rather than asset deterioration.

Set action logic before the trend becomes urgent: continue monitoring, repeat and validate, inspect at the next opportunity, plan corrective work, reduce duty or remove from service. Exact limits require the applicable technical basis. **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

13. Turn failure history into better work

Record enough information to learn from failures:

- asset and operating state;
- symptom, time and detection method;
- immediate safe action;
- confirmed failed function or component;
- evidence supporting the cause;
- repair and parts used;
- functional and production verification;
- downtime and operational consequence; and
- follow-up action, owner and due date.

Use repeat-failure review when the same symptom, component or process loss returns. Ask whether the cause relates to contamination, alignment, overload, installation, lubrication, utility quality, environment, wrong part, weak inspection, poor task design, inadequate competence or an unresolved system condition.

Replacing the same part repeatedly is not a complete corrective action if the cause remains active.

14. Prioritise backlog by consequence and urgency

Backlog includes identified work not yet completed. It should be visible, technically described and actively controlled.

Priority signal	Planning response
Immediate uncontrolled danger or loss of required protection	Stop or restrict use, make safe and escalate through the workplace system
Deteriorating safety, environmental or quality control	Define interim control, responsible owner and earliest competent correction
High production consequence with limited warning	Secure parts, labour and planned window before deterioration becomes failure
Stable defect with controlled consequence	Plan into an efficient work window and monitor condition
Improvement or convenience work	Rank against benefit, readiness and available capacity

Temporary measures must be explicit, time-bound and reviewed. They are not permanent repairs by another name. Record operating restrictions, inspection needs, expiry or review date and the person authorised to remove the measure.

Review ageing backlog, repeated deferrals and jobs with missing scope. A large backlog may contain duplicates, obsolete requests, poorly described work and hidden high-consequence defects. Clean the data without deleting valid obligations.

15. Distinguish work completion from equipment release

The technician may complete the assigned task, but the asset is not ready until affected controls and functions have been restored and verified.

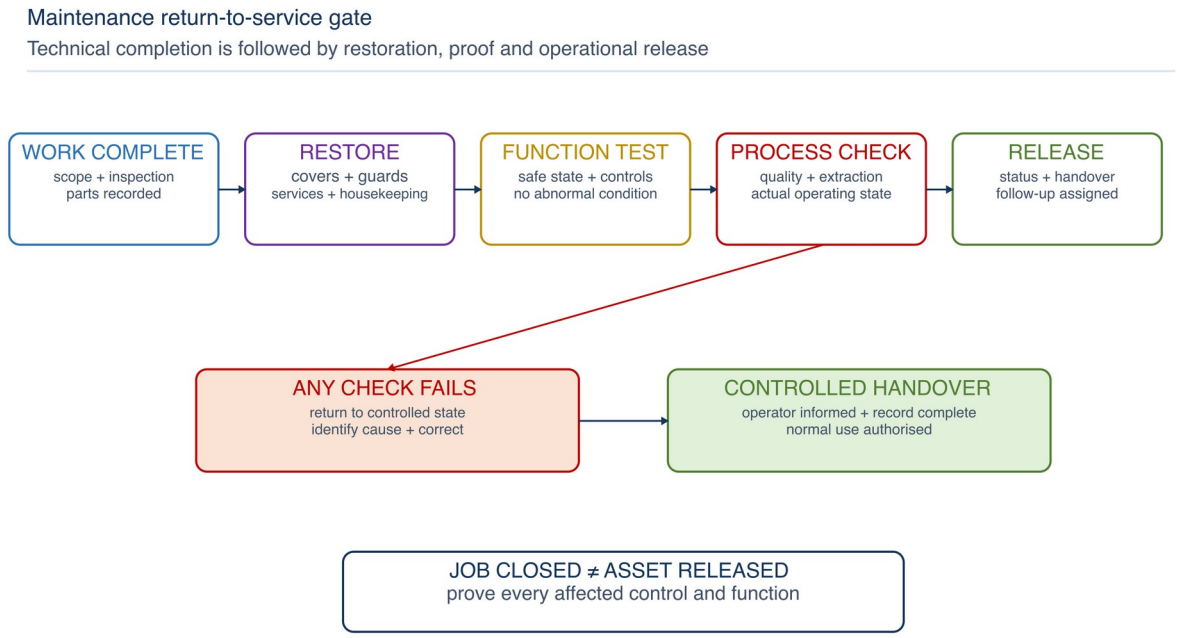


Figure 4. Maintenance return-to-service gate. Technical completion passes through restoration, functional verification and process release before normal operation resumes.

Return-to-service checks

- tools, rags, loose parts, waste and temporary supports removed;
- covers, guards, handles, fasteners, access panels and services restored;
- controlled parts and configuration confirmed;
- lubricants, fluids, filters and connections correctly installed;
- isolation removed through the approved restoration sequence;
- people clear and affected teams informed;
- abnormal noise, vibration, heat, leakage and smell absent;
- safety devices, alarms, interlocks and extraction functions checked as applicable;
- unloaded and loaded functional checks completed where authorised;
- product or process quality verified where maintenance could affect it; and
- asset status, readings, defects and follow-up work recorded.

If a release check fails, return the asset to a controlled state, identify the cause and correct it before normal use.

16. Manage contractors and specialist work

Provide contractors with accurate scope, asset identity, hazards, isolation arrangements, site rules, interfaces and acceptance requirements. Confirm competence for the actual work rather than relying on a general company description.

Coordinate:

- site induction and responsible contact;
- permits, isolation ownership and group-control method;
- chemical, dust, residue, fire and confined-space interfaces where applicable;
- drawings, settings, software backups and configuration access;
- lifting, access and test-equipment responsibilities;

- parts supplied by each party;
- inspection hold points and change authorisation;
- waste, housekeeping and reinstatement; and
- service reports, test results and final handover.

Review proposed substitutions and modifications before installation. A physically fitting component is not automatically technically suitable.

17. Use balanced maintenance KPIs

No single KPI proves maintenance effectiveness. Use a small set that connects work execution with equipment condition and operational outcome.

KPI	Useful interpretation	Common misuse to avoid
Planned-work percentage	Shows how much completed work came through a prepared route	Counting poorly scoped calendar tasks as planned work
Schedule attainment	Indicates whether ready work was completed in the agreed window	Penalising justified emergency or safety intervention
Emergency-work share	Signals reactive demand and planning instability	Reclassifying emergency jobs to improve the number
Repeat-failure rate	Highlights ineffective correction or persistent causes	Counting only identical part numbers and missing repeated symptoms
Backlog age by consequence	Shows exposure from deferred work	Reporting one average that hides old critical jobs
Preventive-task findings	Shows whether tasks detect meaningful deterioration	Rewarding “no defects” without checking inspection quality
Condition-warning closure	Tests response from detection to controlled action	Closing the alert before corrective action or accepted monitoring
Post-maintenance defect rate	Indicates maintenance-induced failure or weak release	Excluding faults discovered during restart
Critical-spares readiness	Shows whether verified spares are usable when needed	Counting unverified, damaged or obsolete stock
Availability or downtime	Shows operational outcome	Attributing every production loss solely to maintenance

Define each KPI’s numerator, denominator, exclusions, data owner and review action. Trend it over a meaningful period and examine the underlying jobs. Targets should not encourage unsafe deferral, superficial closure or excessive low-value maintenance.

18. Hold an effective planning meeting

Keep the meeting focused on decisions. Review:

1111. new high-consequence defects and safe operating status;
1112. work due in the planning horizon;
1113. job-pack readiness and missing resources;
1114. production windows and asset dependencies;
1115. contractor, permit and isolation interfaces;
1116. critical-spares constraints;
1117. condition warnings and trend changes;
1118. overdue work, ageing backlog and temporary measures;
1119. repeat failures and improvement actions; and
1120. shutdown readiness and restart risks.

Finish with named owners, dates and decisions. Do not use the meeting to read every work order aloud.

19. Troubleshooting the maintenance programme

Programme symptom	Likely planning causes	Practical response
Frequent emergency work	Weak defect capture, poor task basis, overloaded schedule, unavailable parts	Review failure modes, operator reporting, task effectiveness and spares

Programme symptom	Likely planning causes	Practical response
Many overdue tasks	Unrealistic frequencies, insufficient capacity, low readiness, unclear priorities	Risk-review tasks, prepare work earlier and protect critical capacity
Repeated same-component failure	Cause not removed, wrong part, installation error, contamination, misalignment or overload	Preserve evidence, verify cause and review the complete system
Shutdown overruns	Scope growth, missing parts, shared isolations, access conflict, weak restart plan	Strengthen readiness gate, sequencing and scope-change control
Inspections always report “OK”	Vague task, poor access, weak competence or unsuitable method	Rewrite task with failure-specific checks and acceptance logic
Condition data is noisy	Inconsistent point, mode, load, instrument or technique	Standardise collection and validate the measurement chain
High schedule attainment but poor reliability	Easy tasks dominate; defects and causes remain open	Balance execution metrics with repeat failures, backlog and outcomes
Spare is in stock but unusable	Wrong configuration, corrosion, damage, expired material or missing preservation	Strengthen identification, storage, inspection and stock review
Maintenance creates quality defects	Contamination, wrong configuration, incomplete cleaning or weak process release	Add cleanliness, configuration and production-verification hold points

20. Maintenance-planning checklist

[ ] Asset identity, function, duty and responsible owner are clear.

[ ] Criticality reflects people, environment, quality, production, deterioration and recovery consequence.

[ ] Daily, weekly and monthly bands have equipment-specific tasks and action routes.

[ ] Task and interval basis reflects manufacturer instructions, risk, duty, environment, condition and history.

[ ] Job packs define scope, safe state, competence, parts, tools, acceptance and release.

[ ] Planned shutdowns have controlled scope, sequencing, hold points and restart plans.

[ ] Critical spares are correctly identified, preserved and linked to the right assets.

[ ] Condition monitoring uses repeatable points, operating states, trends and action logic.

[ ] Failure history records confirmed evidence, repair, verification and follow-up.

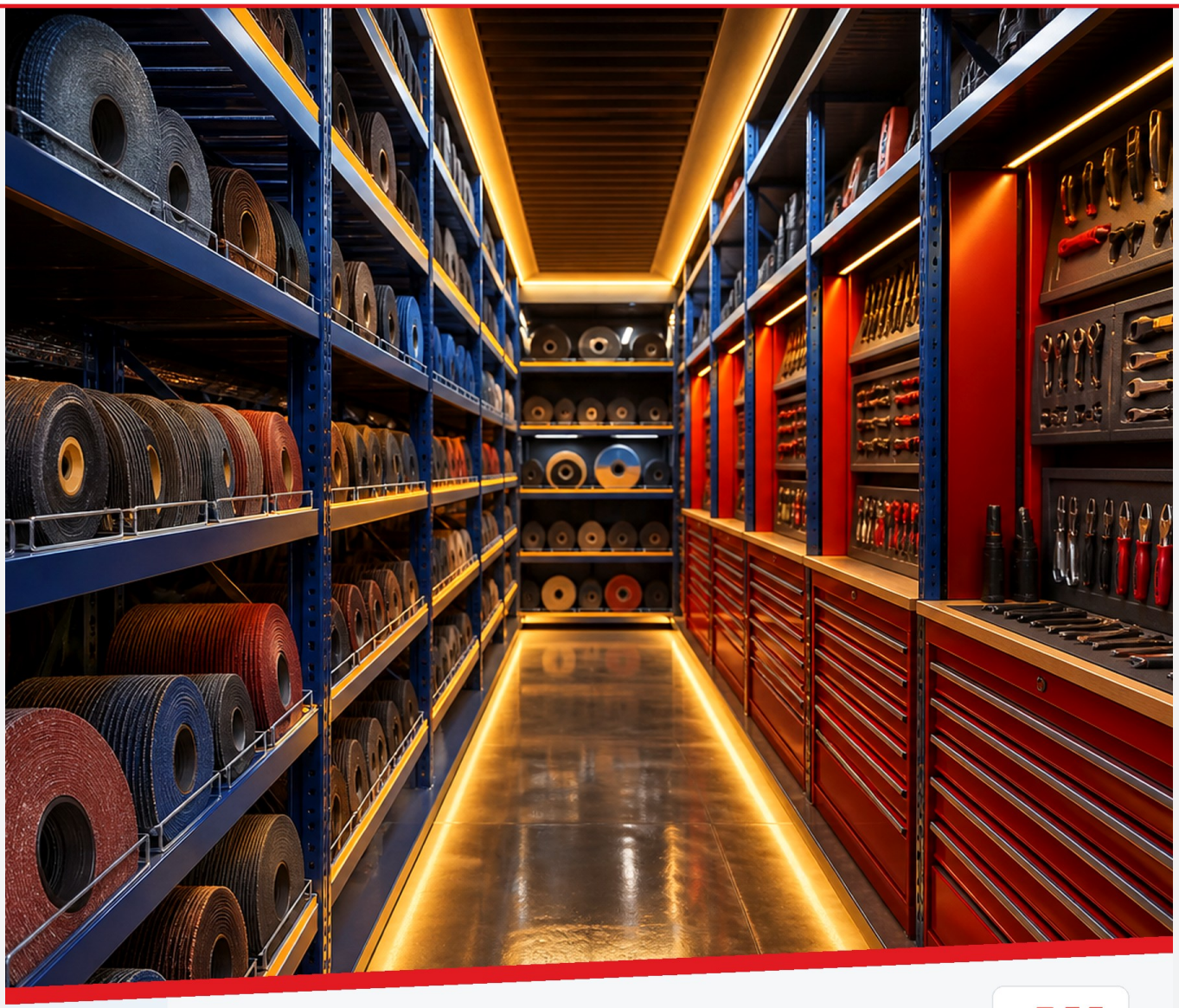
[ ] Backlog priorities and temporary measures remain visible and reviewed.

[ ] Work completion is followed by functional and process release where applicable.

[ ] KPIs are defined, balanced and connected to management action.

21. Practical planning takeaway

Start with the asset’s function and credible failure consequence. Build the task from the correct technical basis, prepare the work before downtime, control every energy and work interface, verify the result and use operating evidence to improve the next plan. The strongest maintenance programme is not the one with the most tasks; it is the one that consistently preserves required function and detects deterioration before consequence.



INSPECTION, SAFETY & MAINTENANCE

CHAPTER 056

Tool and Abrasive Storage

56

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Storekeepers, production supervisors, grinding and finishing personnel, maintenance teams, safety personnel, QA/QC teams and technical buyers

Scope: Receiving; identification; storage environment; racks and cabinets; bonded wheels; cutting wheels; coated abrasives; belts; flap discs; non-woven products; polishing materials; power tools; batteries; pneumatic tools; stock rotation; issue and return; mobile storage; segregation; inspection and troubleshooting.

Core principle — An abrasive product can be damaged before it ever reaches a machine. Correct storage preserves identity, shape and condition while preventing impact, moisture, heat, contamination and uncontrolled ageing.

Chapter objectives

After this chapter, the reader should be able to:

- organise a clean, controlled tool and abrasive store;
- inspect deliveries and separate suspect products;
- select suitable support for different abrasive forms;
- protect coated abrasives from environmental distortion;
- maintain product identity and stock rotation;
- control open packs, returns and mobile storage;
- store tools and accessories without creating hidden damage; and
- recognise storage symptoms and correct their likely causes.

1. Treat storage as a safety and quality control

Bonded wheels can crack or chip through impact and poor support. Thin cutting wheels can warp. Paper, cloth and fibre backings can change shape as moisture conditions change. Adhesive-backed discs can lose protective liners or collect contamination. Polishing compounds can harden, soften or become contaminated. Tools can suffer cable, hose, spindle, battery or bearing damage when piled together.

A controlled store therefore protects four things:

Control objective	Practical result
Identity	The user can verify product type, dimensions, marking and intended application
Physical condition	The product remains supported, clean, dry and protected from impact
Environmental stability	Temperature and moisture changes do not unnecessarily distort or degrade the product
Traceability	Receipt, batch or date information remains connected to the product through issue

2. Design the store around the product flow

Use a one-direction flow where practical: receiving, inspection, accepted stock, issue, point of use, controlled return and segregation. Keep new deliveries out of normal pick locations until their identity, quantity and visible condition have been checked.

Locate abrasive storage away from vehicle routes, crane loads, heavy vibration, water ingress, wash areas, chemical vapour, direct sunlight and strong heat sources. Provide enough aisle and shelf space for safe handling without rolling wheels, dragging cartons or balancing products on edges.

Keep the store clean and well lit. Avoid bare floor storage. Use shelves, drawers, bins or cabinets that prevent products from falling and allow selection with minimal handling. Heavy items belong at a practical lifting height with suitable handling assistance.

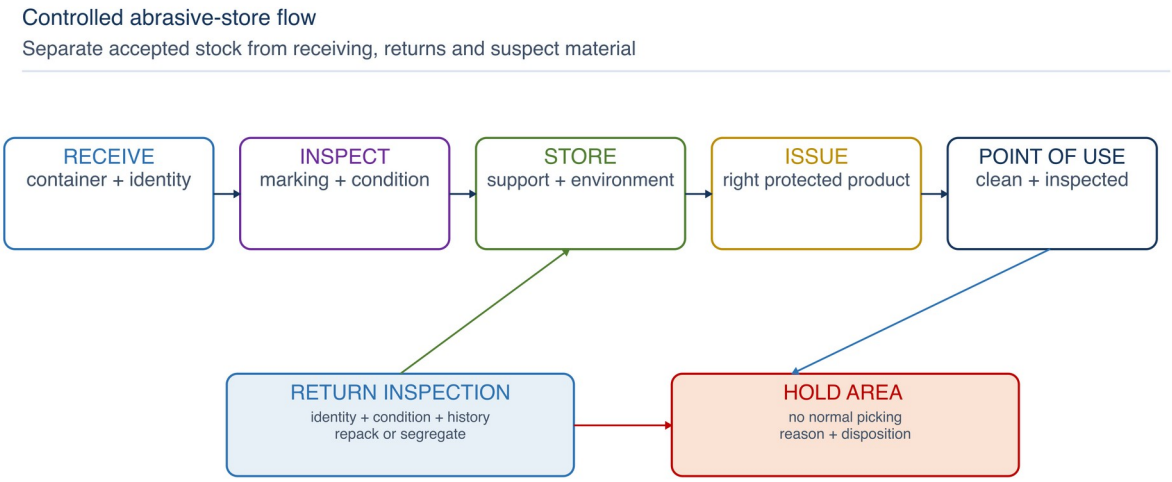


Figure 1. Controlled abrasive-store flow. Deliveries move through inspection and accepted storage to controlled issue; returns and suspect products take separate routes.

3. Control the storage environment

Stable conditions matter more than a generic room-temperature statement. Repeated movement between cool air-conditioned storage and a warm humid workshop can create condensation. Damp walls or floors can transfer moisture to cartons. Sunlight, ovens, steam lines and hot-air ducts can create local heating even when the room average appears acceptable.

Monitor the actual store where environmental variation could affect product condition. Respond to water leaks, condensation, damaged packaging, mould, corrosion, curling or softened cartons promptly. Do not assume that a dehumidifier or air conditioner provides control unless its operation and room conditions are checked.

For an exact storage temperature, humidity range, shelf life or conditioning period, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

4. Receive and inspect deliveries

Check the outer container before opening. Look for crushing, puncture, water marks, broken pallet restraint, impact damage and evidence that cartons have been dropped or stored incorrectly.

When unpacking:

1121. confirm the purchase and delivery identity;
1122. compare the product marking with the ordered type and dimensions;
1123. check quantity and packaging integrity;
1124. inspect accessible products for cracks, chips, warping, crushed edges, delamination, contamination or missing labels;
1125. retain batch, date and product information with the stock; and
1126. place suspect material in a clearly separated hold area.

Do not mount or issue a product that has been dropped, struck, wetted, visibly damaged or separated from reliable identification. Use the supplier or manufacturer route for disposition.

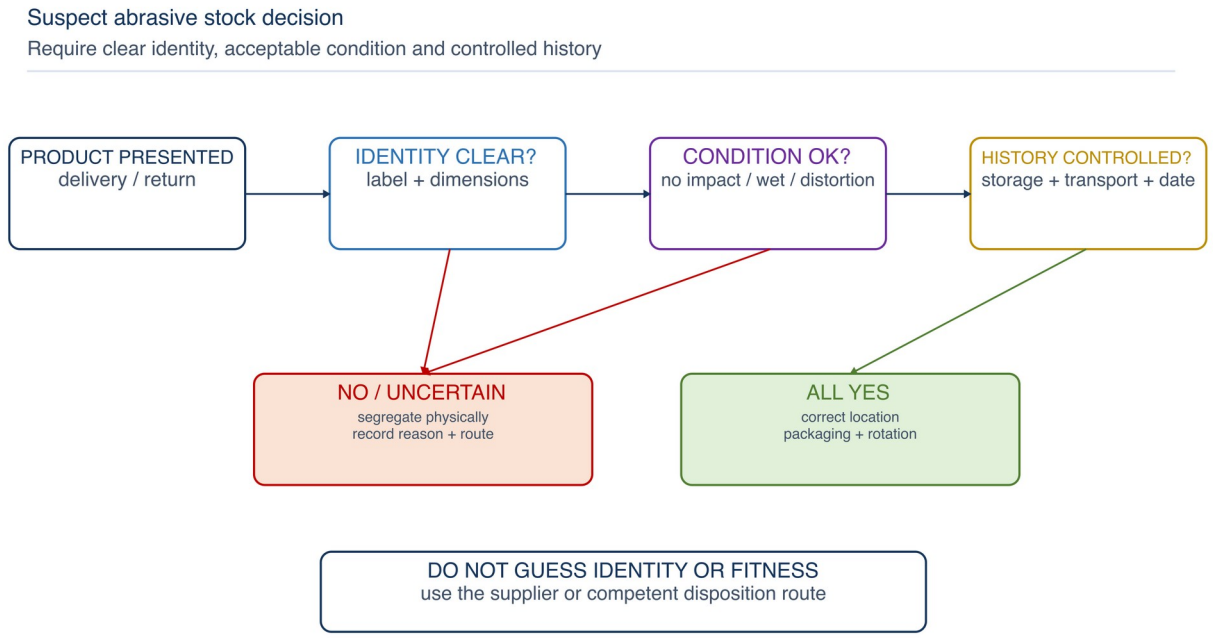


Figure 2. Suspect abrasive stock decision path. Clear identity, acceptable condition and controlled storage history are required before stock returns to normal issue.

5. Store bonded grinding wheels by shape and size

Suitable support depends on wheel form. The aim is to prevent rolling, edge loading, bending, impact and excessive stack pressure.

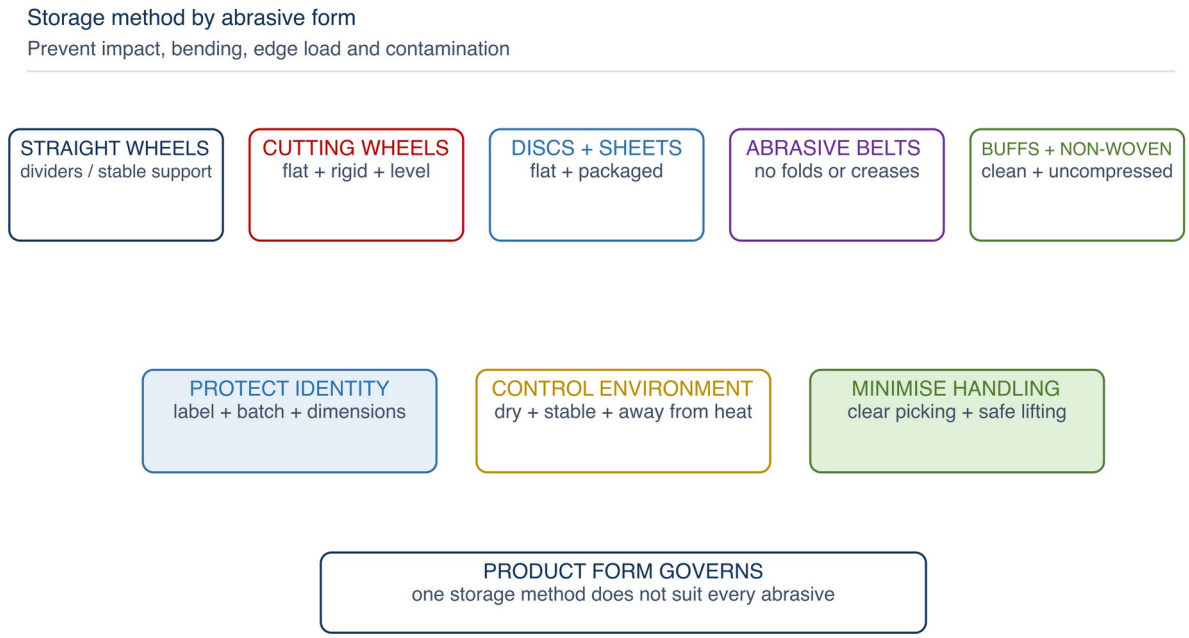


Figure 3. Storage method by abrasive form. Product shape and construction determine the support method; one rack arrangement does not suit every abrasive.

Product form	Storage approach
Small straight wheels	Divided drawers, bins or supported shelves that prevent rolling and edge impact
Large straight wheels	Stable vertical partitions or manufacturer-recommended support with safe handling access
Cup, dish and shaped wheels	Individual compartments or nested support only where the product information permits
Segments and blocks	Divided trays or boxes that preserve identity and prevent chipping
Mounted points	Organised trays or racks that protect the abrasive head and spindle from impact or bending
Superabrasive products	Original protective packaging with identity and mounting surfaces protected

Never use an improvised peg through the bore unless the storage arrangement is specifically suitable for that wheel. Protect bore surfaces, blotters, flanges and mounting faces from damage and contamination.

6. Give thin cutting wheels rigid, flat support

Thin cutting wheels are particularly vulnerable to bending and edge damage. Store them flat on a clean, rigid, level support in their original packaging. Keep stacks modest and stable; do not place unrelated heavy parts on top. Avoid leaning loose cutting wheels against a wall or mixing diameters in an unsupported pile.

If a package has sagged, become wet or been exposed to abnormal heat, separate it for assessment. A wheel that appears flat while constrained in a stack may still have been affected.

For the permitted stacking arrangement or product life, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

7. Protect coated abrasive discs and sheets

Paper, cloth, film and fibre backings respond differently to moisture and heat. Store coated products in their original closed packaging until required. Keep cartons off concrete floors and away from damp external walls, windows and heat sources.

Keep discs flat and supported. Do not fold sheets or place irregular parts on them. Preserve adhesive-disc liners and hook-and-loop faces. Separate products used on stainless steel from stock exposed to carbon-steel debris where contamination control matters.

Curling, cupping, brittle backing, softened backing or edge lift indicates that the storage or packaging condition should be investigated before issue.

8. Store abrasive belts without creases

Keep belts in their original cartons wherever possible. Do not crush cartons or place belts under uneven loads. Loose belts should be supported so they do not kink, fold, develop a sharp bend or collect dust on the joint and abrasive face.

Wide belts may require controlled conditioning before use, particularly when the store and machine area have different environments. Follow the product and machine information; do not apply one conditioning time to every backing, belt width or workshop.

At issue, check joint condition, edges, shape and directional marking where present. A creased or distorted belt can track poorly and should not be forced onto the machine.

9. Store flap discs, fibre discs and backing pads as systems

Keep flap discs flat or in their protective packaging so the flaps are not crushed or bent. Protect the centre and product label. Store fibre discs flat and dry; moisture-related distortion can prevent correct support by the backing pad.

Backing pads, flanges and adapters should be kept clean, identified and free from cuts, distortion and embedded debris. Do not combine accessories in an unlabelled bin where incompatible threads, diameters or support types can be selected by appearance alone.

10. Control non-woven and polishing products

Store non-woven belts, discs, wheels and sheets clean and dry without compression that permanently changes their shape. Protect convolute and unitised wheels from edge damage. Keep polishing mops and buffs in clean bags or cabinets so they do not collect metal particles, grit or shop dust.

Separate compounds by material and finishing stage. Keep containers closed and applicators dedicated where cross-contamination could create scratches or stain a workpiece. Do not return a used compound bar to clean stock when its identity or contamination state is uncertain.

11. Store power tools ready for inspection, not hidden in a pile

Disconnect tools from energy before storage. Remove abrasive products where the tool or product instructions require it. Clean approved exterior and ventilation areas without driving dust into the tool.

Use racks, cases or cabinets that support the tool body and protect the spindle, guard, cable, plug, hose connection and controls. Do not hang a tool by its cable or hose. Avoid tight cable coils, sharp hose bends and drawers that close on leads.

Keep guards, handles, flanges, nuts and dedicated accessories with clear tool-family identification. A complete storage position makes missing or damaged parts visible before the next job.

12. Battery and pneumatic tool storage

Protect battery packs from short circuit, impact, water, heat and contact with metal objects. Store and charge them using the specified equipment and arrangement. Damaged, swollen, overheated or leaking packs require immediate segregation under the workplace battery procedure.

For pneumatic tools, disconnect the air supply, release stored pressure and protect the inlet from dirt. Store hoses without crushing or tight kinks and keep couplings clean. Apply only the lubricant and storage method specified for the tool.

13. Preserve labels and product identity

The label or marking connects the product to its dimensions, type, limitations and traceability. Do not separate loose products from their labelled packaging unless an equivalent controlled identification method is used.

Each pick location should distinguish similar products clearly. Useful information includes product family, dimensions, grit or grade, backing or bond type, material application, batch or date identifier and stock status. Avoid handwritten abbreviations that only one operator understands.

Unidentifiable abrasives should not be guessed into service.

14. Rotate stock without overriding product information

First-in, first-out is a useful default, but date-controlled products require earliest-valid-use logic and current product instructions. Put newly received stock behind or below the existing valid stock where safe. Review slow-moving items, opened packs and products approaching a marked use-by date.

Stock rotation does not make damaged or expired product acceptable. Do not relabel dates, combine batches without traceability or move suspect stock back into normal issue locations.

15. Control issue, open packs and returns

Issue the smallest practical quantity in protective packaging. At point of use, keep abrasives in a clean cabinet or covered container away from sparks, coolant, water, oil and foot traffic.

Returned products need a defined decision:

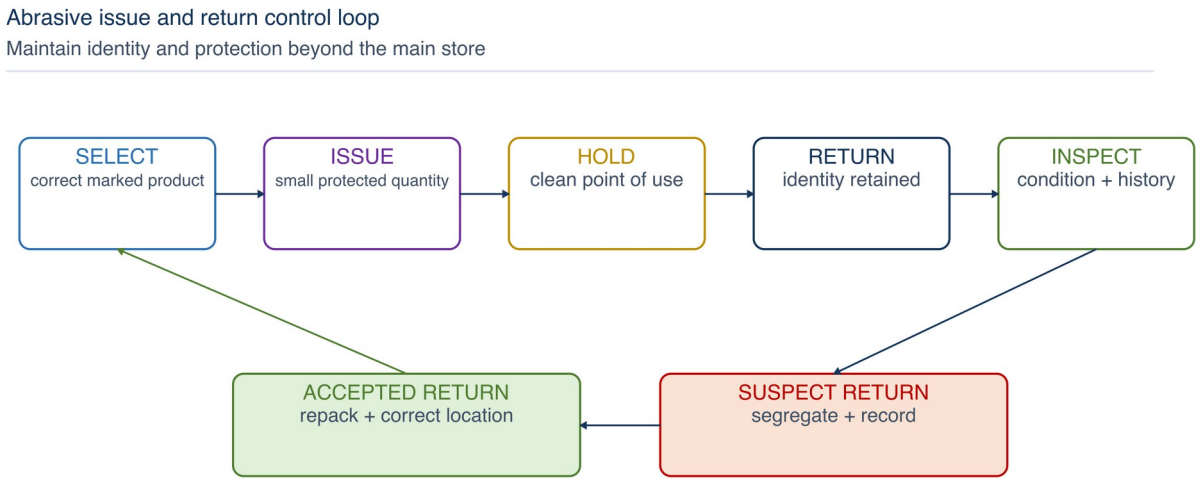


Figure 4. Abrasive issue and return control loop. Small protected issues and a defined return inspection preserve identity and prevent suspect material re-entering accepted stock.

Return condition	Action
Unopened, identified and protected	Inspect and return to the correct controlled location
Opened but clean and fully identified	Repack, preserve the label and use through the controlled open-pack route
Dropped, wet, distorted, contaminated or damaged	Segregate; do not reissue
Identity or storage history uncertain	Hold for supplier or competent disposition

16. Mobile stores and service vehicles

Vehicle and site boxes experience vibration, heat, humidity and impact. Use fixed compartments, rigid support and weather protection. Do not leave cutting wheels loose in a toolbox or under heavy equipment. Inspect mobile stock more frequently when transport conditions are severe.

Carry only the quantity and product range needed for the work. Return unused stock through the same inspection route; do not silently replenish the main store with products of uncertain transport history.

17. Segregate suspect product visibly

The hold area should prevent accidental picking. Mark the status, product identity, quantity, reason for hold, date and responsible decision route. Physical separation is stronger than a note placed on a normal shelf.

Common hold reasons include impact, water exposure, condensation, fire or heat exposure, cracked or crushed packaging, missing marking, warping, chipped edges, delamination, corrosion, chemical contamination and exceeded marked product life.

18. Troubleshooting storage symptoms

Symptom	Likely storage contributors	Corrective action
Cutting wheels no longer lie flat	Poor support, uneven loading, heat or moisture	Segregate stock; correct the shelf and environmental cause

Symptom	Likely storage contributors	Corrective action
Coated discs curl	Humidity change, open packaging or damp storage	Hold affected product; stabilise storage and keep packs closed
Belts crease or track poorly	Crushed cartons, sharp bends or inadequate conditioning	Correct support; inspect belt and machine before use
Labels detach or become unreadable	Moisture, handling or repacking failure	Restore controlled identification; do not guess the product
Repeated chipped wheels	Impact during receipt, picking or transport	Review handling path, compartments and lifting method
Polished surfaces develop random scratches	Contaminated buffs, compound or storage cabinets	Segregate materials and clean the storage and handling system
Tools return with damaged leads or hoses	Piled storage, tight coils or drawer pinch points	Provide dedicated supports and inspect before reissue

19. Storage-area safety reminders

- Handle every bonded wheel as breakable.
- Use suitable assistance for heavy or awkward products.
- Keep aisles, shelves and emergency access clear.
- Do not roll wheels along the floor.
- Do not use abrasive cartons as workbenches or seats.
- Keep chemicals under their label and Safety Data Sheet storage controls.
- Prevent ignition sources and incompatible materials from entering controlled chemical or battery areas.
- Inspect product condition again before mounting or use.

20. Storekeeper checklist

[ ] Receiving stock is separated until identity and visible condition are checked.

[ ] Racks, drawers and cabinets support each product form without edge load or bending.

[ ] Thin cutting wheels are flat, protected and free from unrelated stack loads.

[ ] Coated abrasives remain packaged, dry and away from heat or damp surfaces.

[ ] Belts are protected from crushing, folds and sharp bends.

[ ] Labels, batches and date information remain legible through issue.

[ ] Open packs and returns follow a defined inspection route.

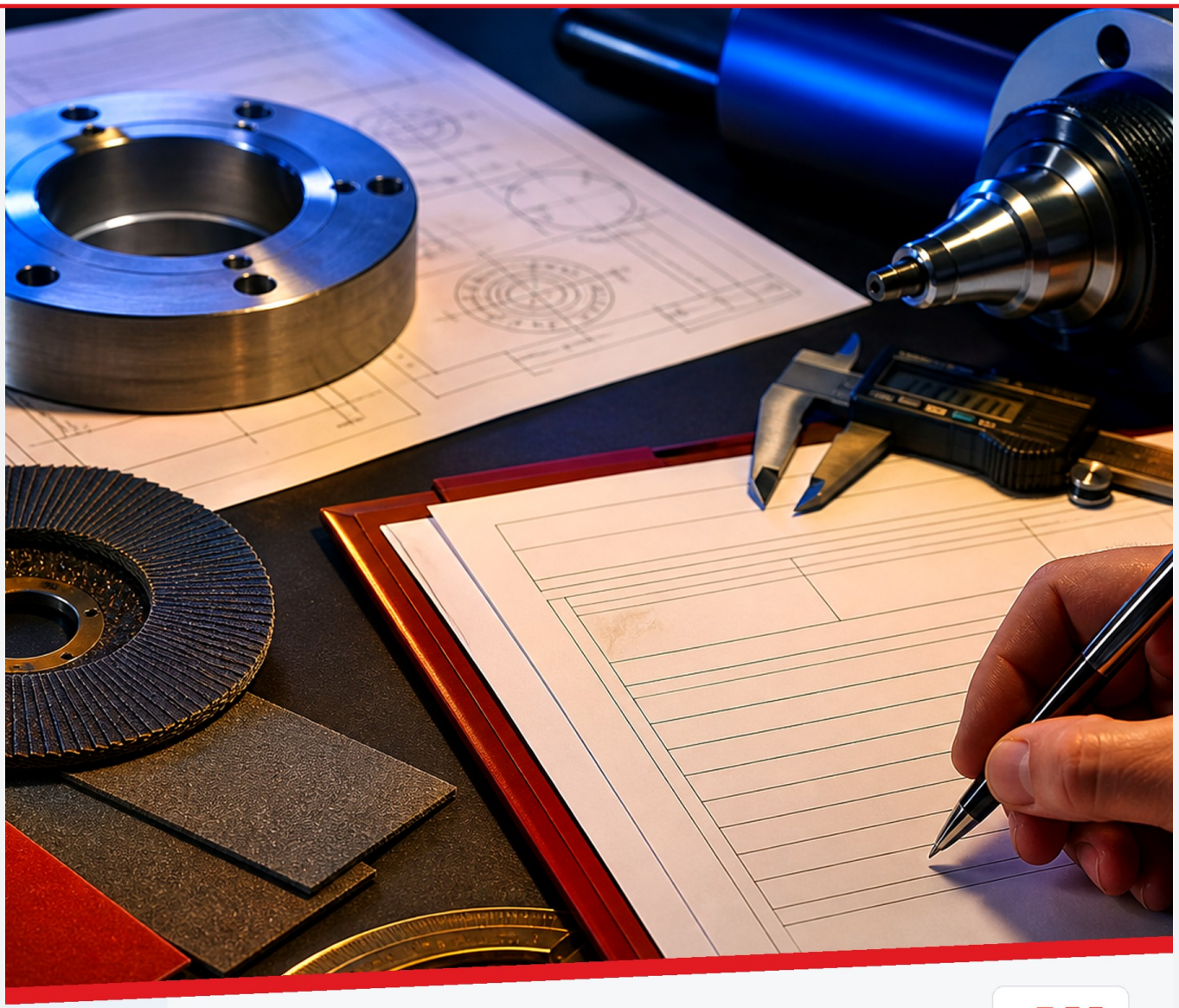
[ ] Suspect, damaged, expired or unidentifiable product is physically segregated.

[ ] Tools, batteries, hoses, cables and accessories have dedicated protected positions.

[ ] Mobile stock is restrained, weather-protected and inspected after transport.

[ ] Stock rotation is working and slow-moving inventory is reviewed.

[ ] Exact product storage conditions are checked against current controlled product information.



SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 057

Writing an Industrial Abrasive Specification

57

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, process engineers, supervisors, technical buyers, QA/QC personnel, maintenance teams, storekeepers, contractors and abrasive users

Scope: Application definition; workpiece and outcome requirements; abrasive form and dimensions; grading systems; machine and interface compatibility; wet or dry use; safety information; inspection and acceptance; supplier alternatives; substitutions; revision control; worked specification examples and troubleshooting.

Core principle — Specify the job, the result and the operating envelope before naming an abrasive. A complete specification allows the supplier, buyer, user and inspector to understand the same requirement.

An industrial abrasive specification should do more than repeat a grit number. It should identify what is being processed, what result is needed, which machine and mounting system will be used, how the product will be accepted and how changes will be controlled. Clear specifications reduce unsuitable quotations, uncontrolled substitutions, receiving disputes, wasted trials and process variation.

This chapter provides a practical method for writing enquiries, purchase descriptions and application specifications. It does not replace the product label, Technical Data Sheet, machine instructions, drawing, process qualification or workplace risk assessment.

Chapter objectives

After this chapter, the reader should be able to:

- distinguish an application specification from a product ordering description;
- define the workpiece, operation and measurable result;
- identify abrasive form, dimensions and mounting details without ambiguity;
- keep coated-abrasive, bonded-abrasive and superabrasive grading systems separate;
- state machine, speed-compatibility, extraction and wet/dry conditions correctly;
- distinguish mandatory requirements from preferences and supplier proposals;
- write a practical inspection and acceptance plan;
- compare alternative offers on a common technical basis; and
- control substitutions and revisions after approval.

1. Use a three-layer specification

A useful industrial specification has three connected layers.

Layer	Main question	Typical content
Application	What work must be done?	Material, condition, geometry, operation, access, allowance, batch pattern
Outcome	What constitutes an acceptable result?	Surface texture, dimensions, edge condition, cleanliness, defect limits, appearance, inspection method
Product and process	What product and operating envelope will deliver the result safely?	Abrasive form, size, mounting, grain system, machine, wet/dry use, controls, traceability

Do not begin with a copied product code unless the exact controlled product is already approved. A code without the application and acceptance basis makes alternatives difficult to assess and can conceal a change in dimensions, construction, backing, bond, mounting or intended use.

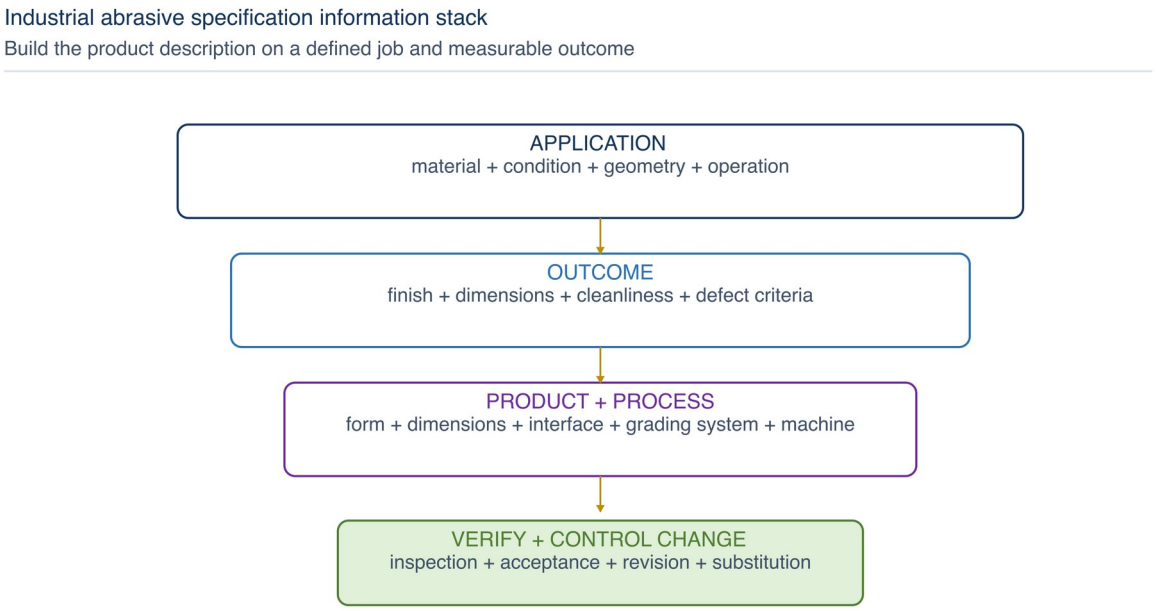

Figure 1. Industrial abrasive specification information stack. The product description sits on a defined application and measurable outcome; safety, verification and change control connect every layer.

2. State the purpose in one sentence

Start with a short duty statement that a technical supplier can understand. A good statement identifies the operation, workpiece and required result without prescribing an unverified solution.

Example: “Blend welded stainless-steel fabrications to a uniform directional finish while preserving drawing dimensions and preventing cross-contamination.”

This is more useful than “supply fine sanding discs” because it identifies the process purpose. The remainder of the specification then defines what “uniform”, “preserving” and “preventing” mean for the job.

3. Define the workpiece

The same abrasive can behave differently on different alloys, hardness levels, coatings, heat-treatment conditions and geometries. Record the workpiece in practical terms.

Workpiece field	What to state	Why it matters
Material	Grade or controlled material description	Guides grain, bond and contamination decisions
Condition	Cast, forged, rolled, welded, heat treated, coated or previously finished	Influences scale, hardness, loading and heat response
Geometry	Flat, edge, radius, bore, tube, profile or complex fabrication	Determines access, contact area and product form
Thickness and stability	Thin sheet, heavy section, supported or flexible feature	Influences distortion, heat and pressure sensitivity
Surface condition	Scale, weld reinforcement, burr, coating, corrosion, scratch or existing finish	Defines the starting state and removal duty
Allowance	Material available for removal	Prevents over-processing and dimensional loss
Sensitive features	Datum, edge, coating boundary, thread, seal face or cosmetic face	Directs protection and inspection
Cleanliness restrictions	Dedicated stainless, non-ferrous, food-contact or coating-preparation controls	Prevents unacceptable contamination

Where several workpiece conditions occur, define the worst credible case or create separate specification lines. Do not assume that one process setting will cover a light blend and heavy stock removal equally well.

4. Define the operation before the product

Use an operation name that describes the intended material-removal or finishing task.

Operation	Primary purpose	Important specification points
Cutting-off	Separate material along a path	Material, section, cut access, cut quality, machine and wheel geometry
Heavy grinding	Remove weld, gate, scale or stock	Removal volume, contact area, geometry preservation and heat sensitivity
Deburring	Remove sharp or loose edge material	Edge profile, burr type, access and acceptable edge break
Blending	Smooth transitions without excessive stock loss	Starting defect, surrounding finish and contour control
Surface preparation	Create a clean, suitably textured surface for the next process	Contaminant condition, coating system and cleanliness/texture criterion
Finishing	Produce a defined texture or appearance	Direction, uniformity, parameter, sampling and visual reference
Polishing	Reduce visible texture or produce a specified appearance	Previous steps, compound system, cleanliness and inspection lighting

Avoid using “polishing”, “sanding” or “grinding” as interchangeable terms. They describe different duties and may lead suppliers toward different product constructions.

5. Convert “good finish” into an acceptance requirement

Terms such as smooth, bright, fine, clean or scratch-free are too subjective unless supported by an inspection method or reference standard. Choose criteria that match the functional risk.

Result category	Possible requirement	Verification approach
Surface texture	Drawing-defined profile parameter and limit	Controlled instrument, stated measurement direction, locations and settings
Dimensional integrity	Drawing tolerance or maximum stock-removal allowance	Calibrated dimensional measurement at defined features
Edge condition	Burr removed; defined edge form maintained	Visual and tactile inspection plus dimensional check where critical
Appearance	Approved reference panel and viewing conditions	Side-by-side comparison under controlled lighting and direction
Cleanliness	No visible residue; process-specific cleanliness requirement	Defined visual, wipe, water-break or other approved method
Defects	Limits for gouges, chatter, burn, heat tint, pull-out or exposed substrate	Defined inspection area, lighting, magnification and acceptance rule
Coating preparation	Coating-system requirement for cleanliness and profile	Applicable coating specification and approved measurement method

ISO 21920-1 provides the current framework for indicating profile surface texture in technical documentation; ISO 21920-2 defines terms and parameters; ISO 21920-3 addresses specification operators. Use the applicable controlled drawing standard and measurement procedure rather than copying an isolated roughness value. [S343; S344; S345]

Specify the measurement location, direction, sample quantity, instrument settings and decision rule. A surface can give different readings across and along a grinding pattern. An average value can also hide a local gouge or edge defect.

6. Identify the machine and interface

The abrasive must be compatible with the actual equipment and mounting arrangement. Record:

- machine or tool type;

- manufacturer, model and identification where relevant;
- spindle, arbor, thread, flange, backing pad, contact wheel or quick-change interface;
- available guards and required product geometry;
- machine speed range or controlled operating setting;
- power source and available power;
- contact-wheel or backing-pad hardness and profile where relevant;
- wet, damp or dry operating condition;
- extraction or coolant arrangement; and
- access, orientation and workholding constraints.

Do not select an abrasive solely because its nominal diameter fits. Hole size, mounting system, flange arrangement, product shape, guard, machine speed and intended use must all be compatible.

When an exact product speed, dimension, mounting requirement, backing-pad compatibility or ordering code is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

7. Name the abrasive form precisely

State the physical form before the grain description.

Product family	Useful identity fields
Bonded wheel	Type/shape, outside diameter, thickness, bore, specification marking, intended operation
Cutting wheel	Flat or depressed-centre form, diameter, thickness, bore, intended material/use
Flap disc	Diameter, bore or thread, profile, flap construction, abrasive grade/system
Fibre disc	Diameter, centre-hole arrangement, abrasive grade/system, compatible backing pad
Hook-and-loop or adhesive disc	Diameter, hole pattern, attachment system, backing and abrasive grade/system
Abrasive belt	Width, length, joint type/direction where relevant, backing, abrasive grade/system
Sheet or roll	Width, length, backing, perforation or cut form, abrasive grade/system
Non-woven product	Form, dimensions, attachment, density/grade designation and intended duty
Mounted point or wheel	Shape, head dimensions, shank dimensions, product marking and intended tool
Superabrasive wheel	Shape, dimensions, abrasive type, grain designation, concentration/bond information and mounting

ISO 525:2020 covers bonded-abrasive shape types, dimensional symbols, specification, designation and marking, but it explicitly does not apply to coated or superabrasive products. Use the correct product-family framework. [S342]

8. Keep abrasive grading systems separate

A grit designation identifies a grain-size distribution within a stated system; it is not a complete product specification and does not guarantee a particular finish.

Designation context	Product use	Specification practice
P-grade	Coated abrasives using the applicable ISO 6344 designation	Write the P prefix and grade; do not omit the system
F-grade	Bonded-abrasive grain designation using the applicable ISO 8486 framework	Write the F context when that controlled designation is intended
Superabrasive designation	Diamond or cubic-boron-nitride grain designation under the applicable system	State the system and product construction; do not reduce the product to grain size alone
Proprietary grade	Manufacturer-specific non-woven, structured, film or specialty product	Use the exact controlled designation and product family

ISO 6344-2:2021 covers coated-abrasive macrogrits P12 to P220, while ISO 6344-3:2021 covers microgrits P240 to P5000. ISO 8486-1 provides the F-macrogrit context for bonded abrasives, and ISO 6106 covers checking and designation of diamond and cubic-boron-nitride grain sizes. [S346; S347; S348; S349]

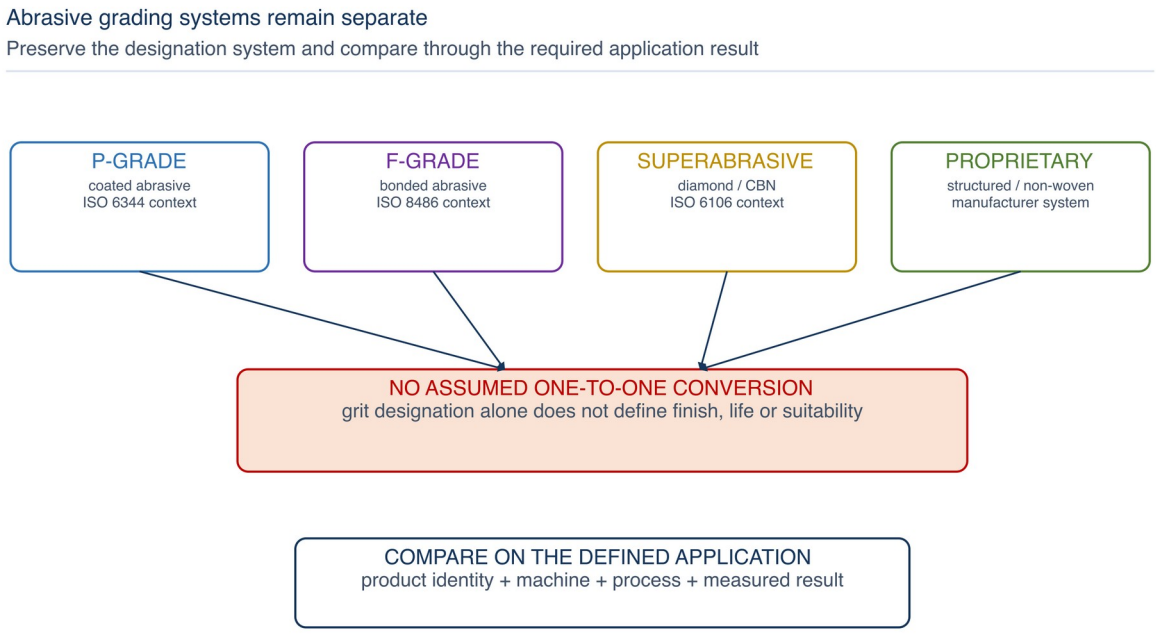

Figure 2. Abrasive grading systems remain separate. Compare products through the intended process result and verified product information; do not create assumed one-to-one conversions between designation systems.

Grit, grain material, coating pattern, backing, bond, structure, product flexibility, contact pressure, speed, coolant, workpiece and previous process steps all influence the result. Two products carrying the same nominal grade can perform differently.

9. Specify attributes at the right level

Use three requirement classes to prevent over-specification.

Requirement class	Meaning	Example treatment
Mandatory	Necessary for safety, fit, process or quality	Correct form, dimensions, interface, intended use and acceptance outcome
Preferred	Beneficial but open to an equivalent solution	Preferred backing flexibility, packaging quantity or product format
Supplier proposal	Best selected using supplier product knowledge	Grain technology, coating design, bond system or alternative sequence

Over-specification can exclude a suitable product without improving the result. Under-specification can produce incomparable quotations. State proprietary construction details only when they are essential to an approved process or exact replacement.

10. Define the operating envelope

The specification should state the conditions within which the product will be evaluated and used:

- workpiece material and starting condition;
- machine and mounting arrangement;
- operation and contact geometry;
- wet or dry use;
- coolant or process-fluid identity where applicable;
- production pattern, such as intermittent repair or repeated batch work;
- thermal, contamination and appearance sensitivities;
- extraction and housekeeping controls;
- operator access and workholding; and
- approved sequence before and after the abrasive step.

Operating values should come from the actual product, machine, process qualification and risk assessment. Do not copy a speed, force, feed, pressure, pass count or coolant setting from a different product or application.

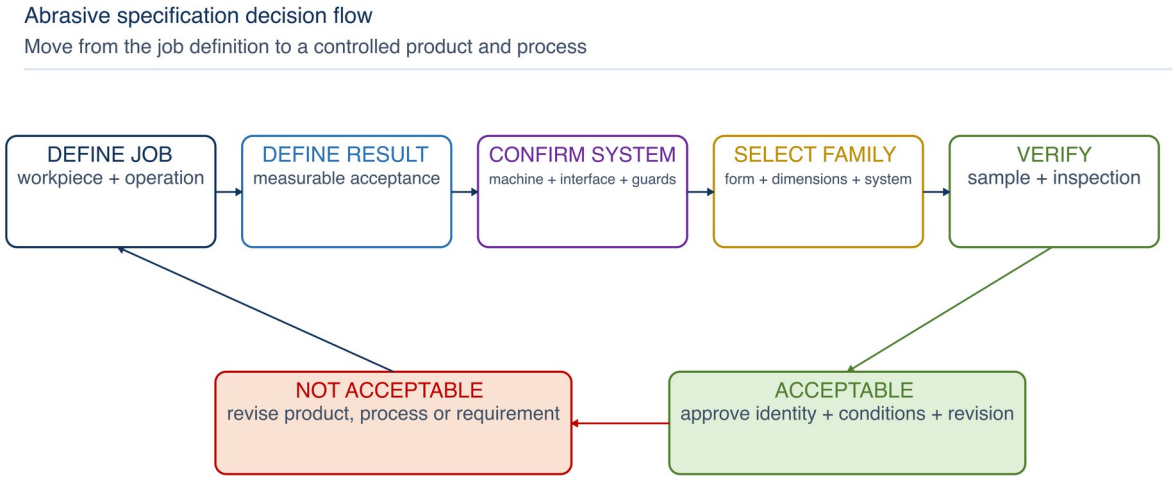

Figure 3. Abrasive specification decision flow. Define the application and outcome, confirm equipment compatibility, select the product family, agree verification, then control the approved product and process.

11. Write safety compatibility into the enquiry

Safety is not a separate purchasing note. Include enough information for the supplier to confirm intended-use compatibility:

- machine and tool type;
- product form and dimensions;
- mounting interface;
- intended operation and workpiece material;
- wet or dry condition;
- guarding constraints;
- hazardous-material or contamination concerns; and
- applicable workplace and customer restrictions.

The product must carry legible identification and be supplied with the information needed for safe selection, storage, mounting and use. FEPA provides separate safety-instruction routes for bonded, coated and superabrasive products, reinforcing the need to match the instructions to the product family. [S352]

Never request removal of a safety marking, alteration of a wheel, use without the specified guard, or operation above the lower permitted speed of the machine/product combination.

12. Define receiving and acceptance checks

Acceptance should confirm identity and condition, not attempt to recreate the manufacturer's product testing.

Check stage	Practical checks
Documentation	Purchase description, product identity, revision, quantity and agreed certificates or data
Marking	Product designation, dimensions, intended use, traceability and safety information as applicable
Physical condition	Packaging damage, moisture, deformation, cracks, edge damage, contamination or illegibility
Fit	Dimensions and interface against the approved machine/accessory arrangement
Application sample	Defined workpiece, operator/machine condition, sequence and acceptance method

Check stage	Practical checks
Release	Authorised decision, approved identity, conditions and revision record

A sample result is meaningful only when the starting condition, machine, setup, operator method and measurement approach are controlled. Record both acceptable and unacceptable outcomes using the same criteria.

13. Build a technically comparable enquiry

Use the following structure for a request for quotation or technical recommendation.

Enquiry field	Customer entry
Application statement	Operation, workpiece and purpose
Material	Grade, hardness/condition and coating where relevant
Geometry	Part form, access, thickness, edge and sensitive features
Starting condition	Scale, weld, burr, coating, scratches or prior finish
Required outcome	Drawing, texture, dimensional, cleanliness and appearance criteria
Machine	Type, model, interface, guard and available operating range
Product form	Wheel, disc, belt, sheet, roll, non-woven or mounted product
Dimensions	Outside size, width/thickness, bore, shank, belt length or attachment system
Use conditions	Wet/dry, extraction, coolant, production pattern and environment
Verification	Sample, measurement method, locations and acceptance rule
Commercial needs	Quantity, packaging, delivery, traceability and documentation
Alternative offers	Technical differences to be declared and separately identified

Attach a drawing or clear photograph when geometry or access is difficult to describe. Mark the exact processing area and protect customer-sensitive information through the agreed document-control route.

14. Control supplier alternatives

Allow alternatives where they can improve availability, quality or cost, but require a clear comparison. The supplier should identify changes in:

- product family and intended use;
- dimensions or mounting;
- abrasive/grading system;
- grain or construction;
- backing, bond, flexibility or density;
- safety or storage information;
- process sequence or operating envelope; and
- expected inspection or acceptance method.

An “equivalent” product is not approved merely because its size and grit appear similar. Evaluate the change against fit, intended use, process result, safety information, contamination risk, storage and repeatability.

15. Control revisions and substitutions

Assign the specification a unique title, number, revision, owner and effective date. Record which product identity and process condition were approved against which workpiece and acceptance method.

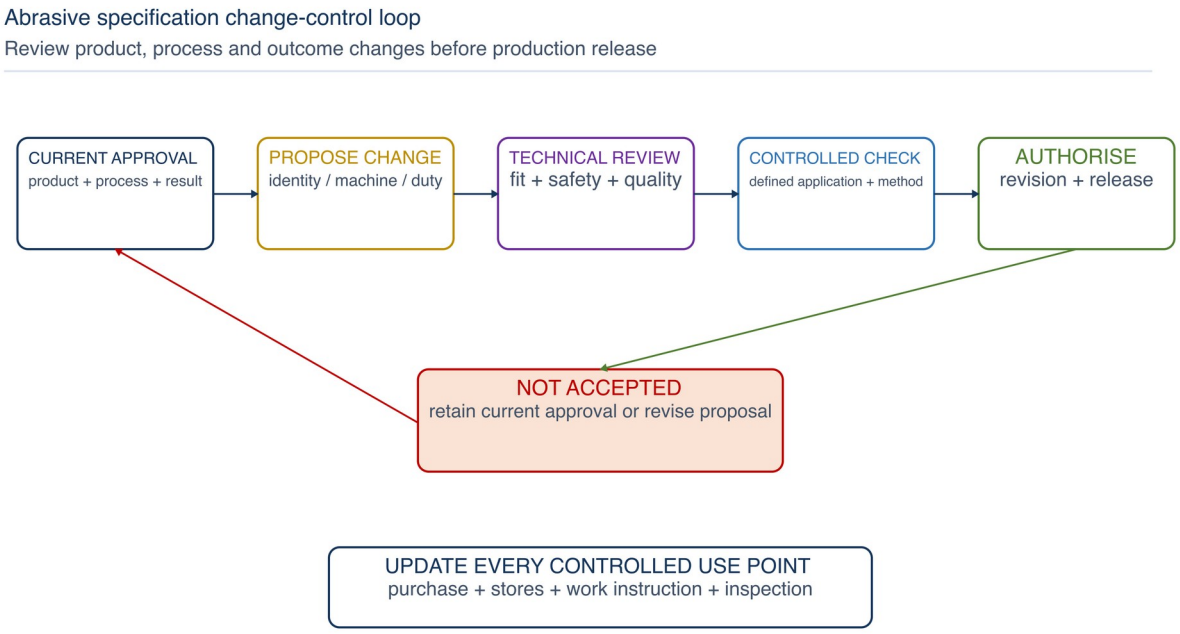

Figure 4. Abrasive specification change-control loop. A proposed change returns through technical review, controlled evaluation and authorisation before purchase or production release.

Changes that may require review include:

- manufacturer or product code;
- product form, dimensions or mounting;
- grading system or grade;
- backing, bond, density, structure or flexibility;
- machine, pad, contact wheel or guard;
- workpiece material or condition;
- wet/dry method, coolant or extraction;
- operating envelope;
- required result or measurement method; and
- packaging, storage or traceability arrangement.

Prevent superseded descriptions from remaining in purchase templates, store labels, work instructions or maintenance systems.

16. Worked specification patterns

16.1 Cutting-off application

Duty: Cut the identified alloy and section on the stated guarded machine.

Specify: workpiece material and section; cut access; flat or depressed-centre wheel form; dimensions and bore; intended operation; machine identity and speed compatibility; cut-quality criteria; burr and heat limits; sample and inspection method; marking and traceability.

Keep product-controlled: exact wheel designation, permitted speed, expiry/use-by information and mounting instructions.

16.2 Weld blending on stainless steel

Duty: Blend the weld transition to the approved contour and directional appearance without unacceptable heat tint, gouging or cross-contamination.

Specify: alloy; weld condition; surrounding thickness; contour; dedicated-product cleanliness; product form and attachment; machine and pad/contact system; required visual reference or texture criterion; protected features; inspection lighting and direction.

16.3 Coating preparation

Duty: Prepare the stated substrate for the named coating system.

Specify: substrate and existing condition; contaminant-removal stage; accessible geometry; coating-system cleanliness and texture requirement; abrasive family; extraction; inspection method; time and cleanliness controls before coating.

The abrasive description should not override the coating manufacturer's preparation requirement.

16.4 Production belt finishing

Duty: Produce the approved texture on a repeated component using the identified belt machine.

Specify: material and prior operation; belt width, length and running direction; joint/interface needs; contact wheel or platen; grading system and starting product family; wet/dry method; reference panel or measured criterion; sampling plan; belt-change trigger and change control.

For exact product construction, storage, compatibility or ordering information, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

17. Troubleshooting the specification

Problem	Likely specification weakness	Improvement
Quotations are not comparable	Application and mandatory fields are unclear	Issue one common enquiry table and require deviations to be declared
Product fits the diameter but not the machine	Interface, bore, pad, flange, guard or speed basis omitted	Record the complete machine and mounting arrangement
Finish varies between batches	Starting condition, sequence, operating envelope or acceptance method uncontrolled	Define the application sample and measurement conditions
“Same grit” gives a different result	Grading system or product construction treated as equivalent	State the system, product family and outcome requirement
Receiving cannot identify approved stock	Product identity, marking or revision not linked to the purchase line	Add controlled identity and traceability fields
Supplier proposes a potentially useful alternative	Specification prohibits all variation or lacks an evaluation path	Separate mandatory requirements from supplier proposals and use change control
Operators rely on catalogue claims	Workpiece and process conditions differ from the published example	Verify on the defined application and acceptance method
Surface passes roughness but looks unacceptable	Visual direction, local defects or reference appearance omitted	Combine measured and visual criteria where function requires both

18. Specification review checklist

Before issue, confirm that the specification:

- identifies the operation, workpiece and starting condition;
- states the required result and how it will be checked;
- identifies the machine, interface, guard and use condition;
- names the abrasive form and dimensions clearly;
- states the grading system rather than an isolated number;
- separates mandatory, preferred and supplier-proposed features;
- includes documentation, marking, condition and traceability checks;
- defines how samples and alternatives will be evaluated;
- controls revisions, substitutions and superseded descriptions;
- contains no invented product value or performance guarantee; and
- directs exact product values to controlled product information.

19. Concise safety reminders

- Confirm product, machine, mounting and intended-use compatibility before purchase and use.
- Never infer a permitted operating speed from product appearance or size.

- Do not mix wheel, flange, pad, guard or attachment components unless the combination is permitted.
- Treat illegible, damaged, wet, distorted, contaminated or suspect products through the site's segregation process.
- Control dust, sparks, noise, vibration, coolant and workholding for the actual task.
- Follow the product label, Technical Data Sheet, machine instructions and workplace risk controls.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 058

Technical RFQ Checklist

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SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, process engineers, supervisors, technical buyers, QA/QC personnel, maintenance teams, storekeepers, contractors and abrasive users

Scope: RFQ ownership; application definition; workpiece and outcome requirements; machine and interface information; abrasive form and dimensions; safety and environmental conditions; quantity, packaging and delivery; samples and inspection; supplier responses; deviations; commercial comparison; revision control and troubleshooting.

Core principle — Give every supplier the same clear description of the job, result and operating conditions. Compare technical compliance first; compare commercial value only after the offers are technically understood.

A request for quotation is a technical communication as well as a purchasing document. “Abrasive disc, fine grade” may be quick to type, but it does not tell a supplier which material is being processed, which machine will be used, what result is acceptable or whether a proposed alternative will fit the mounting system. A structured RFQ reduces clarification cycles, incomparable offers, unsuitable samples, receiving disputes and uncontrolled substitutions.

This chapter converts established abrasive-specification principles into a practical RFQ workflow. It supports product selection and purchasing decisions without assigning unverified product properties or replacing the product label, Technical Data Sheet, machine instructions, drawing, process controls or workplace risk assessment.

Chapter objectives

After this chapter, the reader should be able to:

- assign clear ownership for preparing and approving a technical RFQ;
- describe the application, workpiece and required result in supplier-ready language;
- record machine, interface, guarding and wet/dry conditions accurately;
- identify abrasive form, dimensions and grading system without false equivalence;
- distinguish mandatory requirements, preferences and supplier proposals;
- request useful documentation, marking, samples and traceability;
- obtain declared deviations and structured alternative offers;
- compare technical compliance separately from commercial value; and
- control RFQ revisions and post-award changes.

1. Treat the RFQ as a controlled technical brief

The RFQ should establish one common basis for every bidder. It needs enough information for a competent supplier to understand the application, identify a suitable product family, state assumptions and declare deviations. It should also give the buyer a consistent basis for technical review, quotation comparison and purchase-description preparation.

An effective RFQ answers five questions:

1127. What material and feature will be processed?
1128. What operation and result are required?
1129. Which machine, interface and conditions apply?
1130. How will the offer, sample and delivered goods be checked?
1131. How must alternatives, deviations and changes be declared?

Do not use the RFQ to copy an operating speed, pressure, life claim or result from an unrelated product. Describe the application and let the verified product information and technical review establish the applicable limits.

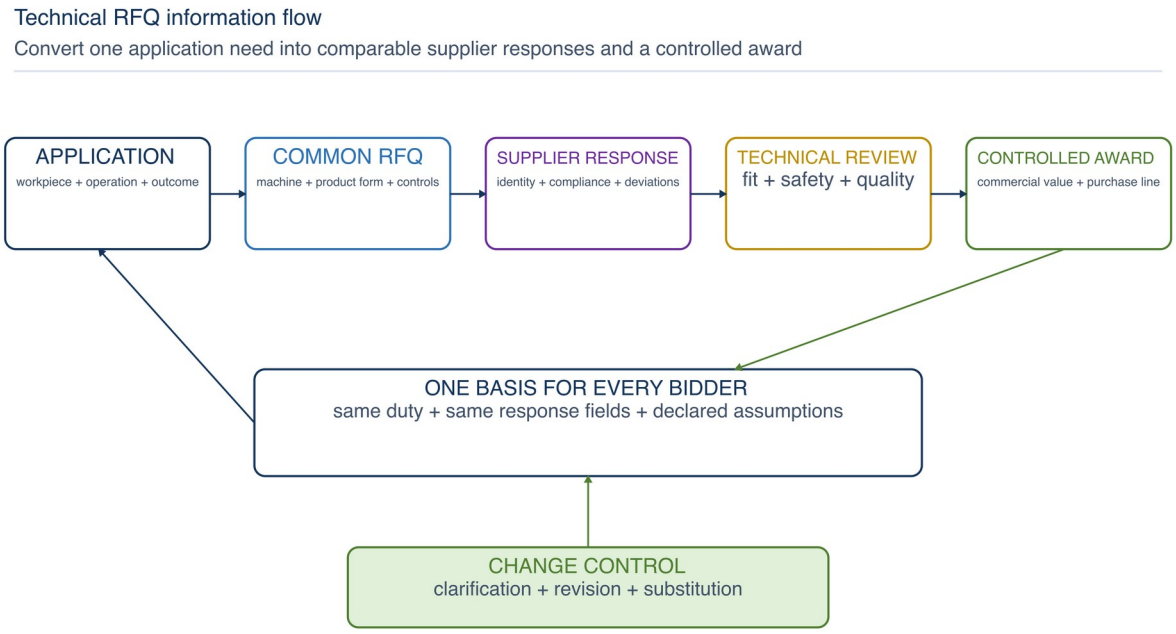


Figure 1. Technical RFQ information flow. Application information becomes a common supplier brief; structured responses then support technical comparison, commercial evaluation and a controlled purchase description.

2. Assign ownership before issue

RFQ quality improves when responsibilities are explicit. One person may perform several roles in a small company, but each decision should still have an owner.

Role	Main responsibility before issue	Main responsibility after response
Requester or production owner	Define the work, access, starting condition and operational need	Confirm that the proposed approach addresses the real task
Engineering or technical owner	Define machine, interface, process envelope and technical constraints	Review compatibility, deviations and alternatives
QA/QC	Define drawing, finish, inspection and acceptance references	Review sample, measurement and conformity information
Safety or EHS	Identify dust, spark, noise, chemical, contamination and workplace controls	Review safety information and use restrictions
Purchasing	Issue one controlled RFQ, manage clarifications and preserve bid comparability	Compare commercial terms after technical classification
Stores or logistics	Define packaging, identification, storage and receiving needs	Confirm delivery, marking, shelf-life and handling arrangements
Authorised approver	Confirm that the RFQ is complete and properly classified	Authorise the selected description and any accepted deviation

Purchasing should not be expected to infer missing process details, and production should not accept a technically different alternative solely because its unit price is lower. Cross-functional review is especially valuable for new applications, high-volume use, safety-critical fit or expensive rework risk.

3. Use an RFQ issue-readiness gate

Before the RFQ is released, confirm that the application, outcome, machine, product form and response format are sufficiently clear. A short clarification before issue is normally less costly than comparing quotations based on different assumptions.

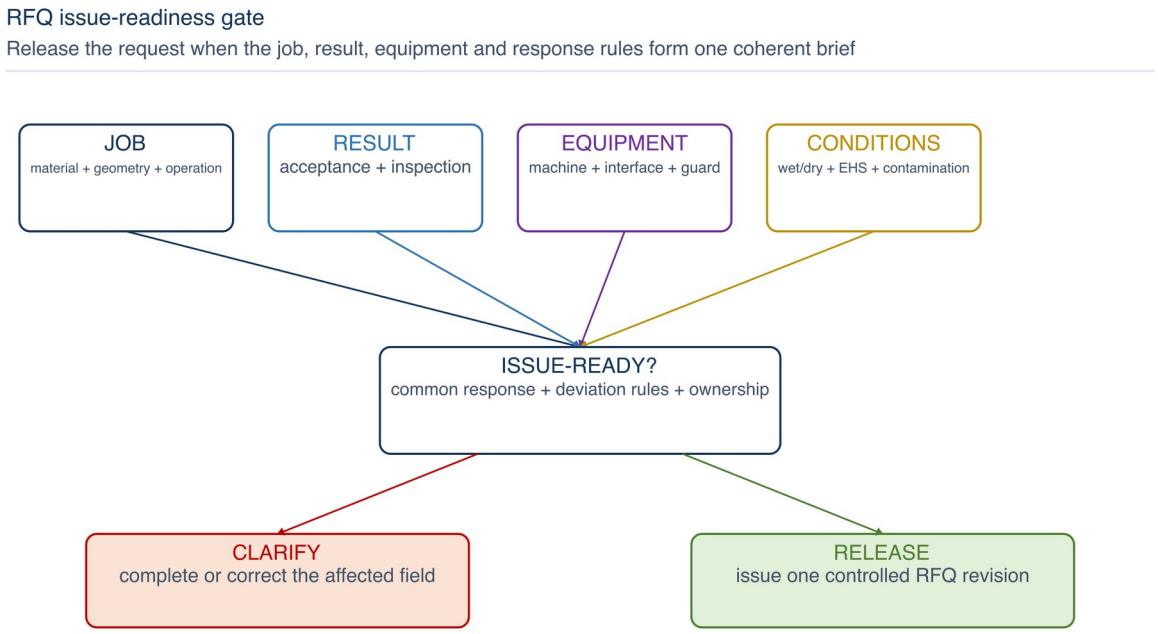


Figure 2. RFQ issue-readiness gate. The request proceeds when the job, result, equipment, safety conditions and supplier-response rules form one coherent brief.

Readiness question	Ready when
Is the duty clear?	Operation, workpiece and processing area are described
Is the result clear?	Acceptance criteria and inspection approach are stated
Is the equipment clear?	Machine, interface, guard and use condition are identified
Is the product request clear?	Form, dimensions and grading context are stated or left deliberately open for proposal
Are special controls clear?	Contamination, extraction, coolant, storage and site restrictions are stated
Is comparison possible?	Every supplier must use the same response and deviation fields

4. Start with a one-page application summary

Place the essential decision information at the front of the RFQ. Attach drawings, photographs, process sheets or detailed tables after the summary.

RFQ application summary	Customer entry
RFQ title, number and revision	Unique controlled identity
Requester and technical contact	Name, role and contact route
Application statement	Operation + workpiece + purpose
Required result	Drawing, measured criterion, visual reference or defect limit
Machine and interface	Tool/machine, model, mounting and accessory arrangement
Product form	Wheel, disc, belt, sheet, roll, non-woven, mounted or supplier-proposed form
Quantity and usage pattern	Initial quantity, expected consumption pattern and delivery need
Sample requirement	Sample quantity or demonstration arrangement, if applicable
Response deadline and format	Date, currency, delivery basis and required response table
Alternative-offer rule	Separate, clearly identified alternative with declared differences

Write the application statement as a complete sentence. For example: “Remove weld spatter and blend local transitions on carbon-steel fabrications before coating while maintaining the drawing-defined edges and surface-preparation requirement.”

5. Describe the workpiece precisely

Product suitability and process behaviour depend on the material, condition and geometry. Include the fields that materially affect the application.

Workpiece field	Useful RFQ description
Material	Controlled grade or material family; coating or cladding where relevant
Condition	Cast, forged, rolled, welded, heat treated, hardened, coated or previously finished
Geometry	Flat, edge, radius, tube, bore, profile, casting, fabrication or complex access
Size and thickness	Section range, wall thickness and stability of the processed feature
Starting surface	Scale, weld reinforcement, burr, corrosion, paint, scratches or prior finish
Removal allowance	Stock available for removal or dimensions that must be preserved
Sensitive features	Datum, thread, seal face, edge, coating boundary, cosmetic face or thin section
Cleanliness restriction	Dedicated stainless/non-ferrous use, coating preparation or other contamination control

Use separate RFQ lines where workpiece conditions create materially different duties. A heavy gate-removal operation and a light cosmetic blend should not be combined under one vague description merely because the material is the same.

6. Define the operation and required outcome

Name the operation by its function: cutting-off, stock removal, weld grinding, deburring, blending, surface preparation, finishing or polishing. Then state what constitutes an acceptable result.

Result category	RFQ field	Practical verification basis
Dimensions	Drawing tolerance or maximum removal allowance	Calibrated measurement at defined features
Surface texture	Drawing-defined parameter and limit	Controlled instrument, direction, locations and settings
Edge condition	Burr removal and permitted edge form	Visual/tactile inspection and dimensional check where important
Appearance	Direction, uniformity and approved reference	Side-by-side comparison under stated lighting and orientation
Defects	Limits for gouge, chatter, burn, heat tint, pull-out or exposed substrate	Defined inspection area, lighting and magnification
Cleanliness	Residue, contamination or coating-preparation condition	Applicable visual or process-specific method
Cut quality	Squareness, burr, kerf or heat-affected appearance as relevant	Drawing or agreed inspection method

The ISO 21920 series provides the current framework for profile surface-texture indication, terms, parameters and specification operators. Apply the controlled drawing and measurement procedure rather than copying an isolated roughness value into an RFQ. [S343; S344; S345]

State measurement direction and location. Grinding patterns can produce different readings along and across the lay, while one average value may not reveal a local gouge or damaged edge.

7. Record the machine and complete interface

A nominal product diameter does not establish machine compatibility. The RFQ should identify:

- machine or powered-tool type;
- manufacturer, model and equipment identification where relevant;
- spindle, arbor, thread, flange, backing pad, contact wheel or quick-change interface;

- guard arrangement and dimensional constraints;
- machine operating range or controlled operating setting;
- power source and available power;
- backing-pad or contact-wheel profile and hardness where applicable;
- access, orientation, workholding and contact geometry;
- extraction or coolant arrangement; and
- intended wet, damp or dry use.

Ask the supplier to state any required accessory, pad, flange or mounting component as part of the offer. Do not assume that visually similar components can be mixed.

When an exact product speed, mounting limit, accessory compatibility or ordering code is needed, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

8. Identify product family, form and dimensions

State the required physical form before describing grain or grade. If the product family is open to supplier recommendation, say so explicitly and retain the fit, outcome and safety requirements.

Product form	Typical identity fields for the RFQ
Bonded or cutting wheel	Shape/type, outside diameter, thickness, bore, intended operation
Flap disc	Diameter, bore/thread, profile, flap construction and grading designation
Fibre disc	Diameter, centre-hole arrangement, grading designation and backing-pad system
Hook-and-loop or adhesive disc	Diameter, hole pattern, attachment system, backing and grading designation
Belt	Width, length, joint/direction where relevant, backing and grading designation
Sheet or roll	Width, length, perforation/cut form, backing and grading designation
Non-woven product	Form, dimensions, attachment, density/grade designation and intended duty
Mounted product	Head shape and dimensions, shank dimensions and intended machine
Superabrasive product	Shape, dimensions, abrasive type, grain designation, bond/concentration information and mounting

ISO 525:2020 supports bonded-abrasive shape, dimensional-symbol, designation and marking practice, but it excludes coated and superabrasive products. Use the framework appropriate to the product family. [S342]

9. Keep grading systems identifiable

Write the complete designation context. P-grade coated abrasive, F-grade bonded abrasive, superabrasive grain designations and proprietary non-woven or structured-abrasive grades are not assumed one-to-one equivalents. [S346; S347; S348; S349]

RFQ situation	Good practice
Exact approved replacement	State the controlled product identity and revision
Coated abrasive requirement	State the P designation when that system applies
Bonded-abrasive grain context	State the applicable F designation context
Superabrasive requirement	State abrasive type, designation system and complete construction fields
Proprietary specialty product	Use the exact manufacturer designation and product family
Open technical recommendation	State the application and outcome; require the proposed designation system to be declared

Do not request “equivalent grit” without defining the result and product construction. Grain size is only one influence among grain type, backing, bond, structure, flexibility, coating pattern, machine, contact condition and workpiece.

10. Classify each requirement

Requirement classes make the RFQ firm where necessary and flexible where supplier product knowledge adds value.

Class	Meaning	Supplier response
Mandatory	Necessary for fit, safety, quality or process control	Confirm compliance or declare a deviation
Preferred	Desirable but not essential	Confirm, offer the nearest option or explain the trade-off
Supplier proposed	Open to technical recommendation	State the proposed construction, rationale and implications

Do not mark every field mandatory. Excessive prescription can exclude a suitable solution; insufficient definition can produce incomparable offers. Classify dimensions, mounting and intended use as mandatory when they govern physical compatibility or safe use.

11. Include safety, environmental and contamination conditions

Describe the actual operating environment so the supplier can assess intended-use compatibility and provide relevant information.

Include, as applicable:

- workpiece hazards, coatings and residues;
- dust, spark, noise and vibration conditions;
- extraction, ventilation and housekeeping arrangements;
- coolant, lubricant or process-fluid identity;
- wet/dry restrictions and electrical environment;
- cross-contamination controls for stainless steel, non-ferrous materials or coating preparation;
- food, pharmaceutical, clean-area or customer-specific restrictions;
- storage temperature, humidity and shelf-life considerations; and
- site rules affecting packaging, chemical documentation or waste handling.

FEPA provides distinct safety-instruction routes for bonded, coated and superabrasive products. This reinforces the importance of identifying the product family and obtaining the applicable safety and use information. [S352]

12. State quantity, packaging, storage and delivery needs

Commercial quantities must still be technically usable. State:

Field	RFQ entry
Initial quantity	Sample, first order or production quantity by line item
Usage pattern	Intermittent maintenance, project demand or repeated production consumption
Pack size	Preferred or mandatory pack quantity and unit of issue
Packaging	Protection from moisture, distortion, impact, contamination or mixing
Identification	Product identity, batch/lot or traceability marking as applicable
Shelf-life/use-by information	Required declaration where applicable to the product
Delivery	Required date, partial-delivery rule and delivery location
Storage information	Manufacturer storage and handling instructions

Avoid requesting a large production quantity before the technical route and acceptance basis are understood. For exact shelf life, storage limits, packaging identity or product marking, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

13. Define samples, inspection and acceptance

A sample request should identify the product, application condition and decision method. State whether the supplier is to provide loose samples, conduct a demonstration or support an on-site evaluation.

The RFQ should specify:

- sample identity and quantity;

- workpiece material and starting condition;
- machine, interface and process condition;
- operator or demonstration responsibility;
- inspection method, locations and timing;
- acceptable and unacceptable outcomes;
- sample disposition and reporting format; and
- relationship between sample acceptance and the final purchase description.

For delivered lots, define appropriate receiving checks such as identity, quantity, marking, packaging, visible condition, dimensions and agreed documentation. If attribute sampling is used, the sampling plan, inspection level, acceptance quality limit and acceptance numbers should come from the organisation's approved quality method and risk basis. ISO 2859-1:2026 provides lot-by-lot attribute-sampling schemes, while ISO 28590:2017 provides general guidance on selecting from the ISO 2859 series. Sampling does not demonstrate that every unit conforms and does not replace supplier process control. [S356; S357]

14. Request documentation, marking and traceability

List the documents and identifiers that are relevant to the product and application rather than using a generic “all certificates” statement.

Information	RFQ treatment
Quotation identity	Supplier quotation number, date and validity
Product identity	Manufacturer, product name/code, form, dimensions and grade/system
Technical information	Current Technical Data Sheet or equivalent product information
Safety information	Applicable safety/use instructions and Safety Data Sheet where relevant
Marking	Product and packaging identification appropriate to the product family
Traceability	Batch/lot or other identifier where required by the purchase control
Conformity documentation	Specific document requested only where applicable and justified
Change notification	Agreed route for product, construction, manufacturing or documentation changes

Quality-management certification provides useful organisational context, but it does not by itself prove that a particular abrasive fits the machine or will achieve the required result. ISO 9001:2015 is the current published edition at the time of this chapter; a replacement is under publication. Confirm application suitability through the product information and the controlled selection process described in this handbook. [S353]

15. Require a structured supplier response

Ask every supplier to return the same table. This makes assumptions visible and avoids comparing a detailed technical offer with a price-only response.

RFQ field	Supplier response
Offered product	Manufacturer, product identity and complete description
Compliance	Complies / deviation / not offered
Dimensions and interface	Offered values and required accessories
Intended application	Supplier-confirmed intended use
Product information	Technical and safety document references
Assumptions	Workpiece, machine, process or volume assumptions
Deviations	Exact difference, reason and practical implication
Alternative	Separately identified option with comparison to the requested basis
Sample/support	Availability, quantity, lead time and technical-support scope
Commercial	Unit, pack quantity, price, currency, validity, lead time and delivery terms

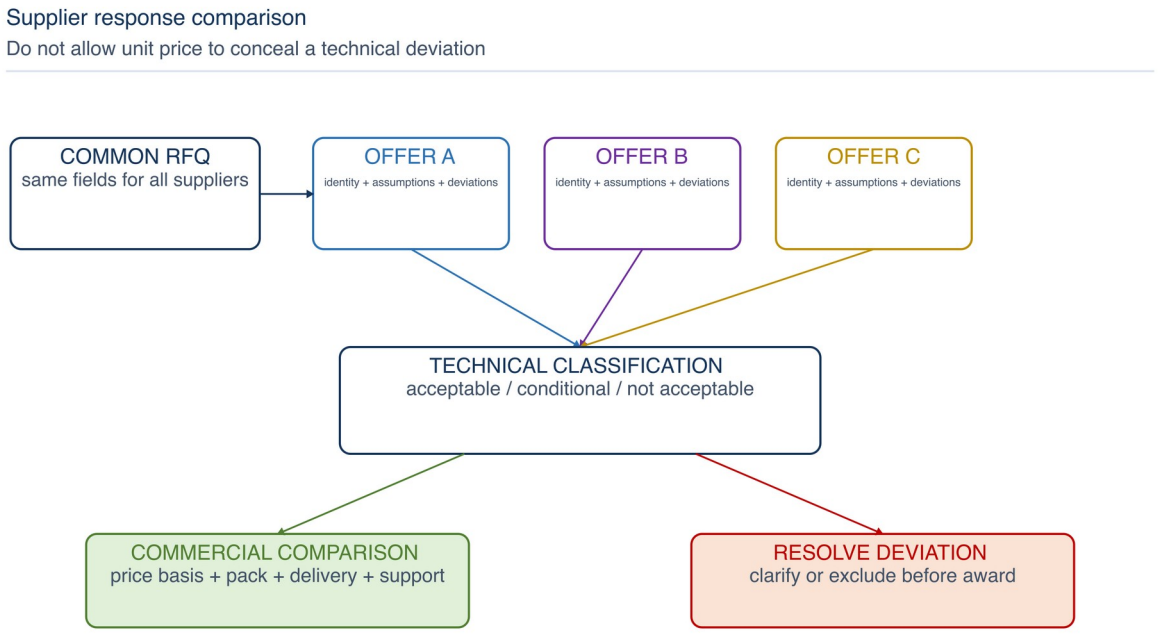


Figure 3. Supplier response comparison. Offers pass through a common technical-compliance review before commercial value is compared.

16. Control alternatives, deviations and substitutions

An alternative can be valuable, but “equivalent” should never be accepted as an unexplained label. Require the supplier to declare differences in:

- product family and intended operation;
- dimensions, mounting and accessories;
- grading system and designation;
- grain, backing, bond, density, flexibility or structure;
- wet/dry use and process sequence;
- product safety, storage and marking information;
- inspection or acceptance method; and
- delivery, packaging or traceability.

Review the impact on fit, guarding, product identification, contamination, process result, operator method, receiving, storage and total cost. Similar diameter and nominal grit do not establish equivalence.

17. Compare technical compliance before price

Use two linked evaluations rather than one blended score that allows a low price to conceal a technical deviation.

Stage	Compare	Decision
1. Technical classification	Mandatory compliance, machine/interface fit, intended use, outcome basis, safety information, deviations	Technically acceptable, conditionally acceptable or not acceptable
2. Commercial comparison	Price basis, pack quantity, usable quantity, lead time, delivery, support and payment terms	Best evaluated commercial value among technically acceptable offers
3. Approval	Product identity, conditions, accepted deviations and purchase description	Controlled award and release

Where cost-per-component or abrasive life matters, define the evaluation method before comparing claims. Do not treat an unsupported catalogue statement as a guaranteed production result.

18. Control clarifications and RFQ revisions

Issue supplier clarifications through one controlled route. If an answer changes the technical basis, update the RFQ revision and provide the same information to every active bidder. Do not allow private assumptions to become an undeclared advantage.

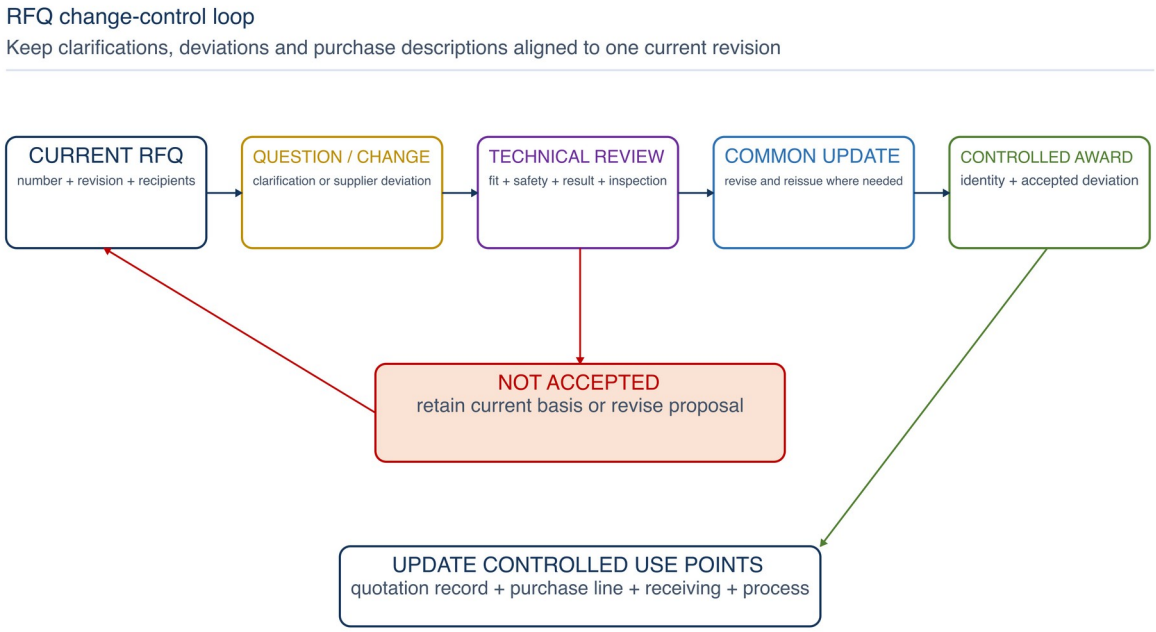


Figure 4. RFQ change-control loop. Clarifications, deviations and post-issue changes return through technical review before the controlled purchase description is updated.

ISO 10005:2018 supports the establishment, review, acceptance, application and revision of quality plans, while ISO 10007:2017 provides configuration-management guidance for controlled identity and change status. These principles support clear RFQ revision and award records without implying product approval by the standards. [S354; S355]

Record:

- RFQ number, revision and issue date;
- recipients of each revision;
- clarification question and common answer;
- changed requirement and reason;
- technical reviewer and authoriser;
- accepted supplier deviation;
- awarded product identity and quotation reference; and
- resulting purchase-description revision.

19. Troubleshooting the RFQ

Problem	Likely cause	Improvement
Quotations describe different products	Application and response format are too open	Issue one common summary and supplier-response table
Supplier cannot recommend a product	Workpiece, operation, machine or required result is unclear	Complete the application and equipment fields
Offered product fits the diameter but not the tool	Interface, accessory or guard information is incomplete	Record the full mounting system and machine identity
Prices cannot be compared	Unit, pack quantity, currency or delivery basis differs	Require one commercial response format

Problem	Likely cause	Improvement
“Same grit” products give different results	Grading system and construction are not declared	State the system and compare through the application outcome
Receiving cannot identify the awarded item	Award record and purchase line omit controlled identity	Carry manufacturer, product, form, dimensions and revision into the order
Alternative is introduced after award	Substitution and change-notification rules are unclear	Require declared change and technical review before release
Sample result cannot be repeated	Starting condition, machine, sequence or inspection method changed	Control the application and verification conditions
Certification is treated as product approval	Supplier-system and product/application decisions are mixed	Evaluate supplier capability and product suitability separately

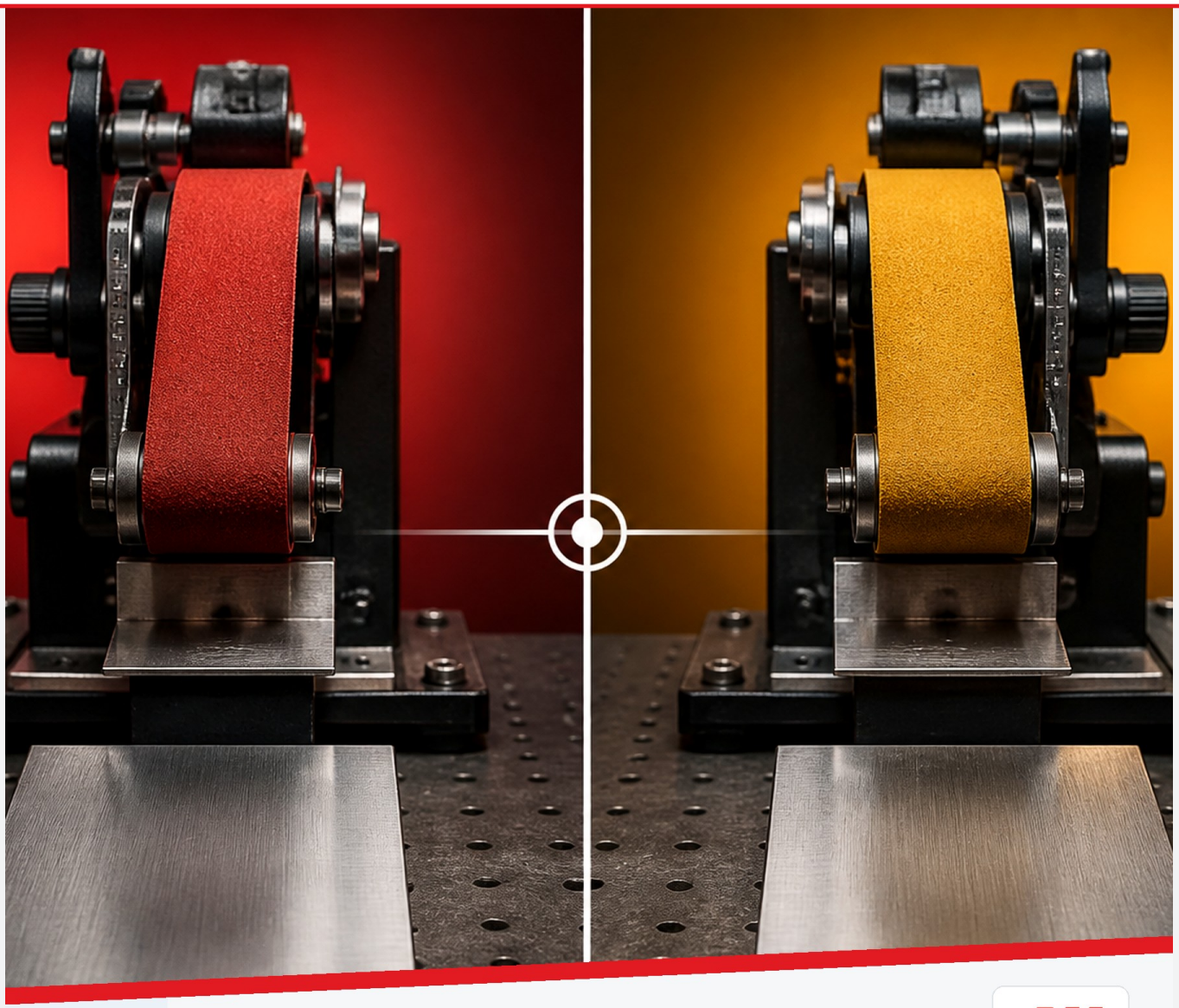
20. RFQ issue checklist

Before release, confirm that the RFQ:

- has a unique title, number, revision, owner and response date;
- describes the operation, workpiece, geometry and starting condition;
- states the required result and inspection basis;
- identifies the machine, interface, guard and wet/dry condition;
- names the abrasive form, dimensions and grading system where prescribed;
- separates mandatory, preferred and supplier-proposed attributes;
- describes safety, environmental and contamination conditions;
- states quantity, packaging, identification, storage and delivery needs;
- defines sample, receiving and acceptance arrangements where applicable;
- requests relevant product, safety, marking and traceability information;
- requires assumptions, deviations and alternatives to be declared;
- separates technical classification from commercial comparison;
- controls clarifications, revisions and substitutions; and
- contains no unverified product value, approval, result or guarantee.

Concise safety reminders

- Confirm product, machine, mounting, guard and intended-use compatibility before purchase and use.
- Never infer a permitted speed or use condition from product appearance, nominal size or a competitor's product.
- Do not request altered wheels, removed safety markings or unapproved mounting combinations.
- Identify dust, sparks, noise, vibration, coolant, workholding and contamination controls for the actual task.
- Segregate damaged, wet, distorted, contaminated or illegibly marked products through the site's controlled process.
- Follow the product label, Technical Data Sheet, machine instructions and workplace risk controls.



SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 059

Alternative Product Approval

59

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production engineers, process engineers, supervisors, technical buyers, QA/QC personnel, safety teams, maintenance teams, storekeepers, contractors and abrasive users

Scope: Alternative-product definition; approval ownership; baseline and proposed-product identity; workpiece and outcome comparison; machine, guard and interface compatibility; safety and environmental review; controlled comparison; acceptance; authorisation; implementation; monitoring; reversion; supplier change notification and troubleshooting.

Core principle — An alternative abrasive is approved for a defined application and operating envelope—not because it looks similar, carries a similar grit description or costs less per unit.

Alternative products can improve availability, process capability, ergonomics or total cost. They can also change fit, aggressiveness, heat generation, finish, contamination risk, dust, vibration, product life, operator technique or downstream quality. A disciplined approval method separates useful innovation from uncontrolled substitution.

This chapter provides a customer-facing method for comparing an alternative against the current approved basis. It does not assign MKTECH-specific product specifications, operating values, performance results or guarantees. Exact product limits and identification remain controlled by the applicable product information.

Chapter objectives

After this chapter, the reader should be able to:

- recognise when a proposed product is an alternative requiring technical review;
- define the current approved application and product baseline;
- compare product identity, construction, dimensions and grading systems correctly;
- confirm machine, mounting, guard and accessory compatibility;
- review safety, contamination and downstream-process implications;
- prepare a controlled comparison with defined acceptance criteria;
- classify approval decisions and authorised conditions;
- update purchasing, stores, work and inspection controls after approval; and
- monitor early production and control later supplier or process changes.

1. Define an alternative product broadly

Treat a product as an alternative when any characteristic relevant to fit, safe use, process behaviour, quality or identification differs from the approved basis. Examples include:

- a different manufacturer or product code;
- a different abrasive family or physical form;
- a change in diameter, thickness, bore, thread, shank, belt size or hole pattern;
- a different grain or grading system;
- a change in backing, bond, density, flexibility, structure or coating pattern;
- a different mounting accessory, backing pad, flange or contact wheel;
- a change in wet/dry use, coolant or process sequence;
- revised safety, storage, marking or shelf-life information; or
- a supplier change that affects product identity or construction.

A packaging change may be purely commercial, but it still needs review if it affects traceability, moisture protection, product condition or store identification. The significance of a change is determined by its practical effect, not by the supplier's label of “equivalent”, “replacement” or “new generation”.

2. Separate alternative approval from routine buying

Routine replenishment purchases an already approved identity under established conditions. Alternative approval determines whether a different identity can enter that controlled route.

Activity	Routine replenishment	Alternative approval
Product identity	Matches the current controlled description	Differs in one or more relevant fields
Technical review	Confirm identity and condition	Compare fit, use, risk and result
Supplier response	Availability and commercial terms	Full identity, technical information, deviations and assumptions

Activity	Routine replenishment	Alternative approval
Evaluation	Receiving checks	Controlled application comparison
Decision	Release approved stock	Approve, approve with conditions, reject or hold for further review
Records	Purchase and receiving record	Comparison, decision, authorised conditions and revision updates

Do not permit a buyer, storekeeper or operator to substitute an unreviewed product solely to avoid a stockout. Urgency changes scheduling; it does not remove compatibility and safety questions.

3. Assign approval ownership

Alternative approval is cross-functional when the change can affect production, safety, quality or stock control.

Role	Approval responsibility
Application owner	Defines the actual work, operating envelope and production need
Engineering or technical owner	Reviews product form, construction, machine/interface fit and process implications
QA/QC	Defines outcome criteria, measurement and acceptance
Safety or EHS	Reviews hazards, controls, product information and worker considerations
Purchasing	Obtains a complete supplier proposal and prevents premature substitution
Stores	Segregates evaluation stock and protects identity/traceability
Operator or worker representative	Provides practical feedback on access, control, loading, vibration and usability
Authorised approver	Records the decision, scope and conditions of release

ISO 45001:2018 provides an occupational health and safety management framework that includes worker participation, hazard identification, risk assessment and operational control. Use the organisation's current safety-management process for the actual workplace. [S359]

4. Start with a controlled change proposal

State why the alternative is being considered. Common reasons include availability, discontinuation, lead time, process improvement, reduced rework, ergonomics, technical support, standardisation or total cost.

The proposal should identify:

- current product and approved application;
- proposed product and supplier;
- reason for the change;
- expected benefit stated as an objective, not a guaranteed outcome;
- known technical differences;
- affected machines, parts, work areas and documents;
- proposed comparison and acceptance method; and
- owner and required decision date.

Do not write “same as current” unless each relevant field has been compared. A clearly stated difference is easier to manage than an assumed equivalence.

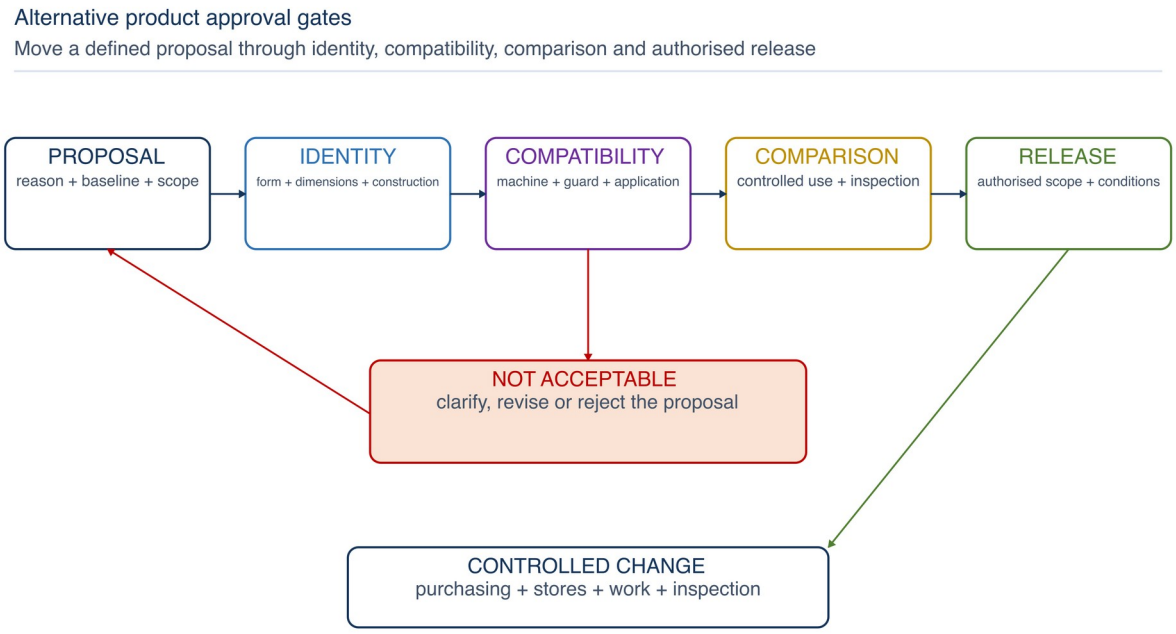

Figure 1. Alternative product approval gates. A proposal progresses through identity, compatibility, controlled comparison and authorised release; an unacceptable result returns to review or rejection.

5. Establish the approved baseline

The baseline is the product, application, machine arrangement, process condition and result against which the alternative will be judged. It should be representative of normal acceptable production rather than an unusually favourable run.

Baseline element	What to define
Product identity	Manufacturer, product name/code, form, dimensions, grade/system and revision
Workpiece	Material, condition, geometry, starting surface and sensitive features
Operation	Cutting, stock removal, deburring, blending, preparation, finishing or polishing
Machine system	Machine, guard, spindle/interface, pad/flange/contact wheel and extraction/coolant
Operating envelope	Wet/dry use, contact geometry, sequence and established controlled conditions
Required result	Drawing, texture, appearance, defect, cleanliness and dimensional criteria
Production context	Batch pattern, access, operator method and downstream process
Current controls	Purchase description, receiving check, work instruction and inspection method

If several approved applications use the current product, do not assume one comparison covers them all. Define the scope of approval by material, machine, operation and outcome.

6. Capture the proposed product identity

Obtain the complete supplier-controlled identity before comparison:

- manufacturer and product name/code;
- abrasive family and intended operation;
- physical form and dimensions;
- bore, thread, shank, attachment or hole pattern;
- grain and grading-system designation;
- backing, bond, density, flexibility or structural description where relevant;
- required accessory or mounting component;
- product and packaging marking;

- Technical Data Sheet and applicable safety information;
- storage and shelf-life/use-by information where relevant; and
- change-notification and traceability information.

When an exact product speed, dimension, construction, compatibility limit, storage condition or ordering code is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

7. Compare baseline and alternative field by field

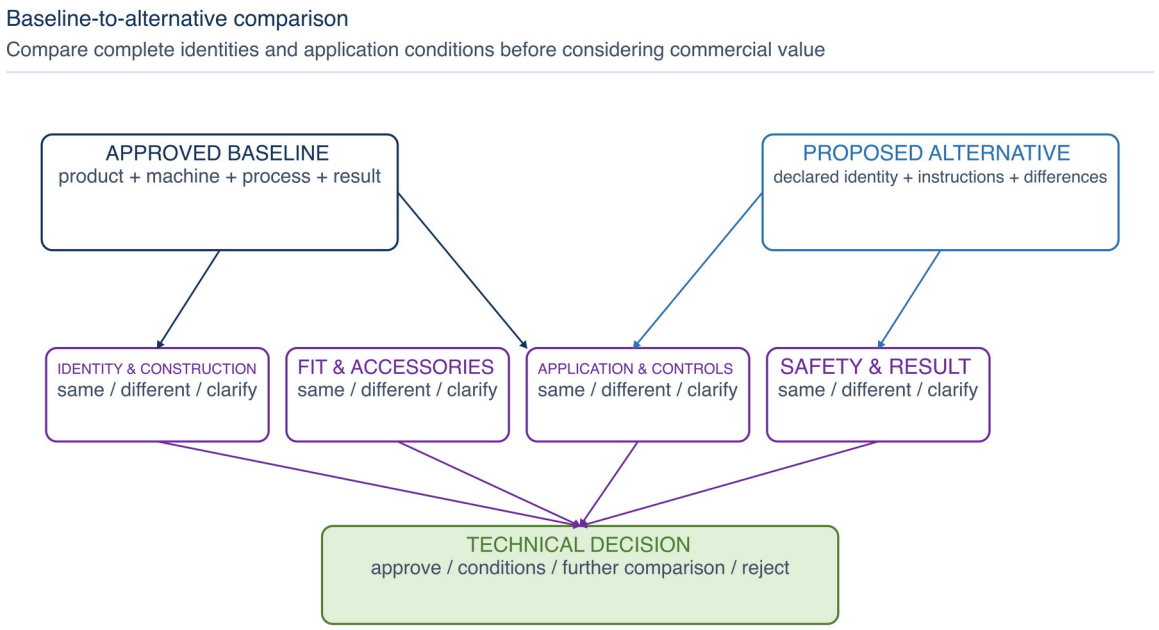

Figure 2. Baseline-to-alternative comparison. Identity, fit, application, safety information and result criteria are compared before commercial evaluation.

Comparison field	Baseline	Proposed alternative	Decision question
Product family/form	Approved form	Offered form	Is the intended operation the same?
Dimensions/interface	Approved values	Offered values	Does it fit the machine and guard correctly?
Grain/grade system	Controlled designation	Declared designation	Are systems being kept separate?
Construction	Backing, bond, density or structure	Declared differences	Could behaviour, flexibility or heat change?
Intended materials/use	Approved application	Supplier-stated use	Does the proposed use cover the actual workpiece and duty?
Accessories	Approved pad/flange/contact system	Required components	Is the complete combination permitted?
Safety information	Current instructions	Proposed instructions	Do hazards or controls change?
Storage/marking	Current arrangement	Proposed arrangement	Can condition and identity remain controlled?
Required result	Approved criteria	Same comparison criteria	Can the alternative be judged on the same basis?

Record “same”, “different”, “not applicable” or “supplier clarification” for each field. Do not leave a blank field to be interpreted as compliance.

8. Keep grading systems separate

P grades for coated abrasives, F grades for bonded abrasives, superabrasive designations and proprietary grades are separate systems. ISO 6344, ISO 8486 and ISO 6106 provide distinct designation contexts. [S346; S347; S348; S349]

Do not approve an alternative because its number resembles the baseline grit. Compare the complete product construction and the result on the defined application. Grain type, backing, bond, structure, flexibility, coating pattern, contact system and process conditions can all change the outcome.

9. Confirm machine, guard and interface compatibility

The proposed abrasive must be checked against the actual machine system, not only against a catalogue diameter.

Confirm:

- machine/tool type, model and operating range;
- product form and intended operation;
- outside diameter, thickness/width and bore or attachment;
- spindle, arbor, thread, shank or quick-change system;
- guard type, position and permitted product geometry;
- flange, blotter, nut, pad, contact wheel or accessory arrangement as applicable;
- available power and contact condition;
- wet/dry use and extraction/coolant arrangement; and
- product and machine speed compatibility using their controlled information.

ISO 12100:2010 provides a general machinery risk-assessment and risk-reduction method covering hazard identification, risk estimation, evaluation, documentation and verification. It remains the current published edition while a replacement is under development. [S358]

OSHA 29 CFR 1910.215 illustrates that abrasive-wheel guarding, mounting and flange provisions depend on wheel type and machinery arrangement. It is a United States regulation and is not presented as Malaysian law; use applicable Malaysian requirements, machine instructions and product information for the actual workplace. [S360]

10. Review workpiece and process risks

An alternative may fit the machine yet behave differently on the workpiece. Review:

- material grade, hardness and coating;
- thin sections, edges, radii, datums and seal faces;
- starting scale, weld, burr, corrosion or prior finish;
- stock-removal allowance and dimensional sensitivity;
- heat, burn, heat-tint or distortion risk;
- loading, glazing, chatter, gouging or pull-out;
- contamination restrictions for stainless steel, non-ferrous materials or coating preparation;
- finish direction, texture and appearance;
- cleaning requirements and residue; and
- effects on welding, coating, sealing, fatigue-sensitive features or later inspection.

If the alternative changes the required process sequence or accessory, treat that as part of the proposal. Do not approve only the consumable while leaving the necessary process change uncontrolled.

11. Review safety and environmental changes

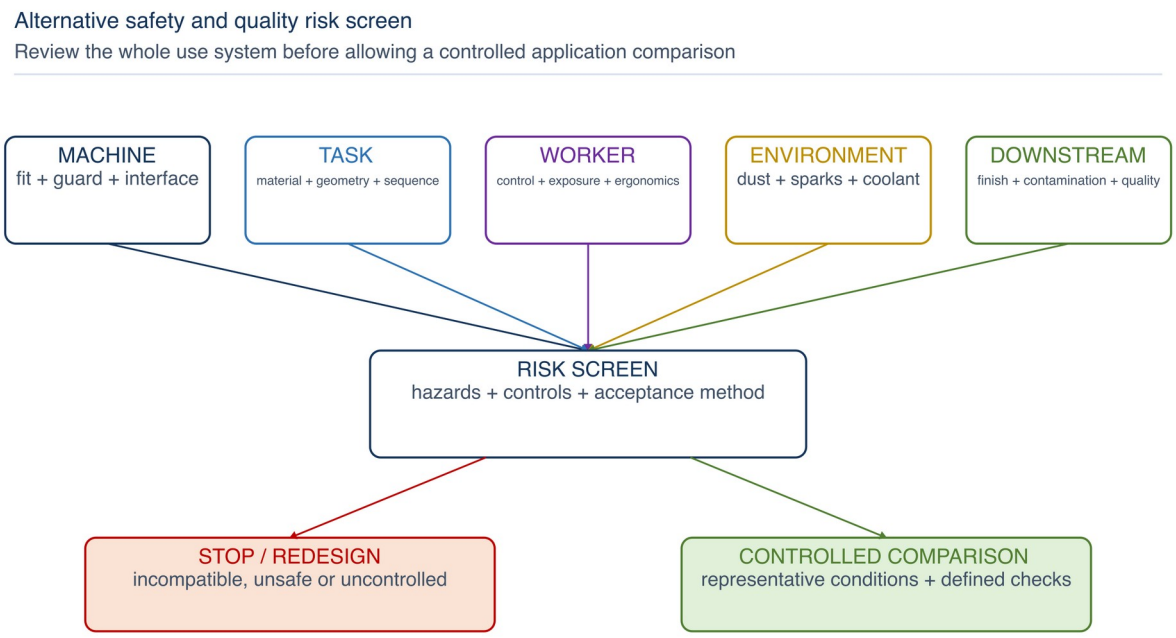

Figure 3. Safety and quality risk screen. A product proceeds to controlled comparison only after machine, task, worker, environment and downstream effects have been reviewed.

Compare the baseline and alternative for:

Area	Review questions
Mechanical	Does form, mounting, guard coverage, accessory or failure mode change?
Dust and fumes	Could dust quantity, particle behaviour, workpiece coating or extraction need change?
Sparks and ignition	Could spark direction, intensity or combustible exposure change?
Noise and vibration	Could operator exposure, tool control or use duration change?
Ergonomics	Does weight, cutting action, pressure sensitivity, access or handling change?
Coolant/chemical	Is the product intended for the stated wet/dry condition and process fluid?
Contamination	Could transferred material or residue affect stainless, non-ferrous, coating or clean-area work?
Storage and disposal	Do packaging, shelf-life, moisture, damage or waste controls change?

FEPA provides separate safety guidance for bonded, coated and superabrasive product families. Use the instructions applicable to the offered product family. [S352]

12. Classify the change before comparison

Use a risk-based classification to set the depth of review without weakening essential checks.

Change class	Typical characteristics	Review approach
Limited	Same approved identity with packaging or administrative change that does not affect condition, traceability or use	Verify identity and document update
Moderate	Different product identity with matching form/interface and no identified change to guarding or process sequence	Full technical comparison and controlled application check

Change class	Typical characteristics	Review approach
Significant	Different form, dimensions, accessory, construction, machine condition, hazard profile or downstream effect	Cross-functional risk review, controlled comparison and explicit authorisation
Unacceptable without redesign	Product cannot be shown compatible with machine, guard, intended use or required result	Reject or redesign the complete system before reconsideration

Classification is not approval. It determines the review path; the final decision still depends on compatibility and the defined result.

13. Plan a controlled comparison

Compare the baseline and alternative under conditions that represent the application and allow a fair decision.

Define:

- sample identity and traceability;
- workpiece material, geometry and starting condition;
- machine, guard, interface and accessory;
- operator method and sequence;
- wet/dry condition, coolant and extraction;
- required outcome and inspection method;
- observation points such as cut control, loading, heat, finish and product condition;
- stop conditions for unsafe, damaging or clearly unacceptable behaviour;
- sample quantity or comparison duration from the approved quality/risk method; and
- responsibility for observation, measurement and decision.

Do not alter several variables at once unless the proposal is intentionally a complete process-system change and the comparison is designed accordingly.

14. Use defined acceptance criteria

Acceptance criteria should reflect the functional and production risks of the application.

Criterion	Possible comparison basis
Fit and mounting	Correct installation with permitted accessories and guard arrangement
Process control	Stable cutting/grinding action without unacceptable loading, chatter or loss of control
Dimensions	Drawing tolerance or stock-removal allowance maintained
Surface result	Defined texture, direction, appearance and defect limits achieved
Thermal effect	No unacceptable burn, heat tint, distortion or substrate damage
Cleanliness	Contamination and residue controls satisfied
Safety/ergonomics	No unacceptable change in hazards, vibration, handling or exposure controls
Productivity	Measured using an agreed method where material to the decision
Product consumption	Compared on a controlled basis where material to total cost
Repeatability	Acceptable results across the approved comparison scope

ISO 2859-1:2026 and ISO 28590:2017 provide frameworks for attribute sampling and selection of sampling systems. Do not assign an AQL, inspection level, sample size or acceptance number without the organisation's approved sampling method and risk basis. Sampling does not prove every unit conforms. [S356; S357]

15. Record observations, not impressions

Replace “better”, “faster” or “feels good” with defined observations and measurements. Useful records can include:

- component or cut identity;
- baseline and alternative product identity;

- machine and accessory;
- start and finish condition;
- inspection results and defect observations;
- product changes or interruptions;
- operator feedback linked to a defined question;
- rework, rejection or downstream effects; and
- deviations from the planned comparison.

Operator feedback is important, especially for control, access, loading and vibration. Combine it with objective inspection where the decision affects quality or safety.

16. Use clear decision categories

Decision	Meaning	Consequence
Approved	Meets the defined technical, safety and quality criteria	Release only for the recorded scope and conditions
Approved with conditions	Acceptable when stated restrictions, accessories or controls are applied	Carry every condition into purchasing, work and inspection controls
Further comparison	Information is insufficient for a reliable decision	Extend or refine the controlled comparison
Rejected	Does not meet compatibility, safety, quality or process criteria	Segregate evaluation stock and retain the current approved basis

Price, lead time or availability may influence the business decision after technical classification. They do not convert a technically unacceptable product into an approved alternative.

17. Define the approval scope precisely

Record the exact boundary of approval:

- proposed product identity and revision;
- approved workpiece material and condition;
- operation and process stage;
- machine/tool and accessory combination;
- product form, dimensions and mounting;
- wet/dry condition and coolant/extraction arrangement;
- required sequence and operating envelope;
- inspection and acceptance method;
- limitations and prohibited uses;
- effective date, owner and authoriser; and
- relationship to the previous product—additional option, preferred option or replacement.

An approval for weld blending on one machine does not automatically cover cutting-off, another machine, another alloy or another product size.

18. Release the change through every use point

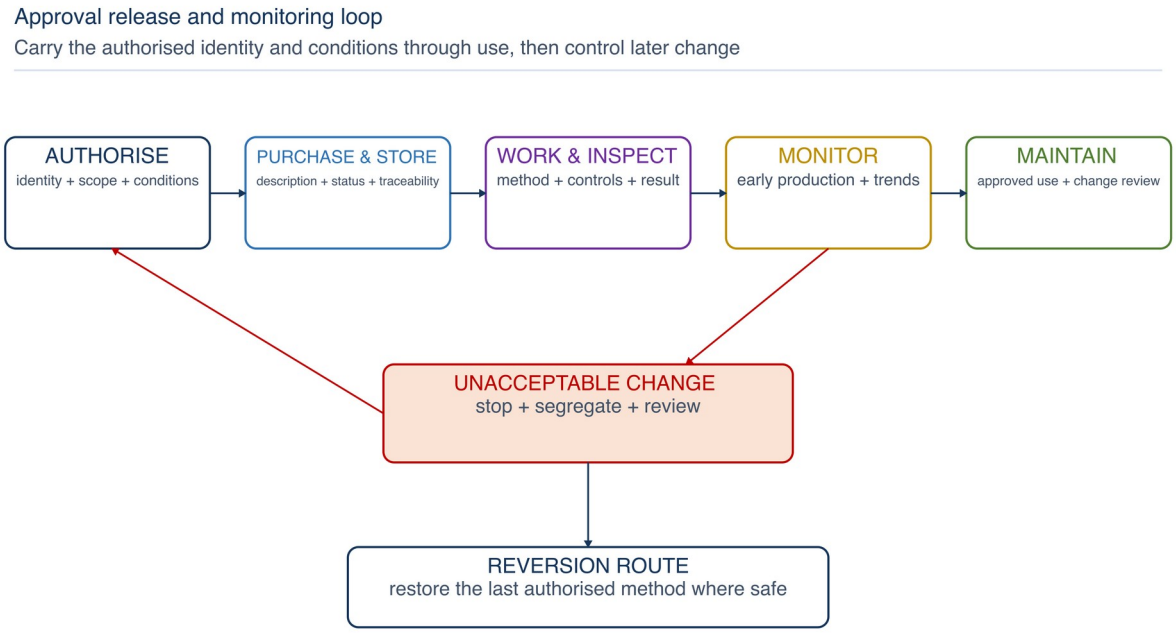

Figure 4. Approval release and monitoring loop. Authorised identity and conditions flow into purchasing, stores, work and inspection controls, followed by early-production monitoring and controlled change review.

Update, as applicable:

- approved-product or specification record;
- purchase description and supplier reference;
- receiving inspection and traceability fields;
- store location, label and segregation status;
- issue and return controls;
- machine, accessory and setup information;
- work instruction and operator communication;
- inspection plan and reference samples; and
- superseded descriptions and emergency-buying lists.

ISO 10005:2018 supports the establishment, review, acceptance, application and revision of quality plans. ISO 10007:2017 supports controlled identity, configuration status and change management. These principles help keep the approved alternative aligned across its lifecycle. [S354; S355]

19. Monitor early production and control later change

Use an appropriate early-production monitoring period for the application risk and usage pattern. Confirm that the released product continues to produce the approved result under normal production variation.

Monitor, where relevant:

- receiving identity and condition;
- fit and mounting consistency;
- process stability and operator control;
- finish, dimensions and defect trends;
- contamination and downstream effects;
- product consumption, rework and interruption;
- safety observations and exposure controls; and
- supplier, packaging, marking or construction changes.

Define a reversion route before release. If the alternative produces an unsafe condition, machine incompatibility, damage or unacceptable quality, stop use, segregate stock and restore the last authorised method where safe and available.

For exact marking, speed, storage, use or compatibility information, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

20. Troubleshooting alternative approval

Problem	Likely weakness	Improvement
Alternative is treated as automatically equivalent	Only size or grit was compared	Compare identity, construction, fit, use, safety information and result
Product fits but cannot be guarded correctly	Guard and accessory arrangement was omitted	Review the complete machine-product system
Finish changes unexpectedly	Grading system, backing, bond or process condition differs	Keep designation systems separate and compare the full construction
Comparison result cannot be repeated	Starting condition, operator method or inspection changed	Control the application and verification method
Useful alternative is rejected on unit price confusion	Technical and commercial decisions are mixed	Classify technical acceptance before total-cost comparison
Receiving mixes evaluation and approved stock	Identity and status are unclear	Segregate, label and trace evaluation material
Conditions are lost after approval	Purchase and work documents were not updated	Release the change through every controlled use point
Supplier changes the product later	Change-notification route is unclear	Require declared change and repeat the applicable review
One approval is applied to unrelated jobs	Approval scope is too broad	State material, machine, operation, size and conditions precisely

Alternative approval checklist

Before authorisation, confirm that:

- the reason for change and approval owner are clear;
- the current baseline and proposed product identities are complete;
- product family, dimensions, mounting and grading system are compared;
- machine, guard, accessory and speed compatibility are confirmed from controlled information;
- workpiece, finish, contamination and downstream risks are reviewed;
- safety, environmental and operator considerations are addressed;
- the controlled comparison uses representative conditions;
- acceptance criteria and inspection methods are defined;
- observations and deviations are recorded;
- the decision category and scope are explicit;
- purchasing, stores, work and inspection controls are updated;
- early-production monitoring and reversion routes are defined; and
- later supplier or process changes return through change control.

Concise safety reminders

- Never use similarity in colour, size or grit as proof of safe interchangeability.
- Confirm the complete product, machine, guard, mounting and accessory combination.
- Do not exceed the lower permitted speed of the machine/product combination.
- Stop comparison immediately for unsafe behaviour, damaged product, loss of control or incompatible mounting.
- Segregate unapproved and rejected evaluation stock from released production stock.
- Follow the product label, Technical Data Sheet, machine instructions and workplace risk controls.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 060

Inventory and Reorder Planning

60

SELECT • APPLY • FINISH • TROUBLESHOOT

MKTech Industry Sdn Bhd | www.mktechindustry.com

Audience: Production planners, buyers, storekeepers, supervisors, maintenance teams, engineers, QA/QC personnel, safety teams and industrial abrasive users

Scope: Item master; demand history; replenishment lead time; inventory status; cycle and safety stock; reorder points; min/max planning; criticality; stock rotation; shelf-life and condition; traceability; cycle counting; stockouts; continuity planning; parameter review and troubleshooting.

Core principle — Reorder planning must balance availability, product condition, traceability, working capital and application risk. A stockout must never become permission for an uncontrolled abrasive substitution.

Industrial abrasive inventories contain many forms, sizes, interfaces, grades and constructions. Two products that look similar may not be interchangeable, while one product code may serve several work areas with different demand patterns. Good planning begins with controlled identity and reliable movement records, then applies demand, lead-time and risk logic appropriate to each item.

This chapter provides a practical customer-facing method. It does not assign MKTECH-specific stock levels, reorder points, service targets, shelf life, storage conditions, order quantities or performance guarantees.

Chapter objectives

After this chapter, the reader should be able to:

- maintain a controlled abrasive item master;
- distinguish physical, available, committed, quarantined and on-order quantities;
- clean issue, return and adjustment history before forecasting demand;
- measure replenishment lead time and its variability;
- separate cycle stock from safety stock;
- calculate a reorder point using approved local inputs;
- choose reorder-point, min/max or periodic-review logic;
- segment inventory by criticality, value and supply risk;
- control dates, condition, rotation, traceability and obsolete stock;
- investigate stock-record differences; and
- manage stockouts without bypassing product approval.

1. Define the inventory objective

The objective is not maximum stock or minimum stock. It is reliable availability of the correct approved product in usable condition at a controlled total cost.

Balance five questions:

- What production or maintenance activity does the item support?
- What happens if it is unavailable?
- How predictable are demand and replenishment?
- How long can the product remain fit for use under its specified conditions?
- What cash, space, handling and obsolescence exposure does stock create?

ISO 55001:2024 frames asset decisions around performance, risk and expenditure. Apply the same disciplined balance to abrasive inventory without treating consumables as permanent assets. [S337]

2. Assign clear ownership

Role	Planning responsibility
Item/application owner	Confirms approved identity, use and criticality
Planning or purchasing	Maintains lead time, order policy and open-order visibility
Stores	Controls receipt, location, status, condition, issue and return
Production/maintenance	Records genuine consumption and upcoming demand changes
QA/QC or technical owner	Controls quarantine, release, substitution and disposition
Finance/management	Reviews working capital, write-off and policy trade-offs

One owner should coordinate parameter changes so demand, ordering and store records do not drift apart.

3. Build a controlled item master

Every stocked identity needs a unique, understandable record.

Include, as applicable:

- internal item code and controlled description;
- manufacturer and product name/code;
- abrasive family and physical form;
- dimensions, bore, thread, shank or attachment;
- grade or grading-system designation;
- pack and base unit of measure;
- approved applications or specification reference;
- storage, date or condition-control fields;
- approved supplier and replenishment route;
- status—active, restricted, superseded or obsolete; and
- alternative-product relationship where formally approved.

Do not merge two products merely because their common description is similar. Keep P-grade, F-grade, superabrasive and proprietary designations within their correct systems. [S342; S346; S347; S348; S349]

4. Keep units of measure consistent

Abrasives may be bought by carton, box, roll, belt, disc, wheel, sheet, kilogram or piece and issued in another unit. Define conversion factors explicitly and control changes in pack size.

Field	Example of required control
Purchase unit	Supplier pack identity
Stock unit	Unit counted in the store
Issue unit	Unit issued to the user
Conversion	Exact controlled relationship between units
Rounding rule	Treatment of partial packs where permitted

A wrong pack conversion can create a false surplus or stockout even when every physical count is correct.

5. Distinguish inventory quantities

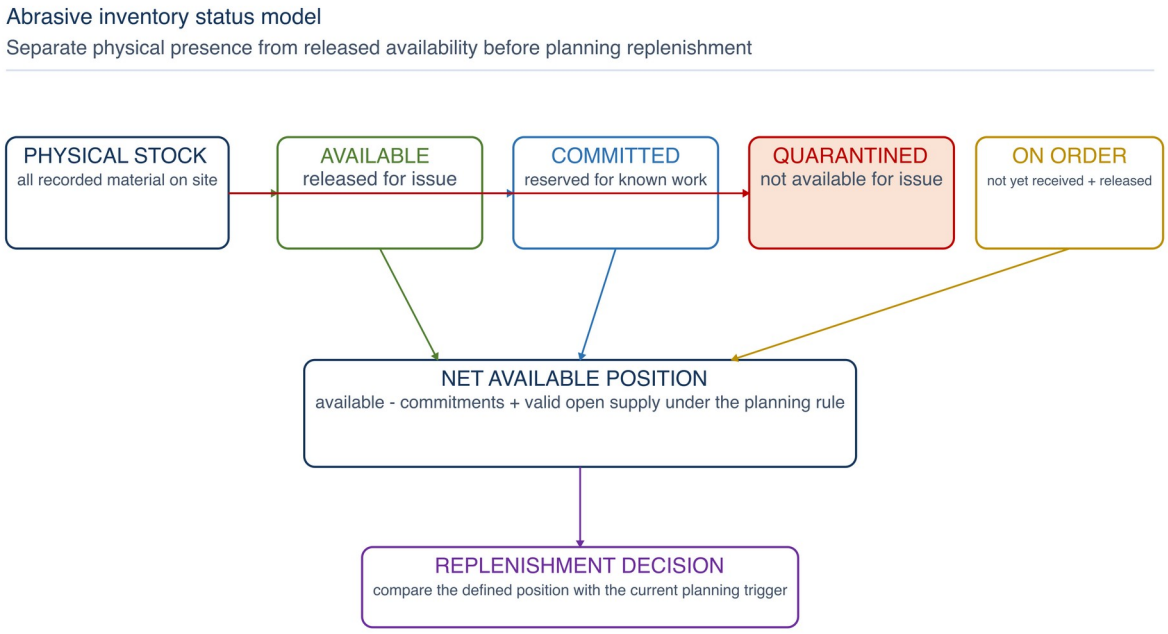

Figure 1. Abrasive inventory status model. Physical stock is separated into available, committed, quarantined and other controlled statuses before open orders are considered.

Use clear definitions:

- **Physical quantity:** material present at recorded locations.
- **Available quantity:** released material that can be issued.
- **Committed quantity:** available material reserved for known work.
- **Quarantined quantity:** material not permitted for normal issue.
- **On-order quantity:** confirmed replenishment not yet received and released.
- **Net available position:** usable supply after commitments, considering only valid open orders under the organisation's planning rule.

Never count damaged, expired where applicable, unidentified or quarantined product as available.

6. Create reliable demand history

ASCM describes inventory management as tracking stock movement while balancing supply and demand. [S361] For abrasive planning, use actual issue and return records rather than purchase history alone.

Clean the history for:

- duplicate or delayed transactions;
- pack/unit conversion errors;
- returns posted as new receipts;
- transfers between locations counted as consumption;
- one-time shutdown, project or trial demand;
- stock adjustments masking unrecorded issues;
- product-code changes or supersession; and
- abnormal demand caused by process problems.

Separate recurring, intermittent, seasonal, project and emergency demand. A simple average can be misleading when demand contains long zero periods or large planned shutdown requirements.

7. Measure replenishment lead time

Lead time should reflect the complete replenishment route, not only the supplier's quoted production time.

Measure relevant components:

- internal request and approval;
- purchase-order processing;
- supplier confirmation and manufacture/picking;
- transport and customs where applicable;
- receiving, inspection and release; and
- movement to the usable store location.

Record actual elapsed times and reasons for exceptional delays. Use a planning lead time that reflects the controlled process and known variability rather than an optimistic single quotation.

8. Separate cycle stock and safety stock

Cycle stock supports expected demand between replenishments. Safety stock protects against uncertainty such as demand variation, forecast error or lead-time variation.

ASCM describes safety stock as inventory carried to reduce stockout exposure arising from uncertainty and notes that policies can differ by strategic importance or other relevant groupings. [S362]

Do not use safety stock to hide:

- inaccurate records;
- late purchasing action;
- uncontrolled consumption;
- unreliable suppliers without improvement action;
- obsolete specifications; or
- recurring process waste.

More buffer may reduce stockout frequency but increases cash, space, condition and obsolescence exposure.

9. Calculate a reorder point

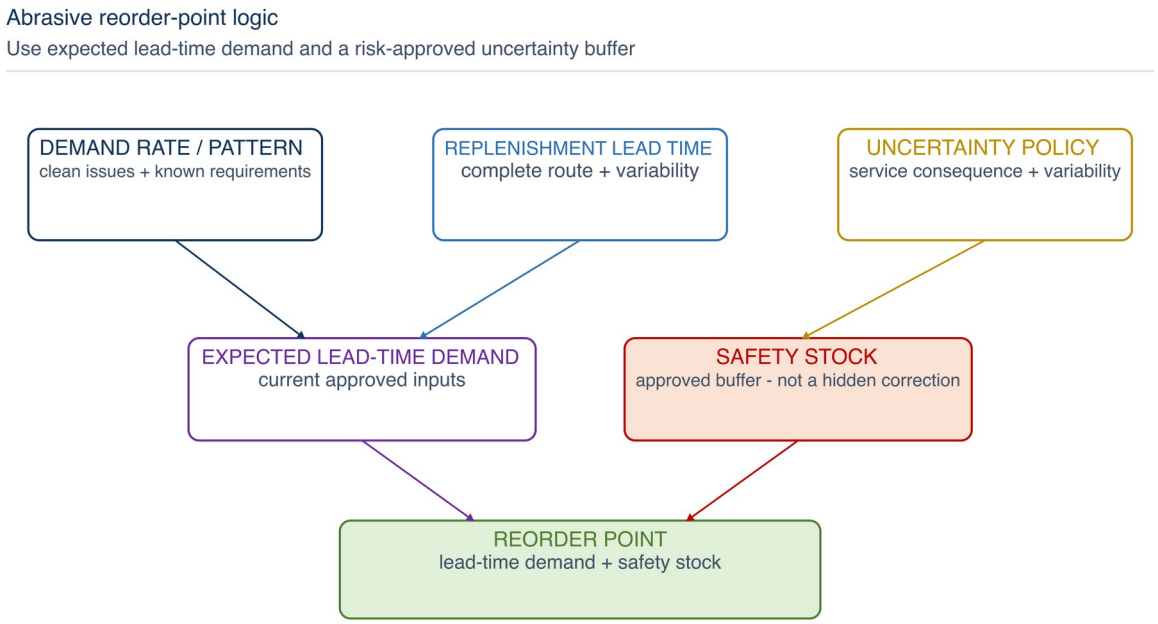

Figure 2. Reorder point logic. The inventory position is compared with expected demand during replenishment lead time plus an approved uncertainty buffer.

Use the general relationship:

Reorder point = expected demand during replenishment lead time + safety stock

For a continuous-review item, trigger replenishment when the defined inventory position reaches or falls below the reorder point. The inventory-position definition should account consistently for available stock, commitments, open orders and backorders where applicable.

Inputs must come from current records and the organisation's approved service/risk policy. Do not insert a universal service level, statistical factor or number of days of cover.

10. Choose an ordering method

Method	Suitable pattern	Main control
Reorder point	Continuous visibility and reasonably stable replenishment	Accurate inventory position and lead-time demand
Min/max	Practical store replenishment within defined bounds	Reviewed minimum, maximum and order-up-to logic
Periodic review	Orders reviewed on a fixed calendar	Include demand across review interval and lead time
Planned requirement	Shutdown, project or known production schedule	Link quantity and date to the controlled work plan
Two-bin/visual signal	Stable low-complexity point-of-use consumption	Clear bin quantity, replenishment ownership and no mixed identity

The same method need not apply to every item. Use the simplest method that reliably controls the actual demand and supply pattern.

11. Determine order quantity

Order quantity should consider expected demand, target position, pack size, minimum order where applicable, storage capacity, product condition, cash exposure and transport economics.

Do not increase quantity only to obtain a lower unit price without checking the total exposure. A price saving can be lost through damage, ageing, changed demand or specification obsolescence.

12. Segment by criticality and value

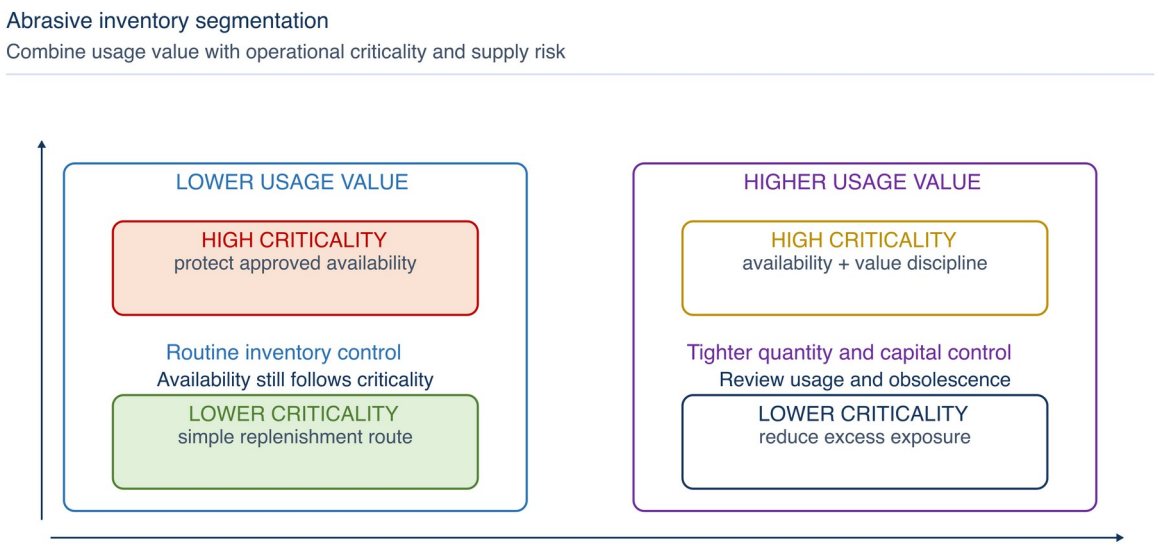

Figure 3. Inventory segmentation matrix. Usage value and operational criticality are considered together so a low-cost but production-critical abrasive receives appropriate control.

Evaluate at least:

- consumption value;
- production, maintenance or safety consequence of stockout;
- replenishment time and variability;
- availability of an already approved alternative;
- product condition or date sensitivity;
- demand predictability; and
- supplier or logistics concentration.

ABC value analysis alone is insufficient. A low-value wheel or belt can stop a critical maintenance job or production line.

13. Control storage condition and rotation

Store abrasives by product family and manufacturer guidance. Protect them from moisture, temperature extremes, deformation, impact, contamination and unauthorised mixing as applicable. Manufacturer and FEPA guidance support careful receipt, suitable support, dry controlled storage, original packaging and stock rotation. [S338; S339; S340; S341]

Use FIFO where receipt sequence governs. Use FEFO where a controlled use-by, expiry or shelf-life date makes earliest expiry the correct issue priority.

For exact storage conditions, shelf life, date interpretation or packaging requirements, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

14. Maintain location and traceability

GS1's Global Traceability Standard distinguishes class-, batch/lot- and instance-level identification and links traceable objects with receipt, shipment, location and status events. [S363]

Choose a traceability level proportionate to product and application risk. Record:

- item identity;
- batch/lot, date or serial information where applicable;
- receipt source and date;
- storage location and status;
- quantity movements; and
- affected destination where needed for controlled recall or investigation.

Do not mix approved, evaluation, returned, quarantined or rejected material in one unlabeled location.

15. Count stock and investigate differences

Use cycle counting or periodic physical inventory according to item criticality and record risk. Count by controlled item, unit, location and status.

When a difference occurs:

1132. secure the affected identity and location;
1133. recount independently where appropriate;
1134. check recent receipts, issues, returns, transfers and conversions;
1135. examine mixed stock, wrong locations and unposted transactions;
1136. correct the record through authorised adjustment; and
1137. address the cause if the difference can recur.

An adjustment restores the balance; it does not by itself correct the process.

16. Control slow-moving and obsolete stock

Review stock with no recent demand, excess cover, superseded identity, damaged packaging or approaching controlled date limits.

Classify it as active slow-moving, project-reserved, excess, restricted, obsolete or pending technical disposition. Before transfer to another application, confirm that the product is approved and suitable for that application. Do not relabel or use obsolete stock merely to avoid a write-off.

17. Manage stockouts safely

Stockout response	Required control
Expedite approved identity	Confirm supplier, product, quantity and delivery status
Transfer between sites	Preserve identity, condition, approval and traceability
Use another approved product	Confirm the approval covers the actual application and machine
Propose a new alternative	Apply Chapter 059 before production release
Reschedule work	Communicate production and customer consequence
Stop work	Use when no safe, approved and suitable route is available

Urgency does not validate a similar-looking product, grit number or mounting arrangement.

18. Plan for disruption and continuity

ISO 22301:2019 provides a business-continuity management framework for preparing for, responding to and recovering from disruption. [S364]

For critical abrasives, consider:

- alternate approved suppliers or products;
- supplier and logistics concentration;
- early-warning and escalation contacts;
- protected stock for defined critical work;
- planned shutdown and seasonal demand;
- recovery priorities; and
- controlled reversion after emergency arrangements.

Contingency stock is not a substitute for supplier improvement, accurate records or approved alternatives.

19. Review planning parameters

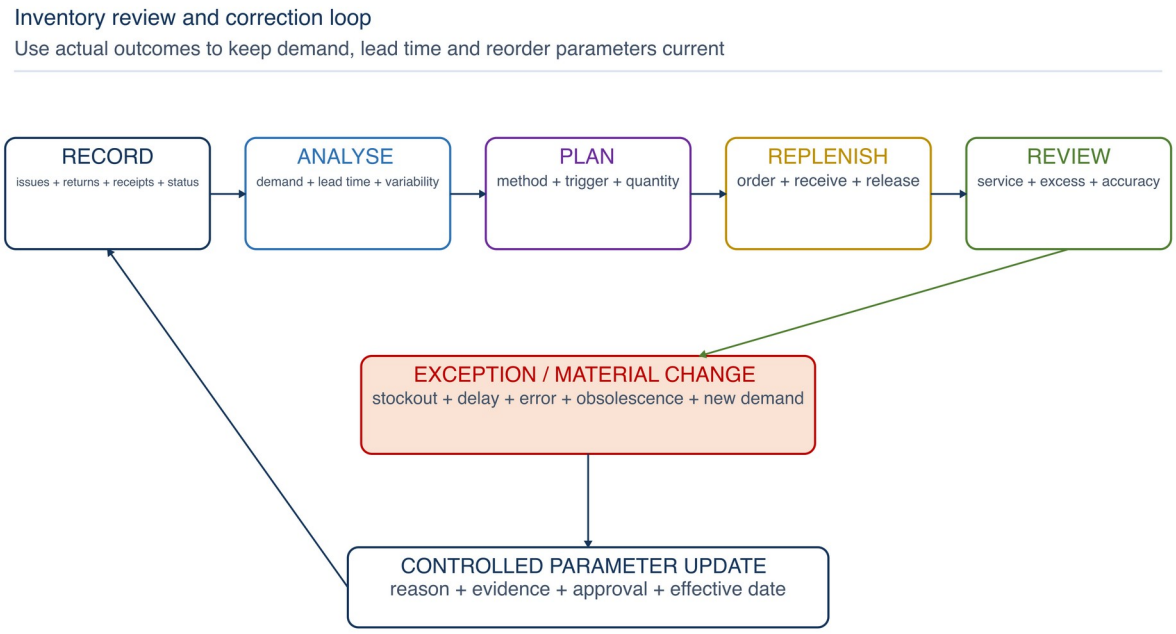

Figure 4. Inventory review and correction loop. Demand, lead time, stock accuracy, condition and service outcomes feed periodic review of planning parameters and corrective action.

Review parameters when:

- demand level or pattern changes;
- lead time or supplier route changes;
- stockouts, expedites or excess stock recur;
- record accuracy deteriorates;
- pack size or unit conversion changes;
- a product is approved, superseded or withdrawn;
- shelf-life or storage information changes; or
- a new process, machine or contract changes criticality.

Keep the reason, approver, effective date and previous value so planning changes remain auditable.

20. Troubleshooting inventory and reorder planning

Problem	Likely cause	Improvement
System shows stock but none is usable	Quarantine, condition or commitment excluded poorly	Separate status and calculate available quantity correctly
Frequent stockouts despite high stock	Wrong identities or demand concentrated in another item	Review item master, usage and substitution controls
Reorder occurs too late	Lead time omits internal or receiving stages	Measure the complete replenishment route
Excess stock grows	Parameters ignore falling demand or pack constraints	Review demand, order quantity and active status
Count differences repeat	Transactions or unit conversions are uncontrolled	Correct the process, not only the balance
Old stock remains while new stock is issued	Rotation and location discipline are weak	Use FIFO/FEFO and visible date control
Emergency substitution occurs	Continuity plan lacks approved alternatives	Approve alternatives before disruption
Average demand misleads planning	Demand is intermittent or project-driven	Segment history and plan known requirements separately
Safety stock increases continuously	Buffer hides process problems	Separate variability protection from corrective action

Inventory and reorder checklist

Before releasing or revising a replenishment policy, confirm that:

- the item identity, unit and approval status are controlled;
- physical, available, committed, quarantined and on-order quantities are distinct;
- demand history excludes transfers, errors and exceptional events appropriately;
- complete replenishment lead time and variability are understood;
- cycle stock and safety stock serve different purposes;
- the reorder formula uses current approved inputs;
- order method and quantity suit the demand pattern and pack constraints;
- criticality, value, condition and supply risk are considered together;
- storage, rotation, dates and traceability protect product fitness;
- count differences are investigated and causes corrected;
- slow-moving and obsolete stock have controlled status;
- stockout routes preserve product approval; and
- parameters are reviewed after material change or recurring exception.

Concise safety reminders

- Never issue quarantined, damaged, unidentified or unapproved abrasive stock.
- Keep product identity and condition visible through receipt, storage, transfer and issue.
- Do not use a stockout to justify uncontrolled substitution.
- Preserve guards, mounting systems, accessories and machine/product compatibility.
- Apply the storage and handling instructions for the actual product family.

- **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 061

Why Unit Price Is Not Total Cost

61

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, engineers, supervisors, buyers, estimators, cost accountants, QA/QC personnel, maintenance teams and industrial abrasive users

Scope: Purchase price; landed cost; consumable use; labour and machine time; changeover; inspection; rework; scrap; downstream effects; energy; waste; risk; comparison boundaries; accepted output; sensitivity and decision control.

Core principle — The lowest-priced abrasive is not automatically the lowest-cost choice. Compare safe, technically acceptable options on the same process boundary and per unit of accepted output.

An abrasive is a relatively small purchased item that can influence a much larger manufacturing cost. Product life, stock-removal rate, finish consistency, operator effort, change frequency, rework and downstream preparation may outweigh a difference in unit price. A useful cost comparison therefore follows the complete operation from product receipt to accepted work.

Use current quotations, actual shop-floor observations and organisation-approved cost rates. Keep every candidate within its marked limits, intended use and approved machine arrangement. When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- distinguish unit price, landed cost, use cost and total process cost;
- define a fair comparison boundary and output unit;
- identify direct and indirect cost drivers;
- capture labour, machine, changeover and inspection time;
- include rework, scrap and downstream consequences;
- avoid double counting and false precision;
- compare products with different pack sizes and useful lives;
- apply safety and technical acceptance as decision gates; and
- prepare reliable inputs for cost per accepted component.

1. Start with the decision

State the question before collecting numbers. Typical decisions include:

- selecting between technically suitable abrasive products;
- reviewing an existing grinding or finishing sequence;
- deciding whether a higher-priced product reduces overall process cost;
- comparing a single product with a multi-step system; or
- evaluating a change in pack size, attachment or point-of-use method.

Keep the decision narrow enough to measure. “Reduce grinding cost” is vague. “Compare two approved fibre-disc systems for removing the same weld condition to the same accepted finish” creates a usable boundary.

2. Separate four levels of cost

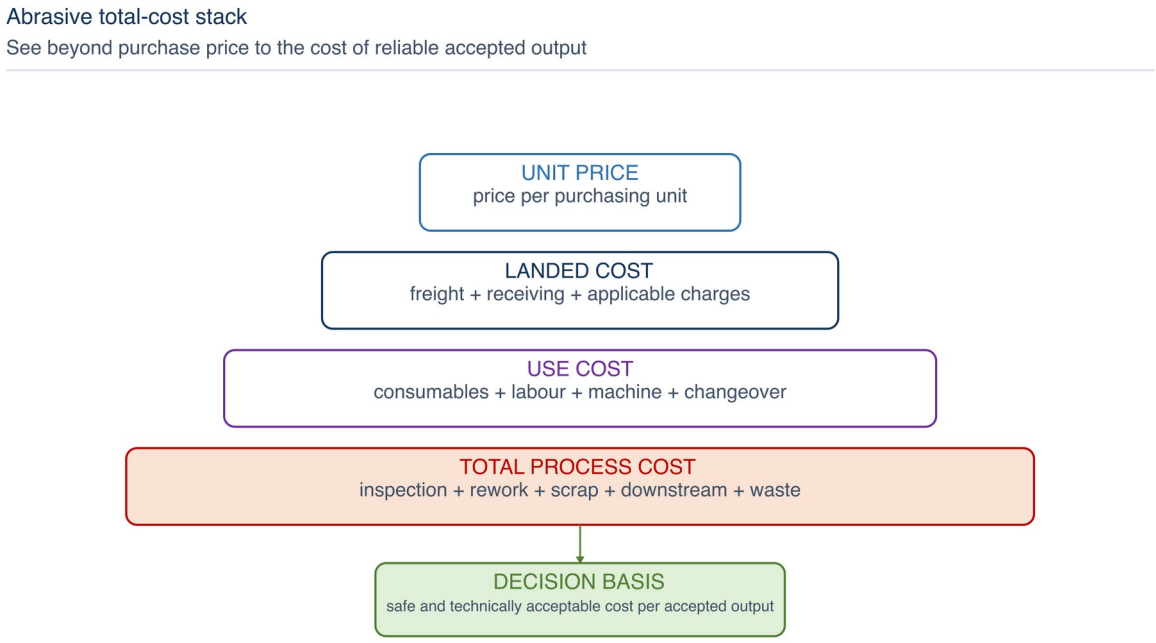


Figure 1. Abrasive total-cost stack. Unit price is only the first layer; delivery, use, quality and disruption costs can change the final decision.

Cost level	Typical content	Main question
Unit price	Price per disc, belt, wheel, sheet, roll or pack	What is paid for one purchasing unit?
Landed cost	Unit price plus freight, duties, taxes where applicable and receiving cost	What does usable stock cost at the store?
Use cost	Landed consumable cost plus accessories, labour, machine and changeover inputs	What does the operation consume?
Total process cost	Use cost plus inspection, rework, scrap, downstream correction, waste and disruption effects	What does accepted output cost?

ASCM distinguishes per-unit cost, total landed cost and total cost of ownership when evaluating value. [S370] For abrasives, the practical focus is the controlled production process rather than ownership of a long-life asset.

3. Define the comparison boundary

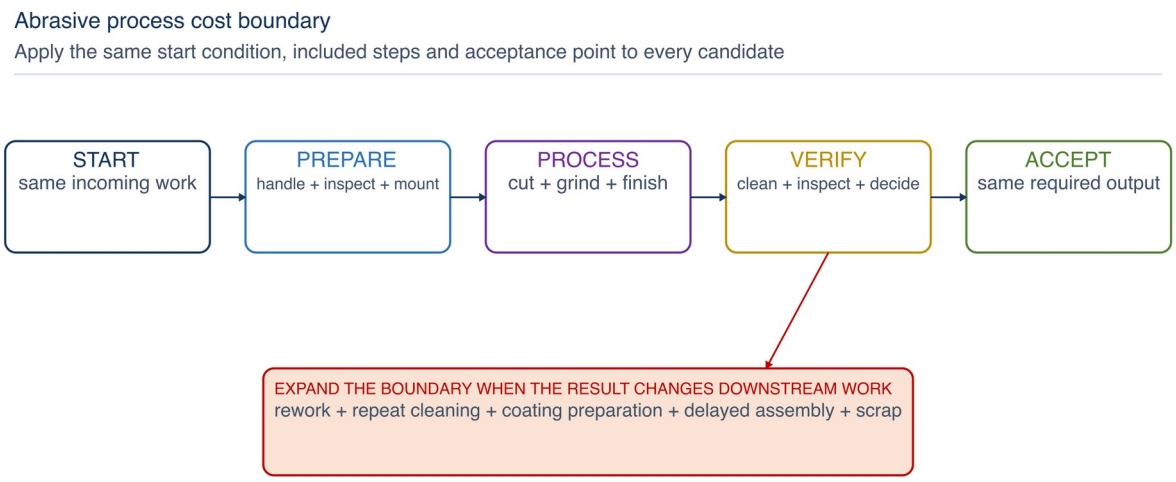


Figure 2. Process cost boundary. The same start condition, operation sequence and acceptance point are used for every candidate.

Define:

- the incoming workpiece condition;
- the first activity included;
- every grinding, cutting, blending, cleaning or inspection step included;
- the final acceptance requirement;
- the point at which time and cost stop;
- the production quantity or observation period; and
- any downstream process affected by the abrasive result.

A narrow boundary may conceal transferred cost. A faster grinding step is not a saving if it creates additional blending, cleaning, coating preparation or inspection. Expand the boundary far enough to capture material differences between candidates.

4. Choose an accepted-output unit

Select a denominator that represents useful production:

- accepted component;
- accepted metre of weld;
- accepted cut;
- accepted square metre of prepared surface;
- accepted edge or feature; or
- another clearly defined unit.

Avoid “cost per disc” as the main performance measure. It describes purchasing or consumption but not useful output. Chapter 062 develops the full cost-per-accepted-component calculation.

5. Establish technical and safety gates

Cost comparison begins only after each candidate is suitable for the actual product, machine, accessory, workpiece and operation. Confirm product identity, dimensions, mounting, intended use, guard arrangement, speed compatibility, workpiece material, process requirement and applicable controls. [S350; S351; S352]

Reject or contain a candidate when it:

- cannot be positively identified;
- is damaged or unsuitable for use;
- does not match the machine or accessory arrangement;
- cannot meet the required result;
- introduces an unacceptable safety, contamination or quality risk; or
- requires operation outside controlled instructions.

A low calculated cost never overrides a safety or technical rejection.

6. Calculate comparable consumable cost

Convert every quotation to the same base:

Landed cost per usable abrasive = landed pack cost ÷ usable quantity in the pack

Then capture actual consumption within the defined boundary:

Abrasive cost for the comparison = landed cost per usable abrasive × quantity consumed

Include partial products only when their remaining useful quantity can be identified and used safely. Do not treat a discarded remnant as productive consumption.

7. Include supporting consumables and accessories

The abrasive may require:

- backing pads, contact wheels, flanges, adaptors or mandrels;
- dressing or truing tools;
- compounds, lubricants, coolant or cleaning materials;
- masking and protection materials;
- filters, extraction consumables or collection bags; and
- inspection consumables.

Allocate reusable accessory cost over an approved and observable basis. Replaceable backing pads or contact elements can materially affect both cost and result. Do not assume unlimited accessory life.

8. Measure productive labour

Labour time includes more than abrasive contact time. Observe:

- workpiece handling and positioning;
- product selection and inspection;
- mounting and adjustment;
- grinding, cutting or finishing;
- intermediate checking;
- cleaning between steps;
- product change;
- final inspection and handling; and
- permitted recovery or rest associated with the task method.

Use the organisation's approved labour-cost basis. Apply the same rate definition and time boundary to every candidate.

9. Capture machine and work-area time

Machine or workstation cost may include depreciation or lease, maintenance, utilities, extraction, floor space and controlled overhead according to the organisation's costing method.

Use:

Machine-time cost = measured included time × approved machine or workstation rate

Keep productive time, planned changeover and unplanned delay visible as separate fields. A single blended number can hide why one option performs differently.

10. Count changeover and preparation

Changing a disc, belt, wheel or compound can stop productive work and require isolation, inspection, cleaning, adjustment or a first-piece check. Capture:

- planned product changes;
- premature changes caused by loading, damage or loss of cut;
- tool or accessory changes between steps;
- dressing, conditioning or cleaning;
- reset and first-piece verification; and
- safe disposal or return of the removed product.

Compare a longer-lasting product against the full avoided change activity, not only the number of abrasives used.

11. Include inspection and appraisal

Inspection is part of process cost when it is necessary to confirm conformity. Depending on the work, this can include dimensional checks, visual standards, surface-texture measurement, cleanliness, edge condition, coating-readiness checks or documented release. [S343; S344; S345]

ASQ classifies measurement and monitoring activities as appraisal costs. It distinguishes these from prevention and failure costs. [S365] Record extra inspection caused by unstable output separately from routine required inspection.

12. Make rework and scrap visible

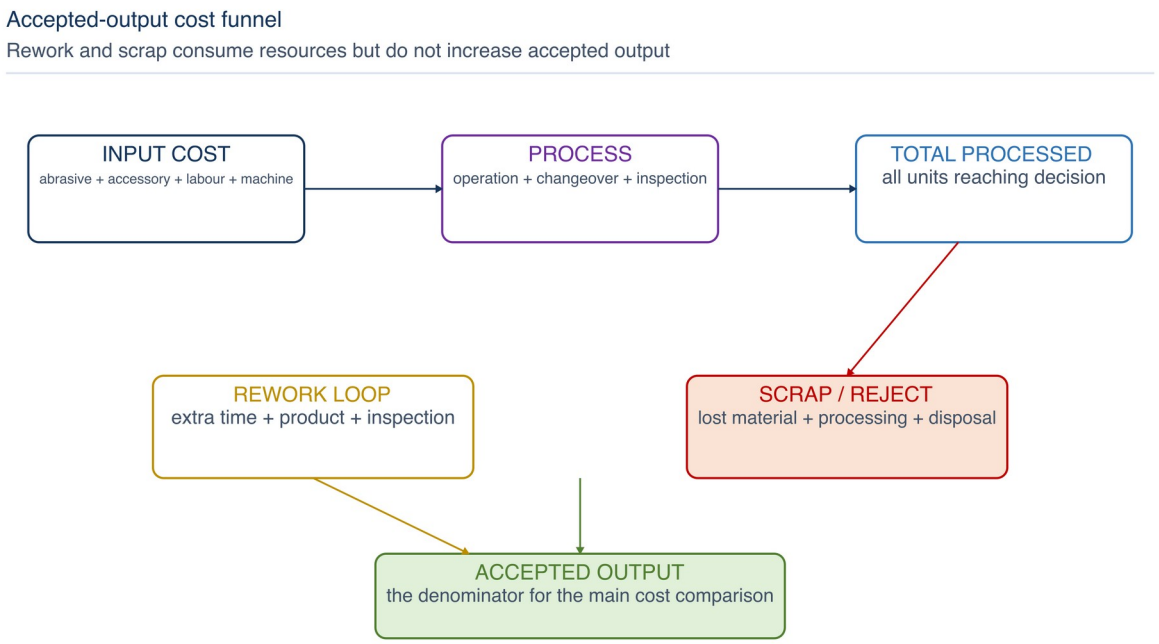


Figure 3. Accepted-output cost funnel. All input and processing effort passes through inspection; rework and scrap reduce the accepted output that carries the cost.

Internal failure cost can include:

- repeated grinding or blending;
- correction of scratches, gouges, geometry loss or heat effect;
- replacement material;
- repeated cleaning or coating preparation;
- extra inspection and handling;
- scrap and disposal; and
- investigation and production interruption.

ASQ identifies rework and scrap as internal failure costs. [S365] Allocate rework labour, machine time, consumables and any replacement material only once.

13. Consider downstream consequences

The abrasive result may affect welding, coating, assembly, sealing, dimensional fit, corrosion performance or visual acceptance. Record a downstream cost only when the link is technically credible and the boundary includes it.

Examples include:

- an additional blending step;
- repeat cleaning before coating;
- coating defects linked to surface preparation;
- dimensional correction after excessive stock removal;
- delayed assembly due to rejected finish; or
- special segregation or cleaning for contamination control.

Do not assign a monetary consequence from assumption alone. Use confirmed events and approved costing rules.

14. Track material, energy and waste

ISO 14051 describes tracing material flows in physical units and evaluating the costs associated with those flows. [S369] Apply this principle to abrasive consumption, removed material where relevant, scrap components, packaging, collection media and waste handling.

Energy can be included when the measurement basis is consistent and material to the decision. Avoid false precision from estimated tool power multiplied by elapsed time when actual load, duty cycle and system efficiency are unknown.

15. Use cost-of-quality categories carefully

Category	Abrasive-process examples	Control against double counting
Prevention	Procedure development, training, product approval, fixture improvement	Treat as a defined improvement investment
Appraisal	Incoming checks, in-process measurement, final inspection	Separate routine inspection from extra checks
Internal failure	Rework, scrap, repeated cleaning, failure analysis	Include before customer release
External failure	Return, complaint handling, field correction, replacement	Include only confirmed attributable events

Cost-of-quality analysis helps reveal where resources prevent, detect or correct poor quality. [S365] It should guide improvement, not encourage removal of necessary prevention or inspection.

16. Build a controlled cost model

Use a transparent relationship:

Total included process cost = abrasive + supporting consumables + labour + machine/workstation + changeover + inspection + rework + scrap + downstream + waste/disposal + other agreed costs

Label every input with:

- definition and unit;
- source;
- observation period;
- owner;
- inclusion rule;
- allocation method where shared; and
- revision date.

ISO 10014 links financial and economic improvement to monitored performance metrics and action based on observed results. [S366] ISO 22400 provides an industry-neutral framework for defining and using manufacturing KPIs. [S367; S368]

17. Compare candidates fairly

Control	Fair comparison	Weak comparison
Workpiece	Same material, geometry and initial condition	Mixed jobs or unknown condition
Requirement	Same measurable acceptance point	“Looks better” without a reference
Machine	Same suitable machine class and controlled setup	Different power, support or maintenance state
Method	Trained operators and defined sequence	Uncontrolled technique changes
Product use	Defined change-out rule and complete identity	Run one product longer to favour it
Time	Same start/stop rules	Contact time for one option, elapsed time for another
Output	Accepted units	Total processed units including rejects
Cost rates	Same approved basis and date	Mixed quotation dates or accounting bases

Where learning effects are likely, stabilise the method before drawing a commercial conclusion.

18. Test sensitivity and uncertainty

Cost inputs vary. Product consumption, cycle time, rework and demand may not be constant. Show a reasonable range using observed low, typical and high cases or another approved method.

Ask:

- Does the ranking change when labour time varies?
- Does it depend on one unusual reject?
- Is a longer-life result repeatable?
- Would a price or pack-size change reverse the decision?
- Is the apparent saving larger than the uncertainty in the data?

Avoid presenting more decimal places than the input quality supports.

19. Read the result with risk and capacity

The lowest calculated total cost is important, but it is not the only decision factor. Review:

- technical conformity and finish stability;
- safety and ergonomics;
- process capability and repeatability;
- available production capacity;
- change-management effort;
- inventory and continuity implications; and
- confidence in the data.

ISO 55001 frames decisions around performance, risk and expenditure. [S337] A modest cost difference may not justify a large operational risk, while a higher unit price may be justified by reliable accepted output or released capacity.

20. Review and improve

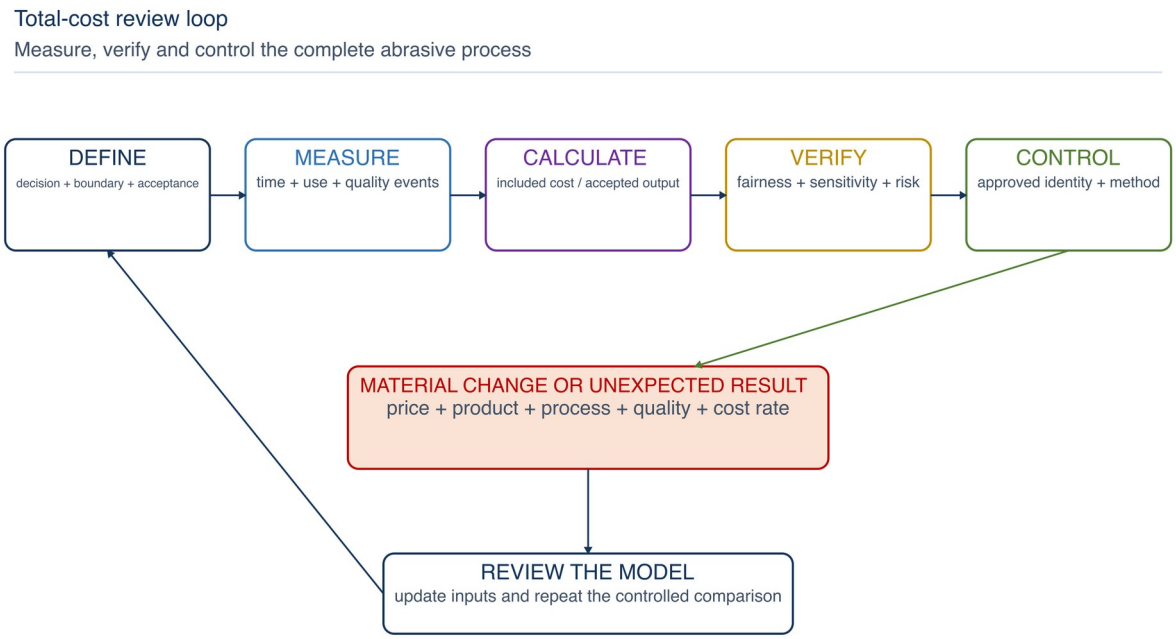


Figure 4. Total-cost review loop. Define the boundary, measure the process, calculate accepted-output cost, verify the result and control the selected method.

Repeat the review when product identity, price, pack size, process sequence, workpiece, machine, acceptance requirement, cost rate or demand pattern changes materially.

Keep the selected method controlled through:

- approved product identity;
- current work instruction;
- operator competence;
- consistent change-out criteria;
- defined inspection;
- consumption and time records; and
- periodic review of actual cost drivers.

Practical decision checklist

Before accepting a total-cost comparison, confirm:

- all candidates passed technical and safety gates;
- the same start and acceptance points were used;
- quotations and pack conversions are current;
- all major consumables and accessories are included;
- labour, machine and changeover time use the same definitions;
- accepted output—not total processed quantity—is the main denominator;
- rework, scrap and downstream correction are visible;
- shared costs use a stated allocation basis;
- no cost is counted twice;
- variability and exceptional events are explained; and
- the conclusion remains valid across a reasonable sensitivity range.

Troubleshooting

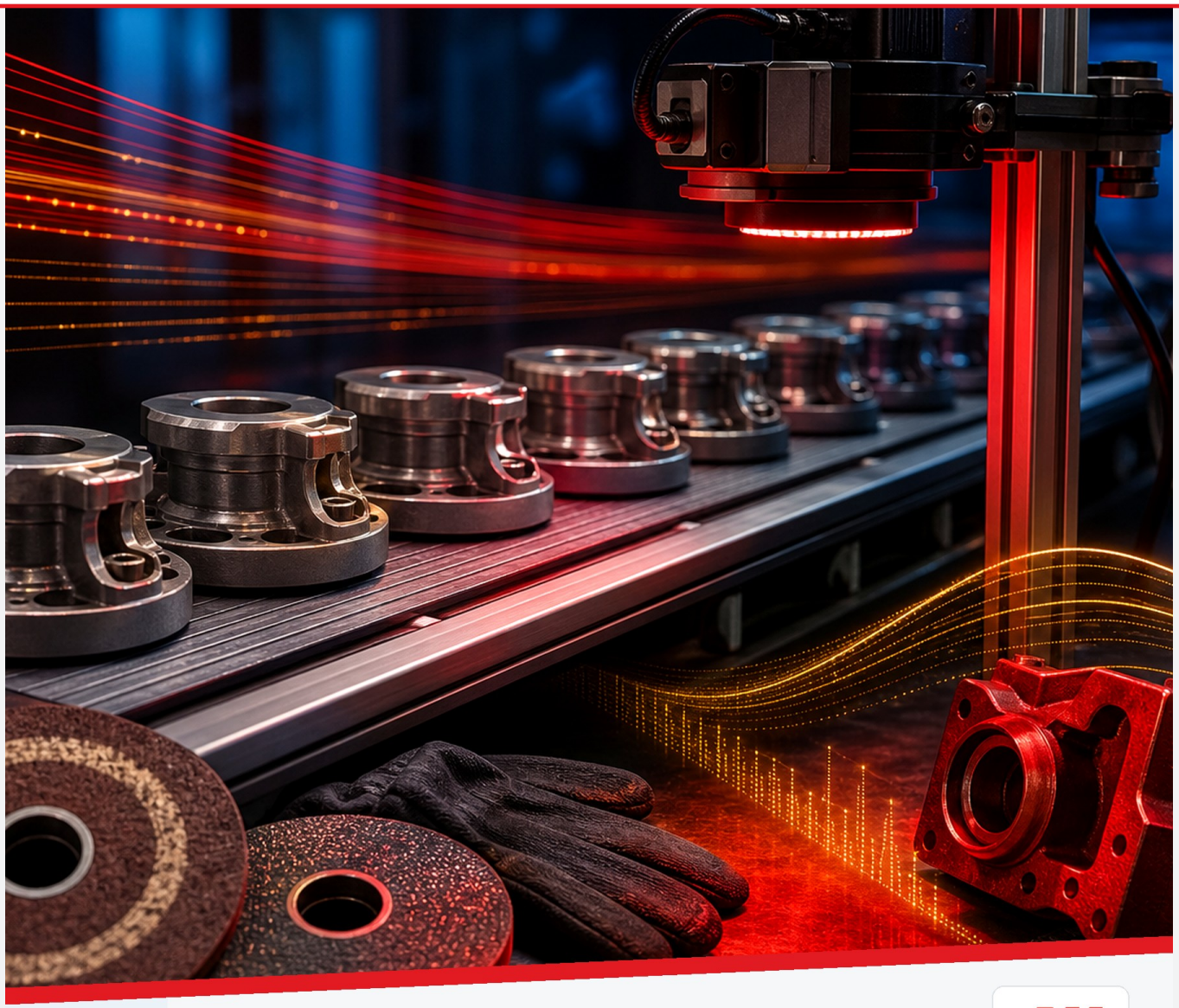
Problem	Likely cause	Improvement
Lowest unit price gives highest process cost	High consumption, slow work or frequent changes	Expand the comparison to complete use cost
Candidate appears fast but rework rises	Acceptance point or technique is uncontrolled	Reinstate the same measurable quality gate
Cost per part changes sharply between shifts	Mixed work, operator method or change-out rule	Stratify data and standardise the method
Consumable cost looks unrealistically low	Pack conversion, partial use or scrap product omitted	Reconcile receipt, issue and actual consumption
Labour saving cannot be reproduced	Timing boundary or learning effect differs	Use common start/stop rules and repeat observations
Machine-cost result dominates everything	Rate includes costs outside the decision boundary	Review the approved allocation basis
Rework is counted twice	Failure cost also remains inside blended overhead	Map every cost once to the model
Energy estimate shows false precision	Nameplate power used as actual load	Measure consistently or treat as a sensitivity item
Saving depends on one exceptional job	Sample is unrepresentative	Extend observation across normal variation
Cheaper option fails safety or compatibility review	Cost was considered before technical acceptance	Apply the safety and suitability gate first

Safety reminder

Cost reduction must never depend on operating beyond a product limit, defeating a guard, extending use after damage, using an unsuitable accessory, reducing required extraction or inspection, or accepting uncontrolled rework. Follow the product marking, machine instructions, workplace risk controls and applicable Malaysian requirements.

Key takeaways

- Unit price is only the first layer of abrasive process cost.
- Define the same process boundary and accepted-output unit for every candidate.
- Include consumables, labour, machine time, changeover, inspection, rework, scrap and downstream effects where material.
- Use actual observations and approved cost rates.
- Keep technical suitability and safety as gates.
- Show uncertainty and avoid double counting.
- Select and control the option that delivers reliable accepted output at the best total process value.



SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 062

Calculating Cost per Accepted Component

62

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, engineers, supervisors, estimators, buyers, cost accountants, QA/QC personnel, continuous-improvement teams and industrial abrasive users

Scope: Accepted-component definition; batch boundary; consumable use; labour and machine time; changeover; inspection; rework; scrap; shared costs; first-pass yield; unit conversion; allocation; sensitivity; reconciliation; reporting and review.

Core principle — Divide the complete included process cost by the number of components that meet the defined acceptance requirement. Keep rework and scrap visible so the denominator cannot hide poor process performance.

Cost per accepted component turns the broad total-cost method from Chapter 061 into an auditable calculation. It answers a practical question: after all included abrasives, labour, machine time, inspection and quality losses are counted, what did each conforming component cost within the defined operation?

The calculation is only as reliable as its boundary, units and source records. Use actual shop-floor observations, current quotations and organisation-approved cost rates. When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- define an accepted component and a consistent observation boundary;
- distinguish first-pass accepted, reworked accepted and scrapped units;
- build a transparent total-cost numerator;
- build a valid accepted-output denominator;
- convert pack, time and rate units consistently;
- allocate shared and one-off costs without double counting;
- calculate first-pass yield and final cost per accepted component;
- compare technically suitable options on a like-for-like basis;
- test sensitivity to variable inputs; and
- reconcile and approve a controlled calculation.

1. Define the result before collecting cost

Describe the component, operation and acceptance requirement. Include the incoming condition, included work steps, final inspection point and the unit that counts as accepted.

Examples of scope language:

- weld removal and blending on one fabricated bracket to the controlled visual and dimensional requirement;
- cut and edge preparation of one tube section ready for the next operation; or
- surface preparation of one panel accepted for coating.

Do not mix different component families, materials or acceptance requirements in one denominator unless the costing method deliberately normalises them.

2. Classify every processed component

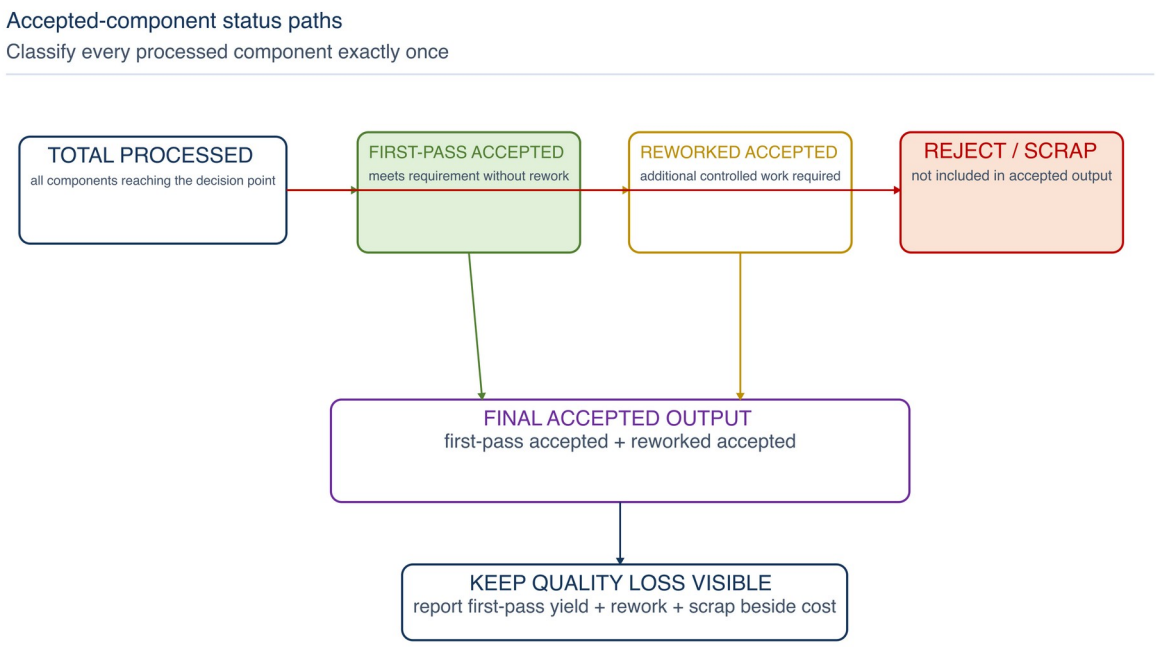

Figure 1. Accepted-component status paths. Every processed component is classified as first-pass accepted, reworked then accepted, or rejected/scrapped.

Output status	Definition	Cost treatment
First-pass accepted	Meets the requirement without rerun, repair or offline correction	Included in accepted output and first-pass yield
Reworked accepted	Meets the requirement only after additional controlled work	Included in final accepted output; rework cost remains visible
Rejected or scrapped	Does not become acceptable within the defined disposition	Excluded from accepted output; incurred cost remains in the numerator
Pending or quarantined	Decision not complete at the calculation cut-off	Exclude or carry forward consistently under the stated rule

ASQ defines first-pass yield around units that complete the process and meet quality guidelines without scrap, rerun, retest, return or offline repair. [S372]

3. Freeze the observation boundary

Record:

- start and end date/time;
- work order, batch, shift or other population identity;
- component and material identity;
- incoming condition;
- included process steps;
- machine and workstation;
- approved abrasive and accessory identity;
- operators or team basis where relevant;
- inspection method and acceptance requirement; and
- treatment of work already in progress at the cut-off.

Use the same boundary for the cost numerator and output denominator.

4. Build the numerator

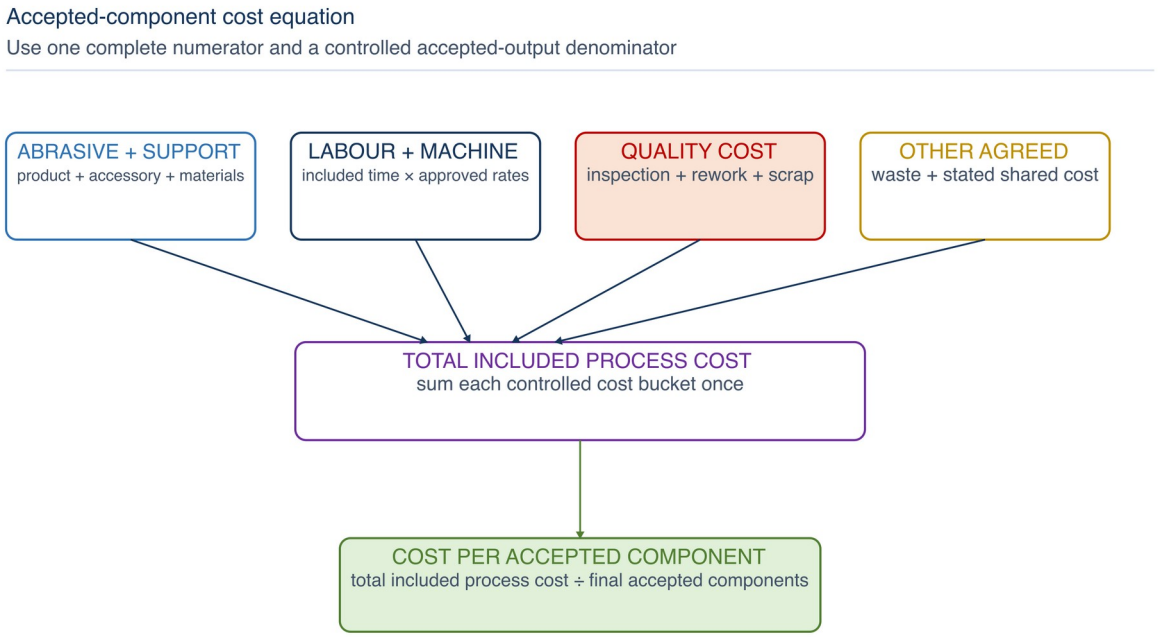

Figure 2. Accepted-component cost equation. All agreed cost buckets form the numerator, which is divided by final accepted output.

Use the general relationship:

Cost per accepted component = total included process cost ÷ final accepted components

Where:

Total included process cost = abrasive + supporting consumables + labour + machine/workstation + changeover + inspection + rework + scrap + waste/disposal + other agreed costs

Document exclusions. A short and consistent model is better than a complex model with unreliable allocations.

5. Build the denominator

Use:

Final accepted components = first-pass accepted + reworked accepted

Also retain:

Total processed = first-pass accepted + reworked accepted + rejected/scrapped + unresolved units treated under the stated cut-off rule

Never increase accepted output with units that have not passed the defined acceptance requirement.

6. Convert abrasive purchase data

Establish the base unit:

Landed cost per abrasive unit = landed pack cost ÷ usable abrasive units per pack

Then:

Abrasive cost = landed cost per abrasive unit × abrasive units consumed

For rolls, compounds or bulk media, use a controlled issue quantity such as length, mass or volume. Reconcile partial products, unused issued material and returned stock consistently. Exact pack identity and product information should remain traceable to the controlled quotation and product record.

7. Include supporting consumables

Capture items materially affected by the option:

- backing pads, contact elements, flanges or adaptors;
- dressing and conditioning tools;
- lubricant, coolant, compound or cleaner;
- masking and protection materials;
- extraction filters or collection media;
- inspection consumables; and
- packaging and waste containers where relevant.

For a reusable accessory:

Allocated accessory cost = observed accessory cost × allocation fraction used by the boundary

State whether allocation is based on uses, time, batches or another approved driver.

8. Calculate labour cost

Convert time and rate to compatible units:

Labour cost = included labour time × approved labour rate

If several people work simultaneously, use person-time rather than elapsed clock time:

Person-hours = sum of each person's included hours

Separate productive processing, preparation, changeover, inspection and rework when the distinction helps identify improvement.

9. Calculate machine or workstation cost

Use:

Machine/workstation cost = included machine or workstation time × approved rate

State whether the rate includes energy, maintenance, depreciation, extraction or overhead. Do not add the same item again as a separate cost.

Where a tool is handheld and the organisation does not apply a machine rate, record that treatment explicitly rather than inventing one.

10. Allocate changeover and preparation

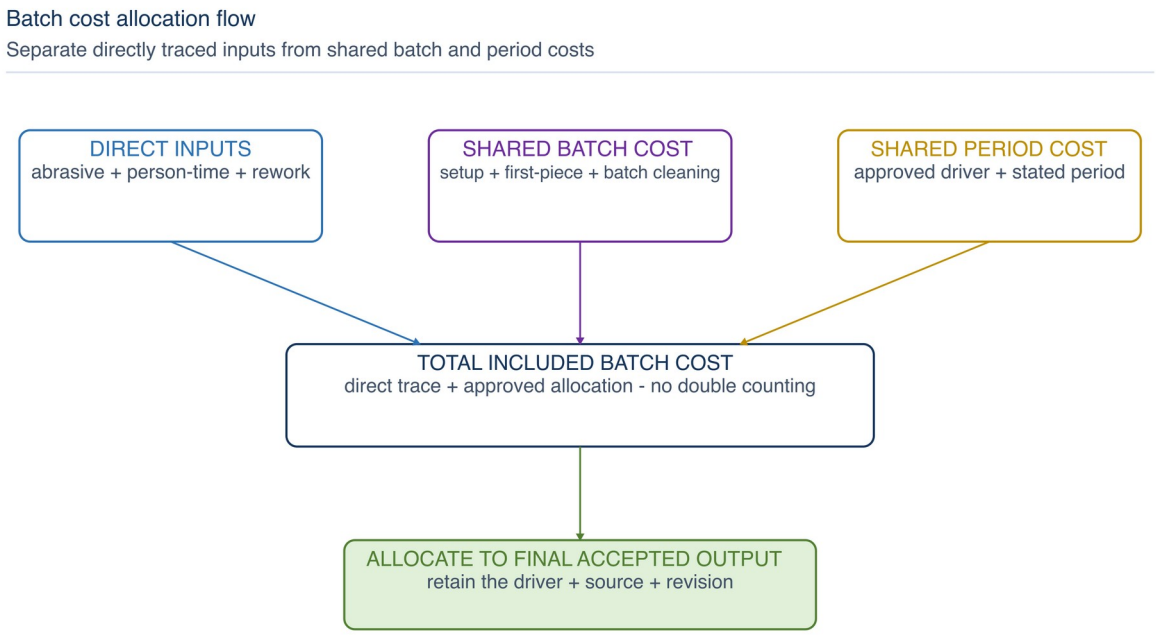

Figure 3. Batch cost allocation flow. Direct component costs and shared batch costs are separated before total cost is divided by accepted output.

Changeover can include isolation, product removal, inspection, mounting, adjustment, dressing, cleaning, reset and first-piece verification.

For a batch-level activity:

Allocated changeover cost per accepted component = total included changeover cost ÷ final accepted components in the batch

Keep abnormal changes caused by damage, loading or process instability visible as exceptions.

11. Include inspection cost

Inspection cost can include inspector labour, operator self-check time, equipment time and necessary consumables. The acceptance method must match the controlled drawing, specification or visual standard. [S343; S344; S345]

Separate:

- routine inspection required for every candidate;
- additional checks introduced by a candidate;
- repeated inspection after rework; and
- investigation or containment inspection after an abnormal result.

12. Calculate rework cost

For each reworked component, include the additional abrasive, accessory, labour, machine, cleaning and inspection cost inside the boundary.

Use:

Total rework cost = sum of all additional controlled rework inputs

Reworked accepted components remain in final accepted output but not in first-pass accepted output. This preserves the final cost calculation while making process instability visible.

13. Calculate scrap cost

Scrap cost can include:

- material value at the stated process stage;
- abrasive and supporting consumables already used;
- labour and machine time already incurred;
- inspection and disposition effort;
- replacement preparation where inside the boundary; and
- waste or recovery treatment.

Use the organisation's approved material and work-in-process valuation. Do not count the same consumed processing cost both inside the normal cost buckets and again in a fully loaded scrap value.

14. Control shared, fixed and one-off costs

Cost type	Examples	Allocation control
Direct variable	Abrasive units, operator minutes, rework materials	Trace to the observed batch or component
Shared batch	Setup, first-piece check, batch cleaning	Allocate across the stated accepted batch
Period shared	Workstation, extraction, supervision	Use the approved cost-driver and period
One-off improvement	Fixture, training, method development	Report separately or amortise on an approved basis
Sunk cost	Past expenditure unaffected by the decision	Do not use to distort the current comparison

NIST manufacturing-cost guidance supports disciplined cost categories and stated data sources. [S373] ISO 14051 similarly links physical material flows with associated costs for internal decision-making. [S369]

15. Calculate the main result

Use a calculation sheet with one row per cost bucket:

Cost bucket	Quantity	Unit	Approved rate or unit cost	Included cost	Source/owner
Abrasive	A	unit	P	A × P	Stores/purchasing
Supporting consumables	S	stated unit	Q	S × Q	Process record
Labour	L	hour	R	L × R	Time record/finance
Machine/workstation	M	hour	T	M × T	Time record/finance
Inspection	I	hour or event	U	I × U	QA/process record
Rework	—	mixed	—	Sum of rework inputs	Rework log
Scrap	—	mixed	—	Approved calculated value	NCR/cost record
Waste/other	—	stated unit	—	Approved calculated value	Disposal/other record

Sum the included-cost column, then divide by final accepted components. Retain currency, rounding rule and calculation revision.

16. Report first-pass performance beside cost

Use:

First-pass yield = first-pass accepted ÷ total processed under the defined rule

Final acceptance proportion = final accepted ÷ total processed under the defined rule

The cost figure and yield measures answer different questions. A stable cost with falling first-pass yield may indicate that rework is being absorbed or misclassified.

17. Compare candidates on the same basis

Comparison field	Candidate A	Candidate B	Control
Product identity	Controlled record	Controlled record	Complete and traceable
Workpiece/boundary	Same	Same	No mixed scope
Total processed	Observed	Observed	Same counting rule
First-pass accepted	Observed	Observed	Same acceptance gate
Reworked accepted	Observed	Observed	Same rework definition
Final accepted	Calculated	Calculated	Denominator
Total included cost	Calculated	Calculated	Same buckets and rates
Cost per accepted component	Calculated	Calculated	Decision input
Safety/technical status	Acceptable	Acceptable	Mandatory gate

Do not compare a mature process with an unstable learning run without explaining the difference.

18. Test sensitivity

Test inputs that can change the conclusion:

- abrasive consumption;
- labour or machine time;
- changeover frequency;
- first-pass acceptance;
- rework severity;
- scrap occurrence;
- quotation or pack-size change; and
- allocation period for one-off cost.

Recalculate with observed low, typical and high cases or another approved method. NIST notes the importance of avoiding double counting and examining uncertainty through sensitivity analysis in manufacturing cost work. [S374]

19. Reconcile the calculation

Before release, verify:

- opening issue plus receipts minus returns and closing balance agrees with consumption;
- recorded person-time agrees with the defined scope;
- machine and labour time units match their rates;
- processed units reconcile to all output statuses;
- final accepted output agrees with inspection records;
- rework and scrap events have not been omitted;
- shared costs use the approved driver;
- no cost appears twice;
- currency and quotation dates are consistent; and
- totals reproduce from the source rows.

Investigate material differences before using the result commercially.

20. Approve, control and review

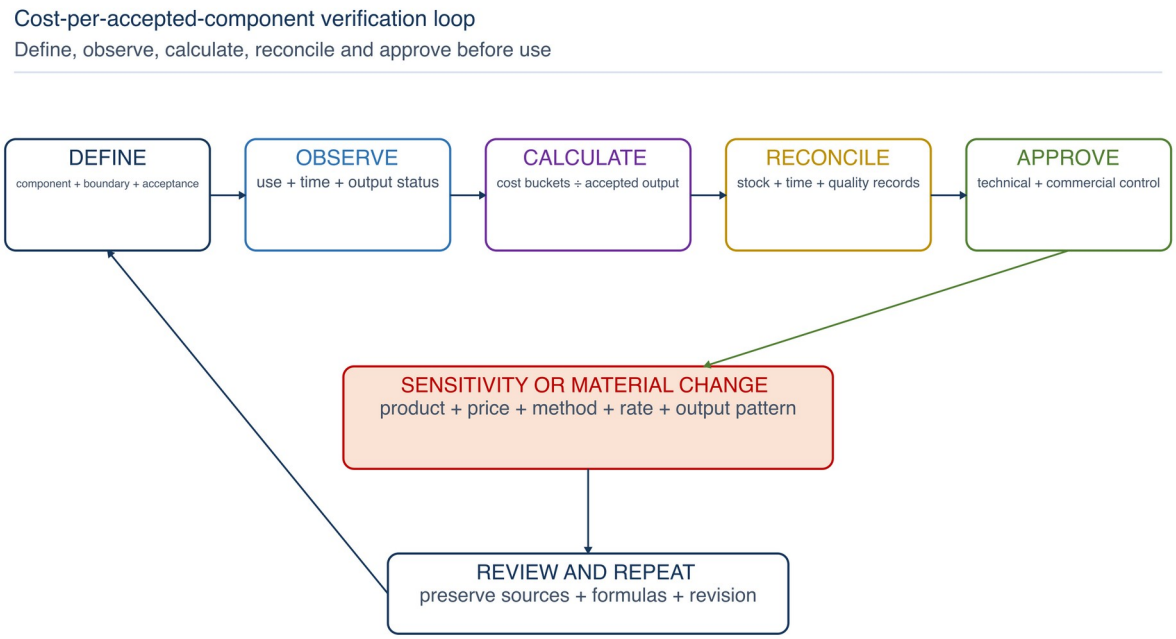

Figure 4. Cost-per-accepted-component verification loop. Define, observe, calculate, reconcile and approve the model, then review after material change.

Release the calculation with:

- title and decision;
- boundary and acceptance definition;
- product/process identities;
- source-period dates;
- input table and formulas;
- result and sensitivity range;
- assumptions and exclusions;
- safety and technical status;
- reviewer and approval status; and
- revision and next review trigger.

Review after a material change in product, price, pack, machine, method, workpiece, acceptance requirement, cost rate or output pattern.

Practical calculation checklist

Confirm:

- the component and acceptance requirement are unambiguous;
- the numerator and denominator use the same boundary;
- every processed unit has one status;
- reworked accepted units remain distinguishable;
- pack and time conversions are correct;
- rates are current and approved;
- all material cost buckets are included once;
- shared and one-off costs use stated allocation rules;
- output counts reconcile with inspection records;
- sensitivity has been tested; and
- the commercial conclusion does not override safety or technical suitability.

Troubleshooting

Problem	Likely cause	Improvement
Cost per accepted component is lower when rejects rise	Rejects remain in the denominator	Use only final accepted output
First-pass yield looks high but rework is common	Rework is classified as routine processing	Define first-pass acceptance before observation
Abrasive consumption will not reconcile	Pack conversion, returns or partial use are uncontrolled	Reconcile issues, returns and remaining stock
Labour cost differs from clock time	Multiple people or excluded preparation time	Use person-time and the stated boundary
Scrap is counted twice	Loaded scrap value repeats direct inputs	Map each cost once
Candidate ranking changes with one event	Observation is too sensitive to an exception	Extend observation and show a range
Shared cost overwhelms the result	Allocation driver or period is unsuitable	Review the approved allocation basis
Cost falls but first-pass yield deteriorates	Rework is hidden or under-costed	Report yield and rework beside cost
Results cannot be reproduced	Sources, units or formulas are not retained	Use the controlled worksheet and revision record
Lowest cost candidate fails suitability review	Commercial result was used before technical gating	Apply safety and technical acceptance first

Safety reminder

Cost per accepted component must never be improved by exceeding a product limit, defeating a guard, omitting required inspection, using damaged product, extending use beyond safe condition, reducing extraction or accepting an unsuitable machine/accessory arrangement. Follow product marking, machine instructions, workplace controls and applicable Malaysian requirements.

Key takeaways

- Define accepted output before calculating cost.
- Keep first-pass accepted, reworked accepted and scrap separate.
- Use one complete and transparent cost numerator.
- Convert pack, time and rate units consistently.
- Allocate shared costs on a stated approved basis.
- Reconcile source records and prevent double counting.
- Report cost, yield, sensitivity and technical status together.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 063

Controlled Product Trials

63

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, engineers, supervisors, QA/QC personnel, safety teams, maintenance personnel, buyers, continuous-improvement teams and industrial abrasive users

Scope: Trial purpose; safety and compatibility gates; baseline; product identity; workpiece population; factors; response measures; measurement; sequence; randomisation; blocking; repetition; stop conditions; execution; deviations; analysis; economics; decision; release and monitoring.

Core principle — A controlled trial changes only what the plan permits, measures the outcomes that matter and protects safety and product conformity before productivity or cost is considered.

A good product trial converts a workshop impression into a defensible operating decision. It compares a candidate with a defined baseline, under conditions that are sufficiently similar to make the observed difference meaningful. It also preserves traceability: which abrasive, machine, workpiece, operator, settings and measurement method produced each result.

A trial does not need to be complicated. Its design should be proportionate to the risk and value of the decision. However, an uncontrolled demonstration—different material, different operator, changing settings and no agreed acceptance requirement—cannot reliably establish comparative performance.

When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- define the decision and the permitted trial scope;
- apply safety, compatibility and product-identity gates;
- establish a representative baseline and comparable workpieces;
- distinguish controlled factors, responses and nuisance variables;
- select fit-for-purpose measurement and comparison methods;
- use sequencing, randomisation, blocking and repeat observations appropriately;
- write start, pause and stop conditions;
- record execution and deviations traceably;
- evaluate quality, productivity, consumable use and cost together; and
- release a successful change within a controlled operating envelope.

1. State the decision

Write one question that the trial must answer. For example:

- Which technically suitable abrasive gives the more consistent accepted finish on the defined component?
- Can a proposed abrasive reduce total process time without increasing rework, heat damage or operator exposure?
- Does a revised sequence improve first-pass acceptance while preserving the specified geometry?

Identify the decision owner, process owner, trial leader, operators, safety reviewer and quality reviewer. State whether the outcome may support rejection, further evaluation, limited release or controlled production release.

2. Define the trial boundary

Record the operation from its starting condition to its acceptance point. Include:

- component, material, geometry and incoming condition;
- required stock removal, edge condition or surface result;
- machine, workstation, guarding, extraction and workholding;
- abrasive, accessory and supporting-consumable identities;
- included preparation, changeover, processing, cleaning and inspection;
- workplace environmental conditions that may affect the result; and
- the final inspection or hand-off point.

The baseline and candidate must use the same boundary. If the candidate changes the required sequence, capture that change rather than comparing only one isolated operation.

3. Pass the safety and compatibility gate

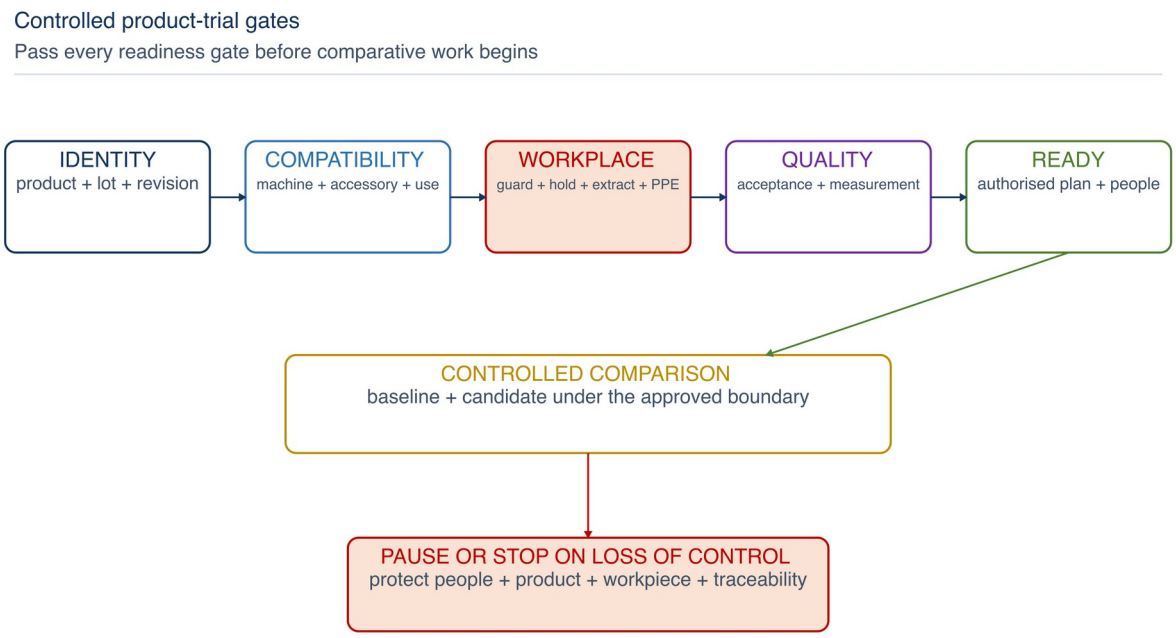

Figure 1. Controlled product-trial gates. Product identity, machine and accessory compatibility, workplace controls and quality readiness are confirmed before comparison begins.

Before mounting or using a candidate, confirm:

- readable product marking and traceable identity;
- correct product type, dimensions and mounting arrangement;
- compatibility with the machine, accessory and intended application;
- product and machine speed relationship;
- product condition, storage history and pre-use inspection;
- guards, flanges, backing pads, contact wheels or adaptors as applicable;
- secure workholding and a stable operator position;
- extraction, ventilation, spark and fire controls;
- suitable PPE and protection of nearby people; and
- applicable machine instructions, workplace risk controls and Malaysian requirements.

Do not trade a safety or conformity failure against a productivity or cost benefit. ISO 12100 provides a general hazard-identification and risk-reduction framework for machinery changes, while ISO 45001 supports worker participation and operational control. [S358; S359]

4. Control product and configuration identity

Use enough detail to distinguish the tested configuration from other products or setups:

Controlled item	Record at trial	Why it matters
Abrasive	Product name/code, form, dimensions, grade/grit, lot/batch where shown	Prevents substitution and supports traceability
Machine	Type, asset ID and relevant condition	Separates product effects from machine differences
Accessory	Backing pad, flange, contact element, adaptor or compound	Accessory choice can change support and performance
Workpiece	Material grade, geometry, source batch and incoming condition	Controls variation in the processed material

Controlled item	Record at trial	Why it matters
Method	Sequence, orientation, passes and inspection point	Preserves a repeatable operating method
Revision	Trial plan, drawing, specification and data-sheet revision	Shows which controlled information governed the work

ISO 10007 supports configuration identification, status accounting and controlled change through the lifecycle. [S355]

5. Establish the baseline

The baseline should represent the current approved process under normal, stable conditions—not an unusually good demonstration or a known abnormal shift. Before comparison:

- confirm that the machine and extraction are serviceable;
- use workpieces representative of the intended population;
- record the current product and method;
- measure the same responses planned for the candidate; and
- note recent changes, unusual wear, operator learning or material variation.

If the baseline is unstable, investigate the instability first or design the comparison to account for it.

6. Choose representative workpieces

Define the population to which the decision will apply. Consider material grade, thickness, geometry, weld type, coating condition, hardness range, casting skin, heat treatment and previous operations.

Do not combine unlike components simply to increase the number of observations. Where distinct families must be represented, treat them as separate blocks or report their results separately. Mark and preserve rejected or unusual workpieces for review where practical.

7. Separate factors, responses and nuisance variables

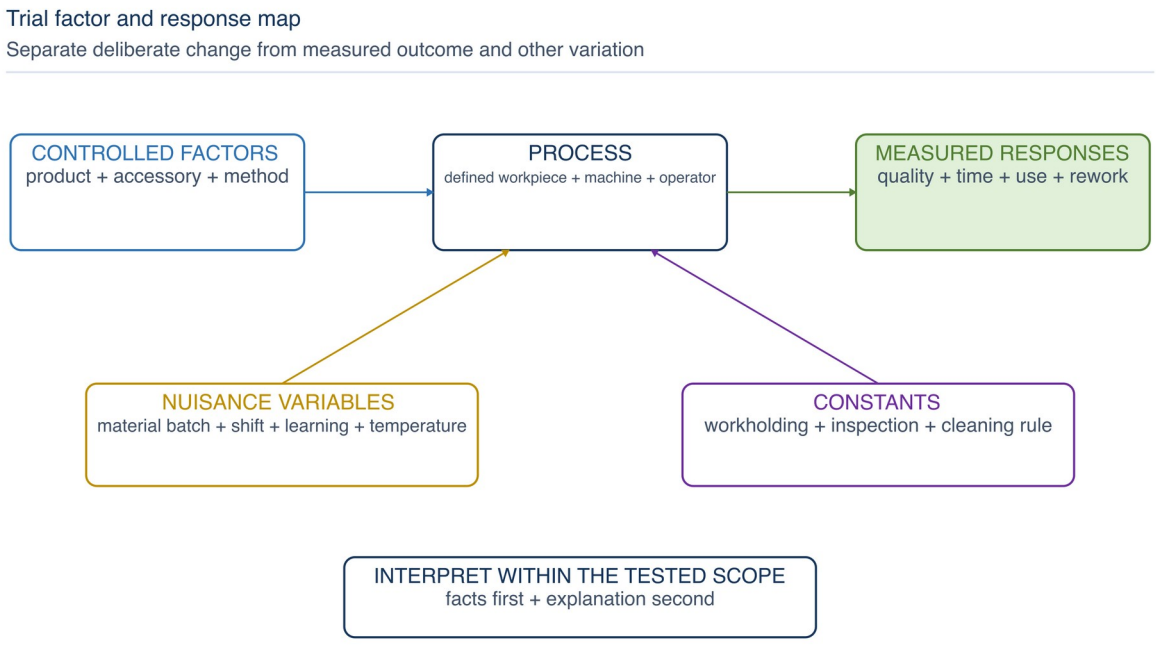

Figure 2. Trial factor and response map. Deliberately changed factors are separated from measured responses and other sources of variation.

Element	Meaning	Abrasive-trial examples
Factor	Variable deliberately set or compared	Product, sequence, accessory or approved setting band
Level	Specific option used for a factor	Baseline product versus candidate product
Response	Outcome measured for the decision	Accepted finish, cycle time, consumption, defects or rework
Nuisance variable	Variation not central to the decision	Operator, shift, material batch, machine or ambient condition
Constant	Condition deliberately held stable	Workholding, inspection method or cleaning stage

A simple trial may compare one factor while holding the others steady. When several interacting factors must change, use a competent designed-experiment approach rather than interpreting a sequence of uncontrolled adjustments. ISO 3534-3 provides recognised design-of-experiments terminology. [S376]

8. Define acceptance before operation

Translate the product drawing, process specification or approved visual standard into observable criteria. Depending on the application, include:

- specified surface-texture parameter and measurement method;
- permitted scratch, gouge, burr, edge or blend condition;
- dimensional or geometric limit;
- heat tint, burning, glazing or metallurgical concern;
- coating-readiness or cleanliness requirement;
- cut geometry and downstream fit;
- absence of contamination or embedded foreign material; and
- required first-pass acceptance status.

Use the controlled drawing or specification to assign exact acceptance values. The ISO 21920 series provides the current profile surface-texture framework. [S343; S344; S345]

9. Select decision measures

Use a balanced set. A candidate that cuts quickly but creates rework is not necessarily an improvement.

Decision dimension	Useful measures	Interpretation control
Safety	Observations, control effectiveness, abnormal events	Mandatory gate; not a weighted benefit
Quality	First-pass acceptance, defect type, measured finish, geometry	Use the same inspection method
Productivity	Process time, total elapsed time, change frequency	Define included and excluded time
Consumption	Abrasives issued, used, remaining and rejected	Reconcile partial and returned products
Operator factors	Handling, visibility, effort, vibration concern	Use structured feedback; investigate concerns
Economics	Total included cost per accepted component	Apply Chapters 062 and 063 consistently

Prioritise the measures that can change the decision. Avoid collecting attractive but unused data.

10. Confirm measurement capability

Measurement must be suitable for the expected distinction. Confirm:

- the characteristic, unit and method;
- instrument identity and current status;
- resolution and usable range;
- fixture, datum, sampling location and surface preparation;
- operator technique and environmental controls;

- repeated-reading rule where appropriate; and
- treatment of invalid, outlying or interrupted measurements.

Check repeat measurements on representative parts before the trial when operator or instrument variation could mask the product difference. ISO 10012:2026 supports fit-for-purpose measurement processes and confidence in valid, reliable results. [S375]

11. Select the comparison structure

Choose a structure proportionate to the risk:

Structure	Suitable use	Main control
Side-by-side screening	Early comparison under closely matched conditions	Keep identity and workpieces controlled
Alternating sequence	Conditions may drift during the session	Alternate baseline and candidate
Randomised order	Sequence or learning could bias results	Use a pre-generated order
Blocked comparison	Known groups differ, such as operators or material batches	Compare candidates within each block
Designed experiment	Multiple factors or interactions matter	Use competent statistical design and analysis
Confirmation run	Verify the selected configuration independently	Repeat under representative production conditions

NIST describes experimental design as an organised approach to relating factors to responses and emphasises clear objectives, design selection, analysis and confirmation. [S377]

12. Control sequence and drift

Long-running tools, operator learning, machine temperature, material batch and extraction condition can change through the day. If all baseline work is performed first and the candidate second, the sequence may be mistaken for a product effect.

Use alternation or randomisation where practical. Keep a visible run-order sheet so the actual sequence is recorded. When a warm-up or conditioning period is necessary, define it consistently and exclude or include it under the same rule.

13. Use blocking for known variation

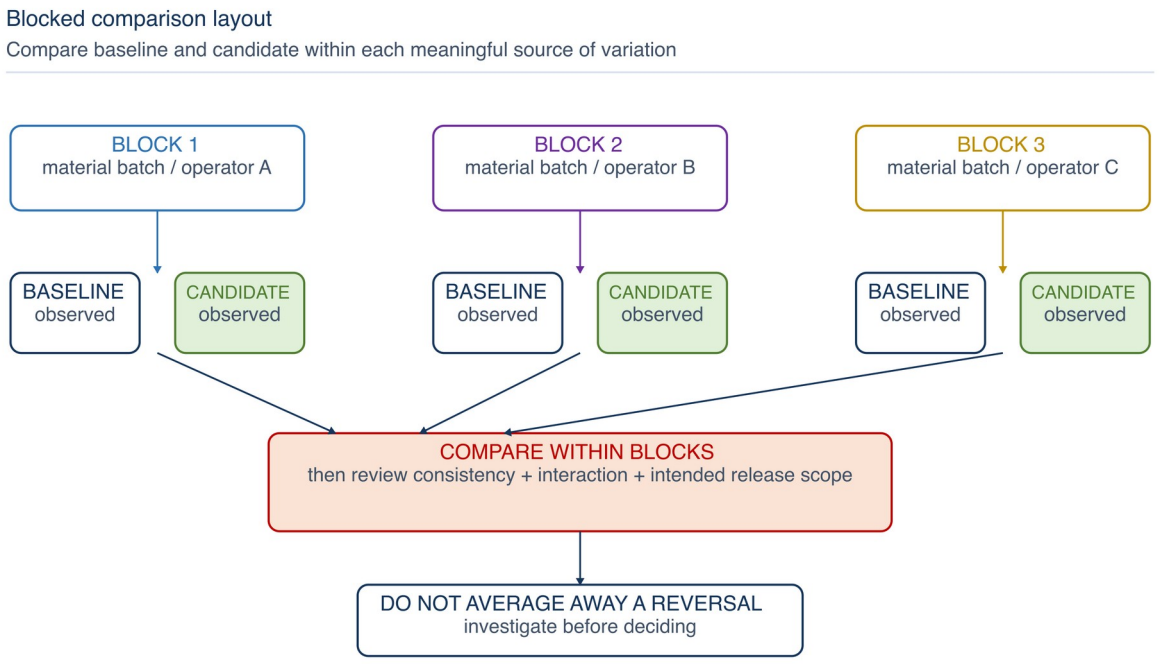

Figure 3. Blocked comparison layout. Baseline and candidate are compared within meaningful groups before the overall conclusion is formed.

A block is a group expected to be more alike internally than the full trial population. Practical blocks include:

- material heat or batch;
- operator;
- machine;
- component family;
- shift; or
- incoming-condition category.

Compare both candidates within each block where feasible. Do not average away a result that reverses between blocks; investigate whether the decision scope must be limited.

14. Set repetition proportionate to the decision

Repeat observations help distinguish a repeatable pattern from a single favourable or unfavourable event. The amount should reflect process variation, measurement capability, consequence of error and intended release scope.

Do not select an arbitrary count and describe it as statistically sufficient. For high-value or high-risk decisions, involve a competent quality or statistical specialist to define sample size, power, confidence and analysis. A confirmation run should use fresh representative work rather than merely recalculating the original data.

15. Write start, pause and stop conditions

Start only when personnel, machine, products, workpieces, controls, measurement equipment and records are ready.

Pause and assess when there is:

- an unplanned process or configuration change;
- measurement failure or loss of traceability;
- unexpected loading, glazing, vibration, noise, heat or spark pattern;
- workholding movement or machine abnormality;
- repeated quality deterioration;
- extraction or guarding concern;
- product damage; or
- operator concern.

Stop immediately for an unsafe condition, incompatible configuration, product damage, loss of control, serious defect or any event covered by workplace emergency procedures. Quarantine affected work and products as appropriate.

16. Execute from a controlled run sheet

For every run, record:

- run number, date/time and planned order;
- baseline or candidate identity;
- workpiece and source batch;
- machine, accessory and operator;
- approved settings and method revision;
- start/end time and interruptions;
- abrasive issue, change and remaining condition;
- quality and measurement results;
- rework, scrap and abnormal observations; and
- actual deviation from the plan.

Record data at the point of work. Preserve original observations; correct entries traceably instead of overwriting an unfavourable value.

17. Control deviations and exclusions

A deviation does not automatically invalidate a trial, but it must not disappear. Describe what changed, when it occurred, affected runs, immediate action and disposition.

Exclude a result only under a pre-defined rule or a documented technical reason. Analyse with and without a disputed observation when its treatment could change the conclusion. Never remove data merely because it weakens the preferred candidate.

18. Analyse the complete result

First verify data completeness and traceability. Then compare:

- acceptance and defect pattern;
- centre and spread of measured responses;
- processing and total elapsed time;
- abrasive and accessory consumption;
- change frequency and interruptions;
- rework and scrap;
- operator observations;
- safety events or control concerns; and
- cost per accepted component.

Separate observed facts from explanations. If the candidate result is better but highly variable, investigate the variation rather than reporting only the average. Where formal statistical inference is used, state the method, assumptions and practical significance.

19. Make and scope the decision

Use a transparent decision table:

Decision status	Meaning	Typical next action
Reject	Safety, compatibility or quality gate failed	Do not release; document disposition
Inconclusive	Difference is unclear or variation dominates	Improve control, measurement or comparison design
Conditional	Suitable only for a defined material, machine or method	Confirm and release within that boundary
Approve for confirmation	Screening result is promising	Conduct independent representative confirmation
Controlled release	Gates passed and result supports use	Issue controlled specification and monitoring plan

State the approved product/configuration identity, application, workpiece range, machine/accessory arrangement, operating envelope, operator competence, inspection method and exclusions. Do not generalise a local result to other applications.

20. Release, monitor and review

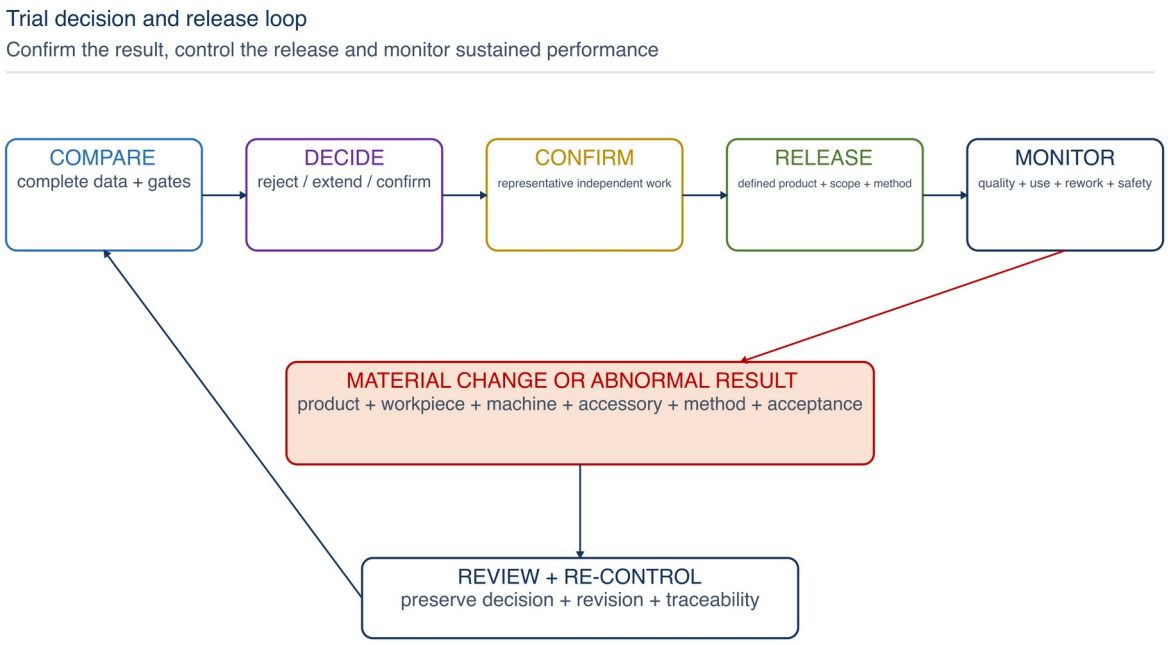

Figure 4. Trial decision and release loop. A successful comparison is confirmed, released within a defined scope and monitored for sustained performance.

Update the applicable specification, work instruction, approved-product record, training material, inspection plan and stores controls. Remove obsolete versions from points of use.

Monitor early production for quality, consumption, rework, abnormal wear and operator feedback. Review after a material change in product, lot behaviour, workpiece, machine, accessory, method, acceptance requirement or workplace control. ISO 9001 and ISO 10005 support controlled operations, monitoring and revision of quality arrangements. [S353; S354]

Practical controlled-trial checklist

Confirm:

- the decision and accountable owners are stated;
- product, machine, accessory and workpiece identities are traceable;
- safety and compatibility gates are passed before operation;
- the baseline is current, stable and representative;
- acceptance criteria and response measures are defined;
- the measurement method is fit for purpose;
- factors, constants and nuisance variables are separated;
- run order, blocks and repetitions suit the risk;
- start, pause and stop conditions are written;
- actual runs and deviations are preserved;
- quality, productivity, consumption and cost are evaluated together;
- the conclusion is limited to the tested scope; and
- release documents and monitoring triggers are controlled.

Troubleshooting

Problem	Likely cause	Improvement
Candidate appears better only late in the shift	Sequence, learning or machine-temperature bias	Alternate or randomise run order
Results differ strongly by operator	Technique or training variation	Block by operator and standardise the method

Problem	Likely cause	Improvement
Average result is good but rejects increase	Variation is hidden by the mean	Report spread, defects and first-pass acceptance
Finish readings do not repeat	Instrument, location or technique variation	Verify the measurement process and datum
Abrasive life cannot be compared	Change/end-of-life rule was undefined	Define and apply a common condition rule
Cost result conflicts with shop-floor experience	Boundary, time or rework is incomplete	Reconcile the Chapter 062 cost model
Trial cannot be reproduced	Identity, settings or deviations are incomplete	Use the controlled run sheet at point of work
One material batch drives the result	Workpiece variation was not controlled	Block by batch and confirm on representative material
Candidate passes quality but raises a safety concern	Safety was treated as a weighted score	Apply safety as a mandatory gate
Successful trial performs poorly after release	Scope, training or monitoring was weak	Limit release and monitor early production

Safety reminder

Product trials introduce change. Confirm abrasive condition, machine and accessory compatibility, speed relationship, guarding, workholding, extraction, PPE and emergency arrangements before work. Never bypass a protective device or exceed a marked limit to obtain a favourable result. Stop for damage, abnormal vibration, unusual heat, loss of work control or any unsafe condition.

Key takeaways

- Begin with one clear decision and a defined boundary.
- Pass safety, compatibility and product-identity gates first.
- Compare against a representative baseline using comparable workpieces.
- Define acceptance and measurement before starting.
- Use sequence control, blocking and repetition to reduce bias.
- Preserve all deviations and evaluate the complete process result.
- Release a successful change only within its verified scope.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 064

Reducing Abrasive Consumption

64

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, engineers, supervisors, operators, maintenance personnel, stores teams, buyers, QA/QC personnel and continuous-improvement teams

Scope: Accepted-output measurement; loss classification; product selection; machine and accessory condition; workholding; contact; force; working-area use; change-out; loading; glazing; damage; storage; issue and return; standard work; trials; monitoring and troubleshooting.

Core principle — Reduce abrasive consumption by removing avoidable loss while preserving safe use, cutting efficiency and accepted quality. A disc or wheel that lasts longer but increases labour, rework or risk is not an improvement.

Abrasive consumption is influenced by much more than product durability. Incorrect selection, excessive or insufficient force, a worn support pad, unstable workholding, poor storage, premature change-out, product damage and unrecorded issue can all increase use. The best control measure links abrasive use to accepted output and makes each loss mechanism visible.

When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- calculate abrasive consumption per accepted output;
- classify normal use and avoidable loss;
- identify selection, equipment, method and stock-control causes;
- define safe, observable change-out rules;
- use the designed working area without unsafe overuse;
- distinguish loading, glazing, shedding and mechanical damage;
- control issue, return and partial-product status;
- standardise work without inventing universal operating settings;
- verify a reduction through a controlled comparison; and
- sustain the improvement with practical indicators and review triggers.

1. Measure the right result

Use a denominator that represents useful production:

Abrasive consumption per accepted unit = abrasive units consumed ÷ final accepted units

For continuous or mixed work, a suitable denominator may be accepted weld length, accepted cut length, accepted area or another defined production unit. Use the same boundary and acceptance rule over time.

Also monitor first-pass acceptance, rework, scrap, processing time and cost per accepted component. A lower disc count with more labour or defects can increase total cost.

2. Establish a reconciled baseline

Before changing the process, record:

- product form and complete identity;
- operation and workpiece family;
- material and incoming condition;
- machine and accessory;
- operator or team basis;
- abrasives issued, returned, damaged and discarded;
- partial products retained for safe reuse;
- accepted output, rework and scrap;
- productive time, interruptions and product changes; and
- reasons recorded at change-out.

Observe enough representative production to include normal variation. Do not build a baseline from one unusually easy or difficult job.

3. Classify the consumption loss

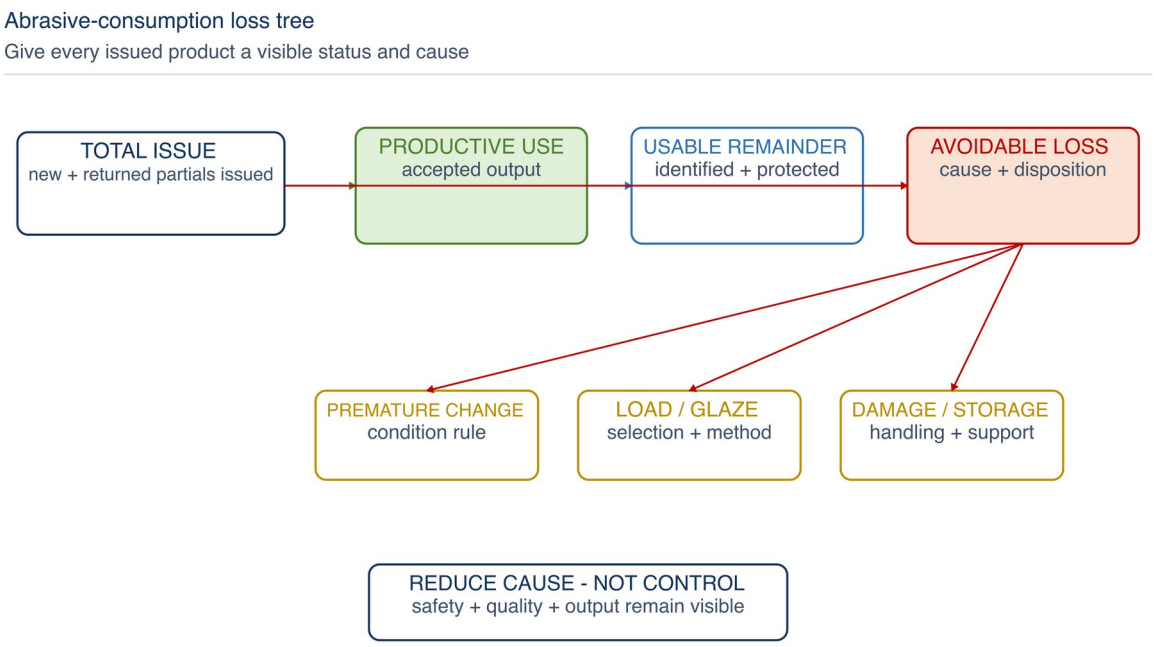

Figure 1. Abrasive-consumption loss tree. Total issue separates into productive use, recoverable remainder and avoidable loss with a stated cause.

Status	Meaning	Control response
Productive wear	Abrasive consumed while producing accepted output	Optimise only through controlled comparison
Safe usable remainder	Product can be identified, protected and safely reused	Return to controlled status
Premature change-out	Product removed before the common condition rule	Improve change-out standard and supervision
Loading or glazing	Cut falls because the surface is obstructed or dull	Diagnose material, product, force, contact and extraction
Mechanical damage	Tear, edge loss, crack, deformation or mounting damage	Stop use, segregate and correct the cause
Storage/handling loss	Product deteriorated or damaged before use	Improve receiving, storage and transport
Untraceable loss	Issue cannot be linked to use, return or disposal	Strengthen point-of-use control

Do not call all discarded abrasive “normal wear.” The cause classification directs the improvement.

4. Protect the safety and quality gates

Consumption reduction must not rely on:

- exceeding a marked product or machine limit;
- using a damaged, contaminated or incorrectly stored abrasive;
- defeating a guard or changing an approved mounting arrangement;
- using a prohibited face, side, edge, hub or core;
- reducing extraction, inspection or PPE;
- accepting a poorer surface, geometry or cut; or
- extending use after safe discard condition.

FEPA safety guidance emphasises correct selection, inspection, marking, speed compatibility and intended use. [S032; S352]

5. Select for the complete task

Match the abrasive to:

- material and hardness;
- stock-removal requirement;
- contact area and geometry;
- required finish and permitted dimensional change;
- machine type, power and speed control;
- accessory or contact element;
- wet or dry process where applicable;
- loading or contamination tendency;
- access, visibility and operator control; and
- downstream operation.

Grit designation alone does not determine product life, finish or suitability. Coated-abrasive P grades, bonded-abrasive F grades and superabrasive designations have different standards contexts. [S346; S347; S348; S349]

6. Avoid false economy from maximum nominal life

The longest-lasting wheel is not automatically the most economical. A product that becomes dull may require greater force and longer contact, increasing vibration exposure, heat and labour.

HSE foundry guidance specifically warns against selecting grinding wheels only for maximum life and instead focuses on cutting efficiency. It notes that an overly hard, poorly cutting wheel can encourage greater force and increase time and vibration. [S378]

Compare accepted output, task time, quality loss and total cost—not nominal life in isolation.

7. Control the machine condition

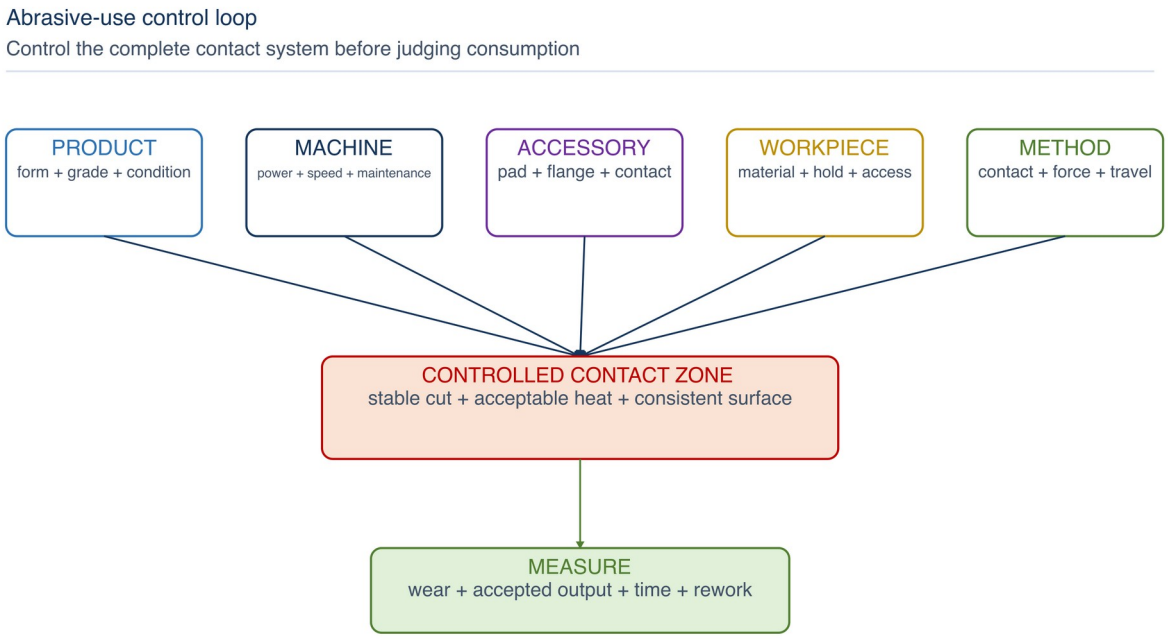

Figure 2. Abrasive-use control loop. Product, machine, accessory, workholding and method combine to produce measurable wear and accepted output.

Check conditions that can waste abrasive:

- spindle, bearings and drive condition;
- air supply, electrical supply or battery condition as applicable;
- free-running speed and speed-control function under the approved maintenance method;
- vibration, runout and abnormal noise;
- guard, flange, mounting and fastener condition;
- ventilation slots, cooling and dust ingress;
- extraction effectiveness; and
- maintenance status.

Abrasive change cannot compensate for a defective or underperforming machine. Remove abnormal equipment from service under workplace procedure.

8. Maintain the support system

Backing pads, contact wheels, flanges, adaptors, mandrels and compounds influence support, contact and wear. A worn or mismatched support can cause edge damage, poor tracking, uneven use, heat or loss of control.

Record accessory identity with the abrasive. Inspect before use and at defined triggers. Replace only under its controlled condition rule. Do not assume that a reusable accessory has unlimited life.

9. Secure and present the workpiece

Unstable work increases abrasive loss through chatter, edge impact, pinching and repeated passes. Confirm:

- secure workholding;
- support that prevents movement or harmful deflection;
- clear access to the intended contact zone;
- safe body and tool position;
- a cut path that does not close on a cutting wheel;
- removal of obstructing scale, contamination or weld projections only by the approved method; and
- consistent presentation for repeated components.

A suitable fixture can improve both consistency and abrasive utilisation, but it must not obstruct guarding or create a trapping hazard.

10. Control contact, travel and dwell

Use the product on its designed working surface and maintain a stable contact pattern. Avoid:

- edge striking or dropping onto the work;
- dwelling in one location;
- rocking that alternately overloads edges;
- repeated contact with sharp projections;
- twisting a cutting wheel in the kerf;
- using only one narrow strip of a wider belt; and
- travel that traps swarf under the product.

Where the product and machine permit, distribute work across the usable abrasive area. Follow the approved method for direction, presentation and access.

11. Apply controlled force

Excessive force can accelerate shedding, damage a coated-abrasive structure, deform a wheel or overheat the work. Too little effective engagement can allow rubbing, glazing and slow processing. The correct condition depends on the product, machine, material and task.

Train operators to recognise a stable cutting sound, controllable spark or swarf pattern, normal tool response and acceptable surface result. Investigate a need for rising force; do not simply press harder. HSE guidance links efficient equipment and consumables with shorter task duration and reduced unnecessary exposure. [S379]

12. Use the safe working area fully

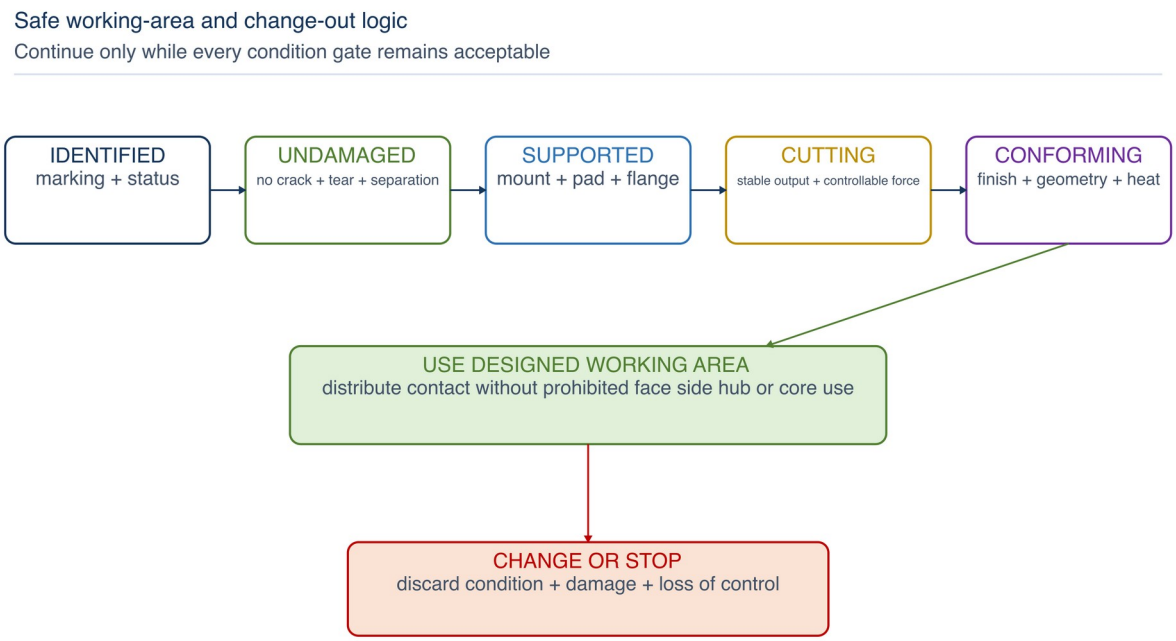

Figure 3. Safe working-area and change-out logic. Continue only while the designed working area remains serviceable and all condition gates pass.

For suitable product forms, improve utilisation by:

- rotating work position or approach to distribute contact;
- using the supported usable face consistently;
- tracking belts so the width is used evenly;
- avoiding local contamination;
- protecting unused portions during pauses; and
- returning identifiable partial products to a protected holder.

Never use a hub, backing, flange-contact zone or other non-working area as abrasive. Safe discard condition depends on wheel construction, guard, flange, spindle and intended grinding surface. [S382]

13. Define a safe change-out rule

Use observable conditions rather than operator preference alone:

Change-out trigger	Required interpretation
Marked or manufacturer-defined discard condition	Mandatory removal
Damage, crack, tear, distortion or separation	Stop, isolate and investigate
Loss of secure mounting or support	Stop and correct configuration
Loading or glazing	Diagnose before replacement; do not force the product
Accepted output or task time deteriorates materially	Confirm cause using the process record
Required finish or geometry is no longer stable	Change under the approved quality rule
Product is contaminated for the next material/process	Segregate; prevent cross-contamination

Apply one rule consistently to baseline and candidate during a controlled trial.

14. Diagnose loading and glazing

Loading is the accumulation of removed material or residue in the abrasive surface. Glazing is a dull, poorly cutting condition in which the abrasive surface does not renew effectively. They can feel similar to the operator but require diagnosis.

Check:

- material and coating tendency;
- abrasive construction, openness and grade family;
- grit choice;
- contact area and support;
- force and dwell;
- machine output and speed control;
- extraction or chip clearance;
- coolant, lubricant or grinding-aid condition where approved; and
- contamination from previous materials.

Do not dress, clean or condition a product unless that action is permitted for the exact product and machine arrangement.

15. Diagnose rapid wear and shedding

Rapid wear may result from unsuitable product construction, excessive force, edge impact, too aggressive a contact element, misalignment, excessive flex, heavy infeed, heat or workpiece movement. Normal self-sharpening must be distinguished from uncontrolled grain or bond loss.

Inspect the discarded product and the workpiece together. Record where wear occurred—centre, edge, one side, one belt track or around a mounting area. A consistent pattern often points to contact or equipment condition rather than product durability alone.

16. Protect products before use

Receiving and storage controls can prevent consumption without changing the process:

- inspect packaging and product condition on receipt;
- retain identification and manufacturer information;
- store dry, protected and in the intended orientation;
- avoid heat sources, damp surfaces, chemical contamination and distortion;
- use suitable racks, bins or flat support for the product form;
- rotate stock by a controlled date or batch rule;
- segregate damaged, suspect or expired stock; and
- transport products in protective containers.

Manufacturer guidance supports original packaging, controlled environment, careful handling and stock rotation, while exact conditions remain product-specific. [S338; S339; S340]

17. Control issue, return and partial products

At point of use:

- issue the correct product against the job or workstation;
- avoid uncontrolled handful issue;
- provide a labelled holder for usable partial products;
- separate new, in-use, returnable and rejected status;
- prevent mixing of visually similar grades or materials;
- record damage and reason for disposal;
- reconcile pack quantity with issue, return and remaining balance; and
- retain lot or batch traceability where applicable.

GS1 traceability principles support identification of traceable objects, batch/lot precision and inventory status, without requiring a particular coding system. [S363]

18. Standardise the method and train operators

Create a concise visual method covering:

- product and accessory identity;
- inspection and mounting;
- approved operating envelope;
- workholding and sequence;
- contact and travel technique;
- quality check point;
- change-out and partial-product status;
- abnormal-condition response; and
- issue/return record.

Involve experienced operators in defining observable cues. Train with representative work, then verify competence. Standard work should preserve a safe method while allowing a clearly controlled response to normal workpiece variation.

19. Verify each improvement

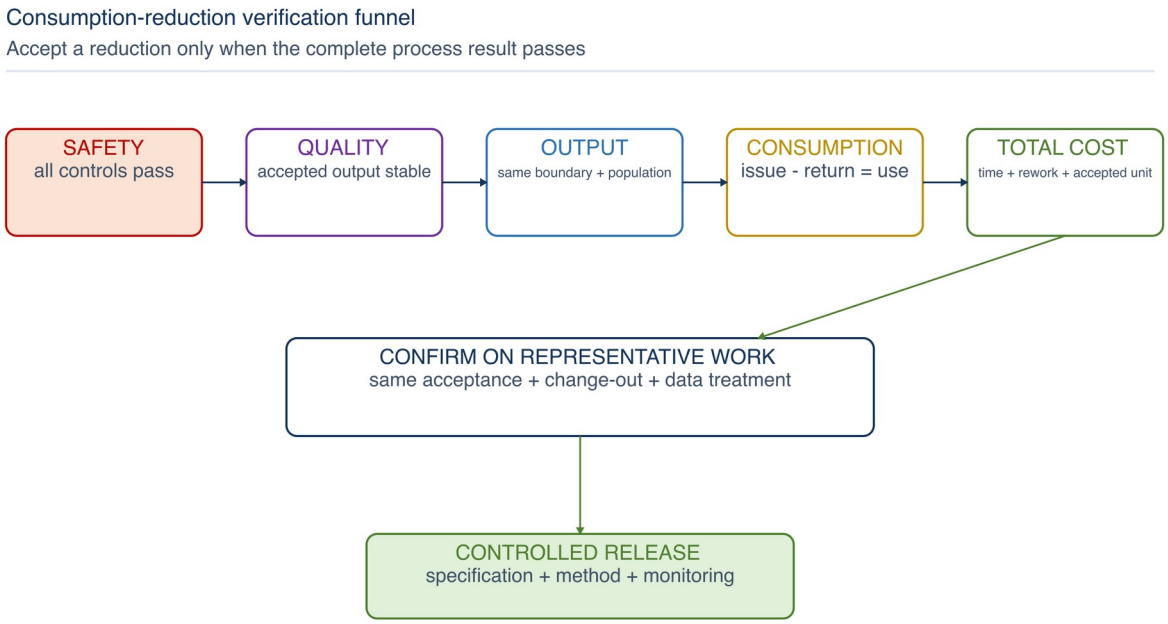

Figure 4. Consumption-reduction verification funnel. A claimed reduction is accepted only after safety, quality, output, consumption and total-cost checks pass.

Use Chapter 063's controlled product-trial method. Compare the baseline and proposed change with the same:

- workpiece population;
- acceptance method;
- machine/accessory configuration;
- process boundary;
- issue and change-out rule; and
- data treatment.

Calculate consumption per accepted unit and cost per accepted component. Confirm the result on representative production before changing the approved specification or work instruction.

20. Sustain and review

Use a small indicator set:

Indicator	What it reveals	Review trigger
Abrasives per accepted unit	Overall use efficiency	Sustained shift from controlled baseline
Premature change-out proportion	Method or behaviour loss	Concentration by operator, shift or job

Indicator	What it reveals	Review trigger
Damage before/use during mounting	Handling or configuration loss	Repeat event or common product form
Loading/glazing occurrence	Selection or process mismatch	Increase by material or operation
Rework and first-pass acceptance	Hidden quality trade-off	Deterioration after use reduction
Task time and cost per accepted component	False economy	Labour or total cost rises
Unreconciled issue	Stock-control weakness	Material unexplained balance

Review after changes to product, material, machine, accessory, method, operator mix, storage condition or acceptance requirement.

Practical consumption-reduction checklist

Confirm:

- consumption is normalised to accepted output;
- every issued abrasive has a use, return, damage or disposal status;
- safety and quality gates remain mandatory;
- product and accessory match the complete task;
- machine, workholding and support condition are stable;
- force, contact, travel and dwell are controlled;
- the safe working area is used without prohibited contact;
- the change-out rule is observable and consistent;
- loading, glazing, shedding and damage are diagnosed separately;
- stock is identified, protected and rotated;
- partial products have a controlled status; and
- improvement is verified through representative comparison.

Troubleshooting

Problem	Likely cause	Improvement
Disc count falls but task time rises	Product used beyond efficient condition	Review change-out against accepted output and time
Operators change at very different conditions	Rule is subjective	Define visible and process-based triggers
Wear is concentrated on one edge	Contact, access or support is uneven	Review presentation, pad and workholding
Product loads rapidly	Material/residue, pressure, dwell or construction mismatch	Diagnose the complete contact system
Product glazes and requires more force	Poor self-renewal or inadequate engagement	Review selection and approved method
Belt wears in one narrow track	Work is not distributed across the usable width	Correct tracking and contact pattern
Edges tear or chip	Impact, projection or unsupported contact	Stabilise entry, support and workpiece condition
New products are discarded as damaged	Receiving, storage or transport is unsuitable	Protect, inspect and segregate stock
Store issue exceeds recorded use	Returns and partials are uncontrolled	Introduce status holders and reconciliation
Consumption improves but rework increases	Finish or geometry gate was weakened	Restore acceptance control and revalidate

Safety reminder

Reducing consumption never justifies use beyond a marked limit, damaged condition, safe discard point or designed working surface. Confirm product condition, machine and accessory compatibility, speed relationship, guard, mounting,

workholding, extraction and PPE. Stop for abnormal vibration, damage, separation, loss of secure mounting or loss of work control.

Key takeaways

- Measure abrasive use per accepted output.
- Classify loss instead of treating every discard as normal wear.
- Select for cutting efficiency, quality and total cost—not nominal life alone.
- Stabilise the machine, support system, workholding and operator method.
- Use the safe working area fully and apply a common change-out rule.
- Protect inventory and reconcile issue, return, partial and disposal status.
- Verify every reduction through a controlled representative comparison.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 065

Reducing Labour and Rework

65

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Production managers, engineers, supervisors, operators, maintenance personnel, QA/QC teams, planners and continuous-improvement teams

Scope: Labour per accepted component; work observation; quality at source; standard work; workplace organisation; ergonomics; equipment readiness; setup and changeover; defect containment; root-cause improvement; verification and sustainment.

Core principle — The best labour reduction removes work that does not create an accepted result. It must preserve safe operation, product conformity, traceability and operator control.

Grinding and surface finishing often contain hidden labour: searching for the correct product, moving parts repeatedly, correcting unstable workholding, waiting for inspection, changing abrasives prematurely, repeating passes and repairing defects detected late. Rework consumes labour and abrasive while adding no accepted output. A stable process prevents the defect or detects it close to the point where it was created.

When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- measure labour and rework against accepted output;
- distinguish processing work from avoidable motion, waiting and correction;
- define a clear incoming condition and accepted handoff;
- build practical standard work for abrasive operations;
- organise products, accessories, gauges and documents at point of use;
- improve work positioning and handling;
- reduce setup and product-change losses;
- contain abnormal output and diagnose the originating cause;
- use balanced indicators that discourage shortcuts; and
- verify improvements under representative production conditions.

1. Measure labour against accepted output

Use a denominator that reflects usable production:

Direct labour per accepted unit = direct labour time within the defined process boundary ÷ final accepted units

Record rework labour separately. Include time spent correcting components that failed the first applicable acceptance check, even if the correction occurs at another workstation or shift. For mixed work, normalise by an agreed unit such as accepted cut length, weld length or finished area, and keep the product family and difficulty visible.

Do not report a labour improvement from fewer inspection, extraction, guarding, handling or quality-control activities unless those activities are genuinely unnecessary and their removal has been approved through the workplace change process.

2. Define the process boundary

State where measurement begins and ends. A useful boundary may begin with a released workpiece and available job information, and end with accepted output handed to the next operation. Include:

- job identification and drawing review;
- product, accessory and machine preparation;
- workholding and part positioning;
- abrasive processing;
- in-process and final checks;
- product changes and normal cleanup;
- internal movement and waiting; and
- correction, repeat inspection and disposition.

Consistent boundaries prevent apparent improvement created by moving work to another person or department.

3. Make labour loss visible

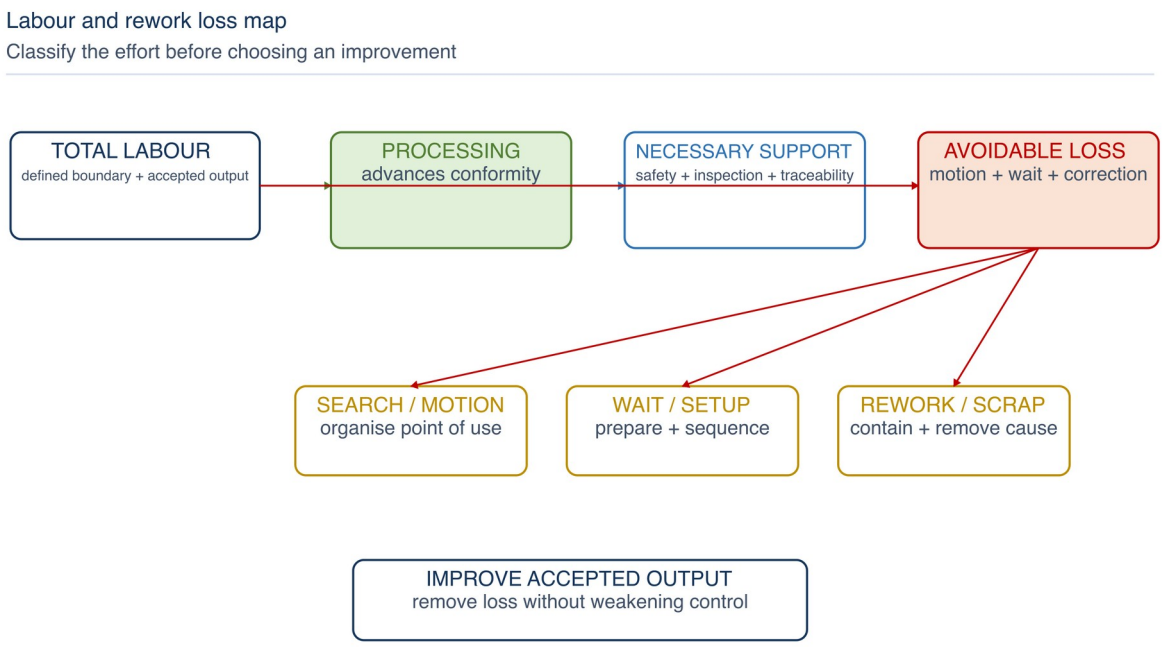

Figure 1. Labour and rework loss map. Separate useful processing and necessary support from avoidable loss before selecting an improvement.

Work category	Typical example	Improvement direction
Value-creating processing	Controlled stock removal or finishing that advances conformity	Stabilise and optimise
Necessary support	Inspection, safe mounting, extraction check or traceability	Make reliable and efficient
Search and motion	Looking for discs, gauges, drawings or fixtures	Point-of-use organisation
Waiting	Machine, material, approval or inspection unavailable	Readiness and flow control
Repeated setup	Re-clamping, re-zeroing or repeated masking	Setup standard and preparation
Over-processing	Unnecessary passes or finish finer than required	Clarify acceptance and sequence
Rework	Correction after a failed check	Contain and remove root cause
Scrap handling	Processing and disposition of unusable work	Prevent recurrence and record cause

Observe the work at the workstation with operators. A time record without the reason for each delay cannot distinguish skill, difficulty, equipment condition and system loss.

4. Define accepted input and handoff

The operator needs a clear answer to two questions: what condition may enter this operation, and what condition may leave it? Define applicable requirements for:

- material and component identity;
- weld, edge, coating or previous-operation condition;
- permitted contamination and damage;
- dimensional or geometric boundaries;
- surface finish or visual comparator;
- protected features and no-touch areas;
- cleaning and inspection status; and

- traceability and route documentation.

Ambiguous acceptance encourages either unnecessary finishing or defects passed downstream. Use controlled drawings, specifications, approved samples or visual standards appropriate to the work.

5. Build quality at the source

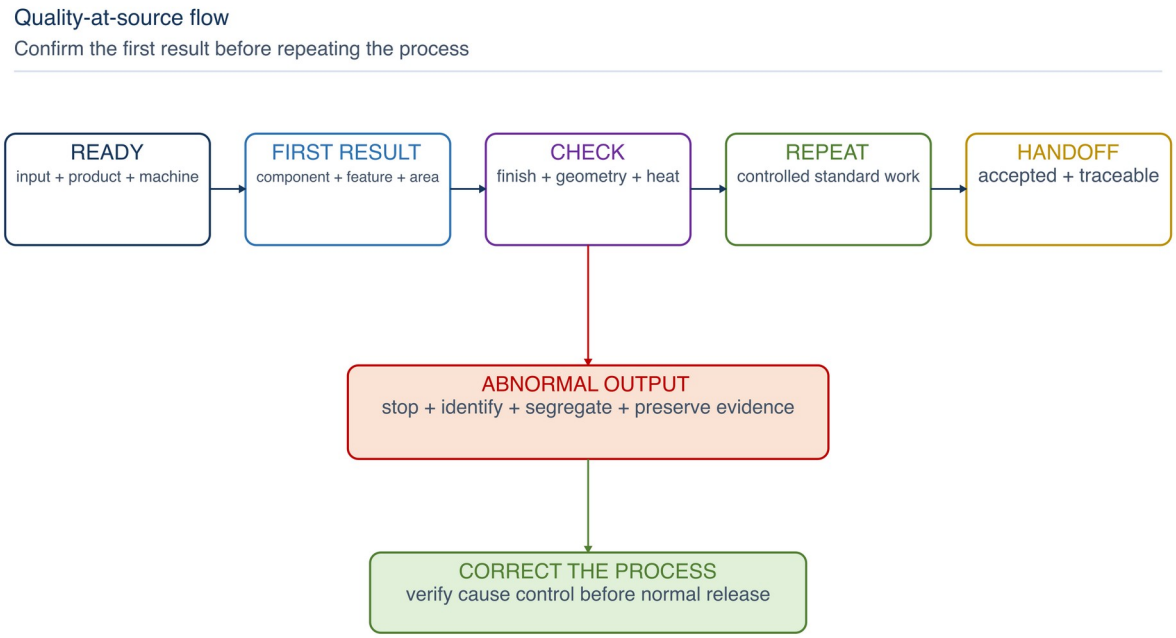

Figure 2. Quality-at-source flow. Confirm readiness and the first result before repeating the process; contain abnormal output immediately.

Check the first component, first feature or first representative area after setup and after a significant change. Select a check point early enough to prevent a full batch from inheriting the same defect. The check may cover:

- required material removal;
- burr or edge condition;
- surface texture or visual appearance;
- dimensional and geometric preservation;
- heat tint, burning or thermal damage indicators;
- scratch direction and transition quality;
- cleanliness and cross-contamination; and
- downstream fit, coating or polishing requirement.

If output is abnormal, stop the affected sequence, identify potentially affected work and investigate before continuing. Re-inspection alone does not remove the cause.

6. Standardise the complete operation

Standard work is the agreed current method for producing a safe, conforming result with available people and equipment. It should be concise, visible and updated after approved improvement. NIST manufacturing guidance connects standard work with reduced variation, mistakes, rework and scrap. [S384; S385]

Cover:

- component and operation identity;
- abrasive and accessory identity;
- pre-use inspection and compatibility checks;
- workholding, protection and presentation;
- safe sequence and processing stages;
- contact, travel and overlap method;
- in-process inspection point;

- observable change-out condition;
- cleaning and material-separation controls;
- abnormal-condition response; and
- accepted handoff.

Do not encode an assumed universal speed, force, angle or service life. The method must follow the exact product, machine and application information.

7. Organise the point of use

Place frequently used items where they can be reached, identified and returned without confusion. Use controlled locations for:

- released abrasive products by full identity;
- backing pads, contact elements, flanges and adaptors;
- guards, keys and permitted mounting tools;
- fixtures, clamps and protection materials;
- inspection equipment and visual standards;
- cleaning tools and material-specific equipment;
- current work instructions; and
- usable partial products and rejected items.

Visual labels should distinguish status, not merely location. Remove obsolete documents and segregate damaged or unidentified abrasives. NIST identifies workplace organisation and point-of-use control as foundations for reducing search, motion and error. [S383; S384]

8. Prepare a job kit

For repeated or planned work, assemble the authorised products, accessories, gauges, fixtures and documents before the machine becomes unavailable for changeover. Confirm quantity and condition without issuing uncontrolled excess stock.

A job kit can reduce walking and interruption, but it must preserve product identification, storage protection and return status. Similar-looking grades should not be placed together without unmistakable identification.

9. Improve work positioning

Position the work so the operator can maintain control with neutral joints, good visibility and supported handling. Consider:

- working height and orientation;
- distance and reach to the contact zone;
- wrist alignment and handle orientation;
- elbow position and body balance;
- fixture access and part rotation;
- cable, hose and extraction routing;
- lifting, turning and transfer method; and
- planned recovery and task rotation where appropriate.

OSHA ergonomic guidance identifies repetitive motion, forceful exertion and awkward posture as risk factors and recommends repositioning work and maintaining more neutral upper-limb posture. [S386] Ergonomic improvement must not bring the operator into the line of fire, obstruct a guard or reduce secure workholding.

10. Support the tool and workpiece

Tool balancers, stands, positioners, manipulators, turntables and purpose-designed fixtures may reduce handling effort where they are suitable for the machine, product and workpiece. A fixture should:

- locate the part consistently;
- resist process forces and vibration;
- provide safe access to required surfaces;
- avoid damaging finished or datum surfaces;
- permit inspection and controlled release;
- avoid pinch, entanglement and ejection hazards; and
- remain compatible with guarding and extraction.

Treat any new support or fixture as a machinery or process change requiring risk review. ISO 12100 provides the recognised framework for hazard identification and risk reduction. [S358]

11. Confirm equipment readiness

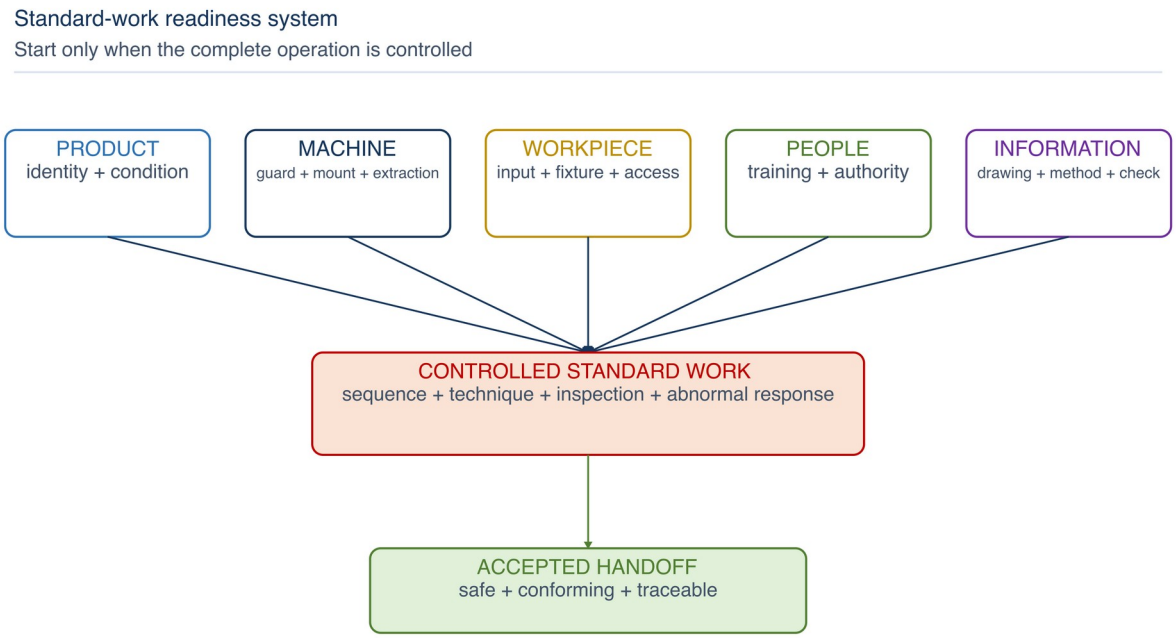

Figure 3. Standard-work readiness system. Product, machine, workpiece, people and information must be ready before controlled work begins.

Before the job starts, confirm:

- correct machine and power source;
- guard, mounting and controls in serviceable condition;
- spindle, bearings, drive and speed control normal;
- extraction and ventilation available;
- correct abrasive and support accessory;
- secure workholding and access;
- calibrated or otherwise controlled measuring equipment where required;
- current drawing, route and work instruction; and
- trained, authorised personnel.

Breakdowns, runout, poor extraction and worn support equipment cause repeat passes and defects. A faster abrasive cannot correct an unready system.

12. Reduce setup and changeover loss

Separate activities into those that require the equipment to be stopped and those that can be completed safely while the preceding job is running. External preparation can include confirming the next job, staging released products, checking gauges, cleaning fixtures off-line and reviewing the drawing.

During the stopped period, use a defined sequence for isolation where required, removal, cleaning, inspection, mounting, guarding, adjustment, first-result check and release. NIST describes quick changeover from the last good piece of one run to the first good piece of the next, keeping quality central to the definition. [S383]

Never pre-loosen a mounting, bypass isolation or leave a machine unguarded to save changeover time.

13. Reduce unnecessary product changes

Product changes consume labour and can introduce mounting error. Reduce avoidable changes by:

- selecting the correct abrasive for the complete operation;

- using a logical grit or stage progression;
- maintaining the support accessory and machine;
- applying a common condition-based change rule;
- preventing loading, contamination and localised wear;
- organising the sequence to minimise incompatible material changes; and
- protecting identified partial products for permitted reuse.

Do not extend a product beyond its designed working area, safe condition or marked limit. A change avoided through unsafe overuse is not an improvement.

14. Remove unnecessary stages carefully

A stage may be unnecessary when it does not change the component toward a stated requirement and does not protect safety or downstream quality. Examples include repeating a grit because the previous stage is poorly controlled, polishing a hidden surface beyond the drawing requirement or inspecting the same feature multiple times because status is unclear.

Before removing a stage, confirm its original purpose, upstream and downstream effects, defect-detection role and process risk. Verify the revised sequence on representative work. Do not remove cleaning, edge treatment, inspection or traceability merely because its benefit is not immediately visible.

15. Classify rework by the observed defect

Rework family	Typical process causes to check	Immediate control
Deep scratch or stray mark	Contamination, wrong sequence, handling, loose particle, uncontrolled contact	Protect and segregate affected work
Heat tint, burn or distortion	Dwell, excessive force, dull product, poor contact, inadequate cooling	Stop processing and inspect extent
Burr remains or returns	Incomplete access, inconsistent presentation, unsuitable stage, damaged edge	Identify affected features and method
Geometry changed	Excess removal, dwell, unsupported edge, poor fixture or measurement	Hold work and verify dimensions
Uneven finish	Variable overlap, worn support, inconsistent pressure, local loading	Contain visual or measured variation
Embedded contamination	Shared tools, unsuitable abrasive, dirty handling or mixed work area	Segregate material and clean system
Missed area	Poor visibility, route ambiguity, fixture obstruction or handoff error	Mark and control feature coverage
Coating failure after finishing	Residue, surface profile, cleaning or environmental condition	Hold downstream work and trace preparation

Record the defect where it is found and where it was most likely created. The detecting process and originating process may be different.

16. Contain abnormal output

When a defect is detected:

1138. Stop further processing when continuation could create more affected work or increase risk.
1139. Identify the last known conforming condition.
1140. Segregate work produced since that point.
1141. Preserve product, machine, accessory and setting identity.
1142. Assess the defect using the approved acceptance method.
1143. Decide correction, concession, scrap or other disposition through authorised quality control.
1144. Correct the process cause before normal release.

Do not blend out a defect automatically. Additional material removal may affect dimensions, fatigue-sensitive geometry, coating preparation or visual consistency.

17. Find the originating cause

Investigate across the complete system:

- specification and incoming condition;
- abrasive identity, condition and storage;
- machine and support accessory;
- workholding and access;
- method, sequence and change-out rule;
- inspection method and equipment;
- environment, extraction and contamination control; and
- training, workload and communication.

Use repeated observations and physical evidence. A defect concentrated on one edge may point to presentation or support; a defect across operators may point to selection, equipment or instruction. Avoid assigning blame before checking the system.

18. Use error prevention and visual control

Simple controls can prevent repeat work:

- keyed or clearly identified fixtures;
- protected no-touch zones;
- templates for coverage or transition boundaries;
- shadow boards and labelled storage;
- separate colour or status locations for material families;
- approved finish samples under controlled lighting;
- first-piece release markers; and
- route cards that expose incomplete features.

Visual controls must remain understandable, durable and revision-controlled. Colour alone should not be the only distinction where misidentification creates risk.

19. Verify the improvement

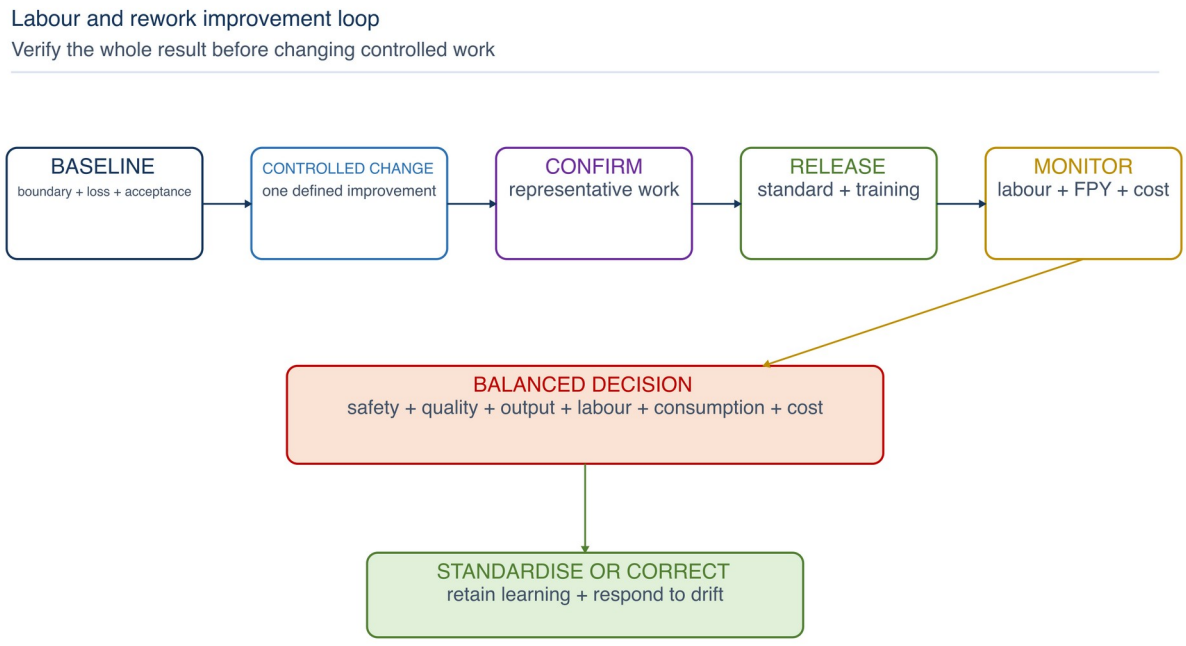

Figure 4. Labour and rework improvement loop. Baseline, controlled change, representative confirmation and monitored release protect the complete process result.

Compare baseline and proposed method using the same process boundary, workpiece population, acceptance method and labour definition. Track:

- labour per accepted unit;

- first-pass yield;
- rework labour and components affected;
- scrap and concession status;
- setup and product-change time;
- waiting and search time;
- abrasive consumption;
- safety or abnormal events; and
- cost per accepted component.

First-pass yield describes output meeting quality requirements without scrap, rerun, retest, return or off-line repair. [S372] Use Chapter 063 for controlled comparisons and Chapter 062 for cost per accepted component. Confirm the result across representative operators, workpiece conditions and production periods before revising controlled work.

20. Sustain the result

Indicator	What it reveals	Review trigger
Labour per accepted unit	Complete processing effort	Sustained movement from baseline
First-pass yield	Prevention effectiveness	Decline by product, job or shift
Rework labour	Hidden correction burden	Repeat defect family or rising hours
Setup/changeover time	Readiness and sequence loss	Variation or recurring wait
Search/wait time	Point-of-use and planning weakness	Repeat location, item or approval delay
Abrasive changes per accepted unit	Selection, use or condition loss	Change without output benefit
Cost per accepted component	Overall economic result	Labour reduction with higher total cost

Review after changes to component design, material, product, machine, accessory, fixture, method, acceptance requirement, staffing or layout. Update the work standard and training after an approved change.

Practical labour-and-rework checklist

Confirm:

- the process boundary ends at accepted handoff;
- labour and rework are measured separately;
- incoming and outgoing conditions are clear;
- the first result is checked after setup or significant change;
- abrasive, accessory, fixture and inspection identities are controlled;
- products, tools, gauges and documents are organised at point of use;
- work height, reach, handling and visibility support control;
- machine, extraction and measurement systems are ready;
- internal and external changeover activities are distinguished;
- defects are contained and traced to the originating process;
- safety, quality, output and cost remain visible together; and
- approved improvements are incorporated into standard work.

Troubleshooting

Problem	Likely cause	Improvement
Labour falls but defects rise	Acceptance or inspection weakened	Restore quality gate and verify method
Operators take very different times	Inputs, sequence or change-out rule vary	Observe work and standardise controllable elements
Rework appears late downstream	Early check does not cover critical feature	Move detection closer to source
Frequent searching interrupts work	Point-of-use locations or status unclear	Organise, label and replenish controlled locations
Product changes are frequent	Wrong selection, loading, damage or subjective rule	Diagnose condition and standardise change-out

Problem	Likely cause	Improvement
Setup time varies widely	Preparation occurs after stoppage	Move safe preparatory work outside stopped period
Finish is inconsistent after breaks	Restart point or overlap is uncontrolled	Define restart and blending method
Operator force rises during task	Product dulling, support wear or machine issue	Stop and diagnose the complete contact system
Same defect returns after correction	Symptom repaired but cause unchanged	Preserve evidence and verify root-cause action
Fixture saves time but access is poor	Productivity change introduced new hazard or variation	Redesign and reassess risk before release

Safety reminder

Labour reduction never justifies bypassing a guard, inspection, extraction, isolation, secure mounting, workholding or PPE requirement. Confirm product and machine compatibility, marked limits, accessory condition and operator authorisation. Stop for abnormal vibration, damage, unexpected heat, loss of secure mounting, unstable work or any condition outside the approved method.

Key takeaways

- Measure labour against accepted output and expose rework separately.
- Define the process boundary so work is not merely transferred elsewhere.
- Prevent defects through clear handoffs, first-result checks and quality at source.
- Standardise product, support, workholding, sequence, inspection and abnormal response.
- Organise the workplace and prepare jobs before the machine stops.
- Improve posture, reach and handling while preserving safeguarding.
- Contain defects quickly and remove the originating cause.
- Verify labour reduction with safety, quality, output, consumption and total cost visible.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 066

Factory Grinding and Finishing KPIs

66

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Factory managers, production engineers, supervisors, QA/QC teams, maintenance personnel, planners, buyers and continuous-improvement teams

Scope: KPI purpose and governance; accepted output; safety and control; quality; flow; labour; abrasive consumption; equipment; cost; data segmentation; visual management; response and review.

Core principle — A useful KPI supports a defined decision and protects the whole result. Grinding output is not successful unless the work is safe, conforming, traceable and economical.

Abrasive operations can look productive while creating hidden rework, excess product use, equipment damage or downstream defects. A balanced measurement system makes these trade-offs visible. It uses a small set of clearly defined indicators, based on comparable work and reliable data, with an agreed response when performance changes.

This chapter provides a practical KPI framework, not universal factory targets. When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- select KPIs from operational decisions and risks;
- create a controlled definition for every measure;
- use accepted output as a common denominator;
- balance safety, quality, flow, labour, abrasive use and cost;
- separate leading controls from lagging results;
- prevent misleading aggregation and metric gaming;
- interpret trends, variation and defect concentration;
- define review limits from local requirements and baselines;
- build a practical tiered dashboard; and
- turn an abnormal signal into controlled improvement.

1. Begin with the decision

Before creating a KPI, state what decision it should support. Examples include:

- Is the process producing accepted output consistently?
- Is a defect increasing, and where is it originating?
- Is abrasive consumption changing after a material or method change?
- Is labour being lost to rework, setup, waiting or product changes?
- Is equipment condition interrupting stable production?
- Has a controlled trial improved total process performance?

NIST research describes KPI assessment as a stakeholder-based activity linked to organisational value, rather than an ad hoc collection of available measures. [S387] If nobody knows what action follows a signal, the measure is probably a report item rather than a key indicator.

2. Build a balanced KPI tree

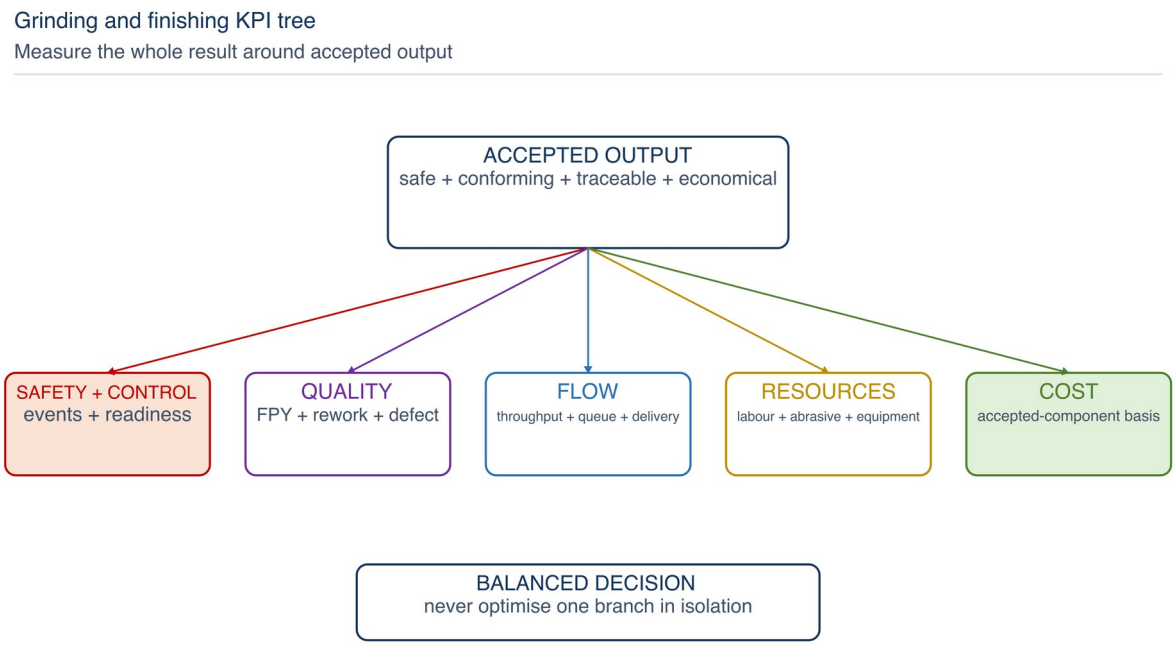


Figure 1. Grinding and finishing KPI tree. Accepted output is supported by safety and control, quality, flow, resources and cost.

Use five connected result families:

Family	Core question	Example indicators
Safety and control	Was work performed within the approved system?	Abnormal events, pre-use control completion, extraction availability
Quality	Did work pass the required checks first time?	First-pass yield, rework, scrap, defect family
Delivery and flow	Did accepted work move as planned?	Accepted throughput, lead time, queue time, schedule completion
Resources and stability	What input was used and where was time lost?	Labour, abrasive use, product changes, downtime
Cost	What did each accepted result consume?	Cost per accepted component, rework cost, material loss

Do not optimise one branch in isolation. Higher output with falling first-pass yield or rising abnormal events is not a sustained improvement.

3. Control the KPI definition

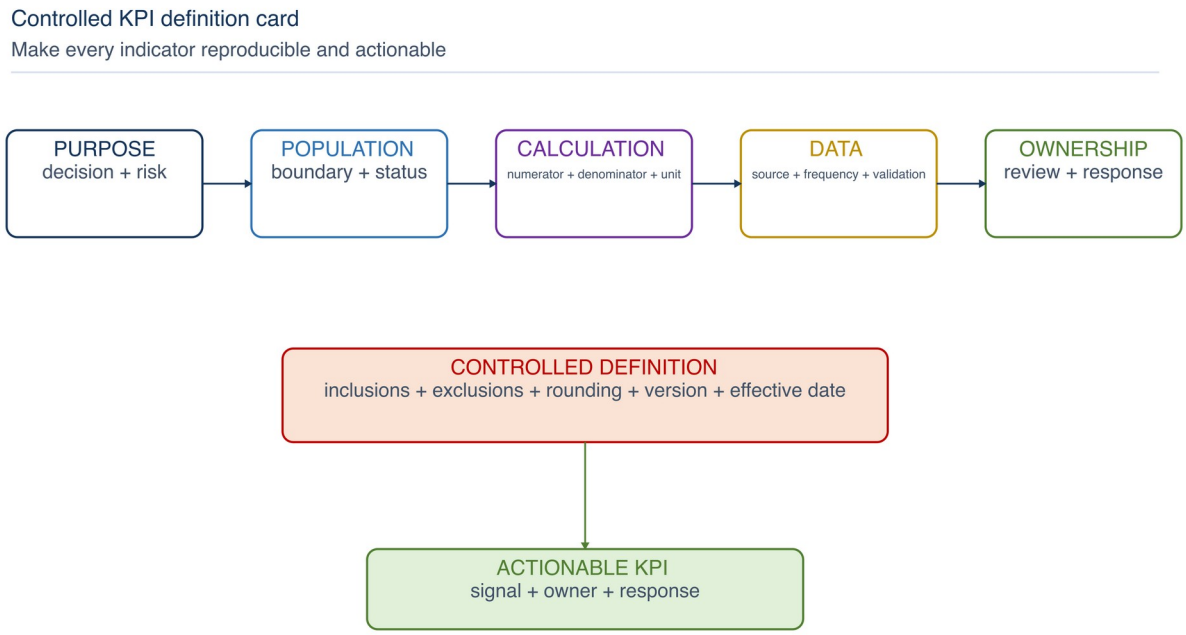


Figure 2. Controlled KPI definition card. Purpose, population, calculation, source, ownership and response make a measure reproducible.

Every KPI needs a controlled definition:

- name and business purpose;
- question or decision supported;
- process boundary and population;
- numerator and denominator;
- included and excluded statuses;
- unit and rounding rule;
- source systems or records;
- collection and reporting frequency;
- responsible owner and reviewer;
- applicable requirement or baseline;
- response to an abnormal result; and
- definition version and effective date.

ISO 22400 provides an industry-neutral framework for defining, composing and using manufacturing-operations KPIs. [S367; S368] This handbook uses transparent shop-floor measures without reproducing proprietary standard tables.

4. Use accepted output as the common denominator

Define output by final status:

- accepted first pass;
- accepted after in-line correction;
- accepted after off-line rework;
- concession or deviation where authorised;
- scrap; and
- unresolved or quarantined.

Where suitable:

Resource per accepted unit = resource used within the boundary ÷ final accepted units

The resource may be direct labour time, abrasive units, energy or total process cost. For continuous work, use accepted length or area. State the unit and keep product family, material and task difficulty visible.

Do not count a partly processed item as accepted output merely because it left the workstation.

5. Separate leading and lagging indicators

Leading indicators show whether controls are in place before loss occurs. Lagging indicators show results after production.

Leading control	Related lagging result
Correct product and accessory verified	Product-related defect or consumption
Machine and extraction ready	Downtime, abnormal event or repeat pass
First-result check completed	Batch rework or late defect detection
Standard work and training current	Method variation and labour spread
Workholding condition confirmed	Geometry, chatter or finish defect
Measurement equipment in controlled status	Invalid acceptance or repeat inspection

Use leading measures to manage the process and lagging measures to verify the outcome. A completed checklist is not proof of conformity, and a good monthly result does not prove every required control was present.

6. Safety and control indicators

Suitable measures may include:

- abrasive, guard, mounting or machine abnormalities reported;
- work stopped for damage, vibration or loss of control;
- extraction unavailable during scheduled work;
- pre-use or first-result control completed;
- overdue machine or accessory condition action;
- unplanned deviation from standard work; and
- corrective actions open beyond their workplace due date.

Use event classification and narrative review rather than chasing a low number. Under-reporting is worse than a visible problem. ISO 45001 supports worker participation, hazard control and continual improvement. [S359]

No generic event target or exposure limit is supplied by this handbook. Applicable Malaysian legal duties and workplace risk controls govern.

7. First-pass yield

First-pass yield shows the proportion of input that completes the defined process and meets its quality requirements without scrap, rerun, retest, return or off-line repair. [S372]

For a clearly defined process:

First-pass yield = first-pass accepted units ÷ units entering the process

State how in-line correction is treated. A brief correction before handoff may be operationally different from off-line rework, but it still consumes time and should not disappear from the record. Use the same rule across the comparison.

For multiple sequential operations, report each operation and the final route result. A high average can hide one weak stage.

8. Rework, scrap and concession

Track these outcomes separately:

Status	Meaning	Recommended companion measure
Rework	Additional authorised processing to meet the original requirement	Rework labour and defect family
Scrap	Work cannot or will not be recovered to accepted status	Material and processing cost already consumed
Concession/deviation	Nonconforming condition accepted by authorised decision	Reason, scope and customer/quality authority

Status	Meaning	Recommended companion measure
Quarantine	Status is unresolved	Age, quantity and decision owner

Do not improve apparent yield by relabelling repair, blending, retest or concession as first-pass work.

9. Defect-family indicators

Use consistent categories that describe the observed condition:

- scratch, gouge or handling mark;
- heat tint, burn or distortion;
- residual burr or sharp edge;
- excessive material removal or geometry change;
- uneven texture, gloss or directional finish;
- embedded contamination or residue;
- missed feature or incomplete coverage;
- cut deviation, breakout or poor edge condition; and
- downstream adhesion or coating-preparation failure.

Report both count and affected output basis. A rare defect may be high risk; a frequent cosmetic correction may dominate labour. Keep severity and occurrence distinct.

10. Accepted throughput and flow

Measure accepted output per defined working period, not gross starts. Useful supporting measures include:

- queue time before grinding or finishing;
- processing time within the operation;
- waiting for product, fixture, information or inspection;
- move and handling time;
- work-in-process quantity and age; and
- schedule completion for released work.

ISO 18828-4 supports multi-level KPI organisation in production planning, while its scope is series production. [S388] For job shops and repair work, segment by comparable route or work family rather than forcing a series-production model.

11. Labour indicators

Use Chapter 065’s defined boundary:

Direct labour per accepted unit = direct labour time ÷ final accepted units

Also record:

- rework labour;
- setup and changeover labour;
- inspection and necessary support time;
- search, movement and waiting loss; and
- assistance or handling labour for large components.

Labour per unit should fall because avoidable work is removed—not because workholding, inspection, rest, extraction or safe handling is weakened.

12. Abrasive-use indicators

Use Chapter 064’s approach:

Abrasive consumption per accepted unit = abrasive units consumed ÷ final accepted units

Companion indicators may include:

- premature change-out;
- loading or glazing occurrence;
- damage before use or during mounting;
- usable partials returned;

- unreconciled issue; and
- abrasive changes per accepted unit.

A lower disc count is not automatically better. Review task time, accepted quality, operator force, rework and safe discard condition together.

13. Equipment and downtime indicators

Classify lost equipment time by cause:

- machine fault or maintenance;
- guard, flange, pad, contact wheel or accessory condition;
- extraction or utility unavailable;
- setup, adjustment or first-result release;
- material, drawing, fixture or inspection unavailable; and
- planned non-production time.

Availability should use an explicitly defined scheduled-time basis. Overall equipment effectiveness combines availability, performance and quality concepts, but it is not a complete measure of manual grinding quality, ergonomics, abrasive consumption or total cost. ASQ describes OEE in terms of operational availability, performance efficiency and first-pass yield. [S372]

Do not calculate OEE merely because the software provides it. Use it only when component factors and the production context are trustworthy.

14. Cost indicators

Chapter 062 defines:

Cost per accepted component = total process cost within the boundary ÷ final accepted components

Keep visible:

- abrasive and accessory cost;
- direct labour;
- machine and energy allocation;
- inspection and normal support;
- rework and scrap;
- disposal and material loss; and
- downstream loss attributable to surface preparation.

ASQ’s cost-of-quality framework distinguishes prevention, appraisal and failure costs. [S365] More prevention or early inspection cost can be economically sound when it reduces internal or external failure.

15. Segment comparable work

A factory-wide average may mix thin sheet, heavy weld removal, stainless finishing, casting cleanup and cutting. Segment by factors that materially affect the work:

- component or work family;
- material and incoming condition;
- operation and finish requirement;
- abrasive form and controlled product identity;
- machine and support accessory;
- manual, semi-automatic or mechanised method;
- shift, team or operator where appropriate; and
- new setup, repeat job or change condition.

Protect personal data and use operator segmentation to identify system support and training needs, not to publish unfair rankings.

16. Protect measurement quality

Confirm that data is complete, traceable and fit for its decision. ISO 10012 requires a managed measurement system that supports confidence in valid and reliable results. [S375]

Check:

- status definitions are understood;
- timestamps use the same boundary;
- counters reset and accumulate correctly;
- manual entries use permitted values;
- measurement equipment is controlled where required;
- rejected and reworked units are not double-counted;
- late entries are reconciled;
- downtime categories are mutually understandable; and
- formula and dashboard versions are controlled.

A precise chart built on inconsistent status codes is not reliable evidence.

17. Use trends and distributions

An average alone hides spread. Review:

- values over time in production sequence;
- median and range where suitable;
- distribution across comparable jobs;
- first-pass and rework paths separately;
- defect Pareto by frequency, labour and cost;
- product/machine combinations; and
- annotations for planned changes or abnormal events.

Do not react to every single fluctuation. First confirm data validity, product mix and known special causes. Investigate a sustained shift, unusual pattern or high-consequence event under the workplace response rule.

18. Set review limits locally

Use these inputs, in order:

1145. safety, legal, customer and drawing requirements;
1146. product and machine limits;
1147. approved process and quality-plan conditions;
1148. stable representative baseline and demonstrated capability;
1149. business objectives and improvement priorities; and
1150. controlled-trial evidence for a proposed change.

Do not copy an internet benchmark into a production target. A target without a comparable boundary, population and acceptance rule can drive the wrong behaviour.

19. Build a tiered dashboard

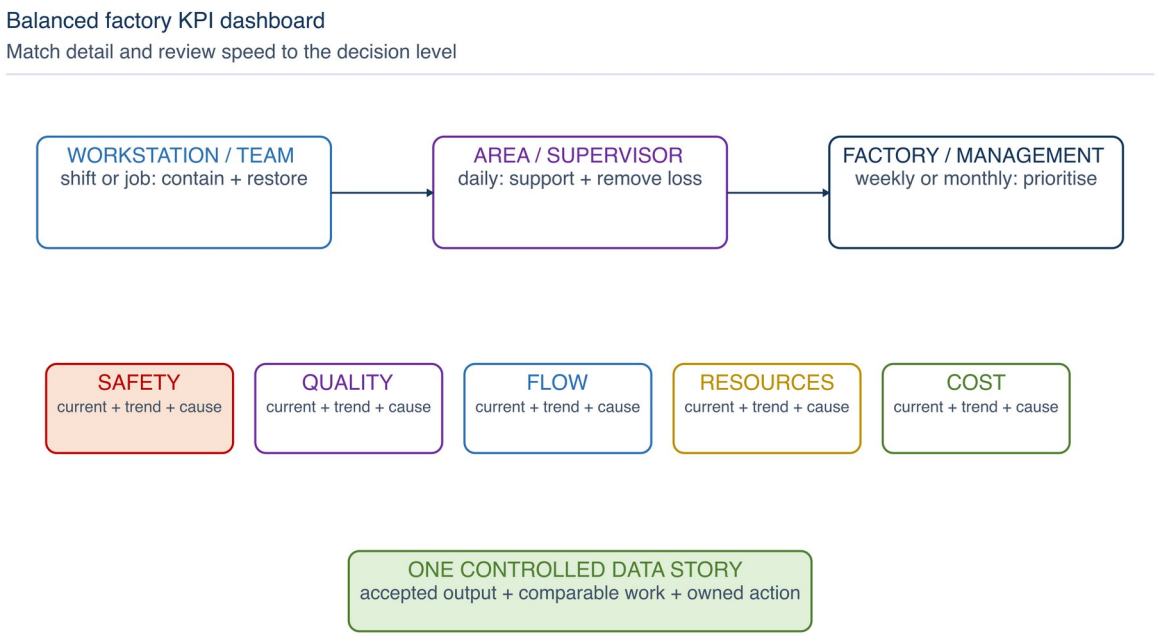


Figure 3. Balanced factory KPI dashboard. Each management level receives enough detail to make its decisions without losing the connection to accepted output.

Review level	Frequency	Useful content	Expected decision
Workstation/team	Shift or job	Safety status, first result, output, defect, downtime cause	Contain and restore control
Area/supervisor	Daily or scheduled	FPY, rework, labour, abrasive use, flow and open action	Allocate support and remove recurring loss
Factory/management	Weekly or monthly	Trends, major defect/cost families, capacity risk, improvement status	Prioritise resources and approve change

Frequency should match risk, volume and decision speed. High-risk abnormalities require immediate response and should not wait for the dashboard meeting.

Use a concise display with current value, local reference, trend, status, cause and action owner. Avoid decorative charts that do not change a decision.

20. Respond to an abnormal signal

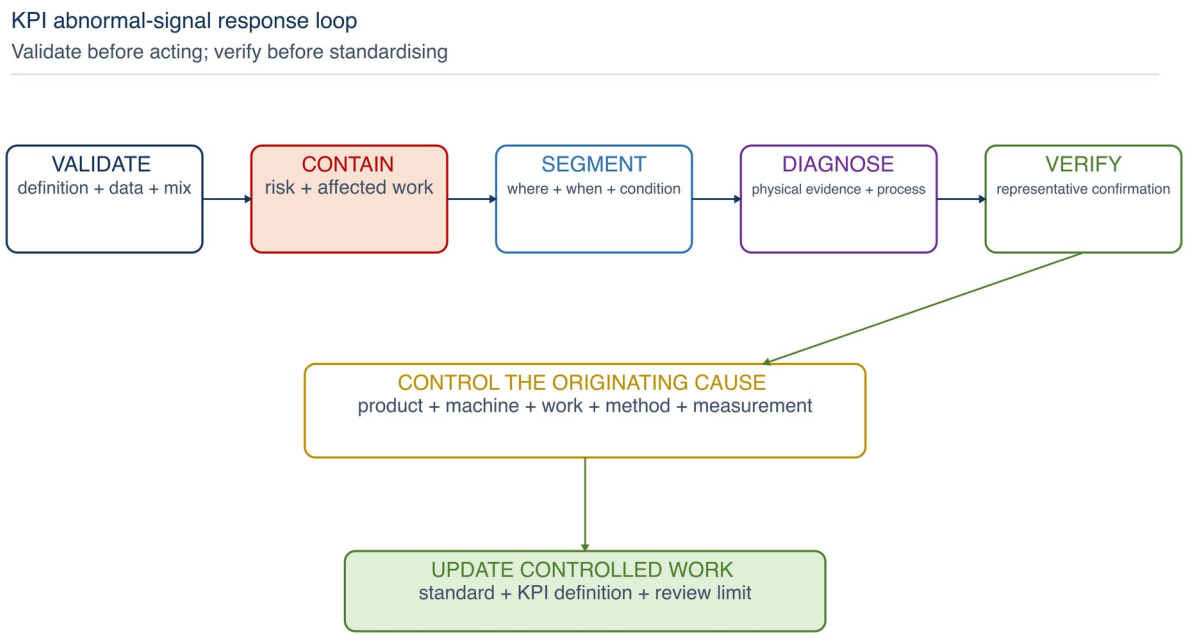


Figure 4. KPI abnormal-signal response loop. Validate the data, contain risk, diagnose the process and verify corrective action before revising the standard.

Use this sequence:

1151. verify the data definition, completeness and calculation;
1152. check whether product mix or process boundary changed;
1153. contain affected work or unsafe conditions;
1154. segment the signal to find where and when it occurs;
1155. inspect physical evidence, equipment and standard-work conditions;
1156. identify and control the originating cause;
1157. verify the action on representative work; and
1158. update the metric definition, work standard or review limit if approved.

Do not change the abrasive specification from a dashboard result alone. Use the controlled product-trial method in Chapter 063 when selection or method change is proposed.

Practical KPI-definition checklist

Confirm:

- the measure supports a named decision;
- the process boundary and population are explicit;
- accepted, rework, scrap, concession and quarantine statuses are separate;
- numerator, denominator, unit and rounding are controlled;
- source data and responsible owner are known;
- product mix and task difficulty remain visible;
- safety, quality, flow, resource and cost measures are balanced;
- leading controls and lagging results are distinguished;
- local review limits have an applicable basis;
- abnormal signals trigger a defined response;
- formulas, dashboards and definitions have revision control; and
- no KPI rewards unsafe speed, overuse or reduced acceptance control.

Troubleshooting

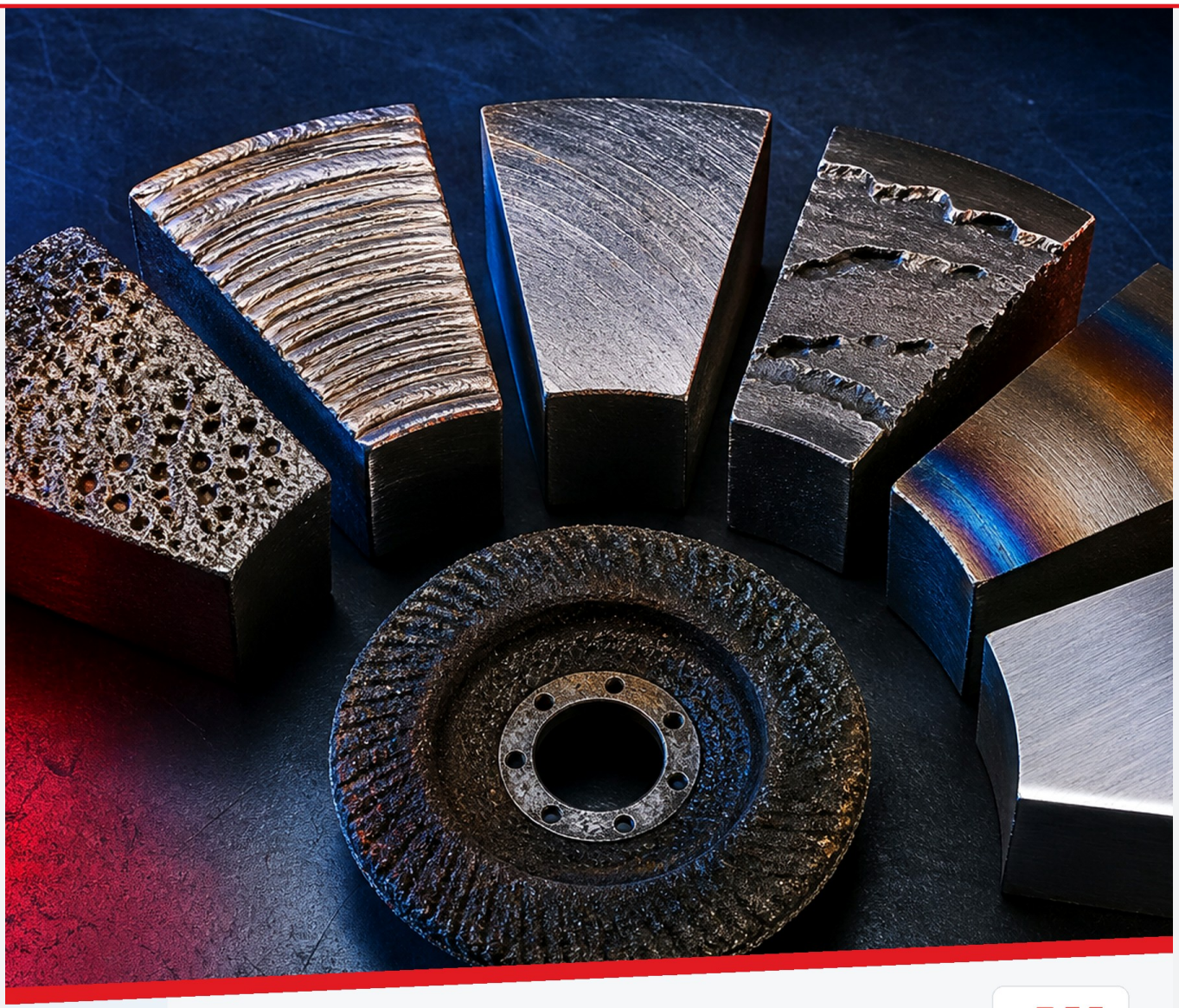
Problem	Likely cause	Improvement
Output rises while customer defects rise	Gross output is used instead of accepted output	Restore quality status to the denominator
FPY looks high but rework labour is rising	In-line correction is hidden	Define and record correction consistently
Abrasive use varies sharply	Product mix or issue/return status is uncontrolled	Segment work and reconcile consumption
OEE rises but finishing cost increases	Equipment metric omits labour, abrasive and rework	Add accepted-component resource and cost measures
Factory average is stable but one cell struggles	Incomparable work is aggregated	Segment by work family, material and operation
Dashboard values are disputed	Definitions or source fields differ	Issue a controlled KPI definition card
Teams stop reporting abnormalities	Low event count is rewarded	Measure reporting and corrective response quality
Every fluctuation causes an adjustment	Natural variation is treated as a special cause	Review trend, mix and evidence before changing
Target is achieved through over-processing	Finish requirement is unclear	Link KPI to controlled acceptance criteria
Reports grow but action does not improve	Measures have no decision owner	Remove or redesign non-actionable indicators

Safety reminder

No productivity, availability, labour, consumption or cost KPI overrides product marking, machine limits, guarding, mounting, extraction, secure workholding, inspection, PPE or stop-work conditions. Never reward an operator for suppressing an abnormal event or using an abrasive beyond its safe condition.

Key takeaways

- Start with decisions, risks and accepted output.
- Give every KPI a controlled definition and owner.
- Balance safety, quality, flow, resources and cost.
- Keep first-pass, correction, rework, scrap and concession distinct.
- Segment comparable work before drawing conclusions.
- Use OEE only where its factors and scope are trustworthy.
- Set review limits from requirements, risk and local evidence.
- Validate the signal, contain risk and verify action before revising controlled work.



SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 067

Grinding Problems

67

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Grinding operators, supervisors, production engineers, maintenance personnel, QA/QC teams and technical buyers

Scope: Stop conditions; evidence preservation; vibration and chatter; heat and burn; slow cutting; rapid wear; loading and glazing; poor finish; deep scratches; geometry loss; edge damage; dust and swarf; hand-held and stationary grinding; controlled correction and verification.

Core principle — A grinding symptom is evidence, not a diagnosis. Check the product, machine, mounting, support, workpiece, method and environment before assigning the cause.

Grinding performance depends on a connected system. A sound abrasive can behave poorly on a worn machine, incorrect support pad, unstable fixture or contaminated surface. Conversely, changing the machine or technique cannot make a damaged or incompatible wheel safe. Effective troubleshooting separates immediate stop conditions from process symptoms, preserves evidence and changes one controlled factor at a time.

When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- recognise conditions that require immediate stop and isolation;
- record a grinding symptom without destroying evidence;
- inspect the complete product–machine–workpiece system;
- distinguish vibration, heat, cutting, wear, loading and finish problems;
- select safe first checks before changing a specification;
- separate hand-held and stationary-machine mechanisms;
- avoid corrections that create a new hazard or defect;
- verify corrective action against accepted output; and
- escalate repeat or high-consequence problems through controlled review.

1. Stop first when the condition is unsafe

Stop, isolate and inspect when there is:

- a crack, tear, separation, deformation or missing abrasive section;
- sudden or increasing vibration, chatter or abnormal noise;
- loose mounting, movement at the flange, pad, adaptor or mandrel;
- contact between the abrasive and guard or machine structure;
- damaged guard, handle, work rest, control or power connection;
- unstable workholding, pinching, kickback or loss of work control;
- smoke, fire, unexpected sparking location or suspected combustible dust event;
- suspected overspeed, wrong product identity or missing marking; or
- any condition outside the approved method.

Manufacturer guidance specifically advises stopping immediately when a tool begins to chatter or vibrate and finding the cause before continuing. [S390] Do not perform a test pass with an already suspect product.

2. Preserve the evidence

Before cleaning, dressing, discarding or adjusting, record:

- product identity, lot/batch and visible condition;
- machine, accessory and mounting arrangement;
- workpiece material, geometry and incoming condition;
- operation, processing stage and acceptance requirement;
- location and pattern of the symptom;
- operator observations of sound, vibration, force, sparks, swarf and heat;
- elapsed use or accepted output since change-out;
- extraction, coolant or lubricant status where applicable; and
- recent changes to product, material, machine, fixture or method.

Photograph the product and workpiece safely after isolation. Segregate damaged or unidentified abrasives so they cannot return to use.

3. Use a complete-system diagnostic sequence

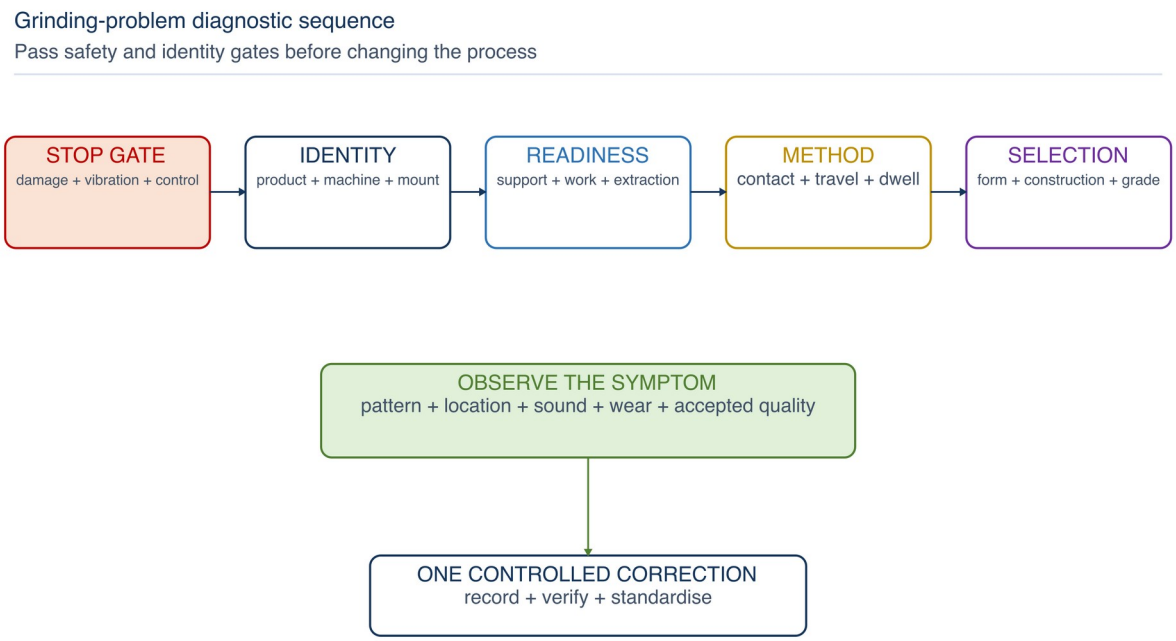


Figure 1. Grinding-problem diagnostic sequence. Safety and identity gates come before machine, support, workpiece, method and selection changes.

Check in this order:

1159. safe condition and product identity;
1160. machine and mounting condition;
1161. support accessory, work rest and workholding;
1162. workpiece material, coating and incoming variability;
1163. contact, travel, dwell, overlap and operator control;
1164. extraction, chip clearance or coolant condition; and
1165. abrasive form, construction and grade family.

This order finds common physical causes before introducing a new product variable.

4. Build a symptom map

Symptom	Immediate concern	First diagnostic focus
Sudden vibration or chatter	Product damage, loose mount, contact or unstable work	Stop; inspect product, mount, machine and fixture
Burn, heat tint or distortion	Thermal damage and altered geometry	Hold work; inspect cutting action, dwell and cooling
Slow cutting or rising force	Dulling, glazing, loading, machine output or wrong selection	Inspect abrasive face and complete contact system
Rapid abrasive loss	Excess force, impact, unsuitable construction or support	Inspect wear pattern and workpiece presentation
Loading	Removed material obstructs cutting surface	Check material, contamination, openness and chip clearance
Glazing	Dull surface is not renewing effectively	Check selection, engagement, dressing permission and method
Deep or random scratches	Coarse particle, contamination, torn product or sequence error	Stop transfer; clean and inspect
Wavy or uneven finish	Vibration, runout, support wear, overlap or workholding	Compare pattern with machine and contact motion

Symptom	Immediate concern	First diagnostic focus
Edge gouging or undercut	Localised contact, hard support, high presentation angle or dwell	Inspect access, pad and edge technique
Dimensional or form error	Excess removal, deflection, thermal growth or wheel truth	Hold work and verify geometry

One symptom can have several causes, and one cause can create several symptoms.

5. Vibration and chatter

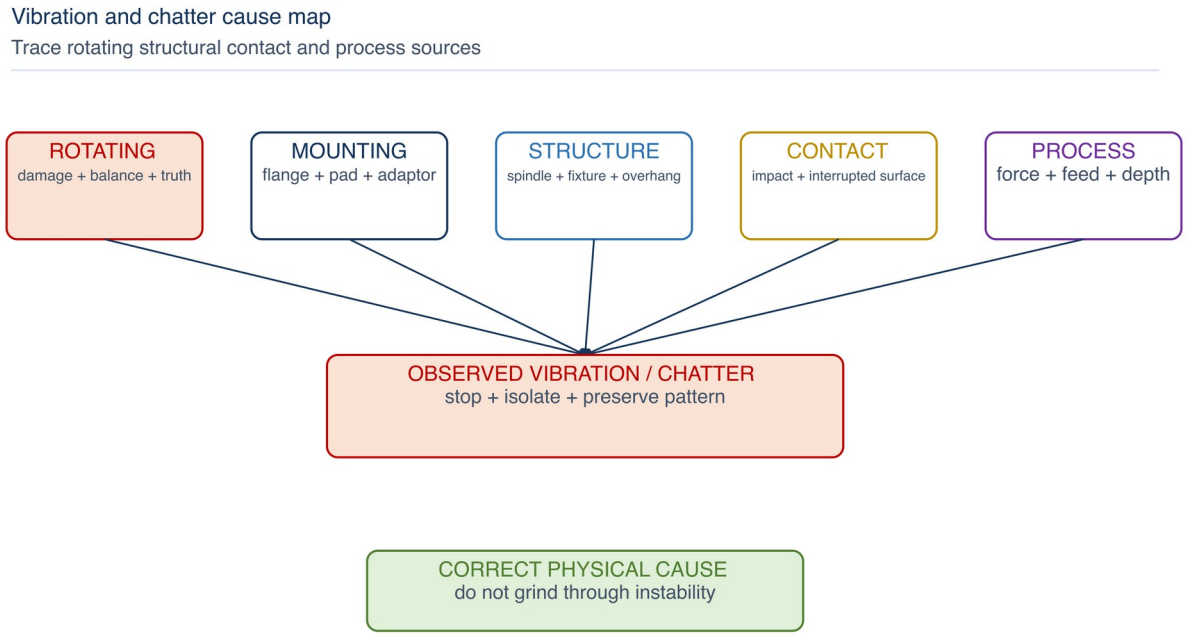


Figure 2. Vibration and chatter cause map. Rotating condition, structural support, contact and process inputs converge at the observed vibration.

Check:

- damaged, distorted or out-of-balance abrasive;
- debris, burrs or incorrect contact at mounting faces;
- loose flange, adaptor, mandrel, collet or backing pad;
- spindle, bearing, drive or air-supply condition;
- guard or accessory contact;
- wheel truth and permitted dressing condition on stationary equipment;
- worn support pad, contact wheel or work rest;
- excessive product or workpiece overhang;
- flexible, loose or resonant workholding;
- intermittent edge contact or impact; and
- force, feed or depth beyond stable engagement.

Chatter can result from loss of truth, mounting slip, wheel condition or insufficient work support. [S389] HSE guidance also connects dull, hard-cutting wheels and excessive force with greater vibration and wheel-distortion risk. [S378]

Do not balance, true or dress a product unless the exact product and machine system permits it and the task is performed by an authorised person.

6. Burning, heat tint and distortion

Heat can be generated by rubbing, dull grains, loading, excessive engagement, long dwell, poor coolant delivery, inadequate chip clearance or a sequence that concentrates heat. Check:

- whether the abrasive is cutting or rubbing;

- loading, glazing or contaminated surface;
- rising operator force;
- dwell, overlap and repeated passes in one zone;
- contact area and support hardness;
- machine output and speed control;
- workpiece thickness, restraint and heat sensitivity;
- coolant delivery, condition and filtration where applicable; and
- abrasive construction and grain-renewal behaviour.

Surface-grinding guidance links friction and heat with chatter, burn and poor finish, and includes grain condition, structure, dressing and coolant among the variables. [S391]

Visible colour removal does not prove that thermal or metallurgical damage is absent. Apply the controlled acceptance and inspection method appropriate to the component.

7. Slow cutting and rising force

When cutting action declines, do not simply press harder. Inspect for:

- abrasive surface loaded with swarf, coating, adhesive or residue;
- glazed or polished cutting surface;
- worn or unsuitable support accessory;
- low machine output, supply restriction or speed-control fault;
- excessive contact area;
- incorrect abrasive form, grain family, grit or construction;
- workpiece hardness or coating different from the expected condition;
- inadequate extraction or chip clearance; and
- product used beyond its efficient or safe condition.

Measure accepted output and task time together. A product that remains physically present but no longer cuts efficiently can increase labour, force, heat and exposure.

8. Rapid abrasive wear or shedding

Inspect the wear pattern. Uniform controlled wear differs from local edge loss, tearing, chunking or one-sided wear.

Likely causes include:

- excessive force or feed;
- impact on edges, projections or interrupted surfaces;
- unsuitable product construction for contact severity;
- excessive flex or insufficient support;
- incorrect pad, flange, contact wheel or mandrel;
- misalignment or poor tracking;
- unstable workpiece;
- heat or chemical contamination; and
- use on a prohibited face or edge.

Do not select a harder or more durable product solely to reduce visible wear. Preserve cutting efficiency, controllability, accepted quality and safe use.

9. Loading

Loading occurs when removed material or residue occupies the abrasive surface and obstructs cutting. It may appear as metallic transfer, packed dust, coating or smeared material.

Check:

- soft or ductile material behaviour;
- paint, scale, adhesive, grease or sealant;
- abrasive openness and chip space;
- grit and construction suitability;
- contact pressure and dwell;
- extraction, air flow or approved coolant;
- support condition and contact area; and

- cross-contamination from previous work.

Do not strike, scrape, burn or solvent-clean a loaded abrasive unless an approved product-specific method permits it.

10. Glazing

Glazing is a dull, smooth condition in which the abrasive surface no longer renews effectively. The operator may hear a changed sound and apply increasing force while removal falls.

Possible contributors include:

- abrasive grade or bond too durable for the engagement;
- insufficient effective engagement;
- inappropriate machine or work speed relationship;
- large contact area with low grain penetration;
- ineffective or overdue permitted dressing;
- contaminated coolant or workpiece; and
- machine output below the intended operating condition.

Loading and glazing can occur together, but they are not identical. Inspect the surface and process evidence before changing the abrasive.

11. Poor or inconsistent finish

Check whether the defect is random, directional, periodic or concentrated at an edge. Then inspect:

- grit and stage progression;
- complete removal of previous-stage scratches;
- torn, contaminated or locally worn abrasive;
- support-pad or contact-wheel condition;
- runout, truth, balance and vibration;
- workholding and component deflection;
- travel speed, overlap, direction and dwell;
- cleaning between stages; and
- inspection lighting, comparator and measurement method.

Grit designation alone does not guarantee a finish. P, F and superabrasive designations belong to different standards contexts and should not be converted casually. [S346; S347; S348; S349]

12. Deep scratches and stray marks

Deep scratches commonly originate from:

- a retained coarse particle from an earlier stage;
- contaminated bench, glove, cloth, compound or work support;
- torn backing or exposed product edge;
- loose swarf trapped under the abrasive;
- incorrect first contact or tool placement;
- mixing products between carbon steel, stainless steel or non-ferrous work; and
- handling after finishing.

Stop before carrying the defect through finer stages. Clean the workpiece and equipment, identify the scratch depth and return to the earliest necessary correction stage without removing more material than permitted.

13. Wavy, lobed or periodic marks

A repeating pattern often points to a repeating mechanical or motion source. Compare mark spacing and direction with:

- wheel, disc, pad or spindle rotation;
- belt splice or contact-wheel rotation;
- workpiece rotation or feed;
- machine vibration or nearby equipment;
- fixture resonance;
- cyclic operator motion; and
- intermittent contact from runout or loss of truth.

Stationary grinding guidance emphasises rigid work support because vibration produces chatter or wave marks. [S389] Correct the mechanical source before changing grit.

14. Edge gouging, undercut and geometry loss

Edges concentrate contact and can remove material quickly. Check:

- approach and presentation angle;
- pad hardness and product flexibility;
- contact on the product edge rather than supported face;
- dwell at starts, stops or direction changes;
- fixture obstruction and poor visibility;
- excessive force;
- abrasive too aggressive for the final geometry; and
- missing protection for adjacent datum or finished surfaces.

Use suitable fixtures, templates or protected zones where approved. Confirm dimensions after correction; visual blending alone does not prove geometry is acceptable.

15. Cracking, chipping or product separation

Treat any crack, chunk loss, delamination, hub damage or separation as a stop condition. Possible origins include impact, poor storage, incorrect mounting, flange mismatch, excessive side pressure, workpiece movement, pinching, wrong machine use or overspeed.

Do not re-mount a damaged product to reproduce the symptom. Preserve it for examination and inspect related stock, packaging, machine mounting parts and workpiece support. Current standards distinguish intended product and machine scopes; for example, angle-grinder grinding wheels, pneumatic grinders, die grinders and stationary grinding machines are not interchangeable categories. [S278; S280; S282; S283; S284]

16. Dust, swarf and extraction problems

Poor capture can obscure the contact zone, promote loading, contaminate surfaces and increase worker exposure. Check:

- hood or nozzle position;
- blocked hose, duct or filter;
- damaged connection or leakage;
- collector and fan status;
- product/work orientation relative to capture;
- material-specific combustible-dust and contamination controls; and
- whether the extraction system is suitable for the actual dust and spark stream.

Never direct hot sparks or incompatible dust into an unsuitable collector. Apply the workplace chemical and combustible-dust risk controls.

17. Hand-held grinder problems

For hand-held operations, give particular attention to:

- two-hand control and handle position;
- operator stance and line of fire;
- cable, hose or battery condition;
- guard and accessory compatibility;
- disc/pad support and secure mounting;
- workpiece security and access;
- tool power under load;
- edge striking, rocking and dwell; and
- increasing fatigue or force.

The operator is part of the control loop, but repeated difficulty across operators often indicates selection, access, support or equipment problems rather than individual technique alone.

18. Stationary grinding problems

For bench, pedestal, surface and other stationary grinding systems, check the applicable machine-specific controls, including:

- wheel mounting, flanges and blotters where required;
- guard and work-rest condition;
- spindle, bearing and drive condition;
- wheel truth, balance and permitted dressing;
- table, chuck, centres or fixture rigidity;
- feed, infeed and work-speed controls;
- coolant delivery, concentration, filtration and temperature where applicable; and
- machine foundation and external vibration.

ISO 16089:2025 provides a current safety framework for specified stationary grinding-machine groups. [S284] It does not replace the machine manual or confirm that a particular wheel, guard or process is suitable.

19. Apply one controlled correction

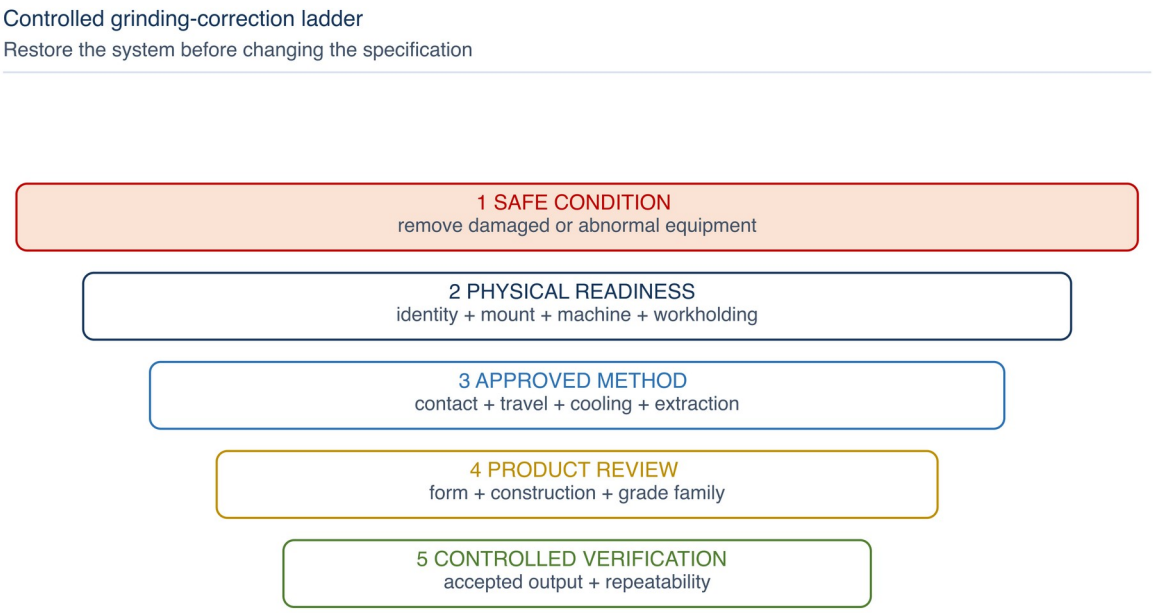


Figure 3. Controlled grinding-correction ladder. Correct safe condition and physical readiness before changing method or abrasive selection.

Use the least disruptive verified correction:

1166. remove unsafe or damaged equipment/product from service;
1167. restore identification, correct mounting and support;
1168. correct machine, extraction, coolant or workholding condition;
1169. restore the approved contact and travel method;
1170. condition or dress only where specifically permitted;
1171. review product form, construction and grade family; and
1172. conduct a controlled comparison before specification change.

Record what changed. Multiple simultaneous changes may hide the cause and make the result impossible to reproduce.

20. Verify and sustain the correction

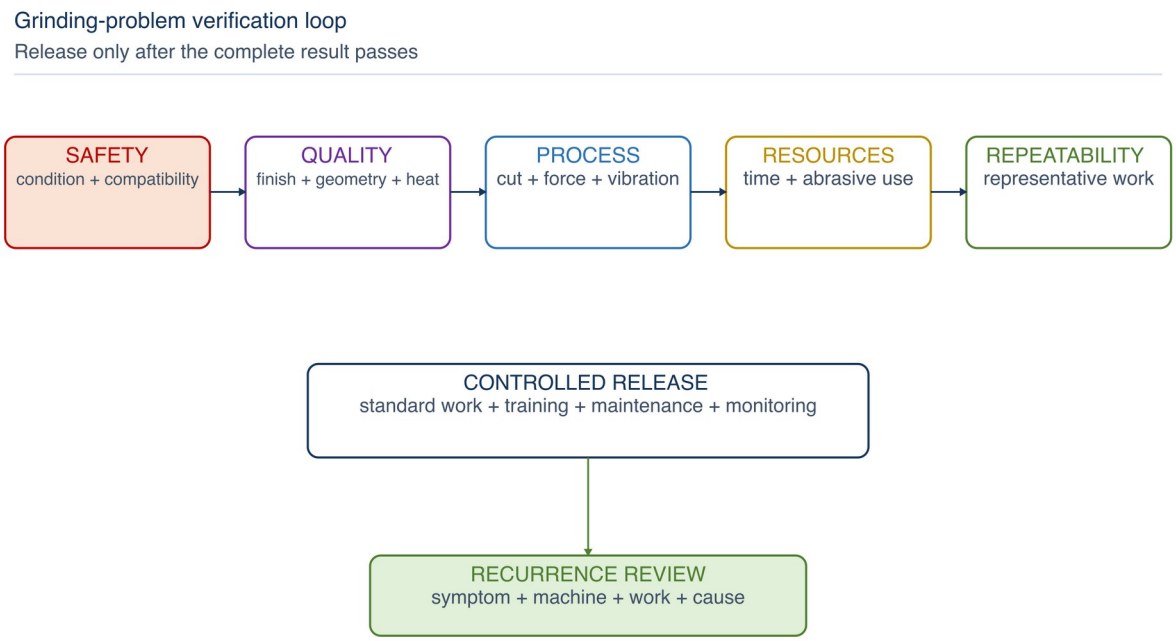


Figure 4. Grinding-problem verification loop. A correction passes safety, quality, process and repeatability gates before controlled release.

Confirm:

- safe condition and compatibility;
- accepted finish, dimensions and geometry;
- absence of unacceptable thermal or surface damage;
- stable sound, vibration and operator control;
- productive cutting without abnormal force;
- task time and abrasive use on an accepted-output basis;
- repeatability across representative work; and
- updated standard work, training or maintenance action.

Monitor recurrence by symptom, product, machine, work family and originating cause. Use Chapter 063 for controlled product or method trials and Chapter 066 for ongoing indicators.

Rapid troubleshooting table

Problem	Check first	Controlled direction
Sudden vibration	Damage, mount, spindle, guard contact, workholding	Stop and correct physical cause
Burn or heat tint	Cutting action, loading/glazing, dwell, cooling	Reduce rubbing and restore controlled removal
Slow cut	Abrasive face, machine output, contact area	Diagnose before applying more force
Rapid wear	Force, impact, support, construction	Stabilise contact and review suitability
Loading	Material/residue, openness, chip clearance	Prevent packing and contamination
Glazing	Grain renewal, engagement, permitted dressing	Restore cutting condition under exact instructions
Random scratches	Contamination, torn product, trapped particle	Clean, isolate and correct from required stage
Wavy finish	Runout, truth, vibration, fixture	Correct repeating mechanical source
Edge gouge	Presentation, support hardness, dwell	Improve access and supported contact

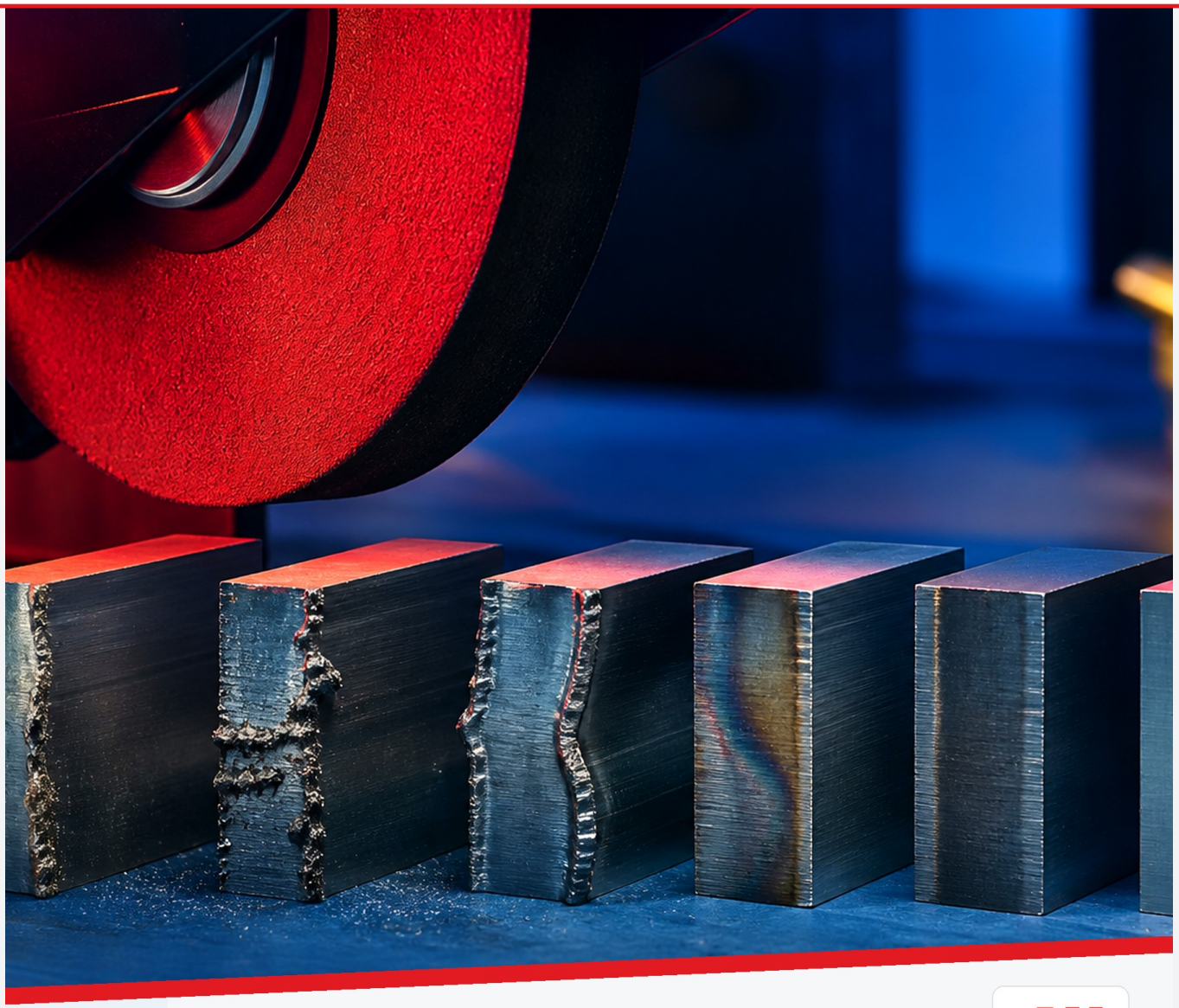
Problem	Check first	Controlled direction
Geometry loss	Excess removal, deflection, heat, measurement	Hold work and verify dimensional status

Safety reminder

Never troubleshoot a rotating or energised machine by touching the abrasive, mount or workpiece. Isolate before inspection or adjustment. Do not exceed marked limits, defeat guards, use a damaged product, force a poor-cutting wheel, dress an unsuitable product or continue after abnormal vibration. Confirm the exact product, machine, accessory, workholding, extraction and PPE requirements.

Key takeaways

- Treat the symptom as evidence, not proof of one cause.
- Stop immediately for damage, looseness, abnormal vibration or loss of control.
- Preserve the product, workpiece and process evidence.
- Check machine, mounting, support and workholding before changing selection.
- Distinguish loading from glazing and heat from visible colour alone.
- Change one controlled factor at a time.
- Verify the complete accepted result before release.



SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 068

Cutting Problems

68

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Cutting operators, supervisors, production engineers, maintenance personnel, QA/QC teams and technical buyers

Scope: Cut-off wheel integrity; guards and mounting; work support; kerf behaviour; binding and kickback; wheel breakage; slow cutting; stalling; cut deviation; burr and breakout; heat; wheel wear; interruption, re-entry and verification.

Core principle — A cutting wheel must remain on its designed cutting surface and in the intended cutting plane. If the work moves, the kerf closes or the wheel binds, stop and correct the physical cause.

Abrasive cutting problems are often system problems. Wheel damage, incorrect flanges, weak work support, a closing kerf, unstable guidance, machine power loss or unsuitable selection can produce the same symptom. Troubleshooting must begin with wheel integrity and control of the cut—not with additional force.

When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- identify cutting conditions that require immediate stop;
- confirm product, machine, guard and mounting compatibility;
- support work so the kerf remains controlled;
- recognise and prevent binding, pinch and kickback;
- diagnose slow cutting, stall, deviation, burr, heat and rapid wear;
- preserve evidence after wheel damage or breakage;
- interrupt and re-enter a cut only under the applicable machine instructions;
- distinguish hand-held and fixed-machine causes; and
- verify a correction against safety, cut quality, time and abrasive use.

1. Immediate stop conditions

Stop, isolate and inspect when there is:

- a cracked, chipped, warped, distorted or partly separated wheel;
- abnormal vibration, noise or contact with the guard;
- loose mounting, damaged flange or visible wheel movement;
- binding, pinching, kickback or uncontrolled tool movement;
- machine stall or repeated severe speed loss;
- workpiece movement or collapsing support;
- smoke, fire, unexpected heating or suspected combustible residue;
- loss of cut-line visibility or safe body position; or
- doubt about product identity, intended use or speed compatibility.

Do not pull a rotating wheel sideways from a cut. Maintain control, release the operating control as directed and allow complete stop before removal. Investigate the cause before restarting.

2. Confirm the complete identity

Check:

- cutting-wheel type and full product marking;
- intended material and operation;
- designed cutting surface;
- wheel dimensions and mounting interface;
- marked maximum speed relative to machine speed;
- machine type and capacity;
- correct cutting guard and handle;
- correct, clean, undamaged flanges and mounting parts;
- product condition and storage history; and
- current machine instructions and workplace method.

ISO 603-16 defines dimensional scope for common hand-held cutting-off wheel types, while ISO 11148-7 and IEC 62841-2-3 cover different non-electric and electric grinder safety contexts. [S088; S096; S280; S283] These standards do not establish an MKTECH product–machine pairing.

3. Use a cutting-problem diagnostic sequence

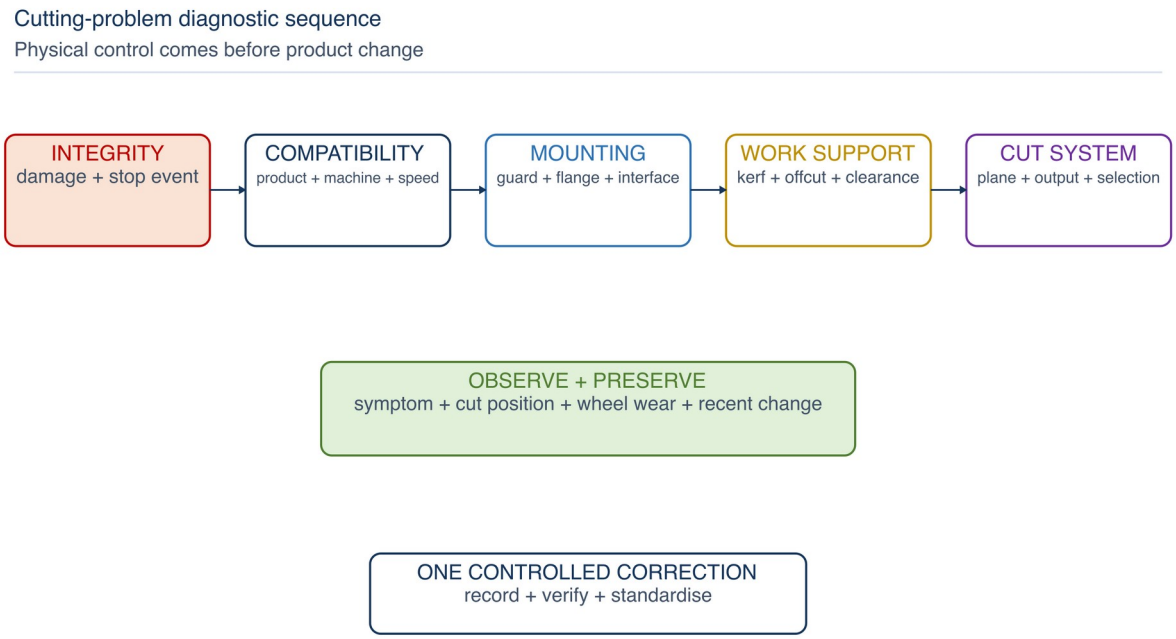

Figure 1. Cutting-problem diagnostic sequence. Integrity, compatibility and work support are checked before technique or product selection is changed.

Check in order:

1173. wheel condition and stop event;
1174. product, machine and speed relationship;
1175. guard, flange and mounting condition;
1176. workpiece support and expected kerf movement;
1177. straight-plane entry, travel and exit;
1178. machine output, extraction or coolant where applicable; and
1179. wheel construction and application suitability.

Record the observed symptom, cut position and wheel wear pattern before disturbing the evidence.

4. Control work support and the kerf

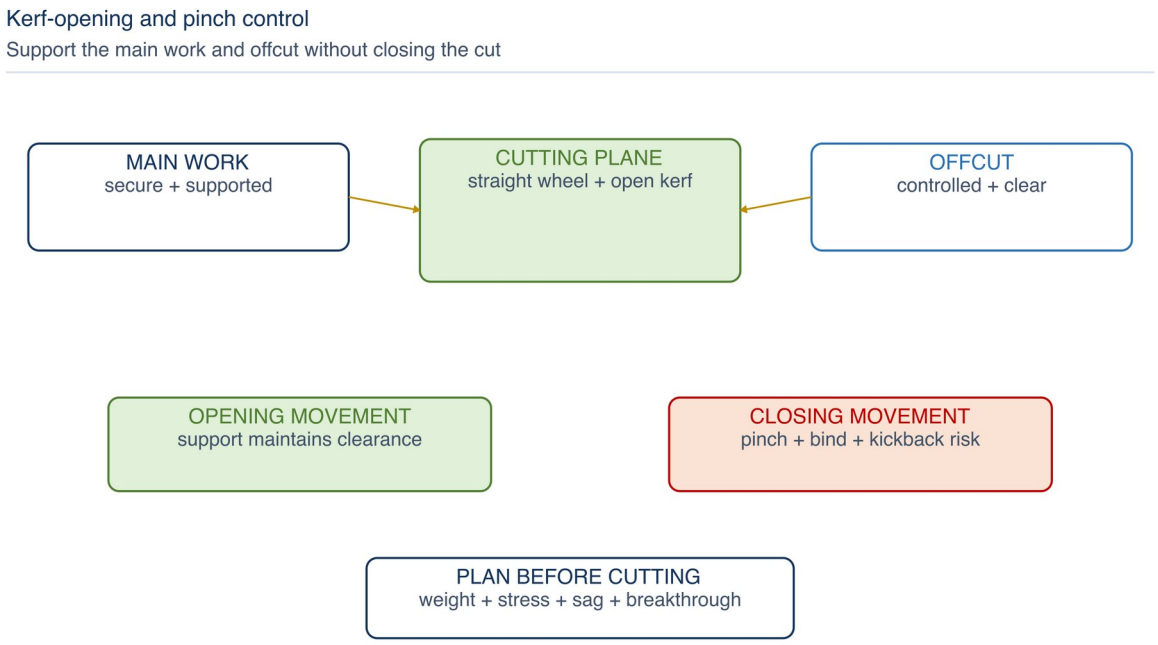

Figure 2. Kerf-opening and pinch control. Support must keep both the main work and offcut controlled while preventing the cut from closing on the wheel.

Plan how the work will move as material is removed. Consider self-weight, residual stress, curvature, section shape, temperature and offcut mass. Support should:

- prevent the main work from shifting;
- prevent the offcut from dropping unpredictably;
- keep the kerf from closing on the wheel;
- avoid excessive sag in sheet, plate, tube or profile;
- provide clearance for the wheel to complete the cut;
- avoid trapping the wheel at breakthrough; and
- retain safe access and line-of-fire control.

Work movement and wheel pinching are major cutting-wheel breakage mechanisms. [S392] The exact support arrangement depends on the component and must be assessed before cutting.

5. Binding, pinching and kickback

Binding occurs when the wheel is squeezed, deflected or obstructed in the cut. Kickback is a sudden reaction that can drive the tool or work unpredictably.

Common causes include:

- the kerf closing under weight or residual stress;
- offcut rotation or drop;
- tool twisting or cut-line correction while engaged;
- misaligned entry or re-entry;
- unsupported large sheet or profile;
- cut through a hidden object;
- wheel stalled by excessive feed;
- workpiece movement; and
- using a wheel or machine outside its intended capacity.

Stop after a bind. Inspect the wheel, mounting and work support. Do not resume with a wheel that may have been side-loaded or damaged.

6. Keep the wheel in the cutting plane

Cutting-off wheels are thin and designed to cut on the permitted periphery. They are not general side-grinding tools. Side pressure can damage reinforcement or overstress the wheel. [S393]

Avoid:

- twisting to steer the cut;
- levering the wheel to widen the kerf;
- grinding a burr with the wheel side;
- forcing a curved cut with a straight-cut product;
- entering at an uncontrolled angle;
- bumping the work at first contact; and
- allowing the work to push the wheel sideways at breakthrough.

If the cut is off line, stop safely and reassess. Do not bend the wheel back toward the mark while it is engaged.

7. Wheel breakage or major damage

After a breakage:

1180. stop and isolate the machine and work area;
1181. attend to people and immediate hazards under emergency procedure;
1182. prevent equipment restart;
1183. retain all wheel fragments, labels and packaging where safe;
1184. preserve flanges, adaptors and mounting arrangement;
1185. record machine, workpiece, cut position and operating observations;
1186. quarantine related products where indicated; and
1187. involve the responsible technical, safety and quality personnel.

Do not discard fragments or rebuild the arrangement merely to reproduce the event. Investigate all credible breakage causes, including overspeed, mounting, clamping, side force, machine condition, feed, coolant and product selection. [S392]

8. Slow cutting and excessive force

Check:

- wheel glazing or loading;
- incorrect wheel family for material or section;
- machine power, supply and speed-control condition;
- wheel used beyond efficient condition;
- excessive contact length;
- thick coating, scale or contamination;
- cut path obstructed by swarf;
- unstable work causing rubbing; and
- operator feed exceeding the wheel’s cutting response.

Do not compensate by leaning harder. Excessive force can heat, deflect or damage the wheel and can increase loss of control. HSE guidance favours cutting efficiency over nominal maximum wheel life. [S378]

9. Machine slows or stalls

A stall or severe speed drop may result from binding, excessive feed, inadequate power supply, worn drive components, incorrect machine capacity or a poorly cutting wheel. Stop and inspect before re-entry.

For pneumatic tools, check supply and hose condition under the machine instructions. For electric tools, check power source, controls and overload response. For fixed cut-off machines, check drive, spindle, slide and feed system. CCOHS advises against forcing a cut so that the motor slows. [S394]

Never restrain a stalled wheel in the kerf while attempting to restart.

10. Cut deviation, wandering and poor squareness

Possible causes include:

- wheel already distorted or damaged;

- side loading or steering pressure;
- flange contamination, mismatch or runout;
- spindle or pivot wear;
- workpiece movement;
- unequal support or sag;
- entry not aligned to the intended plane;
- feed applied unevenly; and
- wheel construction unsuitable for the section or required accuracy.

Check whether deviation begins at entry, develops through the section or appears only at breakthrough. The pattern helps separate alignment, support, machine and technique causes.

11. Excessive burr, breakout or rough edge

Review:

- wheel condition and suitability;
- cut direction and material support;
- feed stability near breakthrough;
- heat and material smearing;
- vibration or wheel deviation;
- section thickness and geometry;
- coating or scale condition; and
- downstream edge requirement.

A burr is not permission to use the cutting-wheel side for deburring. Complete edge treatment with a product designed and mounted for that operation.

12. Heat, discoloration and melting

Heat can arise from a glazing or loaded wheel, excessive force, long contact, slow cutting, poor chip clearance, unsuitable selection or inadequate wet-process control. On plastics, coated parts or low-melting materials, friction may smear or melt the edge.

Check the affected component against its quality requirements. Do not assume that a visually cleaned edge is free from thermal damage, hardness change, coating degradation or distortion. Keep fire and combustible-dust controls active throughout cutting.

13. Rapid wear, edge chipping and uneven wheel loss

Rapid or uneven wear may result from:

- side force or cut misalignment;
- workpiece pinch or movement;
- wheel impact at entry;
- excessive feed;
- unsuitable wheel construction;
- damaged or mismatched flanges;
- spindle or machine vibration;
- unequal coolant delivery on an approved wet process; and
- abrasive contact with an unintended surface.

Inspect the entire circumference and both faces only after isolation. Edge chipping is a damage signal, not a normal change-out cue to ignore.

14. Tube, bar and profile cutting

Hollow and shaped sections can change support as the cut progresses. Plan for:

- curvature or residual stress;
- collapse or rotation of thin-wall tube;
- offcut weight and fall direction;
- multiple wall entries and exits;

- pinching at the final ligament;
- internal contamination or coating; and
- sharp hot edges after separation.

Support the shape without crushing it and keep the offcut controlled. A warped section may move as the cut releases stress; use a competent job-specific support method.

15. Sheet, plate and large workpieces

Large work can sag under its own weight. Provide support near the cut and at free edges so that neither side closes onto the wheel or drops unexpectedly. Confirm that the cut will not release stored energy or destabilise the remaining structure.

For blind areas, walls, floors, tanks or used containers, identify hidden services, contents, residues and structural consequences before authorising work. Grinding or cutting can ignite flammable residues in used containers. [S323]

16. Interrupting and re-entering a cut

If cutting stops unexpectedly:

- keep the tool controlled until the wheel stops;
- remove it only without side loading;
- inspect the wheel and cut;
- correct binding, support or machine cause;
- restore a stable body and tool position; and
- re-enter only according to the exact machine instructions.

Manufacturer guidance commonly warns against restarting a hand-held cutting wheel while it remains in the work because it can bind, walk or kick back. [S097] Direction and re-entry sequence are machine-specific and are not universalised here.

17. Apply a controlled correction

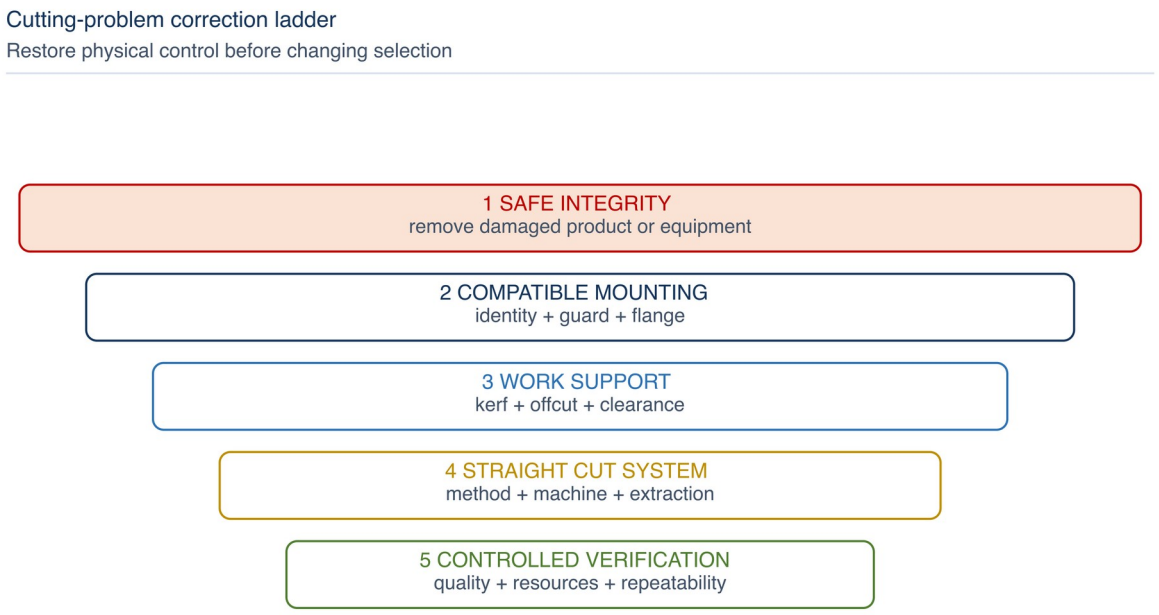

Figure 3. Cutting-problem correction ladder. Restore integrity, mounting and work support before technique or selection changes.

Use this order:

1188. remove damaged product or equipment from service;
1189. restore correct identity, guard, flange and mounting;
1190. correct work support and kerf behaviour;
1191. restore straight-plane entry, travel and exit;

1192. correct machine output, extraction or approved coolant system;
1193. review wheel construction and application suitability; and
1194. verify through a controlled comparison where a specification changes.

Change one controlled factor at a time whenever practical and record the result.

18. Verify and sustain

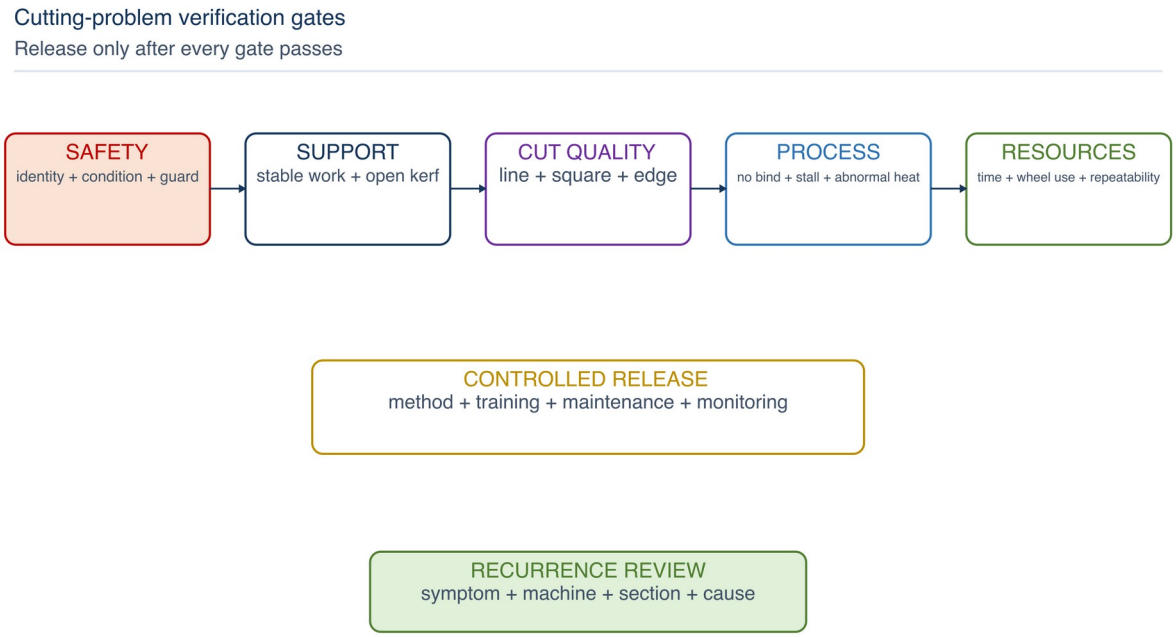

Figure 4. Cutting-problem verification gates. Safe condition, cut quality, process control, resource use and repeatability precede release.

Confirm:

- product, machine, guard and mounting compatibility;
- stable workholding and open kerf behaviour;
- straight, controlled cutting without bind or stall;
- accepted cut location, squareness and edge condition;
- absence of unacceptable thermal or mechanical damage;
- task time and wheel use on an accepted-output basis;
- repeatability across representative work; and
- updated method, training or maintenance action.

Monitor recurrence by symptom, product, machine, section type and originating cause.

Rapid troubleshooting table

Problem	Check first	Controlled direction
Wheel binds	Kerf closure, offcut movement, steering	Stop and correct support
Kickback	Pinch, hidden obstruction, unstable entry	Isolate, inspect and remove cause
Slow cut	Glazing/loading, machine output, selection	Diagnose instead of adding force
Stall	Binding, feed, power or capacity	Stop; restore free cutting and machine readiness
Cut wanders	Side pressure, support, flange or pivot	Restore straight plane and physical alignment
Large burr	Wheel condition, breakthrough support, heat	Stabilise final stage; use correct deburring product
Heat/discoloration	Rubbing, force, contact time, chip clearance	Restore cutting action and inspect quality
Rapid wear	Side load, impact, pinch or unsuitable wheel	Correct mechanics before selection change

Problem	Check first	Controlled direction
Edge chipping	Damage, misalignment, mounting, feed	Remove wheel and investigate
Repeated breakage	Systemic mounting, support, machine or use problem	Isolate process and conduct formal investigation

Safety reminder

Use cutting wheels only on their designed cutting surface. Never twist, lever, side-grind, jam or force the wheel; never exceed a marked limit or operate without the correct guard and secure workholding. Stop for damage, vibration, binding, stall, work movement or loss of control. Allow the wheel to stop completely before inspection or removal.

Key takeaways

- Begin with wheel integrity and compatibility.
- Support both work and offcut so the kerf cannot pinch the wheel.
- Keep the wheel in the intended cutting plane.
- Do not side-grind or deburr with a peripheral cutting wheel.
- Treat binding, stall and kickback as stop-and-investigate events.
- Preserve fragments and mounting evidence after major damage.
- Correct physical causes before changing product selection.
- Verify the complete accepted cut before release.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 069

Surface-Finish Problems

69

SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Grinding and finishing operators, supervisors, production engineers, maintenance personnel, QA/QC teams and technical buyers

Scope: Surface texture; scratch patterns; directional finish; waviness and chatter; edge condition; smearing; contamination; haze; heat effects; over-finishing; staged correction and verification.

Core principle — A surface-finish problem is not always caused by the final abrasive. Define the required surface, preserve the evidence and correct the earliest stage that created or failed to remove the defect.

Surface appearance, measured texture, directionality, geometry, cleanliness and downstream performance are related but not interchangeable. A surface can look uniform yet fail a specified profile requirement; another can meet a roughness value yet show unacceptable directional marks or rounded edges. Diagnose each characteristic against its own acceptance method.

When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- define the finish requirement before changing the process;
- preserve viewing and measurement conditions;
- distinguish scratch, direction, waviness, geometry, contamination and heat defects;
- trace carry-over damage to the earliest responsible abrasive stage;
- diagnose support, motion, product-condition and cleaning causes;
- correct defects without unnecessary material removal;
- recognise conditions requiring stop and technical assessment; and
- verify the corrected surface for appearance, geometry and downstream use.

1. Define what “good finish” means

Start with the drawing, customer sample, fabrication specification or controlled workmanship standard. Establish which characteristics matter:

- measured profile texture and the specified parameter;
- sampling direction, evaluation length and instrument method;
- visual appearance under agreed lighting and viewing direction;
- scratch direction or decorative pattern;
- waviness, flatness, contour and edge geometry;
- coating, bonding, sealing or hygiene requirement;
- freedom from embedded debris, residue or cross-contamination; and
- permissible material removal and remaining thickness.

ISO surface-texture standards separate indication, terms and specification conditions. [S343–S345] A single number does not describe every functional or visual property. Do not substitute an informal comparison for a specified measurement, or impose a universal roughness value where none is stated.

2. Preserve the evidence before rework

Before touching the surface again:

1195. clean only by the approved non-damaging method;
1196. identify the process direction and component orientation;
1197. inspect under stable lighting from consistent positions;
1198. mark the defect boundary outside the functional area where permitted;
1199. photograph the whole area and close detail with scale and orientation;
1200. record the last acceptable stage and first observed defect;
1201. retain the abrasive and backing condition for examination; and
1202. measure geometry or texture before further material removal where relevant.

Changing lighting, viewing angle, cleaning method or measurement direction can change the apparent result. Preserve comparable conditions for diagnosis and verification.

3. Classify the defect correctly

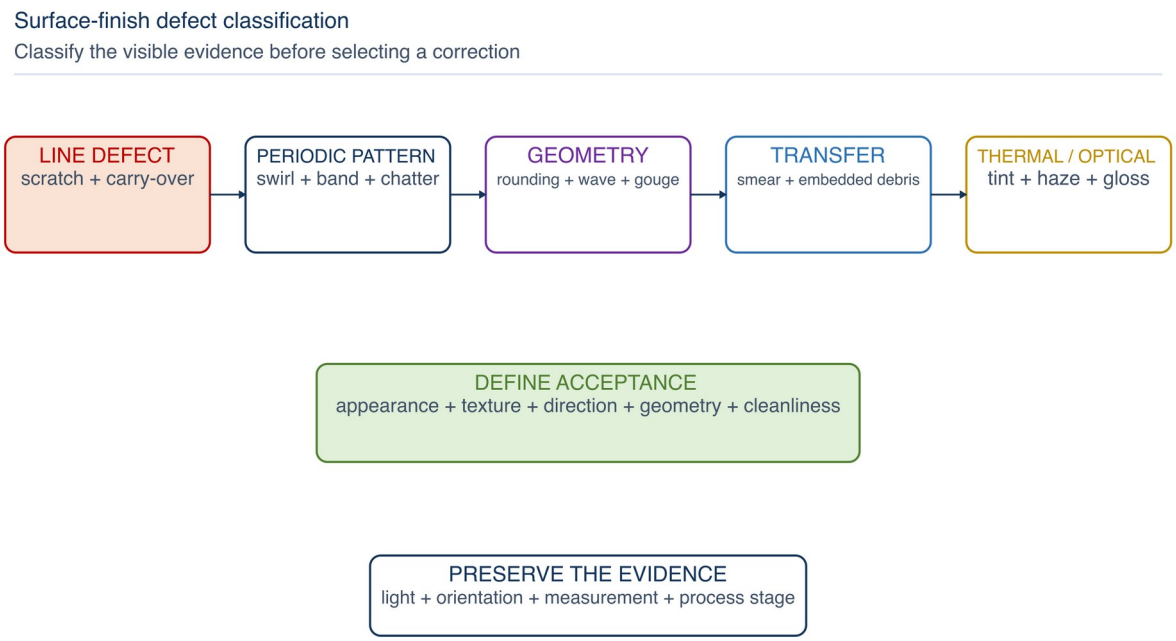

Figure 1. Surface-finish defect classification. Separate line defects, periodic pattern, geometry loss, material transfer and thermal or optical change before selecting a correction.

Use the visible pattern to choose the first investigation path:

Defect family	Typical observation	First checks
Line or scratch	isolated deep line, old scratch remains, cross-scratch	prior-stage removal, contamination, damaged abrasive
Periodic pattern	swirl, banding, chatter, repeated spacing	motion, runout, support, overlap, machine condition
Geometry change	rounded edge, hollow, wave, low spot, gouge	backing stiffness, dwell, access angle, work support
Material transfer	smearing, loading marks, embedded particles	heat, product loading, cleaning, material compatibility
Thermal or optical	tint, burn, haze, patchy gloss or colour	heat input, sequence consistency, cleanliness, over-finishing

Do not judge a crack, lap, seam, corrosion pit or thermal defect as a cosmetic finishing issue. Stop and refer it for the required engineering or quality assessment.

4. Check the complete finishing system

Abrasive grade alone does not control the result. Review:

- incoming surface condition and previous operation;
- abrasive family, grade designation, condition and sequence;
- machine type, stability, runout and power delivery;
- contact wheel, pad or backing hardness and condition;
- workholding, support and component vibration;
- contact angle, pressure, traverse, overlap and dwell consistency;
- access restrictions and operator posture;
- lubricant, coolant or extraction where applicable;
- cleaning between stages; and
- inspection timing, lighting and measurement method.

Grade designations are system-specific, and an apparent grit number does not guarantee equivalence between coated, bonded or superabrasive products. [S346–S349]

5. Deep scratches and scratch carry-over

Deep isolated scratches usually arise from coarse particles, damaged abrasive, trapped swarf, contaminated work support or a previous stage that was not fully removed. A random deep line appearing late in the sequence often indicates contamination rather than a need for a finer product.

Check whether the scratch:

- follows the current abrasive direction;
- crosses the current pattern and therefore predates it;
- starts at an entry point or raised feature;
- repeats with wheel or belt rotation;
- occurs where debris collects; or
- corresponds with a damaged joint, edge or backing feature.

Clean the work, tool, support and surrounding area. Replace damaged or contaminated consumables. Return to the earliest stage capable of removing the scratch without excessive stock loss, then rebuild the sequence completely.

6. Use a stage gate for scratch removal

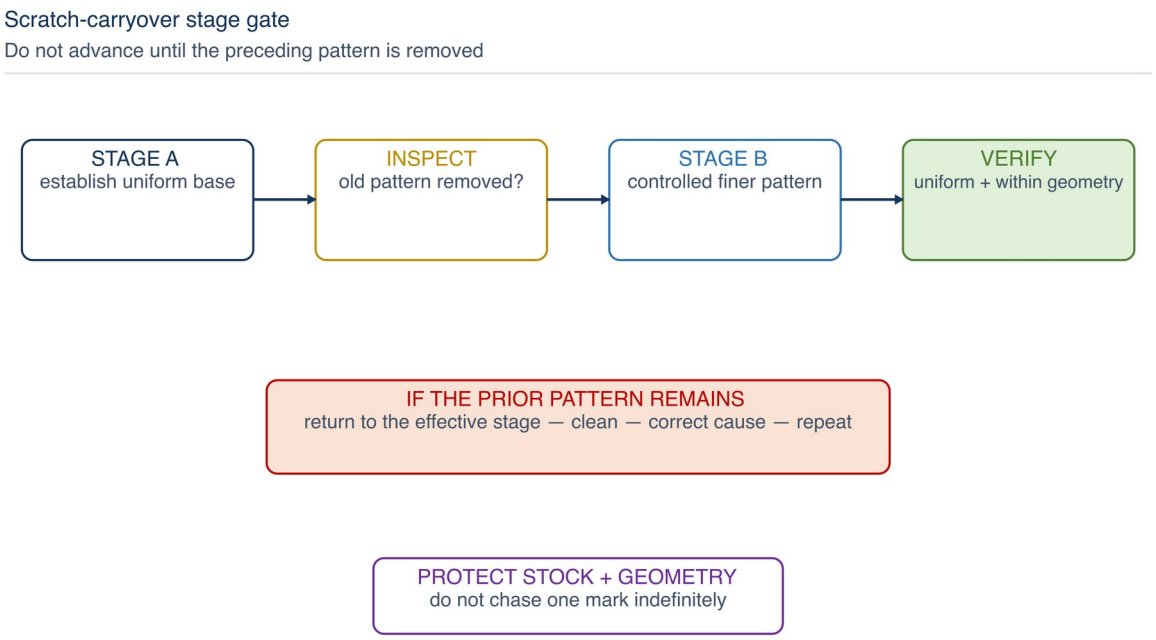

Figure 2. Scratch-carryover stage gate. Each stage must remove the preceding pattern uniformly before the next stage begins.

Change the working direction between stages where the component and specification permit. A changed direction makes residual scratches easier to see. Do not advance until the previous pattern has been removed throughout the controlled area. Materialographic guidance likewise emphasises complete prior-damage removal and cleaning between stages. [S123; S148–S149]

On shaped or directional finishes, a direction change may be unsuitable. Use another controlled indicator such as lighting, contrast inspection or an approved reference surface.

7. Swirl marks, cross-scratches and inconsistent direction

Common causes include:

- uncontrolled tool movement or changing attack angle;
- random-orbit or rotary action used where a directional finish is required;

- insufficient final passes in the specified direction;
- contact area wider than the controlled stroke;
- abrasive edge contact at starts, stops or transitions;
- local hand blending across the established grain; and
- rework that does not extend to a natural boundary.

Restore a repeatable motion and finish toward a defined boundary. Decorative stainless finishes often depend on controlled direction and uniformity, not merely abrasive grade. [S128–S131; S151]

8. Bands, streaks and lap lines

Bands or streaks may follow inconsistent overlap, variable pressure, product loading, uneven contact, belt tracking, coolant distribution or interruption during a pass. Determine whether the spacing matches operator strokes, wheel width, belt oscillation or a machine cycle.

Correct the mechanical or motion cause first. Use steady traverses and controlled overlap under the approved process. Avoid dwelling on a visible band: local correction can create a low spot or glossy patch that is harder to remove.

9. Waviness, ripple and chatter

Waviness is a longer-spacing shape variation than local roughness. Chatter often forms a repeating pattern associated with vibration or periodic motion.

Inspect:

- component clamping and unsupported span;
- machine bearings, spindle, contact wheel and drive condition;
- abrasive joint, tracking, balance and runout;
- backing compliance and contact width;
- resonance associated with a particular position;
- feed or traverse regularity; and
- interrupted contact at slots, holes or edges.

Grinding references connect chatter and poor finish to machine truth, support, dressing, vibration and thermal control. [S389; S391] Do not attempt to hide a geometric wave with finer polishing.

10. Edge rounding and loss of geometry

Flexible products conform readily and can remove more material at edges, corners and raised features. Edge rounding may also result from excessive dwell, steep approach, unsupported sheet or repeatedly blending the same boundary.

Before correction, confirm the permitted edge form and remaining stock. Improve support and use the least compliant contact arrangement compatible with the task. Control entry and exit so the abrasive does not roll over the edge. Materialographic studies identify relief and edge rounding as consequences of preparation mechanics. [S148–S149]

If geometry is already below tolerance, stop further finishing and follow the applicable disposition process.

11. Gouges, low spots and local over-cutting

Gouges commonly begin with hard abrasive edge contact, a sudden angle change, trapped debris, excessive local force or an unstable tool. Low spots can develop when an operator chases a visual mark within a small area.

To prevent recurrence:

- approach the surface smoothly;
- maintain full intended contact support;
- keep cables and hoses from pulling the tool;
- avoid starting or stopping while an edge is digging into the work;
- blend over a sufficiently broad controlled area; and
- check thickness or contour before further removal.

Never cosmetically blend a defect if doing so could conceal unacceptable loss of section.

12. Smearing, loading and embedded debris

Soft, ductile or heat-sensitive materials can smear instead of cutting cleanly. Loaded abrasive can then rub, heat and redeposit material. Embedded foreign particles may originate from the abrasive, previous work, dirty handling or a shared tool.

Check product suitability, abrasive condition, contact heat, chip clearance and cleaning practice. Use material-dedicated tools where contamination control requires them. Replace a loaded or contaminated product rather than pressing harder. Cleaning and control of preparation debris are essential between stages. [S123; S148]

13. Cross-contamination and rust staining

Stainless steel and other contamination-sensitive surfaces can acquire ferrous particles from shared tools, carbon-steel dust, benches, clamps or handling equipment. The stain may appear later, after moisture exposure.

Maintain segregation appropriate to the job:

- dedicated and clearly identified abrasives and brushes;
- clean work supports and handling aids;
- controlled storage away from ferrous grinding dust;
- suitable extraction and housekeeping;
- clean gloves and approved wiping materials; and
- the specified post-finish cleaning or passivation process.

Do not treat staining as proof that the base material itself is defective without investigation.

14. Haze, cloudiness and patchy gloss

Haze or patchiness can arise from incomplete removal of the prior pattern, uneven pressure, inconsistent dwell, contaminated media, residue, mixed abrasive condition or differences in local surface geometry. Highly reflective finishes reveal small variations strongly.

First determine whether the variation is surface texture, residue or lighting reflection. Clean by the approved method and inspect again under controlled conditions. If the texture varies, return to a stage that can establish a uniform base over the full affected zone. Tool-steel finishing guidance identifies haze and orange-peel-type effects as distinct problems with different mechanisms. [S167]

15. Heat tint, burn and thermal change

Unexpected colour, burn marking, local softening, distortion or heat checking requires immediate process review. Possible causes include excessive contact pressure, prolonged dwell, a loaded or dull abrasive, inadequate heat removal, unsuitable sequence or poor coolant delivery in an approved wet process.

Stop and allow safe cooling. Determine whether the component’s material, hardness, coating, corrosion performance or geometry could have been affected. Visual removal of colour does not prove removal of thermal damage. Research on grinding shows that heat, deformation and surface integrity can change together. [S084; S087]

16. Over-finishing and orange-peel effects

More polishing is not always better. Excessive repeated work can round geometry, create relief between microstructural constituents, reveal waviness, produce an orange-peel appearance or reduce consistency across the part. [S167]

Stop when the controlled acceptance criteria are met. Do not continue merely to increase gloss. If an orange-peel or relief pattern develops, reassess the earlier preparation and material-removal method instead of adding more final-stage dwell.

17. Trace causes across the process

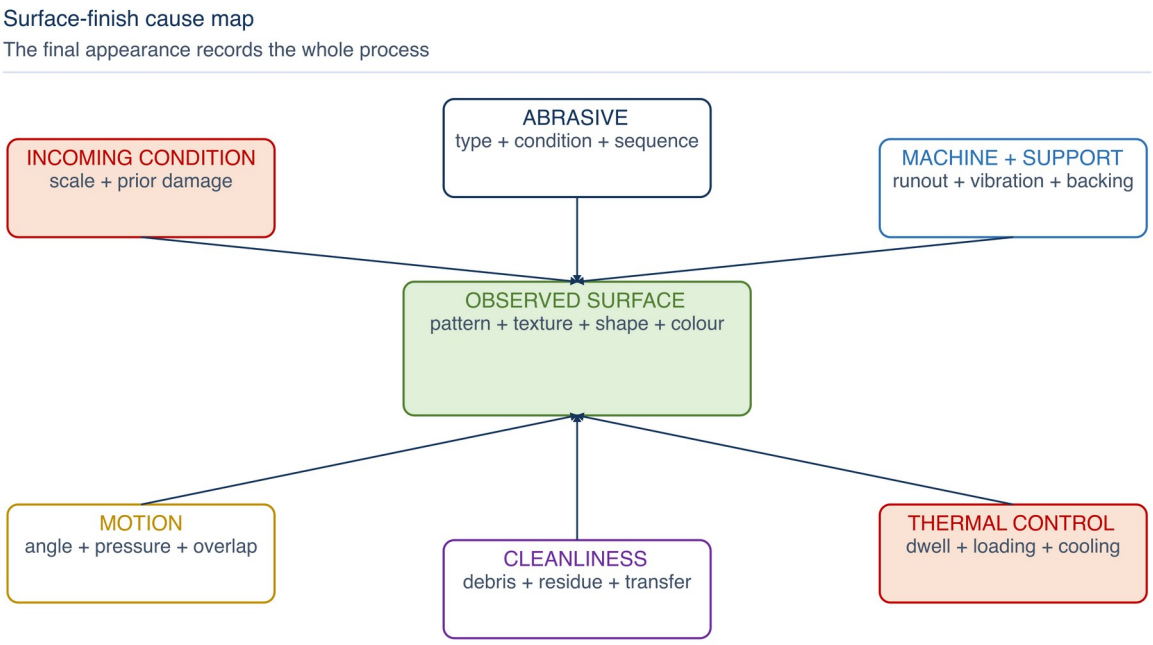

Figure 3. Surface-finish cause map. The observed surface is the combined result of incoming condition, product, support, motion, cleanliness and thermal control.

Use pattern evidence to test one cause family at a time. A repeating mark suggests a rotating or cyclic source; a boundary-aligned patch suggests local rework; a defect appearing after cleaning may be residue or contamination; a defect unchanged through several fine stages probably originated earlier or is geometric.

18. Apply the smallest effective correction

Use this correction sequence:

1203. protect people, isolate unsafe equipment and preserve evidence;
1204. confirm the requirement and the defect family;
1205. correct contamination, machine, support or motion causes;
1206. determine the earliest stage needed to remove the defect;
1207. confirm material-removal and geometry limits;
1208. process a controlled area with one documented change;
1209. rebuild the remaining sequence without skipping stage gates; and
1210. verify the full requirement under consistent conditions.

Changing several variables together obscures the cause. A finer product will not reliably correct waviness, contamination, a deep retained scratch or thermal damage.

19. Verify before release

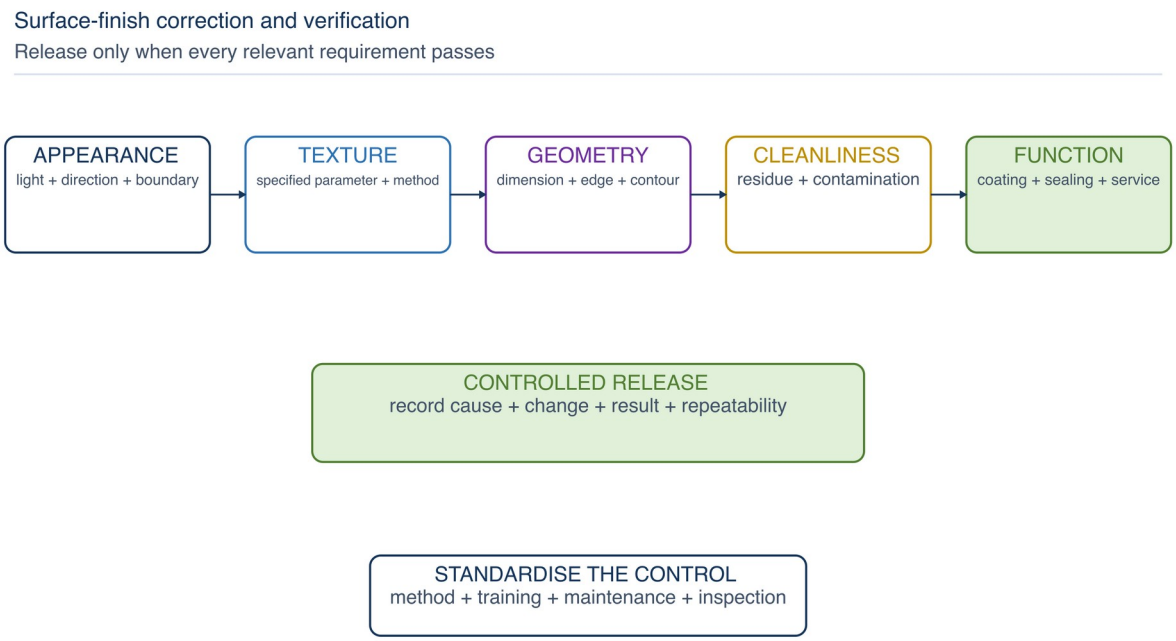

Figure 4. Surface-finish correction and verification. Correction is complete only when the appearance, texture, geometry, cleanliness and downstream-function gates pass.

Verification may include:

- visual comparison under agreed light, distance and orientation;
- profile measurement using the specified parameter and direction;
- dimensional, flatness, contour or edge inspection;
- cleanliness and contamination checks;
- coating, bonding, sealing or hygiene readiness; and
- repeatability across more than one component or process cycle.

Record the defect, cause, controlled change and result. Update the work method, training, maintenance or consumable control when the cause is systemic.

20. Rapid troubleshooting table

Symptom	Likely cause families	Controlled response
One deep random scratch	debris, damaged abrasive, dirty support	preserve pattern, clean system, replace affected product, return to required stage
Old scratches remain	stage advanced too early, inadequate coverage	restore previous effective stage and prove full pattern removal
Swirl or crossed direction	motion or final-pass inconsistency	restore controlled direction and boundary
Bands or streaks	overlap, pressure, loading, tracking or coolant variation	correct source, then refinish the complete affected zone
Ripple or chatter	vibration, runout, weak support, periodic motion	isolate mechanical cause before cosmetic work
Rounded edge	excessive compliance, dwell or rollover	confirm remaining geometry; improve support and contact control
Smear or embedded debris	loading, heat, contamination, unsuitable product	stop rubbing, clean and restore compatible cutting action
Rust stain on stainless	ferrous transfer or shared tooling	segregate tools, clean by approved process, assess contamination

Symptom	Likely cause families	Controlled response
Haze or patchy gloss	incomplete base, residue, variable pressure or dwell	standardise inspection; rebuild uniform base if required
Heat tint or burn	excessive heat input or inadequate cooling	stop, assess surface integrity, correct thermal cause
Orange peel or excessive relief	over-finishing or inadequate earlier preparation	stop final dwell and reassess preparation sequence

21. Concise safety reminders

- Inspect the machine, guard, abrasive and mounting before use.
- Confirm product and machine compatibility, including marked speed limits.
- Secure the work and maintain a stable body and tool position.
- Use extraction, ventilation and respiratory protection appropriate to the dust and material.
- Control sparks, hot particles, combustible dust and nearby flammables.
- Isolate equipment before inspection, cleaning, adjustment or product change.
- Treat cracks, severe heat effects and loss of section as technical defects, not cosmetic marks.
- Follow workplace controls for hazardous coatings, stainless steel, aluminium, composites and other material-specific dusts.

Key takeaways

- Define appearance, texture, direction, geometry and cleanliness separately.
- Preserve the defect pattern before rework.
- Trace scratches and periodic marks to the earliest responsible stage.
- Correct support, motion, contamination and heat causes before changing grade.
- Do not use a finer finish to conceal waviness, thermal damage or geometry loss.
- Remove only the material necessary and verify downstream function.
- Standardise the proven correction so the defect does not return.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 070

Polishing Problems

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SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Polishing and buffing operators, toolroom personnel, supervisors, production engineers, maintenance personnel, QA/QC teams and technical buyers

Scope: Base preparation; compounds and polishing media; contamination; scratches; drag lines; haze; low or patchy gloss; swirl; smearing; relief; edge rounding; pitting; pull-out; orange peel; heat effects; correction and verification.

Core principle — Polishing refines an already controlled surface. It cannot reliably correct deep damage, waviness, poor geometry or thermal defects, and excessive polishing can make the surface worse.

A bright surface is not automatically a conforming surface. The required result may include gloss, texture, direction, flatness, edge retention, cleanliness, coating readiness or mould-release function. Confirm each requirement before polishing or rework.

When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- confirm the required polishing endpoint and inspection method;
- establish a uniform, damage-free base before polishing;
- prevent cross-contamination between compounds and stages;
- diagnose scratches, haze, swirl, smearing, relief, pitting and orange peel;
- recognise when polishing time or pressure is worsening the surface;
- correct the earliest responsible stage without excessive stock loss; and
- verify appearance, geometry, cleanliness and downstream function.

1. Define the polishing endpoint

Use the drawing, controlled sample, customer specification or workmanship standard. Establish:

- whether the finish is visual, measured or both;
- permitted scratch direction and viewing orientation;
- agreed lighting, distance and comparison method;
- surface-texture parameter and measurement direction where specified;
- flatness, contour, edge and dimensional limits;
- cleanliness and residue requirements;
- coating, plating, sealing, hygiene or moulding function; and
- maximum permissible material removal.

ISO surface-texture documents distinguish indication, terminology and specification conditions. [S343–S345] Do not invent a universal “mirror” grade or use gloss alone as proof that all requirements pass.

2. Stop conditions

Stop polishing when there is:

- a crack, seam, lap, delamination or unexpected pit requiring assessment;
- rapid surface deterioration, orange peel or widespread pull-out;
- heat tint, burn, distortion, smoke or ignition;
- abnormal vibration, noise, tool damage or loose mounting;
- a torn, contaminated or unstable mop, pad or cloth;
- unexpected compound spray, dust escape or failed extraction;
- loss of component control or unsafe line of fire; or
- uncertainty about material, coating, product or machine compatibility.

Isolate equipment before inspection, adjustment, cleaning or media change.

3. Establish a uniform base first

Polishing should begin only after the preceding grinding or finishing stage has produced a uniform surface and removed earlier damage. Check the surface at transitions, edges, recesses, weld zones and previous repair boundaries.

If a deep scratch remains, additional fine polishing may brighten the surrounding surface while leaving the scratch intact. This reduces stock elsewhere and makes correction harder. Materialographic guidance requires complete removal of preceding damage before advancing. [S123; S148–S149]

4. Classify polishing defects

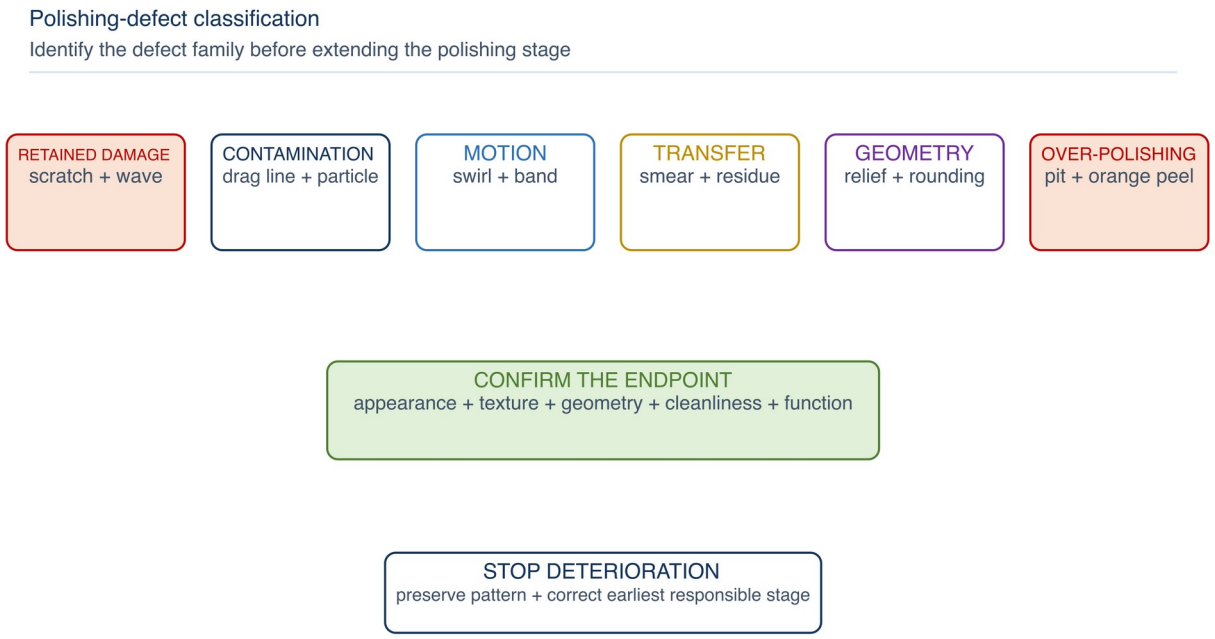

Figure 1. Polishing-defect classification. Separate retained preparation damage, contamination, transfer, geometry change and over-polishing before selecting a response.

Defect family	Common appearance	First investigation
Retained damage	deep line, grinding mark, waviness	previous-stage completeness and stock condition
Contamination	random coarse scratch, drag line, embedded particle	compound, media, work, handling and workplace cleanliness
Motion variation	swirl, arc, band, patchy reflection	stroke, contact, workholding, runout and overlap
Material transfer	smear, streak, loaded media, residue	cutting action, lubricant or compound behaviour, heat
Geometry change	rounded edge, relief, hollow or low spot	media compliance, dwell, pressure, support and access
Over-polishing	orange peel, pull-out, pitting, worsening surface	polishing duration, contact severity and material response

5. Control cleanliness between stages

One coarse particle can create a defect across a nearly finished surface. Keep separate and clearly identified:

- compounds, suspensions or bars;
- mops, pads, cloths, felts and brushes;
- application tools and containers;
- work supports, clamps and handling materials;
- cleaning cloths and inspection gloves; and
- storage for clean and used media.

Clean the component, fixture, machine and immediate work area before moving to a finer stage. Do not place a clean tool on a contaminated bench. Keep lids and protective covers closed when products are not in use.

6. Use a polishing-stage cleanliness gate

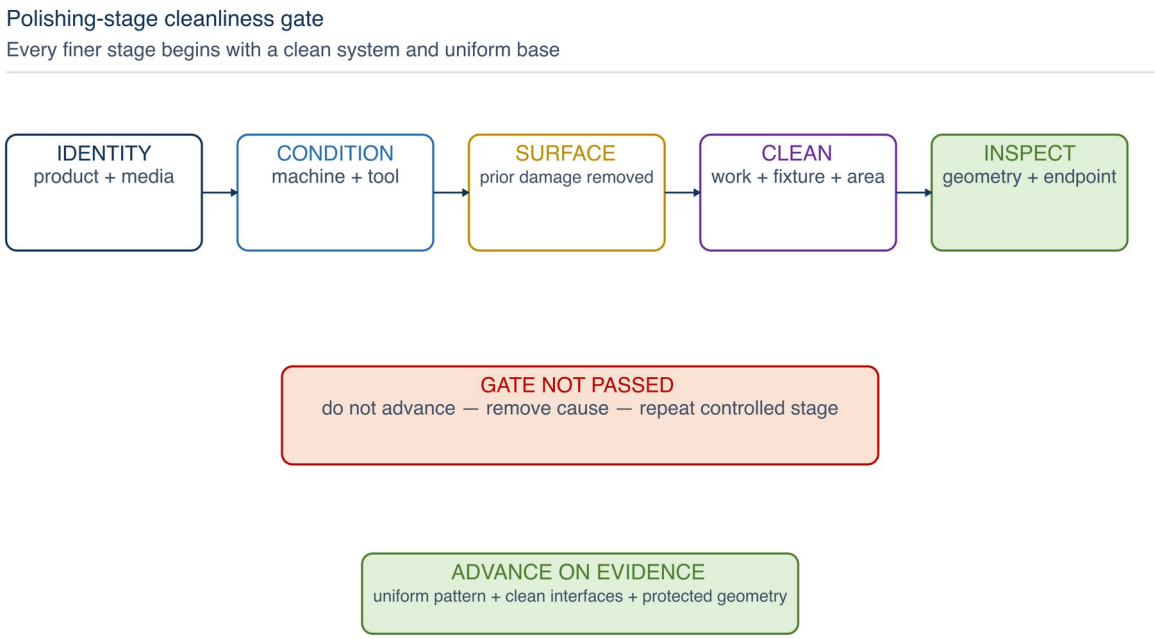

Figure 2. Polishing-stage cleanliness gate. A stage advances only after the surface is uniform, the prior pattern is removed and the work system is clean.

At every stage, confirm:

1211. correct product and media identity;
1212. clean, serviceable machine and contact media;
1213. uniform base condition;
1214. previous damage removed;
1215. geometry remains within requirement;
1216. controlled cleaning complete; and
1217. inspection passed under comparable conditions.

7. Deep scratches that remain after polishing

Determine whether the line follows the current polishing motion or crosses it. A crossed line usually predates the current stage. A fresh line matching the motion may come from debris, damaged media, compound agglomeration or a hard particle released from the work.

Do not chase one deep scratch with prolonged local polishing. Preserve the pattern, clean the system, confirm available stock and return to the earliest stage capable of removing the defect uniformly.

8. Random scratches and drag lines

Random or sudden drag lines commonly indicate contamination, a loose hard particle, dried compound, damaged cloth, a sharp component feature contacting the media or debris trapped during wiping.

Check when the line begins and whether it repeats with tool rotation. Quarantine contaminated media, clean all interfaces and inspect the component for a particle source. Buehler and Struers guidance link late-stage coarse scratches with cross-contamination and incomplete cleaning. [S123; S148–S149]

9. Haze, cloudiness and low gloss

Possible causes include:

- incomplete removal of the preceding pattern;
- uneven compound distribution;

- contaminated or overloaded media;
- unsuitable media condition or compliance;
- residue left by cleaning;
- variable contact pressure or dwell;
- local geometry changing reflected light; and
- surface relief or early over-polishing.

Clean by the approved method before concluding that texture is defective. Inspect under stable lighting. If the haze is within the surface, restore a uniform earlier stage rather than repeatedly polishing the cloudy patch.

10. Patchy gloss, bands and swirl

Patchy reflection can follow inconsistent overlap, hand pressure, tool angle, mop loading, workpiece temperature or local rework. Swirl or arc marks may reflect rotary motion, abrasive-edge contact, runout or a mismatch between the tool action and specified direction.

Correct the motion and mechanical source first. Blend to a natural or specified boundary; isolated spot work can create a visible halo or low area.

11. Compound streaks, build-up and residue

Too little active cutting, excessive product application, dirty media or excessive heat can produce compound build-up and streaks. Residue can imitate haze or hide scratches until the surface is cleaned.

Use only a compatible product by the approved application method. Keep the media conditioned as intended and replace it when contaminated or damaged. Do not use an unapproved solvent merely to remove stubborn residue; consider material, coating, fire, health and downstream-process compatibility.

12. Smearing and embedded abrasive

Ductile materials may smear when the polishing action rubs rather than cuts. Hard particles can embed in soft material, cracks or pores. Contributing factors can include loaded media, unsuitable compound or cloth, poor lubrication in a process designed for it, excessive contact severity and inadequate cleaning.

Smearing and embedding are recognised preparation artifacts. [S123; S148–S149] Restore clean cutting action using a compatible process, and avoid pressing harder against loaded media.

13. Relief, edge rounding and loss of detail

Relief develops when softer areas are removed faster than harder constituents. Highly compliant media, long polishing time and concentrated local contact can increase the effect. Edges and raised features are especially vulnerable to rounding.

Check media support, workholding, dwell distribution and the material response. Use the least compliant arrangement suitable for the finish, protect critical edges and stop when acceptance is reached. Do not polish away dimensional or functional detail to improve gloss.

14. Pitting, pinholes and pull-out

Pits may be pre-existing porosity or corrosion, or may form when hard particles, carbides, inclusions or weakly supported constituents are pulled from a softer matrix. Polishing can undermine a particle until it releases. Uddeholm identifies pull-out-related pitting as a recognised mould-steel polishing problem. [S023; S167]

Do not assume every pit has the same cause. Preserve location and distribution, review the incoming surface and material, and determine whether technical or quality assessment is required. If the artifact is polishing-induced, return to the last sound preparation stage and rebuild with controlled contact.

15. Orange peel and over-polishing

Orange peel is an irregular surface morphology that can worsen with continued polishing. Material condition contributes, but excessive contact severity and prolonged final-stage work are common process factors in mould-steel guidance. [S023; S167]

If the surface begins to deteriorate, stop. Increasing pressure or polishing longer is likely to worsen the condition. Confirm available stock, remove the affected layer through the last effective preparation stage where permitted, and repeat the controlled sequence with reduced exposure to the cause.

16. Apply the over-polishing response

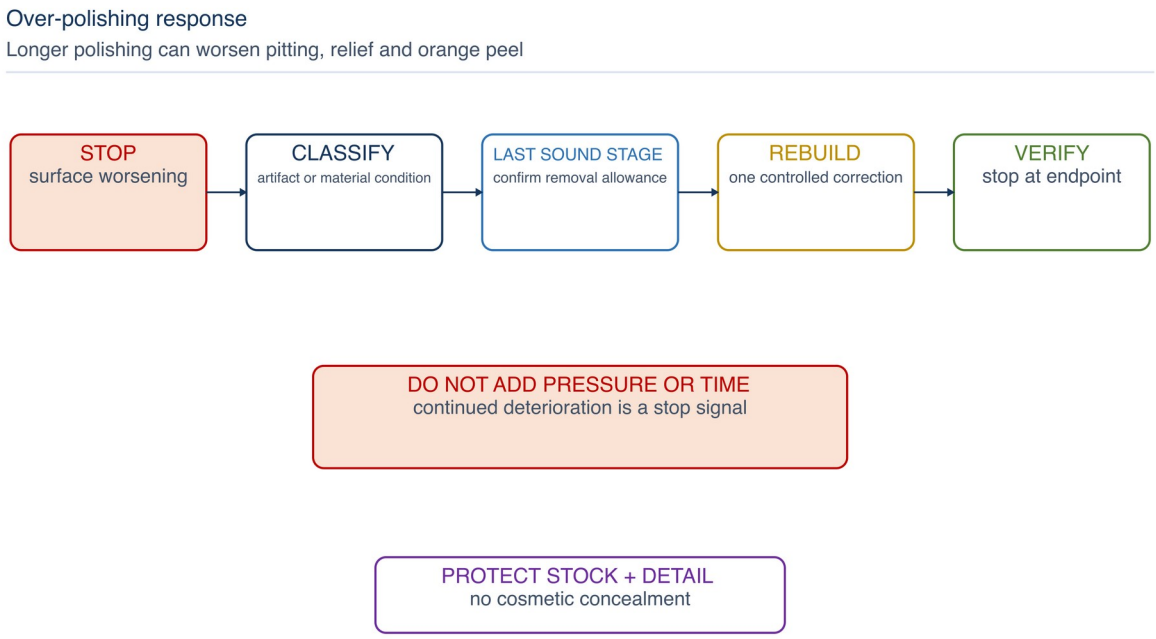

Figure 3. Over-polishing response. Stop deterioration, distinguish surface artifact from material condition and rebuild from the last sound stage.

The response is:

1218. stop and preserve the observed pattern;
1219. confirm surface and geometry requirements;
1220. inspect material condition, media and machine;
1221. identify the last sound stage;
1222. establish whether further removal is permitted;
1223. restore a uniform base with one controlled correction;
1224. repeat only the necessary stages; and
1225. verify without extending polishing beyond the endpoint.

17. Heat tint, burn and distortion

Polishing can generate significant local heat through rubbing, loading, excessive dwell or unsuitable contact. Heat may affect coatings, hardness, residual stress, corrosion behaviour, dimensions or appearance.

Stop after unexpected thermal change. Visual removal of tint does not prove that thermal damage is absent. Review material and quality requirements before rework. Keep hot work, flammable compound, vapour and ignition controls active.

18. Machine, mop, pad and tool condition

Inspect:

- spindle, arbor and bearing condition;
- mounting security and runout;
- guard, extraction hood and work-rest arrangement where applicable;
- mop, pad, cloth or felt integrity and contamination;
- hard joints, exposed hardware or damaged edges;
- compound application condition;
- workholding and access; and

- electrical, pneumatic or drive performance.

Never improvise mounting parts or exceed the product or machine marking. Replace torn, hardened, contaminated or unstable media.

19. Control dust, fibres and combustible material

Polishing and buffing can release fine dust, fibres and compound residue. Provide effective capture and housekeeping for the actual material and process. OSHA ventilation guidance recognises local exhaust needs for polishing and buffing, while DOSH Malaysia has documented a combustible-dust explosion involving polishing machinery. [S008; S152; S310; S319]

Do not mix incompatible metal dusts or use ordinary vacuum equipment where combustible-dust controls require specialised equipment. Collector, duct, electrical classification, fire and explosion protection require competent design for the material and facility. NFPA 660 provides a current consolidated combustible-dust framework. [S325]

20. Verify correction and release

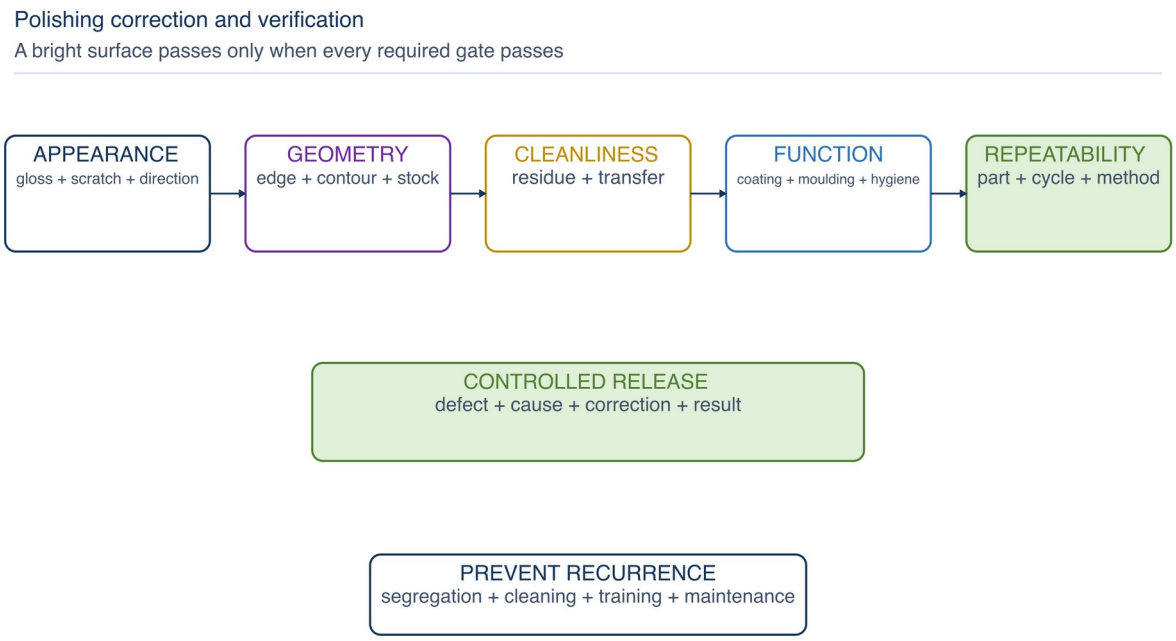

Figure 4. Polishing correction and verification. The polished surface must pass appearance, geometry, cleanliness, function and repeatability gates.

Verify as applicable:

- appearance under agreed lighting and orientation;
- absence of retained scratches, haze, drag lines and residue;
- specified texture measurement;
- flatness, contour, edges, dimensions and remaining section;
- cleanliness and freedom from prohibited transfer;
- coating, plating, hygiene, sealing or moulding readiness; and
- repeatability across more than one part or cycle.

Record the defect, confirmed cause, correction and result. Update media segregation, cleaning, training, machine maintenance or inspection control when recurrence risk remains.

21. Rapid troubleshooting table

Symptom	Likely cause families	Controlled response
Deep retained line	incomplete base preparation	return to earliest effective stage and rebuild uniformly

Symptom	Likely cause families	Controlled response
Fresh random scratch	contamination, debris or damaged media	stop, clean system, replace contaminated media and reassess
Haze or low gloss	residue, incomplete prior pattern, variable contact	clean and inspect; restore uniform base if texture remains uneven
Patchy gloss or halo	local dwell, pressure or boundary mismatch	correct motion and refinish the controlled zone
Swirl or arc marks	rotary motion, edge contact, runout	restore mechanical truth and specified finishing direction
Smearing	rubbing, loading, incompatible media or compound	restore compatible cutting action and cleanliness
Relief or rounded edge	excessive compliance, time or local contact	protect geometry and reduce exposure to the cause
Pitting or pull-out	material constituents, porosity, corrosion or over-polishing	preserve evidence, assess cause, return to last sound stage if permitted
Orange peel	excessive final-stage work and material response	stop; rebuild from last effective preparation stage
Heat tint or burn	excessive heat input or loaded media	stop, assess surface integrity and correct thermal cause

22. Concise safety reminders

- Inspect machine, guards, mounting and polishing media before use.
- Secure the component and maintain a stable position outside the ejection path.
- Tie back hair and control loose clothing, jewellery, gloves and rags around rotating machinery according to the safe work method.
- Use suitable eye, face, hearing, hand, body and respiratory protection.
- Capture dust and control combustible accumulations for the actual material.
- Keep compounds, cleaners and solvents away from incompatible heat and ignition sources.
- Isolate energy before cleaning, adjustment or media change.
- Treat cracking, pitting, burn and geometry loss as technical conditions, not merely visual defects.

Key takeaways

- Polishing depends on a uniform, damage-free base.
- Clean every interface when moving to a finer stage.
- Diagnose random scratches as contamination until the pattern proves otherwise.
- A brighter surface is not proof of geometry or surface integrity.
- Stop when orange peel, pitting or surface deterioration begins.
- Return to the earliest necessary stage rather than extending final polishing.
- Verify appearance, geometry, cleanliness and function separately.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 071

Paint-Booth Filter Problems

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SELECT • APPLY • FINISH • TROUBLESHOOT

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Audience: Paint-shop operators, finish inspectors, maintenance personnel, production engineers, EHS teams, supervisors and technical buyers

Scope: Intake and ceiling filters; exhaust and overspray arrestors; loading; pressure indication; airflow balance; bypass; collapse; contamination; overspray escape; finish defects; clearance; change-out and verification.

Core principle — A booth filter is part of an engineered air-handling and fire-safety system. Diagnose the filter, its installation and the complete airflow path before changing the product or operating the booth.

Filter loading is normal, but uncontrolled loading, bypass, wrong orientation, poor support or unsuitable selection can affect coating quality, exposure control, fire risk, fan performance and emissions. A new filter does not correct a blocked intake, slipping drive, incorrect damper, dirty duct or unbalanced make-up air.

When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- identify booth conditions requiring immediate stop;
- distinguish supply-side, exhaust-side and installation problems;
- diagnose loading, bypass, collapse and uneven airflow;
- connect filter condition with dirt, overspray, finish and clearance symptoms;
- inspect pressure indication and the complete airflow path;
- replace filters without releasing captured residue; and
- verify airflow, capture, cleanliness and booth readiness after correction.

1. Immediate stop conditions

Stop spraying and follow the booth shutdown procedure when there is:

- loss of required ventilation or airflow indication;
- failed fan, drive, interlock, alarm or pressure indicator;
- visible overspray escape or vapour accumulation;
- collapsed, displaced, torn, burning or smoking filter media;
- heavy residue threatening ignition, detachment or obstruction;
- damaged filter frame, support or sealing system;
- solvent, paint or water release into electrical or unsafe areas;
- unexpected odour or exposure outside the controlled zone; or
- doubt about the booth’s safe operating condition.

Do not bypass an interlock or operate beyond the booth manufacturer’s filter or pressure condition.

2. Map the complete air path

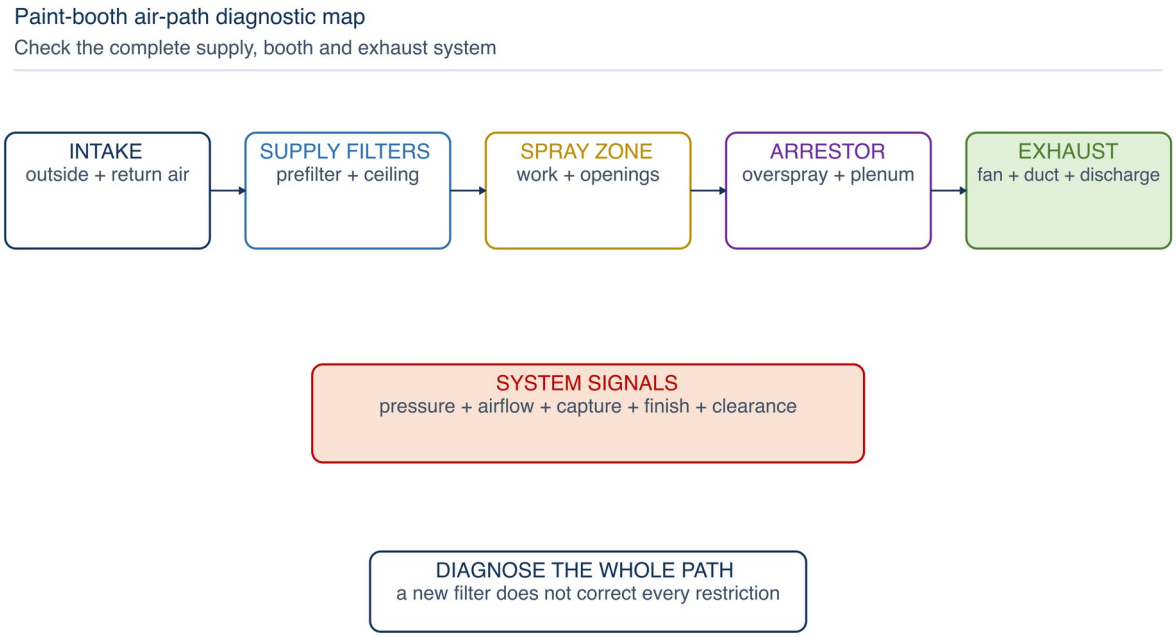

Figure 1. Paint-booth air-path diagnostic map. Supply, booth, exhaust and discharge conditions must be checked as one connected system.

Trace air through:

1226. outdoor or return-air intake where designed;
1227. prefilter and supply filtration;
1228. fan, heating or conditioning section;
1229. ceiling, wall or final supply filter;
1230. occupied spray zone and workpiece;
1231. floor, wall or plenum overspray arrestor;
1232. exhaust fan, duct and discharge; and
1233. make-up-air and building-pressure relationship.

A restriction or leak at any point can alter the booth pattern.

3. Confirm filter identity and intended position

Check:

- exact filter family and dimensions;
- intake, ceiling, exhaust or overspray duty;
- airflow-direction marking;
- frame, pocket, pad, roll or panel format;
- support grid, retaining hardware and gasket arrangement;
- media condition, storage and contamination;
- compatibility with coating, booth and fire controls; and
- replacement instructions for the installed booth.

General-ventilation filter classifications do not automatically describe paint-arrestor capture, holding or fire behaviour. [S181–S183]

4. Use a symptom-led sequence

Start with the observed problem, then check:

1234. pressure indication and recent trend;
1235. visual filter condition and installation;
1236. intake and make-up-air availability;

1237. fan, drive, damper and duct condition;
1238. booth residue and obstruction;
1239. coating or production change; and
1240. verified airflow pattern and clearance.

Record the filter position, date, production condition and symptom before change-out. Do not diagnose from filter colour alone.

5. Rapid or unexpected pressure rise

Possible causes include:

- high overspray or dust loading;
- coating, gun, transfer-efficiency or production change;
- filter installed in the wrong direction;
- media compressed, folded or insufficiently expanded;
- wet, sticky or prematurely blinded media;
- blocked downstream layer or plenum;
- damper or duct restriction; and
- pressure tubing or instrument fault.

Pressure is a system signal, not an isolated filter verdict. EPA and fan-system guidance connect filter loading with increasing resistance and changing airflow. [S178–S179]

6. Low or falling pressure indication

An unexpectedly low reading can indicate:

- torn or missing media;
- filter bypass around a frame;
- collapsed or displaced filter;
- fan, belt, motor or drive loss;
- blocked pressure tube or wrong tapping condition;
- open access panel or duct leak; or
- changed damper or make-up-air condition.

Low resistance is not automatically good performance. Inspect for loss of capture and system integrity before spraying resumes.

7. Uneven airflow across the booth

Common causes include uneven filter loading, mixed filter condition, gaps, incorrect orientation, blocked ceiling sections, poor plenum distribution, fan or damper condition, open doors, building drafts and obstructed exhaust zones.

Look for coating drift, moving masking paper, uneven overspray deposits or local dead zones. Use the booth’s approved airflow verification method; do not rely on hand sensation alone.

8. Dirt, fibres or particles in the finish

Investigate:

- damaged or unsuitable supply filters;
- bypass at frames, seams, doors or access panels;
- dirty plenum, duct, booth or compressed-air source;
- shedding media or disturbed accumulated dust;
- contaminated clothing, masking, workpiece or handling;
- filter change performed without controlled cleaning; and
- excessive booth pressure drawing contamination from adjacent areas.

Changing the exhaust filter alone will not correct supply-side dirt. Preserve defect samples and trace particle type and location.

9. Overspray escape or poor capture

Possible causes include loaded exhaust filters, bypass, missing media, inadequate fan output, slipping drive, obstructed duct, incorrect damper, blocked discharge, excessive spray generation or a disturbed booth opening.

Dry-filter and water-wash booths require different checks. OSHA spray-finishing guidance recognises continuing mechanical ventilation and controlled overspray-residue removal as core system functions. [S175]

Stop if visible material escapes the intended capture zone.

10. Filter bypass and poor sealing

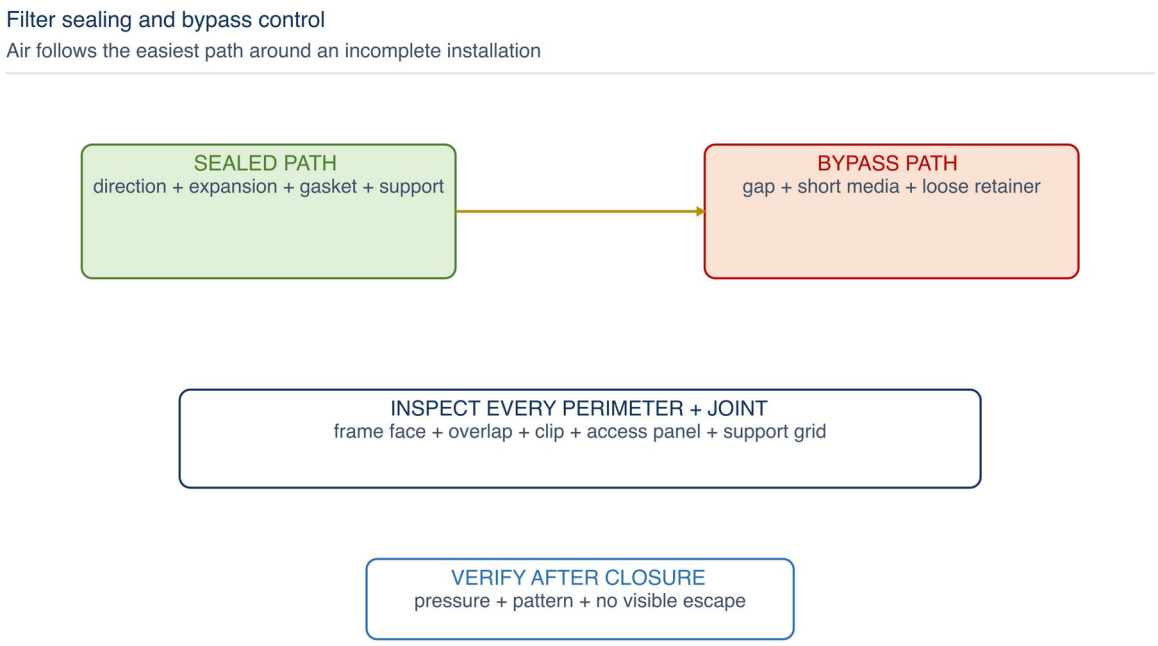

Figure 2. Filter sealing and bypass control. Air follows gaps around a filter when the frame, gasket, overlap, expansion or retention is incomplete.

Inspect the full perimeter and all joints for:

- missing, damaged or compressed gasket;
- warped frame or dirty sealing face;
- short-cut media or inadequate overlap;
- open seams between pads or panels;
- loose clips, retainers or support;
- incorrect pocket or pad seating; and
- access panel or service-door leakage.

Manufacturer installation guidance consistently emphasises direction, gasket compression, frame fit and joint sealing. [S187; S195–S196]

11. Reversed, compressed or poorly expanded media

Some paint-arrestor media depend on staged density, open structure, pocket form or labyrinth geometry. Reversal or compression can change capture and resistance. Roll media may require full designed expansion and secure support.

Follow the filter marking and installation instructions. Do not infer orientation from colour alone. Paper-labyrinth products require the intended expansion and orientation to form their separation path. [S187]

12. Collapse, sagging and media movement

Collapse may follow missing support, incorrect retaining method, wet loading, excessive system condition, damaged media or poor fit. Movement can open bypass paths and release captured residue.

Stop the system before safe inspection. Correct the support or frame cause, clean escaped residue under the approved method and replace affected media. Do not add improvised wire, combustible material or unapproved fasteners inside the booth.

13. Short filter life

Review the whole process:

- coating and solids content;
- spray equipment condition and transfer practice;
- production volume and part geometry;
- booth cleaning and residue control;
- filter area and installation;
- upstream dust or moisture;
- fan and airflow balance; and
- whether the filter is being changed by condition or by appearance alone.

Do not claim a universal service interval. Compare like-for-like production and controlled pressure or airflow trends.

14. Fan strain, noise or energy increase

Loaded filters increase system resistance and can move the fan away from its intended operating condition. Abnormal noise, vibration, motor load, belt condition or reduced flow also can arise from mechanical defects or duct restriction. [S179]

Stop and involve competent maintenance when fan or drive condition is abnormal. A higher-capacity fan is not a routine remedy for an unsuitable or obstructed system.

15. Extended or uncertain clearance time

Clearance time is the period required after spraying stops for airborne mist or vapour to be removed to the controlled criterion. Filter loading, airflow imbalance, leakage and process change can affect it.

HSE guidance recommends clearance verification under representative adverse conditions, including filter loading, and checking for leakage. [S176] Use the booth’s posted and validated clearance control. Do not enter early because the booth looks clear.

16. Change filters as a controlled task

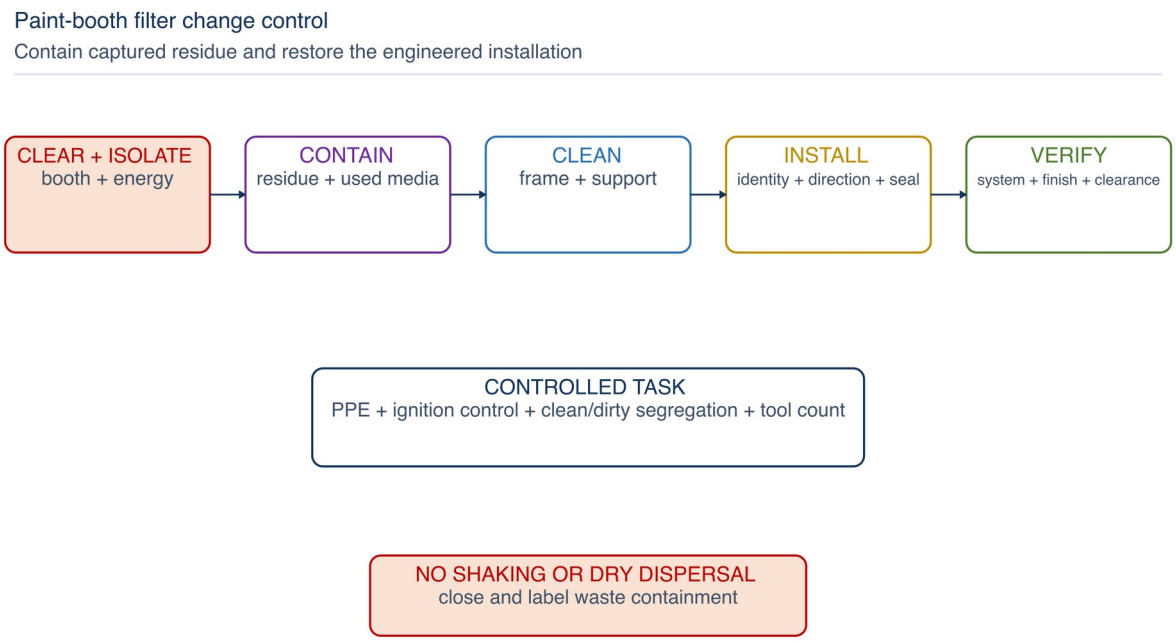

Figure 3. Paint-booth filter change control. Isolation, residue containment, installation and system verification form one controlled change.

Before change-out:

- stop spraying and complete the required clearance;
- isolate relevant energy under the work method;
- prepare compatible replacement media and tools;
- control ignition sources and static risks;
- wear PPE for the coating and residue hazards;
- protect clean supply areas from dirty exhaust media; and
- prepare labelled containment for used filters.

Remove media without shaking captured residue. Clean sealing faces and supports without dispersing dust. Install in the marked direction, secure all joints and account for tools and loose material before closure.

17. Avoid mixed-condition filter banks

Replacing isolated panels in a bank can create uneven resistance if the booth design expects a matched set. Local new-versus-loaded sections may distort airflow.

Follow the booth and filter instructions for bank replacement. If partial replacement is permitted, record locations and verify the full pattern. Never mix unconfirmed filter families merely because dimensions appear similar.

18. Handle used filters and residue correctly

Used filters can contain paint solids, solvent, metal pigment, isocyanate-related residue or other hazardous material. Prevent ignition, incompatible mixing, leakage and unauthorised reuse.

Waste classification follows the actual coating and process. Refer to current Department of Environment Malaysia scheduled-waste requirements and competent site procedures. [S189] Do not label all used filters identically without checking the residue source.

19. Verify after correction

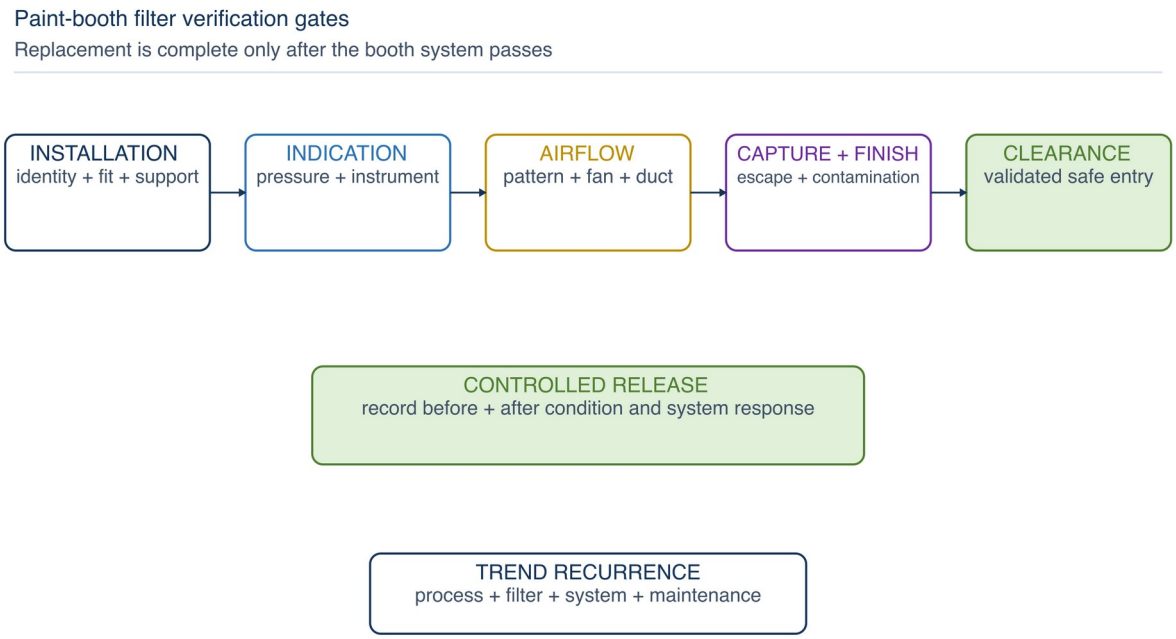

Figure 4. Paint-booth filter verification gates. Installation, system indication, airflow pattern, capture, finish and clearance must all pass before release.

Verify as applicable:

- correct filter identity, direction, fit, support and sealing;
- clean plenum, frame and booth condition;
- pressure indication and tubing condition;
- fan, drive, damper, duct and discharge condition;
- approved airflow pattern or capture test;
- no visible bypass, collapse or overspray escape;
- coating finish under a controlled check; and
- validated clearance and safety-system function.

Record the condition before and after change. A new filter is not proof that the booth is ready.

20. Rapid troubleshooting table

Symptom	Likely cause families	Controlled response
Pressure rises rapidly	loading, reversal, compression, wet media, obstruction	inspect complete path and recent process change
Pressure unexpectedly low	bypass, tear, fan loss, instrument fault	stop, verify integrity and airflow before use
Uneven airflow	mixed loading, gaps, plenum, damper, drafts	restore installation and system balance
Dirt in finish	supply filter, bypass, plenum, clothing, handling	identify particle source; clean and seal controlled areas
Overspray escapes	exhaust loading, bypass, fan or duct problem	stop spraying and restore capture system
Media collapses	support, fit, wet loading or excessive condition	isolate, contain residue, correct support and replace
Filters load too quickly	spray process, production, area, moisture or wrong selection	compare controlled production and system trend
Clearance takes longer	loading, imbalance, leakage or process change	revalidate under approved method before entry

21. Concise safety reminders

- Never spray without the required mechanical ventilation and safety controls.
- Do not bypass pressure indication, alarms, interlocks or fire-protection systems.
- Complete booth clearance before entry or filter work.
- Control ignition, static, solvent vapour, isocyanate and combustible-residue hazards.
- Isolate fans and moving equipment before access.
- Use PPE and respiratory controls for the actual coating and cleaning materials.
- Keep clean supply filters separated from contaminated exhaust media.
- Contain and classify used filters according to the actual residue and current requirements.

Key takeaways

- Treat the filter as part of the complete booth airflow system.
- High and low pressure signals can both indicate unsafe or poor-control conditions.
- Check orientation, expansion, support and sealing at every change.
- Diagnose supply-side dirt separately from exhaust-side capture.
- Never use appearance alone to set filter change timing.
- Verify airflow, capture, finish and clearance after correction.
- Classify used filters from the actual coating residue.

SELECTION, PRODUCTIVITY & TROUBLESHOOTING

CHAPTER 072

Chemical Problems

72

SELECT • APPLY • FINISH • TROUBLESHOOT

MKTech Industry Sdn Bhd | www.mktechindustry.com

Audience: Production operators, supervisors, maintenance personnel, process engineers, EHS teams, QA/QC personnel and technical buyers

Scope: Industrial cleaners; degreasers; descalers; pickling and passivation products; process baths; rinsing; drying; staining; corrosion; surface attack; contamination; storage; spills; waste and verification.

Core principle — Never correct a chemical problem by guessing, mixing or adding more product. Confirm identity, hazard, material compatibility and the controlled process condition before changing anything.

The same symptom can have several causes. Poor cleaning may result from the wrong chemistry, exhausted or contaminated solution, inadequate mechanical action, trapped soil, short contact or poor rinsing. Staining may result from residue, water quality, corrosion, incompatible contact or chemical over-attack. Troubleshoot the complete system.

When an exact product value is required, **Refer to the product label, Technical Data Sheet, or MKTECH representative.**

Chapter objectives

After this chapter, the reader should be able to:

- recognise chemical conditions requiring immediate stop and escalation;
- confirm product identity and current information before use;
- separate soil-removal failure, residue and surface attack;
- diagnose wetting, cleaning, descaling, staining, corrosion and rinse problems;
- prevent incompatible mixing, contamination and trapped chemistry;
- control bath condition only through an approved method; and
- verify the treated surface and downstream readiness.

1. Immediate stop conditions

Stop the task, isolate the area as directed and activate the site response when there is:

- unknown, unlabelled or incorrectly labelled chemical;
- unexpected heat, gas, pressure, vigorous reaction or colour change;
- fire, smoke, strong unexpected odour or ventilation failure;
- splash, inhalation, skin contact or other suspected exposure;
- leaking, swollen, corroded or unstable container;
- incompatible products mixed or likely to meet;
- chemical entering an unauthorised drain, soil or water pathway;
- rapid metal attack, pitting, embrittlement concern or component damage; or
- loss of process control, monitoring or emergency equipment.

Do not smell, touch or mix an unknown material to identify it. Follow the current Safety Data Sheet and workplace emergency procedure.

2. Confirm identity before diagnosis

Check:

- full product name and manufacturer;
- batch or lot where applicable;
- current container label;
- Safety Data Sheet and Technical Data Sheet revision;
- intended operation and compatible materials;
- received, opened and expiry information;
- transfer-container identification;
- storage condition and evidence of contamination; and
- approved work method and chemical assessment.

Malaysia’s USECHH framework places chemical identification, assessment and exposure control within the workplace management system. [S009; S017; S160; S198; S288; S303]

3. Classify the chemical problem

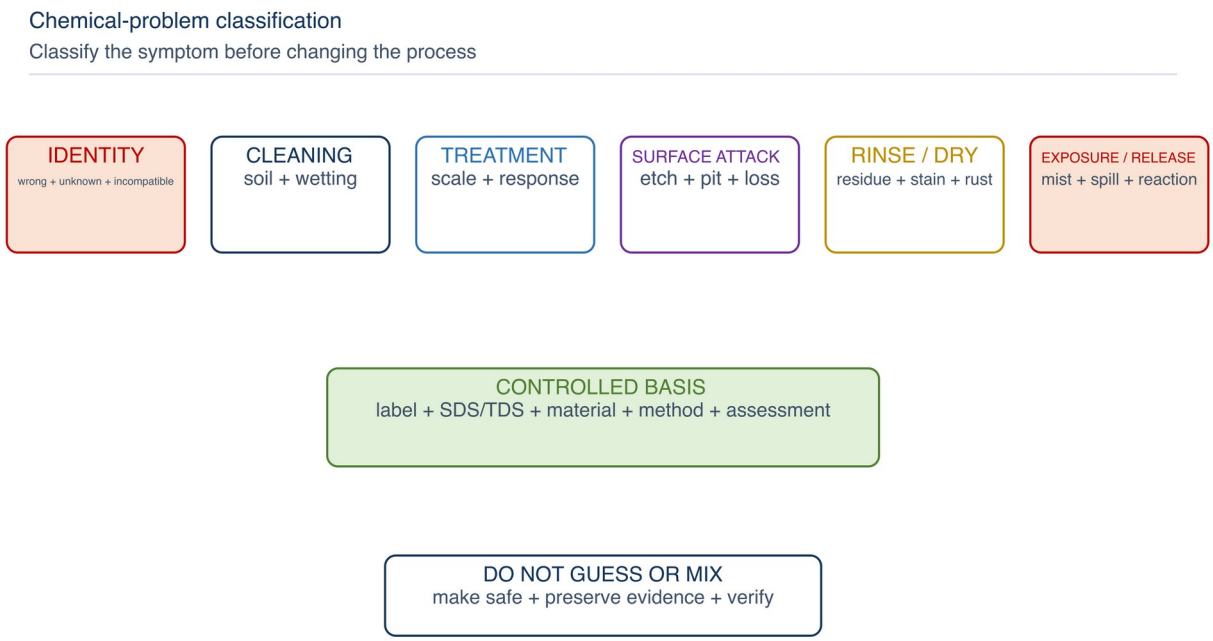

Figure 1. Chemical-problem classification. Separate identity, cleaning, surface attack, bath condition, rinse or drying, and exposure or release problems before correction.

Problem family	Typical symptom	First checks
Identity or compatibility	unexpected reaction, coating damage, wrong odour	label, SDS/TDS, material and prior product
Cleaning failure	oil remains, water breaks, patchy wetting	soil type, precleaning, solution condition, access
Surface-treatment failure	scale remains, uneven colour, poor response	incoming oxide, compatibility, bath control, contact
Surface attack	etch, pit, darkening, dimensional change	material, time, temperature, concentration, contamination
Rinse or drying	streak, residue, watermark, flash rust	rinse condition, carry-over, drainage, drying delay
Exposure or release	mist, splash, leak, drain entry	containment, ventilation, handling, emergency controls

4. Use a controlled diagnostic sequence

Proceed in order:

1241. make the condition safe;
1242. preserve labels, samples and process records;
1243. identify the exact symptom and first affected stage;
1244. confirm material, soil, coating and geometry;
1245. check product and bath condition;
1246. check application, equipment, rinse and drying;
1247. change one controlled factor; and
1248. verify surface, safety and waste outcomes.

Do not add concentrate, solvent, acid, alkali, oxidiser or neutraliser merely because a result appears weak.

5. Poor wetting and water-break behaviour

Beading or discontinuous wetting can indicate retained oil, grease, polishing compound, silicone, temporary protection, incompatible residue or a hydrophobic surface condition. It may also reflect contaminated rinse water or handling after cleaning.

Review soil type, precleaning, access to recesses, solution condition, agitation or mechanical action where approved, and clean handling. AMPP solvent-cleaning context distinguishes removal of visible oil and grease from later surface-preparation operations. [S140; S211]

Do not interpret one informal water test as universal proof of cleanliness.

6. Oil, grease or compound remains

Possible causes include:

- cleaner unsuitable for the actual soil;
- product used outside its controlled condition;
- bath overloaded with removed soil;
- poor access beneath laps, fixtures or heavy deposits;
- insufficient solution movement or contact;
- redeposition during withdrawal;
- contaminated wiping material; and
- soil introduced again during handling.

Remove bulk contamination by an approved method before expecting a fine-cleaning bath to carry excessive soil. Confirm that the cleaner does not damage coatings, seals, plastics or adjacent materials.

7. Scale, oxide or rust remains

Degreasing and oxide removal are different functions. Oil can shield scale from chemical contact, while a degreaser may leave adherent oxide unchanged. Cleaning, descaling, pickling and passivation have distinct purposes in stainless-steel standards and recognised industry guidance. [S212–S213; S217; S221–S223]

Check incoming oxide thickness and type, precleaning, alloy compatibility, solution condition, access and process control. Do not extend treatment indefinitely; persistent oxide may require a different approved preparation route.

8. Uneven cleaning or patchy reaction

Patchiness can follow uneven soil, trapped air, poor immersion, contact with fixtures, local heat, bath stratification, inadequate circulation, mixed materials, previous repair, weld heat tint or inconsistent rinsing.

Map the pattern against component orientation and flow. A line at the liquid level suggests a different cause from a patch under a clamp. Repositioning or agitation must follow the controlled method and must not create splash or exposure.

9. Staining, darkening and unexpected colour

Possible causes include:

- reaction products not rinsed away;
- excessive chemical exposure;
- contaminated bath or rinse;
- incompatible alloy or mixed-metal contact;
- drying marks or mineral residue;
- flash corrosion;
- heat tint that was not fully removed; and
- residue from a prior process.

Do not polish or chemically treat away the evidence before determining whether the colour is residue, corrosion, oxide or base-metal attack.

10. Over-etching, pitting and dimensional loss

Rapid dulling, roughness, grain-boundary appearance, pitting or measurable stock loss indicates that the chemistry may be attacking the base material. Stop treatment and rinse or contain only according to the approved emergency or process method.

Review material identity, bath condition, contact duration, temperature, contamination and mixed-metal effects. ASTM cleaning and passivation standards provide material-specific frameworks rather than one universal treatment. [S212–S213]

Do not release a visibly restored component until geometry and surface integrity are assessed.

11. Hydrogen and material-integrity concerns

Some acidic cleaning or pickling conditions can introduce hydrogen-related risk in susceptible high-strength materials, coatings or components. The actual risk depends on material, strength, stress, chemistry and process history.

Stop and refer the component for competent materials review when the approved process controls were exceeded, the material is uncertain or cracking is suspected. This handbook does not assign a safe material strength, exposure time or post-treatment condition.

12. Foam, carry-over and solution drag-out

Unexpected foam may arise from soil loading, contamination, agitation, incompatible additions, temperature change or product degradation. Carry-over increases chemical loss, contaminates rinse stages and can create residue on parts and floors.

Check bath level, workpiece drainage, basket geometry, withdrawal practice, solution condition and contamination source. Do not add an unapproved defoamer because it may affect cleaning, coating or waste treatment.

13. Bath strength or condition appears unstable

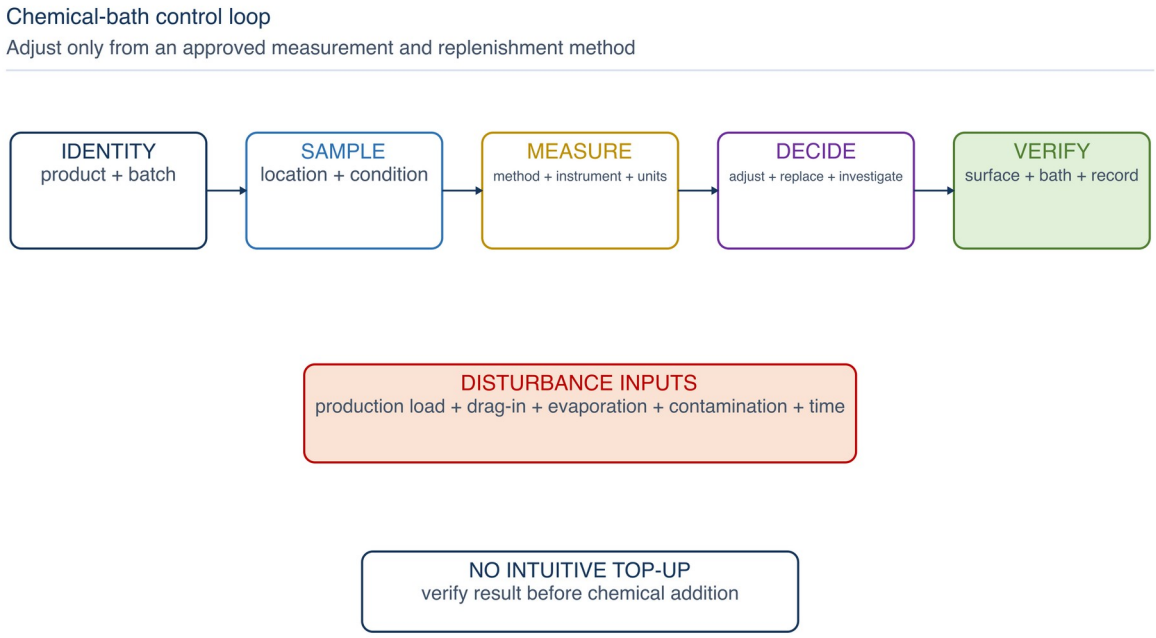

Figure 2. Chemical-bath control loop. Identity, make-up, measurement, contamination, production load and replenishment must remain within one approved control method.

Use only the specified sampling and analysis method. Verify instrument condition, sample location, temperature compensation where required, calculation, units and record traceability. A reading that differs suddenly may reflect sampling or measurement error rather than actual bath change.

Never top up by intuition. Confirm whether the result calls for adjustment, partial replacement, full replacement, filtration or investigation under the approved process.

14. Contamination and incompatible mixing

Cross-contamination can come from shared pumps, hoses, funnels, tanks, baskets, wipes, recycled containers or drag-in from the previous stage. Even small additions can change pH, reaction, foam, precipitation or material attack.

Dedicate and identify transfer equipment where required. Keep container closures clean and closed. Never return unused chemical to the original container unless the product instructions explicitly permit it.

If incompatible mixing is suspected, stop and use the site chemical-emergency system. Do not attempt improvised neutralisation.

15. Rinse failure and residue

Rinsing removes process chemistry and dissolved contamination from the surface. Problems include exhausted rinse, insufficient stages, poor flow into recesses, trapped solution, contaminated spray nozzles, mixed carry-over, inadequate drainage and recontamination.

Inspect crevices, threads, tubes, blind holes and horizontal pockets. Verify rinse quality only by the approved method. Do not assign one universal conductivity, pH or rinse-water specification.

16. Flash rust and corrosion after cleaning

Freshly cleaned metal may corrode rapidly if water, chloride, acidic residue, high humidity or drying delay remains. Possible causes include inadequate rinse, contaminated water, trapped solution, unsuitable drying air, bare reactive metal or contact with contaminated tools.

Identify whether the stain is flash rust, ferrous transfer, process residue or underlying corrosion. Correct rinse, drainage, handling and environmental cause before repeating treatment.

17. Drying marks and trapped chemistry

Watermarks and streaks can form when droplets dry unevenly or dissolved material remains. Trapped chemistry in seams, hollow sections, threads or porous deposits can leak later and attack the surface or downstream coating.

Design the handling orientation to drain safely, use the approved drying method and inspect inaccessible features. Do not seal, paint or pack a component while retained chemistry is suspected.

18. Ventilation, splash and PPE problems

Mist, vapour and splash controls depend on chemical hazard, task, temperature, application and quantity. Check enclosure, local exhaust, covers, transfer method, splash shields, emergency washing facilities and work posture.

Chemical glove and clothing selection requires documented compatibility; one material does not protect against every chemical. Malaysian guidance places PPE after higher-level controls and requires suitable selection, use and maintenance. [S288–S289] ISO 374-1 provides current chemical-glove performance terminology. [S297]

19. Storage, transfer and container problems

Inspect for:

- incompatible chemicals sharing containment;
- damaged, corroded or swollen containers;
- missing labels or open transfer vessels;
- unsuitable pumps, hoses or seals;
- heat, sunlight or moisture exposure;
- stock beyond controlled shelf condition;
- blocked access to spill equipment; and
- leakage paths toward drains or occupied areas.

Malaysian and international guidance emphasises hazard-led segregation, containment, inspection, stock control and emergency readiness. [S224–S228]

20. Spill, exposure or abnormal-reaction response

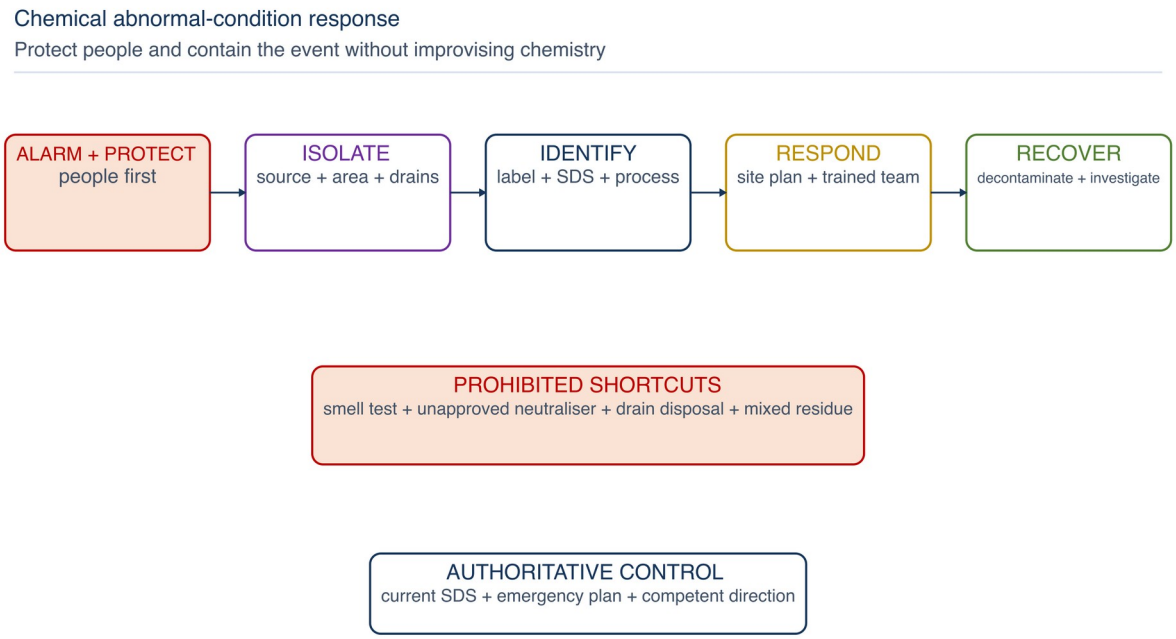

Figure 3. Chemical abnormal-condition response. Protect people, isolate the source, identify the substance and follow the site response—never improvise a chemical reaction.

The first priorities are people, alarm, isolation and prevention of spread. Use the current SDS and site plan for first aid, evacuation, compatible spill materials, ventilation, reporting and cleanup. Keep untrained personnel away.

Do not hose chemicals to a drain, combine spill residues or use a neutraliser without an approved procedure.

21. Manage spent chemistry and contaminated waste

Spent baths, rinse residue, sludge, absorbent, wipes, PPE and containers may require different classification. Determine waste status from the actual chemical, contamination and generating process.

Department of Environment Malaysia guidance controls scheduled-waste classification, packaging, labelling and storage. [S216] Do not assign a waste code solely from the trade name or this handbook.

22. Verify correction and release

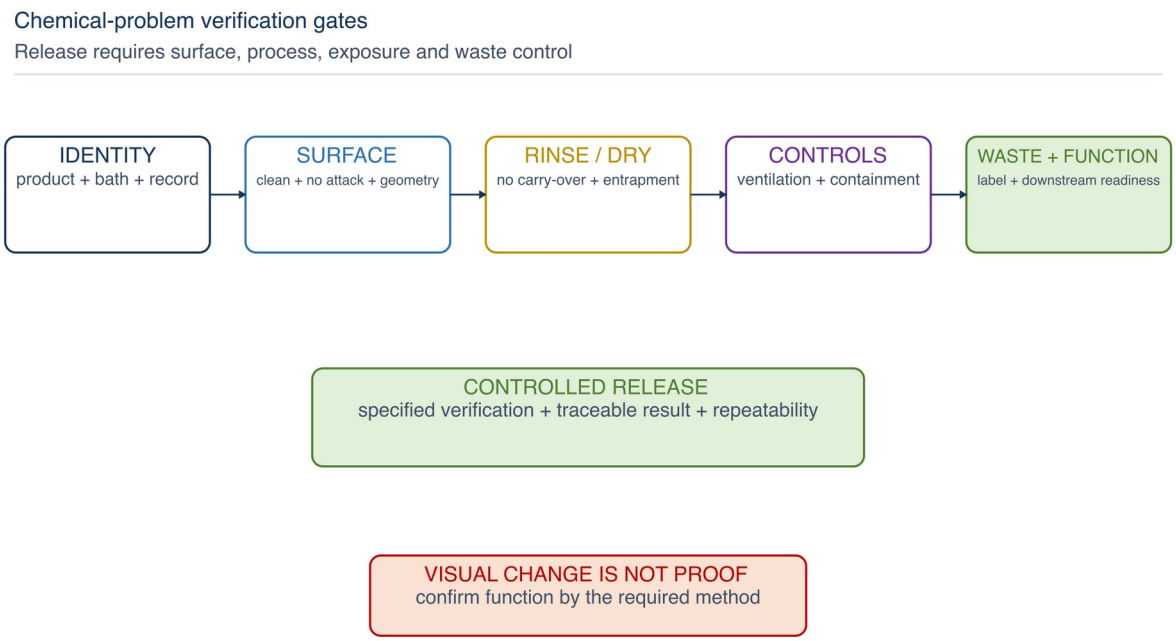

Figure 4. Chemical-problem verification gates. Identity, process control, surface condition, rinse and dry, exposure control and waste disposition must pass before release.

Verify as applicable:

- correct chemical identity and controlled bath condition;
- required soil, oxide or contamination removal;
- no unacceptable etch, pit, stain, residue or dimensional change;
- specified cleanliness or passivation verification;
- complete rinse, drainage and drying;
- coating, bonding, sealing or service compatibility;
- restored ventilation, containment and emergency controls; and
- labelled waste containment and traceable records.

Visual improvement alone does not prove passivation, corrosion resistance or absence of chemical damage.

23. Rapid troubleshooting table

Symptom	Likely cause families	Controlled response
Oil remains	wrong cleaner, overload, access, redeposition	confirm soil and process; restore controlled cleaning condition
Scale remains	incomplete degreasing, wrong function, depleted bath	separate soil and oxide removal; verify approved treatment
Patchy reaction	air trap, fixture, flow, mixed surface, contamination	map pattern and correct contact or bath cause
Dark stain	residue, overexposure, rinse, corrosion	preserve evidence and distinguish deposit from attack
Pitting or roughening	incompatibility, excessive condition, contamination	stop, rinse/contain as directed and assess material integrity
Excessive foam	soil, contamination, agitation, incompatible addition	stop unapproved additions and investigate bath condition
Residue after rinse	carry-over, trapped chemistry, exhausted rinse	restore rinse and drainage control before drying

Symptom	Likely cause families	Controlled response
Flash rust	retained water, chloride, acidic residue, drying delay	correct rinse, handling and environmental cause
Strong unexpected odour	reaction, ventilation failure, wrong product	stop, isolate and activate chemical response
Bath reading changes suddenly	sampling, instrument, unit or actual bath change	verify measurement system before adjustment

24. Concise safety reminders

- Read the current label, SDS, TDS and workplace method before use.
- Never mix products or improvise dilution, neutralisation or top-up.
- Add and transfer chemicals only by the specified method and equipment.
- Keep incompatible groups segregated with compatible containment.
- Maintain ventilation, splash control and emergency washing facilities.
- Use documented chemical-compatible PPE and change it when damaged or contaminated.
- Keep food, drink, smoking and ignition sources out of controlled chemical areas.
- Report exposure, spill, unexpected reaction and loss of containment immediately.

Key takeaways

- Confirm chemical identity before diagnosing performance.
- Separate cleaning failure, surface attack, residue and corrosion.
- Never adjust a bath from appearance or intuition alone.
- Control cross-contamination at every transfer and process stage.
- Rinsing, drainage and drying are part of the chemical process.
- Stop for unexpected reaction, exposure or material attack.
- Verify surface, safety, downstream function and waste control before release.

Complete source index

Resolution key for every [Sxxx] citation used in the handbook

Every source code printed in the chapters resolves in this index. Standards, regulators, engineering institutions, peer-reviewed publications and manufacturer technical sources are identified by publisher and title.

A source citation supports the stated technical principle only; it does not transfer another manufacturer's product specification, approval or performance claim to an MKTECH product.

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