BOMBARDIER
Toronto Site
PROPRIETARY INFORMATION

PPS 42.01

PRODUCTION PROCESS STANDARD

CHEMICAL MILLING OF ALUMINUM AND ALUMINUM ALLOYS

Issue 12
- This standard supersedes PPS 42.01, Issue 11.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- Direct PPS related questions to christie.chung@aero.bombardier.com or (416) 375-7641.
- This PPS is effective as of the distribution date.

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1 SCOPE

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for the following types of chemical milling (chem-milling) of aluminum alloys:

Type I - Conventional chem-milling.

Type II - Chem-milling using special solutions and procedures to obtain a surface finish of Ra 63 or finer.

Type III - Chem-milling for precision forgings using special solutions and procedures to obtain a surface finish of Ra 85 or finer.

Note: When no type is specified, Type I is implied, but Types II and III may be performed. Perform Type II chem-milling if no type and a surface finish of Ra 63 or finer, is specified.

1.1.1 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS shall be followed to ensure compliance with all applicable specifications. In general, if this PPS conflicts with the engineering drawing, follow the engineering drawing. The requirements specified in this PPS are necessary to fulfil the engineering design and reliability objectives.

1.1.2 Refer to PPS 13.26 for the subcontractor provisions applicable to this PPS.

1.1.3 Procedure or requirements specified in a Bombardier BAPS, MPS, LES or P. Spec. do not supersede the procedure or requirements specified in this PPS. Similarly, the procedure and requirements specified in this PPS are not applicable when use of a BAPS, MPS, LES or P. Spec. is specified.

2 HAZARDOUS MATERIALS

2.1 Before receipt at Bombardier Toronto, all materials shall be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier Toronto Environment, Health and Safety Department. Refer to the manufacturer's MSDS for specific safety data on any of the materials specified in this PPS. If the MSDS is not available, contact the Bombardier Toronto Environment, Health and Safety Department.

3 REFERENCES

3.1 BAERD GEN-018 - Engineering Requirements for Laboratories.

3.2 PPS 13.26 - General Subcontractor Provisions.

3.3 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.4 PPS 20.03 - Fluorescent Penetrant Inspection.

3.5 PPS 27.01 - Repair of Surface Defects in Aluminum Alloy Sheet.

3.6 PPS 31.02 - Cleaning Processes for Aluminum and Aluminum Alloys.

3.7 PPS 31.17 - Solvent Usage.

4 MATERIALS, EQUIPMENT AND FACILITIES

4.1 Materials

4.1.1 It is acceptable to use alternate chem-milling materials to those specified herein provided that all the requirements of section 6 are met and the materials have no deleterious effects on the base metals.

4.1.1.1 Maskant that does not degrade base metal, provides complete protection from the etching solution and exhibits good peeling properties.

4.1.1.2 Patch tape, Scotch #471 vinyl tape, Scotch #420 lead foil tape or polyethylene tape.

4.1.1.3 Line sealer, AC 806, AC Products.

4.1.1.4 Repair compound, Turcoform Touchup No. 10, Turco Products.

4.1.1.5 Repair compound, No. 732 RTV Sealant, Dow Corning Co.

4.1.1.6 Corrosion preventive compound, Esso Rust Ban 632 or Rust Ban 392.

4.1.1.7 Abrasive paper, 180 - 220 and 400 grits, aluminum oxide.

4.1.1.8 Protective wrapping paper, neutral Kraft paper.

4.2 Equipment

4.2.1 Chem-milling solution tanks, equipped with temperature indicating, regulating and recording devices capable of controlling the chem-milling solution temperature within ± 5°F and equipped with mechanical or air agitation.

4.2.2 Chemical tanks as specified in PPS 31.02.

4.2.3 Surface roughness measuring equipment, adjustable to provide a 0.01" cutoff and capable of making surface measurements and measurements 45° into chem-milled fillets.

4.2.4 Part thickness measuring device (e.g., a sharp point, deep throated micrometer).

4.2.5 Lint free cotton gloves (e.g., DSC 422-1).

4.3 Facilities

4.3.1 This PPS has been categorized as a “Controlled Critical Process” according to PPS 13.39 and as such only facilities specifically approved according to PPS 13.39 are authorized to perform chemical milling (chem-milling) of aluminum alloys according to this PPS.

4.3.2 Bombardier subcontractors shall direct requests for approval to Bombardier Aerospace Supplier Quality Management. Bombardier Aerospace facilities shall direct requests for approval to the appropriate internal Quality Manager.

4.3.3 Facility approval shall be based on a facility report, a facility survey and completion of a qualification test program, if required. The facility report shall detail the materials and equipment to be used, the process sequence to be followed and the laboratory facilities used to show compliance with the requirements of this PPS. Any deviation from the procedure or requirements of this PPS shall be detailed in the facility report. Based upon the facility report, Bombardier Toronto Engineering may identify additional qualification and/or process control test requirements. During the facility survey, the facility requesting qualification shall be prepared to demonstrate their capability. Once approved, no changes to subcontractor facilities may be made without prior written approval from Bombardier Aerospace Supplier Quality Management.

4.3.3.1 For approval of subcontractor facilities to perform chemical milling (chem-milling) of aluminum alloys according to this PPS, completion of a test program and submission of suitable test samples representative of production parts is required. Test samples shall meet the requirements specified in section 6.

4.3.3.2 All testing and evaluation specified herein shall only be performed by Bombardier Toronto Materials Laboratory or by laboratories accredited according to BAERD GEN-018.

5 PROCEDURE

5.1 General

5.1.1 For the purposes of this PPS, the term “MRB” (Material Review Board) shall be considered to include Bombardier Toronto MRB and Bombardier Toronto delegated MRB.

5.1.2 Chem-milling chemically removes material from parts rather than removing material mechanically by machine milling.

5.1.3 The maximum accumulated processing time (maskant curing plus chem-milling) for 2024 alloys at 200°F and above is limited by the following formula:

[Maskant Curing Temperature (°F) - 193] X Time (hours) +
[Chem Milling Temperature (°F) - 193] X Time (hours) $\leq$ 64

OR

[Maskant Curing Temperature (°C) - 89.4] X Time (hours) +
[Chem Milling Temperature (°C) - 89.4] X Time (hours) $\leq$ 36

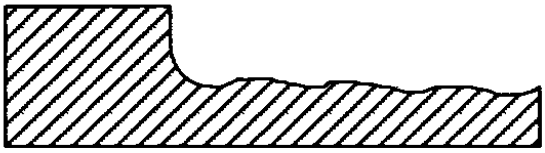
For example, if maskant cures for 6.5 hours at 201°F and the part is chem-milled for 36 minutes at 213°F: [(201 - 193) X 6.5] + [(213 - 193) X (36/60)] = 64. Therefore, no further processing at 200°F or greater is allowed.

5.1.4 Refer to section 5.2 for definitions of terms applicable to the chem-milling process.

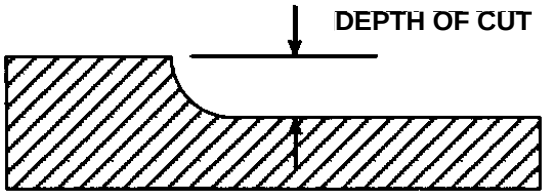
5.2 Terms Applicable to Chem-Milling

5.2.1 *Channelling* - The formation of a groove or channel at the fillet.

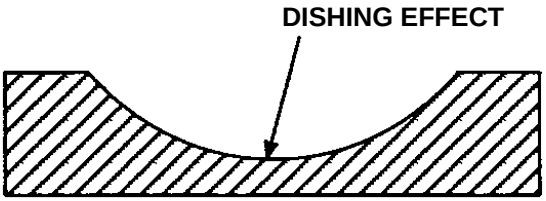
5.2.2 *Channelling, Gas* - The formation of vertical grooves or channels in the etched surface, possibly caused by hydrogen bubbles rising to the etch bath surface.



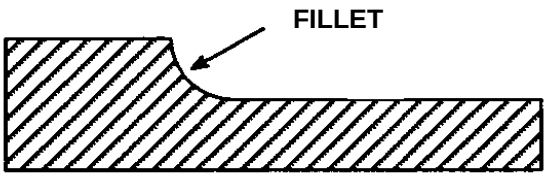
5.2.3 *Cut or Depth of Cut* - The thickness of metal removed, measured vertically from the non-etched part surface to the “nominal” etched surface.



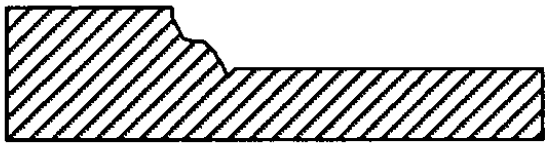
5.2.4 *Dishing* - Central web thinning, resulting from an increasing etch rate from the side to centre, due to improper solution agitation, temperature control or racking.



5.2.5 *Fillet* - The concave or flat shoulder between etched and non-etched surfaces.

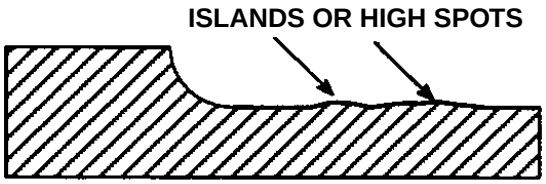


5.2.6 *Fillet Notch* - A notch at the fillet radius bottom, usually caused by scribing too deeply.

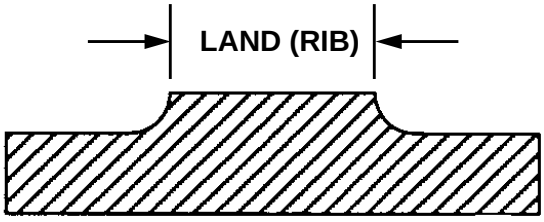


5.2.7 *Gang Milling* - The etching of more than 1 part at once, usually 2 or more parts in 1 sheet, cut apart after chem-milling.

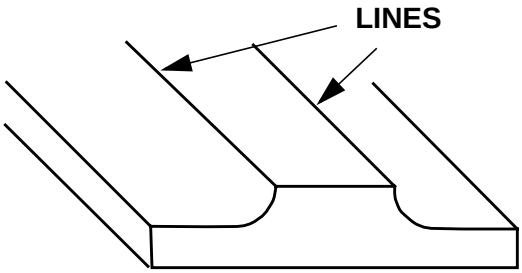
5.2.8 *Islands* - High spots within an etched area, resulting from an uneven etch rate, usually caused by the masking action of dirt or maskant residue left on the surface being etched.



5.2.9 *Land (Rib)* - The raised, non-etched portion of a part.

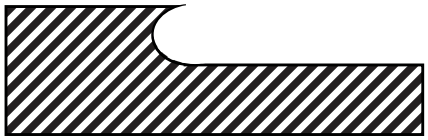


5.2.10 *Line Definition* - The actual quality of the fillet shoulder edge.

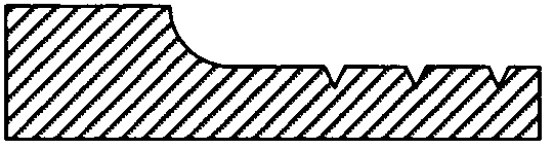


5.2.11 *Monitor Strip* - Test strip of the same alloy and condition as the chem-milled parts. Determine etch rate (material removed/minute/side) by immersing the strip vertically in the etching solution for 30 minutes and dividing the loss in thickness by 60.

5.2.12 *Overhang* - As depicted by the following figure:

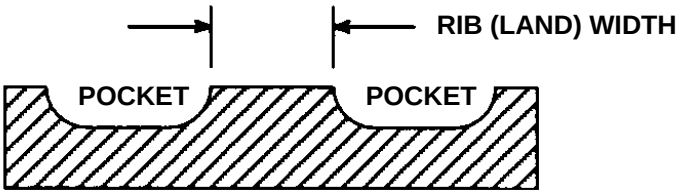


5.2.13 *Pitting* - The formation of pits or depressions in the etched surface.



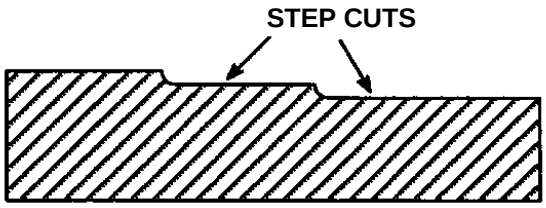
5.2.14 *Pocket* - A cavity formed by chem-milling.

5.2.15 *Rib (Land) Width* - The dimension between pockets, measured from the fillet shoulder edge or line.



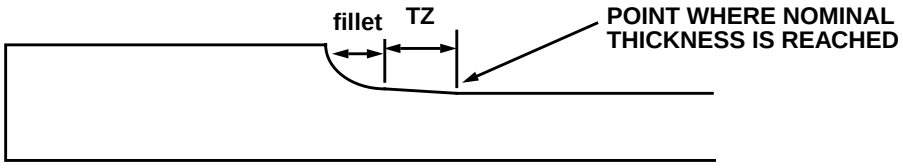
5.2.16 *Ridge* - Formation of a raised ridge at the fillet base.

5.2.17 *Step Cuts* - Multiple cuts of different depths in the same part.



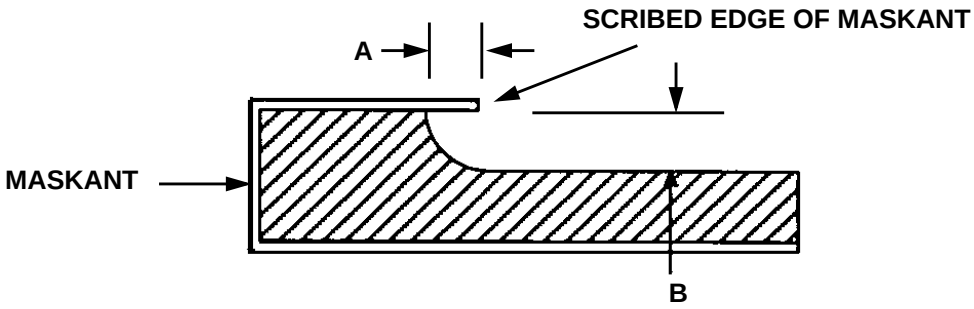
5.2.18 *Taper Milling* - Inducing a taper in a part by immersing in solution and withdrawing it at a continuous controlled slow rate.

5.2.19 *Transition Zone (TZ)* - The distance from the bottom edge of the fillet to the point where the thickness of the chemically milled area becomes constant.



5.2.20 *Undercut* - The amount of material removed by etching underneath the maskant at the scribed edge.

5.2.21 *Undercut Ratio* - The amount of material removed, measured at a point along the original surface from the scribed maskant edge, divided by the depth of cut.



$$\text{UNDERCUT RATIO} = \frac{\text{UNDERCUT (A)}}{\text{DEPTH OF CUT (B)}}$$

5.3 Template Preparation

5.3.1 Allow for the undercut ratio (see paragraph 5.2.21) when preparing templates for chem-milling. The undercut ratio depends on the type and temper of the material, the depth of cut, the line direction relative to the grain direction, the etchant type and the maskant type. The scribe template dimensions shall provide sufficient maskant to compensate for undercutting on all sides (see Figure 1).

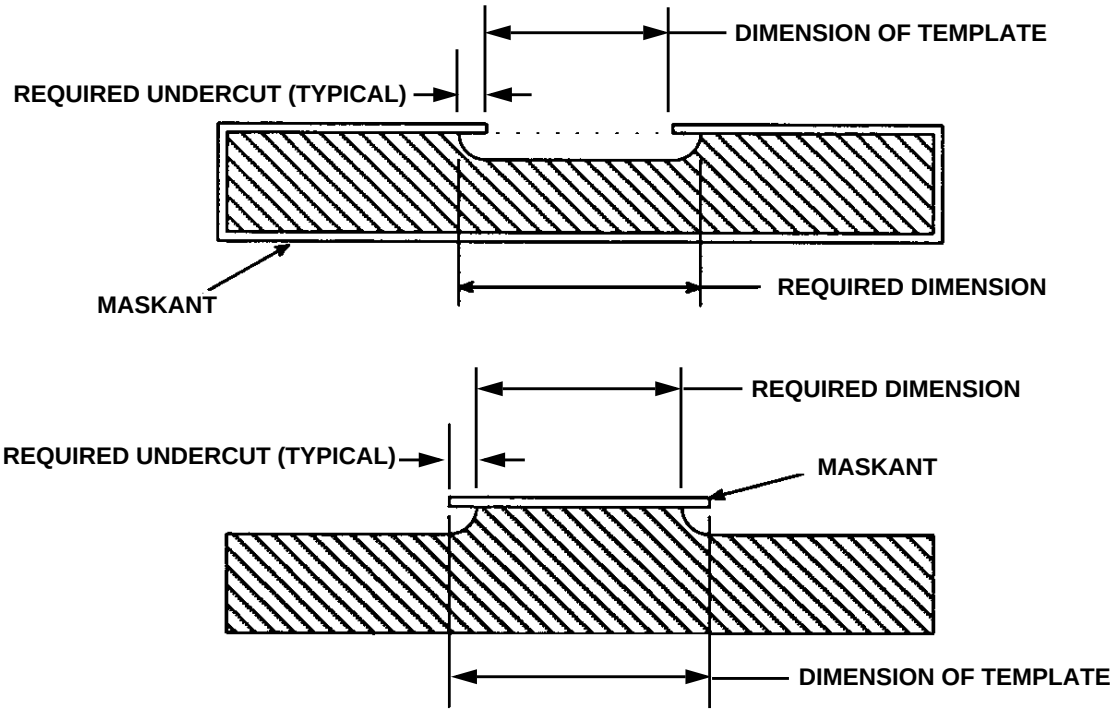


FIGURE 1 - UNDERCUT (TYPICAL)

5.3.2 Radius inside corners of the template to a minimum of 0.125" to permit a continuous scribe line (see Figure 2).

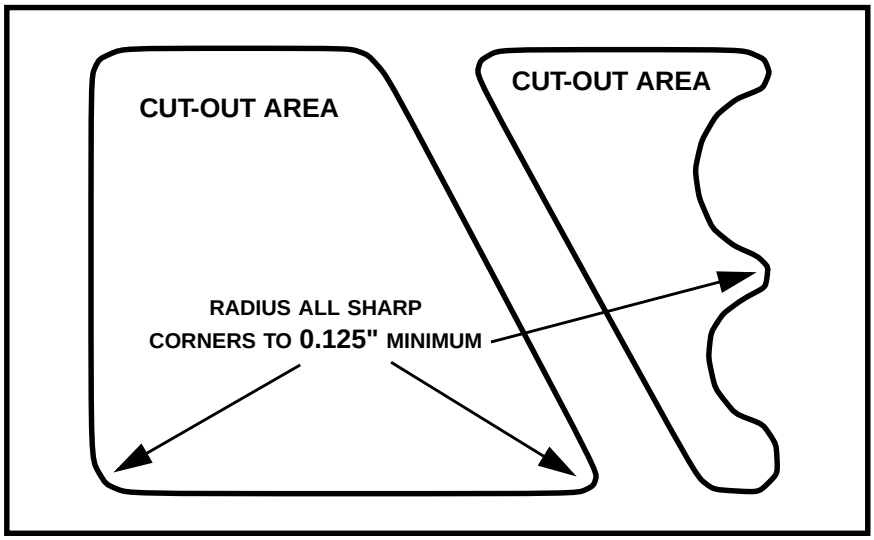


FIGURE 2 - TYPICAL TEMPLATE CORNER RADII

5.4 Pre-Processing Operations

5.4.1 Except as noted in paragraph 5.4.1.1, complete all forming, machining and heat treatment before chem-milling, whenever possible.

5.4.1.1 Perform drilling, other than drilling of tooling holes, after chem-milling.

5.5 Surface Preparation

5.5.1 Ensure surfaces are free of scratches, pits and other irregularities. Except as noted below, remove such defects according to PPS 27.01.

- If possible, re-align the template to avoid a defect in an otherwise acceptable part.
- If a major defect does not penetrate to the final engineering drawing thickness, cover the defective area with maskant and chem-mill to below the defect depth. Rework the defect flush with the etched surface and complete chem-milling. Refer the part to MRB if the defect penetrates to the engineering drawing thickness or beyond.

5.6 Surface Cleaning

5.6.1 Clean oil, grease, pencil marks, etc. from part surfaces, according to PPS 31.02, to obtain proper maskant adhesion and ensure uniform etching.

5.6.2 Apply maskant within 2 hours of cleaning. Wrap parts in clean, neutral Kraft paper if the delay exceeds 2 hours.

5.6.3 Wear clean cotton gloves when handling cleaned parts.

5.7 Maskant

5.7.1 General

5.7.1.1 The maskant may be applied by any suitable method (i.e., spray, dip, etc.) and shall be such as will provide complete protection from the etching solution and it shall also have good peelability.

5.7.1.2 The maskant shall be completely cured at a maximum temperature of 200°F before trimming to the template. Curing time will depend on the type of maskant used and the curing method employed.

5.7.1.3 The final thickness of the applied maskant shall be a minimum of 0.010".

5.7.1.4 After curing, check maskant for defects such as pinholes, blisters, scratches, non-adhering areas, etc. Spark testing to locate defects and pinholes in maskants is acceptable. Repair defects according to section 5.7.2 or section 5.7.3.

5.7.2 Repair of Non-Adhering Areas

5.7.2.1 Repair non-adhering areas as follows:

Step 1. Cut and remove the defective maskant plus a minimum of 1/4 inch around the defect periphery.

Step 2. Solvent clean the base metal according to PPS 31.17.

Step 3. Apply 2 to 4 coats of patching maskant, allowing the solvent to flash off between coats. Allow the final coat to dry for a minimum of 2 hours.

Step 4. If chem-milling for more than 1 hour, apply vinyl or lead foil tape (see paragraph 4.1.1.2) over the entire repaired area. Cover lead foil tape with patching maskant.

5.7.3 Repair of Pinholes, Blisters and Scratches

5.7.3.1 Repair pinholes, blisters, scratches, etc., as follows:

Step 1. Patch with vinyl tape (see paragraph 4.1.1.2) if the depth of cut is less than 0.100". Patch with lead foil tape (see paragraph 4.1.1.2) and cover with maskant if the depth of cut is 0.100" or greater.

Step 2. Extend the patch a minimum of 1/4 inch around the defect periphery.

Step 3. Use a roller or other suitable tool to press down the tape, being careful to avoid air entrapment.

5.8 Maskant Cutting

5.8.1 Locate the scribe template firmly on the masked part surface.

5.8.2 Using only sufficient pressure to cut the maskant, scribe the maskant to the template outline. Take care to prevent scoring the base metal with the scribing tool.

5.8.3 Carefully peel away unwanted maskant, exposing the surface to be etched. Ensure sharply defined maskant edges that follow the template outline. Remove the template and ensure the maskant is free from the defects specified in paragraph 5.7.1.4.

5.8.4 If milling steps in sequence, it is acceptable to scribe all patterns at once, provided that scribe lines subjected to the etching solution are covered with line sealer (see paragraph 4.1.1.3) and the line sealer is peeled before removing maskant for each milling step.

5.8.5 Repair damaged, pulled or inaccurate scribe lines before etching.

5.9 Chem-Milling Procedure

5.9.1 Agitate the chem-milling solution before and, if necessary, during chem milling to ensure uniform etching and to prevent pitting.

5.9.2 Before chem-milling each production batch, use monitor strips (see paragraph 5.2.11) to calculate the solution etch rate or base the etch time on previously processed batch of parts of the same alloy.

5.9.3 Use one part from each batch for process control. Measure the thickness of the sections to be etched and calculate the approximate etch time.

5.9.4 Immerse parts for the required etch time, rinse in cold water and measure the dimensions of the process control part.

5.9.5 When performing Type II chem-milling, deoxidize (de-smut) 7XXX alloys according to PPS 31.02 after the first 5 minutes of milling to produce acceptable Type II fillets.

5.9.6 Deoxidize (de-smut) high copper alloys (i.e., 2XXX series alloys) according to PPS 31.02 at intermediate stages, if necessary, to achieve acceptable surface finish.

5.9.7 On stepped parts, remove the scribed maskant in sequence by deoxidizing (de-smutting) according to PPS 31.02 and rinse in cold water after each milling step. To check the thickness of chem-milled areas, lift or cut a section of maskant to locate a micrometer anvil. Patch the cut section before re-immersing in the etch solution.

5.9.8 If required, obtain tapers by immersing parts in the etch solution and withdrawing at a controlled continuous rate. The maximum obtainable taper is approximately 0.100" per foot of length.

5.9.9 If additional etch time is required to achieve required dimensions, measure the initial depth of cut on the process control part, calculate the actual etch rate and adjust the etch time accordingly.

5.9.10 Process the production batch using the parameters established for the process control part.

5.10 Post Chem-Milling Procedure

5.10.1 Deoxidize (de-smut) parts according to PPS 31.02.

5.10.2 Remove maskant coatings.

5.10.3 Edge corner relieve sharp edges, approximately 0.015", as follows:

- Use fine-cut files, metal scrapers or abrasive paper on all straight edges and curves. When using files, use the draw method and lightly sand with an abrasive cloth after filing.
- Edge corner relieve tooling holes manually, using a rosette countersink cutter.

5.10.4 Protect all chem-milled parts for shipment or storage by interleaving and completely wrapping with neutral Kraft paper.

5.11 Rework of Defects

5.11.1 Remove raised areas greater than specified in Table II using a curved metal scraper or 180 - 220 grit abrasive paper (see Figure 3). Keeping within engineering drawing tolerances, rework local part surfaces that fail to meet surface roughness requirements specified in Table II using abrasive paper (see paragraph 4.1.1.7). Do not use heat generating tools.

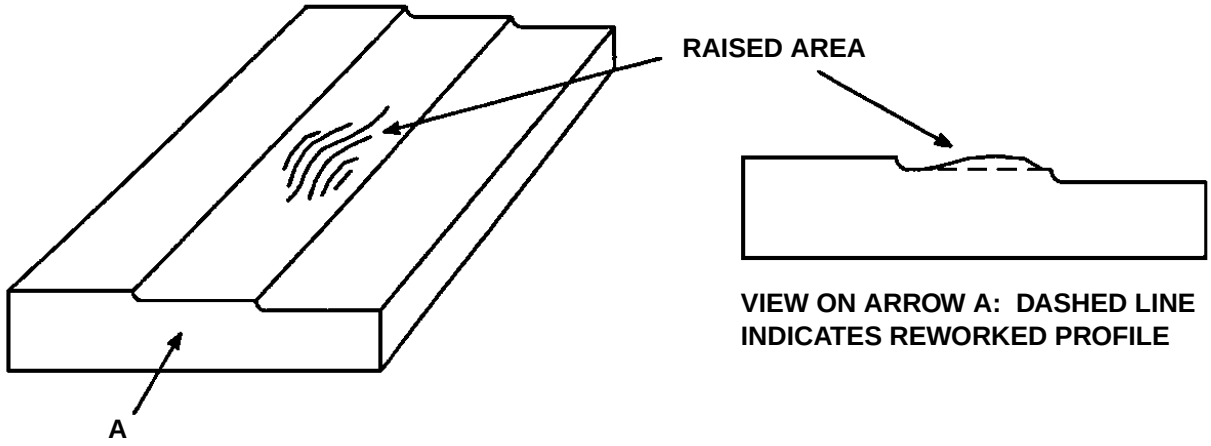


FIGURE 3 - REWORK OF CHEM-MILLED SURFACES (TYPICAL)

5.11.2 Unless otherwise specified on the engineering drawing, obtain the final surface finish in the reworked area using 400 grit abrasive paper.

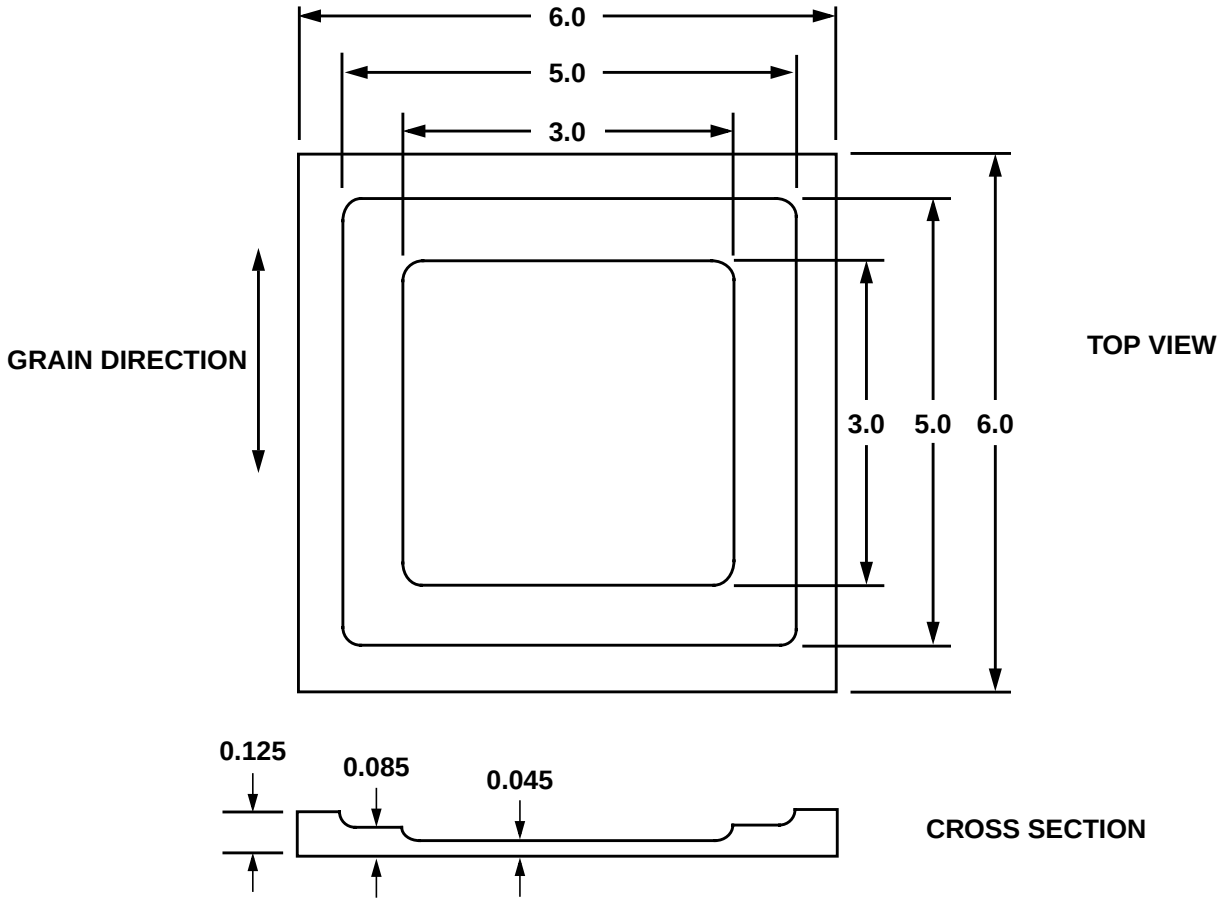
5.11.3 Remove all sanding residue by solvent cleaning according to PPS 31.17.

6 REQUIREMENTS

6.1 Process Qualification Tests

6.1.1 In addition to the requirements specified in PPS 13.26 and PPS 13.39, for qualification to produce parts according to this PPS, and periodically from then as requested by Bombardier, chem-mill 2 test specimens each of clad and bare 2024-T3 and clad and bare 7075-T6 conforming to the dimensions shown in Figure 4. Perform visual, dimensional and metallographic examination on one of the test specimens for each material. The second specimen and the test results of the first specimen of each material shall be submitted to Bombardier Toronto for evaluation and approval. Solution operating parameters shall also be submitted to Bombardier Toronto for review and approval.

6.1.2 Withhold or suspend the qualification process if any chem-milled surfaces show evidence of pitting or intergranular attack greater than the limits specified in Table IV, or if the surface roughness and thickness tolerances of Table II are exceeded after any rework according to section 5.11.



NOTE: ALL DIMENSIONS ARE IN INCHES. THE TOLERANCE FOR THE DIMENSIONS SPECIFIED IN THE TOP VIEW IS ACCORDING TO TABLE III (THE PERMISSIBLE LINE DEVIATION FROM THE IDEAL LINE SPECIFIED IN TABLE III IS PER EDGE). THE TOLERANCE FOR THE THICKNESS DIMENSIONS SPECIFIED IN THE CROSS SECTIONAL VIEW IS ± 0.003".

FIGURE 4 - QUALIFICATION TEST PANELS

6.2 Production Parts

6.2.1 All testing and evaluation specified herein shall only be performed by Bombardier Toronto Materials Laboratory or by laboratories accredited according to BAERD GEN-018.

6.2.2 Chem-milled surfaces shall be free from roughness, sharp edges, ridging, pitting, distortion, and other evidence of poor workmanship that will degrade the performance of the part. Reject parts showing any of these defects and refer such parts to MRB for disposition.

6.2.3 Conditions shown in section 5.2 are acceptable provided that these defects are not sharp bottomed and they meet the following groove width to depth ratios either after chem milling without rework or after chem milling and rework:

- For Type I chem milling, the maximum groove depth (D) shall be no more than 1/2 the groove width (W).
- For Type II and Type III chem milling, the maximum groove depth (D) shall be no more than 1/6 the groove width (W).
- No overhangs are allowed.
- Channelling, measured at the bottom of the channel, shall be within drawing requirements, and the depth of the channel shall not exceed the value listed in Table I.

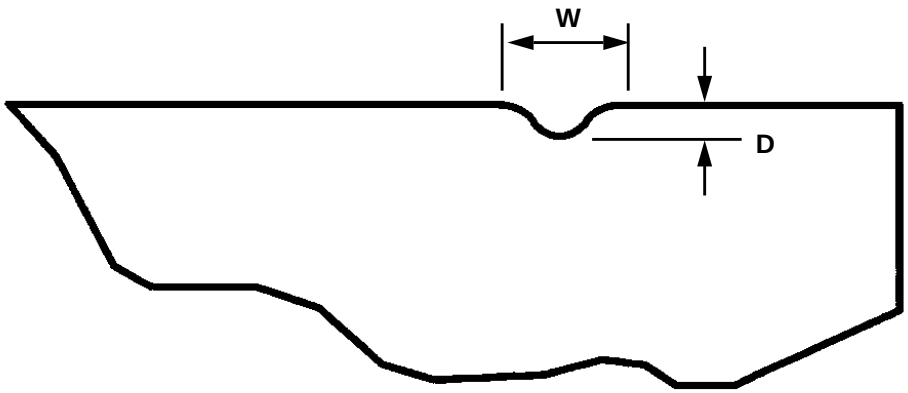
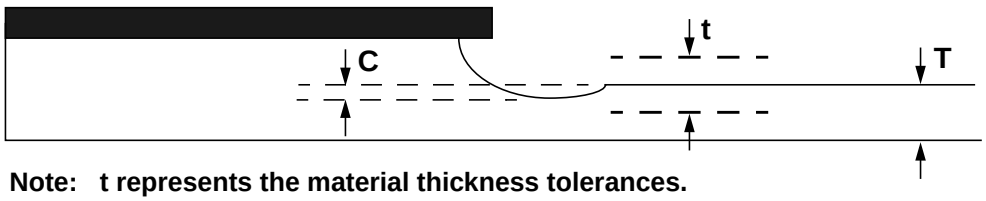


TABLE I - CHANNELLING DEPTH LIMITS

REMAINING MATERIAL THICKNESS (T)	ALLOWABLE CHANNELLING DEPTH (C)
< 0.040"	0.002"
0.040" - 0.080"	0.003"
> 0.080"	0.004"



Note: t represents the material thickness tolerances.

6.2.3.1 Rework raised areas, that exceed the dimensions specified in Table II, according to section 5.11. If after any rework, reject parts failing to meet the dimensional and surface roughness requirements specified in Table II. Refer such parts to MRB for disposition.

TABLE II - DIMENSIONAL REQUIREMENTS FOR CHEM-MILLED PARTS

TYPE OF CHEM-MILLING	AS CHEM-MILLED SURFACE ROUGHNESS	THICKNESS TOLERANCE (UNLESS OTHERWISE SPECIFIED ON THE ENGINEERING DRAWING)	MAXIMUM HEIGHT OF RAISED AREA (SEE FIGURE 3)
Type I	Ra 160 or finer (excluding fillets)	± 0.005"	0.005"
Type II	Ra 63 or finer (including fillets)	± 0.003"	0.002"
Type III	Ra 85 or finer (including fillets)	± 0.003"	0.002"

6.2.3.2 Remaining web thickness shall be as specified on the engineering drawing.

6.2.3.3 Reject parts not meeting the requirements for chem-milled lines, localized pits and indentations and web thickness.

6.2.3.4 Transition zone (see paragraph 5.2.19) length equal to six times the depth of cut or 0.5", whichever is greater, is acceptable. Within this zone, the material thickness may be greater than that specified on the engineering drawing.

6.2.3.5 When specified on the engineering drawing or when requested by Bombardier, fluorescent penetrant inspect according to PPS 20.03 before shot peening or shot peen forming.

6.2.3.6 Inspect one part from each production batch for channelling by measuring, using an adequate thickness measuring device (see paragraph 4.2.4), the thickness of the part directly adjacent to the fillet, and again some distance in from the chem-milled edge. This process will be carried out at 10 different locations along the last cut edge, in the areas most likely to develop channelling (preferably 5 along one axis and 5 in the perpendicular direction). If channelling is determined to exceed the requirements of Table I, reject the part and the batch it represents and refer such parts to MRB for disposition and the chemical milling tanks shall be re-qualified according to section 6.1.

6.2.3.7 Chem-milled lines (rib edges) shall be well-defined and shall not deviate from ideal lines (drawing or loft lines) by more than specified in Table III and Figure 5.

6.2.3.8 After blending, pits and indentations shall not deviate from the ideal line by more than the amounts specified in Table III and Figure 5.

TABLE III - MAXIMUM DEVIATION FROM IDEAL LINE

DEPTH OF CUT	PERMISSIBLE DEVIATION FROM IDEAL LINE (SEE FIGURE 5)	
	LINE	INDENTATION
Up to 0.100"	0.030"	0.040"
0.101" - 0.200"	0.030"	0.065"
0.201" - 0.300"	0.040"	0.080"
0.301" and over	0.050"	0.080"

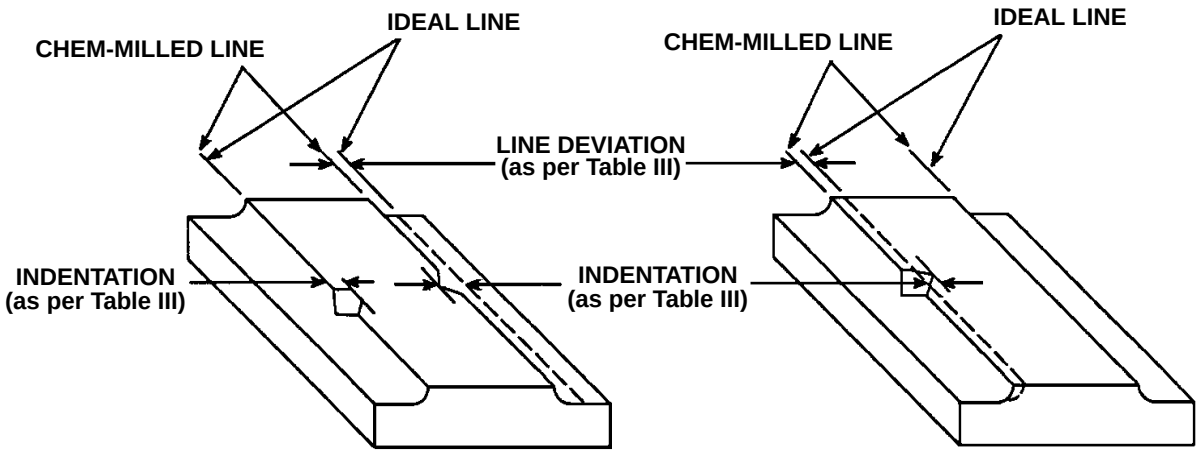


FIGURE 5 - ALLOWABLE DEVIATION FROM IDEAL LINE (TYPICAL)

6.3 Process Check

6.3.1 Except as noted in paragraph 6.3.2, every month prepare clad and bare 2024-T3 and clad and bare 7075-T6 test specimens (4 test specimens in total) conforming to the dimensions shown in Figure 4 for metallographic evaluation to confirm the chem-milling bath performance (i.e., that the requirements of this PPS are met). Pitting or intergranular attack in any of the test specimens shall not exceed the limits specified in Table IV. Submit all test results to Bombardier Toronto and identify and store the tested specimens for a period of one year.

TABLE IV - PITTING AND INTERGRANULAR ATTACK LIMITS

TYPE OF CHEM-MILLING	MAXIMUM ALLOWABLE PITTING	MAXIMUM INTERGRANULAR ATTACK
Type I	0.0008"	0.0008"
Type II	0.0005"	0.0002"
Type III	0.0005"	0.0002"

6.3.2 After 12 consecutive successful evaluations, it is acceptable to prepare test specimens for metallographic evaluation every three months instead of every month. However, in the event that pitting or intergranular attack of any of the test specimens exceeds the limits specified in Table IV, test specimens shall once again be prepared monthly.

7 SAFETY PRECAUTIONS

7.1 Safety precautions applicable to the materials and procedures specified herein shall be defined by the subcontractor performing the work for Bombardier Toronto.

8 PERSONNEL REQUIREMENTS

8.1 This PPS has been categorized as a “Controlled Critical Process” according to PPS 13.39. Refer to PPS 13.39 for personnel requirements.

9 RAW MATERIAL AND FINISHED PARTS PROTECTION

9.1 Keep raw material and finished parts free from moisture, dirt, abrasives, burrs, metal particles, etc.

9.2 Apply a thin coating of corrosion preventive compound (see paragraph 4.1.1.6) to finished parts.

9.3 If stacking parts, separate them with neutral Kraft paper, corrugated paper, webbing or other suitable material.

9.4 Do not slide or draw material sheets across other surfaces, or across each other. Lift sheets carefully to prevent nicking or scoring surfaces.

9.5 Use corner protectors for transport and storage. Properly support and secure raw material and finished parts during transport and storage. Do not place heavy objects on material or parts.