BOMBARDIER
Toronto Site
PROPRIETARY INFORMATION

PPS 24.04

PRODUCTION PROCESS STANDARD

THERMAL SPRAY DEPOSITION COATINGS (M3)

Issue 12
- This standard supersedes PPS 24.04, Issue 11.
- Deletions have been made at this issue and, therefore, detail changes have not been noted.
- 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 high velocity oxy-fuel (HVOF), D-Gun and Super D-Gun thermal spray deposition coatings. The method used to apply coatings to production parts will be limited to the process used during qualification.

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.

1.2 DHMS C4.19 Type I (Tungsten Carbide plus Cobalt) coatings are identified by Protective Treatment code M3 according to PPS 23.02.

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 ASTM C633 - Standard Test Method for Adhesion or Cohesive Strength of Flame-Sprayed Coatings.

3.2 ASTM E384 - Standard Test Method for Microhardness of Materials.

3.3 BAERD GEN-018 - Engineering Requirements for Laboratories.

3.4 BAERD GEN-023 - Contamination Control for Compressed Air.

3.5 DHLPM Procedure No. 5082 - Metallographic Inspection of Tungsten Carbide Coatings.

3.6 DHMS C4.19 - Thermal Spray Powders.

3.7 SAE AMS2430 - Shot Peening, Automatic.

3.8 SAE AMS6345 - Steel, Sheet, Strip, and Plate 0.95Cr - 0.20Mo (0.28 - 0.33C) (SAE 4130) Normalized or Otherwise Heat Treated - UNS G41300.

3.9 PPS 13.26 - General Subcontractor Provisions.

3.10 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.11 PPS 16.23 - Handling and Protection of Aircraft Parts.

3.12 PPS 17.02 - Abrasive Blasting.

3.13 PPS 23.02 - Protective Treatment and Decorative Surface Finish Code System.

3.14 PPS 31.04 - Degreasing Processes.

3.15 PPS 31.17 - Solvent Usage.

4 MATERIALS, EQUIPMENT AND FACILITIES

4.1 Materials

4.1.1 Compressed air utilized herein shall meet the requirements of BAERD GEN-023.

4.1.2 Thermal spray powder to DHMS C4.19.

4.1.3 Abrasive grit, -10 to +120 mesh aluminum oxide or silicone carbide. Maximum free silica 0.75% by weight.

4.1.4 Tape, spray resistant, heat reflective, aluminum foil backed, glass cloth laminated (e.g., 3M Company Scotch Y 9050).

4.1.5 Tape, rubber-backed, grit blast resistant (e.g., 3M Company Scotch #507).

4.1.6 Nitrogen gas, Type I Class I Grade A, BB-N-411.

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

4.1.8 Epoxy cement, (e.g., 3M Company Scotchweld EC-3445).

4.2 Equipment

4.2.1 Abrasive Blast Cleaning Equipment

4.2.1.1 The grit blasting equipment shall be capable of using -10 to +120 mesh particles at air pressures up to 60 psi. To ensure the grit is clean and dry, equip the compressed air system with a desiccant air dryer or draining separator and oil-removing filter at the point of use. Filters shall be changed or maintained at no more than 15 production-day intervals. Do not allow fines produced by breakdown of the grit to accumulate. Use air as the grit carrier gas.

4.2.2 Spraying Equipment

4.2.2.1 The High Velocity Oxy-Fuel (HVOF), Detonation Gun (D-Gun) or Super D-Gun process used shall be capable of depositing a spray of molten, semi-molten or plasticized particles onto a prepared substrate to the requirements of this standard.

4.2.2.2 The spray gun-to-work attitude shall be as close to 90° as possible.

4.2.2.3 The powder feed hopper shall be capable of supplying a metered and constant flow of dry, well-blended powder material to the spray gun.

4.2.2.4 The application guiding equipment shall provide the necessary control to minimize variations in both work-to-gun distance and travel rate. The entire system shall function in a manner that ensures that the coating is deposited at a regulated and constant rate, providing uniform, consistent and repeatable coating quality.

4.2.2.5 Thickness gauge, measuring device base on eddy current (e.g., calibrated elcometer) capable of measurement of ± 0.1 mil (± 0.0001 inch).

4.3 Facilities

4.3.1 This PPS has been identified as a “Critical or Special” process according to PPS 13.39 and as such only facilities specifically approved according to PPS 13.39 are authorized to perform high velocity oxy-fuel (HVOF), D-Gun and Super D-Gun thermal spray deposition coatings according to this PPS.

4.3.2 Bombardier subcontractors shall direct requests for approval to Bombardier Supplier Quality Management. Bombardier 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 high velocity oxy-fuel (HVOF), D-Gun and Super D-Gun thermal spray deposition coatings 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 Do not handle surfaces to be coated after solvent cleaning and before thermal spray deposition. Always wear clean cotton gloves when handling cleaned parts.

5.1.2 Before preparing the surfaces for thermal spray deposition, perform all operations that involve heating, shot peening, acid or alkaline cleaning, plating or anodizing as well as fluorescent penetrant or magnetic particle inspections.

5.1.3 Refer to PPS 16.23 for the proper procedures for handling and protection of parts before, during and after thermal spray deposition coating. In general, protection consists of protective wrapping and boxing of parts to prevent surface damage from parts striking one another, or other objects, during transport and storage.

5.2 Process Control Documentation

5.2.1 General

5.2.1.1 Each part number to be coated shall have an associated qualified Process Control Document (PCD) which contains all applicable processing parameters. As a minimum, PCD's shall contain the following information:

- NC tape used (if applicable)
- part number
- alloy (e.g., PH 13-8 Mo), temper (e.g., H1050), material specification (e.g., AMS 5629)
- gun-to-work distance
- gun travel speed
- fuel/oxygen pressures
- fixtures and set-up
- gun used
- robot/guiding system
- number of passes
- environmental conditions of spray chamber
- spray chamber batch certification tests (see section 5.3)
- type of powder including manufacturer's product identification number
- powder preparation method
- powder flow rates
- outline of method used to control coating thickness
- visual examination of parts (see section 6)
- any further processing to be performed on the part (i.e., grinding, machining, etc.)

5.2.1.2 To qualify a Process Control Document, the following shall be submitted to an approved laboratory according to paragraph 4.3.3.2 for testing as specified in Table I. The material and dimensions of the test specimens shall be as specified in Table II. The test specimens shall be processed according to the applicable Process Control Document they represent. All test pieces shall be coated as a single batch. Test specimens shall be sprayed at the most oblique angle encountered while coating the parts they represent.

- 3 metallographic/bend and 3 residual stress test specimens
- 3 metallographic, 3 bend and 3 residual stress qualification test results
- 5 bond strength test specimens or test results obtained by the subcontractor

5.2.1.3 Process Control Documents, required test specimens, and qualification test reports shall be submitted for review and approval by Bombardier Toronto and adhered to during part processing. The process may require re-qualification according to section 5.2 if there is any technical changes (e.g., processing parameter, material, etc.) made to the Bombardier approved PCD. If unclear whether the change in question is technical in nature, contact Bombardier prior to implementing such change on production parts.

TABLE I - QUALIFICATION AND BATCH ACCEPTANCE TEST REQUIREMENTS

TEST SPECIMEN	PROPERTY	QUALIFICATION TEST	BATCH ACCEPTANCE TEST
BEND TEST & METALLOGRAPHIC	ADHESION	X	X
	VISUAL EXAMINATION	X	X
	MICRO CRACKS	X	X
	INCLUSIONS	X	X
	POROSITY	X	X
	ABRASIVE PARTICLES	X	X
	HARDNESS	X	X
	THICKNESS	X	X
	SURFACE ROUGHNESS	X	X
ALMEN N STRIP	RESIDUAL STRESS	X	X
BOND STRENGTH	BOND STRENGTH	X	X (Note 1)
ACCORDING TO THE ENGINEERING ORDER (EO) OR FUNCTIONAL TEST PROCEDURE (FTP)	PERFORMANCE SPECIFIC TESTS	X	—

Note 1. Bond strength test specimens will not be required beyond the fifth batch of parts, provided that the results from the first five batches meet the requirements of section 5.2.6.

TABLE II - TEST PANEL REQUIREMENTS

SUBSTRATE	TEST SPECIMEN		
	METALLOGRAPHIC AND BEND 1.0" x 5.0" x 0.060"	**BOND STRENGTH 1.0" DIA. X 2.0" THICK**	**RESIDUAL STRESS**
Aluminum Alloys	7075-T6 AMS QQ-A-200/12	7075-T6 AMS QQ-A-200/11	Almen N (see Figure 2)
PH 13-8 Mo AMS 5629 H1050	AISI 4130 Cond N SAE AMS6345	PH 13-8 Mo AMS 5629 H1050	
Stainless Steels (Note 1)	AISI 4130 Cond N SAE AMS6345	17-4PH AMS 5643 H1025	
300M AMS 6419 280-305 ksi	AISI 4130 Cond N SAE AMS6345	300M AMS 6419 280-305 ksi	
Low Alloy Carbon Steels (Note 2)	AISI 4130 Cond N SAE AMS6345	4340 AMS 6415 180-200 ksi	
Titanium Alloys	CP Ti AMS 4900 or Ti-6Al-4V AMS 4911	Ti-6Al-4V AMS 4928	
Nickel and Cobalt Alloys	Inconel 625 AMS 5599 or Inconel 718 AMS 5596	Inconel 625 AMS 5599 or Inconel 718 AMS 5662	

Note 1. Except when processing PH 13-8 Mo.
Note 2. Except when processing 300M.

5.2.2 Bend Test

5.2.2.1 Coat bend test specimens to a thickness of 0.005" ± 0.001" (see Figure 1) and bent over 180° with the uncoated side contacting a cylindrical 0.5" mandrel. The coating on the bend test specimen shall show no evidence of peeling, spalling or separation from the substrate metal. Cracking of the coating is acceptable as long as it is not possible to separate the cracked coating from the substrate using a sharp object.

5.2.2.2 Cut a pristine section (i.e., section undamaged by bending or clamping) from each bend test specimen and perform metallographic examination on each specimen according to section 5.2.3.

5.2.3 Metallographic Examination

5.2.3.1 Prepare and examine metallographic test specimens according to section 5.2.2 and section 5.2.3 or to DHLPM Procedure No. 5082 to display the coating/substrate interface.

5.2.3.2 The coating, when examined at 200X magnification, shall not contain micro cracks or pits. The coating should appear continuous, uniform and smooth.

5.2.3.3 Examine the coating/substrate interface at both 200X and 500X magnification. The coating shall meet the following requirements:

- Porosity of the total microscopic area shall be less than 1%. Coatings exhibiting gross localized porosity are not acceptable.
- Oxide content of the total microscopic area shall be less than 1%. Coatings exhibiting gross localized oxide content are not acceptable.

5.2.3.4 The quantity of inclusions (i.e., unmelted particles in the coating) shall be less than 1% of the examined area.

5.2.3.5 Parts not adequately cleaned after shot peening may contain grit particles along the coating/substrate interface. Count the particles greater than 0.002" in diameter. There shall be no more than 10 grit particles per inch when examining the coating/substrate interface at 200X magnification.

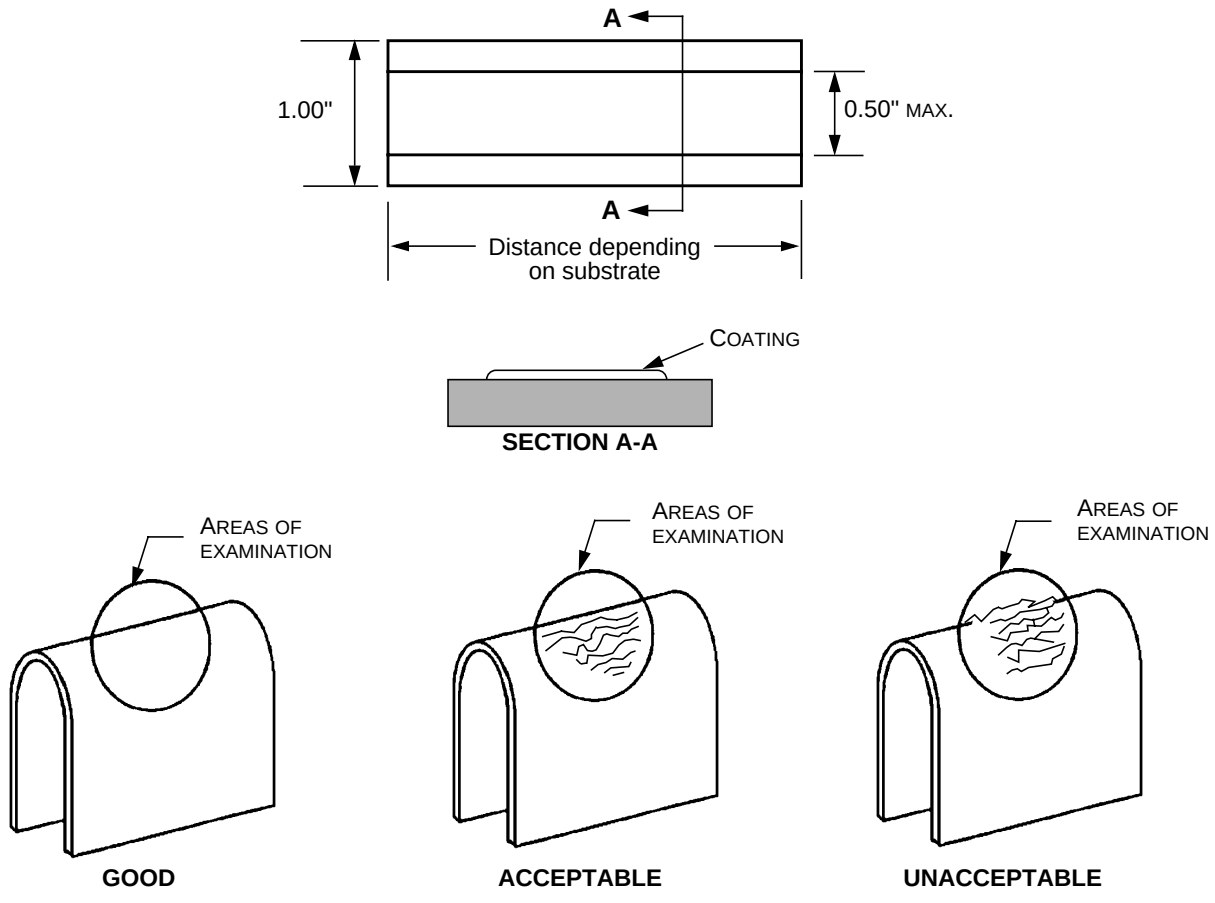


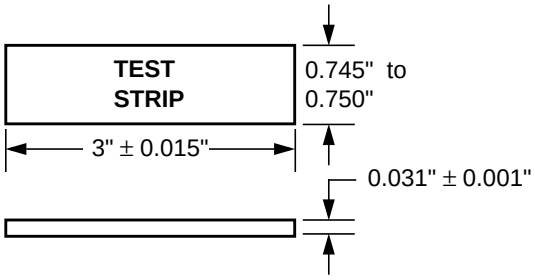
FIGURE 1 - BEND TEST SPECIMEN

5.2.4 Hardness

5.2.4.1 The hardness of the coating shall be determined from a minimum of ten evenly spaced indentations according to ASTM E384 parallel to the substrate/coating interface. The coating hardness for each indentation shall be 1,000 HV_{300} minimum.

5.2.5 Residual Stress

5.2.5.1 Measure residual stress in terms of the intensity value of an Almen N-type test strip according to SAE AMS 2430. Apply a coating of 0.005" ± 0.001" to the test strip. Manufacture Almen test strip holders according to SAE AMS 2430 or Figure 2. The measured deflection of an N-type Almen strip shall be 0.002" to 0.010".



TEST STRIP DIMENSIONS:
Analysis of stock: SAE 1070
Cold rolled spring steel
Square edge number one (on 3" edge)
Finish: Blue temper (or bright)
Uniformly hardened and tempered to 44-50 HRC
Flatness: ± 0.0015" arc height

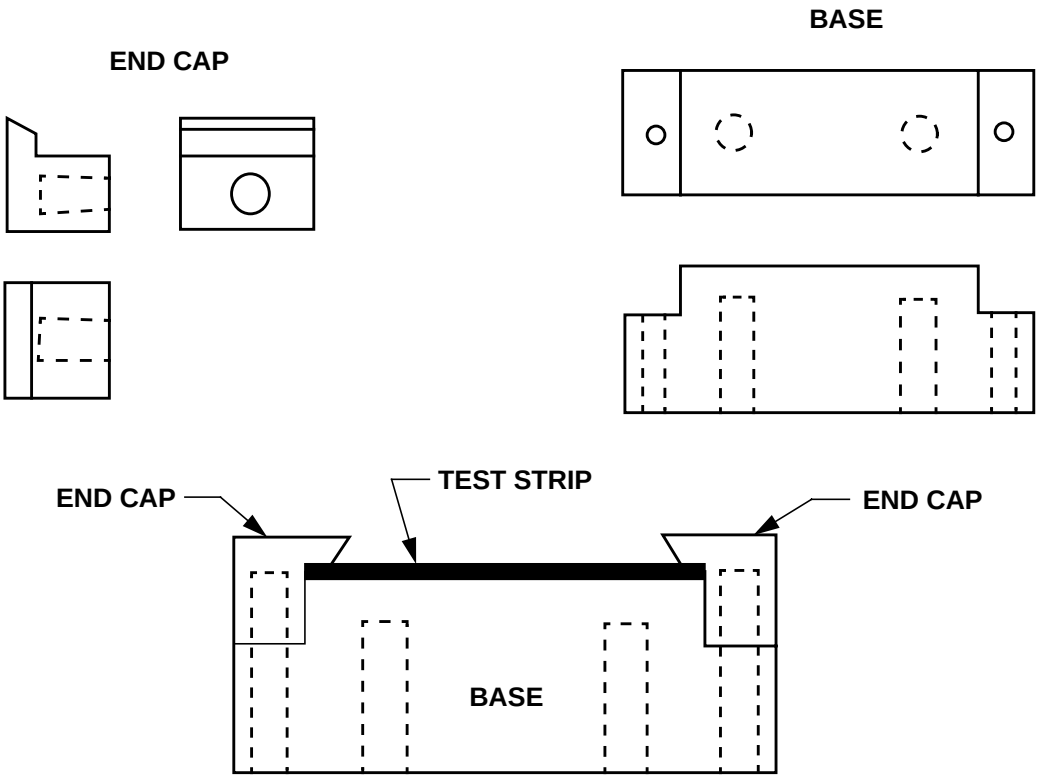


FIGURE 2 - ALMEN N-TYPE RESIDUAL STRESS TEST SPECIMEN AND FIXTURE

5.2.6 Bond Strength Test

5.2.6.1 Prepare and test a minimum of five bond strength tensile test specimens according to ASTM C633.

5.2.6.2 The bond strength of the coating shall be 10,000 psi minimum.

5.2.6.3 If the sample fails due to adhesive failure below 10,000 psi, it may be re-bonded and re-tested. However, if the sample fails cohesively below 10,000 psi, corrective actions shall be taken (i.e., adjustment of the processing parameters) and another set of samples tested before processing of parts.

5.2.7 Application Specific Performance Testing

5.2.7.1 For initial qualification of thermal deposition coatings to be applied to Bombardier Toronto parts, additional performance testing specific to the application may be required at the discretion of Bombardier Toronto.

5.3 Batch Acceptance Testing

5.3.1 A batch is defined as a set of parts processed together under the same conditions and parameters within eight hours of continuous machine operation. Process parts according to the applicable Process Control Document.

5.3.2 For each batch of parts and before coating any production parts, the spray chamber shall undergo batch acceptance testing. After each 8 hours of cumulative machine operation, batch acceptance testing shall be repeated. The spray chamber shall also be re-qualified if the process is suspended for repair or replacement of tooling.

5.3.3 Spray chamber batch acceptance testing requires 6 metallographic/bend and 6 residual stress test specimens to be coated and tested according to this PPS. Use 3 of each specimen type to produce the batch acceptance test report. The first five batches of parts require bond strength test specimens tested according to section 5.2.6. Bond strength test specimens will not be required beyond the fifth batch of parts provided that the results from the first five batches meets the requirements of section 5.2.6.

5.3.4 Test specimens shall be sprayed at the most oblique angle encountered while coating the parts they represent.

5.3.5 Subcontractors are responsible for performing all batch acceptance tests specified in Table I. The material and geometry of the test specimens shall be as per Table II.

5.3.6 Along with each batch of parts, the subcontractor shall submit to Bombardier Toronto the remaining coated test specimens, the batch acceptance test report stating actual numerical test values and the subcontractor batch identification numbers for both coated parts and the powder used.

5.3.7 Bombardier Toronto reserves the right to perform any or all of the tests set forth herein to ensure that the coating continues to meet specified requirements. Any part not meeting the specified requirements will be returned to the subcontractor.

5.4 Recommended Part Preparation

5.4.1 Prepare parts before thermal spray deposition as follows:

Step 1. Degrease or solvent clean parts and machined surfaces to be coated according to PPS 31.04 or PPS 31.17 respectively, to remove all dirt, paint, scale, water, oil, grease and other foreign materials detrimental to coating adhesion.

Step 2. Mask areas not to be coated with abrasion-resistant tape to prevent damage to finishes or dimensions.

Step 3. Abrasive blast clean according to PPS 17.02 all surfaces to be coated with grit size -10 to +120 mesh. Check that blasted surfaces have a uniform matte finish.

Step 4. Remove loose residual grit with clean dry compressed air.

Step 5. Remove maskant and solvent clean according to PPS 31.17 to remove any residual adhesive.

5.5 Recommended Spraying Procedure

5.5.1 Perform spraying operations within 4 hours of grit blasting as follows:

Step 1. Mask parts to prevent coating deposition on unwanted areas.

Step 2. Using a micrometer, measure the part thickness in the area to be coated.

Step 3. Pre-heat areas to be coated to ensure complete condensate removal. Use of the spray gun, with powder feed turned off, for this purpose is acceptable.

Step 4. Unless otherwise specified on the engineering drawing, deposit a coating thickness equal to the finish coat dimension. The maximum substrate temperatures allowed during coating deposition are as follows. Monitor substrate temperatures with a surface heat pyrometer or thermocouples having an accuracy of ± 25°F.

- For carbon, low alloy or precipitation hardened stainless steels, 400°F.
- For titanium or titanium alloys, 400°F.
- For any heat-treated aluminum alloy, 200°F.

Step 5. Using a micrometer, check the thickness of the coating. Spraying operations may be periodically halted for up to 10 minutes to allow base metal cooling and dimensional checks. Cooling may be supplemented with an air, nitrogen or carbon dioxide jet during spraying operations and during halts.

Step 6. Remove any masking material. Remove masking adhesive residue by solvent cleaning according to PPS 31.17.

5.5.2 It is desirable that the spray coating be the last finish applied to the parts except when the adjacent finish is paint. In this case, the paint shall overlap the coating by 1/8".

5.6 Coating Repair Procedure

5.6.1 Any production parts which require stripping of the thermal spray coating shall be submitted to the Bombardier Toronto Material Review Board (MRB) or Bombardier Toronto delegated MRB for disposition.

6 REQUIREMENTS

6.1 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 Every part shall be visually examined. When the surface of the part is examined with the unaided eye, the coating shall be adherent to the base metal and show no evidence of overheating (bluish discolouration), flaking, spalling or lifting. The coating shall be uniform, continuous and free from cracks, gouges, blisters, splatters, chippings, voids open to the surface or other imperfections that could be detrimental to part performance.

6.3 Unless otherwise specified on the engineering drawing, the coating surface roughness shall be at least 125 Ra.

6.4 The coating thickness shall be as specified on the engineering drawing. Measure the coating thickness metallographically as the average of crests and troughs at approximately 200X magnification.

7 SAFETY PRECAUTIONS

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

8 PERSONNEL REQUIREMENTS

8.1 This PPS has been categorized as a “Critical or Special” process according to PPS 13.39. Refer to PPS 13.39 for additional personnel requirements. Certified and/or qualified personnel shall have a good working knowledge of the following, as applicable:

- be familiar with the engineering drawings and work order instructions regarding thermal spray deposition coatings.
- know how to prepare parts for thermal spray deposition coating.
- understand the procedure and requirements for thermal spray deposition coatings as outlined in this specification.
- know how to use thermal spray gun equipment.

9 MAINTENANCE AND STORAGE

9.1 It is recommended that spraying equipment be maintained according to the planned preventative maintenance schedule recommended by the manufacturer.

9.2 Store coating spray powders in moisture-proof vinyl bags placed within a metal container or an equivalent moisture-proof container.