BOMBARDIER
Toronto (de Havilland)
PROPRIETARY INFORMATION

PPS 37.05

PRODUCTION PROCESS STANDARD

Fusion Welding of Titanium

Issue 15
- This standard supersedes PPS 37.05, Issue 14.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- Direct PPS 37.05 related questions to michael.wright@aero.bombardier.com.
- 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 fusion welding of commercially pure titanium.

1.1.1 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS must 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.

2 Hazardous Materials

2.1 Before receipt at Bombardier Toronto (de Havilland), all materials must be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier Toronto (de Havilland) 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 (de Havilland) Environment, Health and Safety Department.

3 References

3.1 ASTM E140 - Hardness Conversion Tables for Metals.

3.2 AWS A2.1-WC - American Welding Society Standard Welding Symbols Wall Chart.

3.3 MIL-T-9046 - Titanium and Titanium Alloy, Sheet, Strip and Plate.

3.4 MIL-A-18455 - Argon, Technical.

3.5 PPS 13.26 - General Subcontractor Provisions.

3.6 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.7 PPS 30.14 - Heat Treatment of Titanium and Titanium Alloys.

3.8 PPS 31.09 - Cleaning of Titanium and Titanium Alloys.

3.9 PPS 31.17 - Solvent Usage.

3.10 PPS 37.06 - Testing and Certification of Aircraft Fusion Welders.

3.11 PPS 37.10 - Requirements for Fusion Welds.

4 Materials, Equipment and Facilities

4.1 Materials

4.1.1 Filler rod used for welding as specified in Table 1. Do not use rods other than those specified herein.

4.1.2 Cotton wipers (e.g., DSC 378-2).

4.1.3 Paper towelling, commercial grade.

4.1.4 Abrasive paper, aluminum oxide, 180 - 240 grit (e.g., 3M Co.).

4.2 Equipment

4.2.1 Air or water cooled TIG (tungsten inert gas) welding torch.

4.2.2 Argon gas, minimum 99.99% pure (e.g., MIL-A-18455).

4.2.3 Wire wheel, soft stainless steel (e.g., No. 164F).

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 fusion welding of titanium according to this PPS.

4.3.2 Bombardier subcontractors must direct requests for approval to Bombardier Aerospace Supplier Quality Management. Bombardier Aerospace facilities must 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 must 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 must be detailed in the facility report. Based upon the facility report, Bombardier Toronto (de Havilland) Materials Technology may identify additional qualification and/or process control test requirements. During the facility survey, the facility requesting qualification must 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 Unless otherwise specified by Bombardier Aerospace Supplier Quality Management, for approval of subcontractor facilities to perform fusion welding of titanium according to this PPS completion of a test program and submission of suitable test samples representative of production parts is required. Test samples must be inspected as specified in PPS 37.10 (including visual, fluorescent penetrant/magnetic particle inspecting, radiographic inspection **and** metallographic inspection).

5 Procedure

5.1 General

5.1.1 To prevent weld contamination, it is imperative that the procedure specified herein be strictly adhered to.

5.1.2 Complete all mechanical operations, such as pre-assembly, fitting and deburring, before cleaning. If practical, draw file the edges of parts with sheared or cut edges before welding.

5.2 Cleaning Before Welding

5.2.1 Before welding, alkaline clean and then acid clean all parts according to PPS 31.09. Weld titanium details within 24 hours of cleaning. Parts which have not been welded within 24 hours of cleaning according to PPS 31.09 must be re-cleaned according to PPS 31.09.

5.2.2 Suitably protect cleaned parts from contamination. Do not handle cleaned parts at the joining surfaces unless clean cotton gloves are worn.

5.2.3 Immediately before welding solvent clean the weld joint area according to PPS 31.17.

5.3 Assembly for Welding

5.3.1 Before commencing welding, fit all parts up correctly using appropriate jigs, fixtures and clamps. Jigs and fixtures are designed to provide easy access for tack welding, as applicable, and welding in the downhand position. Also, provision is made in jig design for dimensional changes during heating and cooling.

5.3.2 If possible, clamp joints rather than tack welding them. If tack welds are used, follow the same cleaning and shielding requirements as for other welds. Remove cracked or contaminated tack welds before proceeding with final welding.

5.3.3 The gap between joint faces must be less than 0.010".

5.4 Control of Welding Rod

5.4.1 Ensure that all spools and containers of welding rod material are identified with the material type and traceability identification (i.e. R.I.P. (Receipt in Process) or M.R.V. (Material Receipt Voucher) number). If a spool or container is not so identified, refer it to Inspection.

5.4.2 Remove only the length of welding rod material necessary to complete the work at hand. Affix a length of masking tape, in the form of a flag, to one end of the rod and legibly print the welding rod material type on the flag.

5.4.3 If unused pieces of welding rod material are of sufficient length to be used on another job, return them to the designated welding rod storage area with the identification flag attached. Appropriately dispose of unusable pieces of welding rod material.

5.4.4 Record the traceability identification (i.e. R.I.P. (Receipt in Process) or M.R.V. (Material Receipt Voucher) number) of the welding rod material on the methods paperwork.

5.5 Manual Fusion Welding Process

5.5.1 Use filler rod as specified in Table 1.

Table 1 - Welding Filler Rod

PARENT METAL		WELD METHOD	FILLER ROD OR WIRE
DESIGNATION	SPECIFICATION		
Commercially Pure Titanium	AMS 4901, AMS 4902 or MIL-T-9046 Classes CP-1 or CP-3	TIG	AMS 4951

5.5.2 Use a clean cotton wiper to solvent clean each cut length of filler rod as specified by PPS 31.17 before use.

5.5.3 If the filler rod is removed from the protective inert atmosphere during welding, cut back the end approximately 1/2" to remove the contaminated metal.

5.5.4 Wear clean, lint-free cotton gloves at all times while handling the filler rod.

5.5.5 Use an air or water cooled TIG, shielded arc type welding torch for all titanium welding. In order to achieve the required weld size and penetration, set up the torch according to the manufacturer's instructions.

5.5.6 In general, use argon for torch shielding because the arc stability is better than with helium. Use argon for trailing and back-up shielding since it is heavier and less susceptible to disturbance than helium. For heavy titanium weldments, use helium or a mixture of argon and helium.

5.5.7 A technique sheet must be developed in conjunction with the Welding Specialist or Welding Engineer before welding each first article production batch. All welding must be performed according to the technique sheet. The technique sheet must include the following (as applicable):

- gas cup size and shape
- shielding gas type and flow rate
- filler rod material and size
- leading and trailing shields, if any
- any other relevant processing parameters or criteria

5.5.8 Before welding, purge the atmosphere around the part to be welded with a “pre-flow” of inert gas.

5.5.9 For manual feeding, continuously feed the welding rod into the puddle. If a joint is being welded from both sides, clean up the back of the weld on the first side and remove excess drop through before welding the second side.

5.5.10 Unless otherwise specified, do not remove weld bead metal and drop through on single welds after welding.

5.5.11 Identify completed weldments according to PPS 37.10.

5.5.12 Check weld discolouration in the “as welded” condition (i.e., before removal of surface discolouration as specified in section 5.6). Refer welds with unacceptable weld discolouration, as specified below, to MRB for disposition. If in doubt, refer to MRB for disposition.

- In the area of the weld bead, light to dark straw coloured weld discolouration is acceptable; any other colour weld discolouration indicating a greater degree of contamination (e.g., blue, gray, white, etc.) is not acceptable in the area of the weld bead.
- In the heat affected zone of the weld, outside the weld bead, light to dark straw and light blue weld discolouration is acceptable; any other colour weld discolouration indicating a greater degree of contamination (e.g., dark blue, gray, white, etc.) is not acceptable in the heat affected zone.

5.6 Post Weld Treatment

5.6.1 Remove weld discolouration which does **not** exceed the limits specified in para. 5.5.12, by mechanically cleaning using aluminum oxide abrasive paper or a stainless steel wire brush or wheel. For test welds for welder certification as specified in PPS 37.06, do not remove weld discolouration.

5.6.2 If specified on the engineering drawing, stress relieve welded assemblies according to PPS 30.14.

5.6.3 Apply protective treatment, such as alodine, primer or paint, after the completion of all welding, weld inspection, stress relief, heat treatment and cleaning.

5.7 Repairing Defective Parts

5.7.1 Do not repair rejected weldments without approval of Bombardier Toronto (de Havilland) MRB or Bombardier Toronto (de Havilland) delegated MRB.

5.7.2 Do not cover up a defect in a weld with an additional weld. Completely remove the defect by grinding or filing. Do not use a welding or cutting torch to remove defects.

5.7.3 Do not build up or repair improperly nibbled or machined parts or sections by welding.

5.7.4 Inspect all repaired welds for cracks and other defects according to PPS 37.10.

6 Requirements

6.1 Refer to PPS 37.10 for fusion weld requirements.

6.2 If there is doubt as to the reliability of the welding process, assemble a test piece by butt welding two 1" X 4" strips of the same material and gauge as the production parts along the 1" side. Bend the test piece through 180° over a mandrel secured in a bench vice. Ensure that the mandrel diameter corresponds to the material gauge for the particular alloy grade shown in Table 2. If there is evidence of cracking in the weld or base metal of the test piece after bending refer the represented parts to MRB for disposition.

Table 2 - Mandrel Diameters for Bend Tests

ALLOY GRADE	COMPOSITION	MANDREL DIAMETER
AMS 4901 or MIL-T-9046 CLass CP-1	Commercially pure, 70ksi yield strength	8T
AMS 4902 or MIL-T-9046 Class CP-3	Commercially pure, 40ksi yield strength	6T

6.3 Submit one part from each batch to either the Bombardier Toronto (de Havilland) Materials Laboratory or a Bombardier Aerospace approved laboratory for hardness testing. The maximum acceptable hardness of the weld bead is 5 Rockwell B points (30 Brinell points, or equivalent) greater than the base metal hardness. If it is not possible to use a production part, butt weld two 1" x 4" strips (of the same material and gauge as the production parts) along the 1" width during the production run and submit this test piece for hardness testing instead.

7 Safety Precautions

7.1 The safety precautions specified herein are specific to Bombardier Toronto to meet Canadian Federal and Provincial government environmental, health and safety regulations. It is recommended that other facilities consider these safety precautions; however, suppliers, subcontractors and partners are responsible for ensuring that their own environmental, health and safety precautions satisfy the appropriate local government regulations.

7.2 Observe general shop safety precautions when performing the procedure specified herein.

7.3 Do not use grease, oil or any other lubricant on welding equipment.

7.4 Wear suitable safety equipment while welding.

7.5 Fume extraction equipment must be provided and be in use when welding is in progress.

8 Personnel Requirements

8.1 Fusion welding of titanium may only be performed by operators who have been certified according to both this PPS and PPS 37.06.

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

9 Maintenance of Equipment

9.1 Keep all welding equipment, including lines and gauges, in good working order.

9.2 Repair or replace defective welding equipment.

10 Additional Information

10.1 It is recommended that a copy of the AWS Welding Symbols Wall Chart be posted wherever welding is being carried out.

10.2 A trailing shield, usually attached to the welding torch, is used to blanket the solidified weld and adjacent hot metal with inert gas. Higher welding speeds or higher welding currents require longer or wider shielding devices. In order to provide a uniform gas blanket, with no high velocities or turbulence, the shield is normally equipped with a metallic wool diffuser to provide even gas flow over the shield surface.

10.3 Back-up shields are similar in design to trailing shields and are usually clamped or taped in place.

10.4 For smaller pipe sizes, or in structures where root access is limited, purging is satisfactory for back-up shielding. Ensure that the interior surface is free from dirt and clean the back-up area, within about 1" of the weld, as specified in section 5.2. Cover the ends of the pipe, or open spaces of the structure, with plexiglass or a thin plastic film and seal the edges with masking tape. Provide suitable inlets and outlets for purging in the seals. Before beginning to weld, purge the weld area with a volume of gas, approximately six times the volume of the space being displaced. Maintain purging at a moderate flow rate until the weld is complete.

10.5 Chamber welding is satisfactory for small assemblies where complex shapes make back-up shielding and trailing extremely difficult. Before beginning to weld, purge the weld area with a volume of gas, approximately six times the volume of the space being displaced. Maintain purging at a moderate flow rate until the weld is complete.