DE HAVILLAND AIRCRAFT OF CANADA LIMITED

PPS 37.04

PRODUCTION PROCESS STANDARD

PROPRIETARY INFORMATION

FUSION WELDING OF FERROUS AND NICKEL ALLOYS

Issue 21
- This standard supersedes PPS 37.04, Issue 20.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- Direct PPS related questions to christie.chung@dehavilland.com.
- This PPS is effective as of the distribution date.

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Signed original on file. Validation of paper prints is the responsibility of the user.

Issue 21 - Summary of Changes (over the previous issue)

The following summaries are not detailed and are intended only to assist in alerting PPS users to changes which may affect them. Refer to the applicable sections of this PPS for detailed procedure and requirements.

- Replaced throughout PPS where “Bombardier” is specified with “De Havilland Aircraft of Canada Limited” or “DHC”.
- Deleted reference to 7140 and H-11 Mod alloys when cross referencing to PPS 37.09 for special welding procedures.
- Specified that all testing and evaluation specified herein must only be performed by laboratories accredited according to DAGER-006.
- Defined MRB.
- In addition to the requirements specified in PPS 13.39, added additional personnel requirements.

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Tables

Figures

1 SCOPE

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for the fusion welding of carbon and low alloy steels, corrosion resistant steels and nickel alloys.

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.

1.2 Class A welds of 4340, HY-Tuf and 300M alloys require special welding procedures and must be welded according to PPS 37.09. Materials not listed herein or in PPS 37.09 must be welded according to instructions from the Welding Specialist or Welding Engineer.

2 HAZARDOUS MATERIALS

2.1 Before receipt at De Havilland Aircraft of Canada Limited (DHC), all materials must be approved and assigned Material Safety Data Sheet (MSDS) numbers by the DHC 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 DHC Environment, Health and Safety Department.

3 REFERENCES

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

3.2 DAGER-006 - Engineering Requirements for Laboratories.

3.3 PPS 13.04 - De-Fuming of Aircraft Fuel Tanks and Fuel Containers.

3.4 PPS 13.26 - General Subcontractor Provisions.

3.5 PPS 13.39 - DASH 8 & Lear 45 Critical and Special Processes PPS Index.

3.6 PPS 16.01 - Application of Hard and Soft Film (F13) Corrosion Preventive Compound.

3.7 PPS 17.02 - Abrasive Blasting.

3.8 PPS 20.01 - Magnetic Particle Inspection.

3.9 PPS 20.03 - Fluorescent Penetrant Inspection.

3.10 PPS 24.01 - Aluminum Wire Spray Coating (M1).

3.11 PPS 30.04 - Steel Heat Treatment - Carbon and Low Alloy Steels.

3.12 PPS 30.06 - Heat Treatment of Precipitation Hardenable (PH) Stainless Steels.

3.13 PPS 30.08 - Heat Treatment of Martensitic Stainless Steels.

3.14 PPS 30.10 - Heat Treatment of Austenitic (Strain Hardenable) Stainless Steels.

3.15 PPS 30.13 - Heat Treatment of Nickel and Nickel Alloys.

3.16 PPS 31.03 - Cleaning of Carbon and Low Alloy Steels.

3.17 PPS 31.05 - Surface Treatment of Corrosion Resistant Steel (C9).

3.18 PPS 31.07 - Cleaning and Stripping of Painted Surfaces.

3.19 PPS 31.12 - Cleaning Nickel and Nickel Alloys.

3.20 PPS 31.17 - Solvent Usage.

3.21 PPS 33.02 - Removal of Metallic Coatings.

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

3.23 PPS 37.09 - Special Welding Procedure.

3.24 PPS 37.10 - Requirements for Fusion Welds.

4 MATERIALS, EQUIPMENT AND FACILITIES

4.1 Materials

4.1.1 Use only welding rods and wire listed in Table IV. Do not use rods and wire other than those specified without authorization from the Welding Specialist (or Welding Engineer).

4.1.2 Flux (e.g., Solar Type B).

4.2 Equipment

4.2.1 MIG and TIG welding equipment.

4.2.2 Tempilstiks, Tempilaq or surface pyrometers.

4.2.3 Welding jigs, fixtures and clamps. Jigs and fixtures must be designed to give easy access to tacking and welding, wherever possible, in the down-hand welding position. Ensure that provisions are made for dimensional changes during heating and cooling.

4.2.4 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 fusion welding of carbon and low alloy steels, corrosion resistant steels and nickel alloys according to this PPS.

4.3.2 Subcontractors must direct requests for approval to DHC Quality.

4.3.3 Facility approval must 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, DHC Engineering 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 DHC Quality.

4.3.3.1 For approval of subcontractor facilities to perform fusion welding of carbon and low alloy steels, corrosion resistant steels and nickel alloys 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 For the purposes of this PPS, the term “MRB” (Material Review Board) is considered to include DHC MRB and DHC delegated MRB.

5.2 Material Condition Before Welding

5.2.1 Before welding, ensure that the heat treat condition of the detail parts is as specified in the Final Heat Treat column of the engineering drawing or as specified in Table I.

TABLE I - MATERIAL CONDITION BEFORE WELDING

MATERIAL	ALLOY	HEAT TREAT CONDITION FOR WELDING
Carbon and Low Alloy Steels	1010 or 1020	Annealed
	4130 or 8630	If the final heat treat condition of the welded assembly (as specified on the engineering drawing) is to be normalized or hardened and tempered to 90 - 120 ksi (i.e. the assembly is used in the as welded condition): • Normalized (N or D) • Normalized and Tempered (E) • Tempered to 90 - 120 ksi • Hardened and Tempered to 90 - 120 ksi
		If the final heat treat condition of the welded assembly (as specified on the engineering drawing) is to be hardened and tempered to 125 - 145 ksi or higher (i.e. hardened and tempered after welding): • Annealed (A or C) • Normalized (N or D) • Normalized and Tempered (E) • Tempered to 90 - 120 ksi • Hardened and Tempered to 90 - 120 ksi
Nickel Alloys	Inconel X-750, Inconel 718, Inconel 600 or Inconel 625	Annealed
Corrosion Resistant Steels	304, 321, 347, 19-9DL or 21-6-9	Annealed
	410	Sub-critical annealed or, if specified on the engineering drawing, full annealed
	Custom 455	Solution annealed
	17-4PH	- Solution heat treated - H1150 or H1150M if high stresses during welding are expected (consult Welding Specialist)
	17-7PH	- Solution heat treated - Solution heat treated and precipitation heat treated

5.3 Preparation of Parts

5.3.1 If any of the parts to be welded are plated, painted, primed or metal sprayed, remove the coating in the area of the weld. Remove plating according to PPS 33.02. Remove paint and/or primer by chemically stripping according to PPS 31.07 or by abrasive blasting according to PPS 17.02. Remove metal spray coating according to PPS 24.01.

5.3.2 After completing all of the mechanical operations, clean the parts according to PPS 31.03, PPS 31.05 or PPS 31.12, as applicable.

5.3.3 If fitting and deburring is required on an assembly, solvent clean the weld area according to PPS 31.17 immediately after these operations.

5.3.4 Ensure that cleaned parts are suitably protected from contamination and do not handle the joining surfaces unless clean cotton gloves are worn.

5.4 Assembly for Welding

5.4.1 Before commencing welding, fit up the parts using the appropriate jigs, fixtures or clamps. Ensure that any gaps between the joint faces conform to the requirements of Table II and that misalignment of butt welds does not exceed 10 percent of the thickness of the thinnest part being joined. If joints incorporate sections of different thicknesses, determine the spacing from the thinnest section. When welding flanges to bleed air duct ends, ensure a light press fit of the tube into the end fitting flange along the entire mating surface.

5.4.2 Shield TIG welds on corrosion resistant steels and nickel alloys at the back and sides using an inert gas atmosphere, metal back-up bars or a combination of both methods. Flux (e.g., Solar Type B) may be used if the other methods are not possible.

5.4.3 When tack welding is used to set-up low alloy steel parts, perform the tacking with high heat input.

5.4.4 Do not correct poor fit by built-up welding.

TABLE II - ALLOWABLE GAP BETWEEN JOINT FACES

MATERIAL GAUGE	MAXIMUM PERMISSIBLE GAP
UNDER 0.063"	1/2 THE MATERIAL THICKNESS
0.063" - 0.080"	0.030"
OVER 0.080"	0.062"

5.5 Pre-Heating

5.5.1 Except as noted below, parts to be TIG or MIG welded which require pre-heating as specified in Table III must be pre-heated using an approved furnace or an induction coil.

- Weld joints having an average material thickness of 0.125" or less do not require pre-heating.
- Weld joints comprised of small details that will be heated during welding so as to raise the temperature of the entire welded assembly above approximately 150°F (66°C) do not require pre-heating.
- Contact the Welding Specialist (or Welding Engineer) whenever there is question regarding the pre-heating requirements of a particular weld joint.

5.5.2 Use either temperature indicating equipment or material of the appropriate temperature range (ref. paragraph 4.2.2) to control the temperature of pre-heated parts.

TABLE III - PRE-HEATING TEMPERATURES

MATERIAL	ALLOY	PRE-HEAT TEMPERATURE
Carbon and Low Alloy Steels	1010	None Required
	1020	200°F - 250°F (93°C - 121°C)
	4130 or 8630	350°F - 400°F (177°C - 204°C)
Corrosion Resistant Steels	304, 321, 347, 19-9DL or 21-6-9	None Required
	410	300°F - 350°F (149°C - 177°C)
	Custom 455	300°F (149°C) Maximum
	17-4PH or 17-7PH	None Required
Nickel Alloys	Inconel X-750, Inconel 718, Inconel 600 or Inconel 625	None Required

5.6 Control of Filler Rod or Wire

5.6.1 Ensure that all spools and containers of welding rod material are identified by material type.

5.6.2 When removing welding rod material from spools or containers, remove only the length and type of material necessary to complete the work at hand.

5.6.3 After removing the required welding rod material, affix a suitable 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.

5.6.4 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 work order or assembly manual.

5.6.5 Dispose of unused pieces of welding rod material or, if they are of sufficient length to be used on another job, return them to the designated welding rod storage area with the identification flag attached.

5.7 Welding Process

5.7.1 Select the appropriate welding rod or wire from Table IV.

5.7.2 Pre-heat the parts as detailed in section 5.5. Commence welding as soon as the pre-heat temperature is attained.

5.7.3 Use the fore-hand method of welding and, if possible, make welds in the down-hand position.

5.7.4 For TIG welding, follow the manufacturer's instructions regarding the use of equipment. Select a suitable amperage, gas cup, gas flow and electrode size to give proper size and penetration of weld. Refer doubtful cases to the Welding Specialist.

5.7.5 For MIG welding, follow the manufacturer's instructions regarding the use of equipment. Evaluate the machine settings for initial weldments before use on production parts.

5.7.6 If a joint is welded from both sides, clean the back of the weld on the first side and remove excess drop through before welding the second side.

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

5.7.8 For welded tubes intended to carry fluids, ensure that the drop through does not restrict the free flow through the bore.

5.7.9 If tubular joints intersect at other than right angles, weld the tubes from the angle of greatest restriction to the angle of least restriction (see Figure 1).

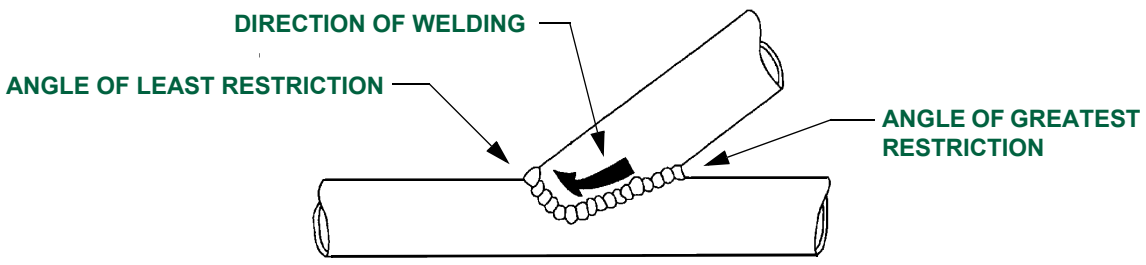

FIGURE 1 - WELDING AT TUBE INTERSECTIONS

TABLE IV - WELDING FILLER RODS AND WIRE

MATERIAL	ALLOY	WELD METHOD (NOTE 1)		FILLER ROD OR WIRE (NOTE 5)		
		TIG	MIG	AWS CLASSIFICATION	COMMERCIAL DESIGN	SPECIFICATION
Carbon & Low Alloy Steels	1010	X	X	ER80S-D2	Linde 83	MIL-E-23765
	1020	X	X	ER70S-3 (Note 2)	Linde 82	
	4130 8630	X	X	ER80S-D2	Linde 83	
		X		RG65	Linde CMS32	AMS6457, AMS6459, MIL-R-5632 (Type I) or MIL-R-5632 (Type IV) (Note 3)
Corrosion Resistant Steels	304	X	X	ER308	-----	MIL-E-19933
	321 347	X	X	ER347 (Note 4)	-----	MIL-E-19933 or AMS 5680
	19-9DL	X	X	ER19-9DL	-----	AMS 5782
	21-6-9	X		ER21-6-9 ER219	-----	-----
	410	X		ER410	Linde #410	AMS 5776
	Custom 455	X	X	-----	Custom 455	AMS 5617E
	17-4PH	X		ER17-4PH ER630	-----	AMS 5825
	17-7PH	X		ER17-7PH ER631	-----	AMS 5824
Nickel Alloys	Inconel X-750	X		ERNiCrFe-7	Inco 69 (Inconel X)	MIL-E-21562 or AMS 5778
	Inconel 718	X		Inconel 718	Inco 718	AMS 5832
	Inconel 600	X		ERNiCrFe-5	Inco 62	MIL-E-21562 or AMS 5679
	Inconel 625	X		ERNiCrMo-3	Inco 625	MIL-E-21562 or AMS 5837

Note 1. TIG welding must be used (where applicable) for welding material with a thickness of 0.049" or less. Either MIG or TIG may be used for material thicker than 0.049". The Welding Specialist (or Welding Engineer) must be contacted if doubt exists as to the welding method to be employed for a particular joint.

Note 2. Filler rod or wire with the classification E70S is obsolete, but may be used until supplies are depleted.

Note 3. Specifications MIL-R-5632 (Type I) and MIL-R-5632 (Type IV) are obsolete, but may be used until supplies are depleted.

Note 4. It is acceptable to use a BS2901 Part 2 Type 347596 British Standard filler rod as an alternate to an AWS ER347 filler rod.

Note 5. Of the filler rod or wires specified for a given material and alloy combination, it is acceptable to use the AWS classification, commercial design, AMS or MIL filler rod or wire as specified herein (e.g., for welding 410 corrosion resistant steel it is acceptable to use an ER410, Linde #410 or AMS 5776 filler rod or wire).

5.7.10 If the entire seam joining a flange to a bleed air duct cannot be welded while the assembly is located in a fixture, the flange may be tack welded as follows and the welding completed after removal from the fixture:

- Up to 2" diameter tube - 4 tack welds.
- Over 2" diameter tube - 8 tack welds.

5.7.10.1 Complete welding on one flange end at a time to prevent excessive shrinkage.

5.7.11 Identify completed weldments according to PPS 37.10.

5.8 Post Weld Heat Treatment, Defluxing and Cleaning

5.8.1 After welding, heat treat all parts according to Table V before further working.

5.8.2 If flux was used, remove residual flux after welding by immersing the part in hot water (140°F - 212°F (60°C - 100°C)). Scrub with a bristle brush to remove adhering particles.

5.8.3 Remove scale and discolouration from fusion welded nickel parts according to PPS 31.12.

5.9 Repairing Defective Welds and Defective Parts

5.9.1 Defects in Class A welds (as found on weld inspection) may be repaired once, without MRB approval, under instructions from the Welding Specialist (or Welding Engineer). Any additional repair to the same defective area must be approved by MRB. Defects in Class B and Class C welds (as found on weld inspection) may be repaired, without MRB approval, under instructions from the Welding Specialist or Welding Engineer. Repair defective welds using the weld procedure as specified herein.

5.9.2 The weld procedure as specified herein may only be used to repair defective parts (as found in service) when authorized by MRB and under instructions from the Welding Specialist or Welding Engineer.

5.9.3 Before repair welding, completely remove all defects by grinding or filing. Do not use a welding or cutting torch to remove such defects. Do not cover a defect in a weld with an additional weld.

5.9.4 Do not repair welded parts that have been heat treated after welding, other than stress relieved parts, unless re-heat treatment is permitted by Engineering. If re-heat treatment is permissible, heat treat the parts to the condition specified in Table I before repair welding.

TABLE V - POST WELDING HEAT TREATMENT

MATERIAL	ALLOY	POST WELD HEAT TREATMENT
Carbon and Low Alloy Steels	1010, 1020, 4130 or 8630	CLASS A - Stress relieve according to PPS 30.04 before radiographic inspection and magnetic particle inspection. CLASS B - Stress relieve according to PPS 30.04 before magnetic particle inspection. CLASS C - Stress relieve according to PPS 30.04.
Nickel Alloys	Inconel X-750 or Inconel 718	Anneal and age harden according to PPS 30.13.
	Inconel 600 or Inconel 625	Stress relieve according to PPS 30.13.
Corrosion Resistant Steels	304	Anneal according to PPS 30.10.
	321 or 347	If assemblies are exposed to service temperatures of 800°F (427°C) or higher, stabilize anneal according to PPS 30.10. Otherwise, no post weld heat treatment is required.
	19-9DL	Anneal according to PPS 30.10.
	410	Harden and temper, if specified on the engineering drawing, according to PPS 30.08 within 4 hours of welding or, if assemblies are left in the as welded condition, sub-critical anneal according to PPS 30.08 within 4 hours of welding.
	Custom 455	Solution heat treat and precipitation heat treat according to PPS 30.06.
	17-4PH	
	17-7PH	Precipitation heat treat or solution heat treat and precipitation heat treat, as specified on the engineering drawing, according to PPS 30.06.

5.10 Straightening of Welded Parts

5.10.1 Straightening of welded parts is permitted before heat treatment (hardening). Straightening of welded parts, after heat treatment to 150-170 ksi and above, is permitted only with authorization and instructions from MRB. After straightening, magnetic particle inspect the parts according to PPS 20.01 or fluorescent penetrant inspect the parts according to PPS 20.03.

5.11 Protective Treatment

5.11.1 Apply protective treatment, such as plating, priming and painting, after completing all welding, welding inspection, stress relieving, heat treatment, abrasive cleaning, machining, shot peening, etc.

5.11.2 If specified on the engineering drawing, treat hollow parts with internal corrosion preventive compound according to PPS 16.01 after welding, weld inspection, stress relieving, heat treatment, abrasive cleaning, machining, shot peening, plating, priming and painting.

6 REQUIREMENTS

6.1 All testing and evaluation specified herein must only be performed by DHC Materials Laboratory or by laboratories accredited according to DAGER-006.

6.2 Inspect all original welds and repair welds according to PPS 37.10.

7 DHC SAFETY PRECAUTIONS

7.1 The safety precautions specified herein are specific to DHC to meet Canadian Federal and Provincial government environmental, health and safety regulations. It is strongly 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 standard plant safety precautions when performing the procedure specified herein.

7.3 Refer to PPS 31.17 for the safety precautions for handling and using solvents.

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

7.5 Wear suitable safety equipment when welding (i.e., gloves, goggles, coveralls, etc.).

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

7.7 Defume tanks or containers in which combustible liquids have been stored according to PPS 13.04 before welding.

8 PERSONNEL REQUIREMENTS

8.1 Fusion welding of ferrous and nickel alloys must only be performed by operators who have been certified according to PPS 37.06.

8.2 This PPS has been categorized as a Controlled Critical Process according to PPS 13.39. Refer to PPS 13.39 for additional personnel requirements. Certified and/or qualified personnel must have a good working knowledge of the following, as applicable:

- engineering drawing and work order notes regarding the fusion welding of ferrous and nickel alloys
- process specifications regarding the fusion welding of ferrous and nickel alloys
- Engineering and Quality Assurance requirements regarding the fusion welding of metals
- fusion welding process
- definitions of standard welding terms
- be able to interpret AWS standard welding symbols
- types of fusion welded joints in different material forms
- the various fusion welding positions
- different classes of fusion welds and how they are determined
- function of filler rods and wire
- importance of pre-weld cleaning of parts
- importance of pre-heating and interpass temperatures
- importance of post-weld heat treatment
- how to use the argon gas flow regulator and the settings for various thicknesses of ferrous and nickel alloys
- type of current to use for fusion welding ferrous and nickel alloys
- high frequency control settings to use for fusion welding ferrous and nickel alloys
- how to select the amperage range based on part thickness
- how to use the remote foot pedal to control amperage within a fixed range
- how to install and dress tungsten electrodes
- how to use fusion welding equipment to produce acceptable weld joints

9 MAINTENANCE OF EQUIPMENT

9.1 Ensure that all welding equipment, including lines and gauges, is in good working order.

9.2 Return defective welding equipment for repair or replacement.

10 ADDITIONAL INFORMATION

10.1 Keep welding rods and filler wires dry, clean and free from grease and shop contamination.

10.2 During welding, take precautions to prevent drafts from windows, cooling systems, electrical machinery or other sources from reaching the weld. Avoid rapid cooling of any weld. Torch stress relieving may be applied, if necessary, to prevent cracking.

10.3 Post a copy of the AWS Standard Welding Symbols Wall Chart wherever welding is being carried out.

10.4 The relationship between current weld classifications and superseded classifications is shown in Table VI.

TABLE VI - CROSS REFERENCE OF WELD CLASSIFICATIONS

CURRENT	SUPERSEDED
Class A	Class 1, Type A
Class B	Class 1, Type B and Class 2
Class C	Class 1, Type C and Class 3