BOMBARDIER

Toronto Site

PROPRIETARY INFORMATION

PPS 30.13

PRODUCTION PROCESS STANDARD

HEAT TREATMENT OF NICKEL AND NICKEL ALLOYS

Issue 13
- This standard supersedes PPS 30.13, Issue 12.
- 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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TABLE OF CONTENTS

Sections **Page**

Tables

1 SCOPE

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for heat treatment of nickel 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 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 AMS 5540 - Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, and Plate 74Ni - 15.5Cr - 8.0Fe Annealed.

3.2 AMS 5542 - Nickel Alloy, Corrosion and Heat Resistant, Sheet, and Plate 72Ni - 15.5Cr - 0.95Cb - 2.5Ti - 0.70Al - 7.0 Fe Annealed.

3.3 AMS 5596 - Alloy Sheet, Strip, and Plate, Corrosion and Heat Resistant 52.5Ni - 19Cr - 3.0 Mo - 5.1(Cb + Ta) - 0.90Ti - 0.50Al - 18Fe Consumable Electrode or Vacuum Induction Melted 1750 Deg. F (955 Deg. C) Solution Heat Treated.

3.4 AMS 5599 - Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, and Plate 62Ni - 21.5Cr - 9.0Mo - 3.7 (Cb + Ta) Annealed.

3.5 AMS 5662 - Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings and Rings 52.5Ni - 19Cr - 3.0Mo - 5.1Cb - 0.90Ti - 0.50Al - 18Fe Consumable Electrode or Vacuum Induction Melted 1775 Deg. F (968 Deg. C) Solution Heat Treated, Precipitation Hardenable.

3.6 AMS 5665 - Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings, and Rings 74Ni - 15.5Cr - 8.0Fe.

3.7 BAERD GEN-018 - Engineering Requirements for Laboratories.

3.8 Bombardier Toronto Laboratory Drawings - LAB 009, LAB 011, LAB 012, LAB 013, LAB 025 and LAB 027.

3.9 PPS 13.26 - General Subcontractor Provisions.

3.10 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.11 PPS 15.01 - Part Marking.

3.12 PPS 20.08 - Hardness Testing of Metals.

3.13 PPS 23.07 - Designation of Nickel Alloys.

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

3.15 PPS 30.12 - General Steel Heat Treatment.

3.16 PPS 31.12 - Cleaning Nickel and Nickel Alloys.

3.17 QQ-N-286 - Nickel-Copper-Aluminum Alloy, Wrought.

4 MATERIALS, EQUIPMENT AND FACILITIES

4.1 Materials

4.1.1 Argon meeting the requirements of Compressed Gas Association (CGA) specification G-11.1, Grade C (dewpoint -76°F or below, oxygen 5 ppm maximum).

4.1.2 Helium meeting the requirements of CGA specification G-9.1, Grade C (dewpoint -76°F or below, oxygen 5 ppm maximum.

4.1.3 Nitrogen meeting the requirements of CGA specification G-10.1, Grade L (dewpoint -90°F or below, oxygen 10 ppm maximum.

4.1.4 Hydrogen, MIL-PRF-27201.

4.2 Equipment

4.2.1 Protective gloves (e.g., DSC 422-3).

4.2.2 Aluminized fire-proof jacket and hood.

4.2.3 All equipment used for heat treating nickel and nickel alloys shall meet the requirements of PPS 30.04.

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 heat treatment of nickel and nickel 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 heat treatment of nickel 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 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 Refer to PPS 30.12 for general information and heat treatment terminology.

5.2 Preparation of Material

5.2.1 Before heat treatment, identify all parts according to PPS 15.01 and clean according to PPS 31.12.

5.3 Control of Furnace Atmospheres

5.3.1 Controlled protective atmospheres include: argon, helium, hydrogen, nitrogen or vacuum. Gases entering the furnace shall have an oxygen content below 10 ppm and a dewpoint of -60°F or drier. Maintain the gas flow rate so as to ensure the dewpoint within the furnace is -25°F or drier.

5.3.2 Do not use a hydrogen atmosphere below a furnace temperature of 1350°F.

5.3.3 Unless argon, helium or a mixture of argon and helium gases is used to provide partial pressure, do not use a vacuum furnace with a pressure of over 10 microns of mercury. Measure and record the furnace pressure over the entire operating range. Check that the leak rate of the furnace when isolated from the pumping system does not exceed 20 microns of mercury per hour when tested at a pressure of 70 microns or less. Parts may be cooled by back-filling the furnace using argon, helium or nitrogen.

5.3.4 Do not use nitrogen from dissociated ammonia for heat treating.

5.3.5 If an air atmosphere is used in a furnace equipped for protective atmosphere processing, purge the furnace of sulphur and/or ammonia before heat treating and keep it free of those gases during heat treatment.

5.3.6 Except for the following parts, use a protective atmosphere when heat treating in excess of 1600°F. After heat treatment, descale parts according to PPS 31.12.

- parts to be machined at least 0.025" over the entire surface
- Inconel 625 parts (may be heat treated up to 1900°F in air for a maximum cumulative exposure time of 60 minutes including stress relief)
- Inconel 718 parts (may be heat treated up to 1900°F in air for a maximum cumulative exposure time of 150 minutes including stress relief)

5.4 Loading

5.4.1 Place or hang parts on suitable racks or supports in a manner which allows free circulation of the heating and quenching media and minimizes warpage during heating and quenching.

5.4.2 Load parts by opening the furnace door, inserting the parts and closing the door as rapidly as possible. When loading and unloading parts, take care to avoid nicks or other damage to the surfaces of finished parts.

5.4.3 Except when using a vacuum furnace, only load furnaces when they are operating at the middle of the specified temperature range. Set temperature control instruments at the correct operating temperature. When using a vacuum furnace, parts may be loaded at room temperature.

5.5 Annealing and Re-Solution Heat Treating

5.5.1 Perform the heat treatment specified on the engineering drawing according to Table I.

TABLE I - HEAT TREATMENT

MATERIAL	TREATMENT	PROCESS (See Note 1)		
Monel K500 Monel K501 (QQ-N-286)	Re-solution Heat Treatment	Soak at 1800 ± 25°F for 2 to 5 minutes and water quench. If section is intricate, air cool to 1200°F ± 15°F and oil quench.		
	Stress Equalization	Soak at 575 - 650°F for 1 - 2 hours and water quench or furnace cool.		
	Age Hardening	Soak at 1080 to 1100°F (time depends on initial hardness). In all cases, furnace cool at a rate of 15 - 25°F per hour to 900°F ± 15°F and then air cool.	**INITIAL ROCKWELL HARDNESS**	**MINIMUM HOLD TIME (hours)**
			B-75 - B-90	16
			C-8 - C-13	16
			C-14 - C-25	8
			C-26 - C-35	6 - 8
Inconel X750 (AMS 5542)	Re-solution Heat Treatment	Soak at 1900 to 2000°F for a minimum of 30 minutes per inch of thickness, or fraction thereof, and water quench.		
	Stress Equalization	Soak at 1200 ± 25°F for a minimum of 4 hours and air cool or water quench.		
	Age Hardening	Soak at 1300 ± 25°F for a minimum of 20 hours and air cool.		
Inconel 718 (AMS 5596)	Re-solution Heat Treatment	Soak at 1750 ± 25°F for a minimum of 1 hour per inch of thickness, or fraction thereof, and air cool or faster.		
	Age Hardening	Soak at 1325 ± 15°F for a minimum of 8 hours, furnace cool at a rate of 100 ± 15°F per hour to 1150 ± 15°F, hold at 1150 ± 15°F for 8 hours and air cool.		
Inconel 718 (AMS 5662)	Re-solution Heat Treatment	Soak at 1750 ± 25°F for a minimum of 1 hour per inch of thickness, or fraction thereof, and air cool or faster.		
	Age Hardening	Soak at 1325 ± 15°F for a minimum of 8 hours, furnace cool at a rate of 100 ± 15°F per hour to 1150 ± 15°F, hold at 1150 ± 15°F for a minimum of 8 hours and air cool.		
Inconel 600 (AMS 5540/ AMS 5665) Inconel 625 (AMS 5599)	Annealing	Soak at 1800 ± 25°F for a minimum of 15 minutes per inch of thickness, or fraction thereof, and water quench (See Note 2).		
	Stress Relief	Soak at 1600 ± 25°F for a minimum of 1 hour and air cool.		

Note 1. Treatment time commences when, after loading the furnace, the temperature has returned to the middle of the specified range and stabilized.

Note 2. Sheet material less than 0.063" in thickness may be cooled by air blast to prevent warpage. For vacuum furnace annealing, it is acceptable to cool by back-filling the furnace using argon, helium or nitrogen.

5.5.2 Annealing

5.5.2.1 Annealing and solution heat treating are usually completed by the mill and do not normally need to be repeated. If heat treating to soften material is necessary, anneal or re-solution heat treat according to Table I.

5.5.3 Stress Equalization

5.5.3.1 Except as noted in paragraph 5.5.3.1.1, stress equalize springs and age hardened parts after cold working.

5.5.3.1.1 Before cold setting, stress equalize coil springs which are to be cold set after coiling.

5.5.4 Stress Relieving

5.5.4.1 Stress relieve Inconel 600 and Inconel 625 parts after welding.

5.5.5 Age Hardening

5.5.5.1 Unless otherwise specified on the engineering drawing, age harden all Monel, Inconel X750 and Inconel 718 parts (except cold worked springs). Perform rough machining operations on assemblies and intricate or irregular shaped parts before age hardening.

5.6 Control of Intergranular Attack

5.6.1 Before initial heat treatment and at least once each month, process a control specimen in each furnace operating over 1600°F for each alloy to be processed. Control specimens are not required if protective atmosphere according to paragraph 5.3.1 are used during heat treatment or if parts are to be machined 0.025" minimum over the entire surface after heat treatment.

5.6.2 Process control test specimens as follows:

Step 1. Fabricate 1" x 1" x 0.188" maximum thickness control samples from the representative alloy with surface finish of 125 Ra or finer.

Step 2. Heat treat for a time equal to the longest accumulated heat treat time for the same alloy parts.

Step 3. Descale the test coupon along with the production parts and prepare metallographic specimens.

Step 4. Examine the unetched and etched metallographic specimens for intergranular corrosion at a magnification of 400X to 500X. If the depth of intergranular corrosion exceeds 0.0003", correct the production process and re-process a control test coupon.

6 REQUIREMENTS

6.1 Include two tensile test specimens with each furnace load of parts undergoing age hardening. Whenever possible, cut the test specimens from the same material batch as the production parts. Test specimen dimensions shall conform to the laboratory drawing listed in Table II. Submit the test specimens to a laboratory as specified in paragraph 4.3.3.2 for testing.

TABLE II - TENSILE TEST SPECIMENS (NOTE 1)

BAR	
DIAMETER	**LAB DRAWING**
less than 1/4"	None (see Note 2)
1/4"	LAB 027-1
3/8"	LAB 027-3
1/2"	LAB 027-2
3/4"	LAB 011-3
7/8"	LAB 011-2
1" and over	LAB 009-1

TUBING	
DIAMETER	**LAB DRAWING**
under 1 1/4"	LAB 012
over 1"	LAB 013

SHEET & PLATE	
THICKNESS	**LAB DRAWING**
all	LAB 025

Note 1. Dimensions given in LAB drawings are finished part dimensions. Unless the material is called up to be issued in length, it will be necessary to increase the length to accommodate chucking.
Note 2. To laboratory instructions.

6.2 After heat treatment, finished part surfaces shall not show evidence of carburization, sulphidation, nitriding nor intergranular corrosion. For surfaces to be machined after heat treatment, the depth of any of these conditions shall not exceed the depth of material to be removed by machining.

6.3 Hardness test the test specimens at three points according to PPS 20.08. For bar and plate, take hardness test measurements midway between the surface and the centre of the part. The minimum acceptable hardness values are specified in Table III. If an alloy or temper is not specified in Table III, use the hardness values specified in PPS 20.08.

6.4 Tensile strength values of the test specimens shall meet the requirements of Table III.

6.5 Parts shall not be rejected on the basis of hardness values provided that the tensile strength requirements of Table III are met.

6.6 Keep the batch of parts represented by the test specimen in the Heat Treat department pending the results of laboratory testing.

6.7 If the test specimens fail to meet the minimum requirements of this standard or the engineering drawing, reject the represented batch of parts.

6.8 The Heat Treat and Inspection departments shall maintain a record of all heat treatment data including: date, part number, batch number, quantity of parts, temperature and time, furnace number and laboratory test results.

TABLE III - MECHANICAL PROPERTIES OF AGE HARDENED MATERIALS

MATERIAL	FORM	MINIMUM HARDNESS	MINIMUM TENSILE STRENGTH (ksi)	MINIMUM YIELD STRENGTH AT 0.2% OFFSET (ksi)	MINIMUM ELONGATION IN 4D OR 2 INCHES (%)
Monel K500 Monel K501 (QQ-N-286)	According to the engineering drawing				
Inconel X750 (AMS 5542)	Sheet/Plate 0.010" - 0.1874"	32 HR_C	165	105	20
	Sheet/Plate 0.1875" - 4.000"	30 HR_B	155	100	20
Inconel 718	Bar (AMS 5662)	331 HR_B	185	150	12
	Bar (AMS 5663)	331 HR_B	185	150	12
	Sheet/Plate 0.010" - 1.000" (AMS 5596)	36 HR_C	180	150	12
Inconel 600 (annealed)	Sheet/Plate less than 2.00" (AMS 540)	—	80	30	30
	Bar 2.50" - 4.00" (AMS 5665)	—	85	35	30
	Sheet/Plate 0.020" - 1.000" (AMS 5599)	—	120	50	30
	Bar over 4.0" (AMS 5666)	—	120	60	30

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 additional personnel requirements. Certified and/or qualified personnel shall have a good working knowledge of the following, as applicable:

- engineering drawings, work order instructions and PPS sections regarding the heat treatment of carbon and low alloy steels
- how to set up and operate the equipment used in the heat treatment of nickel and nickel alloys
- materials and equipment requirements specified herein
- how to correctly handle parts when performing heat treatment
- solution heat treating process and significance of quenching