BOMBARDIER

Toronto Site

PROPRIETARY INFORMATION

PPS 30.01

PRODUCTION PROCESS STANDARD

HEAT TREATMENT OF ALUMINUM AND ALUMINUM ALLOYS

Issue 35
- This standard supersedes PPS 30.01, Issue 34.
- 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 heat treatment of aluminum alloys, except aluminum alloy rivets. Refer to PPS 30.03 for the procedure and requirements for the heat treatment of aluminum alloy rivets.

1.1.1 As an alternative to the procedure and requirements specified herein, it is acceptable to perform heat treatment of aluminum alloys according to BAPS 168-007.

- Perform heat treatment of aluminum alloys according to the procedure and requirements of either BAPS 168-007 or this PPS in their entirety; a piecemeal approach utilizing certain sections or portions of BAPS 168-007 and this PPS is **not** acceptable.
- Subcontractor facilities which have been approved by Bombardier to perform heat treatment of aluminum alloys according to BAPS 168-007 are considered approved to perform heat treatment of aluminum alloys according to this PPS without further approval needed.
- PPS Process Standard Deviations (PSD's) issued against this PPS are **not** applicable to BAPS 168-007. Likewise, requests for deviation (RFD's) allowed against BAPS 168-007 are not applicable to this PPS.
- When processing parts according to BAPS 168-007 as an alternative to processing parts according to PPS 30.01, deviations allowed by an approved RFD against BAPS 168-007 may be used by the applicable subcontractor unless a specific limitation regarding program applicability is specified by the RFD comments/restrictions.

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

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

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 3025 - Polyalkylene Glycol Heat Treat Quenchant.

3.2 ASTM E3 - Standard Practice for Preparation of Metallic Specimens.

3.3 ASTM E8 - Standard Test Methods for Tension Testing of Metallic Materials.

3.4 ASTM G110 - Standard Practice for Evaluating Intergranular Corrosion Resistance of Heat Treatable Aluminum Alloys by Immersion in Sodium Chloride Plus Hydrogen Peroxide Solution.

3.5 BAERD GEN-007 - Quality Control of Heat Treating Equipment and Hot Forming Equipment.

3.6 BAERD GEN-018 - Engineering Requirements for Laboratories.

3.7 BAPS 168-007 - Heat Treatment of Aluminum Alloys.

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

3.9 de Havilland Laboratory Procedure Manual (DHLPM) Procedure No. 2026 - Tensile Testing of Sheet Metal.

3.10 DHLPM Procedure No. 5041 - Preparation of Metallographic Specimens.

3.11 DHLPM Procedure No. 6013 - Intergranular Corrosion Testing.

3.12 Form DH3520 - Process Control Record - *Bombardier Toronto internal operating procedure*.

3.13 Form DH3775 - Aluminum Alloy Heat Treatment Record - *Bombardier Toronto internal operating procedure*.

3.14 Form DH4945 - Non-Conformance Report - *Bombardier Toronto internal operating procedure*.

3.15 MIL-S-10699 - Salt, Heat Treating (for Metals).

3.16 PPS 13.26 - General Subcontractor Provisions.

3.17 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.18 PPS 15.01 - Part Marking.

3.19 PPS 20.07 - Electrical Conductivity Testing of Aluminum Alloys.

3.20 PPS 20.08 - Hardness Testing of Metals.

3.21 PPS 23.01 - Designation of Aluminum Alloys.

3.22 PPS 30.03 - Heat Treatment and Control of 2024 (DD) Rivets.

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

3.24 PPS 32.01 - Chemical Conversion Coating of Aluminum and Titanium Alloys by Immersion (C1).

3.25 PPS 35.07 - Requirements for Investment and Sand Castings.

3.26 PPS 35.08 - Requirements for Aluminum Alloy Forgings.

3.27 QAPI 3.8.7.5 - Stamps Control - *Bombardier internal Quality procedure*.

3.28 QDI-09-02 - Process Control - *Bombardier Toronto internal Quality procedure*.

4 MATERIALS, EQUIPMENT AND FACILITIES

4.1 Materials

4.1.1 Polyalkylene glycol quenching solution, AMS 3025, Type I and Type II.

4.1.2 Sodium fluoborate ($NaBF_4$) or ammonium fluoborate (NH_4BF_4), technical grade.

4.1.3 Bath salt to MIL-S-10699, Class 2 (e.g., Park Thermal Ltd. AL-10699).

4.2 Equipment

4.2.1 General

4.2.1.1 Air furnaces and salt baths used for heat treatment shall be equipped with pyrometric control, and chart recorder controlled according to BAERD GEN-007.

4.2.1.2 Processing facilities shall contain the equipment described in Table I, set up in a suitable sequential manner to allow for effective controlled flow of production parts through all process steps required by this specification.

4.2.1.3 Instrumentation and equipment shall be qualified according to BAERD GEN-007.

4.2.2 Heating Equipment

4.2.2.1 Heat treatment of aluminum alloys shall be performed in air, combusted gas or protective atmosphere furnaces or salt baths with the following exceptions:

- Do not use nitrate salt baths to heat treat aluminum-magnesium alloys (e.g., castings of 520.0 alloy (formerly known as 220 alloy)).
- Do not use salt baths if salt is likely to become entrapped, such as on welded parts or tubes of intricate shape.
- Oil baths may be used for precipitation hardening.

4.2.2.2 The design and construction of the heating equipment shall be such that, with any charge, the temperature of the heating media and metal at any point in the working zone does not vary more than ± 10°F from the furnace control set temperature after the charge has been brought up to temperature.

4.2.2.3 Automatic temperature controlling and recording instruments, preferably of the potentiometric type, shall be used. Ensure that thermocouples located in the working zone are adequately protected.

4.2.3 Quenching and Rinsing Equipment

4.2.3.1 Provide means for adequate circulation of the quenching media and for heating or cooling, as applicable. Water baths used for quenching parts that have been heat treated in salt baths shall be provided with a drain and an inflow of fresh water to prevent unacceptably high concentrations of dissolved salts in the baths. Locate quenching equipment and handling equipment in order to obtain the speed of quench specified in Table III.

4.2.3.2 Rinsing or spraying facilities shall be available to remove any salt residue from the surface of materials that have been treated in molten salt baths. Separate rinse tanks or sprays may not be necessary if the quench tank, under maximum loading conditions, is capable of removing salt residue without becoming contaminated to the extent that its efficiency is reduced.

4.2.3.3 If applicable, rinsing or spraying facilities shall be available to remove the glycol layer from parts that have been quenched in polyalkylene glycol/water solutions.

4.2.4 Safety Equipment

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

4.2.4.2 Bombardier approved splash shield.

4.2.4.3 Aluminized fire-proof jacket.

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 the heat treatment of aluminum alloys, except aluminum alloy rivets, 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 the heat treatment of aluminum alloys, except aluminum alloy rivets, 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.

TABLE I - EQUIPMENT REQUIREMENTS

OPERATION	EQUIPMENT	REQUIREMENT	TEMPERATURE UNIFORMITY
SOLUTION HEAT TREATMENT	Air Furnace Salt Bath	Class 10 Type A per BAERD GEN-007	± 10°F
ARTIFICIAL AGING AND STRESS RELIEF	Air Furnace	Class 10 Type A per BAERD GEN-007	± 10°F
FORCED NATURAL AGING	Furnace	Class 10 Type B per BAERD GEN-007	± 10°F
ANNEALING	Air Furnace Salt Bath	Class 25 Type A per BAERD GEN-007	± 25°F
QUENCHING	Tank	Refer to BAERD GEN-007 Temperature Accuracy of ± 2°F	—
REFRIGERATION	Refrigerators Dry Ice Liquid Bath	Class 10 Type A per BAERD GEN-007	—

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 Carry out heat treating on an entire piece of material or part, never on a portion only, and apply in a manner that will produce the most uniform results.

5.1.3 Whenever possible, avoid including parts of widely varying thickness in the same heat treat load.

5.1.4 A batch of parts includes all parts of the same part number heat treated in the same furnace load.

5.1.5 Except as noted below, do not heat treat different alloys in the same furnace load.

- Parts and material of 2024 and 7075 alloys may be solution heat treated in the same furnace load if the requirements of Table II are all met.
- Parts and material of 2014, 6061 and 7075 alloys may be precipitation hardened in the same furnace load if temperatures and soaking times according to Table VI or Table VII are the same.
- Heat treatable wrought alloys, except 7XXX series, may be annealed in one batch without regard to alloy type. Also, 7075 and 7079 may be annealed in the same batch.
- Non-heat treatable wrought alloys, except 3003, may be annealed in one batch without regard to alloy type.

5.1.6 Refer to PPS 23.01 for an explanation of temper designations and a cross reference between new and superseded material specifications.

5.2 Preparation of Material

5.2.1 If the monthly process control test specimens do not meet the high temperature oxidation and blistering requirements specified in section 6.3.4, any further solution heat treatment of 7000 series alloy parts shall include the use of chemical conversion coating, sodium fluoborate or ammonium fluoborate until process control test specimens submitted meet the requirements of section 6.3.4. Furthermore, all production parts from the past month shall be submitted to MRB for disposition.

5.2.2 Before solution heat treatment, either chemical conversion coat bare 7075 parts according to PPS 32.01 or include a maximum of 1.5 ounces of sodium fluoborate or ammonium fluoborate in a suitable metal container with the load of parts to prevent blistering and high temperature oxidation during solution heat treatment. Except as specified in paragraph 5.2.1, the use of chemical conversion coating, sodium fluoborate or ammonium fluoborate to prevent blistering of 7000 series alloy parts during solution heat treatment is recommended, but not mandatory. However, refer all parts that show any indication of surface blistering to MRB for disposition.

5.2.3 Identify all material according to PPS 15.01.

5.2.4 Clean parts contaminated with oil, grease or wax according to PPS 31.02 before heat treatment.

5.3 Heat Treatment Handling

5.3.1 Place parts or material on suitable racks or hang on supports to allow free circulation of the heating and, if applicable, quenching media and to minimize warpage during heating and quenching.

5.3.2 It is important that adjacent components in the heat treatment lot (including sheets and flat parts, tubes, rods and bars) are separated by suitable means to prevent surface contact, increase the heat transfer rate and, in the case of solution heat treatment, increase the quenching rate.

5.3.3 Set temperature control instruments at the correct operating temperature and, except if overaging, ensure that the furnaces or baths are operating within the specified temperature range before being loaded. If artificial aging or overaging according to section 5.7.2 or section 5.7.3 will be performed, parts may be loaded before the furnace reaches the specified temperature range.

5.3.4 If, as specified in paragraph 5.3.3, the furnace shall be operating within the specified temperature range before loading, load the parts by opening the furnace door, inserting the parts and closing the furnace door as quickly as possible.

5.3.5 Use caution during loading and unloading to avoid nicks or other damage to the surfaces of finished parts or clad sheet.

5.3.6 Use suitable covers on flat racks or baskets containing small parts to prevent loss in the quenching bath.

5.4 Heating and Soaking

5.4.1 Except when loading a heavy charge, measure soaking time in salt baths from the time of immersion. After loading a heavy charge, the temperature of the bath will drop below the specified minimum; in this case, consider the soaking time to commence when the bath again reaches the specified minimum temperature.

5.4.2 Soaking time in air furnaces commences when, after loading the furnace, all furnace control instruments have returned to the specified temperature range.

5.4.3 If a charge includes sections of various thickness, determine the soaking time by the thickness of the heaviest section.

5.4.4 When solution heat treating clad material, ensure that the recovery time between charging the furnace and commencement of the soaking time does not exceed 35 minutes for gauges up to and including 0.102" and 60 minutes for gauges heavier than 0.102".

5.5 Solution Heat Treatment (W Temper)

5.5.1 Solution heat treat by heating the material to the temperature specified in Table II for the time specified in Table III.

5.5.2 At the end of the required soaking period, remove the parts from the furnace and totally immerse them in the quenching solution. Ensure that quench tank media and temperatures are as specified in Table II and maximum quench delay times are as specified in Table III. Quench delay time begins when the furnace door begins to open, or when the first corner of the load emerges from a salt bath, and ends when the last corner of the load is immersed in the quench bath. In order to minimize distortion and locked-in stresses resulting from solution heat treatment, pay careful attention to the orientation that certain parts enter the quench bath (e.g., dip torque tubes into the water vertically and not horizontally). Keep parts immersed in the quench tank for not less than 2 minutes per inch of maximum thickness or fraction thereof.

TABLE II - SOLUTION HEAT TREAT TEMPERATURES & QUENCHING MEDIA

ALLOY	FORM	MATERIAL SPECIFICATION	TEMPERATURE (Note 1)	TEMPER IMMEDIATELY AFTER QUENCH	TEMPER AFTER NATURAL AGING (Note 2)	QUENCHING MEDIUM
CASTINGS						
A201.0	Sand, Permanent Mould & Invest-ment Castings	AMS 4229 AMS-A-21180	975°F - 995°F	—	T4	Polyalkylene glycol/water solution (room temperature)
295.0	Sand Castings	AMS 4231	950°F - 960°F			Water (150°F - 212°F)
520.0	Sand Castings (Note 5)	AMS 4240	800°F - 820°F			Oil (300°F ± 25°F)
356.0	Sand Castings	AMS 4217	990°F - 1010°F	—	T4	Water (150°F - 212°F)
	Permanent Mould & Investment Castings	AMS 4260				
A356.0	Sand, Permanent Mould & Invest-ment Castings	AMS 4218 AMS-A-21180				
A357.0	Sand, Permanent Mould & Invest-ment Castings	AMS 4219 AMS-A-21180	1000°F - 1020°F			
D357.0	Premium Quality Castings	AMS 4241	1000°F - 1020°F			
FORGINGS						
2014	Die & Hand Forgings	AMS-QQ-A-367 AMS-A-22771	925°F - 945°F	W	T4	Water (140°F - 160°F)
6061	Die & Hand Forgings	AMS-QQ-A-367 AMS-A-22771	960°F - 1025°F			
7075	Die & Hand Forgings	AMS-QQ-A-367 AMS-A-22771	860 °F - 890°F		—	Water (140°F - 180°F)
7079	Die & Hand Forgings	AMS-QQ-A-367 AMS-A-22771	820°F - 880°F			

TABLE II - SOLUTION HEAT TREAT TEMPERATURES & QUENCHING MEDIA

ALLOY	FORM	MATERIAL SPECIFICATION	TEMPERATURE (Note 1)	TEMPER IMMEDIATELY AFTER QUENCH	TEMPER AFTER NATURAL AGING (Note 2)	QUENCHING MEDIUM
WROUGHT ALLOYS						
2004	Sheet	AMS 4208 AMS 4209	975°F - 995°F	W	T42	Water (maximum temperature after quench shall be 100°F) OR Polyalkylene glycol and water quench (refer to Table IV for quenching limits in glycol/water solutions)
2014	Flat & Coiled Sheet & Plate	AMS-QQ-A-250/3	925°F - 945°F			
	Rolled Bar & Rod	AMS-QQ-A-225/4				
	Extruded Bar, Rod & Shapes	AMS-QQ-A-200/2				
2024	Flat & Coiled Sheet & Plate	AMS-QQ-A-250/4 AMS-QQ-A-250/5	910°F - 930°F			
	Rolled Bar & Rod	AMS-QQ-A-225/6				
	Extruded Bar, Rod & Shapes	AMS-QQ-A-200/3				
	Drawn Tube	AMS-WW-T-700/3 DHMS M2.21				
2219	Sheet & Plate	AMS-QQ-A-250/30	985°F - 1005°F			
6061	Sheet & Plate	AMS 4026	960°F - 1025°F			
	Rolled Bar & Rod	AMS 4116				
	Extruded Bar, Rod & Shapes	AMS-QQ-A-200/8				
	Drawn Tube	AMS 4081 AMS 4083 AMS-WW-T-700/6 DHMS M2.21				
7075	Sheet & Plate	AMS-QQ-A-250/12 AMS-QQ-A-250/18 AMS 4048 AMS 4049 AMS 4315 AMS 4316 ASTM B 209	860°F - 930°F (Notes 3 & 4)	W	—	
	Rolled Bar & Rod	AMS-QQ-A-225/9	860°F - 930°F (Note 4)			
	Extruded Bar, Rod & Shapes	AMS-QQ-A-200/11 AMS-QQ-A-200/15	860°F - 880°F			

Note 1. Soaking time, maximum quench delay, quenching medium and temperature should comply with section 5.5.

Note 2. Temper after natural aging at room temperature for a minimum of 96 hours.

Note 3. 7075 clad sheet, 0.020" thick or less, may be solution heat treated at 860°F to 930°F to minimize cladding diffusion (860°F to 880°F is preferred).

Note 4. It shall be recognized that under some conditions, eutectic melting can occur when heating 7075 alloy above 900°F and that caution shall be exercised to avoid this problem.

Note 5. Do not solution heat treat 520.0 (220) alloy in salt baths.

TABLE III - SOLUTION HEAT TREAT SOAKING TIME & MAXIMUM QUENCH DELAY

ALLOY	THICKNESS (inches)	SOAKING TIME (Notes 1 & 2)		MAXIMUM QUENCH DELAY
		SALT BATH	AIR FURNACE	
FORGINGS				
2014 2024 2219 7075 7079	1.000" & under	2 hours minimum	2 1/2 hours minimum	20 seconds
	1.001" - 2.000"	3 3/4 hours minimum	4 1/2 hours minimum	
	2.001" - 3.000"	5 1/2 hours minimum	6 1/2 hours minimum	
	3.001" - 4.000"	7 hours minimum	8 1/2 hours minimum	
	4.001" - 5.000"	8 1/2 hours minimum	10 1/2 hours minimum	
	All others	6 hours minimum	6 hours minimum	
WROUGHT ALLOYS				
2004 2014 2024 2219 6061 7075 All forms	0.016" & under	10 - 15 minutes	20 - 25 minutes	5 seconds
	0.017" - 0.020"	10 - 20 minutes	20 - 30 minutes	7 seconds
	0.021" - 0.032"	15 - 25 minutes	25 - 35 minutes	
	0.033" - 0.063"	20 - 30 minutes	30 - 40 minutes	10 seconds
	0.064" - 0.090"	25 - 35 minutes	35 - 45 minutes	
	0.091" - 0.125"	30 - 40 minutes	40 - 50 minutes	15 seconds
	0.126" - 0.250"	35 - 45 minutes	50 - 60 minutes	
	0.251" - 0.500"	45 - 55 minutes	60 - 70 minutes	
	0.501" - 1.000"	60 - 70 minutes	90 - 100 minutes	
	1.001" - 1.500"	90 - 100 minutes	120 - 130 minutes	
	1.501" - 2.000"	105 - 115 minutes	150 - 160 minutes	
	2.001" - 2.500"	120 - 130 minutes	180 - 190 minutes	
	2.501" - 3.000"	150 - 160 minutes	210 - 220 minutes	
	3.001" - 3.500"	165 - 175 minutes	240 - 250 minutes	
	3.501" - 4.000"	180 - 190 minutes	270 - 280 minutes	
CASTINGS				
A201.0	All	14 hours minimum		20 seconds
295.0		6 hours minimum		
520.0		12 hours minimum		
356.0		6 hours minimum		
A356.0		6 hours minimum		
A357.0		8 hours minimum		
D357.0		8 hours minimum		

Note 1. Maximum soaking times shown are applicable to clad alloys only. This is to prevent cladding diffusion. The maximum soaking times for non-clad alloys shall be as close as possible to the specified values for the minimum thickness of the thickest parts in the furnace loads.

Note 2. Handle material 0.090" or less in thickness in small lots which can be manually quenched from the salt bath or heat treated in an air furnace with bottom quenching facilities.

TABLE IV - LIMITS FOR QUENCHING IN GLYCOL/WATER SOLUTIONS (NOTES 1 AND 2)

ALLOY	FORM	AMS 3025 GLYCOL TYPE (Note 3)	THICKNESS (Note 4)	MAXIMUM GLYCOL CONCENTRATION (Note 5)
2004, 2014, 2024 & 2219	All	Type I	0.040" or less	34% by volume
			0.041" - 0.063"	28% by volume
			0.064" - 0.071"	22% by volume
			0.072" - 0.080"	16% by volume
		Type II	less than 0.040"	34% by volume
			0.041" - 0.063"	22% by volume
			0.064" - 0.080"	16% by volume
6061 & 7075	Sheet, Plate, Bar & Extrusion	Type I	0.063" or less	40% by volume
			0.064" - 0.125"	34% by volume
			0.126" - 0.190"	28% by volume
			0.191" - 0.250"	22% by volume
			0.251" - 0.630"	16% by volume
		Type II	0.032" or less	40% by volume
			0.033" - 0.080"	34% by volume
			0.081" - 0.125"	28% by volume
			0.126" - 0.190"	20% by volume
			0.191" - 0.250"	18% by volume

Note1. The temperature of the quenchant shall not rise more than 20°F from quenching a single heat treatment load. The maximum quenchant temperature at the start of the quench shall be 90°F and the quenchant temperature shall not exceed 100°F at any time during quenching.

Note 2. After quenching, remove the thin glycol layer adhering to the parts and loading fixtures by a 10 minute agitated cold water immersion rinse or by a 2 minute cold spray rinse, providing that surfaces are not shielded from the spray by other parts and the water impinges directly on all surfaces.

Note 3. Do not mix Type I with Type II.

Note 4. Thickness is the minimum dimension of the heaviest section at the time of heat treatment.

Note 5. Any concentration equal to or below the maximum may be selected, but the concentration shall be controlled within +0%, -4%.

5.6 Re-Heat Treatment

5.6.1 Solution heat treatment of a material that has been previously heat treated by the mill, by Bombardier or by a subcontractor is considered re-heat treatment.

5.6.2 Except as noted in paragraph 5.6.4, alclad alloys may be re-heat treated a limited number of times as specified in Table V. Approval for additional re-heat treatments of each part number involved shall be submitted to MRB.

5.6.3 Except as noted in paragraph 5.6.4, bare alloys may be re-heat treated as many times as necessary to facilitate forming during manufacture. Keep the number of re-heat treatments to a minimum to avoid excessive high temperature oxidation.

5.6.4 Do not subject aluminum alloy parts or material in any of the following tempers to re-heat treatment, as these mill tempers are produced by specific degrees of cold working or stress relieving during manufacture and are not reproducible:

T35XX	T65XX	T85XX	T36XX	T735X	T86XX
T37XX	T736X	T87XX	T45XX	T765X	

TABLE V - RE-HEAT TREATMENT OF CLAD ALLOYS

ALLOY AND THICKNESS	MAXIMUM NUMBER OF RE-HEAT TREATMENTS
All alclad alloys under 0.020"	1
All alclad alloys 0.020 to 0.125"	2
2024 alclad over 0.125"	2
2014 alclad & 7075 alclad over 0.125"	3

5.7 Precipitation Hardening Treatments (T Temper)

5.7.1 Natural Aging (Room Temperature)

5.7.1.1 Perform natural aging of 2014, 2024, 2219 and 6061 aluminum alloys from the W temper to the T42 temper according to Table VI or Table VII.

5.7.1.2 For room temperature forming of 2000, 6000 and 7000 alloys in the W (as quenched) temper, the total elapsed time between quenching and completion of forming operations, inclusive of the time material is held in refrigeration, shall not exceed the time specified in Table VIII. This table excludes the time allowance for transfer of parts. Ensure that the time lapse between quenching and refrigerating the material is kept to a minimum. Time lapse shall not exceed 15 minutes for 2XXX series alloy, and 30 minutes for all other alloys.

TABLE VI - PRECIPITATION HARDENING SCHEDULE (WROUGHT ALLOYS)

ALLOY	FORM (Note 1)	TEMPER BEFORE AGING		AGING TIME (Note 2)	AGING TEMPERATURE (Note 4)	TEMPER AFTER AGING	MATERIAL SPECIFICATION (Note 6)
		SOLUTION HEAT TREATED BY MILL	SOLUTION HEAT TREATED BY USER				
2004	All	—	W	96 hours minimum	Room temperature	T42	—
	Sheet	T4	—	10 - 11 hour	340°F - 360°F	T6	AMS 4208 AMS 4209
		—	W/T42 (Note 3)			T62 (Note 3)	

TABLE VI - PRECIPITATION HARDENING SCHEDULE (WROUGHT ALLOYS)

ALLOY	FORM (Note 1)	TEMPER BEFORE AGING		AGING TIME (Note 2)	AGING TEMPERATURE (Note 4)	TEMPER AFTER AGING	MATERIAL SPECIFICATION (Note 6)
		SOLUTION HEAT TREATED BY MILL	SOLUTION HEAT TREATED BY USER				
2014	All	—	W	96 hours minimum	Room temperature	T42	—
	Flat Sheet	T3	—	18 hours minimum	310°F - 330°F	T6	AMS-QQ-A-250/3
		—	W/T42 (Note 3)	8 - 10 hours	340°F - 360°F	T62 (Note 3)	
	Coiled Sheet	T4 (Note 3)	—			T6 (Note 3)	
		—	W/T42 (Note 3)			T62 (Note 3)	
	Plate	T451 (Note 3)	—			T651 (Note 3)	
		—	W/T42 (Note 3)			T62 (Note 3)	
	Rolled Bar & Rod	T4	—			T6	AMS-QQ-A-225/4
		T451	—			T6510	
		—	W/T42			T62	
	Extruded Bar, Rod & Shapes	T4	—			T6	AMS-QQ-A-200/4
		T4510	—			T6510	
		T4511	—			T6511	
		—	W/T42			T62	
2024	All	—	W	96 hours minimum	Room temperature	T42	—
	Flat Sheet	T3	—	12 - 13 hours	365°F - 385°F	T81	AMS-QQ-A-250/4 AMS-QQ-A-250/5
		T36	—	9 - 12 hours		T86	
		T361	—			T861	
		—	W/T42			T62	
	Coiled Sheet	T4	—			T6	
		—	W/T42			T62	
	Plate	T351	—	12 - 13 hours	365°F - 385°F	T851	
		T36	—	8 - 9 hours		T86	
		T361	—			T861	
		—	W/T42			T62	
	Rolled Bar & Rod	T351	—	12 - 13 hours		T851	AMS-QQ-A-225/6
		T4	—			T6	
		—	W/T42	16 - 18 hours		T62	
	Extruded Bar, Rod & Shapes	T3510	—	12 - 13 hours		T8510	AMS-QQ-A-200/3
		T3511	—			T8511	
		T4	—			T6	
		—	W/T42	16 - 18 hours		T62	
	Drawn Tube	T3	—	12 - 13 hours		T81	AMS-WW-T-700/3 DHMS M2.21
		—	W/T42	16 - 18 hours		T62	

TABLE VI - PRECIPITATION HARDENING SCHEDULE (WROUGHT ALLOYS)

ALLOY	FORM (Note 1)	TEMPER BEFORE AGING		AGING TIME (Note 2)	AGING TEMPERATURE (Note 4)	TEMPER AFTER AGING	MATERIAL SPECIFICATION (Note 6)
		SOLUTION HEAT TREATED BY MILL	SOLUTION HEAT TREATED BY USER				
2219	All	—	W	96 hours minimum	Room temperature	T42	—
	Sheet	T31	—	17 - 19 hours	340°F - 360°F	T81	AMS-QQ-A-250/30
		—	W/T42	35 - 37 hours	365°F - 385°F	T62	
	Plate	T351	—	17 - 19 hours	340°F - 360°F	T851	
		—	W/T42	35 - 37 hours	365°F - 385°F	T62	
6061	All	—	W	96 hours minimum	Room temperature	T42	—
	Sheet	T4	—	18 - 18.5 hours at 310°F - 330°F OR 8 - 9 hours at 340°F - 360°F		T6	AMS 4027
		—	W/T42			T62	
	Plate	—	W/T42	18 - 18.5 hours at 310°F - 330°F OR 8 - 9 hours at 340°F - 360°F		T62	
		T451	—	18 - 18.5 hours	310°F - 330°F	T651	
	Rolled Bar & Rod	T4	—	18 - 18.5 hours at 310°F - 330°F OR 8 - 9 hours at 340°F - 360°F		T6	AMS 4117
		—	W/T42			T62	
		T451	—	18 - 18.5 hours	310°F - 330°F	T651	
	Extruded Bar, Rod & Shapes	T4	—	18 - 18.5 hours at 310°F - 330°F OR 8 - 9 hours at 340°F - 360°F		T6	AMS-QQ-A-200/8
		—	W/T42			T62	
		T4510	—	8 - 9 hours	340°F - 360°F	T6510	
		T4511	—			T6511	
	Drawn Tube	T4	—	18 - 18.5 hours at 310°F - 330°F OR 8 - 9 hours at 340°F - 360°F		T6	AMS 4081 AMS 4083 AMS-WW-T-700/6 DHMS M2.21
		—	W/T42			T62	
7075	All	—	W	23.5 - 24.5 hours	240°F - 260°F	T62	—
	Sheet & Plate	—	W	6 - 8 hours at 215°F - 235°F (Note 5) followed by 14 - 18 hours at 325°F - 345°F (Note 5) OR 6 - 8 hours at 215°F - 235°F followed by 24 - 30 hours at 315°F - 335°F		T73	AMS-QQ-A-250/12 AMS 4048 AMS 4049
		T6	T62	8 - 10 hours at 340°F - 360°F OR 24 - 30 hours at 315°F - 335°F		T73	AMS-QQ-A-250/18
		T651	—			T7351	AMS-QQ-A-250/12
		—	T62			T73	AMS 4316
		—	W	3 - 5 hours at 240°F - 260°F followed by 15 - 18 hours at 315°F - 335°F		T76	AMS 4048 AMS 4049 ASTM B 209
		T6	—	15 - 18 hours	315°F - 335°F	T76	
		T651	—			T7651	
		—	T62			T76	

TABLE VI - PRECIPITATION HARDENING SCHEDULE (WROUGHT ALLOYS)

ALLOY	FORM (Note 1)	TEMPER BEFORE AGING		AGING TIME (Note 2)	AGING TEMPERATURE (Note 4)	TEMPER AFTER AGING	MATERIAL SPECIFICATION (Note 6)
		SOLUTION HEAT TREATED BY MILL	SOLUTION HEAT TREATED BY USER				
7075	Rolled Bar & Rod	—	W	6 - 8 hours at 215°F - 235°F followed by 8 - 10 hours at 340°F - 360°F		T73	AMS-QQ-A-225/9
		T6	—	8 - 10 hours	340°F - 360°F	T73	
		T651	—			T7351	
		—	T62			T73	
	Extruded Bar, Rod & Shapes	—	W	6 - 8 hours at 215°F - 235°F followed by 6 - 8 hours at 340°F - 360°F OR 6 - 8 hours at 215°F - 235°F (Note 5) followed by 14 - 18 hours at 325°F - 345°F (Note 5)		T73	AMS-QQ-A-200/11 AMS-QQ-A-200/15
		T6	—	6 - 8 hours	340°F - 360°F	T73	
		T6510	—			T73510	
		T6511	—			T73511	
		—	T62			T73	
		—	W	3 - 5 hours at 240°F - 260°F followed by 18 - 21 hours at 310°F - 330°F		T76	AMS-QQ-A-200/11 AMS-QQ-A-200/15
		T6	—	18 - 21 hours	310°F - 330°F	T76	
		T6510	—			T76510	
		T6511	—			T76511	
		—	T62			T76	

NOTES:
1. DEFINITIONS OF SHEET & PLATE: sheet = up to 0.249" thick.
   plate = 0.250" thick and over.
2. Aging time is the time at the aging temperature for material up to 0.500" thick. Add 30 minutes for each additional 0.500" of thickness.
3. Alternate treatment is 18 hours minimum at 310°F to 330°F.
4. If 2 stage aging treatments are used, the material may, but need not, be removed from the furnace and cooled between aging treatments.
5. A heat-up rate of 25°F per hour shall be used until the specified temperature range is achieved, followed by soaking for the specified time.
6. Material specification refers to the specification containing required mechanical and physical properties for the temper after aging.

TABLE VII - PRECIPITATION HARDENING SCHEDULE (FORGINGS & CASTINGS)

ALLOY	FORM	MATERIAL SPECIFICATION	TEMPER BEFORE AGING	AGING TIME (Note 1)	AGING TEMPERATURE (Note 2)	TEMPER AFTER AGING
FORGINGS						
2014	Die & Hand Forgings	AMS-A-22771 AMS-QQ-A-367	W	96 hours minimum	Room temperature	T4
			W/T4	10 - 10 1/2 hours	330°F - 350°F	T6
			T452			T652
6061	Die & Hand Forgings		W	96 hours minimum	Room temperature	T4
			W/T4	8 - 8 1/2 hours (Note 3)	340°F - 360°F	T6
7075	Die & Hand Forgings (Note 4)		W	24 - 24 1/2 hours	240°F - 260°F	T6
			T6	8 - 10 hours	340°F - 360°F	T73
			W	6 - 8 hours at 215°F - 235°F followed by 8 - 10 hours at 340°F - 360°F		T73
7079	Die & Hand Forgings		W	6 - 6 1/2 hours at 190°F - 210°F followed by 48 - 48 1/2 hours at 230°F - 250°F		T6
CASTINGS						
A201.0	Sand, Permanent Mould & Investment Castings	AMS 4229	T4	5 hours minimum	360°F - 380°F	T7
295.0	Sand Castings	AMS 4231	T4	12 - 20 hours	300°F - 320°F	T6
520.0	Sand Castings	AMS 4240	W	96 hours minimum	Room temperature	T4
356.0	Sand Castings	AMS 4217	W	96 hours minimum	Room temperature	T4
			T4	3 - 5 hours (Note 3)	300°F - 320°F	T6
	Permanent Mould & Investment Castings	AMS 4260	T4	3 - 5 hours (Note 3)	300°F - 320°F	T6
				3 - 6 hours (Note 3)	390°F - 410°F	T7
				3 hours minimum	465°F - 485°F	T71
A356.0	Sand, Permanent Mould & Investment Castings	AMS 4218	T4	2 - 6 hours (Note 3)	300°F - 320°F	T6
				6 - 10 hours	300°F - 320°F	T61
				3 - 6 hours (Note 3)	465°F - 485°F	T71
A357.0	Sand, Permanent Mould & Investment Castings	AMS 4219	T4	6 - 10 hours	310°F - 330°F	T61
				2 - 12 hours	310°F - 330°F	T6
D357.0	Premium Quality Castings	AMS 4241	T4	2 - 12 hours	310°F - 330°F	T6

NOTES:
1. Aging time is the time at the aging temperature for material up to 0.500" thick. Add 30 minutes for each additional 0.500" of thickness. Aging times are recommendations; other times may be required depending on casting configuration and property requirements (consult Bombardier Toronto M&P Engineering). Unless otherwise authorized by Bombardier Toronto M&P Engineering, the aging treatment shall not be initiated until at least 16 hours at room temperature have elapsed after quenching.
2. If 2 stage aging treatments are used, the material may, but need not, be removed from the furnace and cooled between aging treatments.
3. Aging time may be increased to 10 hours, where necessary, to meet mechanical strength requirements.
4. 7075-T411 forgings (fabricated) require solution heat treatment before precipitation hardening.

TABLE VIII - W TEMPER STORAGE CONDITIONS (NOTE 1)

IF THE STORAGE TEMPERATURE:	ALUMINUM ALLOY	MAXIMUM TIME HELD IN W CONDITION
STAYS AT OR BELOW -10°F	all	720 hours (30 days)
STAYS AT OR BELOW 0°F	all	168 hours (7 days)
AT ANY TIME, ENTERS THE RANGE OF 0 TO 20°F	all	72 hours (3 days)
REACHES 20 TO 100°F	7000 series	2 hours
	2024	30 minutes
	all other alloys	1 hour
Note 1. The part shall be transferred into the refrigerator within 15 minutes of quenching for 2XXX series alloy and 30 minutes for 2219 and all other alloys.		

5.7.2 Artificial Aging (Elevated Temperature Precipitation Hardening)

5.7.2.1 Perform artificial aging of aluminum alloys to increase strength according to Table VI or Table VII. Follow artificial aging with air cooling to room temperature.

5.7.3 Artificial Overaging (Elevated Temperature Precipitation Hardening)

5.7.3.1 Perform artificial overaging of aluminum alloys to increase resistance to stress corrosion cracking and exfoliation corrosion according to Table VI or Table VII. Follow artificial overaging with air cooling to room temperature.

5.8 Annealing (O Temper)

5.8.1 Anneal aluminum alloys according to Table IX.

5.9 Interstage Stress Relief Annealing (Heat Treatable Alloys)

5.9.1 When orange peel surface effect is evident or likely to occur when forming parts, perform interstage stress relief annealing instead of full annealing or solution heat treating by soaking the parts for 45 to 60 minutes at 645 ± 15°F and then air cooling.

5.9.2 To reduce the possibility of distortion between rough and final machining, stress relieve 7050, 7075 and 7175 alloys in the T7XXX tempers by soaking for a maximum accumulated time of 1 hour at 260 ± 10°F and air cooling.

TABLE IX - ANNEALING (TO O CONDITION)

MATERIAL	TEMPERATURE	SOAKING TIME	COOLING
WROUGHT ALLOYS			
Non-Heat Treatable Alloys (except 3003)	650°F - 775°F (Note 1)	Heat to temperature as rapidly as possible and hold until temperatures of furnace and load are uniform	Furnace cool or air cool to room temperature
3003	750°F - 800°F (Note 1)		
2004 2014 2024 2219 6061	750°F - 800°F	1 hour minimum	Cool at 50°F per hour maximum to 500°F and air cool to room temperature
7075 7079	775°F - 800°F for 2 - 3 hours followed by 425°F - 475°F for 6 hours minimum		Cool at 50°F per hour maximum to 425°F after first heating operation. Air cool to room temperature after second heating operation
CASTINGS			
200 series	800°F ± 25°F	1 - 1 1/2 hours (Note 2)	Air cool
300 series	825°F ± 25°F	1 - 1 1/2 hours (Note 2)	Air cool
500 series	725°F ± 25°F	5 - 5 1/2 hours (Note 2)	Air cool

Note 1. Interstage annealing between forming operations of non-heat treatable alloys (except 5454) may be carried out at 920°F to 950°F.

Note 2. May use air furnace, fluidized beds or salt baths. For air furnaces, soaking time starts when all thermocouples are within 10°F of the set temperature. For other furnaces, soaking time starts when control thermocouples return to set temperature. Soak times listed are for sections up to 0.500" thick. Add 1/2 hour for each additional 0.5" of product or nested stack thickness or fraction thereof.

6 REQUIREMENTS

6.1 General

6.1.1 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 Monthly Furnace Qualification

6.2.1 Once monthly, for every furnace used for heat treatment of aluminum and aluminum alloys, conduct temperature uniformity surveys (TUS) to verify furnace operation. At Bombardier Toronto, conduct TUS according to QDI-09-02.

6.2.2 If the furnace has been overhauled, repaired, relocated, etc., re-qualify the furnace before further fabrication of production parts. At Bombardier Toronto, perform the furnace equipment checks and calibration as specified in QDI-09-02).

6.3 Monthly Process Control Tests

6.3.1 Test Specimens

6.3.1.1 Once monthly, re-qualify each furnace or salt bath used for solution heat treating or precipitation hardening aluminum alloys. Prepare the test specimens (cut to the dimensions given in Table X) for re-qualification as follows:

Step 1. At the start of each month, process the number of test specimens (of each alloy and form) specified in Table XI with the first production load of the month. Cut the test specimens transverse to the rolling direction of the sheet from aluminum alloy corresponding to the material specification, form and gauges specified in Table XI.

Step 2. Distribute the test specimens throughout the production load.

Step 3. Heat treat the test specimens according to Table XI to the specified temper.

Step 4. Stamp the test specimens with the solution heat treat stamp (at Bombardier Toronto, according to QAPI 3.8.7.5) and mark with the precipitation hardening batch number and furnace number.

6.3.1.2 If a production load of a particular alloy is not processed during a particular month, the monthly qualification tests for that particular alloy are not required.

6.3.1.3 For high temperature oxidation, eutectic melting and cladding diffusion tests, prepare a metallographic specimen according to DHLPM Procedure No. 5041 or ASTM E3.

6.3.2 Process Control Test Schedule

6.3.2.1 Test specimens shall be submitted for testing according to the schedule and test procedures specified in Table XI.

6.3.2.2 If any test specimens fail to meet the requirements specified in the test procedure, suspend heat treatment in the relevant furnace until the cause of failure has been established and corrected. Evaluate the acceptability of production parts heat treated together with failed test pieces based on the results of the production tests according to section 6.5.

6.3.3 Tensile Tests

6.3.3.1 Test tensile test specimens to destruction according to DHLPM Procedure No. 2026 or ASTM E8 to determine the ultimate tensile strength, yield strength and elongation.

6.3.3.2 Test specimens shall meet the minimum requirements specified in the applicable material specifications.

TABLE X - RAW MATERIAL DIMENSIONS FOR PRODUCING TEST SPECIMENS

LABORATORY DRAWING	ROLLED OR EXTRUDED ROD, BAR OR PLATE		SHEET		EXTRUDED OR FORMED SHAPES (CV, CS, ETC. SECTIONS)	
	DIAMETER	LENGTH (Note 1)	WIDTH	LENGTH	WIDTH	LENGTH
None (Note 2)	Less than 0.250"	2"	—	—	Full section	9"
LAB 027-1	1/4" minimum	1 3/4"	—	—	—	—
LAB 011-7	1/2" minimum	5"	—	—	—	—
LAB 011-5	9/16" minimum	5"	—	—	—	—
LAB 011-3	3/4" minimum	5 1/2"	—	—	—	—
LAB 011-2	7/8" minimum	6"	—	—	—	—
LAB 009-1	1" and over	7"	—	—	—	—
LAB 025-1 or ASTM E8	—	—	5/8"	9"	—	—

NOTES: 1. Dimensions given are finished part dimensions. Unless the material is to be issued in length, it will be necessary to increase the length to accommodate chucking.
2. To Laboratory instructions.

TABLE XI - SCHEDULE OF MONTHLY PROCESS CONTROL TEST SPECIMENS

TEST SPECIMENS					HEAT TREATMENT		TEST SCHEDULE				
ALLOY & FORM	MATERIAL SPEC.	GAUGE	TEMPER	NO. OF PIECES	OPERATIONS (Note 1)	FINAL TEMPER	TENSILE	EUTECTIC MELTING	HIGH TEMP. OXIDATION/ BLISTERING	CLADDING DIFFUSION	INTERGRANULAR CORROSION
2014 clad sheet	AMS-QQ-A-250/3	0.040" or less	T3 or O	3	SHT & PH	T62	Yes	Yes	Yes (Note 2)	Yes	Yes
		0.063" or 0.080"		2							
2024 clad sheet (Note 3)	AMS-QQ-A-250/5	0.040" or less	O, T3, T4 or T6	3	SHT & R.T. AGE	T42	Yes	Yes	Yes (Note 2)	Yes	Yes
		0.032" or 0.040"	T3	2	PH	T81	Yes	N/A	N/A	N/A	N/A
2219 bare sheet	AMS-QQ-A-250/30	0.040" or less	T31	3	SHT & PH	T81	Yes	Yes	Yes (Note 2)	N/A	N/A
		0.063" or 0.080"		2							
6061 bare sheet	AMS 4025 AMS 4026 AMS 4027	0.040" or 0.063"	O, T4 or T6	3	SHT & PH	T62	Yes	Yes	Yes (Note 2)	N/A	N/A
7075 clad sheet	AMS 4048 AMS 4049	0.040" or less	O or T6	3	SHT & PH	T62	Yes	Yes	Yes (Note 2)	Yes	Yes

NOTES: 1. ABBREVIATIONS: SHT = solution heat treatment
PH = precipitation hardening at elevated temperature (artificial age)
R.T. AGE = room temperature age (natural age), 5 days minimum
2. Applies only to test specimens solution heat treated in an air furnace.
3. 2024 bare sheet may be used in place of 2024 clad sheet as the test specimen if its final temper will be T81.

6.3.4 High Temperature Oxidation and Blistering

6.3.4.1 There shall be no evidence of blistering on the surface of the specimen.

6.3.4.2 A section cut from a spare test specimen shall be polished and the unetched surface examined at 400X magnification for evidence of high temperature oxidation. There shall be no evidence of excessive high temperature oxidation (sub-surface voids).

6.3.5 Eutectic Melting

6.3.5.1 A section cut from a spare test specimen shall be polished, etched for approximately 2 seconds in Keller's Etch and examined at 400X magnification for evidence of eutectic melting.

6.3.5.2 There shall be no evidence of rosette formation or triple-grain boundary intersection melting.

6.3.6 Cladding Diffusion

6.3.6.1 A section cut from a spare test specimen shall be polished, etched for 6 to 20 seconds in Keller's Etch and examined at 100X minimum magnification to check for evidence of diffusion of alloying elements through the cladding. Sections prepared for eutectic melting examination may be used for this test.

6.3.6.2 There shall be no evidence of excessive cladding diffusion. The maximum limit for cladding diffusion is 60% of the clad thickness.

6.3.7 Intergranular Corrosion

6.3.7.1 Prepare and subject a spare test specimen to intergranular corrosion tests according to DHLPM Procedure No. 6013 or ASTM G110. In the case of clad alloys, remove the cladding from both sides by filing, sanding or chemical milling.

6.3.7.2 A section cut from the exposed specimen shall be polished and examined for evidence of intergranular corrosion at 100X minimum magnification in the unetched condition and after etching for 6 to 20 seconds in Keller's Etch.

6.3.7.3 The depth of intergranular corrosion shall not exceed 0.006".

6.4 Daily Quench Delay Check

6.4.1 In order to maintain a close control on quench delay times, as defined in paragraph 5.5.2, carry out a check with a suitable stop watch at least once per shift at each solution heat treat furnace or salt bath and record the results. At Bombardier Toronto, record the results on a Process Control Record (form DH3520) according to QDI-09-02.

6.5 Production Tests

6.5.1 Production Test Schedule

6.5.1.1 Each batch of parts subjected to precipitation hardening shall be tested according to the schedule and using the test procedures specified in Table XII.

6.5.1.2 Any tests specified for forgings or castings are checks to verify response to heat treatment only and are not an authority to depart from the tests required according to PPS 35.07 or PPS 35.08, as applicable.

6.5.1.3 Each production load to be tested shall receive sufficient checks to ensure correct heat treatment response. Refer to Table XII for the percentage of parts from each batch to be tested. If a load consists of more than one batch, check parts from each batch. Parts that have been stacked (with suitable separators) for heat treatment shall have representative tests made on material removed from the centre of the stack as well as material from the outside of the stack.

6.5.1.4 Refer production parts that have failed to meet the requirements of the applicable test procedure specified in Table XII to MRB for disposition.

TABLE XII - PRODUCTION TEST SCHEDULE - PRECIPITATION HARDENED PARTS

<table>
<tr><th>HEAT CONDITION</th><th>ALLOY</th><th>FORM</th><th>ELECTRICAL CONDUCTIVITY TEST</th><th>HARDNESS TEST</th></tr>
<tr><td colspan="5">ALL T TEMPERS EXCEPT T73XX TEMPER</td></tr>
<tr><td rowspan="7">After PH</td><td rowspan="7">All</td><td rowspan="4">Wrought alloys & forgings</td><td>Refer to section 6.5.3</td><td>Refer to section 6.5.4</td></tr>
<tr><td rowspan="3">10% of each batch</td><td>10% of each batch</td></tr>
<tr><td>100% if 1 or more parts have failed conductivity test</td></tr>
<tr><td>100% if 1 or more parts have failed hardness test</td></tr>
<tr><td rowspan="3">Castings</td><td rowspan="3">N/A</td><td>Refer to section 6.5.4</td></tr>
<tr><td>10% of each batch</td></tr>
<tr><td>100% if 1 or more parts have failed hardness test</td></tr>
<tr><td colspan="5">T73XX TEMPER</td></tr>
<tr><td rowspan="2">Before PH</td><td rowspan="2">7075</td><td rowspan="2">All</td><td>Refer to paragraph 6.5.5.1</td><td rowspan="2">N/A</td></tr>
<tr><td>25% of each batch</td></tr>
<tr><td rowspan="2">After PH</td><td rowspan="2">7075</td><td rowspan="2">All</td><td>Refer to paragraph 6.5.5.2</td><td>Refer to paragraph 6.5.5.2</td></tr>
<tr><td>25% of each batch</td><td>25% of each batch</td></tr>
</table>

6.5.2 Conductivity Test Procedure

6.5.2.1 Test for electrical conductivity according to PPS 20.07.

6.5.3 Conductivity Test Requirements for T Tempers (Except T73XX)

6.5.3.1 Conductivity readings shall be within the range specified in PPS 20.07. If a material or temper not specified in PPS 20.07 requires conductivity testing, refer to Bombardier Engineering.

6.5.3.2 Welded 6061 assemblies, welded in the T4 or T6 condition and aged to T6 after welding, shall meet the conductivity requirements of PPS 20.07 when tested as follows:

- If possible, test at least 2" away from the weld bead. The T6 requirements shall be met in this area.
- If testing within 2" of the weld bead, the test results shall not be less than the minimum requirements for the T4 condition.

6.5.3.3 If any part fails to meet the conductivity requirements specified in PPS 20.07, then all parts from the applicable batch shall undergo hardness testing according to PPS 20.08.

6.5.4 Hardness Test Requirements for T Tempers (Except T73XX)

6.5.4.1 Hardness values obtained shall be according to Table XIII or Table XIV. If a material or temper not listed in these Tables requires hardness testing, hardness values shall be according to PPS 20.08.

6.5.4.2 Welded 6061 assemblies, welded in the T4 or T6 condition and aged to T6 after welding, shall meet the hardness requirements of Table XIII when tested as follows:

- If possible, test at least 2" away from the weld bead. The T6 requirements shall be met in this area.
- If testing within 2" of the weld bead, the test results shall not be less than the minimum requirements for the T4 condition.

6.5.4.3 Welded 6061 assemblies solution heat treated and aged to T6 after welding shall meet the T6 hardness requirements in all areas.

6.5.4.4 If any part fails to meet the hardness test requirements, hardness test all parts in the applicable batch. Process each part in the batch that fails to meet the hardness requirements according to section 6.6.

TABLE XIII - HARDNESS REQUIREMENTS (NON-CLAD ALUMINUM ALLOYS)

ALLOY	MATERIAL SPECIFICATION	TEMPER	MINIMUM HARDNESS (Note 1)			
			B SCALE	E SCALE	15T SCALE	BRINELL (Note 2)
2004	AMS 4208	T42/T62	—	92	—	—
2014	AMS-A-22771 AMS-QQ-A-200/2 AMS-QQ-A-225/4 AMS-QQ-A-367	T4	65	95	82	100
		T6	78	102	86	125
2024	AMS-A-22771 AMS-QQ-A-200/3 AMS-QQ-A-225/6 AMS-QQ-A-250/4 AMS-QQ-A-367 AMS-WW-T-700/3	T4	63	94	82	100
		T6	72	98	84	118
		T8	74	99	85	120
2219	AMS-QQ-A-250/30	T4	58	90	78	96
		T6	62	93	81	99
		T8	71	98	83	116
6061	AMS 4027 AMS 4081 AMS 4083 AMS 4116 AMS 4117 AMS-A-22771 AMS-QQ-A-200/8 AMS-QQ-A-367 AMS-WW-T-700/6	T4	—	60	64	50
		T6	42	85	78	80
7075	AMS 4315 AMS-A-22771 AMS-QQ-A-200/11 AMS-QQ-A-200/15 AMS-QQ-A-225/9 AMS-QQ-A-250/12 AMS-QQ-A-250/18 AMS-QQ-A-367	T6	84	106	87	142
		T73	78	102	85	129
		T76	82	104	86	136
7079	AMS-QQ-A-367 AMS-A-22771	T6	86	106	—	—

Note 1. Material gauges 0.032" and less shall be hardness tested using 15T Scale only (i.e., do not use Rockwell B Scale, Rockwell E Scale, or Brinell Scale).

Note 2. 500 kg load, 10 mm ball.

TABLE XIV - HARDNESS REQUIREMENTS (CLAD ALUMINUM ALLOYS)

ALLOY	MATERIAL SPECIFICATION	TEMPER	MATERIAL GAUGE	MINIMUM ROCKWELL HARDNESS (Note 1)		
				B SCALE	E SCALE	15T SCALE
2014	AMS-QQ-A-250/3	T6	0.062" and under	76	102	85
			0.063" and over	75	101	—
2024	AMS-QQ-A-250/5	T4	0.062" and under	57	91	79
			0.063" and over	60	93	—
		T6	0.062" and under	60	93	81
			0.063" and over	62	94	—
		T8	All	65	97	82
7075	AMS 4048 AMS 4049 AMS 4316 AMS-QQ-A-250/18 ASTM B 209	T6	0.032" and under	78	103	86
			0.033" - 0.062"	76	102	—
			0.063" and over	75	101	—
		T76	0.032" and under	76	102	84
			0.033" - 0.062"	75	101	—
			0.063" and over	74	100	—

Note 1. Material gauges 0.032" and less shall be hardness tested using 15T Scale only (i.e., do not use Rockwell B Scale or Rockwell E Scale).

6.5.5 Conductivity and Hardness Test Requirements for 7075-T73XX Alloy

6.5.5.1 Conductivity test each batch of 7075 alloy parts that is to be precipitation hardened to the T73XX temper according to PPS 20.07 before precipitation treatment. Conductivity test parts that have been solution heat treated to the W temper within 15 minutes of quenching.

6.5.5.2 After precipitation hardening to the T73XX temper, conductivity test parts according to PPS 20.07 and hardness test according to PPS 20.08. The electrical conductivity reading shall meet the requirements specified in PPS 20.07 and shall be a minimum of 6% IACS points higher than the reading taken in the W or T6XX temper. The parts shall meet the minimum hardness requirements of Table XIV or Table XIII.

6.5.5.3 If parts meet the requirements for conductivity and hardness, then the batch is acceptable. If parts fail to meet the requirements, subject the batch to a second precipitation treatment at 350 ± 10°F for 2 hours and re-test for conductivity and hardness. After the second precipitation hardening operation, if parts fail to meet the requirements, process the batch according to section 6.6.

6.5.5.4 Maintain a record of all conductivity and hardness readings.

6.6 Conductivity/Hardness Test Failure

6.6.1 Except as noted in paragraph 6.6.1.1 and paragraph 6.6.1.2, all parts that have been precipitation hardened to a final temper of T6, T62, T73 or T76 and have failed to meet conductivity/hardness requirements, shall be re-solution heat treated according to section 5.5, precipitation hardened according to section 5.7 and re-tested. The maximum number of re-heat treatments for clad material shall be as specified in section 5.6.

6.6.1.1 Parts that have been precipitation hardened to the T651, T7351, T7651, T81, T851 or T861 and have failed to meet conductivity/hardness requirements, require MRB approval for re-solution heat treatment as these tempers are not reproducible with re-heat treatment.

6.6.1.2 Refer machined parts and any other parts where re-solution heat treatment would cause unacceptable distortion to MRB for approval to re-heat treat.

7 SAFETY PRECAUTIONS

7.1 Observe standard plant safety precautions when performing the procedure specified herein.

7.2 Whenever possible, remain behind the plexiglass protective wall while working with the salt bath. If it is necessary to work in front of the plexiglass wall, wear a Bombardier approved splash shield, protective gloves (e.g., DSC 422-3) and an aluminized fire-proof jacket at all times when loading or unloading the salt bath.

7.3 Avoid ingesting any of the materials used in the salt bath. Always wash hands before eating or smoking.

7.4 Operators heat treating material or parts in the Park Thermal elevator quench furnace shall be fully aware of the correct operating procedures and shall be approved by the Heat Treat Foreman before operating the furnace.

7.5 Wear protective gloves at all times when unloading hot parts from air furnaces.

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:

8.1.1 Upon completion of training, the trainee shall be familiar with and have a good working knowledge of the following documents regarding the heat treatment of aluminum alloys:

- engineering drawing notes
- work orders
- PPS 20.07, PPS 20.08, PPS 30.01, PPS 23.01 and PPS 31.02
- BAERD GEN-007, QDI-09-02 and QAPI 3.8.7.5

8.1.2 Upon completion of training, the trainee shall be familiar with and have a good working knowledge of the following equipment used in the heat treatment of aluminum alloys:

- #10 air furnace with drop bottom quenching
- thermocouples
- salt bath
- part handling and racking equipment
- protective clothing
- conductivity meter
- hardness testing machines

8.1.3 Upon completion of training, the trainee shall be familiar with and have a good working knowledge of the following theories regarding the heat treatment of aluminum alloys:

- physical and mechanical properties of aluminum alloys as they apply to the aircraft industry
- effects of cold working (mechanical fabrication operations) on the mechanical properties of aluminum alloys
- effects of natural aging on the mechanical properties of aluminum alloys
- the differences between heat treatable and non-heat treatable aluminum alloys
- breakdown and relevance of the American National Standards Institute (ANSI) four digit number alloy designation system for wrought and cast aluminum alloys
- breakdown and relevance of the ANSI alpha or alpha-numeric temper designation, indicating the thermal or mechanical treatment to which the alloy has been subjected in order to produce specific mechanical properties
- physical and mechanical property differences between clad and non-clad aluminum alloys
- definitions and applicability of solution heat treatment, precipitation heat treatment and annealing
- achievement of desired mechanical properties through solution heat treatment, precipitation heat treatment and annealing
- significance of quenching

9 CALIBRATION AND MAINTENANCE OF EQUIPMENT

9.1 Calibration and maintenance of heat treating equipment and instrumentation shall conform to BAERD GEN-007.

9.2 Because sludge accumulation on the bottom of salt baths can cover the heating coils and cause local overheating, clean the tanks by first pumping the clean salt from the tank and then remove and discard any sludge or foreign material. Do this as often as necessary to assure that, during operation, temperature uniformity of the bath is maintained.

9.3 When necessary, dredge quench tanks for lost parts.

9.4 Once weekly, test a sample from the salt bath for a determination of the pH value. The pH shall be maintained within the range of 6.5 to 8.5. Addition of a mixture of 5 parts heat treat salt to 1 part sodium dichromate will lower the pH by 0.5 as long as the amount of sodium dichromate is equal to 0.5% by weight of the salt capacity of the bath. If the small additions are no longer able to maintain the pH, add sodium dichromate. When adding sodium dichromate, lower the salt bath temperature to a 600°F or less. pH values between 8.5 and 10.0 are acceptable during stabilization of the bath following additions of sodium dichromate. Any pH reading above 10 shall be reported to Quality immediately. Keep a record of salt and sodium dichromate additions made.

10 ADDITIONAL INFORMATION

10.1 In order to verify correct heat treat response, all parts or material of 7075 alloy which are to be overaged by precipitation hardening to the T73XX temper (either from the mill T6XX temper or from the solution heat treated W temper) require electrical conductivity tests according to PPS 20.07 before and after precipitation hardening and a hardness test according to PPS 20.08 after precipitation hardening.