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BOMBARDIER
Toronto Site
PROPRIETARY INFORMATION

PPS 35.07

PRODUCTION PROCESS STANDARD

REQUIREMENTS FOR INVESTMENT AND SAND CASTINGS

Issue 17
- This standard supersedes PPS 35.07, Issue 16.
- 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.

Prepared By:	(Christie Chung)	July 20, 2017
	PPS Group	
Approved By:	(*K. Quon*, for Bruce Campbell)	July 25, 2017
	Materials Technology	
	(*M. Lightbody*, for Stephen Pitt)	July 26, 2017
	Quality	

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1 SCOPE

1.1 This Production Process Standard (PPS) specifies the qualification and acceptance inspection requirements for investment and sand castings.

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 2694 - Fusion Welding - Weld Repair of Casting.

3.2 BAERD GEN-012 - Non-Destructive Testing - Certification of Personnel.

3.3 BAERD GEN-018 - Engineering Requirements for Laboratories.

3.4 PPS 13.26 - General Subcontractor Provisions.

3.5 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.6 PPS 15.01 - Part Marking.

3.7 PPS 20.01 - Magnetic Particle Inspection.

3.8 PPS 20.03 - Fluorescent Penetrant Inspection.

3.9 PPS 20.10 - Radiographic Inspection.

3.10 PPS 30.01 - Heat Treatment of Aluminum and Aluminum Alloys.

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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 31.17 - Solvent Usage.

3.16 PPS 37.03 - Fusion Welding of Aluminum Alloys.

3.17 PPS 37.04 - Fusion Welding of Ferrous and Nickel Alloys.

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

3.19 Bombardier Toronto Laboratory Drawings - LAB 003, 006, 007, 014, 019 and 026.

3.20 ASTM E155-60T - Reference Radiographs for Inspection of Aluminum and Magnesium Alloy Castings (Series II).

3.21 ASTM E192-62T - Reference Radiographs of Investment Steel Castings.

3.22 MIL-M-6857 - Magnesium Alloy Castings, Heat Treatment.

3.23 MIL-STD-276 Impregnation of Porous Non-Ferrous Metal Castings.

4 MATERIALS, EQUIPMENT AND FACILITIES

4.1 Materials

4.1.1 No materials specified.

4.2 Equipment

4.2.1 Before use, casting tools shall be qualified by manufacturing one casting from each cavity, platen, mould, or position on a cluster and ensuring that the casting 1) passes radiographic inspection; 2) passes either magnetic particle or fluorescent penetrant inspection; and 3) meets the dimensional requirements of the engineering drawing.

4.3 Facilities

4.3.1 General

4.3.1.1 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 utilize this PPS.

4.3.1.2 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.

4.3.1.3 Facility approval shall be based on a facility report, a facility survey and completion of a qualification test program. 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 Toronto Engineering.

4.3.1.3.1 For approval of subcontractor facilities to utilize 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.

4.3.1.3.2 All testing and evaluation specified herein shall only be performed by Bombardier Toronto Materials Laboratory or by laboratories accredited according to BAERD GEN-018.

4.3.2 Qualification of Facilities

4.3.2.1 Each specific facility shall demonstrate its ability to repeatedly produce castings which meet the requirements of this PPS, the engineering drawing, and the applicable materials specifications by providing batch release data for the past 10 consecutive batches of production castings of similar class and configuration as the parts to be supplied to Bombardier.

4.3.2.2 Re-qualify each facility according to Bombardier Aerospace instructions. When more than one class of casting is being produced for Bombardier, re-qualification only to the highest class of casting being produced is sufficient.

5 PROCEDURE

5.1 General

5.1.1 For the purposes of this standard, a “LOT” is defined as a batch of parts of the same part number produced in a continuous working period from the same heat of material and heat treated in one furnace load.

5.1.2 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.

5.1.3 The procedure for the manufacture of castings is at the discretion of the foundry. It is the responsibility of the foundry to ensure that the foundry practices are capable of producing satisfactory castings which meet the requirements of this specification, the engineering drawing, and the applicable material specification. Record the optimum foundry technique, once established, on a Process Control Document. The process shall be re-qualified if there is any significant technical change to the Process Control Document. As a minimum, Process Control Documents shall contain the following information:

- Part number and drawing revision
- Material specification and final heat treat temper
- Pattern and mould part/serial numbers
- Molten metal holding temperature
- Pouring temperature
- Degassing temperature
- Grain refining and modification procedures
- Chill and insulating sizes and locations
- Gating techniques and procedures
- Filtering techniques
- Risering techniques, procedures, and locations
- Solution heat treatment temperature and time
- Heat treatment racking procedure
- Quenching procedure
- Aging heat treatment temperature and time
- Casting repair techniques to be employed
- Quality control sampling plan
- Methods of inspection

5.1.4 Part mark castings according to PPS 15.01.

5.1.5 Refer to section 5.2 for definitions of welding defects.

5.2 Definitions of Welding Defects

5.2.1 *Cold Crack* - Usually a single crack, starting from the surface. Seen on a radiograph or during fluorescent penetrant or magnetic particle inspection as a straight line which is usually continuous throughout its length.

5.2.2 *Cold Shut* - A discontinuity between 2 flows of metal in a mould which appears as a crack or seam with smooth or rounded edges. It is caused by rapid chilling of the surface metal when the pour speed is too slow.

5.2.3 *Core Shift* - A variation from the specified dimensions of a cored casting section due to a change in position of the core or a misalignment of cores in assembly.

5.2.4 *Foreign Material* - Sand, slag, oxide, dross, metal of different density, etc. which is embedded in the cast metal. Appears as isolated, irregular or elongated variations in radiographic film density.

5.2.5 *Gas Hole(s)* - Individual, clustered or evenly distributed bubbles that appear as round or elongated smooth-edged dark spots on a radiograph. They are generally caused by trapped air or mould gases rejected from the metal during solidification.

5.2.6 *Gas Porosity* - Minute voids, usually distributed throughout the entire casting, that appear as round or elongated dark spots on a radiograph. They are generally caused by trapped air, mould gases, or dissolved gas which is rejected by the metal during solidification.

5.2.7 *Hot Crack* - A crack, starting internally or at the surface, that appears as a ragged dark line of variable width with numerous branches. It has no definite line of continuity and may exist in groups.

5.2.8 *Hot Tears* - Usually caused by contraction of the casting during or immediately after solidification, hot tears appear as ragged dark lines of variable width with definite continuity. They may exist in groups, which can be either internal or starting at the surface of the casting.

5.2.9 *Inline Porosity* - Three or more small voids, separated by a distance of 4 diameters or less, forming a straight line.

5.2.10 *Micro Shrinkage* - Cavities in the metal grain boundaries that appear on radiographs as dark feathery streaks or dark irregular patches.

5.2.11 *Misrun* - Incomplete filling of the mould that appears on a radiograph as prominent darkened areas of variable dimensions with definite smooth outlines.

5.2.12 *Mould Buckle* - An indentation in the surface of the sand casting resulting from expansion of the sand.

5.2.13 *Segregation* - A concentration of alloying elements in specific regions of the casting caused by primary crystallization of one phase with subsequent concentration of the other element in the remaining liquid.

5.2.14 *Shrinkage Cavity* - An internal cavity caused by contraction during solidification that appears on a radiograph as a distinctly outlined dark area with irregular dimensions.

5.2.15 *Shrinkage Porosity or "Sponge"* - Dispersed, spongy dendritic shrinkage within walls of castings caused by contraction during solidification that appears on a radiograph as a lacy or honey-combed dark area with a diffuse outline.

5.2.16 *Surface Irregularities* - Any visible surface casting defect (e.g., seams, scars, flowmarks, grooves, inclusions, fluxed sand or metal).

5.3 First Article Qualification of New Production Parts

5.3.1 For each specific facility, qualify the manufacturing process for each part number as follows:

- Submit Process Control Documents (see paragraph 5.1.3) to Bombardier Toronto for review and approval.
- In conjunction with Bombardier Toronto requirements, prepare a first article test plan specifying the type and location of all test specimens (e.g., tensile, metallographic, and chemical).
- Qualify tooling (see paragraph 4.2.1).
- If radiographic testing is required, develop a Radiographic Test Technique and submit it to Bombardier Toronto for review and approval (see paragraph 6.6.1).
- For each part number, produce a minimum of four castings and any tensile test coupons required by the first article test plan. Test two of the castings according to the schedule specified in Table I and submit the other two castings along with the first article test plan report. If either of the castings fails to meet any requirements, take corrective action and repeat the testing.

TABLE I - FIRST ARTICLE QUALIFICATION TESTS

TEST METHOD	APPLICABILITY	SECTION
Dimensional	All aircraft, all classes	section 6.2
Visual	All aircraft, all classes	section 6.3
Magnetic Particle or Fluorescent Penetrant	All aircraft, all classes	section 6.4
Radiographic	Class 1A, 1B, 1C, 2A and 2B Only (Note 1)	section 6.6
Pressure	Fluid Pressure Castings Only	section 6.7
Metallographic	All aircraft, all classes	section 6.8
Chemical Composition	All aircraft, all classes	section 6.9
Tensile	All aircraft, all classes	section 6.5.1
Note 1. Classifications specified are applicable for the DASH 8 Q400. For DASH 8 Q100, Q200 and Q300, the applicable Classes are: Class 1A, 1.1, 1.2, 2.1 and 2.2 only.		

5.4 Heat Treatment

5.4.1 If heat treatment is specified, heat treat the castings to the final heat treat condition specified on the engineering drawing according to the specification listed in Table II.

TABLE II - HEAT TREATMENT STANDARDS

TYPE OF CASTING	STANDARD
Aluminum and Aluminum Alloys	PPS 30.01
Carbon and Low Alloy Steels	PPS 30.04
Precipitation Hardenable (PH) Stainless Steels	PPS 30.06
Martensitic Stainless Steels	PPS 30.08
Austenitic (Strain Hardenable) Stainless Steels	PPS 30.10
Magnesium Alloy Castings	MIL-M-6857

5.5 Impregnation

5.5.1 Do not impregnate castings without the specific permission of the engineering drawing or MRB. If approval is obtained, non-ferrous castings may be impregnated according to MIL-STD-276. Do not impregnate castings exhibiting structural defects under any circumstances.

5.6 Straightening of Castings

5.6.1 Precipitation hardenable aluminum alloy, stainless steel, or magnesium alloy castings which are straightened in the “AS QUENCHED” condition do not require stress relief after straightening.

5.6.2 Do not straighten aluminum alloy, stainless steel, and magnesium alloy castings in the AGED condition.

5.6.3 Stress relieve low alloy steel castings with a strength range of 180 - 200 ksi or greater according to PPS 30.04 after straightening.

5.6.4 After straightening, examine all castings for cracks through either magnetic particle inspection according to PPS 20.01 or fluorescent penetrant inspection according to PPS 20.03, as applicable.

5.7 Repair of Castings by Welding

5.7.1 The extent of allowable repair is specified on the engineering drawing. Repair of castings by welding is not acceptable if the drawing either does not address repairs or specifies that weld repair is not allowed.

5.7.2 Only the following defects may be repaired by welding:

- gas holes	- porosity	- non-fills
- cuts	- inclusions	- pits
- cracks	- hot tears	- shrinkage

5.7.3 Before welding, remove all repairable defects by a method that does not damage the base metal. Ensure that the reworked area is smooth, uniform, and permits easy filling with the weld material. After removing defects, submit the castings to either magnetic particle, fluorescent penetrant, or radiographic inspection to ensure complete removal of the defect.

5.7.4 Solvent clean areas of castings to be repair welded according to PPS 31.17 before welding.

5.7.5 Parts may be pre-heated before welding. Take care to prevent over-heating and warpage when using local heating techniques. Do not pre-heat Class 2 aluminum alloy castings to more than 900°F before repair welding.

5.7.6 Parts shall be repair welded according to the applicable welding PPS. Only the gas-tungsten arc welding process may be used.

5.7.7 All welders shall be certified according to PPS 37.06. Successful welding of a Weld Capability Test Slab as specified in AMS 2694 as the test joint, will certify the welder for all repair welding of castings.

5.7.8 Use welding filler metal of the same nominal composition as the casting which produces properties in the repair area equivalent to or better than those of the parent metal. In order to minimize the number of passes needed to fill the cavity, use as large a diameter of the filler rod as practical. For heat treatable castings, repair weld before any heat treatment. Do not repair weld castings more than two times.

5.7.9 After repair welding, dress or blend the welded area flush with the parent metal to conform to the drawing requirements.

5.7.10 Unless the engineering drawing specifies that the parts are to be normalized, solution heat treated, annealed, or precipitation hardened, stress relieve castings after welding according to the procedure specified by the applicable heat treatment PPS, as listed in Table II.

5.7.11 After all heat treatments, dressing, blending, etc., re-inspect all repaired castings according to the requirements of the applicable weld class, as specified in Table III and radiographically inspect. Ensure that the castings meet the requirements specified in Table VII or Table VIII, as applicable. On the radiograph, circle and mark with a “W” the repaired areas. Submit the radiographic film to Bombardier Toronto along with the repair welded part.

5.7.12 Identify parts that have been repair welded as such on the Certification of Conformance. In-process inspection reports shall be kept on file and made available to Bombardier Toronto upon request.

5.7.13 Mark castings which have been repaired by welding with a symbol of three concentric circles, the diameter of the outer circle being 1/4" or less. The welder's stamp shall be applied according to PPS 15.01 and encircled with a ring of white paint.

6 REQUIREMENTS

6.1 Production Parts

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.

6.1.2 Examine production parts according to Table III. If any failed casting is determined within the sample size, 100% inspect the LOT and refer unacceptable parts and/or LOTS to MRB for disposition. If requested by Bombardier Toronto, submit test coupons to Bombardier Toronto Materials Laboratory for testing. Maintain a record of all test results.

TABLE III - INSPECTION SCHEDULE

INSPECTION METHOD (NOTE 3)	CASTING CLASS FOR Q100, Q200 & Q300 (Note 1)					CASTING CLASS FOR Q400 (Note 1)			
	1.1, 1.2, 2.1 & 2.2	2.3	2.4	3	FLUID PRESSURE	1A, 1B & 1C	2A, 2B, 2C & 2D	3	FLUID PRESSURE
Dimensional (section 6.2)	100%	100%	100%	100%	100%	100%	100%	100%	100%
Visual (section 6.3)	100%	100%	100%	100%	100%	100%	100%	100%	100%
Magnetic Particle / Fluorescent Penetrant (section 6.4)	100%	100%	Sample as per Table IV	N/A	100%	100%	100%	100%	100%
Tensile Tests (section 6.5.2) (Note 2)	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Radiographic (section 6.6)	100%	N/A	N/A	N/A	N/A	100%	Sample as per Table IV	Sample as per Table IV	N/A
Pressure (section 6.7)	N/A	N/A	N/A	N/A	100%	N/A	N/A	N/A	100%
Metallographic (section 6.8)	The metallography and chemical composition of each LOT of castings, as specified in the Certificate of Conformance, shall meet the requirements specified by the applicable material specification.								
Chemical Composition (section 6.9)									

Note 1. Classification of the casting as specified on the drawing.
Note 2. Tensile testing shall be carried out after all heat treat operations have been performed.
Note 3. Perform radiographic inspection on all weld repaired castings.

TABLE IV - LOT SAMPLING INSPECTION SCHEDULE

LOT SIZE	SAMPLE SIZE (NOTE 1)	LOT SIZE	SAMPLE SIZE (NOTE 1)
2 - 5	ALL	27 - 36	10
6 - 8	5	37 - 51	11
9 - 11	6	52 - 82	12
12 - 15	7	83 - 162	13
16 - 20	8	163 - 971	14
21 - 26	9	972 - Up	15
Note 1. If any failed casting is determined within the sample size, 100% inspect the LOT and refer unacceptable parts and/or LOTS to MRB for disposition.			

6.2 Dimensional Requirements

6.2.1 Ensure that castings conform to the dimensional requirements of the engineering drawing. First article castings shall be inspected for all the dimensions specified by the engineering drawing (i.e., 100% dimensional inspection) with all measurement results recorded and maintained on file. All production parts produced after the first article casting shall be inspected (e.g., using a suitable checking fixture) to ensure compliance with the engineering drawing limits. Refer parts which do not meet the engineering drawing limits to MRB for disposition.

6.3 Visual Inspection

6.3.1 Visually examine castings with the aid of a magnifying lens of at least 5X power in an area illuminated by at least 75 foot candles of light.

6.3.2 Ensure that castings are sound, uniform in quality and condition, and free from foreign material and imperfections which could affect the function of the part.

6.3.3 Reject parts which exhibit any of the following defects:

- Cracks
- Mismatch
- Hot tears
- Depressions
- Cold shuts
- Core shift
- Surface porosity
- Dimensions in excess of drawing tolerances
- Misruns
- Shrinkage
- Surface pits

6.3.4 The surface finish shall comply with the requirements specified on the engineering drawing.

6.4 Magnetic Particle/Fluorescent Penetrant Inspection

6.4.1 For ferro-magnetic low alloy steel, 400 series corrosion resistant steel, and precipitation hardened corrosion resistant steel castings, magnetic particle inspect according to PPS 20.01. For aluminum alloy, magnesium alloy and 300 series corrosion resistant steel castings, fluorescent penetrant inspect according to PPS 20.03.

6.4.1.1 Except as noted, refer castings with any indication of true defects to MRB for disposition. For castings where the engineering drawing specifies a particular grade for the casting **only**, discontinuities within the limits specified in Table V are considered acceptable.

6.4.1.2 If performing sample inspection and **any** of a production LOT sample show evidence of unacceptable defects (including defects which may be removed by subsequent machining) refer the **entire** LOT to MRB for disposition.

TABLE V - MAGNETIC PARTICLE INSPECTION (MPI) AND FLUORESCENT PENETRANT INSPECTION (FPI) LIMITS (NOTE 1)

DISCONTINUITY		GRADE A	GRADE B	GRADE C
Maximum Random Individual Discontinuity Size (length, width or diameter) i.e., gas holes, inclusions, discrete shrinkage, etc. (Notes 2 & 3)	Surface (FPI & MPI)	1/4 T or 0.03" whichever is less	1/3 T or 0.05" whichever is less	1/3 T or 0.09" whichever is less
	Sub-surface (MPI)	1/4 T or 0.05" whichever is less	1/3 T or 0.09" whichever is less	1/3 T or 0.12" whichever is less
Minimum Spacing (see Figure 1) (Note 4)	Random Individual Discontinuities	3 times the maximum dimension of the larger discontinuity	2 times the maximum dimension of the larger discontinuity	
Maximum Shrinkage (Notes 5 & 6)	Linear	0	0	0.12"
	Non-linear	0	0.12"	0.38"
Maximum Number of Allowable Discontinuities within a 2 in^2 Area (Note 7)	Random Individual Discontinuities	2	3	4
	Shrinkage	0	1	1

Note 1. The discontinuities specified in this table are **only** applicable if the engineering drawing specifies a particular casting grade. If a casting grade is not specified by the engineering drawing, castings with indications of true defects shall be referred to MRB for disposition. Note that casting “Class” and casting “Grade” are not synonymous and that there should be no relationship assumed between them (i.e., a Class 1.1, or Class 1A, casting will not necessarily also be a Grade A casting, etc.).

Note 2. “T” represents the thickness of the casting section.

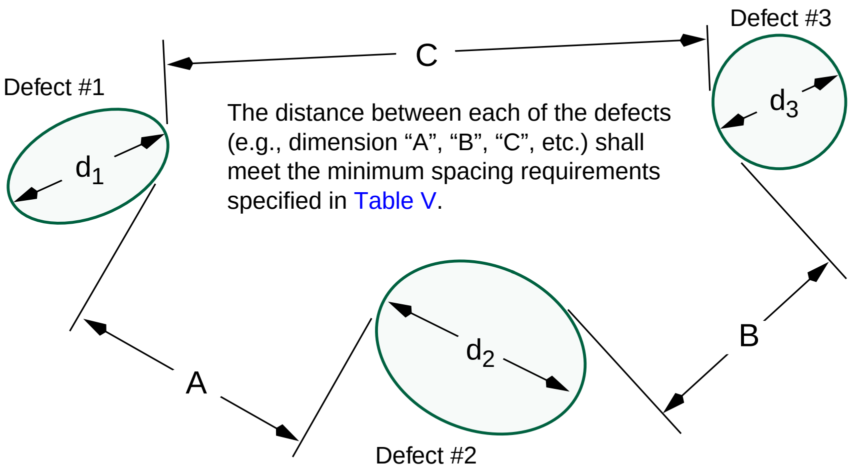
Note 3. Cracks, hot tears, cold shuts and through wall indications are not acceptable.

Note 4. If the total length of the discontinuities that violate the minimum spacing specified does not exceed the maximum length permitted for a single discontinuity, then consider those discontinuities as one discontinuity and as such acceptable.

Note 5. Shrinkage (linear or non-linear) on a flange edge or fillet radius is not acceptable.

Note 6. Linear shrinkage is that which possesses a length to width ratio of 3:1 or greater. Shrinkage with a length to width ratio less than 3:1 is considered non-linear.

Note 7. When determining the number of discontinuities within a 2 in^2 area, do not include discontinuities which are smaller than 1/2 their maximum allowable size.



d1, d2 and d3 represent the maximum dimension of the respective defects shown; use the larger of the two when determining if the minimum spacing requirements have been met (e.g., to determine if distance "A" meets the minimum requirement use the larger of dimension "d_1" or "d_2").

FIGURE 1 - MINIMUM DISCONTINUITY SPACING

6.5 Tensile Testing

6.5.1 First Article Test - Tensile Testing

6.5.1.1 After completing all required non-destructive tests, as specified in Table III, submit two pre-production castings to Bombardier Toronto Materials Laboratory for tensile testing.

6.5.1.2 The number of test specimens and the locations from which they are machined shall be as designated by the first article test plan.

6.5.1.3 Machined tensile test specimens shall conform to the dimensions which are specified on Laboratory Drawing LAB 007, LAB 014, or LAB 019, as applicable, or on the first article test plan.

6.5.1.4 All of the test specimens shall meet the requirements specified in Table VI for test specimens cut from actual castings.

6.5.2 Production Castings - Tensile Testing

6.5.2.1 For each LOT of castings, tensile test a minimum of two test coupons. If the engineering drawing does not specify the type of tensile test coupon to use (i.e., separately cast test bars or integrally cast coupons (prolongations)), refer to the applicable material specification for the type of coupon to use. The location of integrally cast coupons (prolongations) shall be as shown on the engineering drawing. Separately cast test bars shall conform to the dimensions specified on Laboratory Drawing LAB 003, LAB 006, or LAB 026, as applicable.

6.5.2.2 The parting plane flash of separately cast test bars shall be removed by the foundry.

6.5.2.3 Separately cast test bars with an eccentricity in excess of 3% of the specified diameter are unacceptable.

6.5.2.4 Cast separately cast test bars as part of the LOT of castings they represent; it is not acceptable to cast test bars before or after the castings they represent. Identify separately cast test bars with the LOT number and part number of the castings they represent. Mark the test bars in the same manner as the castings they represent.

6.5.2.5 Separately cast test bars shall be processed through all heat treatment together with the production LOT they represent.

6.5.2.6 If the tensile test coupons do not meet the requirements specified in Table VI, refer the represented LOT to MRB for disposition. If required by MRB, cut additional test coupons from the casting, as specified in section 6.5.

TABLE VI - MINIMUM ACCEPTABLE MECHANICAL PROPERTIES

CASTING ALLOY (Note 2)	MATERIAL SPECIFICATION (Note 3)	CLASS OR CONDITION	SEPARATELY CAST OR INTEGRALLY ATTACHED TEST BARS			SPECIMEN CUT FROM CASTING		
			UTS KSI	0.2% YS KSI	%EL (Note 1)	UTS KSI	0.2% YS KSI	%EL (Note 1)
CORROSION RESISTANT STEELS								
347	AMS5362	ANNEALED	70.0	30.0	30.0	70.0	30.0	30.0
410	AMS5350	HARD & TEMP 95-115 ksi	95.0 115.0	75.0	8.0	95.0 115.0	75.0	8.0
		HARD & TEMP 125-160 ksi	125.0 160.0	105.0	6.0	125.0 160.0	105.0	6.0
		HARD & TEMP 180-215 ksi	180.0 215.0	130.0	3.0	180.0 215.0	130.0	3.0
17-4PH	AMS5342	H1100 130-160 ksi	130.0 160.0	120.0	8.0	130.0 160.0	120.0	6.0
	AMS5343	H1000 150-180 ksi	150.0 180.0	130.0	8.0	150.0 180.0	130.0	4.0
	AMS5344	H900 180-210 ksi	180.0 210.0	160.0	6.0	180.0 210.0	160.0	4.0

Notes
1. % Elongation in 4D (round test bars) or 4.5A (rectangular test bars).
2. Superseded alloy designation shown in parentheses.
3. Obsolete material specifications shown in parentheses.
4. For A201.0 alloy castings, test specimens shall only be cut from castings if the engineering drawing designates the casting as “PREMIUM ALLOY”; in all other cases tensile testing shall be based on separately cast test bars.
5. Designated areas are areas which are determined to be heavily loaded by Bombardier Toronto Stress Engineering. Designated areas are shown as hatched on the engineering drawing.

TABLE VI - MINIMUM ACCEPTABLE MECHANICAL PROPERTIES

CASTING ALLOY (Note 2)	MATERIAL SPECIFICATION (Note 3)	CLASS OR CONDITION	SEPARATELY CAST OR INTEGRALLY ATTACHED TEST BARS			SPECIMEN CUT FROM CASTING		
			UTS KSI	0.2% YS KSI	%EL (Note 1)	UTS KSI	0.2% YS KSI	%EL (Note 1)
ALUMINUM ALLOYS								
295.0 (195)	AMS 4231 (QQ-A-601)	T4	29.0	---	6.0	21.75	---	1.50
		T62	36.0	---	---	27.0	---	---
		T7	29.0	---	3.0	21.75	---	0.75
	AMS 4231	T6	32.0	20.0	3.0	24.0	15.0	0.7
	(QQ-A-601)	T6	32.0	20.0	3.0	24.0	15.0	0.75
356.0 (356)	AMS 4217	T51	23.0	---	---	17.25	---	---
		T6	30.0	20.0	3.0	22.5	15.0	0.75
	AMS4260	T6	33.0	22.0	3.0	24.75	16.5	0.75
520.0 (220)	AMS 4240 (QQ-A-601)	T4	42.0	22.0	12.0	31.5	16.5	3.0
A201.0 (A201) (Note 4)	AMS4228	T6	60.0	50.0	5.0	56.0	48.0	3.0
	AMS4229	T7	60.0	50.0	3.0	56.0	48.0	1.5
A356.0 (A356)	MIL-A-2118	CLASS 1	NOT APPLICABLE			38.0	28.0	5.0
		CLASS 2	NOT APPLICABLE			40.0	30.0	3.0
		CLASS 3	NOT APPLICABLE			45.0	34.0	3.0
		CLASS 10	NOT APPLICABLE			38.0	28.0	5.0
		CLASS 11	NOT APPLICABLE			33.0	27.0	3.0
		CLASS 12	NOT APPLICABLE			32.0	22.0	2.0
	AMS 4218	T6	33.0	27.0	3.0	32.0	22.0	2.0
	(QQ-A-601)	T6	34.0	24.0	3.5	25.0	—	1.0
A357.0 (A357)	MIL-A-21180	CLASS 1	NOT APPLICABLE			45.0	35.0	3.0
		CLASS 2	NOT APPLICABLE			50.0	40.0	5.0
		CLASS 10	NOT APPLICABLE			38.0	28.0	5.0
		CLASS 11	NOT APPLICABLE			41.0	31.0	3.0
	AMS 4219	T61	41.0	32.0	3.0	38.0	30.0	2.0
D357.0	AMS 4241	T6	51.0	42.0	N/A	**DESIGNATED AREAS** (Note 5)		
						50.0	40.0	3.0
						NON-DESIGNATED AREAS		
						45.0	36.0	2.0

Notes
1. % Elongation in 4D (round test bars) or 4.5A (rectangular test bars).
2. Superseded alloy designation shown in parentheses.
3. Obsolete material specifications shown in parentheses.
4. For A201.0 alloy castings, test specimens shall only be cut from castings if the engineering drawing designates the casting as “PREMIUM ALLOY”; in all other cases tensile testing shall be based on separately cast test bars.
5. Designated areas are areas which are determined to be heavily loaded by Bombardier Toronto Stress Engineering. Designated areas are shown as hatched on the engineering drawing.

TABLE VI - MINIMUM ACCEPTABLE MECHANICAL PROPERTIES

CASTING ALLOY (Note 2)	MATERIAL SPECIFICATION (Note 3)	CLASS OR CONDITION	SEPARATELY CAST OR INTEGRALLY ATTACHED TEST BARS			SPECIMEN CUT FROM CASTING		
			UTS KSI	0.2% YS KSI	%EL (Note 1)	UTS KSI	0.2% YS KSI	%EL (Note 1)
MAGNESIUM ALLOYS								
AZ81A	QQ-M-56	T4	34.0	11.0	7.0	17.0	9.0	1.75
AZ91C	QQ-M-56	F	23.0	11.0	---	---	---	---
		T4	34.0	11.0	7.0	17.0	9.0	1.75
		T5	23.0	12.0	2.0	---	---	---
		T6	34.0	16.0	3.0	17.0	12.0	0.75
A8	NIL	AC	23.0	12.0	3.0	17.25	9.0	0.75
		T4	34.0	10.0	7.0	25.5	7.5.0	1.75
		T5	34.0	16.0	3.0	25.0	12.0	0.75
LOW ALLOY STEELS								
8615	AMS5333	N	90.0	65.0	18.0	90.0	65.0	18.0
8630 MOD	AMS5334	HARD & TEMP 150-170 ksi	150.0 170.0	125.0	5.0	150.0 170.0	125.0	5.0
4130	AMS5336	HARD & TEMP 100-120 ksi	100.0 120.0	80.0	5.0	100.0 120.0	80.0	5.0

Notes
1. % Elongation in 4D (round test bars) or 4.5A (rectangular test bars).
2. Superseded alloy designation shown in parentheses.
3. Obsolete material specifications shown in parentheses.
4. For A201.0 alloy castings, test specimens shall only be cut from castings if the engineering drawing designates the casting as “PREMIUM ALLOY”; in all other cases tensile testing shall be based on separately cast test bars.
5. Designated areas are areas which are determined to be heavily loaded by Bombardier Toronto Stress Engineering. Designated areas are shown as hatched on the engineering drawing.

6.6 Radiographic Examination

6.6.1 For each part number, perform radiographic examination according to PPS 20.10.

6.6.2 Radiographically examined aluminum and magnesium castings shall meet the requirements specified in Table VII. Radiographically examined steel castings shall meet the requirements specified in Table VIII.

6.6.3 If two or more types of defects are present in a single casting and each defect is equal to or not significantly better than the acceptance standard for that defect, the casting is not acceptable. Refer unacceptable castings to MRB for disposition.

6.6.4 Castings with gas and blow holes, sand spots, or inclusions which are allowed by Table VII and Table VIII, are unacceptable if the defect is located closer than twice its maximum diameter to an edge or extremity of the casting.

6.6.5 Castings with defects which are not individually unacceptable, are unacceptable if they are aligned in such a manner as to create a stress concentration.

6.6.6 If only a sample of the production LOT is being inspected and one or more castings fail to meet the requirements, refer the entire LOT to MRB for disposition.

6.7 Pressure Testing

6.7.1 Pressure test all fluid pressure castings (fuel, hydraulic, etc.) to the values specified on the engineering drawing. Castings which exhibit deformation or leakage during pressure testing are not acceptable.

6.8 Metallographic Inspection

6.8.1 If required, take metallographic samples from the casting in the locations specified by the first article test plan. Mount and test the metallographic samples using standard laboratory practices. The metallography of each LOT of castings shall comply with the requirements of the applicable material specification.

6.9 Chemical Composition Testing

6.9.1 If required, take chemical composition test samples from the casting in the locations specified by the first article test plan. Test the chemical composition of the samples using standard laboratory practices. The chemical composition of each LOT of castings shall comply with the requirements of the applicable material specification.

6.10 LOT Acceptance Test Report

6.10.1 Each LOT of castings shall be submitted with a Certificate of Conformance containing the following information:

- Chemical composition test report
- Mechanical properties test report
- Visual and dimensional inspection report
- Radiography test report and actual radiographs (if applicable)
- Fluorescent penetrant or magnetic particle test report (if applicable)
- Pressure test report (if applicable)
- An outline of all repairs (if applicable)

TABLE VII - MAXIMUM ACCEPTABLE DEFECTS - RADIOGRAPHIC INSPECTION (NON-FERROUS CASTINGS)

DEFECT	APPLICABLE ASTM E155-60T RADIOGRAPH	MAXIMUM DEGREE OF SEVERITY OF DEFECTS AS SPECIFIED IN ASTM REFERENCE RADIOGRAPH							
		CLASS 1.1, 1A CROSS HATCHED		CLASS 1.1, 1A UNMARKED AND CLASS 1.2		CLASS 2.1, 1B		CLASS 2.2, 2A	
		CASTING THICKNESS (INCHES)							
		up to 1/2	1/2 to 2	up to 1/2	1/2 to 2	up to 1/2	1/2 to 2	up to 1/2	1/2 to 2
ALUMINUM									
gas holes	1.1	NONE		1	1	2	2	5	5
gas porosity (round)	1.21	NONE		1	2	3	3	7	7
gas porosity (elongated)	1.22	NONE		1	1	3	4	5	5
shrinkage cavity	2.1	NONE		1	N/A	2	N/A	3	N/A
shrinkage porosity or sponge	2.2	NONE		1	1	2	2	4	3
foreign material (less dense)	3.11	NONE		1	1	2	2	4	4
foreign material (more dense)	3.12	NONE		NONE		2	1	4	3
segregation	N/A	NONE		NONE		NONE		NONE	
hot cracks	N/A	NONE		NONE		NONE		NONE	
cold cracks	N/A	NONE		DWG. TOL.		DWG. TOL.		DWG. TOL.	
cold shuts	N/A	NONE		DWG. TOL.		DWG. TOL.		DWG. TOL.	
surface irregularities	N/A	NONE		DWG. TOL.		DWG. TOL.		DWG. TOL.	
misruns	N/A	NONE		DWG. TOL.		DWG. TOL.		DWG. TOL.	
core shift	N/A	NONE		DWG. TOL.		DWG. TOL.		DWG. TOL.	
MAGNESIUM									
gas holes	1.1	NONE		1	1	3	2	5	4
segregation	1.2	NONE		1	1	2	2	4	4
shrinkage cavity	N/A	NONE		---		---		---	
micro shrinkage - feathery	2.31	NONE		1	1	4	4	7	7
micro shrinkage - sponge	2.32	NONE		1	1	3	4	7	8
foreign material (less dense)	3.11	NONE	1	2	2	3	3	4	4
foreign material (more dense)	3.12	NONE		1	1	2	2	3	3
hot cracks	N/A	NONE		NONE		NONE		NONE	
cold cracks	N/A	NONE		DWG. TOL.		DWG. TOL.		DWG. TOL.	
cold shuts	N/A	DWG. TOL.		DWG. TOL.		DWG. TOL.		DWG. TOL.	
surace irregularities	N/A	DWG. TOL.		DWG. TOL.		DWG. TOL.		DWG. TOL.	
misruns	N/A	DWG. TOL.		DWG. TOL.		DWG. TOL.		DWG. TOL.	
core shift	N/A	DWG. TOL.		DWG. TOL.		DWG. TOL.		DWG. TOL.	

Notes
1. DWG. TOL. - Indicates that the casting is acceptable after these defects have been completely removed by machining or other means, provided the final dimensions are held within drawing tolerance.
2. N/A - Indicates no reference radiograph available.

TABLE VIII - MAXIMUM ACCEPTABLE DEFECTS - RADIOGRAPHIC INSPECTION (LOW ALLOY AND CORROSION RESISTANT STEEL CASTINGS)

DEFECT	APPLICABLE ASTM E192-62T RADIOGRAPH	MAXIMUM DEGREE OF SEVERITY OF DEFECTS AS SPECIFIED IN ASTM REFERENCE RADIOGRAPH											
		CLASS 1.1, 1A CROSS HATCHED			CLASS 1.1, 1A UNMARKED AND CLASS 1.2			CLASS 2.1, 1B			CLASS 2.2, 2A		
		CASTING THICKNESS (INCHES)											
		up to 1/4	1/4 to 1/2	1/2 to 1	up to 1/4	1/4 to 1/2	1/2 to 1	up to 1/4	1/4 to 1/2	1/2 to 1	up to 1/4	1/4 to 1/2	1/2 to 1
gas holes	1.1	NONE			1	1	1	3	3	3	5	5	5
shrinkage cavity	2.1	NONE			NONE			NONE		1	2	2	3
shrinkage sponge	2.2	NONE			1	1	1	2	1	1	5	4	5
shrinkage dendritic	2.4	NONE			1	1	1	2	2	2	4	4	4
shrinkage filamentary	3.5	NONE			NONE			1	1	1	N/A		2
foreign material (less dense)	3.11	NONE			1	1	1	3	3	3	5	5	5
foreign material (more dense)	3.12	NONE			DWG. TOL.			DWG. TOL.			DWG. TOL.		
hot tear	4.1	NONE			NONE			NONE			NONE		
cold crack	4.2	NONE			NONE			NONE			NONE		
cold shut	4.3	NONE			NONE			NONE			NONE		
misrun	5.2	NONE			NONE			NONE			NONE		
core shift	5.3	DWG. TOL.			DWG. TOL.			DWG. TOL.			DWG. TOL.		
excess metal in cracked core	5.5	DWG. TOL.			DWG. TOL.			DWG. TOL.			DWG. TOL.		
mould ridge	5.11	DWG. TOL.			DWG. TOL.			DWG. TOL.			DWG. TOL.		
mould buckle (positive)	5.12	DWG. TOL.			DWG. TOL.			DWG. TOL.			DWG. TOL.		
mould buckle (negative)	5.13	DWG. TOL.			DWG. TOL.			DWG. TOL			DWG. TOL.		

Notes
1. DWG. TOL. - Indicates that the casting is acceptable after these defects have been completely removed by machining or other means, provided the final dimensions are held within drawing tolerance.
2. N/A - Indicates no reference radiograph available.

7 SAFETY PRECAUTIONS

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

7.2 When performing welding repair, observe the safety precautions specified in PPS 37.03 and PPS 37.04.

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 personnel requirements.

8.2 Personnel responsible for repair welding shall be certified according to PPS 37.06.