BOMBARDIER
Toronto (de Havilland)
PROPRIETARY INFORMATION

PPS 37.11

PRODUCTION PROCESS STANDARD

Requirements for Resistance Welding

Issue 12
- This standard supersedes PPS 37.11, Issue 11.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- This PPS is effective as of the distribution date.

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

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1 Scope

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for spot, intermittent spot (stitch) and seam welding of materials as specified herein.

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

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

1.1.3 Procedure or requirements specified in a Bombardier BAPS, MPS, LES or P. Spec. **do not** supersede the procedure or requirements specified in this PPS.

2 Hazardous Materials

2.1 Before receipt at Bombardier Toronto (de Havilland), all materials must be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier Toronto (de Havilland) Environment, Health and Safety Department. Refer to the manufacturer's MSDS for specific safety data on any of the materials specified in this PPS. If the MSDS is not available, contact the Bombardier Toronto (de Havilland) Environment, Health and Safety Department.

3 References

3.1 General

3.1.1 Unless a specific issue is indicated, the issue of the reference documents specified in this section in effect at the time of manufacture shall form a part of this specification to the extent indicated herein.

3.2 Bombardier Toronto (de Havilland) Specifications

3.2.1 PPS 13.26 - General Subcontractor Provisions.

3.2.2 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.2.3 PPS 20.10 - Radiographic inspection.

3.2.4 PPS 37.01 - Resistance Welding of Aluminum Alloys.

3.2.5 PPS 37.02 - Resistance Welding of Non-Hardening Steels and Alloys, Nickel Alloys and Titanium.

4 Materials, Equipment and Facilities

4.1 Materials

4.1.1 Unless otherwise specified in this section, use only the materials specified; use of superseding or alternative materials is not allowed.

4.1.2 Refer to PPS 37.01 or PPS 37.02, as applicable, for resistance welding materials.

4.2 Equipment

4.2.1 Use equipment specified in the applicable welding PPS.

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 spot, intermittent spot (stitch) and seam welding according to this PPS.

4.3.2 Bombardier subcontractors must direct requests for approval to Bombardier Aerospace Supplier Quality Management. Bombardier Aerospace facilities must direct requests for approval to the appropriate internal Quality Manager.

4.3.3 Facility approval shall be based on a facility report, a facility survey and completion of a qualification test program, if required. The facility report must detail the materials and equipment to be used, the process sequence to be followed and the laboratory facilities used to show compliance with the requirements of this PPS. Any deviation from the procedure or requirements of this PPS must be detailed in the facility report. Based upon the facility report, Bombardier Toronto (de Havilland) Materials Technology may identify additional qualification and/or process control test requirements. During the facility survey, the facility requesting qualification must be prepared to demonstrate their capability. Once approved, no changes to subcontractor facilities may be made without prior written approval from Bombardier Aerospace Supplier Quality Management.

4.3.3.1 Unless otherwise specified by Bombardier Aerospace Supplier Quality Management, for approval of subcontractor facilities to perform spot, intermittent spot (stitch) and seam welding according to this PPS, completion of a test program and submission of suitable test samples representative of production parts is required. Test samples must meet the requirements specified in section 6.

5 Procedure

5.1 Definitions

5.1.1 Group (a) materials: Aluminum and magnesium alloys.

5.1.2 Group (b) materials: Austenitic, ferritic and precipitation hardening steels, nickel alloys and cobalt base alloys.

5.1.3 Group (c) materials: Titanium and titanium alloys.

5.1.4 Spot welding is defined as a resistance welding process wherein fusion of 2 or more metal parts is produced by the heat obtained from resistance to the flow of electrical current through the parts held together under pressure.

5.1.5 Resistance spot welding is comprised of a series of non-lapping spots made at a pitch specified on the engineering drawing.

5.1.6 Seam welding is performed using a seam welding machine utilizing electrode wheels and is similar to spot welding in that the resultant weld is comprised of a series of overlapping spot welds effecting a pressure tight joint. Overlapping spot welds prepared using a spot welding machine are not an acceptable substitute for seam welds, unless specifically permitted by the engineering drawing.

5.1.7 Stitch (intermittent spot) welding is similar to spot welding, in that the resultant weld is comprised of a series of non-lapping spots spaced two nugget diameters or less apart.

5.2 General

5.2.1 Refer to PPS 37.01 for the procedure for resistance welding aluminum alloys.

5.2.2 Refer to PPS 37.02 for the procedure for resistance welding non-hardening steel alloys, nickel alloys and titanium.

6 Requirements

6.1 General

6.1.1 In a joint between 2 sheets of different thicknesses or between alloys of different strengths, the minimum shear strength requirement is that of the thinner sheet, or weaker material, whichever is lower. If more than 2 sheets are welded together, the shear strength requirement applies separately to each weld between each pair of outer sheets. The nugget diameter requirement applies between each pair of intermediate sheets.

6.1.2 For unequal thickness combinations, base the minimum acceptable nugget diameter on the thickness of the thinner sheet.

6.1.3 When welding aluminum mesh to aluminum sheet or tubing, welding schedule certification and shear testing are not required.

6.2 Production Parts

6.2.1 For each production part, refer to Table 1 for the maximum percentage of particular weld defects which are acceptable. In some cases, a higher percentage of a particular type of defect may be acceptable if the defects are repaired. Give special attention to any close grouping of defective welds. Refer all parts containing an unacceptable percentage of weld defects to MRB for disposition.

6.2.2 The distance from the edge of each weld to the edge of the sheet must be such that no deformation or bulging of the sheet occurs.

6.2.3 The outer surface of all welds shall be smooth and free of cracks, tip pick-up, spits, blackened spots or other detrimental conditions within the requirements listed in Table 1.

6.2.4 If aerodynamic requirements are applicable, ensure that the electrode indentation does not exceed 0.004". If aerodynamic requirements are not applicable, electrode indentation must not exceed the following limits:

- for Class A and B welds, electrode indentation must not exceed 10% of the thickness of the sheet in which it occurs or 0.005", whichever is greater
- for Class C welds, electrode indentation must not exceed 20% of the thickness of the sheet in which it occurs or 0.005", whichever is greater.

6.2.5 Measure sheet separation at a distance equal to half the diameter of the electrode indentation away from the edge of the weld. Sheet separation must not exceed the following limits:

- for Class A welds on Group (a) materials: a maximum of 10% of the average thickness of the 2 outer sheets joined or 0.005", whichever is greater.
- for Class A welds on Groups (b) and (c) materials: a maximum of 10% of the average thickness of the 2 outer sheets joined or 0.006", whichever is greater.
- for Class B and C welds on all groups of materials: a maximum of 15% of the average thickness of the 2 outer sheets joined or 0.006", whichever is greater.

6.2.6 Unless otherwise specified on the engineering drawing, spot spacing must meet the requirements specified in PPS 37.01 or PPS 37.02, as applicable.

6.2.7 If there is any cause to suspect internal defects, subject the part to radiographic examination according to PPS 20.10 or refer it to MRB for disposition. Refer to Table 2 for the maximum acceptable percentage of welds having defects exceeding the following limits:

- The maximum dimension of any internal defect must not exceed 25% of the weld diameter in Class A welds and 50% of the weld in Class B welds.
- The entire internal defect must be located at least 15% of the weld diameter away from the edge of the weld nugget.

6.2.8 The total of all defects, external and internal, must not exceed 10% for Class A welds, 15% for Class B welds or 20% for Class C welds.

Table 1 - Maximum Acceptable Weld Defects

DEFECT	CLASS OF WELD		
	A	B	C
Cracks open to the surface (except seam welds)	none	none	5% (10%)
Cracks open to the surface in seam welds	none	none	none
Edge bulge cracks	none	none	10%
Excessive sheet separation (ref. paragraph 6.2.5)	3%	5%	10%
Blown spots and pits over 1/16" in diameter	none	none	10% (15%)
Pits less than 1/16" in diameter	3% (5%)	5% (10%)	10% (20%)
Metal expulsion between sheets and surface flashes	3%	5% (10%)	10% (20%)
Tip pick-up	2%	3%	5%
Excessive indentation	5%	10%	10%

Note 1. The percentages specified in this table are the maximum acceptable defects without repair. In some cases, a higher percentage of a defect is acceptable (given in brackets) if the defects are repaired.

Table 2 - Maximum Acceptable Internal Weld Defects

DEFECT	CLASS OF WELD		
	A	B	C
Cracks, porosity	none	6%	n/a
Duds (no fusion)	none (1%)	none (2%)	none (5%)
Insufficient penetration	none	3%	n/a
Excessive penetration	none	3%	n/a

Note 1. The percentages specified in this table are the maximum acceptable defects without repair. In some cases, a higher percentage of a defect is acceptable (given in brackets) if the defects are repaired.

6.3 Machine Qualification and Welding Schedule Certification

6.3.1 Unless otherwise specified by the engineering drawing, the shear strength of each spot weld must meet the minimum requirements specified in Table 3, Table 4 or Table 5, as applicable. If the engineering drawing specifies a higher shear strength, the value specified on the drawing shall take precedence. If the engineering drawing specifies a lower shear strength, as may be the case when reduced flanges are necessary, welding schedule certification shear strength values may be based on the drawing requirements; however, restrict use of that welding schedule to the particular part number involved. If

any weld specimen fails to meet the shear strength requirements, alter the welding method or equipment as necessary and repeat the test for the particular combination involved.

6.3.2 The average shear strength of each set of spot welds must meet the minimum average shear strength specified in Table 3, Table 4 or Table 5, as applicable. If a higher or lower shear strength than the value specified in Table 3, Table 4 or Table 5 is specified by the engineering drawing, the average shear strength of the spot weld set must be at least 25% higher than the shear strength specified on the drawing.

6.3.3 For Class A and Class B welds, variation in shear strength must meet the following requirements:

- For Group (a) materials, 90% of the spot welds in each **set** may vary by ±12.5% of the average shear strength and by ±25% in the remaining spot welds.
- For Groups (b) and (c) materials, 86% of the spot welds in each **set** may vary by ±10% of the average shear strength and by ±20% in the remaining spot welds.

For all Class C welds (i.e., Groups (a), (b) and (c) materials), ensure that the variation in shear strength in each group does not exceed 0.35 when calculated according to the following formula:

$$\text{VARIATION} = \frac{\text{DIFFERENCE BETWEEN HIGHEST \& LOWEST SHEAR STRENGTHS}}{\text{AVERAGE OF INDIVIDUAL SHEAR STRENGTHS}}$$

6.3.4 Each nugget diameter must equal or exceed the minimum diameter specified in Table 6.

6.3.5 For all Class A welds (i.e., Group (a), (b) and (c) materials), perform radiographic examination according to PPS 20.10 to ensure that all welds are sound, free from cracks, spit-outs and cladding inclusions and the nuggets are generally consistent in size and regular in shape. Porosity, either singly or in combination, in the plane in which the radiograph is taken, must not exceed 5% of the total weld nugget area in Group (a) materials or 10% of the total weld nugget area in Groups (b) and (c) materials and must not exceed a linear dimension greater than 15% of the weld diameter nor extend closer to the boundary of the weld nugget than 15% of the weld radius.

6.3.6 When metallographically examined according to section 6.6, porosity in Class A welding schedule certification test specimens must not have an aggregate area in Group (a) materials greater than 5% and, in Groups (b) and (c) materials, greater than 10% of the area of the weld nugget in the sectioned plane.

Table 3 - Shear Strength Requirements - Group (A) Materials

THINNER SHEET NOMINAL THICKNESS	ULTIMATE TENSILE STRENGTH (UTS)							
	56,000 PSI AND ABOVE		35,000 - 55,999 PSI		19,500 - 34,999 PSI		BELOW 19,500 PSI	
	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD
0.016"	110 lbs	140 lbs	100 lbs	125 lbs	70 lbs	90 lbs	50 lbs	65 lbs
0.018"	125 lbs	160 lbs	115 lbs	145 lbs	85 lbs	110 lbs	65 lbs	85 lbs
0.020"	140 lbs	175 lbs	135 lbs	170 lbs	100 lbs	125 lbs	80 lbs	100 lbs
0.022"	160 lbs	200 lbs	155 lbs	195 lbs	120 lbs	150 lbs	95 lbs	120 lbs
0.025"	185 lbs	235 lbs	175 lbs	200 lbs	145 lbs	185 lbs	110 lbs	140 lbs
0.028"	215 lbs	270 lbs	205 lbs	260 lbs	175 lbs	220 lbs	135 lbs	170 lbs
0.032"	260 lbs	325 lbs	235 lbs	295 lbs	210 lbs	265 lbs	165 lbs	210 lbs
0.036"	305 lbs	385 lbs	275 lbs	345 lbs	255 lbs	320 lbs	195 lbs	245 lbs
0.040"	345 lbs	435 lbs	310 lbs	390 lbs	300 lbs	375 lbs	225 lbs	285 lbs
0.045"	405 lbs	510 lbs	370 lbs	465 lbs	350 lbs	440 lbs	260 lbs	325 lbs
0.050"	465 lbs	585 lbs	430 lbs	540 lbs	400 lbs	500 lbs	295 lbs	370 lbs
0.056"	555 lbs	670 lbs	515 lbs	645 lbs	475 lbs	595 lbs	340 lbs	425 lbs
0.063"	670 lbs	840 lbs	610 lbs	765 lbs	570 lbs	715 lbs	395 lbs	495 lbs
0.071"	825 lbs	1035 lbs	720 lbs	900 lbs	645 lbs	810 lbs	450 lbs	565 lbs
0.080"	1025 lbs	1285 lbs	855 lbs	1070 lbs	765 lbs	960 lbs	525 lbs	660 lbs
0.090"	1255 lbs	1570 lbs	1000 lbs	1250 lbs	870 lbs	1090 lbs	595 lbs	745 lbs
0.100"	1490 lbs	1865 lbs	1170 lbs	1465 lbs	940 lbs	1175 lbs	675 lbs	845 lbs
0.112"	1780 lbs	2225 lbs	1340 lbs	1675 lbs	1000 lbs	1255 lbs	735 lbs	920 lbs
0.125"	2120 lbs	2650 lbs	1625 lbs	2035 lbs	1050 lbs	1315 lbs	785 lbs	985 lbs
0.140"	2525 lbs	3160 lbs	1920 lbs	2400 lbs	---			
0.160"	3120 lbs	3900 lbs	2440 lbs	3050 lbs				
0.180"	3725 lbs	4660 lbs	3000 lbs	3750 lbs				
0.190"	4035 lbs	5045 lbs	3240 lbs	4050 lbs				
0.250"	7350 lbs	9200 lbs	6400 lbs	8000 lbs				

Unless otherwise specified, the following alloy designations represent both clad and bare alloys:
UTS 56,000 psi and above: 2014-T3, 2014-T4 (except extrusions), 2014-T451 (except extrusions), 2014-T6, 2014-T651, 2024-T3, 2024-T351, 2024-T36, 2024-T4, 2024-T81, 2024-T851, 2024-T86, 2219-T81, 2219-T87, 7075-T6 & 7075-T651.
UTS 35,000 - 55,999 psi: 2014-T4 extrusions, 2014-T451 extrusions, 2219-T31, 2219-T37, 2219-T4, 2219-T62, 5052-H26, 5052-H36, 5052-H28, 5052-H38, 6061-T6 & 7075-O.
UTS 19,500 - 34,999 psi: 1100-H18, 1100-H28, 2014-O, 2024-O, 2219-O, 3003-H14, 3003-H16, 3003-H26, 3003-H18, 3003-H28, 5052-O, 5052-H22, 5052-H32, 5052-H24, 5052-H34, 6061-O & 6061-T4.
UTS below 19,500 psi: 1100-O, 1100-H22, 1100-H14, 1100-H16, 3003-O, 3003-H12 & 3003-H22.

Table 4 - Shear Strength Requirements - Group (B) Materials

THINNER SHEET NOMINAL THICKNESS	ULTIMATE TENSILE STRENGTH							
	185,000 PSI AND ABOVE		150,000 - 184,999 PSI		90,000 - 149,999 PSI		BELOW 90,000 PSI	
	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD
0.016"	480 lbs	595 lbs	400 lbs	495 lbs	295 lbs	365 lbs	215 lbs	260 lbs
0.018"	590 lbs	725 lbs	490 lbs	600 lbs	340 lbs	415 lbs	250 lbs	305 lbs
0.020"	635 lbs	785 lbs	530 lbs	655 lbs	390 lbs	480 lbs	280 lbs	345 lbs
0.022"	730 lbs	905 lbs	610 lbs	755 lbs	450 lbs	550 lbs	330 lbs	405 lbs
0.025"	870 lbs	1075 lbs	725 lbs	895 lbs	530 lbs	655 lbs	400 lbs	495 lbs
0.028"	1025 lbs	1260 lbs	855 lbs	1055 lbs	635 lbs	785 lbs	465 lbs	575 lbs
0.032"	1250 lbs	1545 lbs	1045 lbs	1280 lbs	775 lbs	955 lbs	565 lbs	695 lbs
0.036"	1500 lbs	1850 lbs	1255 lbs	1545 lbs	920 lbs	1140 lbs	690 lbs	860 lbs
0.040"	1750 lbs	2150 lbs	1460 lbs	1800 lbs	1065 lbs	1310 lbs	815 lbs	1000 lbs
0.045"	2100 lbs	2600 lbs	1795 lbs	2210 lbs	1285 lbs	1585 lbs	1005 lbs	1240 lbs
0.050"	2450 lbs	3000 lbs	2125 lbs	2620 lbs	1505 lbs	1855 lbs	1195 lbs	1475 lbs
0.056"	2880 lbs	3550 lbs	2550 lbs	3145 lbs	1770 lbs	2185 lbs	1460 lbs	1800 lbs
0.063"	3550 lbs	4375 lbs	3090 lbs	3815 lbs	2110 lbs	2595 lbs	1760 lbs	2170 lbs
0.071"	4200 lbs	5150 lbs	3730 lbs	4595 lbs	2535 lbs	3125 lbs	2080 lbs	2560 lbs
0.080"	4850 lbs	6000 lbs	4410 lbs	5440 lbs	3005 lbs	3705 lbs	2455 lbs	3025 lbs
0.090"	5600 lbs	6900 lbs	5090 lbs	6275 lbs	3515 lbs	4335 lbs	2885 lbs	3560 lbs
0.100"	6300 lbs	7750 lbs	5720 lbs	7050 lbs	4000 lbs	4935 lbs	3300 lbs	4070 lbs

UTS above 185,000 psi: Type 301 hard.
UTS 150,000 - 185,000 psi: Type 301 1/2 hard & Type 301 3/4 hard.
UTS 90,000 - 149,999 psi: Type 301 1/4 hard, Type 302 1/4 hard, Type 316 1/4 hard & Inconel 625 (AMS 5599) annealed.
UTS below 90,000 psi: Type 301 annealed, Type 302 annealed, Type 321 annealed, Type 316 annealed, Type 347 annealed & plain carbon steels.

Table 5 - Shear Strength Requirements - Group (C) Materials

THINNER SHEET NOMINAL THICKNESS	ULTIMATE TENSILE STRENGTH (UTS)			
	ALLOYS WITH TENSILE STRENGTH OVER 100 KSI		COMMERCIALLY PURE TITANIUM (MIL-T-9046 CP1, CP2 & CP3)	
	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD	MINIMUM LBS/WELD	MINIMUM AVERAGE LBS/WELD
0.016"	400 lbs	520 lbs	295 lbs	385 lbs
0.018"	490 lbs	635 lbs	340 lbs	445 lbs
0.020"	530 lbs	690 lbs	390 lbs	510 lbs
0.022"	610 lbs	795 lbs	450 lbs	585 lbs
0.025"	725 lbs	945 lbs	530 lbs	690 lbs
0.028"	855 lbs	1110 lbs	635 lbs	825 lbs
0.032"	1045 lbs	1360 lbs	775 lbs	1000 lbs
0.036"	1255 lbs	1630 lbs	920 lbs	1200 lbs
0.040"	1460 lbs	1900 lbs	1065 lbs	1385 lbs
0.045"	1795 lbs	2340 lbs	1285 lbs	1670 lbs
0.050"	2125 lbs	2760 lbs	1505 lbs	1910 lbs
0.056"	2550 lbs	3320 lbs	1770 lbs	2300 lbs
0.063"	3000 lbs	3900 lbs	2110 lbs	2730 lbs
0.071"	3380 lbs	4400 lbs	2395 lbs	3115 lbs
0.080"	3810 lbs	4960 lbs	2700 lbs	3510 lbs
0.090"	4290 lbs	5570 lbs	3040 lbs	3955 lbs
0.100"	4760 lbs	6170 lbs	3380 lbs	4395 lbs

6.4 Routine Tests

6.4.1 For Class A welds, the average shear strength of the 3 single spot shear test specimens must be at least 90% of the average shear strength obtained during certification of the welding schedule. Unless the shear strength limits are specified on the engineering drawing, the individual shear strength values must meet the minimum acceptable values specified in Table 3, 4 or 5, as applicable.

For Class B and C weld shear tests, the individual shear strengths of the 3 single spot shear test specimens must meet the requirements specified in Table 3, Table 4 or Table 5, as applicable, or the requirements specified on the engineering drawing if higher or lower shear strength values are specified there. The variation in shear strength for each set of test welds must not exceed 0.35 as determined by the following formula:

$$\text{VARIATION} = \frac{\text{DIFFERENCE BETWEEN HIGHEST \& LOWEST SHEAR STRENGTHS}}{\text{AVERAGE OF INDIVIDUAL SHEAR STRENGTHS}}$$

6.4.2 After shear testing, visually (macroscopically) examine test specimens of all weld classes for fusion and evidence of defects such as cracks, porosity, spits and cladding inclusions.

6.5 Nugget Diameter Measurement

6.5.1 In each of the following instances, measure and record the nugget diameter of each weld at each separate interface:

- intermittent spot welding
- intermediate planes in 4 or more thickness combination spot welded joints
- if it is necessary to use nugget diameter measurements in place of shear strength tests.

Ensure that the nugget diameter of each test specimen equals or exceeds the minimum diameter specified in Table 6. Also, for Class A welds, the average nugget diameter of each set of welds must be no more than 10% or 0.02" (whichever is greater) **less than** the average nugget diameter obtained during certification of the welding schedule. If 4 thicknesses are welded together, this requirement only applies to the intermediate plane. When taking nugget diameter measurements, visually (macroscopically) examine the welds for fusion and evidence of internal defects such as cracks, porosity, spits and cladding inclusions.

Table 6 - Nugget Diameter (All Metals)

THINNER SHEET NOMINAL THICKNESS	MINIMUM SPOT DIAMETER
0.016"	0.085"
0.018"	0.090"
0.020"	0.100"
0.022"	0.105"
0.025"	0.120"
0.028"	0.130"
0.032"	0.140"
0.036"	0.150"
0.040"	0.160"
0.045"	0.170"
0.050"	0.180"
0.056"	0.190"

THINNER SHEET NOMINAL THICKNESS	MINIMUM SPOT DIAMETER
0.063"	0.200"
0.071"	0.210"
0.080"	0.225"
0.090"	0.240"
0.100"	0.250"
0.112"	0.260"
0.125"	0.280"
0.140"	0.300"
0.160"	0.320"
0.180"	0.340"
0.190"	0.350"

6.6 Metallographic Examination

6.6.1 If metallographic examination of a weld is specified, ensure that the requirements specified within this section are met.

6.6.2 Defects such as porosity, cracks, lack of fusion or voids within the weld nugget of all alloys, and macro segregation (localized alloy segregation in the weld at the interface) within nickel and cobalt base alloy weld nuggets, are acceptable if they do not exceed the following limits:

- Maximum defect dimension (as a percentage of weld diameter): Class A welds - 10%; Class B welds - 15%; Class C welds - 25%.
- Maximum defect extension into an outer sheet (as a percentage of the respective sheet thickness): Class A and B welds - 25%; Class C welds - 50%.
- Minimum defect distance away from the boundary of the weld nugget (as a percentage of weld diameter): For all classes of welds - 15%.
- Incipient melting, within the weld-affected area, is considered acceptable provided it does not extend to within 10% of an outer sheet surface or result in excessive sheet separation.

6.6.3 For welds in clad aluminum, the outline of the nugget area at the interface must be generally smooth and regular and the extent of cladding into the columnar zone (see Figure 1) must not exceed 10% of the weld diameter. There must be no other unfused cladding within the nugget.

6.6.4 For seam welds, use transverse sections to ensure that the width of the fused zone meets the minimum nugget diameter specified in Table 6. Also ensure that the outline of the nugget zone on a plane perpendicular to the joined sheets through the centre line of the seam weld shows overlapping of welds and consistency of penetration.

6.6.5 For spot and seam welds, penetration of the nugget zone into each outer sheet must meet the following requirements. For spot welds, the minimum penetration requirement only applies over 80% of the weld diameter at the interface.

- For 2 sheet combinations (of equal or unequal thickness), penetration into each of the sheets must meet the requirements specified in Table 7 for the thinner sheet (e.g., for a Class B weld of Group (a) materials with the nominal thickness of thinner sheet 0.032", a minimum penetration of 0.25 x 0.032" or 0.008" into each sheet is required).
- For multiple sheet welds (of equal or unequal thickness), the penetration into the thinner outer sheet must meet the requirements specified in Table 7. For the thicker outer sheet, the penetration must meet the requirements specified in Table 7 for the thicker outer sheet or not less than the sum of the inter-sheet thicknesses plus the percentage value specified in Table 7 for the thinner sheet, whichever is less.
- For Class A and B spot, intermittent spot and seam welds in Group (a) materials, penetration into each outer sheet must not exceed 80% of the reduced sheet thickness (i.e., thickness at the weld centre-line). In all other cases, penetration into each outer sheet must not exceed 90% of the reduced sheet thickness.

Table 7 - Minimum Penetration

WELD METHOD	WELD CLASS	Group (a) Materials	Groups (b) & (c) Materials
Spot, Intermittent Spot and Seam	A	30%	20%
	B	25%	
	C	20%	

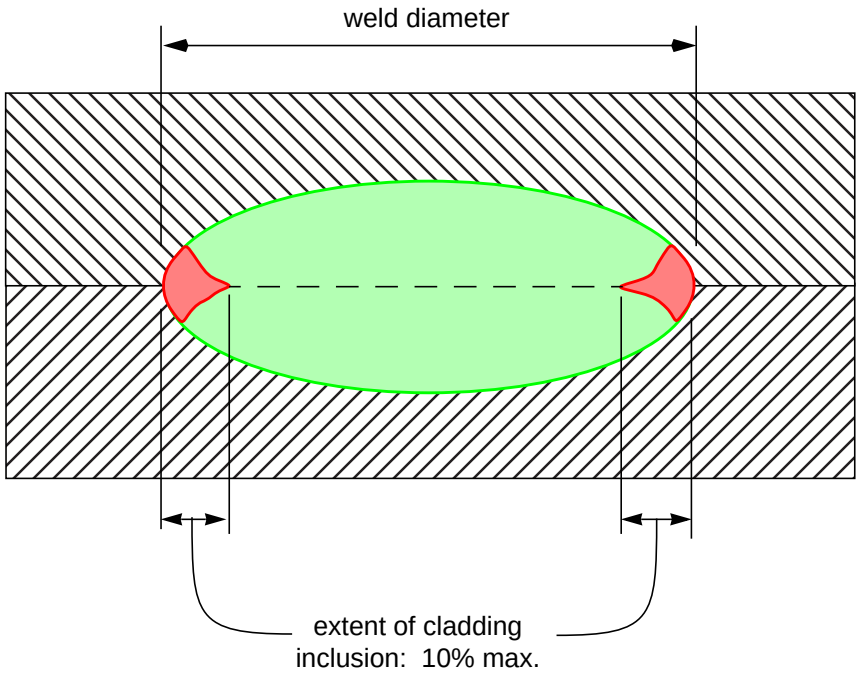

Figure 1 - Cladding Inclusion

7 Safety Precautions

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

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

8 Personnel Requirements

8.1 Resistance welding shall only be performed by personnel who have met the personnel requirements specified in PPS 37.01 and/or PPS 37.02, as applicable.

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