

AIPS
Airbus Process Specification
Resistance Welding

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1 Scope

This Airbus Process Specification defines the technical requirements for Resistance welding.

The purpose of this specification is to give design and quality requirements to manufacturers. Although the essential requirements of a process are defined, this specification does not give detailed in-house process instructions; these shall be given in the manufacturers detailed process instruction and supporting documentation.

This specification shall not be used as an inspection document unless parts or assemblies have been manufactured according to this specification. It shall be applied when mentioned in the relevant standard, material specification or drawing.

2 Normative references

This Airbus specification incorporates by dated or undated reference provisions from other publications. All normative references cited at the appropriate places in the text are listed hereafter. All normative references cited at the appropriate places in the text are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this Airbus specification only when incorporated in it by amendment of revision. For undated references, the latest issue of the publication referred to shall be applied.

National standards should be applied if Airbus standards are not available. List of normative references is following:

AIPS01-04-001	Airbus Process Specification - General requirements for welding and allied processes
AITM 6-7002- Annex B	Aitbus Test Method - X Radiographic inspection: Radiographic inspection of welded parts and components
AMS6858	Welding Resistance: Spot and Seam
EN1321	Aerospace Series - Destructive tests on welds in metallic materials - Macroscopic and microscopic inspection of welds
EN9103	Quality management systems - Variation management of key characteristics
ISO 15609-5	Specification and qualification of welding procedures for metallic materials- Welding procedure specification – Part 5- Resistance Welding

3 Definitions, applicability and limitations

3.1 Definitions

Definitions given in AIPS01-04-001 and below shall apply.

3.1.1 Resistance welding

Welding with pressure in which the heat necessary for welding is produced by resistance to an electrical current flowing through the welding zone.

Spot welding is discontinuous operation, joining two or more items.

Seam welding is a continuous operation, joining two or more items and making a tight joint.

3.1.2 Nugget, Nugget diameter and Joint width

Nugget is the weld metal joining the parts.

Nugget diameter is measured at the plane of the faying surfaces.

Joint width is the fused length between the interfay gap; may be larger than the actual nugget diameter (cast area).

See appendix A, figure A1 (unclad aluminium, stainless steel and titanium) and figure A2 (clad aluminum).

3.1.3 Clear annulus and center area.

Clear annulus is referred to an outer ring of 25% of the nugget diameter.

The center area is the remainder of the nugget which does not belong to the clear annulus.

See appendix A, figure A 3.

3.1.4 Penetration

Extent of the nugget into the original thickness of a joined member. See appendix A, figure A 4.

3.1.5 Imperfections

Indentation: Compression of the sheet in the area above the weld nugget.

Expulsion/spew: Weld metal expelled from the nugget during the welding process.

Pile-up: The surface of the sheet is deformed to form a ridge at the edge of the weld.

Sheet separation: The gap between the top and bottom sheet which occurs during welding.

Flash or Copper pick-up: Particles embedded in surface of the material above the weld nugget.

See appendix A, figure A 5.

3.1.6 Shear, Peel and Chisel test

Shear is a test in which two overlapping pieces of metal that have been spot welded together are pulled apart in a tensile testing machine.

Peel is the separating of a spot or seam welded test piece by pulling apart one side of the test-piece using pliers while the other side is gripped in a device.

Chisel test is the separating of a welded test piece using a blunt chisel, working on each side of the weld.

See appendix A, figure A 6.

3.1.7 Sheet and Foil

Sheet, material with a thickness, of 0.2 mm to 6.35 mm.

Foil, material with a thickness, of less than 0.2 mm.

3.2 Applicability

This Airbus specification is applicable when invoked by the drawing directly or through another document for the purpose given in the scope. When processing to AIPS01-04-004 is required, it shall be invoked on the drawing by the words "Resistance welding to AIPS01-04-004".

3.3 Limitations of the process

Materials are divided into groups defined in AIPS01-04-004 and shown in table 1.

Alloys from different material groups shall not be joined by resistance welding.

Dissimilar alloys may be welded provided that they fall within the same group.

Table 1: Materials Groups

Material Group	Alloys
I	Unalloyed and Low alloyed steels (up to 5% alloying elements)
II	High alloyed steels and Nickel based alloys
III	Titanium and Titanium alloys
IV	Aluminium and Aluminium alloys

The thickness ratio of the thickest to the thinnest outer sheet in the combination shall not exceed 4:1.

For sheets, this process is limited currently within the following thickness limitations:

Table 2: Thickness Limitations

Material Group	I & II	III	IV
Thickness range	0,4 to 2,0 mm	0,4 to 3,2 mm	0,6 to 2,0 mm

No limits for foils are established.

Through a qualification process in accordance with the Reference Manufacturing Shop (RMS), these limits can be expanded when a new need arises.

4 Requirements

4.1 Technical requirements

4.1.1 Engineering requirements for technical process qualification

4.1.1.1 Qualification test specimens

For sheets from each material group, three sets of test pieces shall be prepared, as explained below and defined in table 3:

- Two test sets will be performed to verify the limits of the process. A material representative of each material group is defined as the basis in qualification for these first two sets.
- The third set will be chosen as representative of the most difficult thickness combination to be performed in the production parts. Normally, this combination will be the one with the greatest difference between the thickness of the sheets.

For foils only the representative test set will be required.

Table 3: Test sets definition

Material Group	Base material	Configuration	
I and II	Inconel 718	Lower	0,4 : 0,4 mm
		Upper	2,0 : 2,0 mm
	Representative		To be determinated by the Qualification Body according to the the series production
III	Ti6Al-4V	Lower	0,4 : 0,4 mm
		Upper	3,2 : 3,2 mm
	Representative		To be determinated by the Qualification Body according to the the series production
IV	2024 T3 clad sheet	Lower	0,6 : 0,6 mm
		Upper	2,0 : 2,0 mm
	Representative		To be determinated by the Qualification Body according to the series production

As a general rule, this qualification test program defined below should be followed if technical qualification of the process in a Manufacturing Shop different to the RMS is required, but the M&P specialist in charge may change base materials or number/type of specimens for qualification testing in order to adapt it to the particular case.

The quantity and type of specimens for each test set is defined in table 4.

Table 4: Quantity and type of specimens for technical process qualification

Process	Material Group	Inspection			
		Visual	Radiography	Metallography	Mechanical Test
Spot Welds Sheet	IV	All	All	5 micro figure A 7	Shear, 20 spots figure A 7
	I, II & III			3 micro figure A 7	Shear, 10 spots figure A 7
Seam Welds Sheet	All	All	All	4 micro transverse 4 micro longitudinal figure A 8	Shear, 3x25 mm figure A 8
Spot Welds Foil	All	All	Not required	Not required	Peel, 2x75 mm figure A 9
Seam Welds Foil	All	All	Not required	Not required	Peel, 2x75 mm figure A 9

4.1.1.2 Requirements

Requirements for visual, radiographic and metallographic inspections are defined in appendix B, tables B 1 and B 2.

Requirements for mechanical testing are defined in appendix B, tables B 3 to B 7.

Results from Qualification Test Program are to be assessed against the requirements of AIPS acceptance level A.

If the technical qualification of the process needed is not full, and with the agreement of the Qualification Body, it might be carried out against a lower acceptance level (B or C). However, this will limit the scope of qualification and the sub-contractor shall be qualified to weld only some particular assemblies.

Compliance with the requirements of AIPS acceptance level A infers that the qualified process is capable of meeting the less stringent requirements of AIPS acceptance levels B and C.

4.1.1.3 Key Characteristics

Key Characteristics acc. to EN9103 are defined by responsible engineering based on a risk analysis for parts manufactured by this process. Key characteristics shall be defined on product level and if necessary also on process level.

They shall be subject to variation control by production organization according to EN9103.

Key Characteristics do not relieve the production organization from meeting all engineering requirements defined in this document.

Table 5: Key Characteristics

Product Key Characteristic			Process Key Characteristic		
No.	Designation	Requirement/ Limit	Sub.- No.	Designation	Requirement/ Limit
1	Shear strength	Material specification or appendix B	1.1	Welding cycle - current - pressure - time	see Process Instruction
			1.2	Electrode preparation	
2	Material properties	Material specification	2	Surface preparation	Imperfections acc. App. B

4.2 Quality requirements

4.2.1 Welding Procedure Specification (WPS)

For each material/thickness/machine combination, the local Quality Assurance Authority will validate a Welding Procedure Specification (WPS). All production welding shall be carried out against a validated WPS. The content of the WPS shall be in accordance with ISO 15609-5. The WPS validation tests shall be carried out as stated in Table 6.

Table 6: Quantity and type of specimens for WPS validation

Process	Material Group	Inspection		
		Visual	Metallography	Mechanical Test
Spot Welds Sheet	All	All	3 micro transverse figure A 7	Shear, 8 spots figure A 7
Seam Welds Sheet	All	All	2 micro transverse 1 micro longitudinal figure A 8	Shear, 3x25 mm figure A 8
Spot Welds Foil	All	All	Not required	Peel, 1x35 mm figure A 9
Seam Welds Foil	All	All	Not required	Peel, 1x35 mm figure A 9

The requirements for visual, radiographic and metallographic inspections are defined in table B 2. Requirements for mechanical testing are defined in appendix B, tables B 3 to B 7.

4.2.2 Personnel and equipment

Requirements established to personnel and equipment by the Local Quality Assurance Authority must be in accordance to AIPS01-04-001.

Every resistance welding machine shall be qualified against AMS6858 or equivalent national standards.

5 Technical qualification

The Technical Qualification shall be performed according to the relevant Airbus procedure.

6 First part qualification

For the introduction of new structural components or major changes to serial production processes for class 1 parts, a First Part Qualification (FPQ) according to the relevant Airbus procedure is mandatory. For class 2 parts FPQ is mandatory when specified on the drawing. Main objective of a FPQ is to prove, that the inner quality of a structural part / component meets the requirements defined in the Definition Dossier taking into account materials and key parameters of the manufacturing process and tooling.

7 Series production inspection

7.1 Witness test specimens

Witness test specimens shall accompany the production parts. They shall represent the joint combination manufactured in production in terms of material type, thickness combinations and surface condition. Results of testing on the witness test specimens shall be recorded. Production welds and witness test specimens shall be manufactured in accordance with the requirements of the validated WPS. Test lots of witness specimens for production parts shall be as listed below.

7.1.1 Pre-production lot.

This witness pre-production lot shall be tested at the start of each working day or after a machine shutdown.

7.1.2 Routine lot.

This witness specimens lot shall be tested every 2 hours of continuous operation or at the beginning of a new production lot and change in material type, thickness combinations or welding parameters. The pre-production and the routine lot test shall consist of the configuration and method of evaluation as given in Table 7.

Table 7: Tests and requirements for witness tests specimens

Process	Test Set		Requirements	
	Tests	Specimen	Visual & Metallography	Mechanical
Spot Welds Sheet	Metallography ⁽¹⁾ and Shear	1x10 spot Figure A 7	Table B 2	Tables B 3 to B 5
Seam Welds Sheet	Metallography ⁽¹⁾ and Chisel	1x35 mm Figure A 8	Table B 2	Table B 7
Spot Welds Foil	Peel	1x10 spots Figure A 9	Table B 2 (only visual)	Table B 7
Seam Welds Foil	Peel	1x35 mm Figure A 9	Table B 2 (only visual)	Table B 7
⁽¹⁾ Metallography: 1 micro only required for pre-production lot				

The quantity and configuration of witness test specimens may be changed with prior agreement from the Airbus Materials and Processes specialist.

7.2 Production parts

Inspection methods and requirements for the non-destructive inspection on welded production parts according to the acceptance level are given in table 8.

Table 8: Inspections on resistance welded production parts

Acceptance Level	Inspection method	Inspection Quantity (% welds in a production batch)	Requirements
A	Radiography Visual	100%	Table B 2
B	Radiography Visual	10% ⁽¹⁾ 100%	
C	Visual	100%	
⁽¹⁾ The first batch of parts shall be submitted for 100% radiographic inspection. For subsequent batches the frequency of inspection may be progressively reduced to a recommended minimum of 10% after a technique and standard has been established and maintained to the satisfaction of the Airbus Quality Assurance Authority The frequency of inspection shall be tightened if there is an increase in imperfections that fail to meet the AIPS requirements or at the request of the Airbus Quality Assurance Authority.			

Production parts and lots are acceptable as welded with imperfections above the sizes stipulated, provided the quantity does not exceed:

Table 9: Allowables imperfections

	Acceptance level		
	A	B	C
Visual inspection			
Indentation	3 %	10 %	10 %
Radiography	A	B	C
Porosity and incomplete fusion	0 %	6 %	N/A

This fraction is related to the total number of spots inspected in a part or production batch.

These quantities of imperfections are allowed if they are randomly distributed and not clustered in one area, in one part, or in a group of parts. In any case, a concession to inform the competent departments will be raised.

Parts or lots with imperfections exceeding the quantity as determined from table A 7 shall be rejectable.

8 Rework

Re-welding shall not be carried out.

9 Environment, health and safety

Process shall be in line with Airbus environmental policy.

Banned substances, as per relevant Airbus procedure, shall not be applied.

Hazardous materials shall comply with rules defined in relevant Airbus procedure.

Appendix A: Figures

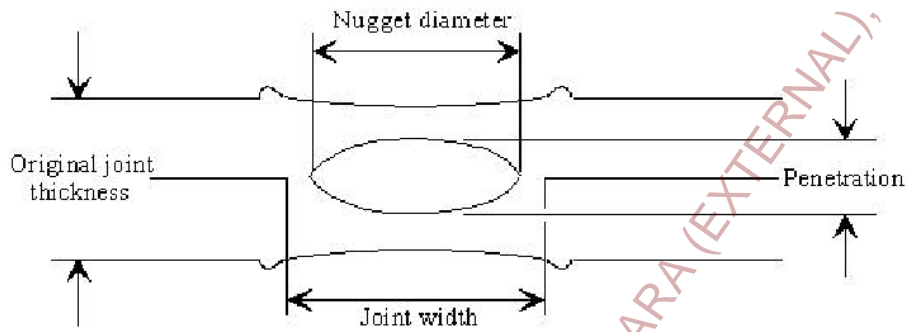


Figure A.1: Joint width and nugget diameter for unclad aluminium, stainless steel and titanium

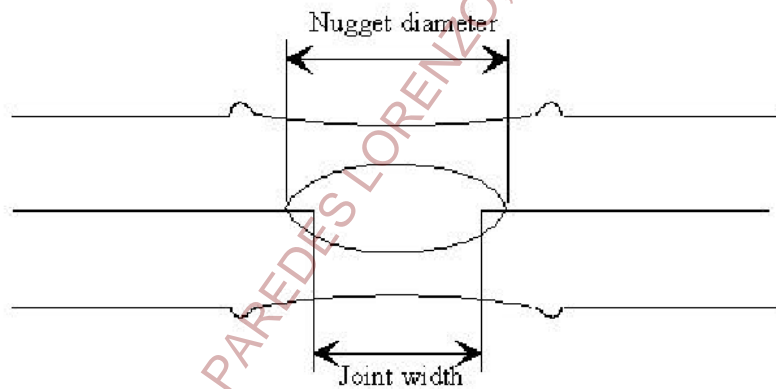


Figure A.2: Joint width and nugget diameter for clad aluminium

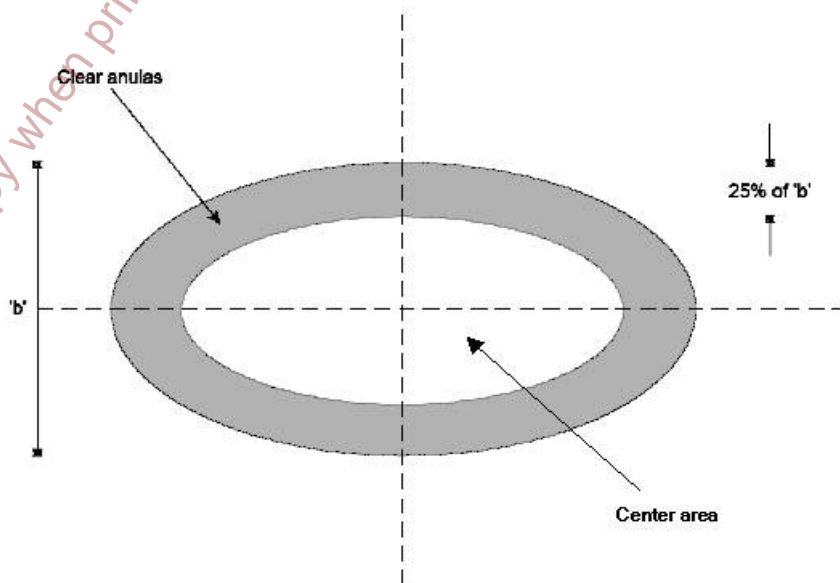
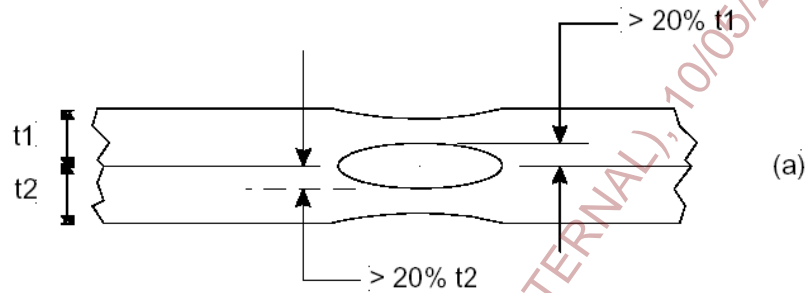
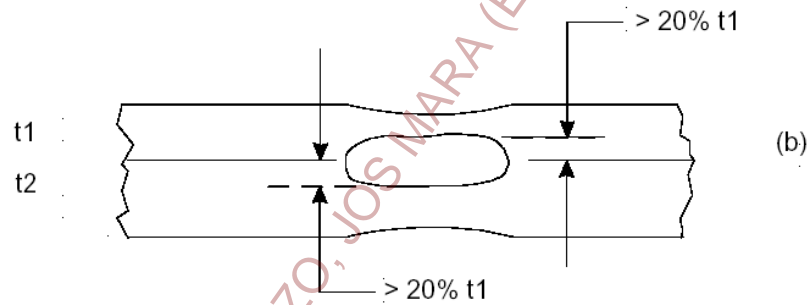


Figure A.3: Clear annulus and nugget centre

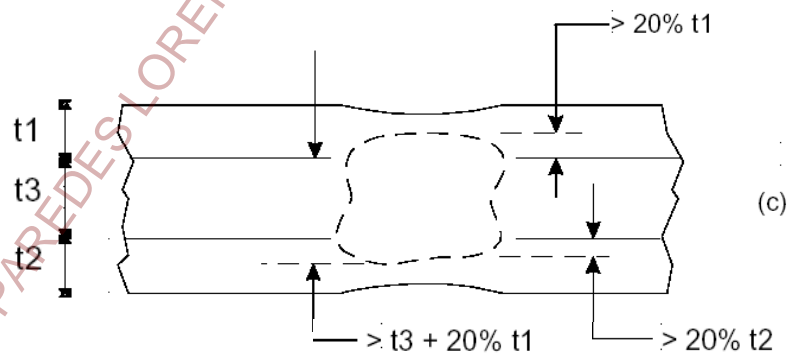
Same thickness
Sheets
($t_1=t_2$)



Dissimilar thickness
sheets
($t_2 > t_1$)



Three thickness
multi-combination
($t_3 > t_2 > t_1$)



Four thickness
multi combination
($t_4=t_3 > t_2 > t_1$)

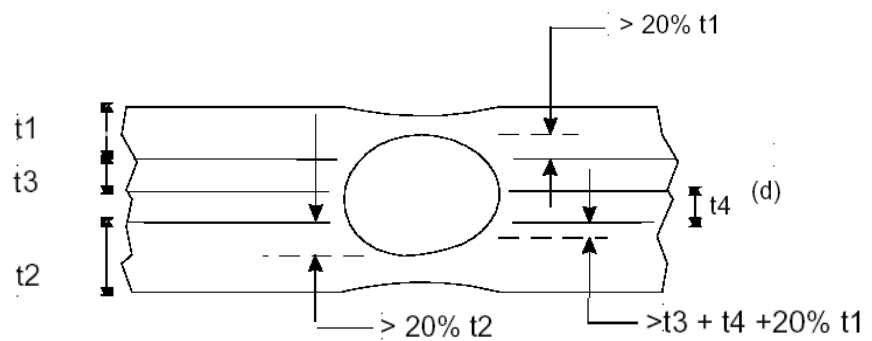


Figure A.4: Penetration minima for sheets

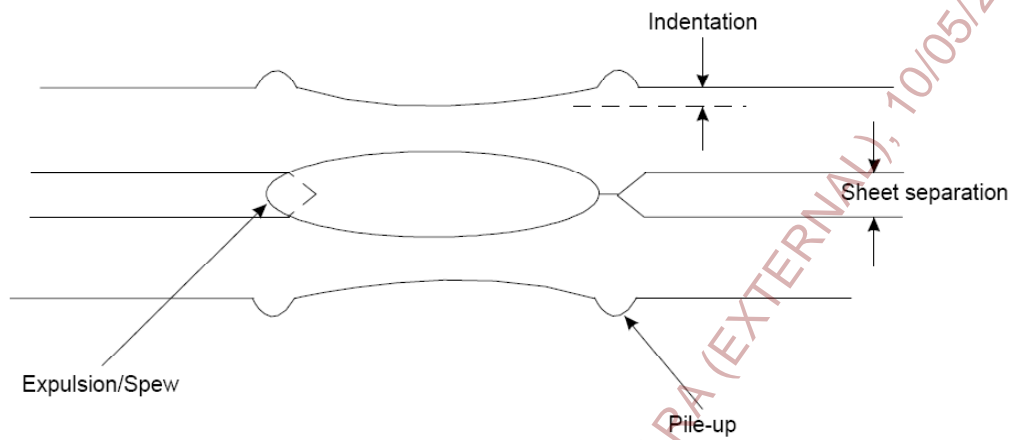


Figure A.5: Imperfections

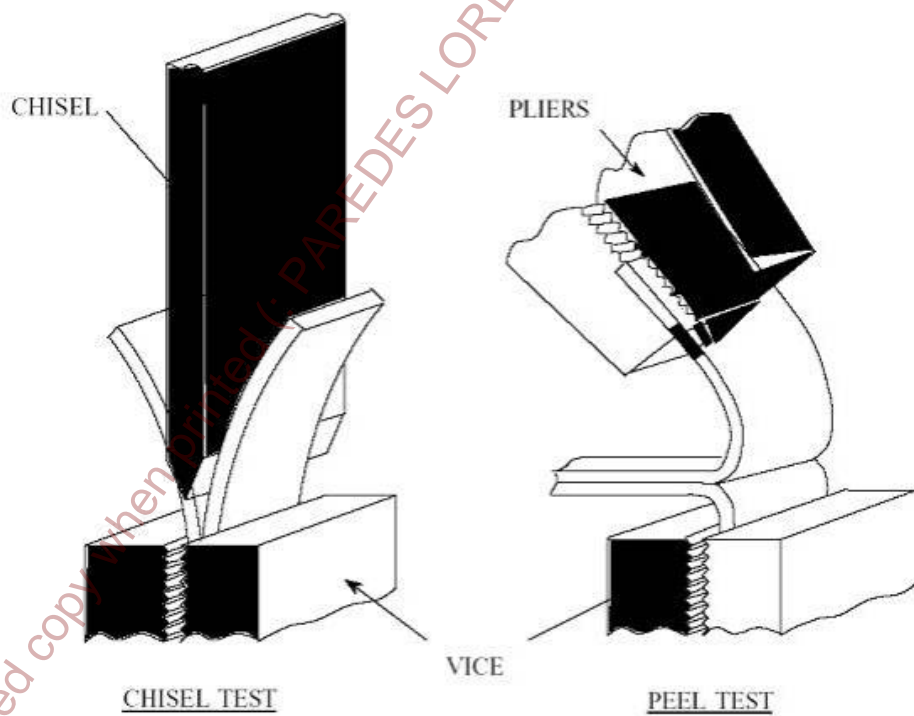


Figure A.6: Chisel and peel test

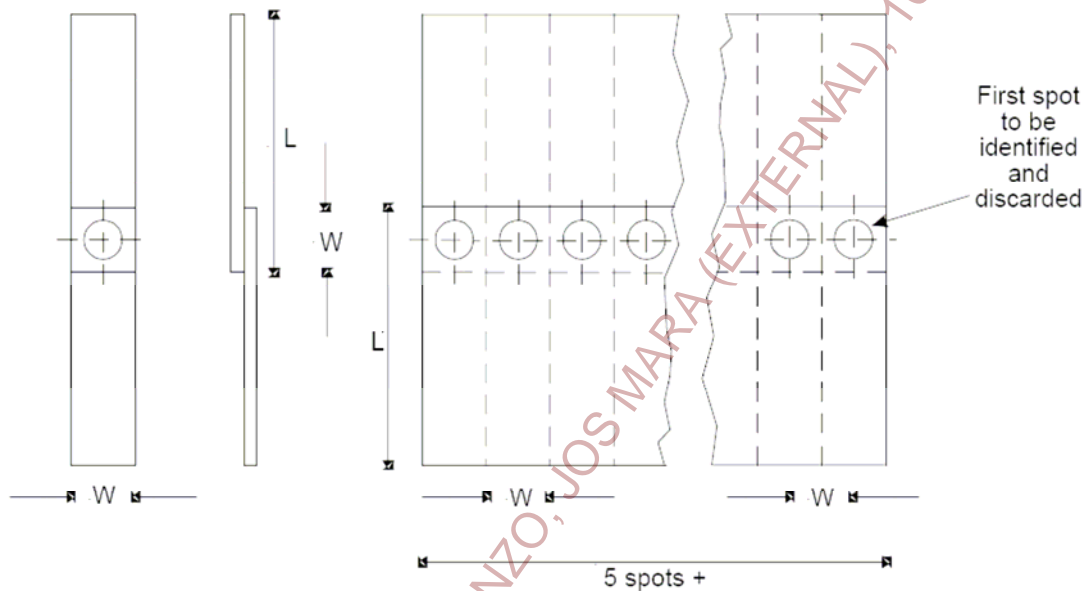


Figure A.7a: Single spot specimen

Figure A.7b: Multiple spot specimen

Note 1

Nominal Thickness of thinnest sheet (mm)	W_{min}
Over 0.20 to 0.75	17.0
Over 0.75 to 2.50	25.0
Over 2.50 to 3.20	32.0
Over 3.20	38.0

Note 2

L shall not be less than 4W

Note 3

Figure A7b shall be made of 5 or more specimens

Figure A.7: Spot welds in sheet. Shear/Micro test specimens

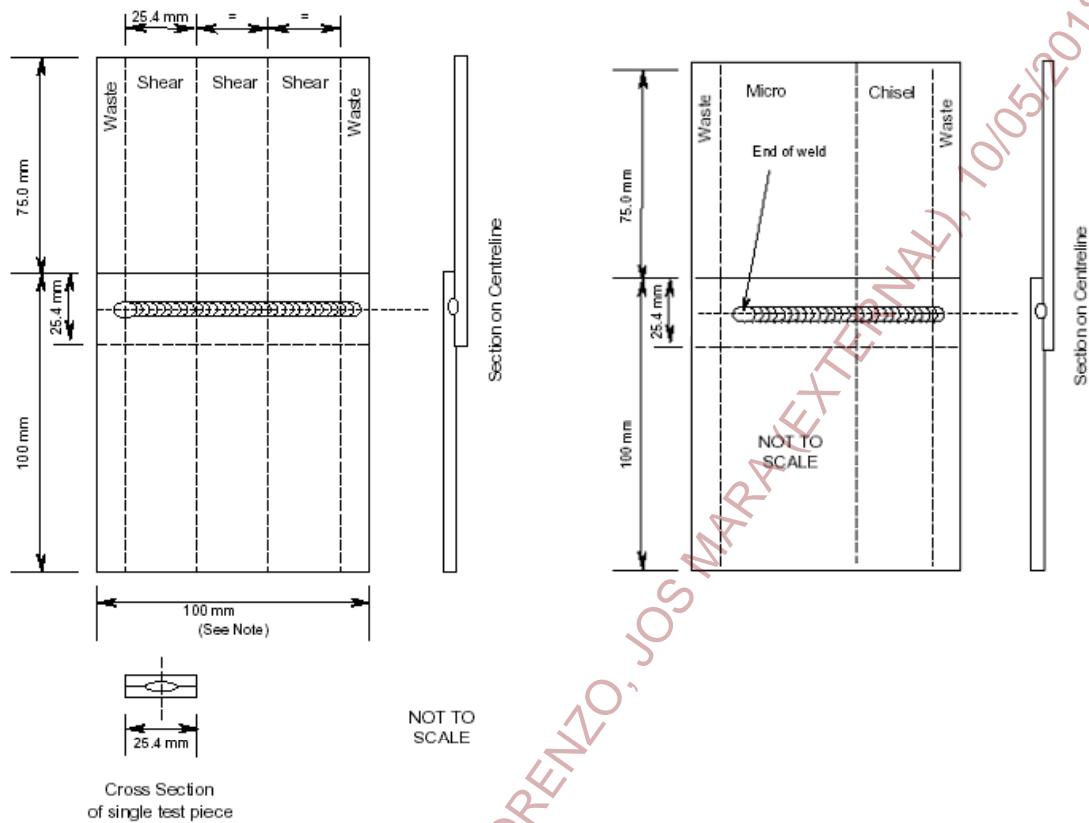


Figure A.8: Seam in sheets. Shear/Peel/Chisel/Micro specimens

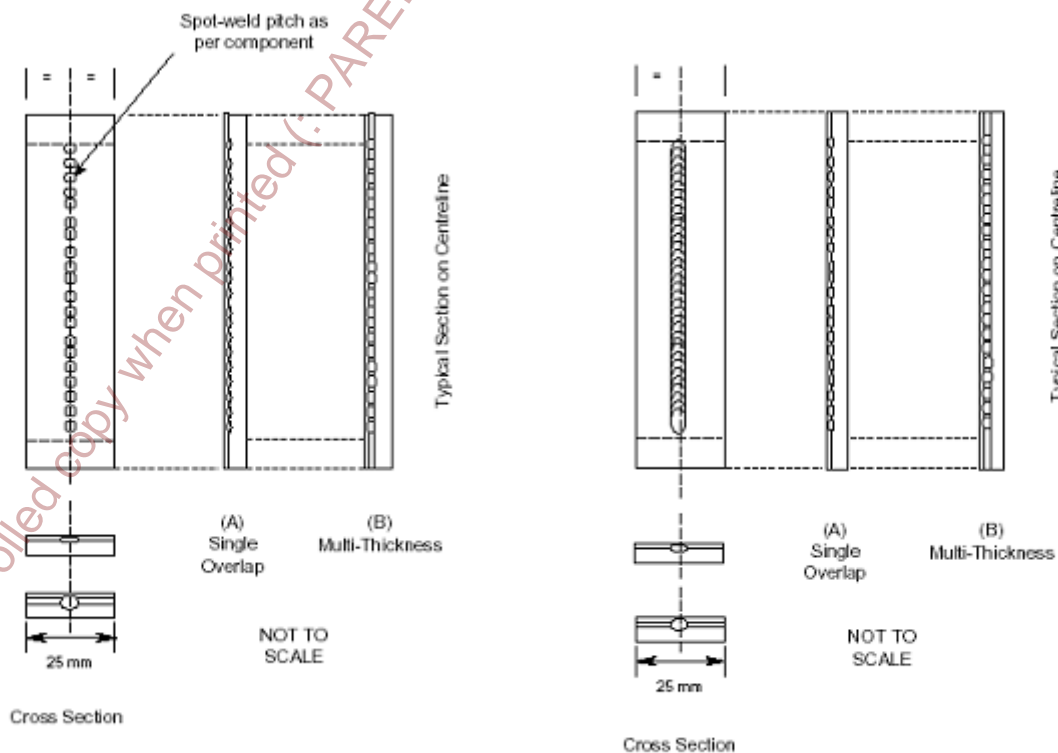


Figure A.9: Spot/Seam in foils. Peel/Chisel test specimens

Appendix B: Requirements

Table B.1: Minimum nugget diameter for spot and seam welds

Thickness of thinnest sheet (mm)	Nugget diameter (mm)	Thickness of thinnest sheet (mm)	Nugget diameter (mm)	Thickness of thinnest sheet (mm)	Nugget diameter (mm)
0.25	1.52	0.70	3.30	2.50	6.35
0.30	1.78	0.80	3.56	2.80	6.60
0.40	2.16	0.90	3.81	3.20	7.11
0.45	2.29	1.00	4.06	3.60	7.62
0.50	2.54	1.10	4.32	4.10	8.13
0.55	2.68	1.20	4.57	4.60	8.64
0.65	3.05	2.30	6.10	4.80	8.89

Table B.2: Imperfections requirements for spot and seam welds in sheets

Criteria \ Acceptance level		A	B	C
Visual criteria	Surface indentation ⁽¹⁾ (t, thinnest sheet)	≤ 0,1 t	≤ 0,2 t	
	Cracks (open to surface)	None		
	Flash and copper pick-up	Acceptable if removed by brushing		
Radiographic criteria (AITM 6-7002-Annex B)	Porosity Incomplete fusion	No defect with linear dimension > 15% nugget diameter and shall not extend into the clear annulus		Not applicable
	Cracks	None		Not applicable
Metallographic criteria (EN 1321)	Cracks	None	No defect with linear dimension > 10% nugget diameter	No defect with linear dimension > 30 % nugget diameter
	Porosity Incomplete fusion	Shall not have an aggregate area > 5% of nugget area		
	Penetration	Between 0,2t to 0.9t (see figure A1)		
	Sheet separation (t, combined thickness)	≤ 0,1 mm	≤ 0,1t or 0,15mm, whichever is greater	
	Overlap of spots (for seam welds)	25% minimum		
	Nugget diameter ⁽²⁾	As per table B1		

⁽¹⁾ 0,15 mm for aerodynamic surfaces

⁽²⁾ For CP titanium joint width may be used instead of nugget diameter

Table B.3: Shear strengths for Group I & II materials

Group I & II materials								
Ultimate Strength Rm (MPa)								
Nominal thickness of thinnest material (mm)	Rm < 620		620 ≤ Rm < 1034		1034 ≤ Rm < 1275		Rm ≥ 1275	
	N per spot							
	Min	Min avg	Min	Min avg	Min	Min avg	Min	Min avg
0,22	440	555	580	710	780	935	890	1090
0,25	510	625	710	865	910	1135	1090	1355
0,30	665	825	890	1090	1225	1510	1555	1825
0,40	955	1155	1310	1625	1780	2200	2135	2645
0,45	1110	1355	1510	1845	2200	2670	2625	3225
0,50	1245	1535	1735	2135	2355	2915	2825	3490
0,55	1470	1800	2000	2445	2715	3360	3245	4025
0,65	1780	2200	2355	2915	3225	3980	3870	4780
0,70	2070	2555	2825	3400	3805	4690	4560	5604
0,80	2515	3090	3445	4250	4650	5695	5560	6870
0,90	3070	3825	4090	5070	5582	6870	6670	8230
1,00	3626	4450	4735	5825	6495	8005	7785	9565
1,10	4470	5515	5715	7050	7985	9830	9340	11565
1,30	5315	6560	6695	8250	9450	11655	10900	13345
1,40	6495	8005	7875	9720	11340	13990	12810	15790
1,60	7830	9650	9385	11545	13745	16970	15790	19460
1,80	9250	11385	11275	13900	16590	20440	18680	22906
2,00	10920	13455	13365	16480	19615	24195	21575	26690
2,30	12830	15835	15635	19280	22640	27910	24910	30690
2,50	14680	18105	17790	21950	25445	31360	28020	34470
2,80	16880	20795	20215	24955	28310	34940	31135	38255
3,20	19125	23620	22530	27800	31490	38830	34630	42700

Table B.4: Shear strengths per spot in sheets for Group III materials

Group III materials								
Ultimate Strength Rm (MPa)								
Nominal thickness of thinnest materials (mm)	Rm < 420		420 ≤ Rm < 550		550 ≤ Rm < 750		Rm > 750	
	N per spot							
	Min	Min avg	Min	Min avg	Min	Min avg	Min	Min avg
0.25	350	450	400	550	500	650	900	1200
0.30	500	650	600	750	750	950	1250	1600
0.40	750	950	900	1150	1100	1450	1800	2300
0.45	-	-	-	-	-	-	-	-
0.50	850	1150	1050	1350	1300	1700	2350	3050
0.55	-	-	-	-	-	-	-	-
0.60	950	1250	1150	1450	1450	1850	3000	3900
0.65	-	-	-	-	-	-	-	-
0.70	-	-	-	-	-	-	-	-
0.80	1850	2400	2200	2900	2800	3650	4450	5900
0.90	-	-	-	-	-	-	-	-
1.00	2400	3150	2900	2750	2650	4800	6350	8250
1.10	-	-	-	-	-	-	-	-
1.20	2900	3800	3500	4550	4550	5800	8650	11500
1.30	-	-	-	-	-	-	-	-
1.40	3500	4550	4200	5450	5300	6900	10000	14500
1.60	3900	5100	4700	6100	5950	7750	13500	17000
1.80	4250	5550	5100	6650	6450	8400	15000	19500
2.00	4900	6400	5900	7650	7450	9700	16500	22000
2.30	-	-	-	-	-	-	-	-
2.50	6000	7800	7200	9350	9100	11900	21000	27000
2.80	-	-	-	-	-	-	-	-
3.00	7200	9350	8650	11200	10900	14200	25000	32000
3.20	7680	9970	9230	11940	11620	15120	26600	34000

Table B.5: Shear strengths per spot in sheets for Group IV materials

Group IV materials								
Ultimate Strength Rm (MPa)								
Nominal thickness of thinnest material (mm)	Rm < 135		135 ≤ Rm < 240		240 ≤ Rm < 386		Rm ≥ 386	
	N per spot							
	Min	Min avg	Min	Min avg	Min	Min avg	Min	Min avg
0,25	-	-	-	-	225	290	265	335
0,30	90	110	135	175	290	380	335	425
0,40	225	290	310	400	445	555	490	625
0,45	290	380	380	490	510	645	555	710
0,50	355	445	445	555	600	755	625	780
0,55	425	535	535	665	690	865	710	890
0,65	490	625	645	825	780	890	825	1045
0,70	600	755	780	980	910	1155	955	1200
0,80	735	935	935	1180	1045	1310	1155	1445
0,90	865	1090	1135	1425	1225	1535	1355	1710
1,00	1000	1270	1335	1670	1380	1735	1535	1935
1,10	1155	1445	1555	1955	1645	2070	1800	2270
1,30	1310	1645	1780	2225	1910	2400	2070	2600
1,40	1510	1890	2110	2645	2290	2870	2470	2980
1,60	1755	2200	2535	3180	2715	3400	2980	3635
1,80	2000	2515	2780	3600	3200	4005	3670	4605
2,00	2335	2935	3400	4270	3805	4760	4560	5715
2,30	2645	3315	3870	4850	4450	5560	5580	6985
2,50	3000	3660	4180	5225	5205	6515	6630	8295
2,80	3270	4090	4450	5580	5960	7450	7915	9895
3,20	3490	4380	4670	5850	7228	9050	9430	11785
3,60	-	-	-	-	8540	10675	11230	14055
4,10	-	-	-	-	10585	13565	13880	17345
4,60	-	-	-	-	13345	16680	16570	20730
4,80	-	-	-	-	14410	18015	17950	22440
6,40	-	-	-	-	28465	35585	32695	40920

Table B.6: Shear strengths in seam welds in sheets

Requirement
The ultimate shear strength must be greater than 90% of the minimum ultimate tensile strength (UTS) of the parent material
Test specimens must fracture in the parent metal or in the heat affected zone (HAZ)

Table B.7: Requirements for Peel/Chisel tests

	Requirement
Spots	95 % of the welds shall exhibit a plug-type failure whereby a plug of metal is left fused to one of the sheets and, depending on the thickness of the material, a hole may be left opposite the plug in the other sheet. The remaining 5%, or less, may fail at the interface plane, but the cleavage in each case shall be of a fused zone that is at least 0.8 times the average button size
Seam	For seam welds, the failure shall occur by tearing of the metal adjacent to the weld nugget for more than 95% of the weld length. The remaining portion of the weld length may fail by fracture across the faying plane, but the smallest nugget size shall not be less than 80% the average nugget size.

RECORD OF REVISIONS

Issue	Clause modified	Description of modification
1 09/97		New standard
2 01/07	All	New issue
3 09/09	§ 5 to 9	Editorial changes due to modified standardization module
4 04/10	4.1.1.3	Implementation of Key Characteristics