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WELDING DESIGN CONSIDERATIONS AND REQUIREMENTS

1.0 GENERAL

1.1 Purpose

This standard provides design requirements and guidelines to assist engineers in designing ferrous automotive components and assemblies that are to be welded using resistance spot welding, resistance projection welding, arc welding, and drawn arc welding techniques.

1.2 Coverage of this Standard

The requirements and guidelines herein specified have been updated and agreed upon by Materials Engineering (Welding), Advanced Manufacturing Engineering, and Core Engineering. Following the specifications and guidelines listed will ensure manufacturability of a quality component.

1.2.1 Types of welding covered in this standard

A. Resistance Welding

- Spot Welding

B. Projection Welding

- Projection Welding of Screws and Nuts
- Embossed Projection Welding (Sheet to Sheet)

C. Arc Welding

- Metal Inert Gas Braze
- Gas Metal Welding
- Flux Core Arc Welding
- Gas Tungsten Arc Welding
- Plasma Arc Welding

1.3 Limitations on Usage***

This standard is not to be referenced on any detail, adaptation, assembly CATIA/NX model/drawing or engineering graphic overviews. Any information or construction taken from this standard must be completely detailed in the part CATIA/NX models/drawings or applicable Appearance, Performance, Process, or System Performance Standards. Designs Standards are for the use of Chrysler Group LLC personnel and shall not be distributed outside the Corporation without the consent of the issuing department's manager.

This design specification compiles information to be used when designing a component which involves one of the most commonly used welding techniques. Other techniques not herein specified are available for use. For additional information contact Materials Engineering.

1.4 Correlation to Process Standards

When considering a specific welding technique, the users must also familiarize themselves with the appropriate Process Standard.

1.4.1 Resistance Spot Welding Standards

PS-10947<S>	Resistance Spot Welding Automotive Components and Assemblies Including Advanced High Strength Steel
PS-9496<S>	Resistance Spot Weld Design Flange Width, Design Lap Joint Contact Overlap, and Weld Requirements for Body-in-White Door, Window and Roof Flanges

1.4.2 Projection Welding Standards

PS-1791<S>	Weld Screws - Projection Welding
PS-1804<S>	Weld Nuts - Projection Welding
PS-4446<S>	Resistance Projection Welding - Automotive Components

1.4.3 Arc Welding Standards

PS-9472<S>	Arc Welding Automotive Components
PS-9184<S>	Welding and Forming - Exhaust System Components

1.4.4 Drawn Arc Welding

PS-5368<S>	Drawn Arc Welding of Steel Fasteners

1.4.5 Other Welding Standards

Please consult Materials Engineering for Design Guidelines for the following Process Standards.

PS-5598<S>	Friction and Inertia Welding - Automotive Components
PS-9059<S>	High Energy Beam Welding - Automotive Components (includes Laser Beam Welding)

1.5 Welding Responsibilities

The Design Release Engineer has the responsibility for acceptable joint design. The Manufacturing Process Engineer has the responsibility for implementing the specified joining process.

The Welding Group of Materials Engineering should be consulted for more information on the use of a specific welding process before finalizing a design.

2.0 DESIGN REQUIREMENTS

Ferrous sheet metal should be welded using spot welding, embossed projection welding or arc welding, depending on production volume and design limitations. Sections 2.1 through 2.3 define the design requirements for Resistance Spot Welding, Projection Welding and Arc Welding.

2.1 Resistance Spot Welding

Resistance Spot Welding is a process in which localized coalescence of metals is produced at the faying surfaces by the heat generated from the resistance of the stack-up to the passage of electric current. In spot welding, a nugget of weld metal is produced at the electrode site.

2.1.1 Material Restriction

Refer to PS-10947<S> for sheet steel approved for welding.

2.1.2 Weld mechanical properties (UTS ≥ 350 MPa)

Weld mechanical performance of steels may depend upon the loading mode, loading rate and degree of constraint. The strength of a weld is quantified by the peak load achieved during shear or cross tension testing. Weld strength can be recorded using the test methods described in AWS D8.9.

The minimum Shear Tension Strength and Cross Tension Strength for steel with Ultimate Tensile Strength equal to or greater than 350 MPa, when tested following the test procedures detailed in AWS D8.9, are represented by Equations 1 and 2. The equations are applicable to welds between two sheets of the same grade and gauge, with sheet thicknesses between 0.6 mm and 3.0 mm, and with weld size assumed to be at minimum per PS-10947<S>.

The minimum Shear Tension strength is computed using Equation 1.

$$ST = \frac{\left(-6.36E^{-7} \times S^{2} + 6.58E^{-4} \times S + 1.674\right) \times S \times 4 \times t^{1.5}}{1000}$$

Equation 1

ST = Shear Tension Strength (kN)
S = Base Metal Tensile Strength (MPa)
t = Material Thickness (mm)

The minimum cross tension strength is computed using Equation 2.

$$CT = 1.25 \times t^{2.2}$$

Equation 2

CT = Cross Tension Strength (kN)
t = Material Thickness (mm)

2.1.3 Governing Metal Thickness (GMT)

The Governing Metal Thickness (GMT) is the metal gage in a stack-up that is used to determine design criteria like minimum weld size, minimum weld spacing, and minimum flange width.

For both Two Thickness (2T) and Three Thickness (3T) stack-ups, the GMT is the second thickest sheet. For example, if T1 = 2.0mm; T2 = 1.5mm; T3 = 1.7mm; the GMT is 1.7mm. If two sheets are the same thickness in either a 2T or 3T stack-up, that thickness is the GMT.

2.1.4 Maximum Stack-up

A maximum of three thicknesses (3T) welding of sheet steel can be specified. In all cases, the combined thickness must not exceed 8.0 mm.

2.1.5 Sheet Thickness Ratio

2.1.5.1 Steels with Ultimate Tensile Strength Less than 690 MPa

The thickness ratio for two metal thicknesses should not exceed a three to one (3:1) ratio. In a three metal thicknesses stack-up, the thickness ratio of adjacent sheets or the two outside sheets should not exceed three to one (3:1). The thickness ratio of adjacent sheets can exceed three to one (3:1) if the thinnest sheet is in the middle.

2.1.5.2 Steels with Ultimate Tensile Strength Greater than or Equal to 690 MPa

When welding stack-ups involving steels with Ultimate Tensile Strength (UTS) ≥ 690 MPa, it would be beneficial for manufacturing to use a more restrictive thickness ratio to compensate for differences in resistivity and improve heat balance. For 2T stack-ups consider using a ratio of 2.5:1 where the thick sheet is of UTS ≥ 690 MPa, and the thin sheet is of UTS< 690 MPa. For 3T stack-ups, consider using the guidelines included in Table 1.

TABLE 1: RECOMMENDED THICKNESS RATIO FOR 3T STACK UPS INVOLVING HIGH STRENGTH STEELS OF UTS≥690 MPA		
CONFIGURATION	SHEET RATIO	EXAMPLES
All sheet of equal thickness	Not applicable	
Symmetrical arrangement with thin sheet in the inside	$\frac{t_{outside}}{t_{inside}} \leq 3$	3.0/1.0/3.0 allowed
Symmetrical arrangement with thick sheet in the inside	$\frac{t_{inside}}{t_{outside}} \leq 2$	1.0/1.75/1.0 allowed 0.8/1.75/0.8 not allowed
Ascending thickness	$\frac{t_{inside}}{t_{outside\ thin}} \leq 2 \quad and$ $\frac{t_{outside\,thick}}{(t_{inside} + t_{outside\,thin})} \leq 1$	0.8/1.0/1.5 allowed 0.8/1.75/2.0 not allowed 0.8/0.88/1.75 not allowed
Mixed arrangement with thinnest sheet inside	$\frac{t_{outside\ thick}}{t_{outside\ thin}} \leq 2$ $\frac{t_{outside\ thick}}{t_{inside\ thin}} \leq 3$	1.0/0.8/2.0 allowed 0.88/0.8/2.0 not allowed
Mixed arrangement with thickest sheet inside	$\frac{t_{inside\,thick}}{t_{outside\,thin}} \leq 2$	0.8/1.5/1.25 allowed 0.8/1.75/1.0 not allowed

2.1.6 Minimum Weld Spacing

Minimum Weld Spacing for a 2T or 3T stack-up is listed in Table 2 as a function of the Governing Metal Thickness (GMT).

TABLE 2: MINIMUM WELD SPACING		
GMT (1) (mm)	2T (mm)	3T (mm)
0.6	14	19
0.7	16	22
0.8	18	25
0.88	19	27
1	21	28
1.1	22	29
1.25	25	31
1.35	26	32
1.5	28	34

TABLE 2: MINIMUM WELD SPACING		
GMT (1) (mm)	2T (mm)	3T (mm)
1.75	32	37
2	36	43
2.25	40	48
2.5	42	50
2.75	44	50
3	46	54
NOTE 1: When a GMT value falls between 2 listed values, use the weld spacing listed for the smaller GMT.		

2.1.7 Minimum Contact Overlap for Lap Joints

Contact Overlap is the term used to define the minimum space needed to ensure a resistance spot weld is fully contained within the edges of the sheets being welded.

Different requirements are listed for Lap Joint Flanges depending on the bend radius due to differences in geometrical electrode access. Figure 1 shows examples of contact overlap for 2T and 3T stacks. Figure 2 indicates basic different contact overlap geometries. When the bend angle ϴ is smaller than 90º (Figure 2 - Example 4), additional space is needed to allow for electrode clearance. Body, Manufacturing and Materials Engineering will review these atypical conditions to specify electrode to wall clearance.

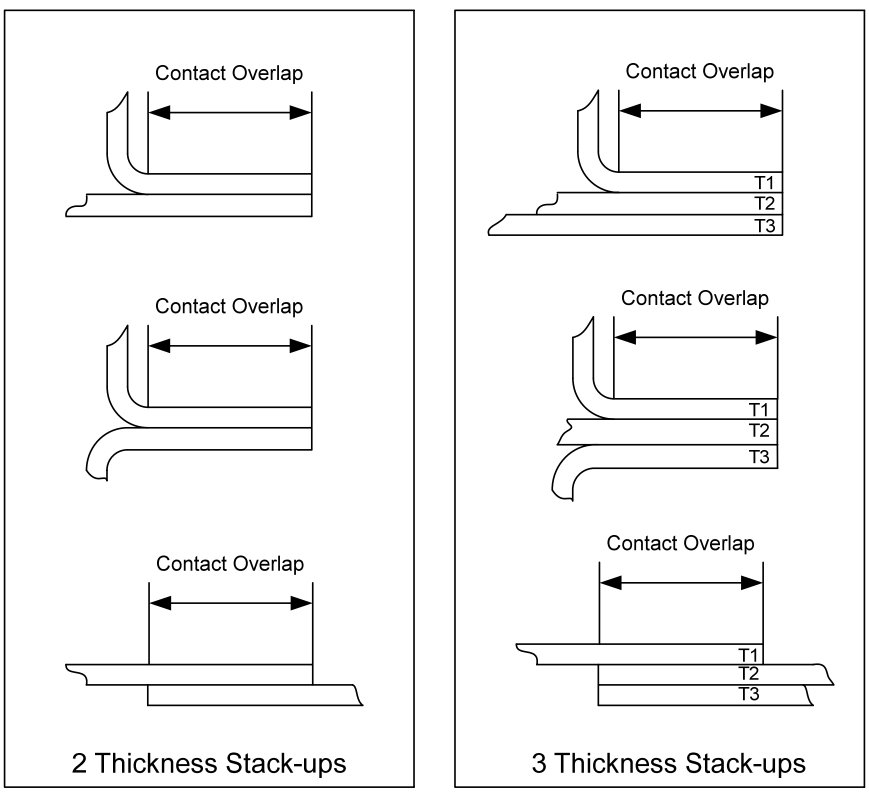


FIGURE 1: CONTACT OVERLAP EXAMPLES FOR 2T AND 3T STACK-UPS

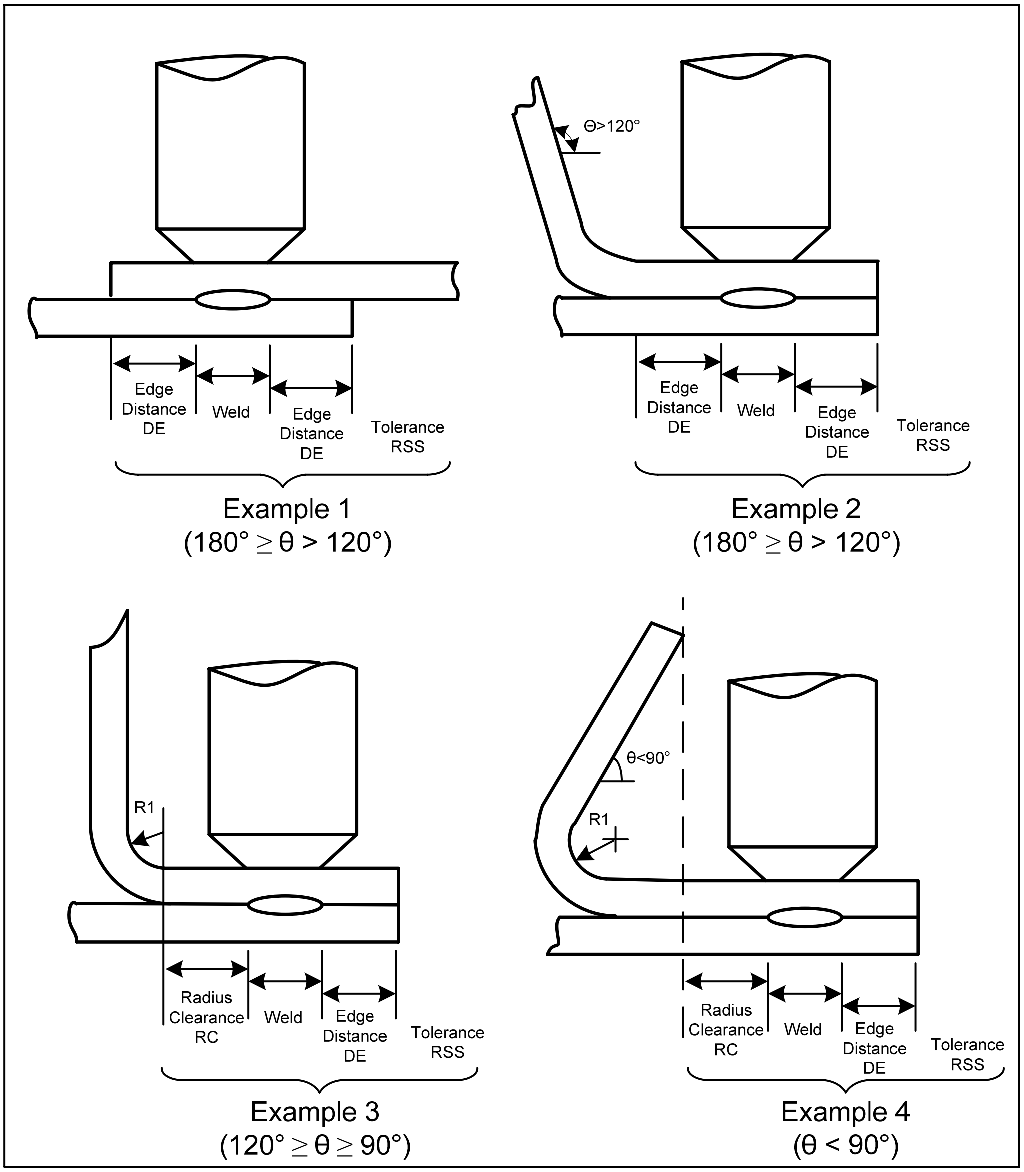


FIGURE 2: MINIMUM CONTACT OVERLAP FOR LAP JOINTS

The Minimum Contact Overlap for Lap Joints is a function of variables like bend radius, electrode size, electrode face wear and more. Table 3 lists the values as a function of GMT as agreed upon by Body, Manufacturing and Materials Engineering. Figure 3 indicates contact overlap legend for Table 3.

TABLE 3: MINIMUM NOMINAL CONTACT OVERLAP FOR LAP JOINT FLANGLES FOR 2T AND 3T
180° ≥ θ ≥ 90° (EXAMPLES 1-3 OF FIGURE 1)

Electrode Dia.	Face Dia.	Nominal GMT Range		Weld Size	Minimum Contact Overlap	Center to Edge (Ref.)	Center to Wall (Ref.)	Weld Dam (Ref.)	Wall to Edge (Ref.)	Radius (Ref.)
D	d	(Min.)	(Max.)	W	Lo	B	C	w	Lw	R
16		0.64	0.79	3.5	12	6	11	10	17	5
		0.80	0.99	4.0						

TABLE 3: MINIMUM NOMINAL CONTACT OVERLAP FOR LAP JOINT FLANGLES FOR 2T AND 3T 180° ≥ θ ≥ 90° (EXAMPLES 1-3 OF FIGURE 1)										
Electrode Dia.	Face Dia.	Nominal GMT Range		Weld Size	Minimum Contact Overlap	Center to Edge (Ref.)	Center to Wall (Ref.)	Weld Dam (Ref.)	Wall to Edge (Ref.)	Radius (Ref.)
D	d	(Min.)	(Max.)	W	Lo	B	C	w	Lw	R
	4.8	1.00	1.29	4.5						
		1.30	1.49	5.0						
19	4.8	1.50	1.59	5.0	15	7.5	13	12	21	6
		1.60	1.89	5.5						
		1.90	2.29	6.0						
		2.30	2.69	6.5						
		2.70	3.04	7.0						

NOTE 1: Part, process and electrode position tolerances are included in the minimum nominal contact overlap values.

NOTE 2: Radius changes will change the wall to edge length; a minimum gap of 2mm from wall to electrode must be maintained.

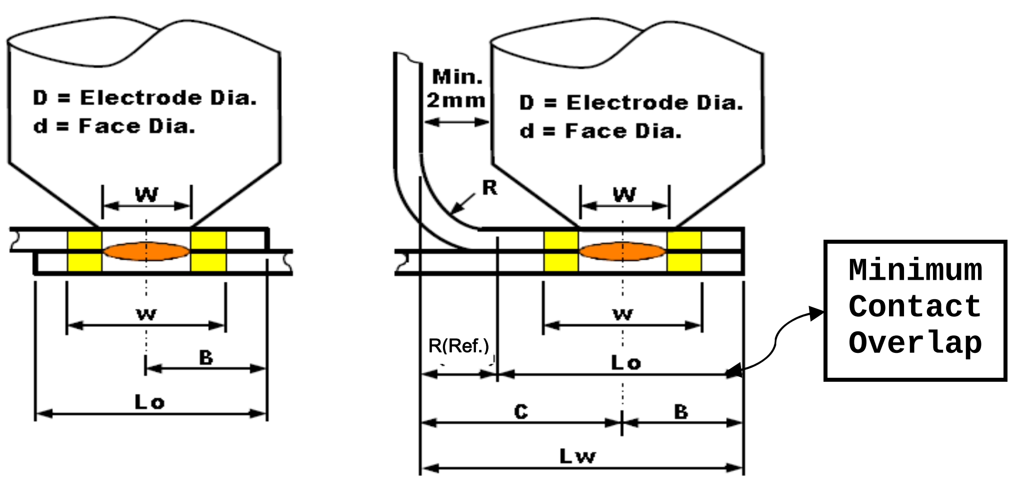


FIGURE 3: CONTACT OVERLAP LEGEND

2.1.8 Welding Tip Access:

Examples of clearance conditions for weld tips are shown in Figure 4. The “C” dimension is the Center to Wall dimension from Table 3 in Section 2.1.7 above.

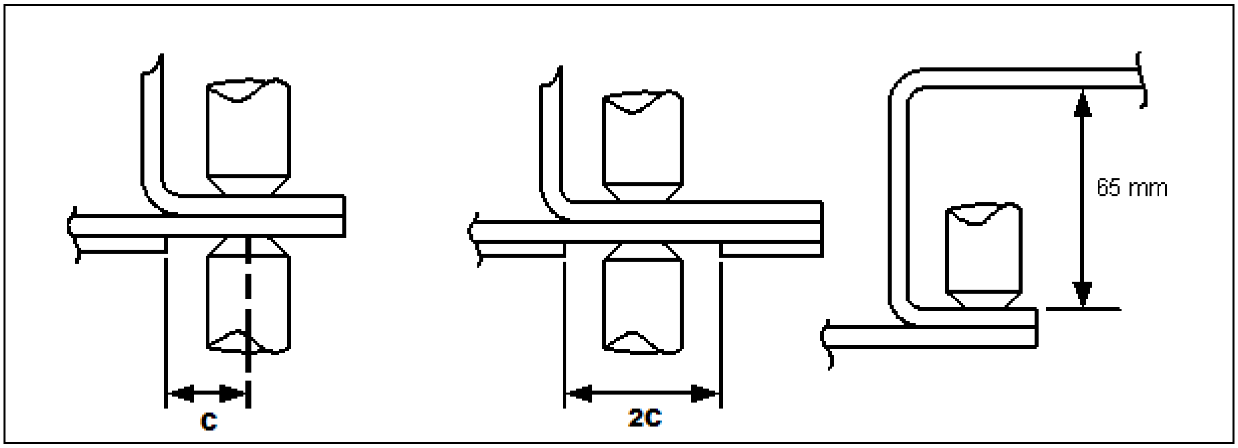


FIGURE 4: MINIMUM ACCESS REQUIREMENTS FOR WELD TIPS

2.2 Projection Welding

Projection Welding is an electric resistance welding process that produces a weld by the heat obtained from the resistance to the flow of current. The resulting welds are localized at predetermined points by projections or embossments.

2.2.1 Projection Welding of Screws and Nuts

Fasteners covered by this standard shall meet the general specifications for dimension, material and finish listed in PS-7099 “General Specifications: Fasteners and Fittings”.

Projection type weld stud and nut part numbers can be found in the “Engineering Standards” Standard Parts book located at http://roadmap.tcc.chrysler.com/d5810/capme/hmpgfast.htm. These parts are found on the Design tab “Standard Parts” for weld studs, hex weld and hex flange weld nuts.

2.2.1.1 Material Restriction

This standard is applicable to steel nuts fabricated from MS-210 or MS-2717 steel (see MS-BAR<S>). This standard is applicable to steel screws fabricated from MS-210, MS-2717 or MS-5378 steel (see MS-BAR<S>).

Refer to PS-1791<S> and PS-1804<S> for sheet steel approved for projection welding of fasteners.

2.2.1.2 Design Considerations

The surface of the adjacent steel in the immediate weld area shall be sufficiently flat to permit uniform contact of all projections of the weld screw or nut with that surface.

The minimum distance (d) from the nearest feature of the weld screw or nut to an adjacent sheet metal edge or radius shall not be less than 2t (t = metal thickness) or 3 mm, whichever is less, as shown in Figure 5.

The required dimension of the hole in the panel is usually given in the drawing or standard that covers the dimensional requirements of the fastener. The rule of thumb for piloted nuts is that the maximum installation panel hole should be 0.5 mm larger than the maximum outer diameter of the pilot as shown on the correspondent nut drawing or specification. The minimum installation panel hole should be 0.3 mm smaller than the maximum installation panel hole.

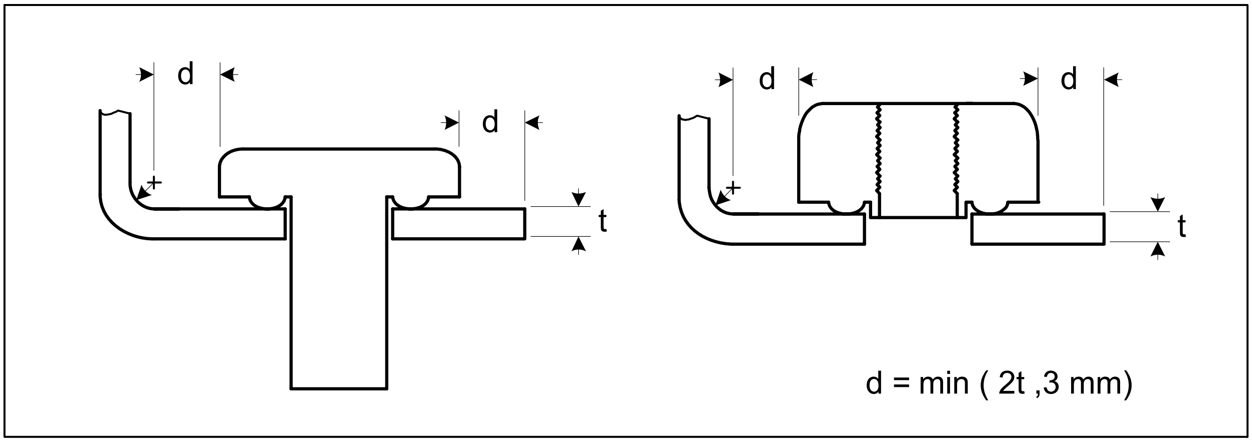


FIGURE 5: MINIMUM DISTANCE OF FASTENER TO EDGE OR RADIUS

2.2.2 Embossed Projection Welding (Sheet to Sheet)

Embossed projection welding is used to join 2T stack-ups when the metal thickness ratio is greater than 3 to 1. The thickness ratio normally should not exceed 6 to 1. Projection welds should be made in one plane.

2.2.2.1 Application Restriction

A resistance projection weld is not a direct substitution for a resistance spot weld. Structural requirements must be evaluated for size and quantity of projections.

2.2.2.2 Material Restriction

Refer to PS-4446<S> for information on material restrictions.

2.2.2.3 Spherical Stamped Projections Design

The dimensional requirements for spherical stamped projections are shown in Table 4 and Figure 6. Table 4 lists the contact overlap (L) and Figure 6 indicates minimum spacing (S) dimension. Do not interpolate/extrapolate the values for projection sizes.

Use the thinner of the two (2) metal thicknesses to determine the spherical projection diameter (D), height (H), and the minimum contact overlap (L). Note that the minimum contact overlap width (L) does not include the bend radius or edge tolerance.

The spherical projection should be placed on the thicker of the two metal thicknesses where possible.

The minimum spacing between projections (S), center to center, should not be less than two (2) times the diameter (D) of the spherical projection.

2.2.2.4 Elongated Stamped Projections

Use where structural requirements cannot be satisfied by the spherical projection.

The requirements for elongated stamped projections are as follows:

- The width and height of the elongated projection should be equal to the diameter and height of the spherical projection as specified in Spherical Stamped Projections Size Requirements in Section 2.2.2.3.

- The length of the elongated projection should be based on the structural requirements and are subject to approval by the responsible Engineering and Manufacturing personnel.

- In the “width” direction of the Embossed Projection, the dimensional (L) requirements and minimum spacing (S) requirements should be as specified for the spherical projection in Minimum Contact Overlap (L) and Spacing (S) Requirements in Section 2.2.2.3.

- Where possible the elongated projection should be placed so that its length is perpendicular to the contacting overlap width (L).

- The minimum distance from an edge or radius should be the same as that required for the spherical projection (see Table 4).

- The minimum spacing between projections (edge to edge) should not be less than two (2) times the elongated projections width.

TABLE 4: PROJECTION WELDING, SPHERICAL STAMPED PROJECTIONS (1)									
T (mm) (2)	D (mm) +/-0.1	R (mm) (REF)	H (mm) +0.1/-0.0	F (mm) +/-0.1 (REF)	E (mm) +/-0.1 (REF)	J (mm) MAX (REF)	L (mm) MIN (3)	Df (mm) MIN	TS (N) (4)
0.25	1.4	0.8	0.4	0.4	0.9	0.1	3.0	1.0	270
0.3	1.4	0.8	0.4	0.4	0.9	0.1	3.0	1.0	310
0.35	1.4	0.8	0.4	0.4	0.9	0.1	3.0	1.0	360
0.4	1.7	1.1	0.4	0.5	1.0	0.1	4.1	1.2	490
0.5	1.7	1.1	0.4	0.5	1.0	0.1	4.1	1.2	670
0.6	2.1	1.3	0.5	0.6	1.1	0.1	4.8	1.4	930
0.8	2.4	1.6	0.6	0.8	1.3	0.1	5.6	1.7	1330
0.9	2.4	1.6	0.6	0.8	1.3	0.1	5.6	1.7	1470
1.1	3.0	2.0	0.7	0.9	1.6	0.1	7.1	2.1	2400
1.3	3.0	2.0	0.7	0.9	1.6	0.1	7.1	2.1	2760
1.6	4.0	2.7	0.9	1.1	2.1	0.1	9.7	2.8	4450
1.8	4.0	2.7	0.9	1.1	2.1	0.1	9.7	2.8	5030
2.0	4.7	3.3	1.0	1.4	2.6	0.3	11.2	3.3	6720
2.4	5.5	3.8	1.2	1.7	2.9	0.3	12.7	3.9	9430
2.8	6.4	4.4	1.4	1.9	3.5	0.4	15.7	4.4	12540
3.2	7.1	4.9	1.5	2.2	3.9	0.4	17.5	5.0	16150
3.6	7.9	5.5	1.7	2.4	4.4	0.4	19.0	5.5	20110
4.0	8.7	6.2	1.8	2.7	4.9	0.4	20.6	6.1	24600
4.3	9.5	6.7	2.0	3.0	5.3	0.4	22.4	6.7	29490
4.8	10.3	7.2	2.2	3.3	5.8	0.4	23.9	7.2	34920
5.2	11.1	7.8	2.3	3.6	6.1	0.5	25.4	7.8	40790
6.4	13.5	9.5	2.8	4.4	7.2	0.6	31.8	9.4	61030

TABLE 4: PROJECTION WELDING, SPHERICAL STAMPED PROJECTIONS (1)									
T (mm) (2)	D (mm) +/-0.1	R (mm) (REF)	H (mm) +0.1/-0.0	F (mm) +/-0.1 (REF)	E (mm) +/-0.1 (REF)	J (mm) MAX (REF)	L (mm) MIN (3)	Df (mm) MIN	TS (N) (4)
NOTE 1: T: Thickness of the thinnest sheet, D: Diameter of the spherical projection, R: Spherical radius, H: Projection height, F: Projection depth, E: Punch face diameter, J: Punch face radius, L: Contact overlap, Df: Diameter of fused zone at weld interface, TS: Typical shear strength (one projection only NOTE 2: The size of projection is normally determined by the thickness of the thinner piece, and the projection should be formed on the thicker piece where possible. NOTE 3: Contacting overlap does not include the forming radius. The weld should be located in center of overlap. NOTE 4: Projection weld shear strengths (single projection only) are based on low carbon steel strength of 324.1 MPa.									

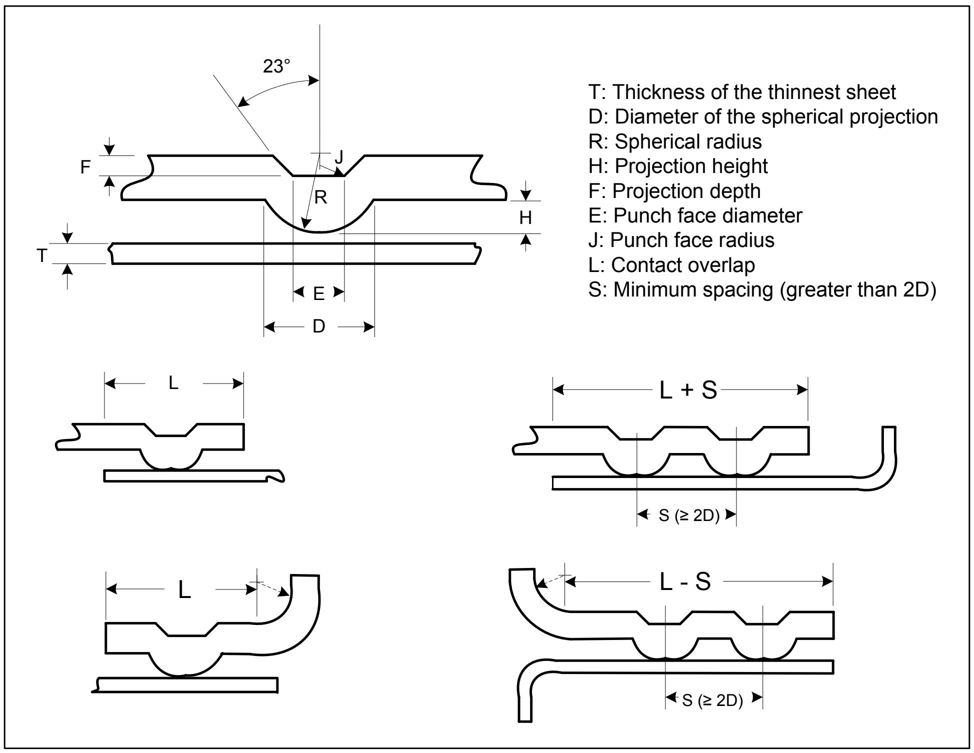


FIGURE 6: EMBOSSED PROJECTION DESIGN

2.3 Arc Welding

Use where resistance spot or projection welding is not practical or where structural requirements cannot be satisfied by spot or projection welding.

2.3.1 Materials

Refer to PS-9472<S> for information on material restrictions.

2.3.2 Process Specification

Metal Inert Gas Braze Arc Welding (MIG Braze). A process similar to GMAW. "MIG Braze" specifies the pulsed-arc (or STT “Surface Tension Transfer”) welding process and MS-6408 silicon bronze filler metal with 100% argon shielding gas.

Gas Metal Welding (GMAW). Gas metal arc welding process with solid filler metals MS-3684, MS-5365, MS-7023. CO_2 gas or gas blends shall be used as long as the resulting weld meets the requirements of PS-9472<S>. Applications requiring another filler metal and/or shielding gas shall have additional requirements specified on the engineering releases. When un-coated steels with yield strength ranging between 413 and 552 MPa (60,000 and 80,000 psi) are welded to themselves or to higher strength steels, MS-7023 solid filler metal shall be used and specified on the weld releases.

Flux Core Arc Welding (FCAW). A process similar to GMAW. The continuous wire electrode is a metal tube filled with flux and metal powders. The flux provides the protective atmosphere and leaves the completed weld covered with a thin slag coating. FCAW utilizes filler metal MS-6995 and “Gas-Less” Flux Cored Arc Welding Electrode for zinc and iron-zinc coated steels. Applications requiring another filler metal shall specify the filler metal Material Standard.

Gas Tungsten Arc Welding (GTAW or TIG). Welding process that does not require the use of filler metal. The use of filler metal may be specified if necessary. When filler metal is required, it shall be specified on the weld releases.

2.3.3 Process Limitations

Certain restrictions apply to MIG-Braze, GMAW, FCAW and GTAW welding of bare, galvanized, galvannealed, zinc rich coated steels and sealers or adhesive which are defined in Table 5.

No arc welding closer than 25 mm to surfaces or edges coated with sealers or adhesives.

TABLE 5: ARC WELDING METAL COATING AND STEEL THICKNESS REQUIREMENTS (METAL GAUGE SPECIFICATION REFERS TO THE THINNER OF THE TWO PIECES TO BE JOINED)

STEEL CONDITION	MIG-BRAZE (MS-6408) Thickness Required mm (in.)	GMAW (MS-3684), (MS-5365), or (MS-9421) Thickness Required mm (in.)	FCAW (Flux-Core) (MS-6995) Thickness Required mm (in.)	GTAW Thickness Required mm
UN-COATED BARE STEEL	0.71 (0.028) min. 1.02 (0.040) max.	0.89 (0.035) min.	1.02 (0.040) min. Permissible/Not Required	4.00 Max
IRON-ZINC ALLOY COATED Hot Dip Process Only	0.71 (0.028) min. 1.02 (0.040) max.	0.89 (0.035) min. See NOTE (1)	1.02 (0.040) min.	4.00 Max
ELECTRO COATED ZINC OR IRON-ZINC	0.71 (0.028) min. 1.02 (0.040) max.	0.89 (0.035) MIN.	1.02 (O.040) MIN.	4.00 Max

TABLE 5: ARC WELDING METAL COATING AND STEEL THICKNESS REQUIREMENTS (METAL GAUGE SPECIFICATION REFERS TO THE THINNER OF THE TWO PIECES TO BE JOINED)				
STEEL CONDITION	MIG-BRAZE (MS-6408) Thickness Required mm (in.)	GMAW (MS-3684), (MS-5365), or (MS-9421) Thickness Required mm (in.)	FCAW (Flux-Core) (MS-6995) Thickness Required mm (in.)	GTAW Thickness Required mm
ZINCROMETAL (MS-5973)	0.71 (0.028) min. 1.02 (0.040) max.	0.89 (0.035) min.	1.02 (0.040) min.	Do Not Use
ZINC RICH PRIMER (MS-PB-1)	0.71 (0.028) min. 1.02 (0.040) max.	0.89 (0.035) min.	1.02 (0.040) min.	Do Not Use
SEALERS AND ADHESIVES	NO ARC WELDING CLOSER THAN 25.4 MM (1.0 IN.) TO SURFACES OR EDGES COATED WITH SEALER OR ADHESIVE			
NOTE 1: Iron-Zinc alloy coatings (Galvannealed) - as produced by the hot dip process with a coating Weight of 40 g/m^2 or less only. Use Filler Wire MS-5365 with 75%Ar-25%CO_2 gas coverage only.				

2.3.4 Design Considerations

All released parts using the arc welding process shall show mating parts to be in “line to line” contact. The maximum acceptable manufacturing gap shall be the lesser value of the thinner metal thickness or 1.5 mm (0.060”) for the GMAW and FCAW (Flux Core) process, or one-half the metal thickness of the thinner part for the MIG-Braze process.

In a lap joint configuration, it is always desirable to arc weld with the thinnest member on top.

The part and tooling should be designed to provide sufficient torch access to allow the full specified length of weld to be performed using the optimized torch and work angles.

Fillet welds should be designed to allow fitting the torch without any interference from other parts, stamping features or tooling, and to obtain the electrode stick-out distance recommended by the electrode manufacturer’s technical data sheet. In most instances it is sufficient to design the join to fit a 40 mm cylinder at 45° from the weld joint root as shown in Figure 7.

Mechanical properties are not homogeneous in a welded region. The designer should be aware of how the materials, welding process, and filler metals selected will affect the overall properties of the welded joint.

Excessively large weld sizes increase costs, thermal distortion and residual stresses. In fillet welds, the amount of filler metal increases as square proportion to the weld bead size.

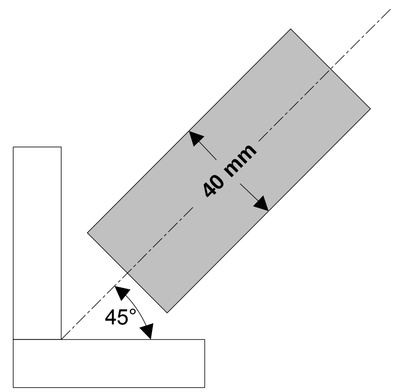


FIGURE 7: TORCH ACCESS EXAMPLE

2.3.4.1 Length and Quantity

The weld length and quantity shall be determined by structural requirements. The minimum acceptable weld length should not be less than 13 mm.

The length of the weld shall be specified and located as noted on the weld release (see Section 3.0 for Weld Symbols). Weld lengths are classified as either “Full Length” or “Specific Length” as follows:

- A “Full Length” weld is a weld along the entire junction or joint formed by the mating parts. These welds are identified as “Full Length” welds by the absence of a length dimension in the welding symbol on the weld release. “Full Length” welds permits a 3 mm (0.12 in.) discrepant start and a 5 mm (0.20 in.) discrepant stop (including the crater). No discrepancy is permitted in the first 13 mm (0.50 in.) weld beyond the existing start and stop. Of the remaining weld length, at least 90% shall be free of discrepant lengths.

- A “Specific Length” weld is a weld with a minimum length dimension requirement. Weld “Start” and “Weld Finish” (crater), not meeting the leg and throat requirements of PS-9472<S>, or the weld release, are not considered part of the required “Specific” weld length. These welds are identified as “Specific Length” welds by a length dimension in the welding symbol on the weld releases. Discrepant lengths are permitted in the remaining weld length provided they do not reduce the overall weld length below that required.

When specifying a “Specific Length” weld, the weld joint shall be at least as great (under a worst case dimensional stack-up) as the weld length specified. It is preferred that the specified length be smaller than the available joint, because it is difficult and as a result costly (i.e. cost and cycle time) to produce welds without start and/or stop discrepancies, therefore a design is more robust if the weld joint length is greater than the specified length of the weld.

2.3.4.2 Fillet Weld Contact Overlap (Wf) Requirements

A sufficient amount of contact overlap is required to support the molten weld pool and allow for sufficient flange length to obtain the required fused leg size. The minimum contact overlap discussed below, must be provided even with the worst case stack-up scenario of all of the manufacturing tolerances.

2.3.4.3 Two thickness (2T) Edge of Metal Fillet Joint

The minimum contact overlap (Wf) requirements are listed below and shown in Figure 8. These are based on the thinnest metal being welded in the joint.

- Wf (min.) = 3 mm for all metal thickness up to 1 mm.

- Wf (min.) = 3 mm +0.75T for all metal thickness over 1 mm.

A notched flange requirement is shown in Figure 9.

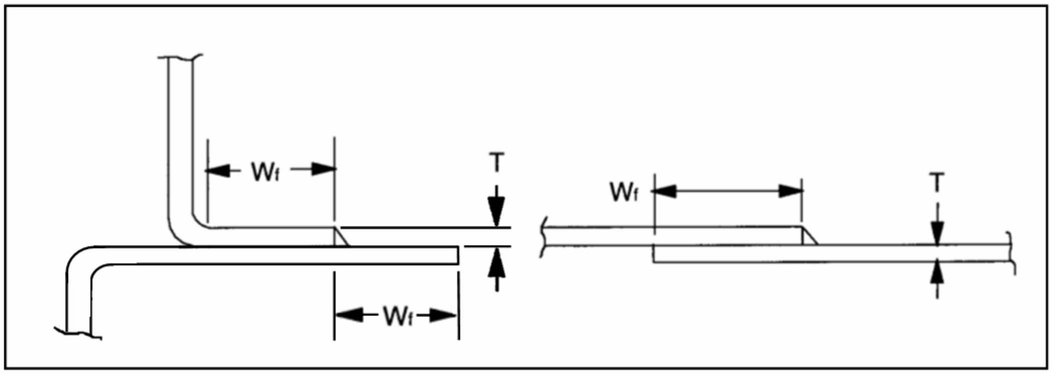


FIGURE 8: 2T LAP FILLET MINIMUM CONTACT OVERLAP (Wf)

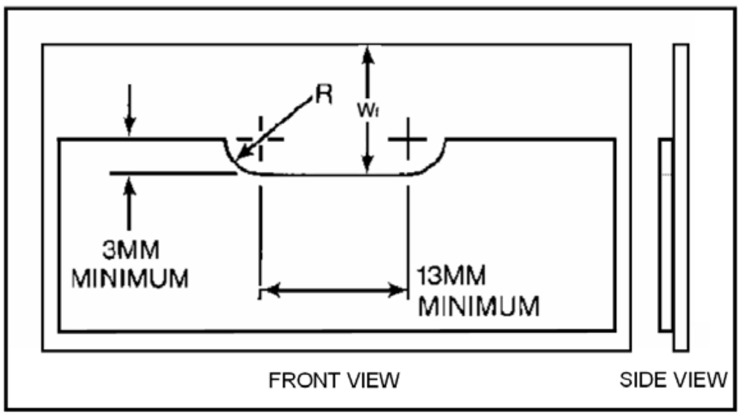


FIGURE 9: NOTCHED LAP FILLET Wf

2.3.4.4 Three thickness (3T) Edge of Metal Fillet Joint

When three thicknesses of metal are joined, the center part must have 3 mm of metal exposed after when all part tolerances are satisfied (See Figure 10). This joint configuration should be welded as two separate welds.

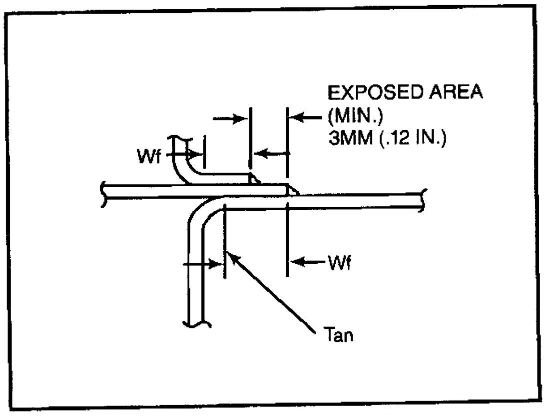
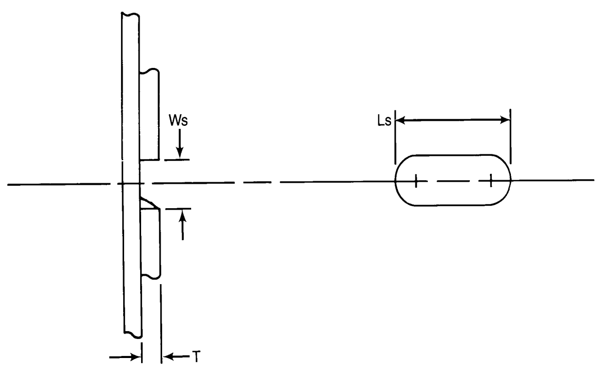


FIGURE 10: 3T LAP FILLET Wf

2.3.4.5 Fillet Slot Weld

The minimum slot width and length requirements are shown in Table 6.

TABLE 6: FILLET WELDING SLOT SIZES (1,2)



T Specified Metal Thickness (of Slotted Panel) (mm)	W_S Minimum (mm)	L_S Minimum (mm)
.7 - 1.5	6.4	19.1
1.5 - 2.3	7.9	25.4
2.3 - 3.1	9.5	25.4
3.1 - 3.9	11.1	31.8
3.8 - 4.6	12.7	31.8

NOTE 1: Surface coating conditions must be checked in Table 5 prior to determining arc-welding requirements.
NOTE 2: Slot length (L_S) shall be determined by structural requirements. Minimum requirement is shown in this table.

2.3.4.6 Part Fit-Up

Parts must be designed with line to line fit-up for arc welding. The maximum acceptable design gap between metals for arc welding is contained in Figure 11. A tolerance stack-up must be performed on all arc welded joints. The worst case maximum designed gap including tolerance stack-up shall not exceed what is listed in Figure 10. It is preferable to target the smallest possible gap.

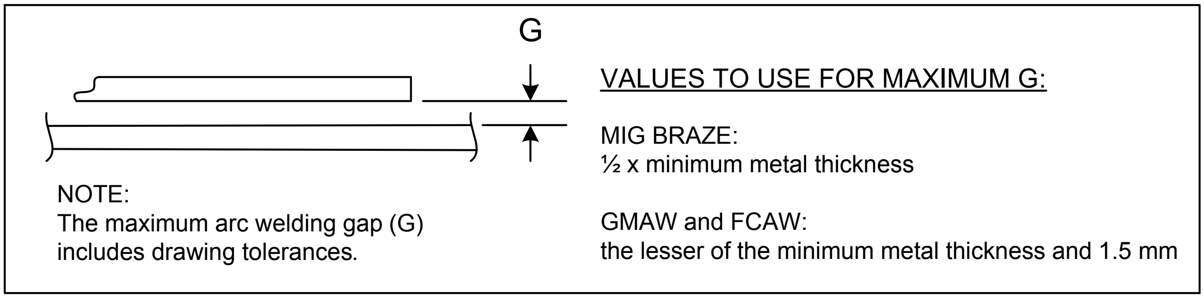


FIGURE 11: MAXIMUM ARC WELDING GAP

2.4 Drawn Arc Welding of Studs and Nuts

Drawn arc welding is a welding process that uses an arc between a metal stud, or nut, and the workpiece or sheet steel substrate. The process is used without filler metal, with or without shielding gas or flux, with or without partial shielding from a ceramic or graphite ferrule surrounding the stud (also called collet), and with the application of pressure after the faying surfaces are sufficiently heated.

The nomenclature used in this section is depicted in Figure 12.

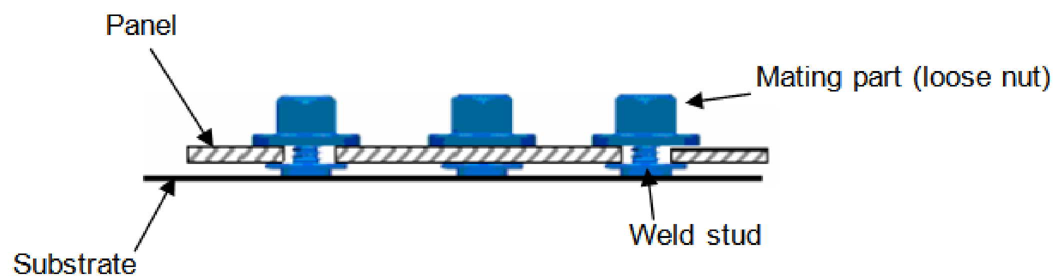


FIGURE 12: NOMENCLATURE

2.4.1 Fasteners

Fasteners covered by this standard shall meet the general specifications for dimension, material and finish listed in PS-7099 “General Specifications: Fasteners and Fittings”.

Drawn Arc weld stud and nut part numbers can be found in the “Engineering Standards” Standard Parts book located at http://roadmap.tcc.chrysler.com/d5810/capme/hmpgfast.htm. These parts are found on the Design tab “Standard Parts” for weld studs, hex weld and hex flange weld nuts. Part numbers for drawn arc weld studs and nuts are available but require review with the fastener application engineer shown on the above website Home tab “Contact Info.” Fastener Engineering.

2.4.2 Material Restriction

This standard is applicable to steel nuts fabricated from MS-210 or MS-2717 steel (see MS-BAR<S>) and steel studs fabricated from MS-210, MS-2717 or MS-5378 steel (see MS-BAR<S>). Refer to PS-5368<S> for sheet steel approved for drawn arc welding of fasteners.

Figure 13 shows the type of stand-off that is required when welding studs to Aluminized steel (MS-11418<S>).

2.4.3 Design Considerations

2.4.3.1 Substrate

The curvature of the substrate in either direction (upward or downward) shall not be smaller than 150 mm (Figure 14). If deviations are required, consult with Advanced Manufacturing Engineering and Equipment Manufacturers.

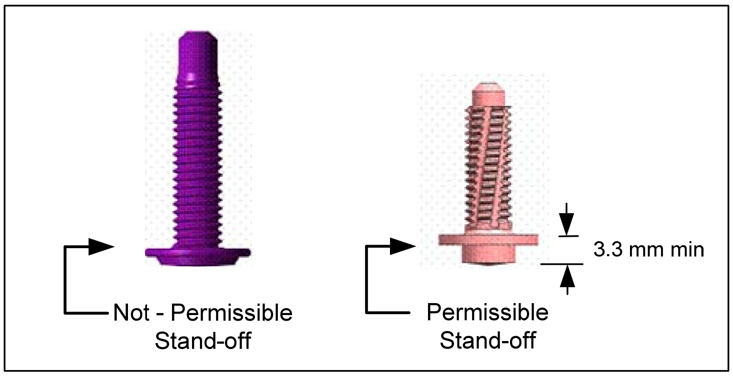


FIGURE 13: EXAMPLE OF STUD STAND OFF THAT IS REQUIRED WHEN WELDING ON ALUMINIZED STEEL.

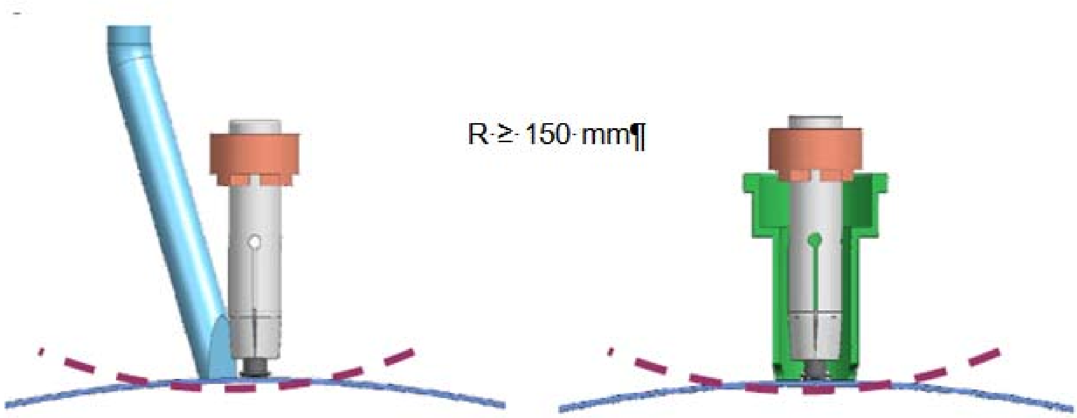


FIGURE 14: PANEL MINIMUM RADII IN EITHER DIRECTION

2.4.3.2 Fastener to Part and Features Clearance

The minimum distance from the centerline of a stud or nut to edges, radii, spot weld, holes and adhesive beads shall be 25 mm. This dimension accommodates the largest gun type used within Chrysler Group LLC (Figure 15). Deviations from this requirement shall be agreed upon by Advanced Manufacturing Engineering and Equipment Manufacturers. An example of the distance from the centerline of a stud to an edge or wall is shown in Figure 16.

Welding in a depression or coined area is not recommended because drawing compounds and other contaminants may accumulate on the substrate. When not avoidable, pressurized air should be used to disperse the contaminants.

2.4.3.3 Fastener to Fastener Clearance

The distance from centerline to centerline of welded fasteners (studs or nuts) should not be less than 25 mm as shown in Figure 17. If deviations are required, consult with Advanced Manufacturing Engineering and Equipment Manufacturers.

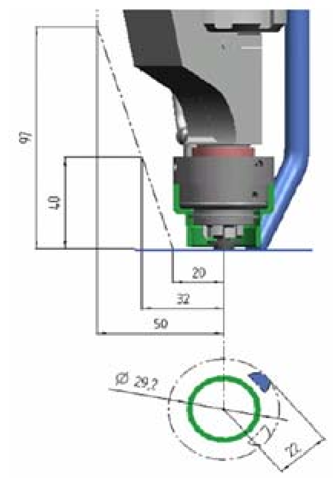


FIGURE 15: GUN HEAD CLEARANCE FOR LARGE FLANGE STUDS (KTO Styles 21032, 21034) APPLIED WITH SHIELDING GAS

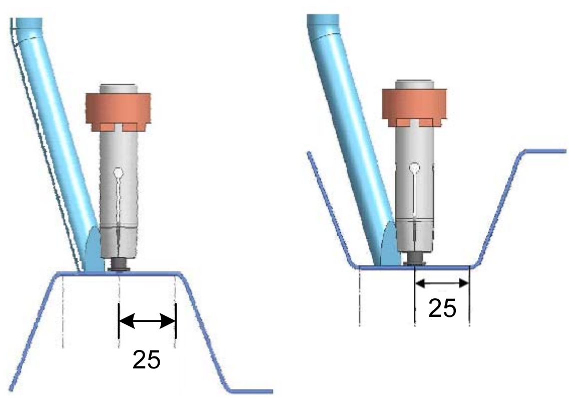


FIGURE 16: DISTANCE TO CONVEX AND CONCAVE FORMINGS (GUN SHOWN HAS NO SHIELDING GAS)

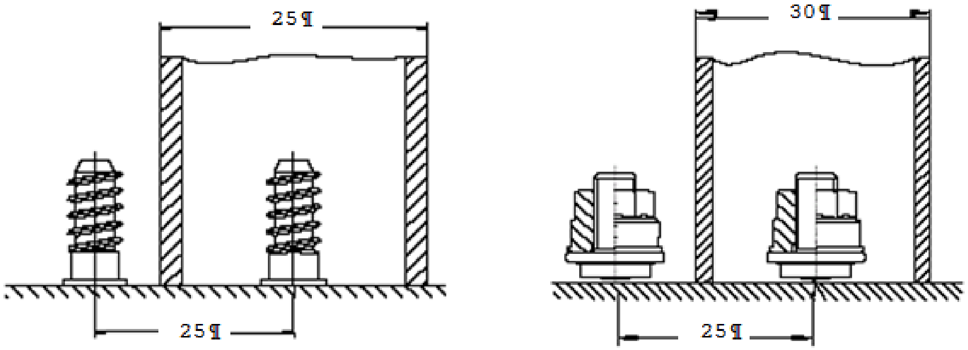


FIGURE 17: STUD TO STUD CLEARANCE

2.4.3.4 Mating Parts Considerations

The robustness of an attachment involving a drawn arc welded fastener depends greatly on the configuration of the mating parts. The quantity and location of attachment points are a function of the size, weight and geometry of the part attached.

Figure 18 depicts the suggested clearance holes to be designed in the mating plastic, metal or fabric panels. Table 7 lists the Normal Clearance Diameter (D_{NC}) required as a function of the thread size. Note that the counter bore suggested in the panel when using studs with large flange will limit loading the weld when torque is applied to the loose nut. This is intended to minimize the distortion of the substrate, and allows for the use of higher clamping loads.

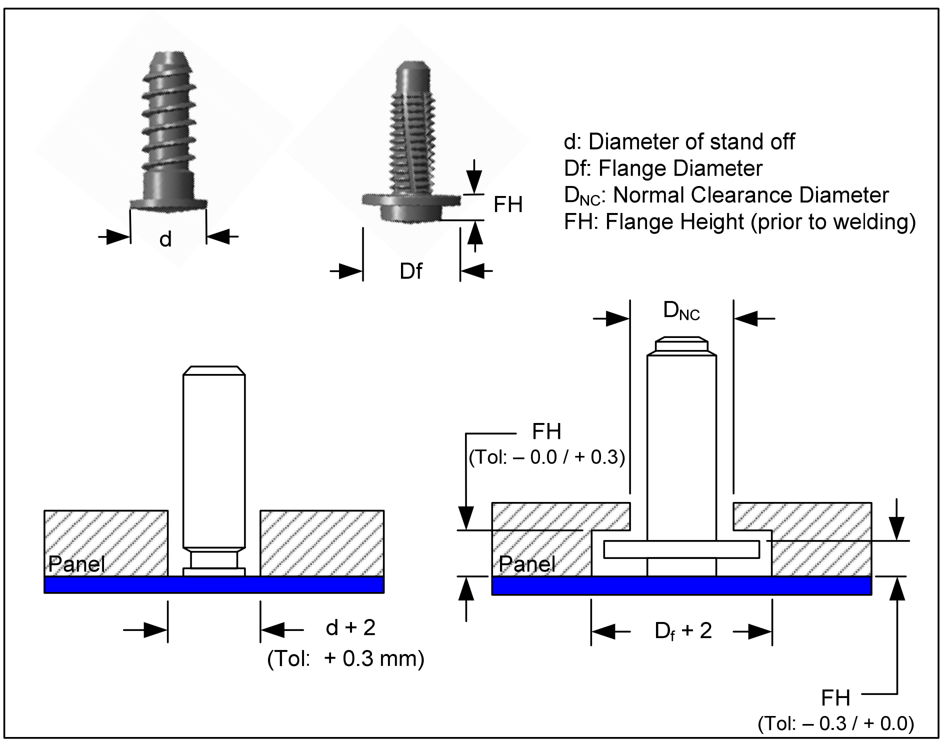


FIGURE 18: PANEL CLEARANCE HOLE SIZE IN MILLIMETERS

TABLE 7: RECOMMENDED CLEARANCE HOLE SIZES – NORMAL CLEARANCE (D_{NC})		
Size	Min	+ Tol
M5	5.5	0.3
M6	6.6	0.3
M8	9.0	0.3
NOTE: Fastener Design Handbook. Information integrated in Catia V5.		

Two different approaches can be taken to eliminate warping of substrates or panels (Figure 19). Option 1 consists of placing 3 studs close to each other, and Option 2 consists of forming a resting feature on the panel.

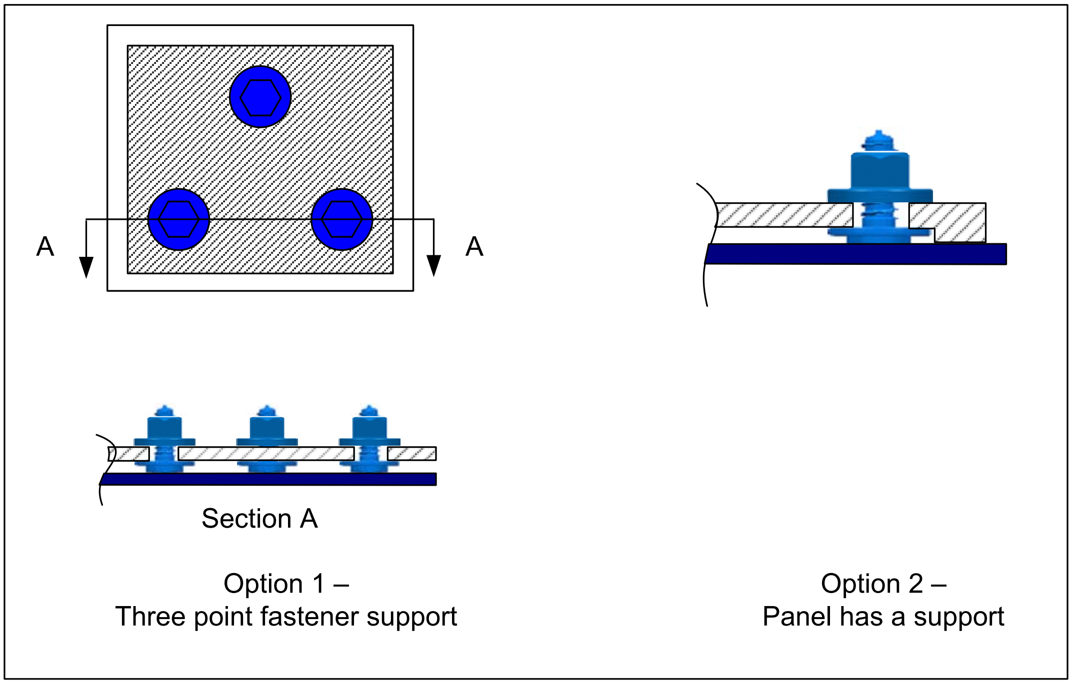


FIGURE 19: OPTIONS TO PREVENT WARPING OF COMPONENTS

2.4.3.5 Manufacturing Tolerances

The typical tolerance of fastener location on assemblies, when the stud is applied manually is equal to +/- 1.5 mm, and when the fastener is applied robotically is equal to +/- 1.0 mm. The typical tolerance for fastener perpendicularity to the substrate surface is equal to +/- 5°. Note that when possible, for robustness, mating parts should be designed to be tolerant to greater variations.

2.4.3.6 Manufacturing Considerations

In some cases a backup must be used behind the material being welded to ensure the stabilization of the substrate. Table 8 lists a guideline for need of weld support based on the type of fastener, stand-off diameter (Figure 20), and substrate thickness. When the weld support backing is needed, account for a minimum 20 mm square clearance on the opposite side of the weldment.

TABLE 8: NEED FOR WELD SUPPORT OR BACKING PLATE (1)						
Substrate Thickness	Stud Stand-off diameter, d				Ring Studs	Weld Nuts (M5,M6, M8)
	≥ 6 mm	≥ 7 mm	≥ 9 mm	≥ 10 mm		
0.65 < 0.8	Yes	Yes	Not permissible	Not permissible	Yes	Yes
0.8 < 1.0	No	No	Yes	Yes	Yes	No
≥ 1.0	No	No	No	No	No	No

NOTE 1: Exceptions to this table are possible with careful review of application by Product, Advanced Manufacturing Engineering and Equipment Supplier.

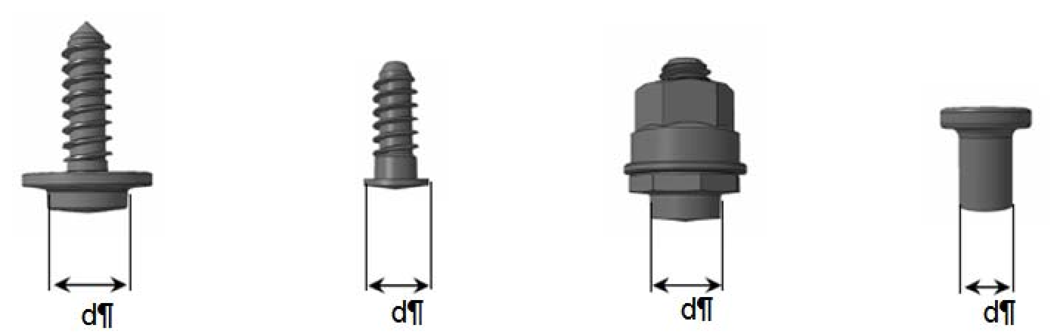


FIGURE 20: STUD STAND-OFF DIAMETER (d)

2.4.3.7 Mechanical Performance

The performance of the weld under tension or torsion is covered in PS-5368<S>.

2.4.3.8 Rework Considerations

When designing with drawn arc studs, careful consideration of repair procedures must be taken. Consult with Materials Engineering, Joining Technology, on available riv-studs and clearance needed for their installation.

3.0 SYMBOLS

3.1 Symbols For Welding

Symbols for welding to be used on CATIA V4/V5 models can be found in CEP-040.

3.2 Application of Welding Symbols

Complete welding information is placed on engineering weld documents to specify the total requirements for the weldments indicated. Use of welding symbols enables the designer to specify the engineering requirements in a concise and orderly manner. The standardization of welding symbols presented in this section is applicable to engineering weld documents for the purpose of supplying such information.

3.3 Source

Most symbols in this manual are taken from the American Welding Society Standard AWS A2.4. However, certain symbols have been modified and take precedence over symbols specified in the American Welding Society Standard.

3.4 Welding Symbol

The complete welding symbol is shown in Figure 21. It consists of the following eight elements:

- Reference Line (shown horizontally)
- Arrow
- Weld Symbol
- Dimensions and Other Data
- Supplementary Symbols
- Finish Symbol
- Tail
- Process Standards, Specifications, or Other References

The elements of a welding symbol have definite locations in respect to one another as illustrated in Figure 21. Not all elements need be used unless required for clarity. The Reference Line, Arrow, and Tail elements of the Welding Symbol should be drawn with a relatively heavy line width.

3.4.1 Reference Line

This is the line to which the arrow, basic weld symbol, and tail are attached. It is placed horizontally on the drawing (Figure 22).

3.4.2 Arrow

The arrow segment of the Welding Symbol shown in Figure 21 includes a leader line and arrowhead connecting the reference line to the weld joint. The location of the arrow is significant in relation to the location of the weld joint itself as shown in Figure 22. Moreover, the location of weld symbols above or below the reference line will also be affected as described in Location of Weld Symbol in Section 3.4.3.1.

Symbols with No Side Significance: Spot, Seam, Friction or Inertia weld symbols have no “arrow side” or “other side” significance, although supplementary symbols used with them may have such significance.

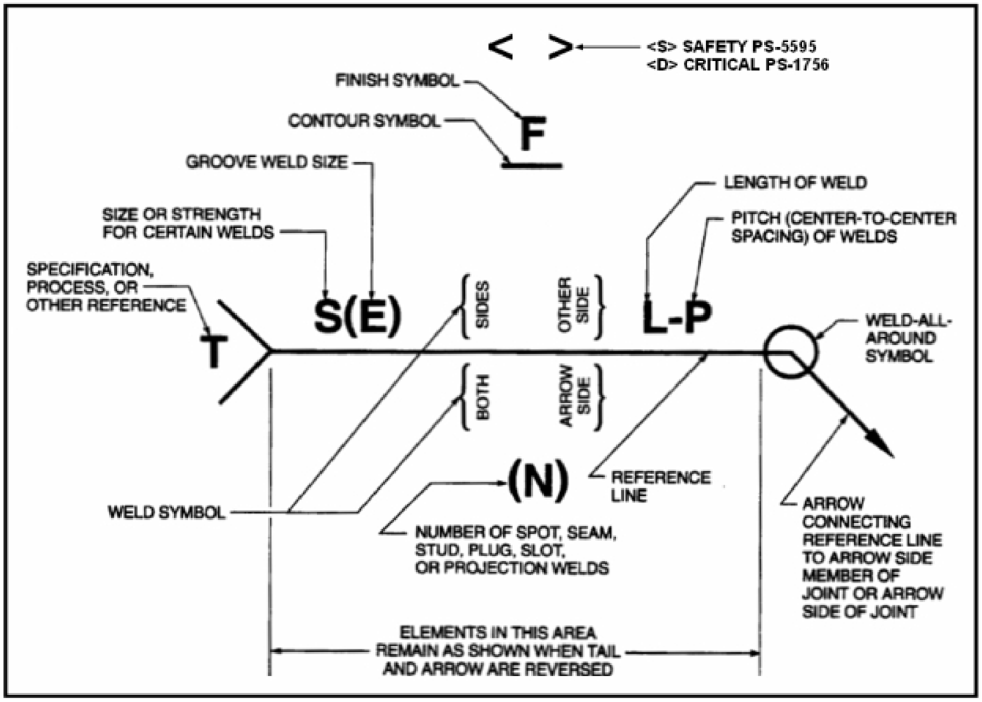


FIGURE 21: LOCATION OF ELEMENTS OF A WELDING SYMBOL

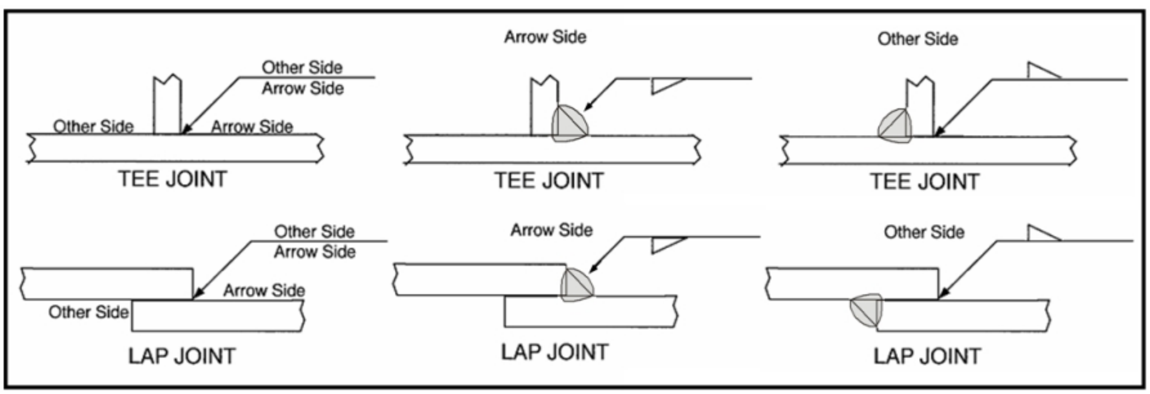


FIGURE 22: SIGNIFICANCE OF ARROW TO LOCATION OF WELDS AND WELD SYMBOLS

3.4.3 Weld Symbols

The Weld Symbol is part of the Welding Symbol. These symbols denote the type of weld desired and are placed above or below the Welding Symbols reference line as shown in Figure 22. They basically depict the type of weld desired at the joint to which the arrow is pointed. Commonly used Weld Symbols are shown in Figure 23.

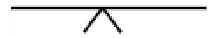
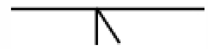
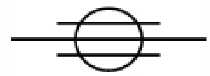
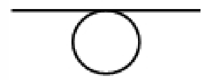
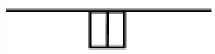
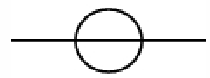
TYPE	SYMBOL		TYPE	SYMBOL
Fillet			V Groove	
Flare-V Groove			Bevel Groove	
Flare-Bevel Groove			Seam	
Square or Butt Groove			Projection	
Edge			Spot	
Plug			Friction or Inertia Weld	
Weld-All-Around				

FIGURE 23: BASIC WELD SYMBOLS

3.4.3.1 Location of Weld Symbol

When the basic weld symbol is placed below the reference line, it indicates that a weld is to be made only on the "arrow-side" of the joint. When the weld symbol is above the reference line, a weld is required only on the "other-side" of the joint. When the weld symbol appears on both sides of the reference line, a weld is required on both the "arrow-side" and "other-side" of the joint (See Figure 22).

3.4.4 Dimensions and Other Data

The area immediately above or below the reference line is used for additional dimensions, data, and/or symbols as required.

3.4.4.1 Size of Weld

The size of the weld, as portrayed in Figure 24 for fillet type welds, is placed in the spaces marked "S" in Figure 21 for clarification, or when engineering requirements exceed the minimum allowable in the applicable weld Process Standard. The weld size should be expressed in millimeters.

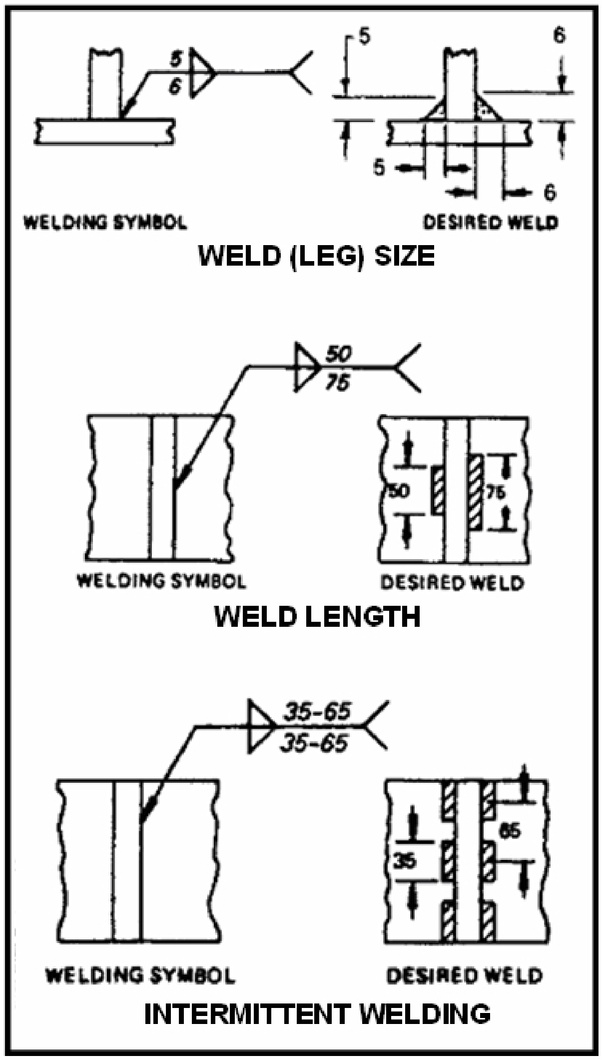


FIGURE 24: WELD (LEG) SIZE, WELD LENGTH AND INTERMITTENT WELDING

3.4.4.2 Length of Weld

The length of the weld, as shown in Figure 24 for fillet type welds, is placed within the spaces marked "L" in Figure 21. The weld size should be expressed in millimeters or degrees on circular joints.

3.4.4.3 Pitch

This is a term used for non-continuous or intermittent welding of a joint in which welding begins and ends with so-called increments of welding as shown in Figure 24. The distance from the center of one weld increment to the center of the next is called the "pitch", and is placed within the spaces marked "P" in Figure 21. It is normally expressed in millimeters or in degrees if increments are located on a circular arc.

3.4.4.4 Strength of Weld

The strength of the weld is placed in the spaced marked "S" in Figure 21 when necessary, i.e., for clarification or when strength requirements exceed the minimum allowable per the applicable Process Standards. The strength should be expressed in Newton (N) for tension loads. Torsion loads should be expressed in Newton-meters (Nm).

3.4.4.5 Number of Welds

The number of spot or projection welds required shall be shown in parenthesis under the basic weld symbol as shown in Figure 21.

3.4.4.6 Contour Symbol

A symbol indicating the desired surface contour of the weld shall be placed above the weld symbol as shown in Figure 21 when required. Symbols to be used for this purpose are given in Figure 25.

3.4.4.7 Groove Angle

The groove angle when required shall be placed below the contour symbol as shown in Figure 21. The angle shall be expressed in degrees.

CONTOUR		
FLUSH	**CONVEX**	**CONCAVE**
		

FIGURE 25: CONTOUR SYMBOLS

3.4.5 Supplementary Symbols

Supplementary symbols may be used in conjunction with the basic weld symbols described in Section 3.4.3 when required.

3.4.5.1 Weld-All-Around Symbol

The weld-all-around symbol signifies that the weld should be made all around the joint. See Figures 21 and 23. The circle shown on the welding symbol shall have a diameter of approximately 6 mm.

3.4.5.2 PF-Safety/Emissions Weld Area Symbol

All PF-Safety/Emissions weld areas shall be identified by placing the symbol <S> above the Welding Symbol reference line away from the reader and by placing PS-5595<S> item number first in the tail of the Welding Symbol in addition to all other required welding specifications (See Figure 26).

3.4.5.3 "Diamond" Weld Area Symbol

"Diamond" weld areas shall be identified by placing the symbol <D> above the Welding Symbol reference line as shown in Figure 26.

The item number referring to PS-1756 in the Standards area of the drawing Title Block for these welds shall be placed first in the tail of the Welding Symbol, followed by other welding specifications as required.

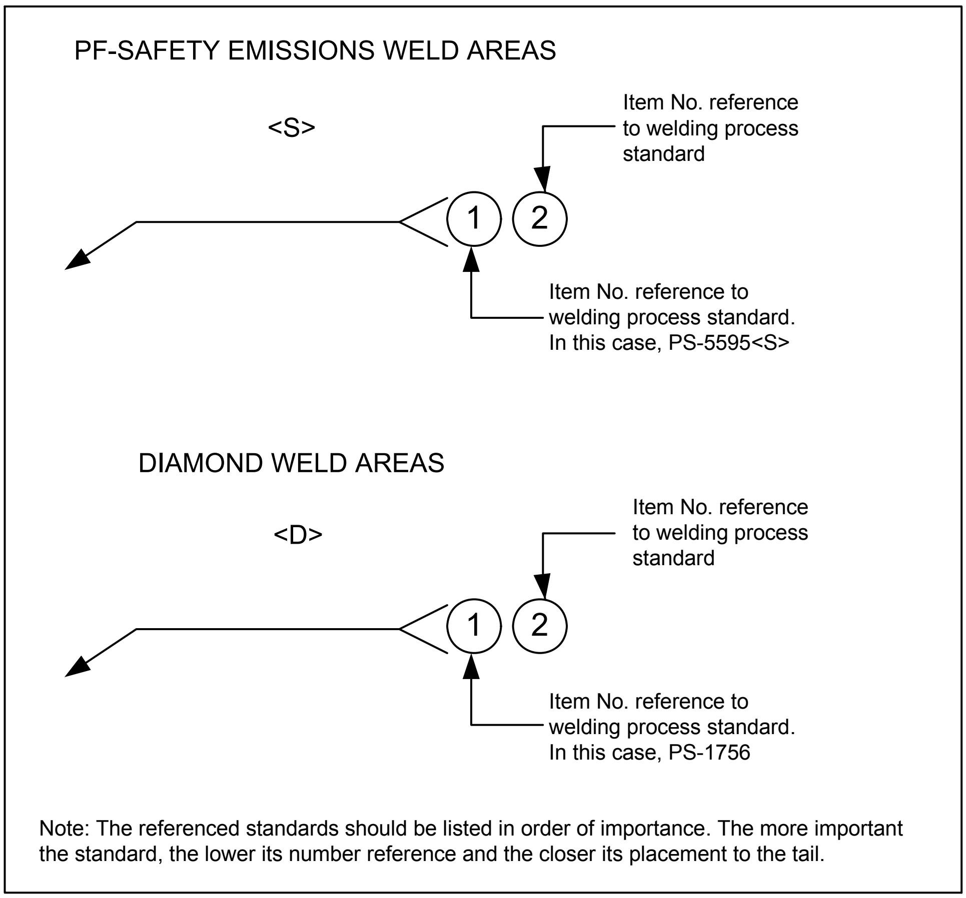


FIGURE 26: EXAMPLE OF IDENTIFICATION OF PF-SAFETY/EMISSIONS AND DIAMOND WELD AREAS USING BALOONS

3.4.6 Finish Symbols

Finish symbols when required are used in conjunction with Contour symbols described in Section 3.4.4.6. They are placed as shown in Figure 21, and are used to describe the type of finish to be used on welding areas, when required, following welding. A list of these symbols is given in Table 9.

TABLE 9: FINISH SYMBOLS	
METHOD	SYMBOL
Chipping	C
Grinding	G
Hammering	H
Machining	M
Rolling	R
Peening (1)	P
NOTE 1: Area to be peened must be indicated.	

3.4.7 Tail

Located in the Tail element of the Welding Symbol as shown in Figure 21 are applicable process standards, specifications references, or notes. An area is reserved immediately to the left (or right) of the Tail for this purpose, and data is placed in this space as described in Section 3.4.8.

3.4.8 Process Standards, Specification, and Other References

3.4.8.1 Process Standard Reference

The applicable assembly or detail drawing Welding Process Standard Number shall be identified by an Item Number placed in a balloon to the immediate left (or right) of the tail of the Welding Symbols shown in Figure 26.

3.4.8.2 Specification Reference

Amplification of basic Welding Symbol and other symbol information shall be accomplished by abbreviating the necessary additional data and placing the representative abbreviation in the Welding Symbol tail as shown in Figure 27.

3.4.8.3 Other References

When the symbol information cannot be abbreviated sufficiently to prevent confusion and/or use of unwarranted space; or where multiple references can be made to a single note, interpretation may be gained by placing the note in the lower right corner of the drawing and keying it to a welding symbol which consists of "Double" Letters placed in the symbol tail. The first of the double letters shall be "W" indicating reference to a welding note while the second letter refers to the alphabetical sequence of the notes required. Examples are shown in Figure 28.

3.5 Supplementary Methods of Designating Welding

For further clarifying engineering weld documents the following symbols may be used to indicate a pattern type of welded joint, ends of weld joints, weld center lines, and stagger locations. These symbols differ from present American Welding Society symbols but are consistent with Chrysler’s usage (See Figure 29).

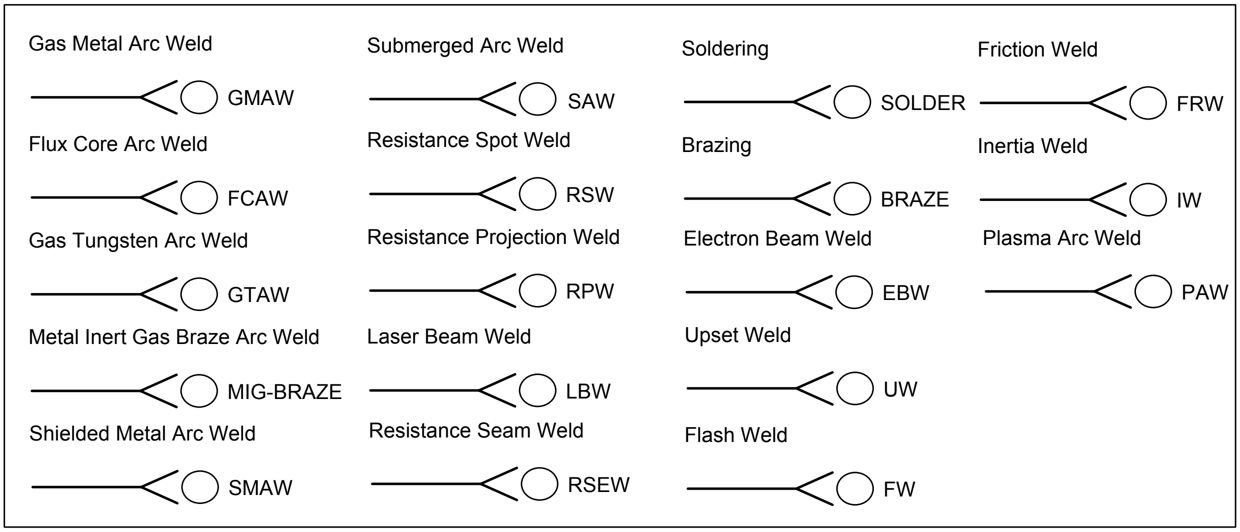


FIGURE 27: WELDING PROCESS ABBREVIATIONS FOR PLACEMENT IN WELDING SYMBOL TAIL

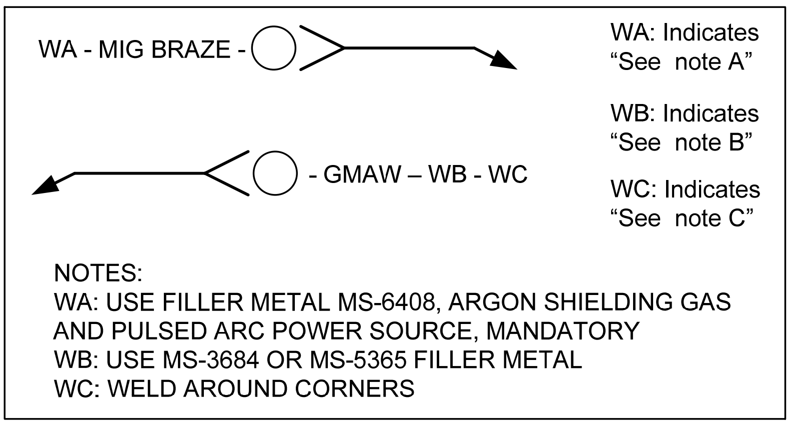


FIGURE 28: EXAMPLES OF WELD NOTES IN CONJUNCTION WITH WELDING SYMBOLS

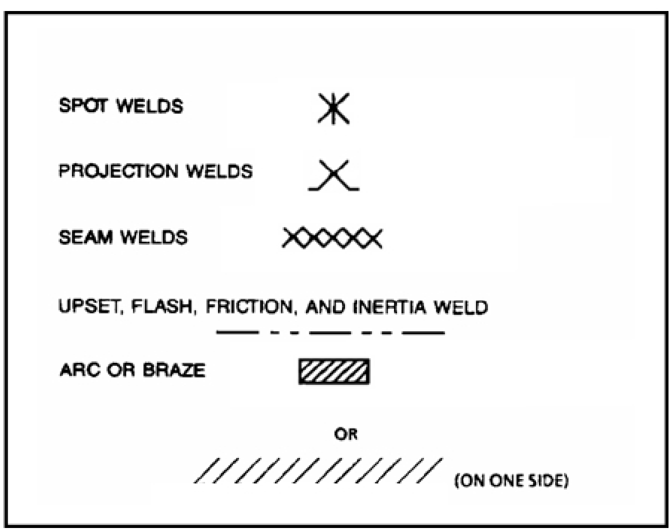


FIGURE 29: METHOD OF DESIGNATING WELDING AT ITS LOCATION

4.0 DEFINITIONS/ABBREVIATIONS/ACRONYMS

Diamond Weld Area: Weld area(s) where compliance to customer satisfaction (or expectations) of product's durability mandate adherence to the requirements as specified by engineering per the applicable standard(s), and engineering release(s).

Drawn Arc Welding: Drawn arc welding is a welding process that uses an arc between a metal stud, or nut, and the work piece or sheet steel substrate. The process is used without filler metal, with or without shielding gas or flux, with or without partial shielding from a ceramic or graphite ferrule surrounding the stud (also called collet), and with the application of pressure after the faying surfaces are sufficiently heated.

Gas Metal Arc Welding (GMAW): An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. This process is sometimes referred to as MIG or CO_2 welding.

Faying Surface: The mating surface of a member that is in contact with or in close proximity to another member to which it is to be joined.

Manufacturing Spot Welds: These welds are required for production sequencing and processing and must hold through assembly. There is no minimum weld size requirement for these welds. The function of the part remains unaffected whether or not these welds are present.

PF-Safety/Emissions Weld Area(s): Weld area(s) where compliance with corporate and/or government vehicle regulatory requirements mandate adherence as specified by engineering per the applicable standard(s), and engineering release(s).

Projection Welding: A resistance welding process that produces a weld by the heat obtained from the resistance to the flow of the welding current. The resulting welds are localized at predetermined points by projections, embossments, or intersections.

Resistance Spot Welding (RSW): A resistance welding process that provides a weld at the faying surfaces of a joint by the heat obtained from resistance to the flow of welding current through the work-pieces from electrodes that serve to concentrate the welding current and pressure at the weld area.

Standard Weld: Weld area(s) where compliance to neither PF Safety/Emissions nor customer satisfaction requirements are necessary, but where criteria may be specified by engineering per the applicable standard(s), and engineering release(s).

Weld: A localized coalescence of metals or non-metals produced either by heating the materials to the welding temperature, with or without the application of pressure, or by the application of pressure alone and with or without the use of filler material.

5.0 GENERAL INFORMATION

Three asterisks "***" after the section/paragraph header denotes single or multiple technical changes to the section/paragraph. Specific technical changes within a section, subsection, table, or figure may be highlighted in yellow.

Certain important information relative to this standard has been included in separate standards. To assure the processes submitted meet all of Chrysler requirements, it is mandatory that the requirements in the following standards be met.

CS-9800 - Application of this standard, the subscription service, and approved sources

CS-9003 - Regulated substances and recyclability

Within Engineering Standards, the Regulatory (Government-mandated) requirements are designated by <S> and <E> which correspond to Safety and Emission Shields respectively. When applicable, the Chrysler mandated requirements are designated by <D> which correspond to the Diamond symbol and by <A> for Appearance related objectives, respectively.

For specific information on this document, please refer to the contact person shown in the "Publication Information" Section of this document. For general information on obtaining Engineering Standards and Laboratory Procedures, see CS-9800 or contact the Engineering Standards Department at engstds@chrysler.com.

6.0 REFERENCES

Chrysler Standards		ASTM Standards	ISO Standards	SAE Standards	Federal Standards
CEP-040	PS-1756				
CS-9003	PS-1791<S>				
CS-9800	PS-1804<S>				
MS-11418<S>	PS-4446<S>				
MS-210	PS-5368<S>				
MS-2717	PS-5595<S>				
MS-3684	PS-5598<S>				
MS-5365	PS-7099				
MS-5378	PS-9059<S>				
MS-6408	PS-9184<S>				
MS-6995	PS-9472<S>				
MS-7023	PS-9496<S>				
MS-9421	PS-10947<S>				
MS-BAR<S>					
Quality and Reliability Documents					
Other Documents					
Knowledge Based Engineering Requirement Sections Lotus Database – Available from American Welding Society: 1-800-443-9353. American Welding Society AWS D8.9 American Welding Society AWS A2.4 - Symbols For Welding and Nondestructive Testing					

7.0 ENGINEERING APPROVED SOURCE LIST

Not applicable.

8.0 PUBLICATION INFORMATION

Contact/Phone Number: James Chapp 248-576-7210
Alternate Contact/Phone Number: Joseph Beckham 248-722-6498
Department Name & Department Number/Tech Club/Organization: System & Components Engineering-Body/Department 1610
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Change Notice:

Description of Change:
- Add NX to Section 1.3
- Delete DBL-4093 from section 2.4.2 and References section 6.0, replace with MS-11418<S>

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