

F_{xx} = Tensile strength of electrode classification

E2.2 Arc Spot Welds

Arc spot welds, where permitted by this *Specification*, shall be for welding sheet steel to thicker supporting members or sheet-to-sheet in the flat position. Arc spot welds (puddle welds) shall not be made on steel where the thinnest connected part exceeds 0.15 in. (3.81 mm) in *thickness*, nor through a combination of steel sheets having a total thickness over 0.15 in. (3.81 mm).

Weld washers, as shown in Figures E2.2-1 and E2.2-2, shall be used where the thickness of the sheet is less than 0.028 in. (0.711 mm). Weld washers shall have a thickness between 0.05 (1.27 mm) and 0.08 in. (2.03 mm) with a minimum prepunched hole of 3/8 in. (9.53 mm) diameter. Sheet-to-sheet welds shall not require weld washers.

Arc spot welds shall be specified by minimum effective diameter of fused area, d_e . The minimum allowable effective diameter shall be 3/8 in. (9.5 mm). B

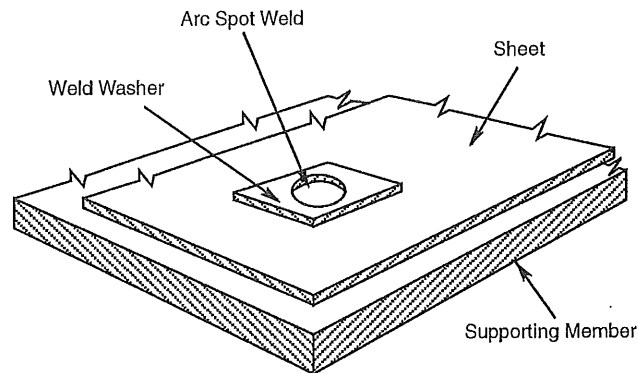


Figure E2.2-1 Typical Weld Washer

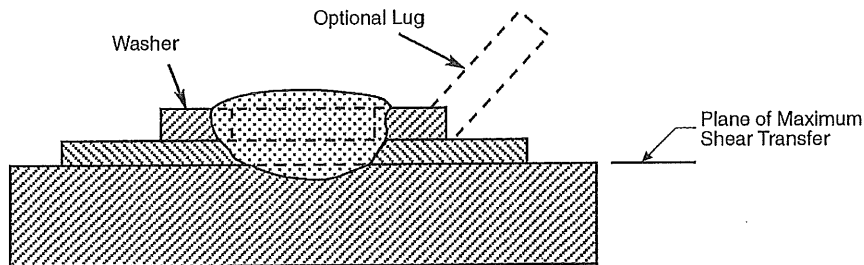


Figure E2.2-2 Arc Spot Weld Using Washer

E2.2.1 Shear

E2.2.1.1 Minimum Edge Distance

The distance measured in the line of force from the centerline of a weld to the nearest edge of an adjacent weld or to the end of the connected part toward which the force is directed shall not be less than the value of e_{\min} determined in accordance with Eq. E2.2.1.1-1 or Eq. E2.2.1.1-2, as applicable. See Figures E2.2.1.1-1 and E2.2.1.1-2 for

edge distance of arc welds. The corresponding *safety factors* and *resistance factors* shall be used to determine the *allowable strength* or *design strength* [factored resistance] in accordance with the applicable design method in Section A4, A5, or A6.

$$e_{\min} = \frac{P\Omega}{F_u t} \quad \text{for ASD} \quad (\text{Eq. E2.2.1.1-1})$$

$$e_{\min} = \frac{\bar{P}}{\phi F_u t} \quad \text{for LRFD and LSD} \quad (\text{Eq. E2.2.1.1-2})$$

When $F_u/F_{sy} \geq 1.08$

$$\Omega = 2.20 \quad (\text{ASD})$$

$$\phi = 0.70 \quad (\text{LRFD})$$

$$= 0.60 \quad (\text{LSD})$$

When $F_u/F_{sy} < 1.08$

$$\Omega = 2.55 \quad (\text{ASD})$$

$$\phi = 0.60 \quad (\text{LRFD})$$

$$= 0.50 \quad (\text{LSD})$$

where

P = Required shear strength (nominal force) transmitted by weld (ASD)

F_u = Tensile strength as determined in accordance with A2.1, A2.2, or A2.3.2

t = Total combined base steel thickness (exclusive of coatings) of sheet(s) involved in shear transfer above plane of maximum shear transfer

\bar{P} = Required shear strength [factored shear load] transmitted by weld

= P_u (LRFD)

= P_f (LSD)

F_{sy} = Yield stress as determined in accordance with Section A2.1, A2.2, or A2.3.2

In addition, the distance from the centerline of any weld to the end or boundary of the connected member shall not be less than $1.5d$. In no case shall the clear distance between welds and the end of member be less than $1.0d$.

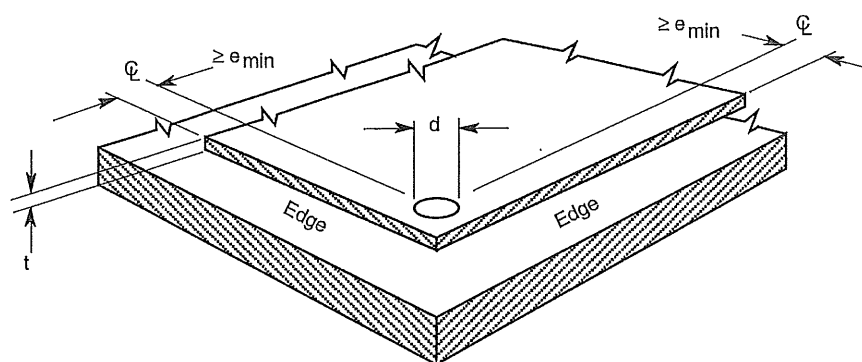


Figure E2.2.1.1-1 Edge Distance for Arc Spot Welds – Single Sheet

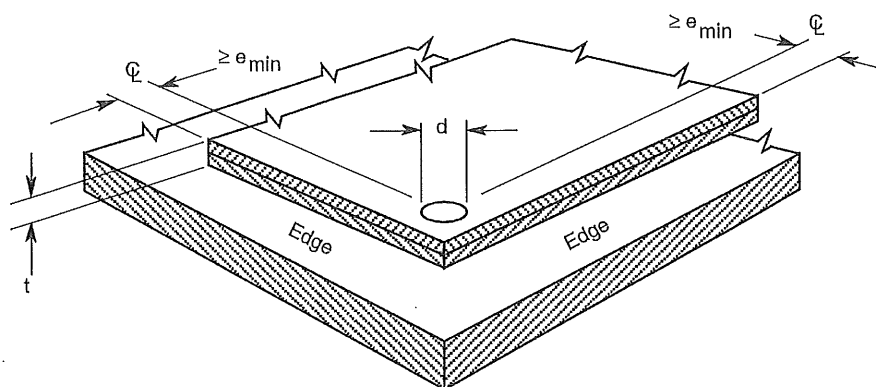


Figure E2.2.1.1-2 Edge Distance for Arc Spot Welds – Double Sheet

E2.2.1.2 Shear Strength [Resistance] for Sheet(s) Welded to a Thicker Supporting Member

The nominal shear strength [resistance], P_n , of each arc spot weld between the sheet or sheets and a thicker supporting member shall be determined by using the smaller of either (a) or (b). The corresponding *safety factor* and *resistance factors* shall be used to determine the *allowable strength* or *design strength* [factored resistance] in accordance with the applicable design method in Section A4, A5, or A6.

$$(a) P_n = \frac{\pi d_e^2}{4} 0.75 F_{xx} \quad (Eq. E2.2.1.2-1)$$

$$\Omega = 2.55 \quad (ASD)$$

$$\phi = 0.60 \quad (LRFD)$$

$$= 0.50 \quad (LSD)$$

$$(b) \text{ For } (d_a/t) \leq 0.815 \sqrt{E/F_u}$$

$$P_n = 2.20 t d_a F_u \quad (Eq. E2.2.1.2-2)$$

$$\Omega = 2.20 \quad (ASD)$$

$$\phi = 0.70 \quad (LRFD)$$

$$= 0.60 \quad (LSD)$$

$$\text{For } 0.815 \sqrt{E/F_u} < (d_a/t) < 1.397 \sqrt{E/F_u}$$

$$P_n = 0.280 \left[1 + 5.59 \frac{\sqrt{E/F_u}}{d_a/t} \right] t d_a F_u \quad (Eq. E2.2.1.2-3)$$

$$\Omega = 2.80 \quad (ASD)$$

$$\phi = 0.55 \quad (LRFD)$$

$$= 0.45 \quad (LSD)$$

$$\text{For } (d_a/t) \geq 1.397 \sqrt{E/F_u}$$

$$P_n = 1.40 t d_a F_u \quad (Eq. E2.2.1.2-4)$$

$$\Omega = 3.05 \quad (ASD)$$

$$\phi = 0.50 \quad (LRFD)$$

$$= 0.40 \quad (LSD)$$

where

P_n = Nominal shear strength [resistance] of arc spot weld

d_e = Effective diameter of fused area at plane of maximum shear transfer
 $= 0.7d - 1.5t \leq 0.55d$ (Eq. E2.2.1.2-5)

where

d = Visible diameter of outer surface of arc spot weld

t = Total combined base steel *thickness* (exclusive of coatings) of sheets involved in shear transfer above plane of maximum shear transfer

F_{xx} = Tensile strength of electrode classification

d_a = Average diameter of arc spot weld at mid-thickness of t where $d_a = (d - t)$ for single sheet or multiple sheets not more than four lapped sheets over a supporting member. See Figures E2.2.1.2-1 and E2.2.1.2-2 for diameter definitions.

E = Modulus of elasticity of steel

F_u = Tensile strength as determined in accordance with Section A2.1, A2.2, or A2.3.2

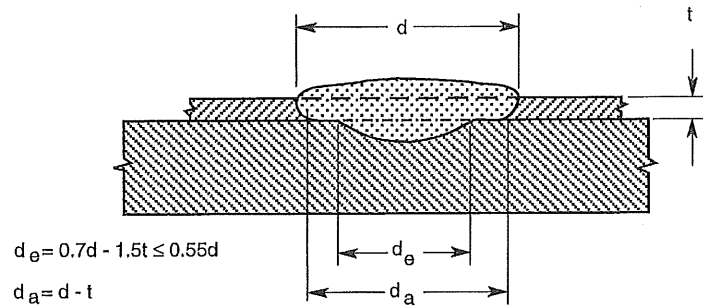


Figure E2.2.1.2-1 Arc Spot Weld – Single Thickness of Sheet

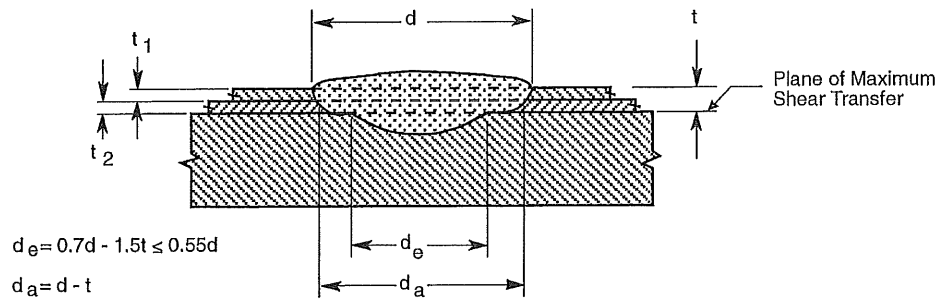


Figure E2.2.1.2-2 Arc Spot Weld – Double Thickness of Sheet

E2.2.1.3 Shear Strength [Resistance] for Sheet-to-Sheet Connections

The nominal shear strength [resistance] for each weld between two sheets of equal *thickness* shall be determined in accordance with Eq. E2.2.1.3-1. The *safety factor* and *resistance factors* in this section shall be used to determine the *allowable strength* or *design strength* [*factored resistance*] in accordance with the applicable design method in Section A4, A5, or A6.

$$P_n = 1.65t d_a F_u \quad (\text{Eq. E2.2.1.3-1})$$

$$\Omega = 2.20 \quad (\text{ASD})$$

$$\phi = 0.70 \quad (\text{LRFD})$$

$$= 0.60 \quad (\text{LSD})$$

where

P_n = Nominal shear strength [resistance] of sheet-to-sheet *connection*

t = Total combined base steel *thickness* (exclusive of coatings) of sheets involved in shear transfer above plane of maximum shear transfer

d_a = Average diameter of arc spot weld at mid-thickness of t . See Figure E2.2.1.3-1 for diameter definitions.

$$= (d - t)$$

where

d = Visible diameter of the outer surface of arc spot weld

d_e = Effective diameter of fused area at plane of maximum shear transfer

$$= 0.7d - 1.5t \leq 0.55d \quad (\text{Eq. E2.2.1.3-2})$$

F_u = *Tensile strength* of sheet as determined in accordance with Section A2.1 or A2.2

In addition, the following limits shall apply:

- (1) $F_u \leq 59 \text{ ksi (407 MPa or 4150 kg/cm}^2\text{)}$,
- (2) $F_{xx} > F_u$, and
- (3) $0.028 \text{ in. (0.71 mm)} \leq t \leq 0.0635 \text{ in. (1.61 mm)}$.

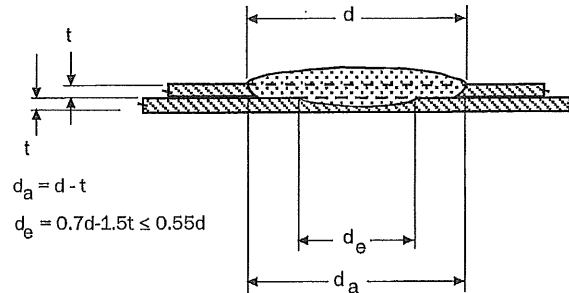


Figure E2.2.1.3-1 Arc Spot Weld – Sheet-to-Sheet

E2.2.2 Tension

The uplift nominal tensile strength [resistance], P_n , of each concentrically loaded arc spot weld connecting sheets and supporting member shall be computed as the smaller of either Eq. E2.2.2-1 or Eq. E2.2.2-2 as follows. The *safety factor* and *resistance factors* shall be used to determine the *allowable strength* or *design strength* [factored resistance] in accordance with the applicable design method in Section A4, A5, or A6.

$$P_n = \frac{\pi d_e^2}{4} F_{xx} \quad (\text{Eq. E2.2.2-1})$$

$$P_n = 0.8(F_u/F_y)^2 t d_a F_u \quad (\text{Eq. E2.2.2-2})$$

For panel and deck applications:

$$\Omega = 2.50 \quad (ASD)$$

$$\phi = 0.60 \quad (LRFD)$$

$$= 0.50 \quad (LSD)$$

For all other applications:

$$\Omega = 3.00 \quad (ASD)$$

$$\phi = 0.50 \quad (LRFD)$$

$$= 0.40 \quad (LSD)$$

The following limits shall apply:

$$t \leq d_a F_u \leq 3 \text{ kips (13.34 kN),}$$

$$e_{\min} \geq d,$$

$$F_{xx} \geq 60 \text{ ksi (410 MPa or 4220 kg/cm}^2\text{),}$$

$$F_u \leq 82 \text{ ksi (565 MPa or 5770 kg/cm}^2\text{) (of connecting sheets), and}$$

$$F_{xx} > F_u.$$

See Section E2.2.1 for definitions of variables.

For eccentrically loaded arc spot welds subjected to an uplift tension load, the nominal tensile strength [resistance] shall be taken as 50 percent of the above value.

For *connections* having multiple sheets, the strength [resistance] shall be determined by using the sum of the sheet *thicknesses* as given by Eq. E2.2.2-2.

At the side lap connection within a deck system, the nominal tensile strength [resistance] of the weld connection shall be 70 percent of the above values.

Where it is shown by measurement that a given weld procedure consistently gives a larger effective diameter, d_e , or average diameter, d_a , as applicable, this larger diameter shall be permitted to be used provided the particular welding procedure used for making those welds is followed.

E2.3 Arc Seam Welds

Arc seam welds (See Figure E2.3-1) covered by this *Specification* shall apply only to the following *joints*:

- (a) Sheet to thicker supporting member in the flat position, and
- (b) Sheet to sheet in the horizontal or flat position.

The nominal shear strength [resistance], P_n , of arc seam welds shall be determined by using the smaller of either Eq. E2.3-1 or Eq. E2.3-2. The *safety factor* and *resistance factors* in this section shall be used to determine the *allowable strength* or *design strength* [*factored resistance*] in accordance with the applicable design method in Section A4, A5, or A6.

$$P_n = \left[\frac{\pi d_e^2}{4} + L d_e \right] 0.75 F_{xx} \quad (\text{Eq. E2.3-1})$$

$$P_n = 2.5 t F_u (0.25 L + 0.96 d_a) \quad (\text{Eq. E2.3-2})$$

$$\Omega = 2.55 \quad (ASD)$$

$$\phi = 0.60 \quad (LRFD)$$

$$= 0.50 \quad (LSD)$$

where

P_n = Nominal shear strength [resistance] of arc seam weld