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Calibrations of Cold-Formed Steel Welded Connections

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CALIBRATIONS OF COLD-FORMED STEEL WELDED CONNECTIONS

Final Report

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1.0 Introduction

In the current AISI Specification for the Design of Cold-Formed Steel Structural Members[1] (from hereon simply referred to as AISI) different resistance factors are given for the various cases of welded connections in Section E2, however, only one factor of safety is given for all of these cases. Having only one factor of safety is not consistent with the different resistance factors. Based on this, a calibration study was initiated to establish the respective factors of safety in conjunction with the different resistance factors currently used in AISI[1]. Since the CSA S136[3] (from hereon simply referred to as S136) committee for the design of cold formed steel members is considering adopting the current AISI[1] welded connection approach as part of the North American Specification initiative under the NAFTA umbrella, resistance factor calibrations for the S136 Standard were also carried out.

It is important to point out that only the data from McGuire and Peköz [4] was used in the calibration of the applicable welded connection equations currently in AISI[1]. Two calibration approaches were used, namely, 1) based on the calibration method given in the Commentary on the AISI Specification[2] and 2) based on Chapter F (Tests for Special Cases) of AISI[1].

Contained in this report are the calibration results of the applicable welded connection equations contained in AISI[1]. More specifically, factors of safety and resistance factors obtained from both calibration procedures presented in the AISI Commentary[2] and in Chapter F of AISI[1] have been established. In addition, calibrations were also carried out for the resistance factors to be used in S136[3].

2.0 Calibration

Resistance factors, ϕ, are used with the LRFD design method in AISI[1] and the LSD design method in S136[3] to reduce the nominal resistances. They are determined in conformance with load factors to provide a target reliability index, β, of 3.5 according to the AISI[1] provisions and 4.0 for the S136[3] provisions.

The general equation for β as presented in Reference 2:

$$\beta = \frac{\ln\left(R_m / Q_m \right)}{\sqrt{V_R^2 + V_Q^2}} \tag{2.1}$$

Where R_m and Q_m are the mean nominal resistance and load effect, respectively, while V_R and V_Q are the corresponding coefficients of variations. These terms are defined by Equations 2.2 to 2.5 [2].

$$R_m = R_n P_m M_m F_m \tag{2.2}$$

$$Q_m = C(D_m + L_m) \tag{2.3}$$

$$V_R = \sqrt{V_P^2 + V_M^2 + V_F^2} \tag{2.4}$$

$$V_Q = \frac{\sqrt{(D_m V_D)^2 + (L_m V_L)^2}}{D_m + L_m} \tag{2.5}$$

Where:
- R_n = nominal resistance
- P_m = mean ratio of experimental to calculated results
- M_m = mean ration of actual yield point to minimum specified value
- F_m = mean ratio of actual to specified section modulus
- C = coefficient
- D_m = mean dead load intensity (= 1.05 D_n*)
- L_m = mean live load intensity (= L_n*)
- D_n = nominal dead load intensity
- L_n = nominal live load intensity
- V_P = coefficient of variation of experimental to calculated results
- V_M = coefficient of variation reflecting material properties' uncertainties
- V_F = coefficient of variation reflecting geometric uncertainties
- V_D = coefficient of variation of the dead load intensities
- V_L = coefficient of variation of the live load intensities

*Values recommended by Hsiao et al. [5]

A satisfactory design can be obtained by equating the factored resistance to the factored loads:

$$\phi R_n = C (\alpha_D D_n + \alpha_L L_n) \tag{2.6}$$

Where α_D and α_L are the dead and live load factors, respectively, such that the load combinations are 1.2D+1.6L for AISI[1] and 1.25D+1.5L for S136[3]. The dead to live load ratios, D/L, are 1/5 in AISI[1] and 1/3 in S136[3].

The previously given equations can be substituted into Equation 2.6 to obtain the following expressions for ϕ [6]:

For AISI
$$\phi = \frac{1.521(P_m M_m F_m)}{e^{\beta\sqrt{V_R^2+V_Q^2}}} \tag{2.7}$$

For S136
$$\phi = \frac{1.420(P_m M_m F_m)}{e^{\beta\sqrt{V_R^2+V_Q^2}}} \tag{2.8}$$

If Chapter F of AISI [1] is considered, an alternative expression for the resistance factor, ϕ, is obtained.

For AISI
$$\phi = \frac{1.521(P_m M_m F_m)}{e^{\beta\sqrt{V_M^2+V_F^2+C_P V_P^2+V_Q^2}}} \tag{2.9}$$

For S136
$$\phi = \frac{1.420(P_m M_m F_m)}{e^{\beta\sqrt{V_M^2+V_F^2+C_P V_P^2+V_Q^2}}} \tag{2.10}$$

Where C_P = correction factor
= (1 + 1/n)m/(m - 2) for n ≥ 4, and 5.7 for n = 3
m = degrees of freedom
= n-1
n = number of tests ≥ 3
e = natural logarithmic base
and all other terms were previously defined.

By knowing the ϕ factor, the corresponding factor of safety, Ω, can be computed as follows:

For AISI
$$\Omega = \frac{1.2\, D/L + 1.6}{\phi(D/L + 1)} \tag{2.11}$$

Where all terms have been previously defined.

2.1 Difference between AISI [1] and S136 [3]

Since the S136 Commentary [7] does not contain a detailed description and development of resistance factors, it was decided to use the methodology outlined in the AISI Commentary [2]. Consequently, the values of M_m, V_M, F_m, and V_F were adopted in this report and were taken from Table F1 – Statistical Data for the Determination of Resistance Factor in AISI [1]. The relevant portions for welded connections of Table F1 are summarised in Table 2.1.

Table 2.1 – Statistical Data for Welded Connections and Tearing of Plate Material [1]

Type of Component	M_m	V_M	F_m	V_F
Welded Connections				
Arc Spot Welds				
Shear Strength of Welds	1.10	0.10	1.00	0.10
Plate Failure	1.10	0.08	1.00	0.15
Arc Seam Welds				
Shear Strength of Welds	1.10	0.10	1.00	0.10
Plate Failure	1.10	0.10	1.00	0.10
Fillet Welds				
Shear Strength of Welds	1.10	0.10	1.00	0.10
Plate Failure	1.10	0.08	1.00	0.15
Flare Groove Welds				
Shear Strength of Welds	1.10	0.10	1.00	0.10
Plate Failure	1.10	0.10	1.00	0.10
Tearing of Plate Material				
Plate Failure	1.10	0.10	1.00	0.05

It can be observed from Table 2.1 that the values of M_m, V_M, F_m, and V_F are consistent for each type of weld, with the exception of Plate Failure for Arc Spot Welds and Fillet Welds. In that case, V_M and V_F are 0.08 and 0.15 instead of 0.10 and 0.10, respectively. Changing these two values to 0.10 in both cases would not change the calibration results by any appreciable amount.

3.0 Data and Calibration Results

The data used for the calibration of the resistance factors were obtained from McGuire and Peköz [4]. A total of 342 tests were carried out on symmetric fillet, flare bevel, arc spot, and arc seam welded connections subjected to monotonically increasing static loading [4]. The breakdown of test specimens is summarised in Table 3.1. Contained in Appendix A are all of data used in the calibration procedures of this report. Figure A1 of Appendix A shows the typical weld types and failure modes according to Reference 4, with the specific descriptions of these failure modes summarized in Table A1 of Appendix A.

Table 3.1 – Number of Test Specimens Used from Reference 4

Weld Type	Number of Specimens
Arc Spot Welds	124
Arc Seam Welds	23
Longitudinal Fillet Welds	64
Transverse Fillet Welds	55
Transverse Flare-Bevel Welds	42
Longitudinal flare-Bevel Welds	32
Total	**340**

The calibration results of the McGuire and Peköz [4] data are presented in detail according to the type of welded connection, as follows.

3.1 Arc Spot Welds

In AISI[1] arc spot welds are divided into two types, i.e., Section E2.2.1 Shear and Section E 2.2.2 Tension. The data obtained from reference [4], however, only dealt with arc spot welds subjected to shear and the data are summarized in Table A2 of Appendix A.

Section E2.2.1 Shear

The governing equations are as follows.

The nominal shear strength, P_n, of each arc spot weld between sheet or sheets and supporting member shall be determined by using the smaller of either

(a) $P_n = \frac{\pi d_e^2}{4} 0.75 F_{xx}$ (*Eq*. E2.2.1-1)

$\Omega = 2.50$ (ASD)

$\phi = 0.60$ (LRFD)

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

$$P_n = 2.20\, t\, d_a\, F_u \qquad (Eq.\ E2.2.1\text{-}2)$$

$\Omega = 2.50$ (ASD)

$\phi = 0.60$ (LRFD)

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

$$P_n = 0.280\left[1 + 5.59\frac{\sqrt{E/F_u}}{d_a/t}\right] t d_a F_u \qquad (Eq.\ E2.2.1\text{-}3)$$

$\Omega = 2.50$ (ASD)

$\phi = 0.50$ (LRFD)

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

$$P_n = 1.40\, t\, d_a\, F_u \qquad (Eq.\ E2.2.1\text{-}4)$$

$\Omega = 2.50$ (ASD)

$\phi = 0.50$ (LRFD)

Where

P_n = Nominal shear strength of an arc spot weld

d = Visible diameter of outer surface of arc spot weld

d_a = Average diameter of the arc spot weld at mid-thickness of t where $d_a = (d - t)$ for a single sheet, and $(d - 2t)$ for multiple sheets (not more than four lapped sheets over a supporting member)

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

$$= 0.7d - 1.5t \text{ but} \leq 0.55d \qquad (Eq.\ E2.2.1\text{-}5)$$

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

F_{xx} = Filler metal strength designation in AWS electrode classification

F_u = Tensile strength as specified in Section A3.1 or A3.2 or as reduced for low ductility steel.

The data collected were divided according to the governing failure equation presented in Section E2.2.1-1 of AISI [1]. Failure of 37 specimens was governed by Eq. E2.2.1-1, while 55 specimens by Eq. E2.2.1-2, 12 specimens by Eq. E2.2.1-3, and 11 specimens by Eq. E2.2.1-4. The calibration results are summarised in Tables 3.2 and 3.3. The detailed comparisons can be found in Table A3 of Appendix A.

Table 3.2 – Factors of Safety and Resistance Factors for Arc Spot Welded Connections Governed by Eq. E2.2.1-1 of AISI [1]

			Sec. E2.2.1(a) Eq. E2.2.1-1
		No. of specimens (n)	37
		Mean	1.14
		S. D.	0.263
		C.O.V.	0.231
		M_m	1.10
		V_M	0.10
		F_m	1.00
		P_m	1.14
		V_f	0.10
		m	36
		C_P	1.09
		β (AISI)	3.5
		D/L (AISI)	0.20
		V_Q **(AISI)**	0.207
		β (S136)	4
		D/L (S136)	0.33
		V_Q **(S136)**	0.187
AISI Commentary	AISI	**Ω**	2.66
		ϕ	0.577
	S136	**ϕ**	0.476
Chapter F of AISI Spec	AISI	**Ω**	2.72
		ϕ	0.563
	S136	**ϕ**	0.463

The 37 specimens that were used in the calibration of Table 3.2, were specimens that were identified by the researchers of Reference 8 as having failed in weld shear.

As can be observed in Table 3.2, a factor of safety, Ω, of 2.66 and a resistance factor, ϕ, of 0.577 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.476 was obtained for a β value of 4 (S136). Taking the number of specimens into account in accordance with Chapter F of AISI [1], a factor of safety, Ω, of 2.72 and a resistance factor, ϕ, of 0.563 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.463 was obtained for a β value of 4 (S136).

Table 3.3 – Factors of Safety and Resistance Factors for Arc Spot Welded Connections Governed by Eq. E2.2.1-2, Eq. E2.2.1-3, and Eq. E2.2.1-4 AISI [1]

			Sec. E2.2.1(b)		
			Eq. 2.2.1-2	**Eq. 2.2.1-3**	**Eq. 2.2.1-4**
		No. of specimens (n)	55	12	11
		Mean	1.20	1.00	0.999
		S. D.	0.166	0.175	0.221
		C.O.V.	0.139	0.174	0.221
		M_m	1.10	1.10	1.10
		V_M	0.08	0.08	0.08
		F_m	1.00	1.00	1.00
		P_m	1.20	1.00	1.00
		V_f	0.15	0.15	0.15
		m	54	11	10
		C_P	1.06	1.32	1.36
		β (AISI)	3.5	3.5	3.5
		D/L (AISI)	0.20	0.20	0.20
		V_Q (AISI)	0.207	0.207	0.207
		β (S136)	4	4	4
		D/L (S136)	0.33	0.33	0.33
		V_Q (S136)	0.187	0.187	0.187
AISI Commentary	AISI	**Ω**	2.20	2.79	3.09
		ϕ	0.698	0.549	0.496
	S136	**ϕ**	0.591	0.459	0.408
Chapter F of AISI Spec	AISI	**Ω**	2.21	2.95	3.37
		ϕ	0.693	0.521	0.455
	S136	**ϕ**	0.586	0.431	0.368

As shown in Table 3.3 for the 55 specimens whose failure was predicted by Eq. E2.2.1-2, a factor of safety, Ω, of 2.20 and a resistance factor, ϕ, of 0.698 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.591 was obtained for a β value of 4 (S136). Taking the number of specimens into account in accordance with Chapter F, a factor of safety, Ω, of 2.21 and a resistance factor, ϕ, of 0.693 were obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.586 was obtained for a β value of 4 (S136).

For the 12 specimens whose failure was predicted by Eq. E2.2.1-3, a factor of safety, Ω, of 2.79 and a resistance factor, ϕ, of 0.549 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.459 was obtained for a β value of 4 (S136). Taking the number of specimens into account in accordance with Chapter F, a factor of safety, Ω, of 2.95 and a resistance factor, ϕ, of 0.521 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.431 was obtained for a β value of 4 (S136).

Finally, for the 11 specimens whose failure was predicted by Eq. E2.2.1-4, a factor of safety, Ω, of 3.09 and a resistance factor, ϕ, of 0.496 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.408 was obtained for a β value of 4 (S136). Taking the number of specimens into account in accordance with Chapter F, a factor of safety, Ω, of 3.37 and a resistance factor, ϕ, of 0.455 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.368 was obtained for a β value of 4 (S136).

It can be observed from Table 3.4, where the current and calculated factors of safety and resistance factors are being compared using the Commentary of AISI [2] that:

- for Eq. E2.2.1-1 the recommended factor of safety, Ω, is 6.4% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 3.8% less than the current value specified by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 29% smaller than the current value used.
- for Eq. E2.2.1-2 the recommended factor of safety, Ω, is 12% smaller than the current value used in AISI[1] and the recommended resistance factor, ϕ, is 15% greater than the current value specified by AISI[1]; while the recommended resistance factor, ϕ, for S136 [3] is 12% smaller than the current value used.
- for Eq. E2.2.1-3 the recommended factor of safety, Ω, is 12% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 10% greater than the current value specified by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 31% smaller than the current value used.
- for Eq. E2.2.1-4 the recommended factor of safety, Ω, is 24% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 0.8% smaller than the current value specified by AISI [1]; while the resistance factor, ϕ, for S136 [3] is 39% smaller than the current value used.

Table 3.4 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Arc Spot Welded Connections (Using Commentary of AISI [2])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.2.1-1	2.50	0.60	2.66	0.577	0.67	0.476
Eq. E2.2.1-2	2.50	0.60	2.20	0.698	0.67	0.591
Eq. E2.2.1-3	2.50	0.50	2.79	0.549	0.67	0.459
Eq. E2.2.1-4	2.50	0.50	3.09	0.496	0.67	0.408

If the number of specimens are taken into account, it can be observed from Table 3.5, where the current and calculated factors of safety and resistance factors are being compared using Chapter F of AISI [1] that:

- for Eq. E2.2.1-1 the recommended factor of safety, Ω, is 8.8% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 6.2% smaller than the current value specified by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 31% smaller than the current value used.
- for Eq. E2.2.1-2 the recommended factor of safety, Ω, is 12% smaller than the current value used in AISI[1] and the recommended resistance factor, ϕ, is 16% greater than the current value specified by AISI[1]; while the recommended resistance factor, ϕ, for S136 [3] is 13% smaller than the current value used.
- for Eq. E2.2.1-3 the recommended factor of safety, Ω, is 18% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 4.2% larger than the current value specified by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 36% smaller than the current value used.
- for Eq. E2.2.1-4 the recommended factor of safety, Ω, is 35% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 9% smaller than the current value specified by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 45% smaller than the current value used.

Table 3.5 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Arc Spot Welded Connections (Using Chapter F of AISI [1])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	φ	Ω	φ	φ	φ
Eq. E2.2.1-1	2.50	0.60	2.72	0.563	0.67	0.463
Eq. E2.2.1-2	2.50	0.60	2.21	0.693	0.67	0.586
Eq. E2.2.1-3	2.50	0.50	2.95	0.521	0.67	0.431
Eq. E2.2.1-4	2.50	0.50	3.37	0.455	0.67	0.368

3.2 Arc Seam Welds

A total of 23 specimens were available from Reference 4 for this weld type, which are summarized in Table A4 and the respective comparisons are shown in Table A5, both of which are located Appendix A.

In AISI [1], arc seam welds are covered as follows:

Section E2.3

Arc seam welds [Figure E2.A3] covered by this *Specification* apply only to the following joints:

(a) Sheet to thicker supporting member in the flat position.

(b) Sheet to sheet in the horizontal or flat position.

The nominal shear strength, P_n, of arc seam welds shall be determined by using the smaller of either:

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

(b) $$P_n = 2.5 t F_u \left(0.25L + 0.96 d_a\right)$$ (*Eq.* E2.3-2)

Ω=2.50 (ASD)

φ=0.60 (LRFD)

Where

P_n = Nominal shear strength of an arc seam weld

d = Width of arc seam weld

L = Length of seam weld not including the circular ends (For computation purposes, L shall not exceed 3d)

d_a = Average width of seam weld

where

d_a = (d - t) for a single sheet, and (*Eq.* E2.3-3)

(d - 2t) for a double sheet (*Eq.* E2.3-4)

d_e = Effective width of arc seam weld at fused surfaces

d_e = 0.7d - 1.5t (*Eq.* E2.3-5)

and F_u and F_{xx} are defined in Section E2.2.1. The minimum edge distance shall be as determined for the arc spot weld, Section E2.2.1.

Since only one factor of safety and one resistance factor is given for Arc Seam Welds in the AISI Specification, the data analysed and summarised in Table 3.6 makes no distinction between specimens governed by either Eq. E2.3-1 or Eq. E2.3-2.

As can be observed from Table 3.6, a factor of safety, Ω, of 2.47 and a resistance factor, ϕ, of 0.622 was obtained for a β value of 3.5 (AISI)[1], while a resistance factor, ϕ, of 0.519 was obtained for a β value of 4 (S136)[3]. Taking the number of specimens into account in accordance with Chapter F of AISI [1], a factor of safety, Ω, of 2.55 and a resistance factor, ϕ, of 0.602 was obtained for a β value of 3.5 (AISI)[1], while a resistance factor, ϕ, of 0.499 was obtained for a β value of 4 (S136)[3].

Table 3.6 – Factors of Safety and Resistance Factors for Arc Seam Welded Connections Governed by Eq. E2.3-1 or Eq. E2.3-2 of AISI [1]

			Sec. E2.3
			Eq. E2.3-1, 2
		No. of specimens (n)	23
		Mean	1.15
		S. D.	0.234
		C.O.V.	0.203
		M_m	1.10
		V_M	0.10
		F_m	1.00
		P_m	1.15
		V_f	0.10
		m	22
		C_P	1.15
		β (AISI)	3.5
		D/L (AISI)	0.20
		V_Q (AISI)	0.207
		β (S136)	4
		D/L (S136)	0.33
		V_Q (S136)	0.187
AISI Commentary	AISI	Ω	2.47
		ϕ	0.622
	S136	ϕ	0.519
Chapter F of AISI Spec	AISI	Ω	2.55
		ϕ	0.602
	S136	ϕ	0.499

It can be observed from Table 3.7, where the current and calculated factors of safety and resistance factors are being compared using the Commentary of AISI [2] that:

- for Eq. E2.3-1 of Eq. E2.3-2 the recommended factor of safety, Ω, is 1.2% smaller than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 3.7% greater than the current values specified by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 23% smaller than the current value used.

Table 3.7 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Arc Seam Welded Connections (Using Commentary of AISI [2])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.3-1 or Eq. E2.3-2	2.50	0.60	2.47	0.622	0.67	0.519

If the number of specimens are taken into account, it can be observed from Table 3.8, where the current and calculated factors of safety and resistance factors are being compared using Chapter F of AISI [1] that:

- for Eq. E2.3-1 of Eq. E2.3-2 the recommended factor of safety, Ω, is 2 % greater than the current AISI [1] and the recommended resistance factor, ϕ, is 0.3% greater than the current value specified by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 26% smaller than the current value in S136 [3].

Table 3.8 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Arc Seam Welded Connections (Using Chapter F of AISI [1])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.3-1 or Eq. E2.3-2	2.50	0.60	2.55	0.602	0.67	0.499

3.3 Longitudinal Fillet Welds

A total of 44 data values were available from Reference 4 and they are summarized in Table A6, with the respective comparisons shown in Table A7, both of which are contained in Appendix A.

In AISI [1], Longitudinal Fillet Welds are covered as follows:

Section E2.4(a)

Fillet welds covered by this *Specification* apply to the welding of joints in any position, either

(a) Sheet to sheet, or
(b) Sheet to thicker steel member.

The nominal shear strength, P_n, of a fillet weld shall be determined as follows:

(a) For longitudinal loading:

For L/t < 25 :

$$P_n = \left(1 - \frac{0.01L}{t}\right) tLF_u \qquad (Eq.\ E2.4\text{-}1)$$

Ω = 2.50 (ASD)

ϕ = 0.60 (LRFD)

For L/t ≥ 25:

$$P_n = 0.75\ tLF_u \qquad (Eq.\ E2.4\text{-}2)$$

Ω = 2.50 (ASD)

ϕ = 0.55 (LRFD)

The data collected were divided according to the governing failure equation presented in Section E2.4 of AISI[1]. Failure of 30 specimens was governed by Eq. E2.4-1, while 14 specimens by Eq. E2.4-2.

As can be observed from Table 3.9, for the 30 specimens whose failure was predicted by Eq. E2.4-1, a factor of safety, Ω, of 2.59 and a resistance factor, ϕ, of 0.592 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.505 was obtained for a β value of 4 (S136). Taking the number of specimens into account in accordance with Chapter F, a factor of safety, Ω, of 2.61 and a resistance factor, ϕ, of 0.587 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.500 was obtained for a β value of 4 (S136).

While, for the 14 specimens whose failure was predicted by Eq. E2.4-2, a factor of safety, Ω, of 3.31 and a resistance factor, ϕ, of 0.463 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.391 was obtained for a β value of 4 (S136).

Taking the number of specimens into account in accordance with Chapter F of AISI [1], a factor of safety, Ω, of 3.42 and a resistance factor, ϕ, of 0.449 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.377 was obtained for a β value of 4 (S136).

Table 3.9 – Factors of Safety and Resistance Factors for Longitudinal Fillet Welded Connections Governed by Eq. E2.4-1 or Eq. E2.4-2 of AISI [1]

			Sec. E2.4(a)	
			Eq. E2.4-1	**Eq. E2.4-2**
		No. of specimens (n)	30	14
		Mean	0.977	0.807
		S. D.	0.109	0.119
		C.O.V.	0.112	0.147
		M_m	1.10	1.10
		V_M	0.08	0.08
		F_m	1.00	1.00
		P_m	0.977	0.807
		V_f	0.15	0.15
		m	29	13
		C_P	1.11	1.27
		β (AISI)	3.5	3.5
		D/L (AISI)	0.20	0.20
		V_Q (AISI)	0.207	0.207
		β (S136)	4	4
		D/L (S136)	0.33	0.33
		V_Q (S136)	0.187	0.187
AISI Commentary	AISI	**Ω**	2.59	3.30
		ϕ	0.592	0.464
	S136	**ϕ**	0.505	0.391
Chapter F of AISI Spec	AISI	**Ω**	2.61	3.42
		ϕ	0.587	0.449
	S136	**ϕ**	0.500	0.377

It can be observed from Table 3.10, where the current and calculated factors of safety and resistance factors are being compared using the Commentary of AISI [2] that:

- for Eq. E2.4-1 the recommended factor of safety, Ω, is 3.6% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 1.3% smaller than the current values specified by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 19% smaller than the current value used.
- for Eq. E2.4-2 the recommended factor of safety, Ω, is 32% greater than the current value used in AISI[1] and the recommended resistance factor, ϕ, is

16% smaller than the current value adopted by AISI[1]; while the recommended resistance factor, ϕ, for S136 [3] is 37% smaller than the current value used.

Table 3.10 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Longitudinal Fillet Welded Connections (Using Commentary of AISI [2])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.4-1	2.50	0.60	2.59	0.592	0.67	0.505
Eq. E2.4-2	2.50	0.55	3.31	0.463	0.67	0.391

If the number of specimens are taken into account, it can be observed from Table 3.11, where the current and calculated factors of safety and resistance factors are being compared using Chapter F of AISI [1] that:

- for Eq. E2.4-1 the recommended factor of safety, Ω, is 4.4% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 2.2% smaller than the current values adopted by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 25% smaller than the current value used.
- for Eq. E2.4-2 the recommended factor of safety, Ω, is 37% greater than the current value used in AISI[1] and the recommended resistance factor, ϕ, is 18% smaller than the current value adopted by AISI[1]; while the recommended resistance factor, ϕ, for S136 [3] is 42% smaller than the current value.

Table 3.11 – Comparison Between Current and Calculated Factors of Safety and Resistance Factors for Longitudinal Fillet Welded Connections (Using Chapter F of AISI [1])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.4-1	2.50	0.60	2.61	0.587	0.67	0.500
Eq. E2.4-2	2.50	0.55	3.42	0.449	0.67	0.377

3.4 Transverse Fillet Welds

A total of 54 specimens were available in this category and they are summarized in Table A8, with the respective comparisons shown in Table A9 of Appendix A.

In AISI [1], Transverse Fillet Welds are covered as follows:

Section E2.4 (b)

Fillet welds covered by this *Specification* apply to the welding of joints in any position, either

(a) Sheet to sheet, or
(b) Sheet to thicker steel member.

The nominal shear strength, P_n, of a fillet weld shall be determined as follows:

(b) For transverse loading:

$$P_n = tLF_u \quad (Eq.\ E2.4\text{-}3)$$

$\Omega = 2.50$ (ASD)

$\phi = 0.60$ (LRFD)

where t = Least value of t_1 or t_2, Figures E2.A4 and E2.4B [1]; all other terms were defined previously

It can be observed from Table 3.12, which shows the calibrated results, that a factor of safety, Ω, of 2.38 and a resistance factor, ϕ, of 0.643 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.556 was obtained for a β value of 4 (S136). Taking the number of specimens into account in accordance with Chapter F of AISI [1], a factor of safety, Ω, of 2.40 and a resistance factor, ϕ, of 0.640 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.553 was obtained for a β value of 4 (S136).

Table 3.12 – Factors of Safety and Resistance Factors for Transverse Fillet Welded Connections Governed by Eq. E2.4-3 of AISI [1]

			Sec. E2.4(b)
			Eq. E2.4-3
		No. of specimens (n)	54
		Mean	1.00
		S. D.	0.109
		C.O.V.	0.109
		M_m	1.10
		V_M	0.10
		F_m	1.00
		P_m	1.00
		V_f	0.10
		m	53
		C_P	1.06
		β (AISI)	3.5
		D/L (AISI)	0.20
		V_Q (AISI)	0.207
		β (S136)	4
		D/L (S136)	0.33
		V_Q (S136)	0.187
AISI Commentary	AISI	**Ω**	2.38
		ϕ	0.643
	S136	**ϕ**	0.556
Chapter F of AISI Spec	AISI	**Ω**	2.40
		ϕ	0.640
	S136	**ϕ**	0.553

It can be observed from Table 3.13, where the current and calculated factors of safety and resistance factors are being compared using the Commentary of AISI [2] that:

- for Eq. E2.4-3 the recommended factor of safety, Ω, is 64.0% smaller than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 7.2% greater than the current values adopted by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 17% smaller than the current value used.

Table 3.13 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Transverse Fillet Welded Connections (Using Commentary of AISI [2])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.4-3	2.50	0.60	2.38	0.643	0.67	0.556

If the number of specimens are taken into account, it can be observed from Table 3.14, where the current and calculated factors of safety and resistance factors are being compared using Chapter F of AISI [1] that:

- for Eq. E2.4-3 the recommended factor of safety, Ω, is 4.0% smaller than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 6.6% greater than the current values adopted by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 17% smaller than the current value used.

Table 3.14 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Transverse Fillet Welded Connections (Using Chapter F of AISI [1])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.4-3	2.50	0.60	2.40	0.640	0.67	0.553

3.5 Transverse Flare-Bevel Groove Welds

A total of 42 data values were available from Reference 4 and they are summarized in Table A10, with the respective comparisons in Table 1A1 of Appendix A.

In AISI [1], Transverse flare-bevel groove welds are covered as follows:

Section E2.5 (a)

Flare groove welds covered by this *Specification* apply to welding of joints in any position, either:

(a) Sheet to sheet for flare-V groove welds, or
(b) Sheet to sheet for flare-bevel groove welds, or
(c) Sheet to thicker steel member for flare-bevel groove welds.

The nominal shear strength, P_n, of a flare groove weld shall be determined as follows:

(a) For flare-bevel groove welds, transverse loading [see Figure E2.A5]:

$$P_n = 0.833 t L F_u \qquad (Eq.\ E2.5\text{-}1)$$

$\Omega = 2.50$ (ASD)

$\phi = 0.55$ (LRFD)

Where

P_n = Limiting nominal strength of the weld

L = Length of the weld

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

F_u = Tensile strength as specified in Section A3.1 or A3.2 or as reduced for low ductility steel.

As can be observed from Table 3.15, a factor of safety, Ω, of 2.60 and a resistance factor, ϕ, of 0.591 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.501 was obtained for a β value of 4 (S136). Taking the number of specimens into account in accordance with Chapter F of AISI [1], a factor of safety, Ω, of 2.63 and a resistance factor, ϕ, of 0.584 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.494 was obtained for a β value of 4 (S136).

Table 3.15 – Factors of Safety and Resistance Factors for Transverse Flare-Bevel Groove Welded Connections Governed by Eq. E2.5-1 of AISI [1]

It can be observed from Table 3.16, where the current and calculated factors of safety and resistance factors are being compared using the Commentary of AISI [2] that:

- for Eq. E2.4-3 the recommended factor of safety, Ω, is 4.0% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 7.5% greater than the current values adopted by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 25% smaller than the current value used.

Table 3.16 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Transverse Flare-Bevel Groove Welded Connections (Using Commentary of AISI [2])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.5-1	2.50	0.55	2.60	0.591	0.67	0.501

If the number of specimens are taken into account, it can be observed from Table 3.17, where the current and calculated factors of safety and resistance factors are being compared using Chapter F of AISI [1] that:

- for Eq. E2.4-3 the recommended factor of safety, Ω, is 5.2% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 6.2% greater than the current values adopted by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 26% smaller than the current value used.

Table 3.17 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Transverse Flare-Bevel Groove Welded Connections (Using Chapter F of AISI [1])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.5-1	2.50	0.55	2.63	0.584	0.67	0.494

3.6 Longitudinal Flare-Bevel Groove Welds

A total of 10 data values were used from Reference 4 and they are summarized in Table 1A2, with the respective comparisons shown in Table 1A3 of Appendix A.

In AISI [1], Transverse Flare Bevel Welds are covered as follows.

> The nominal shear strength, P_n, of a flare groove weld shall be determined as follows:
>
> (b) For flare groove welds, longitudinal loading [see Figures E2.5B through E2.5G]:
>
> (1) For $t \le t_w < 2t$ or if the lip height, h, is less than weld length, L:
>
> $$P_n = 0.75tLF_u \quad (Eq.\ E2.5\text{-}2)$$
>
> $\Omega = 2.50$ (ASD)
>
> $\phi = 0.55$ (LRFD)
>
> (2) For $t_w \ge 2$ t and the lip height, h, is equal to or greater than weld length L:
>
> $$P_n = 1.50tLF_u \quad (Eq.\ E2.5\text{-}3)$$
>
> $\Omega = 2.50$ (ASD)
>
> $\phi = 0.55$ (LRFD)

The data obtained from McGuire and Peköz [4] fell into category (1) above (i.e., $t \le t_w < 2t$), therefore only Eq. E2.5-2 was used in the computation of the weld strength. In addition, of the original 32 specimens [4], only 10 were used as indicated in reference [8].

It can be observed from Table 3.18 that a factor of safety, Ω, of 2.71 and a resistance factor, ϕ, of 0.565 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.478 was obtained for a β value of 4 (S136). Taking the number of specimens into account in accordance with Chapter F of AISI [1], a factor of safety, Ω, of 2.90 and a resistance factor, ϕ, of 0.529 was obtained for a β value of 3.5 (AISI), while a resistance factor, ϕ, of 0.442 was obtained for a β value of 4 (S136).

Table 3.18 – Factors of Safety and Resistance Factors for Longitudinal Flare-Bevel Groove Welded Connections Governed by Eq. E2.5-2 of AISI [1]

			Sec. E2.5(b)
			Eq. E2.5-2
		No. of specimens (n)	10
		Mean	0.970
		S. D.	0.163
		C.O.V.	0.168
		M_m	1.10
		V_M	0.10
		F_m	1.00
		P_m	0.970
		V_f	0.10
		m	9
		C_P	1.41
		β (AISI)	3.5
		D/L (AISI)	0.20
		V_Q (AISI)	0.207
		β (S136)	4
		D/L (S136)	0.33
		V_Q (S136)	0.187
AISI Commentary	AISI	Ω	2.71
		ϕ	0.565
	S136	ϕ	0.478
Chapter F of AISI Spec	AISI	Ω	2.90
		ϕ	0.529
	S136	ϕ	0.442

It can be observed from Table 3.19, where the current and calculated factors of safety and resistance factors are being compared using the Commentary of AISI [2] that:

- for Eq. E2.5-2 the recommended factor of safety, Ω, is 8.4% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 5.8% smaller than the current values adopted by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 29% smaller than the current value used.

Table 3.19 – Comparison Between Current and Calculated Factors of Safety and Resistance Factors for Longitudinal Flare-Bevel Groove Welded Connections (Using Commentary of AISI [2])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.5-2	2.50	0.55	2.72	0.564	0.67	0.478

If the number of specimens are taken into account, it can be observed from Table 3.20, where the current and calculated factors of safety and resistance factors are being compared using Chapter F of AISI [1] that:

- for Eq. E2.5-2 the recommended factor of safety, Ω, is 16% greater than the current value used in AISI [1] and the recommended resistance factor, ϕ, is 12% smaller than the current values adopted by AISI [1]; while the recommended resistance factor, ϕ, for S136 [3] is 34% smaller than the current value used.

Table 3.20 – Comparison Between Current and Calculated Values of Factors of Safety and Resistance Factors for Longitudinal Flare-Bevel Groove Welded Connections (Using Chapter F of AISI [1])

	AISI				S136	
	Current		Calculated		Current	Calculated
	Ω	ϕ	Ω	ϕ	ϕ	ϕ
Eq. E2.5-2	2.50	0.55	2.90	0.528	0.67	0.442

3.7 Tearing of Plate Material

In Section E2.7 of the 1999 Supplement to the AISI Specification the following expression is given for calculating the nominal tensile strength based on fracture in the gross section of a longitudinally welded plate:

$$P_n = A_g F_u \qquad (Eq.\ E2.7\ \text{-}1)$$

Where
A_g = gross area of plate
F_u = ultimate strength of plate

Twenty specimens from Reference [4] were grouped under "Longitudinal Fillet Welds" as having failed by tensile tearing across the plate. No data for plate tearing was contained in Reference 4 for "Transverse Fillet Welds". The data taken from Reference 4 is summarized in Table 1A4. Using Equation E2.7-1, the respective comparisons are shown in Table 1A5 of Appendix A. As can be observed from Table 1A5, the correlation results are conservative.

In Reference 4, the following equation was proposed for sheet tearing:

$$P_n = 1.6\, t_{av}\, S_{av}\, \sigma_u \qquad (2)$$

Where
t_{av} = average cover plate thickness

S_{av} = average cover plate width
σ_u = measured ultimate strength of the cover plate material

The respective correlation results are summarized in Table 1A6 of Appendix A. As can be observed from Table 1A6, the mean and coefficient of variation of the 20 specimens result in a much better correlation when Equation (2) is used.

3.8 Summary of Calibrated Results

The calibration results of this study are summarized in Tables 3.21 and 3.22. More specifically, Table 3.21 contains the results based on using the Commentary to the AISI Specification and the results using Chapter F of the AISI Specification are tabulated in Table 3.22.

Table 3.21 – Calibrated Factors of Safety and Resistance Factors (Using Commentary of AISI [2])

AISI Equations	AISI				S136	
	Ω		ϕ		ϕ	
	Current	Calibrated	Current	Calibrated	Current	Calibrated
Eq. E2.2.1-1	2.50	**2.66**	0.60	**0.577**	0.67	**0.476**
Eq. E2.2.1-2	2.50	**2.20**	0.60	**0.698**	0.67	**0.591**
Eq. E2.2.1-3	2.50	**2.79**	0.50	**0.549**	0.67	**0.459**
Eq. E2.2.1-4	2.50	**3.09**	0.50	**0.496**	0.67	**0.408**
Eq. E2.3-1 or Eq. E2.3-2	2.50	**2.47**	0.60	**0.622**	0.67	**0.519**
Eq. E2.4-1	2.50	**2.59**	0.60	**0.592**	0.67	**0.505**
Eq. E2.4-2	2.50	**3.31**	0.55	**0.463**	0.67	**0.391**
Eq. E2.4-3	2.50	**2.38**	0.60	**0.643**	0.67	**0.556**
Eq. E2.5-1	2.50	**2.60**	0.55	**0.591**	0.67	**0.501**
Eq. E2.5-2	2.50	**2.72**	0.55	**0.564**	0.67	**0.478**

Table 3.22 – Calibrated Factors of Safety and Resistance Factors (Using Chapter F of AISI [1])

AISI Equations	AISI				S136	
	Ω		ϕ		ϕ	
	Current	Calibrated	Current	Calibrated	Current	Calibrated
Eq. E2.2.1-1	2.50	**2.72**	0.60	**0.563**	0.67	**0.463**
Eq. E2.2.1-2	2.50	**2.21**	0.60	**0.693**	0.67	**0.586**
Eq. E2.2.1-3	2.50	**2.95**	0.50	**0.521**	0.67	**0.431**
Eq. E2.2.1-4	2.50	**3.37**	0.50	**0.455**	0.67	**0.368**
Eq. E2.3-1 or Eq. E2.3-2	2.50	**2.55**	0.60	**0.602**	0.67	**0.499**
Eq. E2.4-1	2.50	**2.61**	0.60	**0.587**	0.67	**0.500**
Eq. E2.4-2	2.50	**3.42**	0.55	**0.449**	0.67	**0.377**
Eq. E2.4-3	2.50	**2.40**	0.60	**0.640**	0.67	**0.553**
Eq. E2.5-1	2.50	**2.63**	0.55	**0.584**	0.67	**0.494**
Eq. E2.5-2	2.50	**2.90**	0.55	**0.528**	0.67	**0.442**

4.0 Proposed Factors of Safety and Resistance Factors for Design

The resistance factors, ϕ, summarised in Section 3 of this report were rounded off to the nearest 0.05 values, while the factors of safety, Ω, were recalculated using equation 2.11, to obtain the recommended values summarised in Tables 4.1 and 4.2.

Table 4.1 – Proposed Factors of Safety and Resistance Factors for Design (Using Commentary of AISI [2])

AISI Equations	AISI				S136	
	Ω		ϕ		ϕ	
	Current	Proposed	Current	Proposed	Current	Proposed
Eq. E2.2.1-1	2.50	**2.55**	0.60	**0.60**	0.67	**0.50**
Eq. E2.2.1-2	2.50	**2.20**	0.60	**0.70**	0.67	**0.60**
Eq. E2.2.1-3	2.50	**2.80**	0.50	**0.55**	0.67	**0.45**
Eq. E2.2.1-4	2.50	**3.05**	0.50	**0.50**	0.67	**0.40**
Eq. E2.3-1 or Eq. E2.3-2	2.50	**2.55**	0.60	**0.60**	0.67	**0.50**
Eq. E2.4-1	2.50	**2.55**	0.60	**0.60**	0.67	**0.50**
Eq. E2.4-2	2.50	**3.05**	0.55	**0.50**	0.67	**0.40**
Eq. E2.4-3	2.50	**2.35**	0.60	**0.65**	0.67	**0.60**
Eq. E2.5-1	2.50	**2.55**	0.55	**0.60**	0.67	**0.50**
Eq. E2.5-2	2.50	**2.80**	0.55	**0.55**	0.67	**0.45**

Table 4.2 – Proposed Factors of Safety and Resistance Factors for Design (Using Chapter F of AISI [1])

AISI Equations	AISI				S136	
	Ω		ϕ		ϕ	
	Current	Proposed	Current	Proposed	Current	Proposed
Eq. E2.2.1-1	2.50	**2.80**	0.60	**0.55**	0.67	**0.45**
Eq. E2.2.1-2	2.50	**2.20**	0.60	**0.70**	0.67	**0.60**
Eq. E2.2.1-3	2.50	**3.05**	0.50	**0.50**	0.67	**0.45**
Eq. E2.2.1-4	2.50	**3.40**	0.50	**0.45**	0.67	**0.35**
Eq. E2.3-1 or Eq. E2.3-2	2.50	**2.55**	0.60	**0.60**	0.67	**0.50**
Eq. E2.4-1	2.50	**2.55**	0.60	**0.60**	0.67	**0.50**
Eq. E2.4-2	2.50	**3.40**	0.55	**0.45**	0.67	**0.40**
Eq. E2.4-3	2.50	**2.35**	0.60	**0.65**	0.67	**0.55**
Eq. E2.5-1	2.50	**2.55**	0.55	**0.60**	0.67	**0.50**
Eq. E2.5-2	2.50	**3.05**	0.55	**0.50**	0.67	**0.45**

5.0 Proposed Factors of Safety for Other Cases of Welded Connections

A number of other cases of welded connections are contained in the AISI Specification [1] for which no calibrations were carried out in this study. The reason for this was simply due to the unavailability of cold formed steel data in the literature. As a result, it was decided to use the current resistance factors to establish the respective factors of safety in accordance with Equation 2.11, the results of which are summarized in Table 5.1.

Table 5.1 – Proposed Factors of Safety for Other Cases of Welded Connections

AISI Item	AISI		
	Ω		ϕ
	Current	Proposed	Current
Eq. E2.1-1	2.50	**1.70**	0.90
Eq. E2.1-2	2.50	**1.90**	0.80
Eq. E2.1-3	2.50	**1.70**	0.90
Section E2.2.1($F_u \geq F_{sy}$)	2.00	**2.20**	0.70
Section E2.2.1 ($F_u < F_{sy}$)	2.22	**2.55**	0.60
Section E2.2.2	2.50	**2.55**	0.60
Section E2.3	2.50	**2.55**	0.60
Eq. E2.4-4	2.50	**2.55**	0.60
Eq. E2.5-3	2.50	**2.80**	0.55
Eq. E2.5-4	2.50	**2.55**	0.60
Section E2.6	2.50	**2.35**	0.65

6.0 Other Consideration

To maintain consistency with the way in which other factors of safety and resistance factors are expressed in Section E2 of the Specification, the data for some welded connections were grouped together. More specifically, the data of Eq's. E2.2.1-2, E2.2.1-3 and E2.2.1-4 were grouped together in one single calibration, with the results summarised in Table 6.1. This was also done with the data of Eq's. E2.4-1 and E4.2-2, with the results summarised in Table 6.2.

Table 6.1 – Combined Factors of Safety and Resistance Factors for Arc Spot Welded Connections Governed by Eq. E2.2.1-2, 3, 4 of AISI [1]

		Sec. E2.2.1(b)
		Eq. E2.2.1-2, 3, 4
	No. of specimens (n)	78
	Mean	1.14
	S. D.	0.196
	C.O.V.	0.172
	M_m	1.10
	V_M	0.08
	F_m	1.00
	P_m	1.14
	V_f	0.15
	m	77
	C_P	1.04
	β (AISI)	3.5
	D/L (AISI)	0.20
	V_Q **(AISI)**	0.207
	β (S136)	4
	D/L (S136)	0.33
	V_Q **(S136)**	0.187
AISI	**Ω**	2.45
	ϕ	0.626
S136	**ϕ**	0.524
AISI	**Ω**	2.47
	ϕ	0.622
S136	**ϕ**	0.520

Table 6.2 – Combined Factors of Safety and Resistance Factors for Longitudinal Fillet Welded Connections Governed by Eq. E2.4-1, 2 of AISI [1]

		Sec. E2.4 (a)
		Eq. E2.4-1,2
	No. of specimens (n)	44
	Mean	0.923
	S. D.	0.137
	C.O.V.	0.148
	M_m	1.10
	V_M	0.08
	F_m	1.00
	P_m	0.92
	V_f	0.15
	m	43
	C_P	1.07
	β (AISI)	3.5
	D/L (AISI)	0.20
	V_Q (AISI)	0.207
	β (S136)	4
	D/L (S136)	0.33
	V_Q (S136)	0.187
AISI	Ω	2.90
	ϕ	0.529
S136	ϕ	0.447
AISI	Ω	2.92
	ϕ	0.524
S136	ϕ	0.442

7.0 Conclusions

Currently in the AISI Specification [1] different resistance factors are given for the various cases of welded connections, however, only one factor of safety is presented for all of these cases. This is not consistent with the variable resistance factors.

Using the data of McGuire and Peköz [4], calibrations for factors of safety and resistance factors based on AISI [1] have been established and are contained in this report. Similar calibrations were also carried out for S136 [3]. More specifically, it can be observed from Table 4.1 that there is a need to review the current factor of safety values, Ω, and resistance factors, ϕ, in Section E2 of AISI[1].

Finally, it can be concluded that the calibration of the resistance factors of this study, show strong agreement with the existing resistance factors of the AISI Specification, as developed in References 5 and 8.

It is recommended that the proposed calibrated values of Tables 4.1 and 5.1 be used by AISI in the formulation of a ballot to initiate a change in Section E2 of welded connections.

8.0 References

1 – American Iron and Steel Institute, “Specification for the Design of Cold-Formed Steel Structural Members”, 1996 Edition, Washington, DC, U.S.A., 1996 – Including Supplement No.1, July 30, 1999.

2 - American Iron and Steel Institute, “Commentary of the 1996 Edition of the Cold-Formed Specification”, 1996 Edition, Washington, DC, U.S.A., 1996.

3 – Canadian Standards Association, “S136 – Cold Formed Steel Structural Members”, 1994 Edition, Toronto, ON, Canada, 1994.

4 – McGuire, W., Peköz, T., “Welding of Sheet Steel”, Report SG-79-2, American Iron and Steel Institute, January 1979.

5 – Hsiao, L., Yu, W. W., Galambos, T. V., “Load and Resistance Factor Design of Cold Formed Steel, Calibration of the AISI Design Provisions”, Ninth Progress Report, Civil Engineering Study 88-2, University of Missouri-Rolla, Rolla, Missouri, U.S.A., 1998.

6 – Beshara, B., “Web Crippling of Cold Formed Steel Members”, M.A.Sc. Thesis, University of Waterloo, Waterloo, Canada, 1999.

7 – Canadian Standards Association, “Commentary on CSA Standard S136-94, Cold Formed Steel Structural Members”, 1995 Edition, Toronto, ON, Canada, 1995.

8 – Galambos, T. V., Yu, W. W., “Load and Resistance Factor Design of Cold-Formed Steel: Revised Tentative Recommendations – Load and Resistance Factor Design Criteria for Cold-Formed Structural Members with Commentary”, Seventh Progress Report, Civil Engineering Study 85-2, University of Missouri-Rolla, Rolla, Missouri, U.S.A., 1985.

APPENDIX A

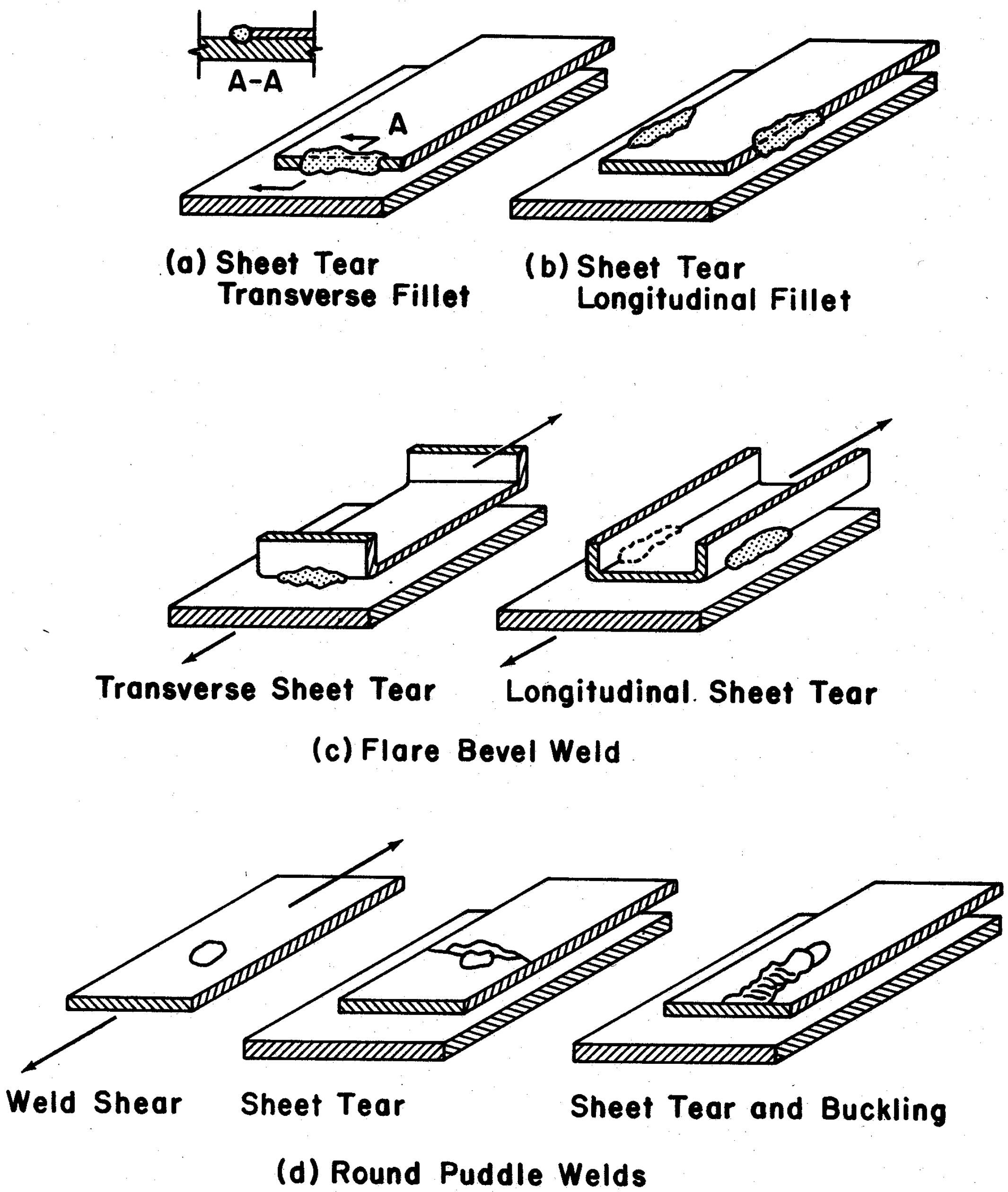

Figure A1 – Typical Failure Modes of Welded Connections
(Taken from Reference 4)

Table A1 – Description of Specific Failure Modes Used in Reference 4

Failure Mode	**Description**
PC	Tearing along the weld contour
PT	Tensile tearing along the plate
WS	Weld shear
PL	Out-of-plane plastic deformation
W	Weld failure due to the bending of the cover plate
PS	Shearing of the sheets along the sides of the weld

Table A2 - Arc Spot Weld Data taken from Reference 4

Specimen Designation	Observed Data σ_u (ksi)	d (in.)	t_{av} (in.)	P_{uo} (kips)	Failure
A A/B 18/7 D1	67.0	0.790	0.049	13.5	PC+PL+PT
A A/B 18/7 D2	67.0	0.800	0.050	12.4	PC+PL+PT
A A/B 18/7 D3	67.0	0.810	0.049	13.1	PC+PL+PT
A A/B 18/7 D4	67.0	0.850	0.050	14.4	PC+PL+PT
A A/B 28/7 C1	109.8	0.640	0.016	2.76	PS+PB
A A/B 28/7 C2	109.8	0.640	0.016	1.94	PS+PB
A A/B 28/7 C3	109.8	0.570	0.016	2.60	PS+PB
A A/B 28/7 C4	109.8	0.590	0.016	2.54	PS+PB
A A/B 28/7 C5	109.8	0.560	0.016	2.72	PS+PB
A A/B 18/7 D1	64.7	0.780	0.044	7.68	PL+PS+PB
A A/B 18/7 D2	64.7	0.740	0.044	9.04	PL+PS+PB
A A/B 18/7 D3	64.7	0.730	0.044	8.02	PL+PB+PT
A A/B 18/7 D4	64.7	0.730	0.044	10.0	PL+PB+PT+WS
A A/B 18/7 D5	64.7	0.740	0.044	10.0	PL+PB+PT+WS
A E/B 28/7 C1	98.0	0.430	0.018	1.90	PL+PB
A E/B 28/7 C2	98.0	0.440	0.018	2.20	PL+PS+PB
A E/B 28/7 C3	98.0	0.460	0.018	1.40	PL+PB
A E/B 28/7 C4	98.0	0.520	0.018	3.00	PL+PS+PB
A A/B 12/7 D1	51.1	0.790	0.108	13.5	WS
A A/B 12/7 D2	51.1	0.780	0.108	8.84	WS
A A/B 12/7 D3	51.1	0.780	0.108	8.11	WS
A A/B 12/7 D4	51.1	0.800	0.108	8.22	WS
A A/B 12/7 D5	51.1	0.820	0.108	11.3	WS
A E/C 28/16 C1	98.0	0.390	0.018	2.55	PL+PS+PB
A E/C 28/16 C2	98.0	0.400	0.018	1.36	PL+PB+PT
A E/C 28/16 C3	98.0	0.410	0.018	2.00	PL+PS+PB+PP
A E/C 28/16 C4	98.0	0.410	0.018	2.30	PB+PT
A E/C 28/16 C5	98.0	0.440	0.018	2.70	PB+PL
A E/B 14/7 D1	56.4	1.00	0.081	28.3	PS+PB+PL
A E/B 14/7 D2	56.4	1.01	0.081	27.6	PS+PB+PL
A E/B 14/7 D3	56.4	1.03	0.081	27.8	PS+PB+PL
A E/B 14/7 D4	56.4	1.00	0.081	28.9	PS+PB+PL
A E/B 14/7 D5	56.4	1.10	0.082	27.9	PS+PB+PL
A E/B 18/7 D1	56.4	0.870	0.054	13.9	PS+PB+PL
A E/B 18/7 D2	56.4	0.810	0.054	15.0	PS+PB+PL
A E/B 18/7 D3	56.4	0.830	0.055	14.5	PS+PB+PL
A E/B 18/7 D4	56.4	0.870	0.054	14.5	PS+PB+PL
A E/B 18/7 D5	56.4	0.880	0.054	14.0	PS+PB+PL
A E/B 18/16 D1	56.4	0.790	0.055	12.9	PS+PB+PL+W
A E/B 18/16 D2	56.4	0.800	0.056	10.8	PS+W+PL
A E/B 18/16 D3	56.4	0.810	0.056	12.4	PS+PB+PL+W
A E/B 18/16 D4	56.4	0.830	0.054	10.9	PS+PB+PL
A E/B 18/16 D5	56.4	0.850	0.054	13.2	PS+W+PL
A A/B 12/7 D(B-C)1	54.9	0.900	0.101	20.6	WS
A A/B 12/7 D(B-C)2	54.9	0.920	0.101	24.8	WS
A A/B 12/7 D(B-C)3	54.9	0.920	0.102	20.3	WS
A A/B 12/7 D(F-C)1	54.9	0.920	0.101	24.1	WS
A A/B 12/7 D(F-C)2	54.9	0.950	0.101	24.9	WS

Table A2 - Arc Spot Weld Data taken from Reference 4 (continued)

Specimen Designation	Observed Data σ_u (ksi)	d (in.)	t_{av} (in.)	P_{uo} (kips)	Failure
A A/B 12/7 D(E-C)1	54.9	0.950	0.101	24.1	WS+W
A A/B 12/7 D(E-C)2	54.9	0.980	0.102	24.1	WS
A A/B 18/7 D(B-C)1	59.0	0.800	0.047	11.7	PC+PL+W
A A/B 18/7 D(B-C)2	59.0	0.850	0.047	10.0	PC+PL+W
A A/B 18/7 D(B-C)3	59.0	0.790	0.047	10.0	PC+PL+PS+W
A A/B 18/7 D(F-C)1	59.0	0.820	0.047	11.1	PC+PL+PS+W
A A/B 18/7 D(F-C)2	59.0	0.840	0.047	12.7	PC+PL+PS+W
A A/B 18/7 D(F-C)3	59.0	0.850	0.047	11.8	PC+PL+W
A A/B 18/7 D(E-C)1	59.0	0.870	0.047	9.74	PC+PL+W
A A/B 18/7 D(E-C)2	59.0	0.830	0.047	11.5	PC+PL+W
A A/B 18/7 D(E-C)3	59.0	0.860	0.047	10.8	PC+PL+W
A A/B 12/7 D(AA-C)1	54.9	1.04	0.101	24.5	WS
A A/B 12/7 D(AA-C)2	54.9	0.960	0.101	22.5	WS+PS+PB
A A/B 12/7 D(AA-C)3	54.9	0.900	0.101	14.0	WS
A A/B 18/7 D(BB-C)1	59.0	0.850	0.048	12.6	PC+PS+W
A A/B 18/7 D(BB-C)2	59.0	0.780	0.048	11.1	PC+PS+W
A A/B 12/7 C(E-AA)2	54.9	0.850	0.101	10.7	WS
A A/B 12/7 C(E-D)1	54.9	1.00	0.101	28.7	WS+PC+W
A A/B 12/7 C(E-D)2	54.9	0.970	0.101	26.5	WS+PC+W+PL
A A/B 12/7 C(E-D)3	54.9	0.990	0.101	29.1	WS+PL
A A/B 18/7 C(E-AA)1	59.0	0.640	0.047	10.0	PC+W+PS
A A/B 18/7 C(E-AA)2	59.0	0.620	0.047	7.46	PC+W+PS
A A/B 18/7 C(E-AA)3	59.0	0.650	0.047	10.5	PC+W+PS
A A/B 24/7 C(E-AA)1	107.6	0.540	0.024	3.80	PS+PB
A A/B 24/7 C(E-AA)2	107.6	0.600	0.024	4.48	PS+PB
A A/B 24/7 C(E-AA)3	107.6	0.560	0.024	4.90	PS+PB
A E/B 24/7 D(E-C)1	107.6	0.720	0.024	6.00	PS+PT+PB+W
A E/B 24/7 D(E-C)2	107.6	0.710	0.024	6.30	PS+PB+W
A E/B 24/7 D(E-C)3	107.6	0.730	0.024	6.16	PS+PB+W
A A/B 10/7 D(E-CC)1	48.8	1.04	0.139	26.1	WS
A A/B 10/7 D(E-CC)2	48.8	1.05	0.139	20.9	WS
A A/B 10/7 D(E-E)1	48.8	1.14	0.139	34.5	WS
A A/B 10/7 D(E-E)2	48.8	1.24	0.140	28.3	WS
B A/B 18/7 D1	67.0	1.39	0.095	28.6	PC+PT+PL
B A/B 18/7 D2	67.0	1.35	0.095	37.3	PC+PT+PL
B A/B 18/7 D3	67.0	1.37	0.095	32.4	PC+PT+PL
B A/B 18/7 D4	67.0	1.41	0.097	26.3	PC+PT+W
B A/B 18/7 D1S	64.7	0.770	0.088	12.7	WS
B A/B 18/7 D2S	64.7	0.820	0.088	16.2	WS
B A/B 18/7 D3S	64.7	0.820	0.088	15.4	WS
B A/B 18/7 D4S	64.7	0.720	0.088	11.7	WS
B A/B 18/7 D5S	64.7	0.820	0.088	8.60	WS
B A/B 12/7 D1	51.1	0.770	0.216	10.8	WS
B A/B 12/7 D2	51.1	0.830	0.216	6.00	WS
B A/B 12/7 D3	51.1	0.840	0.216	5.00	WS
B E/C 28/16 C1	98.0	0.380	0.036	3.78	PL+PB+PT
B E/C 28/16 C2	98.0	0.450	0.036	4.72	PL+PB+PP
B E/C 28/16 C3	98.0	0.420	0.036	4.16	PL+PB+PP

Table A2 - Arc Spot Weld Data taken from Reference 4 (continued)

	Observed Data				
Specimen Designation	σ_u (ksi)	d (in.)	t_{av} (in.)	P_{uo} (kips)	Failure
B E/C 28/16 C4	98.0	0.380	0.036	3.48	PL+PB+PP
B A/B 14/7 D(A-C)1	47.6	1.01	0.154	17.2	WS
B A/B 14/7 D(A-C)2	47.6	1.08	0.155	20.9	WS
B A/B 14/7 D(D-C)1	47.6	1.04	0.154	16.1	WS
B A/B 14/7 D(D-C)2	47.6	0.950	0.154	11.8	WS
B A/B 14/7 D(F-C)1	47.6	1.00	0.154	14.8	WS
B A/B 14/7 D(F-C)2	47.6	0.960	0.153	16.5	WS
B A/B 18/7 D(A-C)1	59.0	0.960	0.094	22.4	PC+PL+W+PT
B A/B 18/7 D(A-C)2	59.0	1.00	0.094	24.5	PC+PS+PL
B A/B 18/7 D(A-C)3	59.0	0.950	0.094	21.7	PC+PL+W+PS
B A/B 18/7 D(D-C)1	59.0	1.01	0.093	23.4	PC+PS+W+PL
B A/B 18/7 D(D-C)2	59.0	0.940	0.094	24.1	WS+PC+PL
B A/B 18/7 D(D-C)3	59.0	0.920	0.094	22.2	PC+PS+W+PL
B A/B 18/7 D(F-C)1	59.0	1.04	0.093	24.9	WC+PS+PL
B A/B 18/7 D(F-C)2	59.0	1.02	0.093	24.5	PC+PS+W
B A/B 18/7 D(F-C)3	59.0	0.980	0.092	24	PC+PS+PL
B A/B 14/7 D(D-E)1	47.6	1.16	0.153	38.9	WS
B A/B 14/7 D(D-E)2	47.6	1.17	0.153	39.4	WS
B A/B 28/7 C(C-AA)1	105.4	0.700	0.039	9.18	PS+PB+W
B A/B 28/7 C(C-AA)2	105.4	0.720	0.039	8.84	PS+PB+W
B A/B 28/7 C(C-AA)3	105.4	0.730	0.039	9.54	PS+PB+W
B A/B 18/7 C(D-AA)1	59.0	0.750	0.093	18.9	WS
B A/B 18/7 C(D-AA)2	59.0	0.740	0.094	12.6	WS
B A/B 18/7 D(D-D)1	59.0	1.20	0.094	28.6	PC+PS+W
B A/B 18/7 D(D-D)2	59.0	1.20	0.094	30.1	PC+PS+W
B A/B 18/7 D(D-D)3	59.0	1.25	0.093	31	PC+PS+W
B A/B 14/7 D(E-D)1	47.6	1.09	0.153	18.8	
B A/B 14/7 D(E-D)2	47.6	1.08	0.154	22.5	
				No. of specimens	124

Table A3 – Arc Spot Weld Data and Comparison

Specimen Designation	σ_u (ksi)	d (in.)	t_{av} (in.)	P_{uo} (kips)	Failure	d_e (in.)	d_a (in.)	d_a/t	Eq. E2.2.1-1 P_n (kips)	Eq. E2.2.1-1 P_{uo}/P_n	Eq. E2.2.1-2 P_n (kips)	Eq. E2.2.1-2 P_{uo}/P_n	Eq. E2.2.1-3 P_n (kips)	Eq. E2.2.1-3 P_{uo}/P_n	Eq. E2.2.1-4 P_n (kips)	Eq. E2.2.1-4 P_{uo}/P_n
	Observed Data					Calculated Values										
A A/B 18/7 D1	67.0	0.790	0.049	13.5	PC+PL+PT	0.435	0.741	15.1	NA	NA	10.7	1.26	NA	NA	NA	NA
A A/B 18/7 D2	67.0	0.800	0.050	12.4	PC+PL+PT	0.440	0.750	15.0	NA	NA	11.1	1.12	NA	NA	NA	NA
A A/B 18/7 D3	67.0	0.810	0.049	13.1	PC+PL+PT	0.446	0.761	15.5	NA	NA	11.0	1.19	NA	NA	NA	NA
A A/B 18/7 D4	67.0	0.850	0.050	14.4	PC+PL+PT	0.468	0.800	16.0	NA	NA	11.8	1.22	NA	NA	NA	NA
A A/B 28/7 C1	109.8	0.640	0.016	2.76	PS+PB	0.352	0.624	39.0	NA	NA	NA	NA	NA	NA	3.07	0.90
A A/B 28/7 C2	109.8	0.640	0.016	1.94	PS+PB	0.352	0.624	39.0	NA	NA	NA	NA	NA	NA	3.07	0.63
A A/B 28/7 C3	109.8	0.570	0.016	2.60	PS+PB	0.314	0.554	34.6	NA	NA	NA	NA	NA	NA	2.73	0.95
A A/B 28/7 C4	109.8	0.590	0.016	2.54	PS+PB	0.325	0.574	35.9	NA	NA	NA	NA	NA	NA	2.82	0.90
A A/B 28/7 C5	109.8	0.560	0.016	2.72	PS+PB	0.308	0.544	34.0	NA	NA	NA	NA	NA	NA	2.68	1.02
A A/B 18/7 D1	64.7	0.780	0.044	7.68	PL+PS+PB	0.429	0.736	16.7	NA	NA	9.22	0.833	NA	NA	NA	NA
A A/B 18/7 D2	64.7	0.740	0.044	9.04	PL+PS+PB	0.407	0.696	15.8	NA	NA	8.72	1.04	NA	NA	NA	NA
A A/B 18/7 D3	64.7	0.730	0.044	8.02	PL+PB+PT	0.402	0.686	15.6	NA	NA	8.59	0.933	NA	NA	NA	NA
A A/B 18/7 D4	64.7	0.730	0.044	10.0	PL+PB+PT+WS	0.402	0.686	15.6	NA	NA	8.59	1.16	NA	NA	NA	NA
A A/B 18/7 D5	64.7	0.740	0.044	10.0	PL+PB+PT+WS	0.407	0.696	15.8	NA	NA	8.72	1.15	NA	NA	NA	NA
A E/B 28/7 C1	98.0	0.430	0.018	1.90	PL+PB	0.237	0.412	22.9	NA	NA	NA	NA	2.13	0.891	NA	NA
A E/B 28/7 C2	98.0	0.440	0.018	2.20	PL+PS+PB	0.242	0.422	23.4	NA	NA	NA	NA	2.14	1.03	NA	NA
A E/B 28/7 C3	98.0	0.460	0.018	1.40	PL+PB	0.253	0.442	24.6	NA	NA	NA	NA	NA	NA	2.18	0.64
A E/B 28/7 C4	98.0	0.520	0.018	3.00	PL+PS+PB	0.286	0.502	27.9	NA	NA	NA	NA	NA	NA	2.48	1.21
A A/B 12/7 D1	51.1	0.790	0.108	13.5	WS	0.391	0.682	6.31	10.8	1.25	NA	NA	NA	NA	NA	NA
A A/B 12/7 D2	51.1	0.780	0.108	8.84	WS	0.384	0.672	6.22	10.4	0.848	NA	NA	NA	NA	NA	NA
A A/B 12/7 D3	51.1	0.780	0.108	8.11	WS	0.384	0.672	6.22	10.4	0.778	NA	NA	NA	NA	NA	NA
A A/B 12/7 D4	51.1	0.800	0.108	8.22	WS	0.398	0.692	6.41	11.2	0.734	NA	NA	NA	NA	NA	NA
A A/B 12/7 D5	51.1	0.820	0.108	11.3	WS	0.412	0.712	6.59	12.0	0.940	NA	NA	NA	NA	NA	NA
A E/C 28/16 C1	98.0	0.390	0.018	2.55	PL+PS+PB	0.215	0.372	20.7	NA	NA	NA	NA	2.1	1.22	NA	NA
A E/C 28/16 C2	98.0	0.400	0.018	1.36	PL+PB+PT	0.220	0.382	21.2	NA	NA	NA	NA	2.1	0.65	NA	NA
A E/C 28/16 C3	98.0	0.410	0.018	2.00	PL+PS+PB+PP	0.226	0.392	21.8	NA	NA	NA	NA	2.1	0.95	NA	NA
A E/C 28/16 C4	98.0	0.410	0.018	2.30	PB+PT	0.226	0.392	21.8	NA	NA	NA	NA	2.1	1.09	NA	NA
A E/C 28/16 C5	98.0	0.440	0.018	2.70	PB+PL	0.242	0.422	23.4	NA	NA	NA	NA	2.1	1.26	NA	NA
A E/B 14/7 D1	56.4	1.00	0.081	28.3	PS+PB+PL	0.550	0.919	11.3	NA	NA	18.5	1.53	NA	NA	NA	NA
A E/B 14/7 D2	56.4	1.01	0.081	27.6	PS+PB+PL	0.556	0.929	11.4	NA	NA	18.8	1.47	NA	NA	NA	NA
A E/B 14/7 D3	56.4	1.03	0.081	27.8	PS+PB+PL	0.567	0.950	11.8	NA	NA	19.0	1.46	NA	NA	NA	NA
A E/B 14/7 D4	56.4	1.00	0.081	28.9	PS+PB+PL	0.550	0.919	11.4	NA	NA	18.4	1.57	NA	NA	NA	NA
A E/B 14/7 D5	56.4	1.10	0.082	27.9	PS+PB+PL	0.605	1.018	12.5	NA	NA	20.6	1.35	NA	NA	NA	NA
A E/B 18/7 D1	56.4	0.870	0.054	13.9	PS+PB+PL	0.479	0.817	15.3	NA	NA	10.8	1.28	NA	NA	NA	NA
A E/B 18/7 D2	56.4	0.810	0.054	15.0	PS+PB+PL	0.446	0.756	14.0	NA	NA	10.1	1.48	NA	NA	NA	NA

Table A3 - Arc Spot Weld Data and Comparisons (continued)

	Observed Data					Calculated Values												
Specimen Designation	σ_u (ksi)	d (in.)	t_{av} (in.)	P_{uo} (kips)	Failure	d_e (in.)	d_a (in.)	d_a/t	Eq. E2.2.1-1		Eq. E2.2.1-2		Eq. E2.2.1-3		Eq. E2.2.1-4	
									P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n
A E/B 18/7 D3	56.4	0.830	0.055	14.5	PS+PB+PL	0.457	0.775	14.2	NA	NA	10.5	1.38	NA	NA	NA	NA
A E/B 18/7 D4	56.4	0.870	0.054	14.5	PS+PB+PL	0.479	0.816	15.1	NA	NA	10.9	1.33	NA	NA	NA	NA
A E/B 18/7 D5	56.4	0.880	0.054	14.0	PS+PB+PL	0.484	0.826	15.3	NA	NA	11.1	1.26	NA	NA	NA	NA
A E/B 18/16 D1	56.4	0.790	0.055	12.9	PS+PB+PL+W	0.435	0.735	13.4	NA	NA	10.0	1.28	NA	NA	NA	NA
A E/B 18/16 D2	56.4	0.800	0.056	10.8	PS+W+PL	0.440	0.744	13.2	NA	NA	10.4	1.04	NA	NA	NA	NA
A E/B 18/16 D3	56.4	0.810	0.056	12.4	PS+PB+PL+W	0.446	0.755	13.6	NA	NA	10.4	1.20	NA	NA	NA	NA
A E/B 18/16 D4	56.4	0.830	0.054	10.9	PS+PB+PL	0.457	0.776	14.4	NA	NA	10.4	1.05	NA	NA	NA	NA
A E/B 18/16 D5	56.4	0.850	0.054	13.2	PS+W+PL	0.468	0.796	14.7	NA	NA	10.7	1.23	NA	NA	NA	NA
A A/B 12/7 D(B-C)1	54.9	0.900	0.101	20.6	WS	0.479	0.799	7.91	16.2	1.27	NA	NA	NA	NA	NA	NA
A A/B 12/7 D(B-C)2	54.9	0.920	0.101	24.8	WS	0.493	0.819	8.11	17.1	1.45	NA	NA	NA	NA	NA	NA
A A/B 12/7 D(B-C)3	54.9	0.920	0.102	20.3	WS	0.491	0.818	8.02	17.0	1.19	NA	NA	NA	NA	NA	NA
A A/B 12/7 D(F-C)1	54.9	0.920	0.101	24.1	WS	0.493	0.819	8.11	17.1	1.41	NA	NA	NA	NA	NA	NA
A A/B 12/7 D(F-C)2	54.9	0.950	0.101	24.9	WS	0.514	0.849	8.41	18.6	1.34	NA	NA	NA	NA	NA	NA
A A/B 12/7 D(E-C)1	54.9	0.950	0.101	24.1	WS+W	0.514	0.849	8.41	18.6	1.29	NA	NA	NA	NA	NA	NA
A A/B 12/7 D(E-C)2	54.9	0.980	0.102	24.1	WS	0.533	0.878	8.61	20.1	1.20	NA	NA	NA	NA	NA	NA
A A/B 18/7 D(B-C)1	59.0	0.800	0.047	11.7	PC+PL+W	0.440	0.753	16.0	NA	NA	9.2	1.27	NA	NA	NA	NA
A A/B 18/7 D(B-C)2	59.0	0.850	0.047	10.0	PC+PL+W	0.468	0.803	17.1	NA	NA	9.8	1.02	NA	NA	NA	NA
A A/B 18/7 D(B-C)3	59.0	0.790	0.047	10.0	PC+PL+PS+W	0.435	0.743	15.8	NA	NA	9.1	1.10	NA	NA	NA	NA
A A/B 18/7 D(F-C)1	59.0	0.820	0.047	11.1	PC+PL+PS+W	0.451	0.773	16.4	NA	NA	9.4	1.18	NA	NA	NA	NA
A A/B 18/7 D(F-C)2	59.0	0.840	0.047	12.7	PC+PL+PS+W	0.462	0.793	16.9	NA	NA	9.7	1.31	NA	NA	NA	NA
A A/B 18/7 D(F-C)3	59.0	0.850	0.047	11.8	PC+PL+W	0.468	0.803	17.1	NA	NA	9.8	1.20	NA	NA	NA	NA
A A/B 18/7 D(E-C)1	59.0	0.870	0.047	9.74	PC+PL+W	0.479	0.823	17.5	NA	NA	10.0	0.970	NA	NA	NA	NA
A A/B 18/7 D(E-C)2	59.0	0.830	0.047	11.5	PC+PL+W	0.457	0.783	16.7	NA	NA	9.6	1.20	NA	NA	NA	NA
A A/B 18/7 D(E-C)3	59.0	0.860	0.047	10.8	PC+PL+W	0.473	0.813	17.3	NA	NA	9.9	1.08	NA	NA	NA	NA
A A/B 12/7 D(AA-C)1	54.9	1.04	0.101	24.5	WS	0.572	0.939	9.30	NA	NA	22.9	1.07	NA	NA	NA	NA
A A/B 12/7 D(AA-C)2	54.9	0.960	0.101	22.5	WS+PS+PB	0.521	0.859	8.50	19.2	1.17	NA	NA	NA	NA	NA	NA
A A/B 12/7 D(AA-C)3	54.9	0.900	0.101	14.0	WS	0.479	0.799	7.91	16.2	0.87	NA	NA	NA	NA	NA	NA
A A/B 18/7 D(BB-C)1	59.0	0.850	0.048	12.6	PC+PS+W	0.468	0.802	16.8	NA	NA	10.0	1.26	NA	NA	NA	NA
A A/B 18/7 D(BB-C)2	59.0	0.780	0.048	11.1	PC+PS+W	0.429	0.732	15.3	NA	NA	9.1	1.22	NA	NA	NA	NA
A A/B 12/7 C(E-AA)2	54.9	0.850	0.101	10.7	WS	0.444	0.749	7.42	13.9	0.77	NA	NA	NA	NA	NA	NA
A A/B 12/7 C(E-D)1	54.9	1.00	0.101	28.7	WS+PC+W	0.549	0.899	8.90	21.3	1.35	NA	NA	NA	NA	NA	NA
A A/B 12/7 C(E-D)2	54.9	0.970	0.101	26.5	WS+PC+W+PL	0.528	0.869	8.60	19.7	1.35	NA	NA	NA	NA	NA	NA
A A/B 12/7 C(E-D)3	54.9	0.990	0.101	29.1	WS+PL	0.542	0.889	8.80	20.7	1.40	NA	NA	NA	NA	NA	NA
A A/B 18/7 C(E-AA)1	59.0	0.640	0.047	10.0	PC+W+PS	0.352	0.593	12.5	NA	NA	7.3	1.37	NA	NA	NA	NA
A A/B 18/7 C(E-AA)2	59.0	0.620	0.047	7.46	PC+W+PS	0.341	0.574	12.3	NA	NA	6.9	1.08	NA	NA	NA	NA
A A/B 18/7 C(E-AA)3	59.0	0.650	0.047	10.5	PC+W+PS	0.358	0.603	12.9	NA	NA	7.3	1.44	NA	NA	NA	NA
A A/B 24/7 C(E-AA)1	107.6	0.540	0.024	3.80	PS+PB	0.297	0.516	21.5	NA	NA	NA	NA	4.0	0.960	NA	NA
A A/B 24/7 C(E-AA)2	107.6	0.600	0.024	4.48	PS+PB	0.330	0.576	24.0	NA	NA	NA	NA	NA	NA	4.16	1.08

Table A3 - Arc Spot Weld Data and Comparisons (continued)

	Observed Data					Calculated Values										
Specimen Designation	σ_u (ksi)	d (in.)	t_{av} (in.)	P_{uo} (kips)	Failure	d_e (in.)	d_a (in.)	d_a/t	Eq. E2.2.1-1		Eq. E2.2.1-2		Eq. E2.2.1-3		Eq. E2.2.1-4	
									P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n
A A/B 24/7 C(E-AA)3	107.6	0.560	0.024	4.90	PS+PB	0.308	0.536	22.3	NA	NA	NA	NA	4.0	1.23	NA	NA
A E/B 24/7 D(E-C)1	107.6	0.720	0.024	6.00	PS+PT+PB+W	0.396	0.696	29.0	NA	NA	NA	NA	NA	NA	5.03	1.19
A E/B 24/7 D(E-C)2	107.6	0.710	0.024	6.30	PS+PB+W	0.391	0.686	28.5	NA	NA	NA	NA	NA	NA	4.98	1.27
A E/B 24/7 D(E-C)3	107.6	0.730	0.024	6.16	PS+PB+W	0.402	0.706	29.4	NA	NA	NA	NA	NA	NA	5.10	1.21
A A/B 10/7 D(E-CC)1	48.8	1.04	0.139	26.1	WS	0.520	0.901	6.49	19.1	1.37	NA	NA	NA	NA	NA	NA
A A/B 10/7 D(E-CC)2	48.8	1.05	0.139	20.9	WS	0.526	0.911	6.55	19.6	1.07	NA	NA	NA	NA	NA	NA
A A/B 10/7 D(E-E)1	48.8	1.14	0.139	34.5	WS	0.589	1.001	7.19	24.5	1.41	NA	NA	NA	NA	NA	NA
A A/B 10/7 D(E-E)2	48.8	1.24	0.140	28.3	WS	0.659	1.101	7.89	30.7	0.923	NA	NA	NA	NA	NA	NA
B A/B 18/7 D1	67.0	1.39	0.095	28.6	PC+PT+PL	0.765	1.2	12.6	NA	NA	33.6	0.851	NA	NA	NA	NA
B A/B 18/7 D2	67.0	1.35	0.095	37.3	PC+PT+PL	0.743	1.16	12.2	NA	NA	32.5	1.15	NA	NA	NA	NA
B A/B 18/7 D3	67.0	1.37	0.095	32.4	PC+PT+PL	0.754	1.18	12.4	NA	NA	33.0	0.980	NA	NA	NA	NA
B A/B 18/7 D4	67.0	1.41	0.097	26.3	PC+PT+W	0.776	1.216	12.5	NA	NA	34.8	0.756	NA	NA	NA	NA
B A/B 18/7 D1S	64.7	0.770	0.088	12.7	WS	0.407	0.594	6.8	11.7	1.08	NA	NA	NA	NA	NA	NA
B A/B 18/7 D2S	64.7	0.820	0.088	16.2	WS	0.442	0.644	7.3	13.8	1.17	NA	NA	NA	NA	NA	NA
B A/B 18/7 D3S	64.7	0.820	0.088	15.4	WS	0.442	0.644	7.3	13.8	1.12	NA	NA	NA	NA	NA	NA
B A/B 18/7 D4S	64.7	0.720	0.088	11.7	WS	0.372	0.544	6.2	9.8	1.20	NA	NA	NA	NA	NA	NA
B A/B 18/7 D5S	64.7	0.820	0.088	8.60	WS	0.442	0.644	7.3	13.8	0.623	NA	NA	NA	NA	NA	NA
B A/B 12/7 D2	51.1	0.830	0.216	6.00	WS	0.257	0.398	1.8	4.7	1.29	NA	NA	NA	NA	NA	NA
B A/B 12/7 D3	51.1	0.840	0.216	5.00	WS	0.264	0.408	1.9	4.9	1.01	NA	NA	NA	NA	NA	NA
B A/B 14/7 D(A-C)1	47.6	1.01	0.154	17.2	WS	0.476	0.702	4.6	16.0	1.07	NA	NA	NA	NA	NA	NA
B A/B 14/7 D(A-C)2	47.6	1.08	0.155	20.9	WS	0.524	0.77	5.0	19.4	1.08	NA	NA	NA	NA	NA	NA
B A/B 14/7 D(D-C)1	47.6	1.04	0.154	16.1	WS	0.497	0.732	4.8	17.5	0.922	NA	NA	NA	NA	NA	NA
B A/B 14/7 D(D-C)2	47.6	0.950	0.154	11.8	WS	0.434	0.642	4.2	13.3	0.886	NA	NA	NA	NA	NA	NA
B A/B 14/7 D(F-C)1	47.6	1.00	0.154	14.8	WS	0.469	0.692	4.5	15.5	0.952	NA	NA	NA	NA	NA	NA
B A/B 14/7 D(F-C)2	47.6	0.960	0.153	16.5	WS	0.443	0.654	4.3	13.8	1.19	NA	NA	NA	NA	NA	NA
B A/B 18/7 D(A-C)1	59.0	0.960	0.094	22.4	PC+PL+W+PT	0.528	0.772	8.2	NA	NA	18.8	1.19	NA	NA	NA	NA
B A/B 18/7 D(A-C)2	59.0	1.00	0.094	24.5	PC+PS+PL	0.550	0.812	8.6	NA	NA	19.8	1.24	NA	NA	NA	NA
B A/B 18/7 D(A-C)3	59.0	0.950	0.094	21.7	PC+PL+W+PS	0.523	0.762	8.1	NA	NA	18.6	1.17	NA	NA	NA	NA
B A/B 18/7 D(D-C)1	59.0	1.01	0.093	23.4	PC+PS+W+PL	0.556	0.824	8.9	NA	NA	19.9	1.18	NA	NA	NA	NA
B A/B 18/7 D(D-C)2	59.0	0.940	0.094	24.1	WS+PC+PL	0.517	0.752	8.0	NA	NA	18.4	1.31	NA	NA	NA	NA
B A/B 18/7 D(D-C)3	59.0	0.920	0.094	22.2	PC+PS+W+PL	0.503	0.732	7.8	NA	NA	17.9	1.24	NA	NA	NA	NA
B A/B 18/7 D(F-C)1	59.0	1.04	0.093	24.9	WC+PS+PL	0.572	0.854	9.2	NA	NA	20.6	1.21	NA	NA	NA	NA
B A/B 18/7 D(F-C)2	59.0	1.02	0.093	24.5	PC+PS+W	0.561	0.834	9.0	NA	NA	20.1	1.22	NA	NA	NA	NA

Table A3 - Arc Spot Weld Data and Comparisons (continued)

	Observed Data					Calculated Values										
Specimen Designation	σ_u (ksi)	d (in.)	t_{av} (in.)	P_{uo} (kips)	Failure	d_e (in.)	d_a (in.)	d_a/t	Eq. E2.2.1-1		Eq. E2.2.1-2		Eq. E2.2.1-3		Eq. E2.2.1-4	
									P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n
B A/B 18/7 D(F-C)3	59.0	0.980	0.092	24	PC+PS+PL	0.539	0.796	8.7	NA	NA	19.0	1.26	NA	NA	NA	NA
B A/B 14/7 D(D-E)1	47.6	1.16	0.153	38.9	WS	0.583	0.854	5.6	24.0	1.62	NA	NA	NA	NA	NA	NA
B A/B 14/7 D(D-E)2	47.6	1.17	0.153	39.4	WS	0.590	0.864	5.6	24.6	1.60	NA	NA	NA	NA	NA	NA
B A/B 28/7 C(C-AA)1	105.4	0.700	0.039	9.18	PS+PB+W	0.385	0.622	15.9	NA	NA	NA	NA	9.9	0.93	NA	NA
B A/B 28/7 C(C-AA)2	105.4	0.720	0.039	8.84	PS+PB+W	0.396	0.642	16.4	NA	NA	NA	NA	10.0	0.89	NA	NA
B A/B 28/7 C(C-AA)3	105.4	0.730	0.039	9.54	PS+PB+W	0.402	0.652	16.7	NA	NA	NA	NA	9.9	0.96	NA	NA
B A/B 18/7 C(D-AA)1	59.0	0.750	0.093	18.9	WS	0.385	0.563	6.0	10.5	1.80	NA	NA	NA	NA	NA	NA
B A/B 18/7 C(D-AA)2	59.0	0.740	0.094	12.6	WS	0.378	0.553	5.9	10.1	1.249	NA	NA	NA	NA	NA	NA
B A/B 18/7 D(D-D)1	59.0	1.20	0.094	28.6	PC+PS+W	0.660	1.012	10.8	NA	NA	24.7	1.16	NA	NA	NA	NA
B A/B 18/7 D(D-D)2	59.0	1.20	0.094	30.1	PC+PS+W	0.660	1.013	10.8	NA	NA	24.6	1.223	NA	NA	NA	NA
B A/B 18/7 D(D-D)3	59.0	1.25	0.093	31	PC+PS+W	0.688	1.063	11.4	NA	NA	25.8	1.20	NA	NA	NA	NA
B A/B 14/7 D(E-D)1	47.6	1.09	0.153	18.8		0.534	0.784	5.1	20.1	0.934	NA	NA	NA	NA	NA	NA
B A/B 14/7 D(E-D)2	47.6	1.08	0.154	22.5		0.525	0.772	5.0	19.5	1.15	NA	NA	NA	NA	NA	NA
								No. of specimens		37		55		12		11
								Mean		1.14		1.20		1.00		1.00
								Std. Dev.		0.263		0.166		0.175		0.221
								C.O.V.		0.231		0.139		0.174		0.221

Table A4 – Arc Seam Weld Data taken from Reference 4

	Observed Data					
Specimen Designation	σ_u (ksi)	t_{av} (in.)	$L_{w\,av}$ (in.)	$B_{w\,av}$ (in.)	P_{uo} (kips)	Failure
A A/B 18/7 X1	59.0	0.048	1.96	0.580	15.6	PC+PS+PL
A A/B 18/7 X2	59.0	0.047	1.88	0.630	15.5	PC+PS+PL+PT
A A/B 18/7 X3	59.0	0.047	2.01	0.520	15.0	PC+PT+PL
A A/B 18/7 Y1	49.0	0.047	1.36	0.540	13.1	PC+PT
A A/B 18/7 Y3	59.0	0.046	1.33	0.580	10.9	PC+PS+W+PT
A A/B 22/7 X1	50.0	0.030	2.15	0.470	7.61	PC+PT+PL
A A/B 22/7 X2	50.0	0.030	2.21	0.470	7.50	PC+PT+PL
A A/B 22/7 X3	50.0	0.030	1.95	0.420	7.06	PC+PT+PL
A A/B 22/7 Y1	50.0	0.030	1.36	0.420	3.90	PC+PT+W
A A/B 22/7 Y2	50.0	0.029	1.30	0.400	6.04	PC+PT+PS
A A/B 22/7 Y3	50.0	0.030	1.24	0.440	4.76	PC+PT+W
B A/B 18/7 X1	59.0	0.094	1.91	0.650	30.2	PC+PT+PL
B A/B 18/7 X2	59.0	0.094	1.91	0.690	31.1	PC+PT+W
B A/B 18/7 X3	59.0	0.094	2.01	0.640	31.0	PC+PS+PT
B A/B 18/7 Y1	59.0	0.094	1.30	0.600	23.9	PC+W+PT
B A/B 18/7 Y2	59.0	0.093	1.39	0.480	25.7	PC+W+PT
B A/B 18/7 Y3	59.0	0.093	1.40	0.580	24.9	PC
B A/B 22/7 X1	50.0	0.060	2.06	0.460	15.6	PC+PT+PL
B A/B 22/7 X2	50.0	0.060	2.07	0.470	15.1	PC+PT+PL
B A/B 22/7 X3	50.0	0.060	2.06	0.480	15.4	PC+PT+PL
B A/B 22/7 Y1	50.0	0.060	1.42	0.500	12.1	PC+PT+W
B A/B 22/7 Y2	50.0	0.060	1.24	0.490	12.4	PC+PT
B A/B 22/7 Y3	50.0	0.060	1.33	0.500	11.2	PC+PT+W
				No. of specimens		23

Table A5 - Arc Seam Weld Data and Comparisons

Specimen Designation	σ_u (ksi)	t_{av} (in.)	$L_{w\,av}$ (in.)	$B_{w\,av}$ (in.)	P_{uo} (kips)	Failure	d_e (in.)	$L_{w\,av}$ <3d (in.)	Eq. E2.3-1 P_n (kips)	Eq. E2.3-1 P_{uo}/P_n	Eq. E2.3-2 P_n (kips)	Eq. E2.3-2 P_{uo}/P_n
	Observed Data						**Calculated Values**					
A A/B 18/7 X1	59.0	0.048	1.96	0.580	15.6	PC+PS+PL	0.334	1.74	NA	NA	14.0	1.11
A A/B 18/7 X2	59.0	0.047	1.88	0.630	15.5	PC+PS+PL+PT	0.371	1.88	NA	NA	14.9	1.04
A A/B 18/7 X3	59.0	0.047	2.01	0.520	15.0	PC+PT+PL	0.294	1.56	NA	NA	12.3	1.22
A A/B 18/7 Y1	49.0	0.047	1.36	0.540	13.1	PC+PT	0.308	1.36	NA	NA	9.88	1.33
A A/B 18/7 Y3	59.0	0.046	1.33	0.580	10.9	PC+PS+W+PT	0.337	1.33	NA	NA	12.1	0.903
A A/B 22/7 X1	50.0	0.030	2.15	0.470	7.61	PC+PT+PL	0.284	1.41	NA	NA	6.02	1.26
A A/B 22/7 X2	50.0	0.030	2.21	0.470	7.50	PC+PT+PL	0.284	1.41	NA	NA	6.02	1.25
A A/B 22/7 X3	50.0	0.030	1.95	0.420	7.06	PC+PT+PL	0.249	1.26	NA	NA	5.38	1.31
A A/B 22/7 Y1	50.0	0.030	1.36	0.420	3.90	PC+PT+W	0.249	1.26	NA	NA	5.38	0.725
A A/B 22/7 Y2	50.0	0.029	1.30	0.400	6.04	PC+PT+PS	0.237	1.20	NA	NA	4.96	1.22
A A/B 22/7 Y3	50.0	0.030	1.24	0.440	4.76	PC+PT+W	0.263	1.24	NA	NA	5.49	0.867
B A/B 18/7 X1	59.0	0.094	1.91	0.650	30.2	PC+PT+PL	0.314	1.91	30.5	0.991	NA	NA
B A/B 18/7 X2	59.0	0.094	1.91	0.690	31.1	PC+PT+W	0.342	1.91	NA	NA	31.6	0.984
B A/B 18/7 X3	59.0	0.094	2.01	0.640	31.0	PC+PS+PT	0.307	1.92	29.9	1.04	NA	NA
B A/B 18/7 Y1	59.0	0.094	1.30	0.600	23.9	PC+W+PT	0.279	1.30	19.1	1.25	NA	NA
B A/B 18/7 Y2	59.0	0.093	1.39	0.480	25.7	PC+W+PT	0.197	1.39	13.7	1.88	NA	NA
B A/B 18/7 Y3	59.0	0.093	1.40	0.580	24.9	PC	0.267	1.40	19.3	1.29	NA	NA
B A/B 22/7 X1	50.0	0.060	2.06	0.460	15.6	PC+PT+PL	0.232	1.38	NA	NA	11.8	1.32
B A/B 22/7 X2	50.0	0.060	2.07	0.470	15.1	PC+PT+PL	0.239	1.41	NA	NA	12.0	1.25
B A/B 22/7 X3	50.0	0.060	2.06	0.480	15.4	PC+PT+PL	0.246	1.44	NA	NA	12.3	1.25
B A/B 22/7 Y1	50.0	0.060	1.42	0.500	12.1	PC+PT+W	0.260	1.42	NA	NA	12.5	0.967
B A/B 22/7 Y2	50.0	0.060	1.24	0.490	12.4	PC+PT	0.253	1.24	NA	NA	11.7	1.06
B A/B 22/7 Y3	50.0	0.060	1.33	0.500	11.2	PC+PT+W	0.260	1.33	NA	NA	12.2	0.920

	Eq. E2.3-1 P_{uo}/P_n	Eq. E2.3-2 P_{uo}/P_n	Total
No. of specimens	5	18	23
Mean	1.29	1.11	1.15
Std. Dev.	0.355	0.183	0.234
C.O.V.	0.275	0.165	0.203

Table A6 – Longitudinal Fillet Weld Data taken from Reference 4

	Observed Data					
Specimen Designation	σ_u (ksi)	s_{av} (in.)	t_{av} (in.)	$L_{w\ av}$ (in.)	P_{uo} (ksi)	Failure
C A/B 18/7 C1	67.0	3.00	0.050	0.81	10.32	PC+PL+WS
C A/B 18/7 C2	67.0	3.00	0.050	0.91	11.20	PC+PL+WS
C A/B 18/7 C3	67.0	3.00	0.049	0.87	10.80	PC+PL+WS
C A/B 18/7 C4	67.0	3.00	0.050	0.93	11.20	PC+PL+WS
C A/B 18/7 F1	67.0	2.98	0.050	1.40	13.20	WS+PC+PL
C A/B 18/7 F2	67.0	2.98	0.049	1.46	13.30	WS+PC+PL
C A/B 18/7 F3	67.0	3.00	0.049	1.41	14.20	WS+PC+PL
C A/B 18/7 F4	67.0	3.00	0.048	1.43	13.10	WS+PC+PL
C A/B 18/18 F1	67.0	3.00	0.049	1.59	12.14	PC+PL
C A/B 18/18 F2	67.0	2.98	0.048	1.59	12.16	PC+PL
C A/B 18/18 F3	67.0	2.98	0.049	1.52	12.86	PC+PL
C A/B 18/18 F4	67.0	2.98	0.049	1.59	12.78	PC+PL
C A/B 18/7 J1	67.0	2.99	0.049	2.46	17.10	PT
C A/B 18/7 J2	67.0	2.98	0.049	2.51	15.90	PT
C A/A 18/18 J1	67.0	3.00	0.048	2.51	15.80	PT
C A/A 18/18 J2	67.0	2.97	0.047	2.64	14.30	PT
C A/A 18/18 J3	67.0	3.00	0.049	2.66	15.84	PT
C A/A 18/18 J4	67.0	2.99	0.049	2.66	15.70	PT
C A/B 12/7 C1	51.4	3.00	0.107	1.09	23.00	WS+PL
C A/B 12/7 C2	51.4	2.98	0.107	1.12	23.20	WS+PL
C A/B 12/7 C3	51.4	2.99	0.107	1.15	24.60	WS+PL
C A/B 12/7 C4	51.4	2.98	0.107	1.22	25.00	WS+PL
C A/B 12/7 F1	51.4	3.00	0.107	1.57	27.30	PC+PL
C A/B 12/7 F2	51.4	3.00	0.107	1.65	28.40	PC+PL
C A/B 12/7 F3	51.4	2.98	0.107	1.64	28.20	PC+PL
C A/B 12/7 F4	51.4	2.98	0.107	1.62	28.30	PC+PL
C A/A12/12 F1	51.4	2.98	0.107	1.44	24.50	WS+PL
C A/A12/12 F2	51.4	3.00	0.107	1.52	24.90	WS+PL
C A/A12/12 F3	51.4	2.98	0.107	1.56	26.00	WS+PC+PL
C A/A12/12 F4	51.4	2.98	0.107	1.52	25.90	WS+PC+PL
C A/A12/12 F5	51.4	2.98	0.107	1.52	26.70	WS+PC+PL
C A/B 12/7 J1	51.4	3	0.107	2.52	31.10	PT
C A/B 12/7 J2	51.4	2.98	0.107	2.56	30.40	PT
C A/B 18/7 C1	64.7	3.00	0.052	1.09	11.40	WS+PC+PL
C A/B 18/7 C2	64.7	3.00	0.052	1.04	10.66	PL+PC+PT
C A/B 18/7 C3	64.7	3.00	0.052	1.02	10.16	PL+PC+PT
C A/B 18/7 C4	64.7	3.00	0.052	1.10	11.18	WS+PC+PL
C A/B 18/7 C4	64.7	3.00	0.052	1.17	12.30	PC+PL
C A/B 12/7 C1	51.1	2.99	0.108	1.26	22.80	WS+PC+PL
C A/B 12/7 C2	51.1	2.99	0.108	1.31	25.10	WS+PC+PL
C A/B 12/7 C3	51.1	3.00	0.108	1.24	23.00	WS+PC+PL
C A/B 12/7 C4	51.1	2.99	0.108	1.17	23.60	WS+PC+PL+PT
C A/B 12/7 C5	51.1	3.00	0.108	1.15	22.70	PT
C A/B 18/7 J1	64.7	2.99	0.052	2.80	15.40	PT
C A/B 18/7 J2	64.7	3.00	0.052	2.91	16.24	PT
C A/B 18/7 J3	64.7	2.99	0.052	2.91	16.30	PT
C A/B 18/7 J4	64.7	2.99	0.052	2.77	16.60	PT

Table A6 – Longitudinal Fillet Weld Data taken from Reference 4 (continued)

	Observed Data					
Specimen Designation	σ_u (ksi)	s_{av} (in.)	t_{av} (in.)	$L_{w\,av}$ (in.)	P_{uo} (ksi)	Failure
C A/B 18/7 J5	64.7	2.99	0.052	2.78	15.10	PT
C A/B 12/7 P1	51.1	3.00	0.108	3.64	31.10	PT
C A/B 12/7 P2	51.1	2.99	0.108	3.73	31.50	PT
C A/B 12/7 P3	51.1	3.00	0.108	3.61	32.00	PT
C A/A 18/18 F1	64.7	3.00	0.050	1.80	12.76	PL+PC+PT+W
C A/A 18/18 F2	64.7	3.00	0.050	1.82	13.35	PL+PC+PT+W+PP
C A/A 18/18 F3	64.7	3.00	0.050	1.83	13.56	PL+PC+PT+W
C A/A 18/18 F4	64.7	3.00	0.050	2.00	13.96	PL+PC+PT+W
C A/A 12/12 F1	51.1	3.00	0.110	1.64	24.20	PL+PT+W+WS
C A/A 12/12 F2	51.1	3.00	0.110	1.60	24.30	PL+PT+WD+WS
C A/A 12/12 F3	51.1	3.00	0.110	1.62	23.80	PL+PT+W+WS
C A/A 12/12 F4	51.1	3.00	0.110	1.65	24.40	PL+PT+W+WS
C A/A 18/18 J1	64.7	3.00	0.050	2.52	15.24	PT+W+PL
C A/A 18/18 J2	64.7	3.00	0.050	2.46	15.14	PL+PT+W+PP
C A/A 18/18 J3	64.7	3.00	0.050	2.46	14.70	PL+PT
C A/A 18/18 J4	64.7	3.00	0.050	2.57	15.50	PL+PT
C A/A 18/18 J5	64.7	3.00	0.050	2.54	14.93	PL+PT
				No. of specimens		64

Table A7 - Longitudinal Fillet Weld Data and Comparisons

	Observed Data						Calculated Values				
Specimen Designation	σ_u (ksi)	s_{av} (in.)	t_{av} (in.)	$L_{w\,av}$ (in.)	P_{uo} (ksi)	Failure	$L_{w\,av}/t_{av}$	Eq. E2.4-1		Eq. E2.4-2	
								P_n (kips)	P_{uo}/P_n	P_n (kips)	P_{uo}/P_n
C A/B 18/7 C1	67.0	3.00	0.050	0.81	10.32	PC+PL+WS	16.2	8.92	1.16	NA	NA
C A/B 18/7 C2	67.0	3.00	0.050	0.91	11.20	PC+PL+WS	18.2	9.75	1.15	NA	NA
C A/B 18/7 C3	67.0	3.00	0.049	0.87	10.80	PC+PL+WS	17.8	9.19	1.17	NA	NA
C A/B 18/7 C4	67.0	3.00	0.050	0.93	11.20	PC+PL+WS	18.6	9.91	1.13	NA	NA
C A/B 18/7 F1	67.0	2.98	0.050	1.40	13.20	WS+PC+PL	28.0	NA	NA	14.1	0.938
C A/B 18/7 F2	67.0	2.98	0.049	1.46	13.30	WS+PC+PL	29.8	NA	NA	14.4	0.925
C A/B 18/7 F3	67.0	3.00	0.049	1.41	14.20	WS+PC+PL	28.8	NA	NA	13.9	1.02
C A/B 18/7 F4	67.0	3.00	0.048	1.43	13.10	WS+PC+PL	29.8	NA	NA	13.8	0.950
C A/B 18/18 F1	67.0	3.00	0.049	1.59	12.14	PC+PL	32.4	NA	NA	15.7	0.775
C A/B 18/18 F2	67.0	2.98	0.048	1.59	12.16	PC+PL	33.1	NA	NA	15.3	0.793
C A/B 18/18 F3	67.0	2.98	0.049	1.52	12.86	PC+PL	31.0	NA	NA	15.0	0.859
C A/B 18/18 F4	67.0	2.98	0.049	1.59	12.78	PC+PL	32.4	NA	NA	15.7	0.816
C A/B 12/7 C1	51.4	3.00	0.107	1.09	23.00	WS+PL	10.2	21.3	1.08	NA	NA
C A/B 12/7 C2	51.4	2.98	0.107	1.12	23.20	WS+PL	10.5	21.8	1.06	NA	NA
C A/B 12/7 C3	51.4	2.99	0.107	1.15	24.60	WS+PL	10.7	22.3	1.10	NA	NA
C A/B 12/7 C4	51.4	2.98	0.107	1.22	25.00	WS+PL	11.4	23.5	1.07	NA	NA
C A/B 12/7 F1	51.4	3.00	0.107	1.57	27.30	PC+PL	14.7	29.0	0.943	NA	NA
C A/B 12/7 F2	51.4	3.00	0.107	1.65	28.40	PC+PL	15.4	30.1	0.942	NA	NA
C A/B 12/7 F3	51.4	2.98	0.107	1.64	28.20	PC+PL	15.3	30.0	0.940	NA	NA
C A/B 12/7 F4	51.4	2.98	0.107	1.62	28.30	PC+PL	15.1	29.7	0.953	NA	NA
C A/A12/12 F1	51.4	2.98	0.107	1.44	24.50	WS+PL	13.5	27.0	0.908	NA	NA
C A/A12/12 F2	51.4	3.00	0.107	1.52	24.90	WS+PL	14.2	28.2	0.883	NA	NA
C A/A12/12 F3	51.4	2.98	0.107	1.56	26.00	WS+PC+PL	14.6	28.8	0.902	NA	NA
C A/A12/12 F4	51.4	2.98	0.107	1.52	25.90	WS+PC+PL	14.2	28.2	0.918	NA	NA
C A/A12/12 F5	51.4	2.98	0.107	1.52	26.70	WS+PC+PL	14.2	28.2	0.946	NA	NA
C A/B 18/7 C1	64.7	3.00	0.052	1.09	11.40	WS+PC+PL	21.0	11.3	1.01	NA	NA
C A/B 18/7 C2	64.7	3.00	0.052	1.04	10.66	PL+PC+PT	20.0	10.9	0.976	NA	NA

Table A7 - Longitudinal Fillet Weld Data and Comparisons (continued)

Specimen Designation	Observed Data σ_u (ksi)	s_{av} (in.)	t_{av} (in.)	$L_{w\,av}$ (in.)	P_{uo} (ksi)	Failure	Calculated Values $L_{w\,av}/t_{av}$	Eq. E2.4-1 P_n (kips)	Eq. E2.4-1 P_{uo}/P_n	Eq. E2.4-2 P_n (kips)	Eq. E2.4-2 P_{uo}/P_n
C A/B 18/7 C3	64.7	3.00	0.052	1.02	10.16	PL+PC+PT	19.6	10.8	0.944	NA	NA
C A/B 18/7 C4	64.7	3.00	0.052	1.10	11.18	WS+PC+PL	21.2	11.4	0.984	NA	NA
C A/B 18/7 C4	64.7	3.00	0.052	1.17	12.30	PC+PL	22.5	11.8	1.038	NA	NA
C A/B 12/7 C1	51.1	2.99	0.108	1.26	22.80	WS+PC+PL	11.7	24.2	0.940	NA	NA
C A/B 12/7 C2	51.1	2.99	0.108	1.31	25.10	WS+PC+PL	12.1	25.1	1.00	NA	NA
C A/B 12/7 C3	51.1	3.00	0.108	1.24	23.00	WS+PC+PL	11.5	23.9	0.962	NA	NA
C A/B 12/7 C4	51.1	2.99	0.108	1.17	23.60	WS+PC+PL+PT	10.8	22.8	1.04	NA	NA
C A/A 18/18 F1	64.7	3.00	0.050	1.80	12.76	PL+PC+PT+W	36.0	NA	NA	17.5	0.730
C A/A 18/18 F2	64.7	3.00	0.050	1.82	13.35	PL+PC+PT+W+PP	36.4	NA	NA	17.7	0.756
C A/A 18/18 F3	64.7	3.00	0.050	1.83	13.56	PL+PC+PT+W	36.6	NA	NA	17.8	0.764
C A/A 18/18 F4	64.7	3.00	0.050	2.00	13.96	PL+PC+PT+W	40.0	NA	NA	19.4	0.719
C A/A 12/12 F1	51.1	3.00	0.110	1.64	24.20	PL+PT+W+WS	14.9	30.8	0.785	NA	NA
C A/A 12/12 F2	51.1	3.00	0.110	1.60	24.30	PL+PT+WD+WS	14.5	30.2	0.804	NA	NA
C A/A 12/12 F3	51.1	3.00	0.110	1.62	23.80	PL+PT+W+WS	14.7	30.5	0.780	NA	NA
C A/A 12/12 F4	51.1	3.00	0.110	1.65	24.40	PL+PT+W+WS	15.0	31.0	0.788	NA	NA
C A/A 18/18 J1	64.7	3.00	0.050	2.52	15.24	PT+W+PL	50.4	NA	NA	24.5	0.623
C A/A 18/18 J2	64.7	3.00	0.050	2.46	15.14	PL+PT+W+PP	49.2	NA	NA	23.9	0.634
								No. of specimens	30		14
								Mean	0.977		0.807
								Std. Dev.	0.109		0.119
								C.O.V.	0.112		0.147

Table A8 – Transverse Fillet Weld Data taken from Reference 4

Specimen Designation	Observed Data					Calculated Values Eq. E2.4-3	
	σ_u (ksi)	t_{av} (in.)	$L_{w\ av}$ (in.)	P_{uo} (kips)	Failure	P_n (kips)	P_{uo}/P_n
H A/B 18/7 C1	67.0	0.049	0.890	7.12	PC	5.84	1.22
H A/B 18/7 C2	67.0	0.048	0.940	7.18	PC	6.05	1.19
H A/B 18/7 C3	67.0	0.049	0.870	6.34	PC	5.71	1.11
H A/B 18/7 F1	67.0	0.048	1.51	10.7	PC	9.71	1.11
H A/B 18/7 F2	67.0	0.049	1.45	10.3	PC	9.52	1.08
H A/B 18/7 F3	67.0	0.049	1.57	10.1	PC	10.3	0.980
H A/B 18/7 L1	67.0	0.049	2.99	19.5	PC	19.6	0.993
H A/B 18/7 L2	67.0	0.049	3.04	19.6	PC	20.0	0.982
H A/B 18/7 L3	67.0	0.049	3.00	18.1	PC	19.7	0.919
H A/B 18/7 P1	67.0	0.048	3.98	23.0	PC	25.6	0.898
H A/B 18/7 P2	67.0	0.049	4.00	25.6	PC	26.3	0.975
H A/B 18/7 P3	67.0	0.049	4.00	26.3	PC+PT	26.3	1.00
H A/B 12/7 C1	51.4	0.106	0.990	12.6	PC	10.8	1.17
H A/B 12/7 C2	51.4	0.107	0.960	10.9	PC	10.6	1.03
H A/B 12/7 C3	51.4	0.106	0.960	11.9	PC	10.5	1.14
H A/B 12/7 F1	51.4	0.107	1.57	18.8	PC	17.3	1.09
H A/B 12/7 F2	51.4	0.106	1.54	18.8	PC	16.8	1.12
H A/B 12/7 F3	51.4	0.106	1.60	18.0	PC	17.4	1.03
H A/B 12/7 L1	51.4	0.107	3.06	31.3	PC	33.7	0.930
H A/B 12/7 L2	51.4	0.107	3.11	32.1	PC	34.2	0.938
H A/B 12/7 L3	51.4	0.107	3.13	32.3	PC	34.4	0.938
H A/B 12/7 P1	51.4	0.107	3.97	44.7	PC	43.7	1.02
H A/B 12/7 P2	51.4	0.107	3.99	44.0	PC	43.9	1.00
H A/B 12/7 P3	51.4	0.106	3.97	45.2	PC	43.3	1.04
H A/B 12/7 P1	51.1	0.110	3.92	39.0	PC	44.1	0.885
H A/B 12/7 P2	51.1	0.110	3.92	43.0	PC+PT	44.1	0.976
H A/B 12/7 P3	51.1	0.110	3.94	42.1	PC+PT	44.3	0.950
H A/B 12/7 P4	51.1	0.110	3.90	42.3	PC	43.8	0.965
H A/B 18/7 C1	64.7	0.051	1.16	7.56	PC	7.66	0.988
H A/B 18/7 C2	64.7	0.051	1.12	8.17	PC	7.39	1.11
H A/B 18/7 C3	64.7	0.051	1.19	8.45	PC	7.85	1.08
H A/B 18/7 C4	64.7	0.051	1.16	8.67	PC	7.66	1.13
H A/B 18/7 P1	64.7	0.051	3.89	23.8	PC	25.7	0.927
H A/B 18/7 P2	64.7	0.051	3.92	24.8	PC	25.9	0.959
H A/B 18/7 P3	64.7	0.051	3.94	24.2	PC	26.0	0.931
H A/B 18/7 P4	64.7	0.051	3.96	23.4	PC+PL+PT	26.1	0.895
H A/B 12/7 C1	51.1	0.110	1.09	13.0	PC	12.3	1.06
H A/B 12/7 C2	51.1	0.110	1.07	13.4	PC	12.0	1.12
H A/B 12/7 C3	51.1	0.110	1.13	14.2	PC	12.7	1.12
H A/A 18/18 P1	64.7	0.051	3.90	20.8	PL+PC	25.7	0.808
H A/A 18/18 P2	64.7	0.051	3.88	20.2	PL+PC	25.6	0.789
H A/A 18/18 P3	64.7	0.051	3.82	20.6	PL+PC	25.2	0.817
H A/A 18/18 C1	64.7	0.051	1.12	8.10	PC	7.39	1.10
H A/A 18/18 C2	64.7	0.051	1.08	8.22	PC	7.13	1.15
H A/A 18/18 C3	64.7	0.051	1.17	5.80	PC	7.72	0.751

Table A8 – Transverse Fillet Weld Data taken from Reference 4 (continued)

	Observed Data					Calculated Values	
Specimen Designation	σ_u (ksi)	t_{av} (in.)	$L_{w\ av}$ (in.)	P_{uo} (kips)	Failure	Eq. E2.4-3	
						P_n (kips)	P_{uo}/P_n
H A/A 18/18 C4	64.7	0.051	1.12	6.72	PC+WS	7.39	0.909
H A/A 18/18 C5	64.7	0.051	1.09	7.22	PC	7.19	1.00
H A/A 12/12 F1	51.1	0.108	3.83	34.8	PC+WS+PL	42.3	0.823
H A/A 12/12 F2	51.1	0.108	3.88	36.8	PC+WS+PL	42.8	0.859
H A/A 12/12 F3	51.1	0.108	3.93	36.4	PC+WS+PL	43.4	0.839
H A/A 12/12 C1	51.1	0.108	1.26	14.7	PC+WS	13.9	1.06
H A/A 12/12 C2	51.1	0.108	1.14	12.9	PC+WS	12.6	1.02
H A/A 12/12 C3	51.1	0.108	1.21	13.7	PC+WS	13.4	1.03
H A/A 12/12 C4	51.1	0.108	1.14	13.9	PC+WS	12.6	1.10
						No of specimen	54
						Mean	1.00
						Std Dev	0.109
						C.O.V.	0.109

Table A9 – Transverse Fillet Weld Data and Comparisons

	Observed Data					Calculated Values	
Specimen Designation	σ_u (ksi)	t_{av} (in.)	$L_{w\ av}$ (in.)	P_{uo} (kips)	Failure	Eq. E2.4-3 P_n (kips)	P_{uo}/P_n
H A/B 18/7 C1	67.0	0.049	0.890	7.12	PC	5.84	1.22
H A/B 18/7 C2	67.0	0.048	0.940	7.18	PC	6.05	1.19
H A/B 18/7 C3	67.0	0.049	0.870	6.34	PC	5.71	1.11
H A/B 18/7 F1	67.0	0.048	1.51	10.7	PC	9.71	1.11
H A/B 18/7 F2	67.0	0.049	1.45	10.3	PC	9.52	1.08
H A/B 18/7 F3	67.0	0.049	1.57	10.1	PC	10.3	0.980
H A/B 18/7 L1	67.0	0.049	2.99	19.5	PC	19.6	0.993
H A/B 18/7 L2	67.0	0.049	3.04	19.6	PC	20.0	0.982
H A/B 18/7 L3	67.0	0.049	3.00	18.1	PC	19.7	0.919
H A/B 18/7 P1	67.0	0.048	3.98	23.0	PC	25.6	0.898
H A/B 18/7 P2	67.0	0.049	4.00	25.6	PC	26.3	0.975
H A/B 18/7 P3	67.0	0.049	4.00	26.3	PC+PT	26.3	1.00
H A/B 12/7 C1	51.4	0.106	0.990	12.6	PC	10.8	1.17
H A/B 12/7 C2	51.4	0.107	0.960	10.9	PC	10.6	1.03
H A/B 12/7 C3	51.4	0.106	0.960	11.9	PC	10.5	1.14
H A/B 12/7 F1	51.4	0.107	1.57	18.8	PC	17.3	1.09
H A/B 12/7 F2	51.4	0.106	1.54	18.8	PC	16.8	1.12
H A/B 12/7 F3	51.4	0.106	1.60	18.0	PC	17.4	1.03
H A/B 12/7 L1	51.4	0.107	3.06	31.3	PC	33.7	0.930
H A/B 12/7 L2	51.4	0.107	3.11	32.1	PC	34.2	0.938
H A/B 12/7 L3	51.4	0.107	3.13	32.3	PC	34.4	0.938
H A/B 12/7 P1	51.4	0.107	3.97	44.7	PC	43.7	1.02
H A/B 12/7 P2	51.4	0.107	3.99	44.0	PC	43.9	1.00
H A/B 12/7 P3	51.4	0.106	3.97	45.2	PC	43.3	1.04
H A/B 12/7 P1	51.1	0.110	3.92	39.0	PC	44.1	0.885
H A/B 12/7 P2	51.1	0.110	3.92	43.0	PC+PT	44.1	0.976
H A/B 12/7 P3	51.1	0.110	3.94	42.1	PC+PT	44.3	0.950
H A/B 12/7 P4	51.1	0.110	3.90	42.3	PC	43.8	0.965
H A/B 18/7 C1	64.7	0.051	1.16	7.56	PC	7.66	0.988
H A/B 18/7 C2	64.7	0.051	1.12	8.17	PC	7.39	1.11
H A/B 18/7 C3	64.7	0.051	1.19	8.45	PC	7.85	1.08
H A/B 18/7 C4	64.7	0.051	1.16	8.67	PC	7.66	1.13
H A/B 18/7 P1	64.7	0.051	3.89	23.8	PC	25.7	0.927
H A/B 18/7 P2	64.7	0.051	3.92	24.8	PC	25.9	0.959
H A/B 18/7 P3	64.7	0.051	3.94	24.2	PC	26.0	0.931
H A/B 18/7 P4	64.7	0.051	3.96	23.4	PC+PL+PT	26.1	0.895
H A/B 12/7 C1	51.1	0.110	1.09	13.0	PC	12.3	1.06
H A/B 12/7 C2	51.1	0.110	1.07	13.4	PC	12.0	1.12
H A/B 12/7 C3	51.1	0.110	1.13	14.2	PC	12.7	1.12
H A/A 18/18 P1	64.7	0.051	3.90	20.8	PL+PC	25.7	0.808
H A/A 18/18 P2	64.7	0.051	3.88	20.2	PL+PC	25.6	0.789
H A/A 18/18 P3	64.7	0.051	3.82	20.6	PL+PC	25.2	0.817
H A/A 18/18 C1	64.7	0.051	1.12	8.10	PC	7.39	1.10
H A/A 18/18 C2	64.7	0.051	1.08	8.22	PC	7.13	1.15
H A/A 18/18 C3	64.7	0.051	1.17	5.80	PC	7.72	0.751

Table A9 – Transverse Fillet Weld Data and Comparisons (continued)

Specimen Designation	Observed Data σ_u (ksi)	t_{av} (in.)	$L_{w\ av}$ (in.)	P_{uo} (kips)	Failure	Calculated Values Eq. E2.4-3 P_n (kips)	P_{uo}/P_n
H A/A 18/18 C4	64.7	0.051	1.12	6.72	PC+WS	7.39	0.909
H A/A 18/18 C5	64.7	0.051	1.09	7.22	PC	7.19	1.00
H A/A 12/12 F1	51.1	0.108	3.83	34.8	PC+WS+PL	42.3	0.823
H A/A 12/12 F2	51.1	0.108	3.88	36.8	PC+WS+PL	42.8	0.859
H A/A 12/12 F3	51.1	0.108	3.93	36.4	PC+WS+PL	43.4	0.839
H A/A 12/12 C1	51.1	0.108	1.26	14.7	PC+WS	13.9	1.06
H A/A 12/12 C2	51.1	0.108	1.14	12.9	PC+WS	12.6	1.02
H A/A 12/12 C3	51.1	0.108	1.21	13.7	PC+WS	13.4	1.03
H A/A 12/12 C4	51.1	0.108	1.14	13.9	PC+WS	12.6	1.10
						No of specimen	54
						Mean	1.00
						Std Dev	0.109
						C.O.V.	0.109

Table A10 – Transverse Flare-Bevel Weld Data taken from Reference 4

Specimen Designation	Observed Data σ_u (ksi)	t_{av} (in.)	$L_{w\,av}$ (in.)	P_{uo} (kips)	Failure
E A/B 18/7 F1	67.0	0.049	1.50	7.04	PC
E A/B 18/7 F2	67.0	0.048	1.52	9.58	PC
E A/B 18/7 F3	67.0	0.049	1.52	7.82	PC
E A/B 18/7 C1	67.0	0.049	0.940	2.66	PC
E A/B 18/7 C2	67.0	0.048	0.890	3.7	PC
E A/B 18/7 C3	67.0	0.049	0.940	4.7	PC
E A/B 18/7 C4	67.0	0.048	0.870	2.84	PC
E A/B 18/7 L1	67.0	0.048	3.13	16.2	PC
E A/B 18/7 L2	67.0	0.049	3.01	16.6	PC
E A/B 18/7 L3	67.0	0.049	2.96	16.6	PC
E A/B 18/7 P1	67.0	0.049	3.86	20.8	PC
E A/B 18/7 P2	67.0	0.050	3.98	21.5	PC
E A/B 18/7 P3	67.0	0.049	3.99	20.5	PC
E A/B 12/7 C1	51.4	0.107	0.950	9.5	PC+W
E A/B 12/7 C2	51.4	0.107	0.850	8.94	PC+W
E A/B 12/7 C3	51.4	0.106	0.900	9.44	PC+W
E A/B 12/7 F1	51.4	0.107	1.51	13	PC
E A/B 12/7 F2	51.4	0.106	1.55	10.8	PC
E A/B 12/7 F3	51.4	0.106	1.57	14.56	PC+W
E A/B 12/7 F4	51.4	0.107	1.51	14.3	PC+W
E A/B 12/7 L1	51.4	0.107	3.01	27.5	PC
E A/B 12/7 L2	51.4	0.107	3.00	27.5	PC
E A/B 12/7 L3	51.4	0.107	3.02	27.5	PC
E A/B 12/7 P1	51.4	0.107	4.00	33.1	PC
E A/B 12/7 P2	51.4	0.107	3.99	32.9	PC
E A/B 12/7 P3	51.4	0.106	3.99	33.3	PC
E A/B 12/7 P1	51.1	0.110	3.85	35.2	PC
E A/B 12/7 P2	51.1	0.110	3.87	35.7	PC
E A/B 12/7 P3	51.1	0.110	3.88	35.8	PC
E A/B 12/7 C1	51.1	0.110	1.08	13.96	PL+PC
E A/B 12/7 C2	51.1	0.110	1.10	12.62	PL+PC
E A/B 12/7 C3	51.1	0.110	1.15	13.06	PL+PC
E A/B 12/7 C4	51.1	0.110	1.22	12.58	PL+PC
E A/B 12/7 C5	51.1	0.110	1.21	12.62	PL+PC
E A/B 18/7 P1	64.7	0.050	3.84	19.25	PL+PC
E A/B 18/7 P2	64.7	0.050	3.91	20	PC
E A/B 18/7 P3	64.7	0.050	3.86	19.9	PL+PC
E A/B 18/7 C1	64.7	0.050	1.04	6.84	PL+PC
E A/B 18/7 C2	64.7	0.050	1.06	6.82	PL+PC
E A/B 18/7 C3	64.7	0.050	1.09	6.4	PL+PC
E A/B 18/7 C4	64.7	0.050	1.02	7.08	PL+PC
E A/B 18/7 C5	64.7	0.050	1.15	7.26	PL+PC
				No. of specimens	42

Table A11 – Transverse Flare-Bevel Weld Data and Comparisons

	Observed Data					Calculated Values	
Specimen Designation	σ_u (ksi)	t_{av} (in.)	$L_{w\ av}$ (in.)	P_{uo} (kips)	Failure	Eq. E2.5-1 P_n (kips)	P_{uo}/P_n
E A/B 18/7 F1	67.0	0.049	1.50	7.04	PC	8.20	0.858
E A/B 18/7 F2	67.0	0.048	1.52	9.58	PC	8.14	1.18
E A/B 18/7 F3	67.0	0.049	1.52	7.82	PC	8.31	0.941
E A/B 18/7 C1	67.0	0.049	0.940	2.66	PC	5.14	0.517
E A/B 18/7 C2	67.0	0.048	0.890	3.7	PC	4.77	0.776
E A/B 18/7 C3	67.0	0.049	0.940	4.7	PC	5.14	0.914
E A/B 18/7 C4	67.0	0.048	0.870	2.84	PC	4.66	0.609
E A/B 18/7 L1	67.0	0.048	3.13	16.2	PC	16.8	0.966
E A/B 18/7 L2	67.0	0.049	3.01	16.6	PC	16.5	1.01
E A/B 18/7 L3	67.0	0.049	2.96	16.6	PC	16.2	1.03
E A/B 18/7 P1	67.0	0.049	3.86	20.8	PC	21.1	0.985
E A/B 18/7 P2	67.0	0.050	3.98	21.5	PC	22.2	0.968
E A/B 18/7 P3	67.0	0.049	3.99	20.5	PC	21.8	0.939
E A/B 12/7 C1	51.4	0.107	0.950	9.5	PC+W	8.70	1.09
E A/B 12/7 C2	51.4	0.107	0.850	8.94	PC+W	7.79	1.15
E A/B 12/7 C3	51.4	0.106	0.900	9.44	PC+W	8.17	1.16
E A/B 12/7 F1	51.4	0.107	1.51	13	PC	13.8	0.940
E A/B 12/7 F2	51.4	0.106	1.55	10.8	PC	14.1	0.768
E A/B 12/7 F3	51.4	0.106	1.57	14.56	PC+W	14.3	1.02
E A/B 12/7 F4	51.4	0.107	1.51	14.3	PC+W	13.8	1.03
E A/B 12/7 L1	51.4	0.107	3.01	27.5	PC	27.6	0.997
E A/B 12/7 L2	51.4	0.107	3.00	27.5	PC	27.5	1.00
E A/B 12/7 L3	51.4	0.107	3.02	27.5	PC	27.7	0.994
E A/B 12/7 P1	51.4	0.107	4.00	33.1	PC	36.7	0.903
E A/B 12/7 P2	51.4	0.107	3.99	32.9	PC	36.6	0.900
E A/B 12/7 P3	51.4	0.106	3.99	33.3	PC	36.2	0.919
E A/B 12/7 P1	51.1	0.110	3.85	35.2	PC	36.1	0.976
E A/B 12/7 P2	51.1	0.110	3.87	35.7	PC	36.2	0.985
E A/B 12/7 P3	51.1	0.110	3.88	35.8	PC	36.3	0.985
E A/B 12/7 C1	51.1	0.110	1.08	13.96	PL+PC	10.1	1.38
E A/B 12/7 C2	51.1	0.110	1.10	12.62	PL+PC	10.3	1.23
E A/B 12/7 C3	51.1	0.110	1.15	13.06	PL+PC	10.8	1.21
E A/B 12/7 C4	51.1	0.110	1.22	12.58	PL+PC	11.4	1.10
E A/B 12/7 C5	51.1	0.110	1.21	12.62	PL+PC	11.3	1.11
E A/B 18/7 P1	64.7	0.050	3.84	19.25	PL+PC	20.7	0.930
E A/B 18/7 P2	64.7	0.050	3.91	20	PC	21.1	0.949
E A/B 18/7 P3	64.7	0.050	3.86	19.9	PL+PC	20.8	0.957
E A/B 18/7 C1	64.7	0.050	1.04	6.84	PL+PC	5.61	1.22
E A/B 18/7 C2	64.7	0.050	1.06	6.82	PL+PC	5.71	1.19
E A/B 18/7 C3	64.7	0.050	1.09	6.4	PL+PC	5.87	1.09
E A/B 18/7 C4	64.7	0.050	1.02	7.08	PL+PC	5.50	1.29
E A/B 18/7 C5	64.7	0.050	1.15	7.26	PL+PC	6.20	1.17
						No of specimens	42
						Mean	1.01
						Std Dev	0.165
						C.O.V.	0.164

Table A12 – Longitudinal Flare-Bevel Weld Data taken from Reference 4

	Experimental Results				
Specimen Designation	σ_u (ksi)	t_{av} (in.)	$L_{w\ av}$ (in.)	P_{uo} (kips)	Failure
D A/B 18/7 C1	67.0	0.050	0.790	17.6	PC+WS+PL
D A/B 18/7 C2	67.0	0.050	0.790	19.4	PC+WS+PL
D A/B 18/7 C3	67.0	0.049	0.880	21.2	PC+WS+PL
D A/B 18/7 F1	67.0	0.049	1.61	21.0	PC+PT+PS
D A/B 18/7 F2	67.0	0.049	1.72	23.4	PC+PT+PL
D A/B 18/7 F3	67.0	0.049	1.71	21.9	PC+PT+PL
D A/B 18/7 L1	67.0	0.050	2.99	29.4	PT
D A/B 18/7 L2	67.0	0.049	3.01	27.4	PT
D A/B 18/7 L3	67.0	0.049	2.99	28.6	PT
D A/B 12/7 C1	51.4	0.107	0.910	28.5	WS
D A/B 12/7 C2	51.4	0.107	0.870	25.2	WS
D A/B 12/7 C3	51.4	0.107	0.890	29.0	WS
D A/B 12/7 F1	51.4	0.107	1.46	39.3	PC+PT+PL
D A/B 12/7 F2	51.4	0.107	1.39	39.1	PT
D A/B 12/7 F3	51.4	0.107	1.51	39.6	PC+PT+PL
D A/B 12/7 F6	51.4	0.107	1.42	35.5	WS
D A/B 12/7 L1	51.4	0.108	2.96	45.9	PT
D A/B 12/7 L2	51.4	0.109	2.99	44.9	PT
D A/B 12/7 L3	51.4	0.109	3.00	45.0	PT
D A/B 18/7 C1	64.7	0.051	1.14	22.3	PC+PT+PL
D A/B 18/7 C2	64.7	0.051	1.03	20.2	PC+PT+PL+WS
D A/B 18/7 C3	64.7	0.051	1.10	21.3	PC+PT+PL+WS
D A/B 18/7 C4	64.7	0.051	1.09	21.5	PL+PC+PT
D A/B 18/7 L1	64.7	0.051	2.90	27.4	PL+PT
D A/B 18/7 L2	64.7	0.051	3.02	26.9	PT
D A/B 18/7 L3	64.7	0.051	3.06	26.6	PT
D A/B 12/7 C1	51.1	0.110	1.06	30.1	PC+WS
D A/B 12/7 C2	51.1	0.110	1.08	31.0	WS
D A/B 12/7 C3	51.1	0.110	1.06	31.6	WS
D A/B 12/7 L1	51.1	0.110	3.14	47.3	PT
D A/B 12/7 L2	51.1	0.110	3.09	46.7	PT
D A/B 12/7 L3	51.1	0.110	3.04	47.2	PT
			No. of specimens		32

Table A13 – Longitudinal Flare-Bevel Weld Data and Comparisons

	Experimental Results					Predicted Results	
						Eq. E.2-5	
Specimen Designation	σ_u (ksi)	t_{av} (in.)	$L_{w\,av}$ (in.)	P_{uo} (kips)	Failure	P_n (kips)	P_{uo}/P_n
D A/B 18/7 C1	67.0	0.050	0.790	17.6	PC+WS+PL	15.9	1.11
D A/B 18/7 C2	67.0	0.050	0.790	19.4	PC+WS+PL	15.9	1.22
D A/B 18/7 C3	67.0	0.049	0.880	21.2	PC+WS+PL	17.3	1.22
D A/B 12/7 C1	51.4	0.107	0.910	28.5	WS	30.0	0.949
D A/B 12/7 C2	51.4	0.107	0.870	25.2	WS	28.7	0.878
D A/B 12/7 C3	51.4	0.107	0.890	29.0	WS	29.4	0.987
D A/B 12/7 F6	51.4	0.107	1.42	35.5	WS	46.9	0.758
D A/B 12/7 C1	51.1	0.110	1.06	30.1	PC+WS	35.7	0.842
D A/B 12/7 C2	51.1	0.110	1.08	31.0	WS	36.4	0.851
D A/B 12/7 C3	51.1	0.110	1.06	31.6	WS	35.7	0.884
						No. of specimens	10
						Mean	0.970
						Std. Dev.	0.163
						C.O.V.	0.168

Table A14 – Tearing of Plate Material Data taken from Reference 4

	Observed Data				
Specimen Designation	σ_u (ksi)	s_{av} (in.)	t_{plate} (in.)	P_{uo} (ksi)	Failure
C A/B 18/7 J1	67.0	2.99	0.049	17.10	PT
C A/B 18/7 J2	67.0	2.98	0.049	15.90	PT
C A/A 18/18 J1	67.0	3.00	0.048	15.80	PT
C A/A 18/18 J2	67.0	2.97	0.047	14.30	PT
C A/A 18/18 J3	67.0	3.00	0.049	15.84	PT
C A/A 18/18 J4	67.0	2.99	0.049	15.70	PT
C A/B 12/7 J1	51.4	3	0.107	31.10	PT
C A/B 12/7 J2	51.4	2.98	0.107	30.40	PT
C A/B 12/7 C5	51.1	3.00	0.108	22.70	PT
C A/B 18/7 J1	64.7	2.99	0.052	15.40	PT
C A/B 18/7 J2	64.7	3.00	0.052	16.24	PT
C A/B 18/7 J3	64.7	2.99	0.052	16.30	PT
C A/B 18/7 J4	64.7	2.99	0.052	16.60	PT
C A/B 18/7 J5	64.7	2.99	0.052	15.10	PT
C A/B 12/7 P1	51.1	3.00	0.108	31.10	PT
C A/B 12/7 P2	51.1	2.99	0.108	31.50	PT
C A/B 12/7 P3	51.1	3.00	0.108	32.00	PT
C A/A 18/18 J3	64.7	3.00	0.050	14.70	PL+PT
C A/A 18/18 J4	64.7	3.00	0.050	15.50	PL+PT
C A/A 18/18 J5	64.7	3.00	0.050	14.93	PL+PT

Table A15 – Tearing of Plate Material Data and Comparisons (Using Equation E2.7-1 of AISI)

	Observed Data					Calculated Values	
Specimen Designation	σ_u (ksi)	s_{av} (in.)	t_{plate} (in.)	P_{uo} (ksi)	Failure	Eq. E2.7-1 P_n (kips)	P_{uo}/P_n
C A/B 18/7 J1	67.0	2.99	0.049	17.10	PT	9.82	1.74
C A/B 18/7 J2	67.0	2.98	0.049	15.90	PT	9.78	1.63
C A/A 18/18 J1	67.0	3.00	0.048	15.80	PT	9.65	1.64
C A/A 18/18 J2	67.0	2.97	0.047	14.30	PT	9.35	1.53
C A/A 18/18 J3	67.0	3.00	0.049	15.84	PT	9.85	1.61
C A/A 18/18 J4	67.0	2.99	0.049	15.70	PT	9.82	1.60
C A/B 12/7 J1	51.4	3	0.107	31.10	PT	16.50	1.88
C A/B 12/7 J2	51.4	2.98	0.107	30.40	PT	16.39	1.85
C A/B 12/7 C5	51.1	3.00	0.108	22.70	PT	16.56	1.37
C A/B 18/7 J1	64.7	2.99	0.052	15.40	PT	10.06	1.53
C A/B 18/7 J2	64.7	3.00	0.052	16.24	PT	10.09	1.61
C A/B 18/7 J3	64.7	2.99	0.052	16.30	PT	10.06	1.62
C A/B 18/7 J4	64.7	2.99	0.052	16.60	PT	10.06	1.65
C A/B 18/7 J5	64.7	2.99	0.052	15.10	PT	10.06	1.50
C A/B 12/7 P1	51.1	3.00	0.108	31.10	PT	16.56	1.88
C A/B 12/7 P2	51.1	2.99	0.108	31.50	PT	16.50	1.91
C A/B 12/7 P3	51.1	3.00	0.108	32.00	PT	16.56	1.93
C A/A 18/18 J3	64.7	3.00	0.050	14.70	PL+PT	9.71	1.51
C A/A 18/18 J4	64.7	3.00	0.050	15.50	PL+PT	9.71	1.60
C A/A 18/18 J5	64.7	3.00	0.050	14.93	PL+PT	9.71	1.54

No. of specimens	20
Mean	1.657
Std. Dev.	0.158
C.O.V.	0.095

Table A16 – Tearing of Plate Material Data and Comparisons (Using Equation (2) of Reference 4)

Specimen Designation	Observed Data σ_u (ksi)	s_{av} (in.)	t_{plate} (in.)	P_{uo} (ksi)	Failure	Calculated Values Eq. 2 [4] P_n (kips)	P_{uo}/P_n
C A/B 18/7 J1	67.0	2.99	0.049	17.10	PT	15.71	1.09
C A/B 18/7 J2	67.0	2.98	0.049	15.90	PT	15.65	1.02
C A/A 18/18 J1	67.0	3.00	0.048	15.80	PT	15.44	1.02
C A/A 18/18 J2	67.0	2.97	0.047	14.30	PT	14.96	0.96
C A/A 18/18 J3	67.0	3.00	0.049	15.84	PT	15.76	1.01
C A/A 18/18 J4	67.0	2.99	0.049	15.70	PT	15.71	1.00
C A/B 12/7 J1	51.4	3	0.107	31.10	PT	26.40	1.18
C A/B 12/7 J2	51.4	2.98	0.107	30.40	PT	26.22	1.16
C A/B 12/7 C5	51.1	3.00	0.108	22.70	PT	26.49	0.86
C A/B 18/7 J1	64.7	2.99	0.052	15.40	PT	16.10	0.96
C A/B 18/7 J2	64.7	3.00	0.052	16.24	PT	16.15	1.01
C A/B 18/7 J3	64.7	2.99	0.052	16.30	PT	16.10	1.01
C A/B 18/7 J4	64.7	2.99	0.052	16.60	PT	16.10	1.03
C A/B 18/7 J5	64.7	2.99	0.052	15.10	PT	16.10	0.94
C A/B 12/7 P1	51.1	3.00	0.108	31.10	PT	26.49	1.17
C A/B 12/7 P2	51.1	2.99	0.108	31.50	PT	26.40	1.19
C A/B 12/7 P3	51.1	3.00	0.108	32.00	PT	26.49	1.21
C A/A 18/18 J3	64.7	3.00	0.050	14.70	PL+PT	15.53	0.95
C A/A 18/18 J4	64.7	3.00	0.050	15.50	PL+PT	15.53	1.00
C A/A 18/18 J5	64.7	3.00	0.050	14.93	PL+PT	15.53	0.96
						No. of specimens	20
						Mean	1.04
						Std. Dev.	0.099
						C.O.V.	0.095

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