ARC International, LLC

REQUIRED CLEARANCE FOR WELDED JOINTS

Report for

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

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Submitted by

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INTRODUCTION

Adequate clearance must be provided adjacent to welded joints to ensure proper welding and inspection. If optimal clearance is not provided, fabrication efficiency can be reduced. For small clearances, the weld can be obstructed enough to affect the weld quality, potentially reducing the weld strength. This research project addresses three weld clearance issues:

1. Welding near obstructions
2. Doubler plate welds
3. Acute angle welds

Welding Near Obstructions

Weld clearance recommendations published by Grover (1946) and LEC (1994) are shown in Figures 1 and 2, respectively. According to Shaw (1996), generally "access requires a minimum of at least 18 in. of clear space around the joint." Weld clearance requirements are also discussed on page 8-15 of the AISC *Manual* (AISC, 2011). For horizontal welds using the SMAW process, page 8-15 of the AISC *Manual* recommends a 30° angle as shown in Figure 1, with an absolute minimum angle of 27°. If the proper clearance cannot be attained, the more expensive alternative details in Figure 2 can be used.

Another common weld access problem is shown in Figure 5, where a plate is welded to the web of an I-shape member with a complete-joint-penetration (CJP) weld. In many cases, the arc cannot be properly directed against the base metal due to an obstruction caused by the flange. There is not a direct line of sight for the welder or the inspector to view the beveled weld preparation surface.

The recommendations by Grover (1946), LEC (1994) and AISC (2011) are based on the SMAW process; however, due to the low production rates, SMAW is primarily used only for tack welding. Most structural shops now use FCAW or GMAW for production shop welding. FCAW-g is the most used process for shop fabrication of structural steel, and FCAW-ss is the most used process for field welding of steel structures. The geometry of a FCAW welding gun, including gas nozzle for FCAW-g, is much different from a SMAW stick electrode. Additionally, electrode manipulation techniques may be different between the two processes. Therefore, the historic values previously developed for the SWAW process may need to be updated for use with FCAW. It is believed that clearances required for FCAW-g will be larger than for FCAW-ss due to the presence of the gas nozzle; therefore, the research plan includes only shop welding with the FCAW-g process.

An additional parameter that may affect weld clearance requirements is the "banking" of weld metal to counteract the effect of gravity for welds made in the horizontal position. To obtain equal leg fillet welds, the welder typically rotates the electrode toward the horizontal surface, so the arc is directed more toward the vertical surface. Based on this, a vertical obstruction element may be more critical than a horizontal obstruction in the welding of joints in the horizontal position.

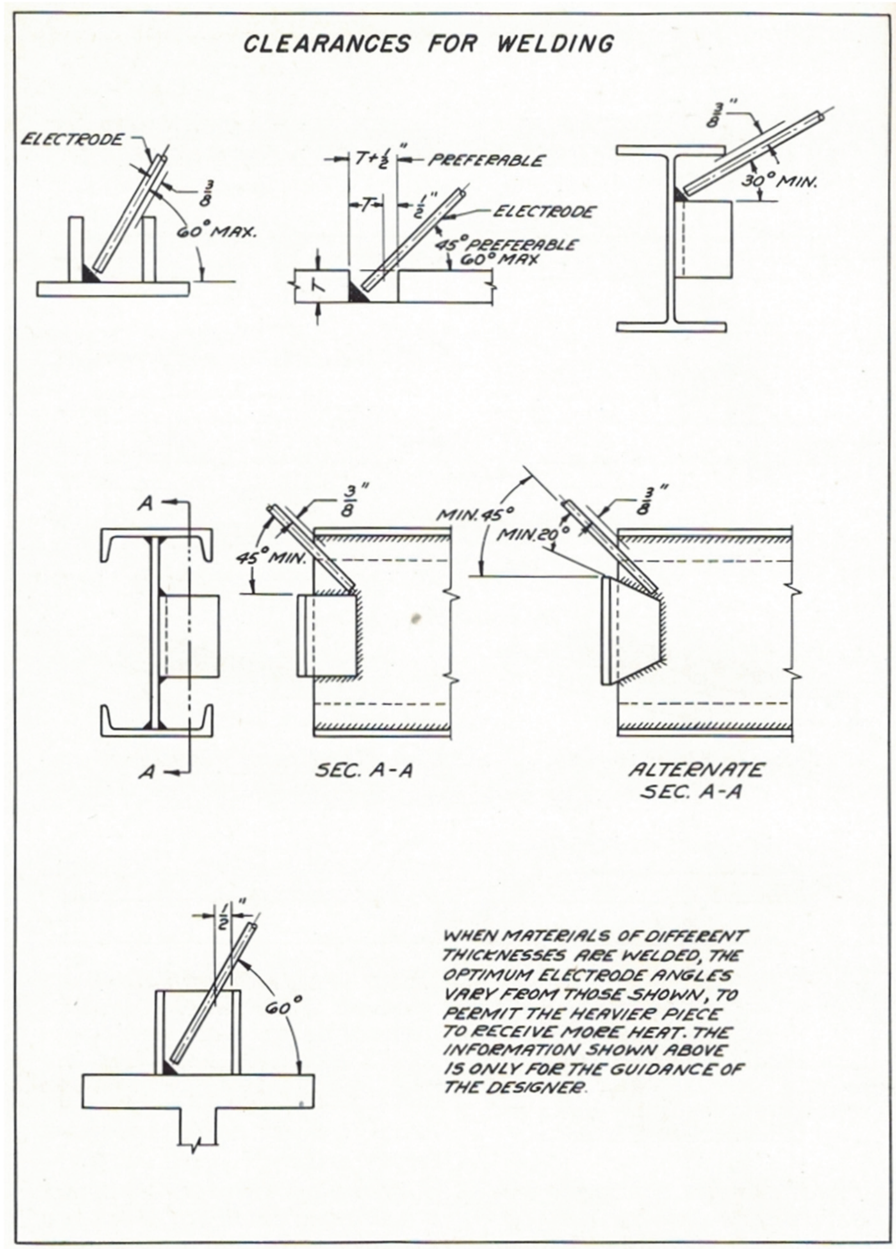


Fig. 1. Weld clearance recommendations by Grover (1946).

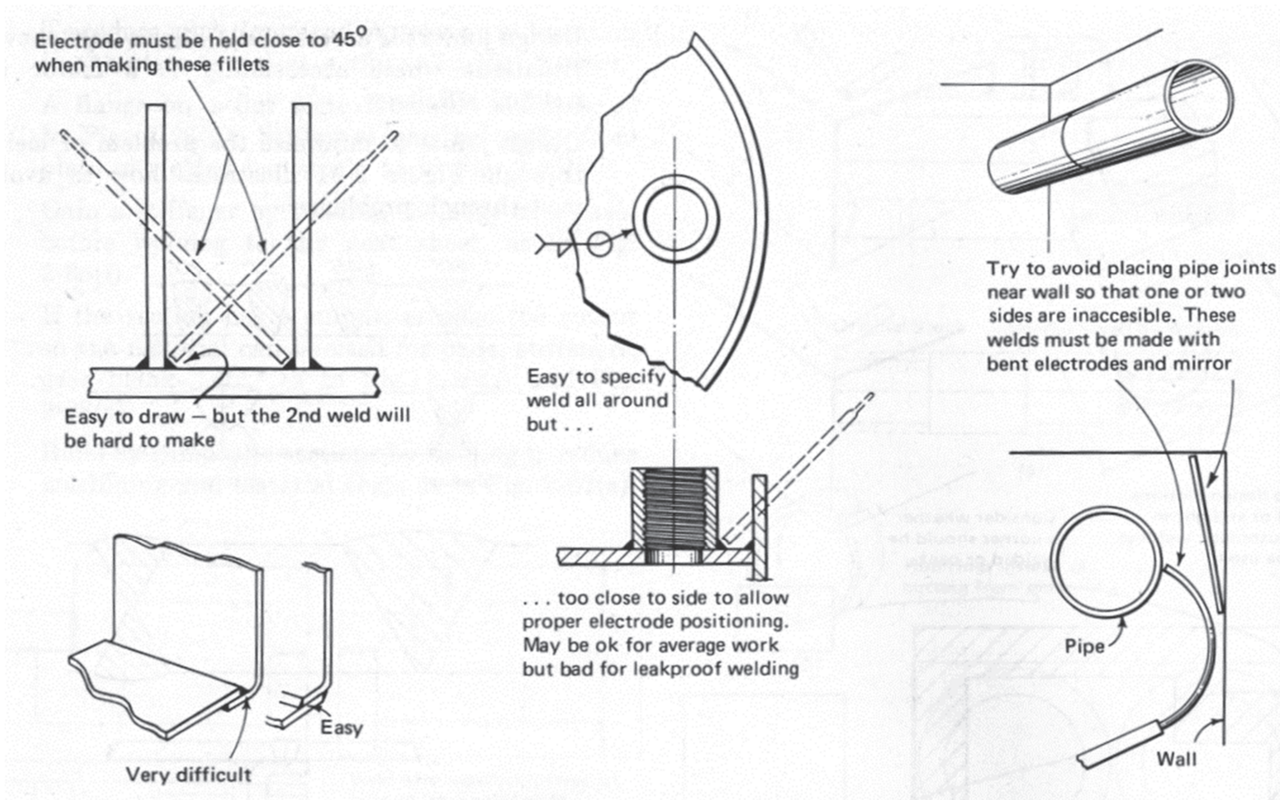


Fig. 2. Weld clearance recommendations by LEC (1994).

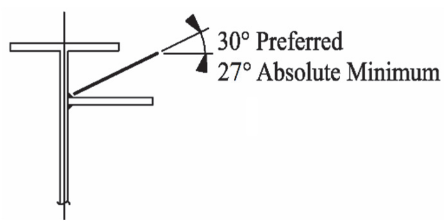
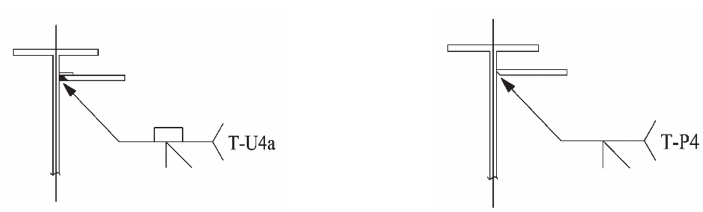


Fig. 3. Clearance for welding and inspection.



a. CJP Weld *b. PJP Weld*

Fig. 4. Alternative welds for joints with clearance on one side only.

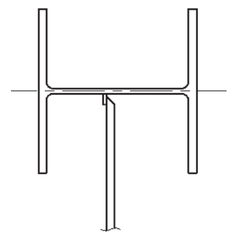


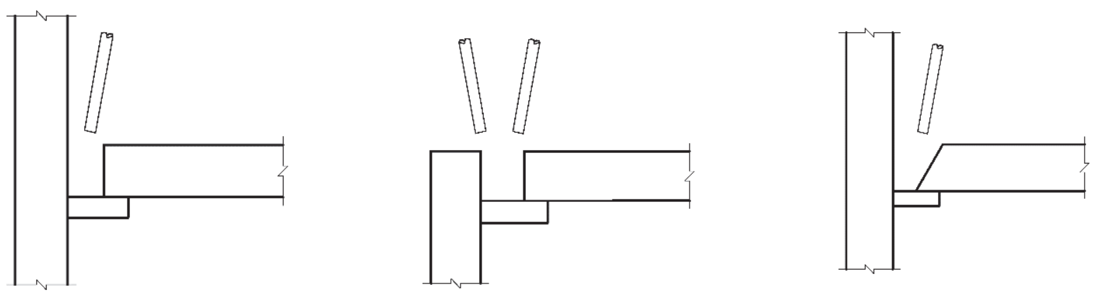
Fig. 5. Complete-joint-penetration weld with access problems.

Doubler Plate Welds

The main function of a weld preparation is to facilitate the required weld metal penetration. The preparation must provide adequate access, so the arc can be directed against the base metal. Figure 6a shows a Tee joint with a square groove preparation that is not prequalified because the arc cannot be directed against the base metal. A similar detail is shown for a corner joint in Figure 6b. For relatively thin materials, the corner joint is prequalified because arc access is not obstructed as it is for the Tee joint. A prequalified Tee joint with a single-bevel weld preparation is shown in Figure 6c, where the arc can be directed against the beveled surface.

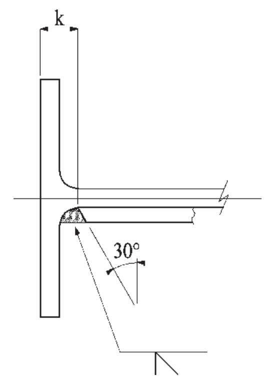
Typical doubler plate-to-column flange welds are shown in Figure 7, where Option 1 is fillet-welded and Option 2 is groove-welded. The groove welds are considered full-strength welds, although they are not AWS prequalified joints. For thin doubler plates, fabricators often eliminate the weld preparation by welding the edge of a square-cut plate, relying on the welding heat to provide adequate penetration at both the plate and the column. For thick doubler plates, the 30° preparation shown for Option 2 is often used because the geometry is similar to the prequalified joint in Figure 6c. Fabrication practices vary, but generally, plates less than ⅜ in. thick are cut square and plates ⅜ in. and thicker are beveled at 30°. The variables for the weld joint geometry are shown in Figure 8.

Allowing a slight encroachment into the flange-to-web fillet radius reduces the volume of weld metal, which also reduces both the cost of the joint and the weld shrinkage stresses. Distortion of the column due to weld shrinkage at a web doubler plate is shown in Figure 9. The weld metal volume can also be reduced by using square-cut plate edges.

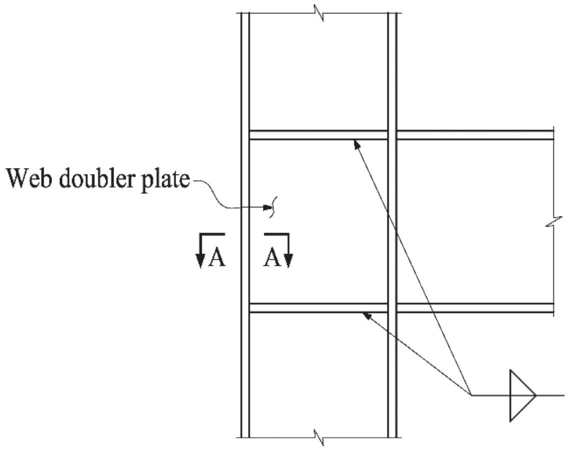


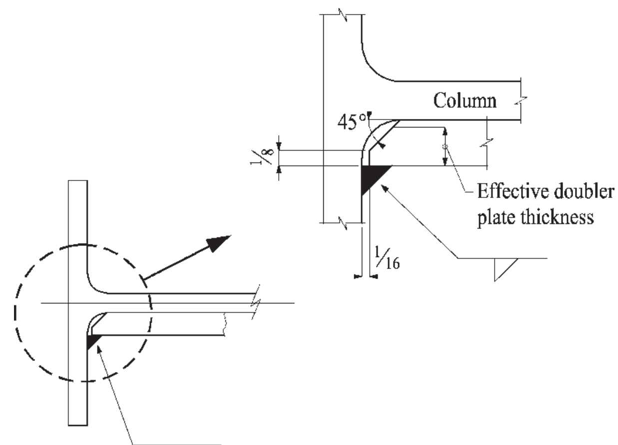
a. not prequalified   *b. prequalified for limited thickness*   *c. prequalified for unlimited thickness*

Fig. 6. Arc access.



Option 2: Groove weld





Option 1: Fillet weld

Fig. 7. Web doubler plate welds at column flanges.

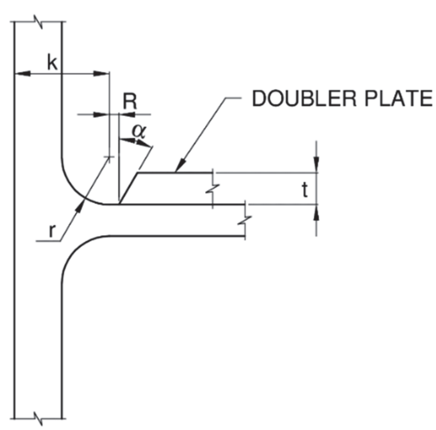


Fig. 8. Doubler plate weld geometry.

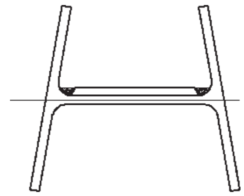
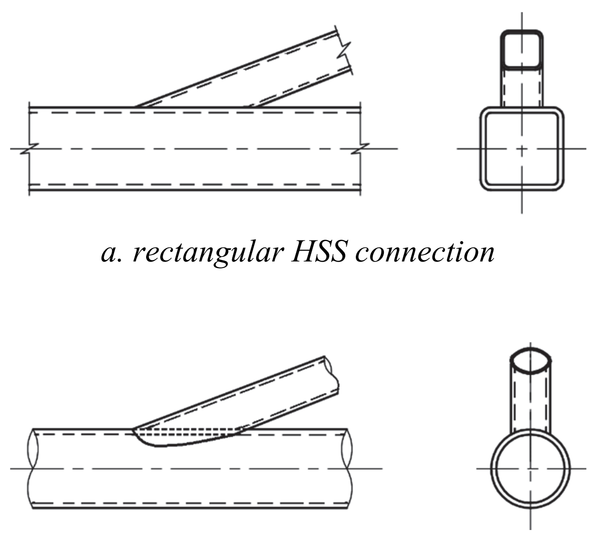


Fig. 9. Exaggerated distortion due to weld shrinkage at a web doubler plate.

Acute Angle Welds

Figure 10 shows typical HSS truss joints, where the heel of the joint must be welded at an acute angle. Acute-angle welds can be problematic when the dihedral angle is less than 30°. AWS D1.1:2015 Subclause 9.15.4.2 discusses the qualification requirements for tubular joints with dihedral angles less than 30°. At small angles, limited access to the joint root causes a lack of penetration and the weld metal near the root can be used only as backup to the sound weld passes. In design, this dimension, known as the z-loss dimension, is subtracted from the theoretical weld throat. Although tapered gas nozzles can be used at joints with small angles, weld quality can be reduced where wider gas coverage is required to protect the arc. Also, production efficiency is reduced when tapered nozzles are used. The effectiveness of welding practices common to structural steel fabricators is unclear at dihedral angles less than 30°.



a. rectangular HSS connection

b. round HSS connection

Fig. 10. HSS truss joints.

OBJECTIVES

The objectives of this research are to determine practical limits on connection geometry for welding near obstructions and welding acute-angle heel joints.

Welding Near Obstructions
The objective of the obstructed fillet weld research is to determine the minimum clearance required for fillet welded joints, and the effect of small clearances on weld quality and production efficiency.

Doubler Plate Welds
The objective of the doubler plate tests is to provide preliminary information regarding the root-pass penetration for square-cut plates, based on the plate thickness and the distance from the inner surface of the flange to the edge of the plate.

Acute Angle Welds
The objective of the acute-angle tests is to provide preliminary information regarding the viability, quality, economy and geometry of skewed joints fabricated according to AWS D1.1 Figure 3.8 Detail D with dihedral angles, ϕ, less than 30°.

PROCEDURE

For the three weld clearance issues discussed, specimens were fabricated, sectioned and inspected. All specimens were fabricated by AISC Certified fabricators using the FCAW-g process. Each shop selected a welder to participate in the project, based on an average level of skill and experience. The selected welders completed a questionnaire and the engineering/production managers were interviewed for further information. All specimens were sectioned into sub-specimens by cold-sawing at two locations perpendicular to the weld. The saw-cut sections were macro-etched with a 10% Nital etchant, which consists of 10 ml nitric acid and 90 ml ethyl alcohol.

Welding Near Obstructions

The weld clearance specimens used a ¼ × 8 in. plate to simulate an obstruction. Each specimen was fabricated with seven test welds, as shown in Figure 11. The outermost ¼ × 2 in. plate was welded first and the assembly sequence progressed toward the obstruction plate. Figure 12 shows the weld sequences, labeled Location 1 through Location 7, with Location 7 closest to the obstruction plate.

One large fabricator and two medium-size fabricators participated in this part the project. Each fabricator supplied three specimens, with two specimens welded in the horizontal position and one specimen welded in the vertical position. For the specimens welded in the horizontal position, Position A was oriented with the obstruction plate in the vertical direction and Position B had the obstruction plate in the horizontal direction as shown in Figures 13a and 13b, respectively. A specimen welded in the vertical-position, designated Position C, is shown in Figure 14c. The weld position for each specimen was identified by the fabricator. The specimens were inspected by the fabricator and the leg sizes were measured using a fillet weld gage as shown in Figure 15.

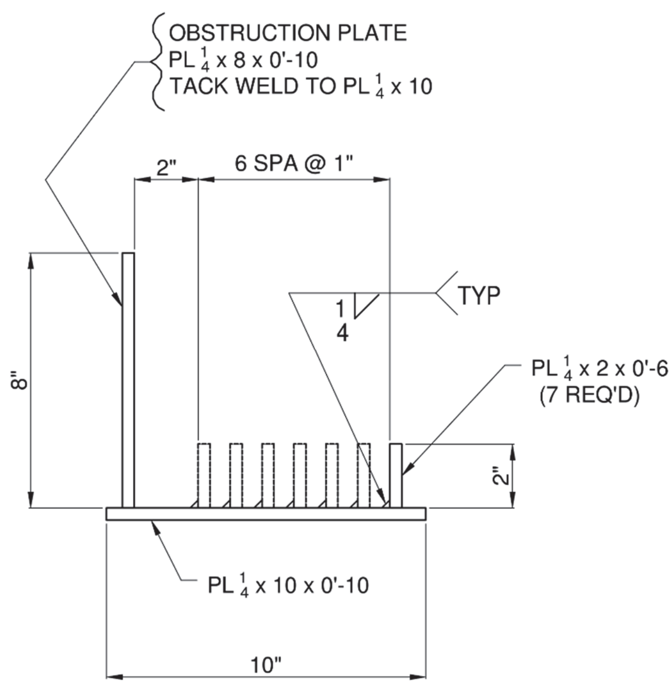


Fig. 11. Weld clearance specimen detail.

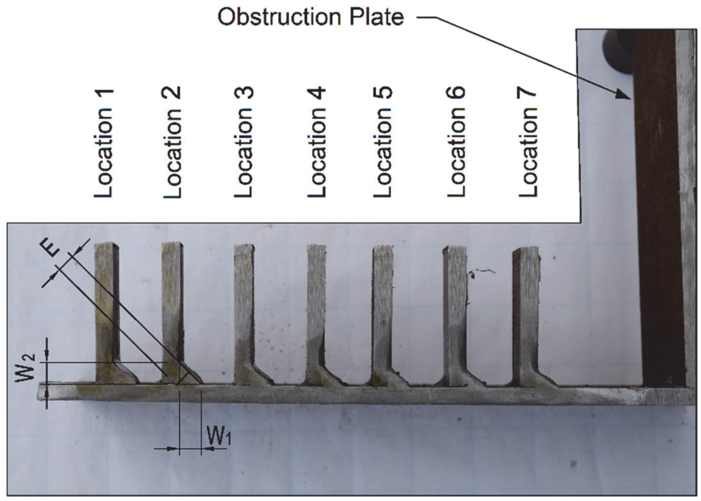
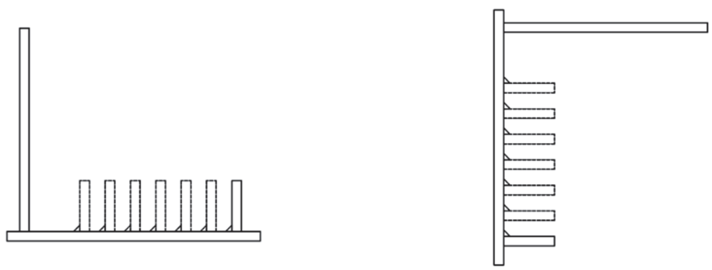


Fig 12. Section of a completed weld clearance specimen.



a. Position A *b. Position B*

Fig. 13. Orientations for horizontal welding positions.

a. Position A *b. Position B* *c. Position C*

Fig. 14. Specimen positions.

Fig. 15. Measurement of weld leg size.

Each weld specimen is identified with the designation, FPC-L, where F is the fabricator number, P is the welding position, C designates the cross-sectional cut location along the weld length and L is the weld location number. After sectioning and etching the specimens, the weld leg sizes and effective throat dimensions were measured from a digital image.

Doubler Plate Welds

Fabricator 1 supplied eight simulated doubler plate specimens. Four of the fabricated specimens are shown in Figure 16. The specimens are 9 in. long and were welded in the horizontal position. Drop material from a recent project was used for the W-shape, with extension tabs tack-welded to the flange tips to simulate a W14×90 column.

The simulated doubler plate was square-cut ($\alpha = 0°$) with variable dimensions are shown in Figure 17. The distance from the inner surface of the flange to the edge of the plate, *x*, was either ⅝ in. or 1¼ in. and four different plate thicknesses were used: ¼, ⅜, ½ and ¾ in. Because the concerns are associated with penetration at the root pass, only the first pass was completed and the remaining passes required to complete the joint were omitted.

Fig. 16. Doubler plate specimens.

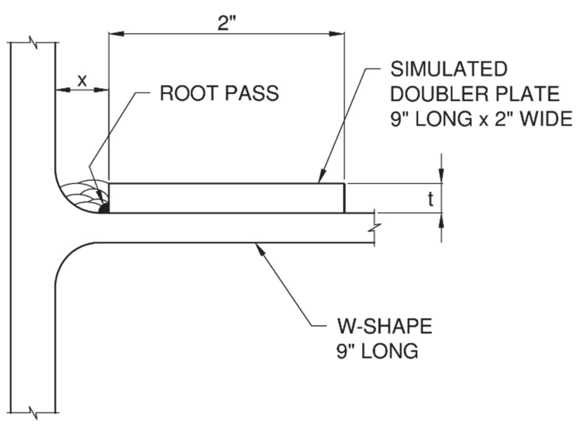
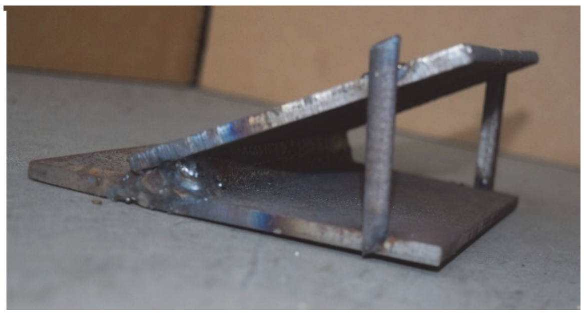


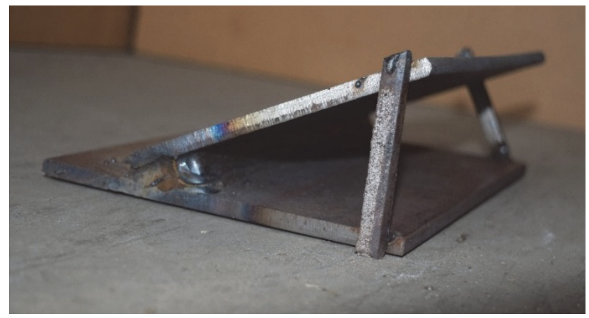
Fig. 17. Doubler plate specimens.

Acute Angle Welds

Fabricator 1 supplied four acute-angle specimens, shown in Figure 18. The specimens are 8 in. long and were welded in the horizontal position. The weld geometry was based on AWS D1.1 (AWS, 2015) Figure 3.8 Detail D (see Figure 19) and Table 3.6 with t_b = ¼ in., t_w = ½ in. and F = ⅛ in. Four different dihedral angles, ϕ, were used: 15°, 20°, 25° and 30°.

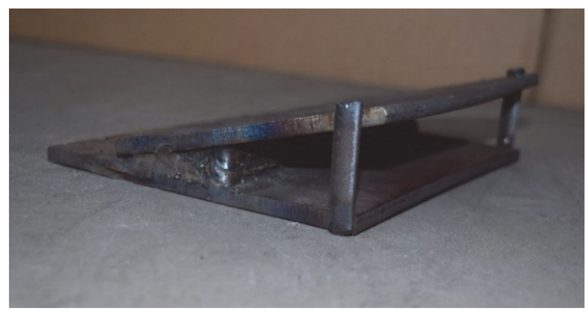


a. 30° Angle



b. 25° Angle

c. 20° Angle



d. 15° Angle

Fig. 18. Acute-angle specimens.

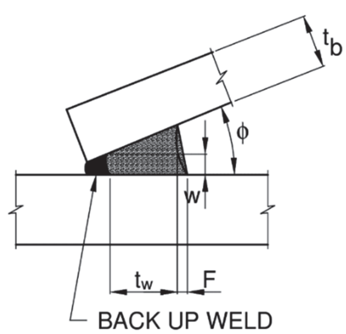


Fig. 19. Acute-angle specimens.

RESULTS

The completed welder interview questionnaires are in Appendix D and the Welding Procedure Specifications for Fabricators 1 and 2 are in Appendix E. The Welding Procedure Specification for Fabricator 3 was not available. The weld inspection report from Fabricator 1 is in Appendix F. Fabricators 2 and 3 verbally reported that all welds were inspected, and accepted as-delivered.

Welding Near Obstructions
All photographs for the sectioned clearance specimens are in Appendix A. Representative samples are shown in Figures 20, 21 and 22 for the specimens welded in Position A, B and C, respectively. The digitally-measured weld leg sizes and effective throat dimensions are listed in Table B-1 of Appendix B. The measured values, shown in Figure 12, are the effective throat, *E*, and the fillet weld leg sizes, w_1 and w_2.

As indicated in Table B-1, several of the weld leg measurements are less than the specified size of ¼ in. However, these welds passed the fabricator's visual inspection and meet the visual inspection acceptance criteria requirements of AWS D1.1 Table 6.1, which allows a minimum size of ¼ in. – 3⁄32 in. = 0.156 in. over 10% of the weld length. Based on the specified leg size, the theoretical effective throat is

$$E_t = \frac{1/4\text{ in.}}{\sqrt{2}} = 0.177\text{ in.}$$

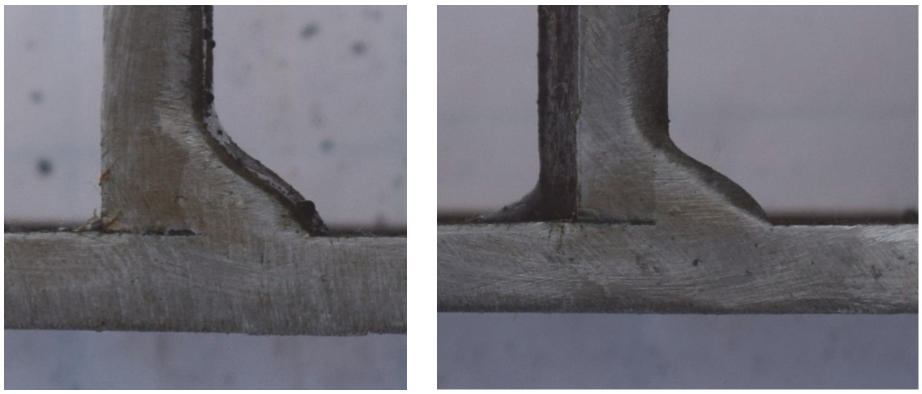
Specimen 1B2-3 is the only weld with a measured effective throat less than 0.177 in. At this section, the measured dimension is only 4% less than the theoretical value. A reduction in the effective throat at this location could be predicted by evaluating the slightly undersized Leg 1. Because Leg 1 was undersized over less than 10% of the weld length, the slightly undersized effective throat can be considered within tolerance.

The welds for Specimens 1A1-1, 1A1-2, 1A2-1, 1A2-2, 1B1-1, 1B1-2, 1B2-1 and 1B2-2 were rejected by the inspector without repair. The rejected welds were in Positions 1 and 2, which were farthest from the obstruction plate. Several of the rejected specimens have undersized weld legs; however, the effective throat dimensions for these specimens are greater than the theoretical values.

As the distance between the weld and the obstruction plate decreases, the electrode angle changes, causing the arc to be increasingly directed toward the ¼ × 10 in. plate and away from the ¼ × 2 in. plates. This causes an increase in the leg aspect ratio, w_1/w_2, and a decrease in the penetration into the base metal at Leg 2. The leg aspect ratios for each specimen are listed in Table B-1. The mean values for all specimens are plotted in Figure 23, which shows approximately equal leg sizes for Locations 1 through 5. For Locations 6 and 7, the mean value for w_1 is approximately 15 to 20% greater than w_2. This effect is clearly demonstrated in Figures 22d, 22e and 22f, where the specimen locations are 5, 6 and 7, respectively. The aspect ratios for Locations 5, 6 and 7 are 1.20, 1.25 and 1.70, respectively.

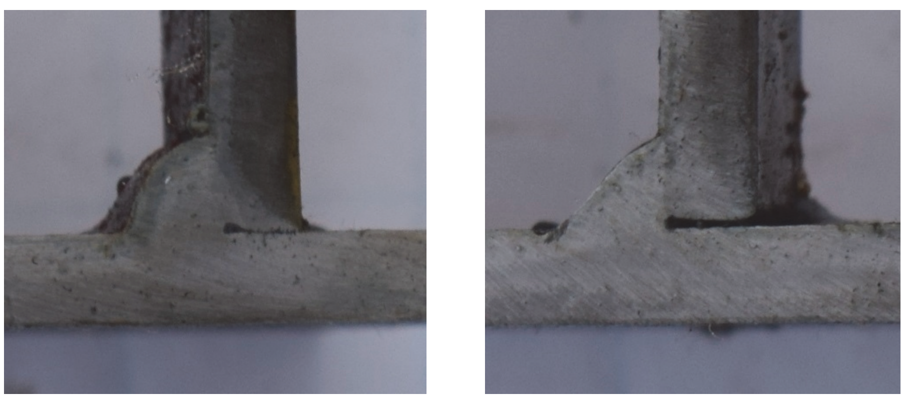
Generally, all welds showed good fusion at both plates; however, the penetration depth at the ¼ × 2 plates (Leg 2) decreased as the distance between the weld and the obstruction plate decreased. The specimen in Figure 21a, at Location 1, showed normal root penetration. For the weld closest to the obstruction plate, Figure 21b shows a lack of significant penetration at Leg 2.

An estimate of the reduction in efficiency is the area ratio, A_m/A_t, where A_m is the weld metal area calculated with the measured leg sizes and A_t is the theoretical weld metal area calculated with the specified leg size. The area ratios for each specimen are listed in Table B-1. And the mean values for all specimens are plotted in Figure 24. At Location 1, A_m is approximately 20% more than A_t. As the distance between the weld and the obstruction plate decreases the area ratio shows an upward trend to a maximum mean value of 1.33 at Location 5.



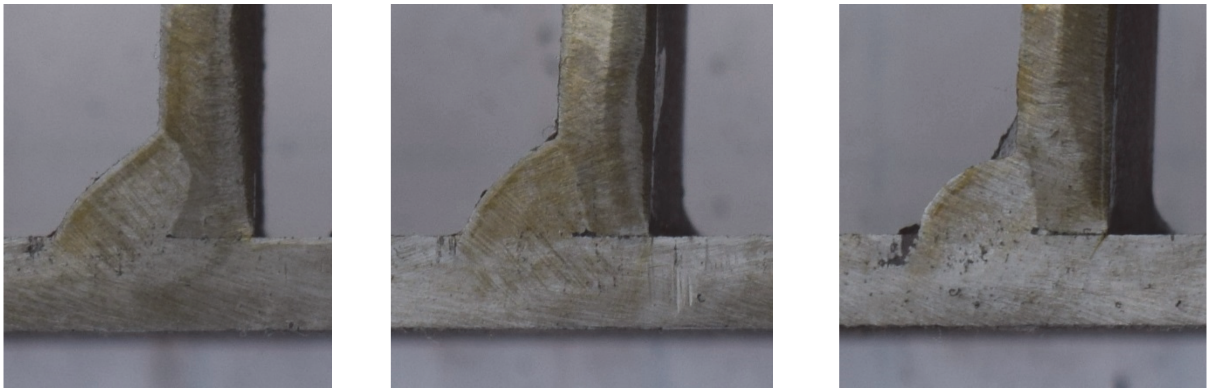
a. Location 3 *c. Location 7*

Fig. 20. Clearance specimens-Position A.

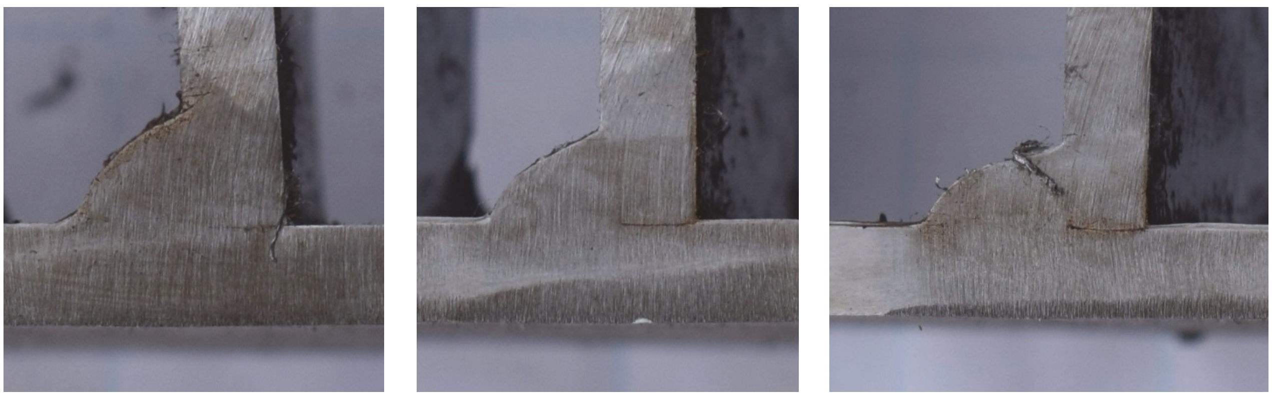


a. Location 1 *c. Location 7*

Fig. 21. Clearance specimens-Position B.



a. Fabricator 1-Location 5 *b. Fabricator 1-Location 6* *c. Fabricator 1-Location 7*



d. Fabricator 2-Location 5 *e. Fabricator 2-Location 6* *f. Fabricator 2-Location 7*

Fig. 22. Clearance specimens-Position C.

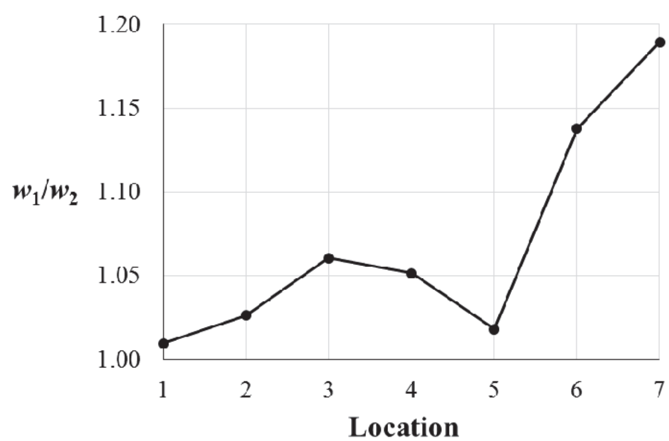


Fig. 23. Mean leg aspect ratio, w_1/w_2, for each weld location.

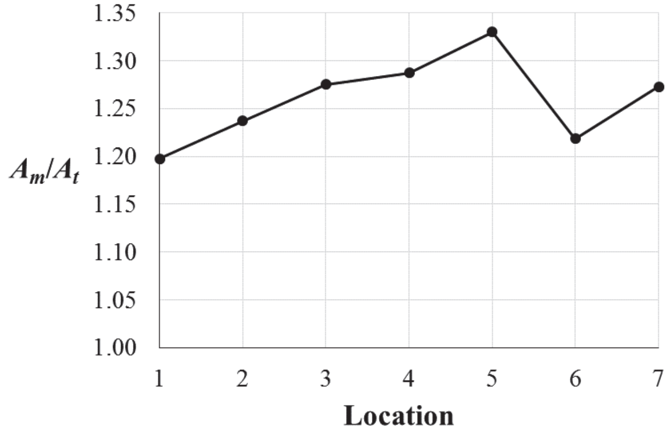


Fig. 24. Mean area ratio, A_m/A_t, for each weld location.

Doubler Plate Welds

All photographs for the sectioned doubler plate specimens are in Appendix C. Representative samples are shown in Figures 25, 26, 27 and 28 for the specimens with ¼, ⅜, ½ and ¾ in. simulated doubler plate thicknesses, respectively. As shown in Figure 25, all specimens with a ¼ in. doubler plate showed good fusion and penetration into both the column and the plate. The heat input from welding melted the plate edge, creating adequate access for the welder to direct the arc toward the base metal.

The welding heat did not have the same effect on the thicker specimens. Many of the ⅜, ½ and ¾ in. specimens had adequate fusion and significant penetration, as shown for the ⅜ in. doubler plate specimen shown in Figure 26b and the ¾ in. doubler plate specimen shown in Figure 28a. However, the specimens in Figures 26c, 27b, 28b and 28c, had a lack of root penetration and the specimens in Figures 27c and 28b had a low penetration depth at the doubler plate. Although these problems were more prevalent for the specimens with x = ⅝ in., they were also present for the specimens with x = 1¼ in.

a. x = 1 ¼ in.

b. x = ⅝ in.

Fig. 25. ¼ in. doubler plate specimens.

a. x = 1¼ in.

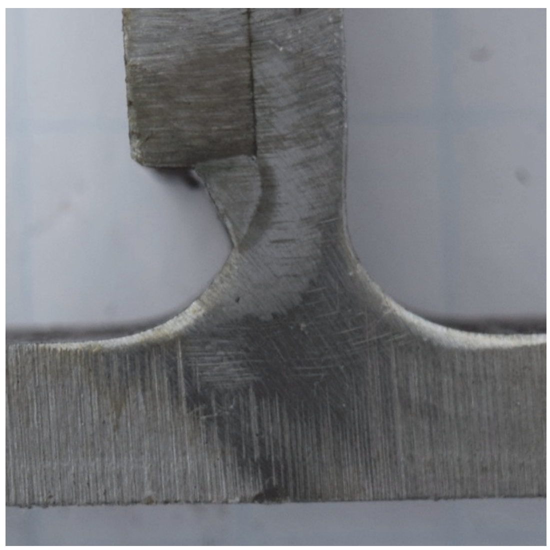
b. x = ⅝ in.

c. x = ⅝ in.

Fig. 26. ⅜ in. doubler plate specimens.

a. x = 1 ¼ in.

b. x = 1 ¼ in.



c. x = ⅝ in.

Fig. 27. ½ in. doubler plate specimens.

a. x = 1 ¼ in.

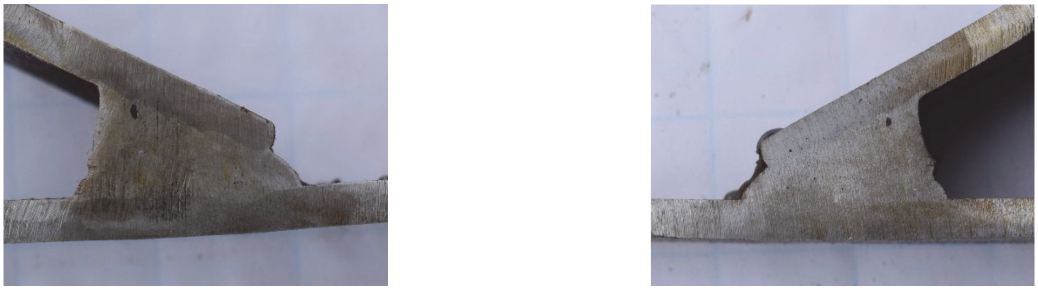
b. x = ⅝ in.

c. x = ⅝ in.

Fig. 28. ¾ in. doubler plate specimens.

Acute Angle Welds

The acute-angle weld specimens are shown in Figure 29. In all cases, t_w was significantly greater than ½ in., which is the required value from AWS D1.1 (AWS, 2015) Figure 3.8 Detail D and Table 3.6. The specimens with dihedral angles, ϕ, of 20°, 25° and 30° showed good penetration and fusion throughout the joint. The specimen with ϕ = 15° had shallow fusion, but observation of the etched sections revealed no lack of fusion at any of the weld-to-base metal boundaries. A portion of the weld length, shown in Figure 29d, had a lack of penetration at the root of approximately ¼ in. maximum.



a. 30° Angle

b. 25° Angle

c. 20° Angle

d. 15° Angle

Fig. 29. Acute-angle specimens.

CONCLUSIONS

Welding Near Obstructions

All welds at Locations 3 through 7 passed the fabricator's visual inspection and meet the visual inspection acceptance criteria requirements of AWS D1.1 Table 6.1. Although one weld section had a measured effective throat that was slightly less than the theoretical value, all welds were deemed adequate. As the distance between the weld and the obstruction plate decreases, the leg aspect ratio, w_1/w_2, increases and the penetration into the base metal at Leg 2 decreases. The production efficiency, as measured by both the leg aspect ratio and the area ratio, was reduced at Locations 6 and 7, relative to welding at Location 1. Another issue at Location 7 is the 2 in. clearance between the welded plate and the obstruction plate will not allow access to measure Leg 2 with a standard fillet weld gage.

The welder for Fabricator 2 reported no problems except that the angle of the welding gun was restricted for welding in the vertical position at Location 7. This affected the weld leg ratio (see Figure 22f) and the production efficiency. The welder for Fabricator 3 noted that, for all three welding positions, weld quality and production efficiency was affected only for welds at Locations 6 and 7. Although the production efficiency was perceived to be the primary issue, the welder also expressed concerns regarding the potential effects on the weld fusion and penetration.

At locations 6 and 7, if a reduction in efficiency is acceptable, it appears that consistent weld quality is achievable in all three welding positions. Considering all of the issues discussed in this report, the recommended clearance for FCAW welding is 3½ in., with an absolute minimum of 2 in.

Doubler Plate Welds

Based on the results discussed in this report, adequate fusion and penetration for a full-strength weld can be consistently obtained for ¼ in. square-cut ($\alpha = 0°$) doubler plates welded with the FCAW process. In this case, the root opening, R, had no observable effect on the weld quality; therefore, $R = 0$ is recommended.

For doubler plates thicker than ¼ in., a groove angle, α, of 15° to 30° may be required to ensure consistent weld quality. Based on the results of the ¼ in. doubler plate specimens, it is expected that a ¼ in. land could be used for these joints to reduce the weld metal while maintaining weld quality.

For Question 1 of the welder questionnaire response (Appendix D1), the welder noted that proper access with a standard (non-tapered) nozzle requires a minimum groove angle of 15° to 30° for ¾ in. doubler plates and thicker. This implies that doubler plates less than ¾ in. can be square-cut. However, the results showed inconsistent fusion and penetration for the ⅜ in. and ½ in. square-cut plates. Therefore, adequate welding clearance does not guarantee consistent weld quality.

Acute Angle Welds

Although the specimen with $\phi = 15°$ had a lack of penetration at the root for a portion of the weld length, all of the acute-angle specimens met the requirements of AWS D1.1 (AWS, 2015) Figure 3.8 Detail D and Table 3.6. The shallow fusion for the specimen with $\phi = 15°$ indicated the lack of proper access for manipulating the electrode.

Based on the welder questionnaire response (Appendix D1), a minimum angle of 15° is required for proper access. All acute-angle specimens required a non-standard nozzle. The 15° specimen was welded with a non-standard stick-out, resulting in a decrease in production efficiency.

Weld Joint Clearance

For question 3 of the questionnaire, the welder explained that acute angle welds are less problematic for round HSS compared to rectangular HSS. This is because the angle changes around the perimeter of the joint, with the smallest angle (at the heel) comprising only a small portion of the total weld length. Also, the curvature allows better access from the side of the joint.

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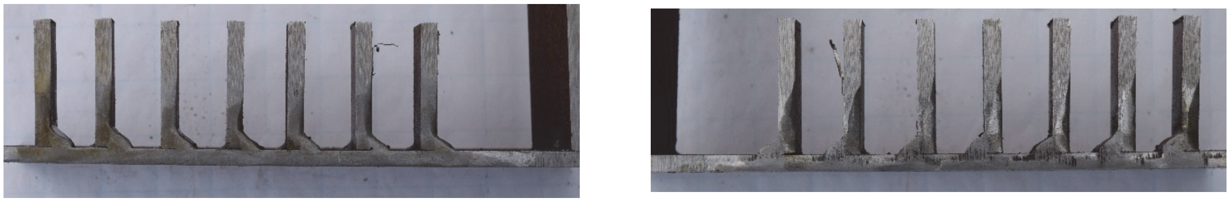
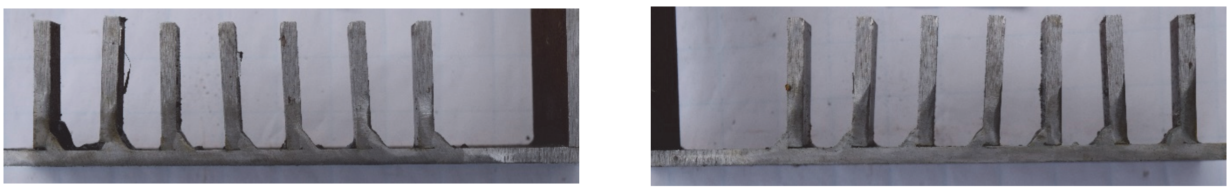
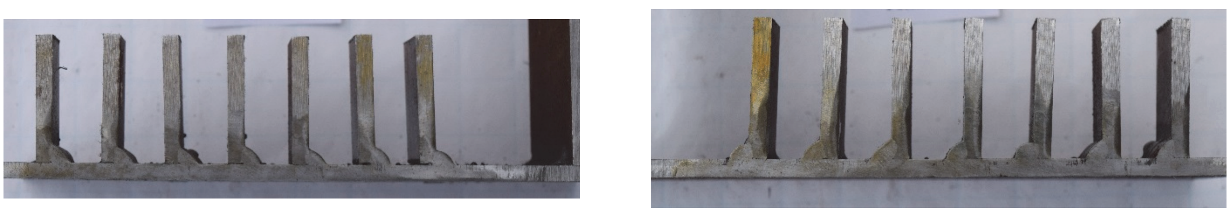
APPENDIX A
WELDING NEAR OBSTRUCTIONS
PHOTOGRAPHS OF SPECIMEN SECTIONS



a. Position A

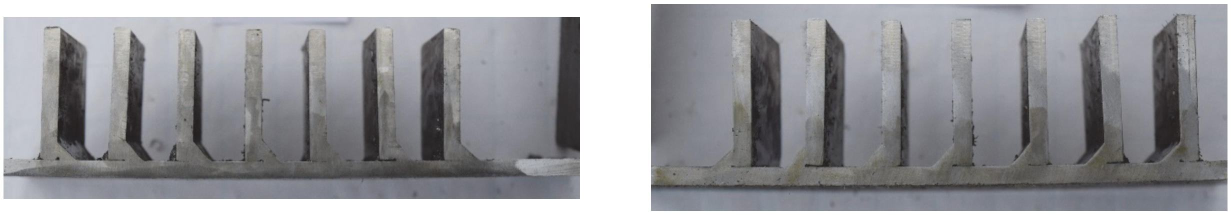


b. Position B

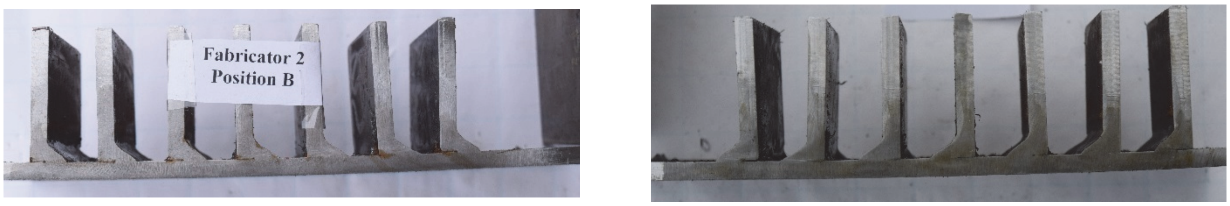


c. Position C

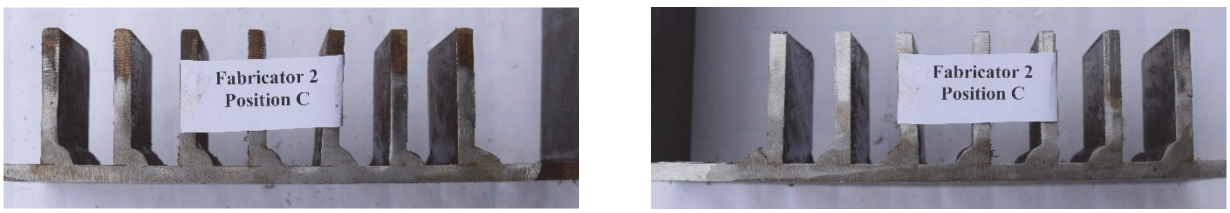
Fig A-1. Specimen sections for Fabricator 1



a. Position A

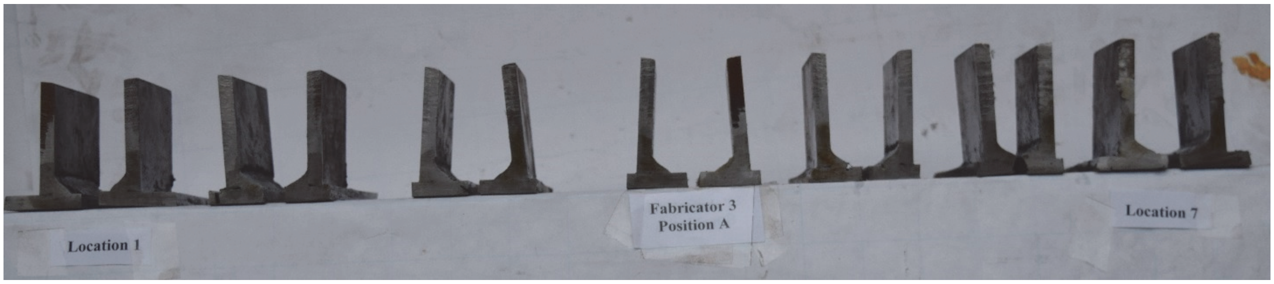


b. Position B

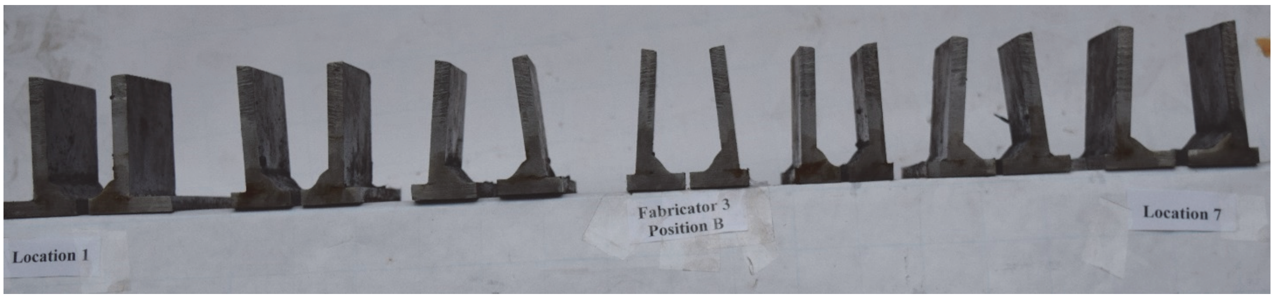


c. Position C

Fig A-2. Specimen sections for Fabricator 2



a. Position A



b. Position B

c. Position C

Fig A-3. Specimen sections for Fabricator 3

APPENDIX B
WELDING NEAR OBSTRUCTIONS
MEASURED WELD DIMENSIONS

Table B-1. Measured Specimen Dimensions

Specimen	w_1	w_2	E	w_1/w_2	A_m	A_m/A_t
1A1-1	0.33	0.31	0.23	1.06	0.051	1.64
1A1-2	0.30	0.31	0.25	0.97	0.047	1.49
1A1-3	0.29	0.28	0.21	1.04	0.041	1.30
1A1-4	0.25	0.23	0.19	1.09	0.029	0.92
1A1-5	0.24	0.27	0.21	0.89	0.032	1.04
1A1-6	0.26	0.24	0.20	1.08	0.031	1.00
1A1-7	0.29	0.24	0.20	1.21	0.035	1.11
1A2-1	0.26	0.27	0.21	0.96	0.035	1.12
1A2-2	0.26	0.31	0.22	0.84	0.040	1.29
1A2-3	0.28	0.24	0.20	1.17	0.034	1.08
1A2-4	0.29	0.30	0.23	0.97	0.044	1.39
1A2-5	0.28	0.26	0.22	1.08	0.036	1.16
1A2-6	0.27	0.24	0.20	1.13	0.032	1.04
1A2-7	0.30	0.28	0.25	1.07	0.042	1.34
1B1-1	0.20	0.26	0.19	0.77	0.026	0.83
1B1-2	0.20	0.30	0.20	0.67	0.030	0.96
1B1-3	0.28	0.27	0.20	1.04	0.038	1.21
1B1-4	0.24	0.26	0.20	0.92	0.031	1.00
1B1-5	0.24	0.30	0.20	0.80	0.036	1.15
1B1-6	0.26	0.29	0.21	0.90	0.038	1.21
1B1-7	0.27	0.25	0.21	1.08	0.034	1.08
1B2-1	0.21	0.24	0.19	0.88	0.025	0.81
1B2-2	0.21	0.26	0.21	0.81	0.027	0.87
1B2-3	0.24	0.25	0.17	0.96	0.030	0.96
1B2-4	0.27	0.24	0.18	1.13	0.032	1.04
1B2-5	0.25	0.27	0.20	0.93	0.034	1.08
1B2-6	0.26	0.25	0.18	1.04	0.033	1.04
1B2-7	0.24	0.22	0.18	1.09	0.026	0.84
1C1-1	0.26	0.29	0.21	0.90	0.038	1.21
1C1-2	0.25	0.23	0.21	1.09	0.029	0.92
1C1-3	0.27	0.24	0.21	1.13	0.032	1.04
1C1-4	0.24	0.28	0.22	0.86	0.034	1.08
1C1-5	0.27	0.23	0.21	1.17	0.031	0.99
1C1-6	0.23	0.25	0.23	0.92	0.029	0.92
1C1-7	0.26	0.22	0.21	1.18	0.029	0.92
1C2-1	0.20	0.23	0.19	0.87	0.023	0.74
1C2-2	0.22	0.25	0.19	0.88	0.028	0.88
1C2-3	0.24	0.21	0.19	1.14	0.025	0.81
1C2-4	0.21	0.23	0.20	0.91	0.024	0.77
1C2-5	0.27	0.28	0.22	0.96	0.038	1.21
1C2-6	0.25	0.25	0.22	1.00	0.031	1.00
1C2-7	0.25	0.21	0.19	1.19	0.026	0.84
2A1-1	0.29	0.28	0.20	1.04	0.041	1.30
2A1-2	0.27	0.30	0.22	0.90	0.041	1.30
2A1-3	0.27	0.30	0.21	0.90	0.041	1.30

2A1-4	0.29	0.32	0.21	0.91	0.046	1.48
2A1-5	0.29	0.32	0.21	0.91	0.046	1.48
2A1-6	0.25	0.29	0.19	0.86	0.036	1.16
2A1-7	0.29	0.25	0.21	1.16	0.036	1.16
2A2-1	0.25	0.27	0.18	0.93	0.034	1.08
2A2-2	0.24	0.27	0.20	0.89	0.032	1.04
2A2-3	0.28	0.30	0.20	0.93	0.042	1.34
2A2-4	0.27	0.30	0.20	0.90	0.041	1.30
2A2-5	0.26	0.29	0.20	0.90	0.038	1.21
2A2-6	0.28	0.30	0.21	0.93	0.042	1.34
2A2-7	0.27	0.24	0.18	1.13	0.032	1.04
2B1-1	0.28	0.28	0.22	1.00	0.039	1.25
2B1-2	0.33	0.28	0.21	1.18	0.046	1.48
2B1-3	0.34	0.31	0.23	1.10	0.053	1.69
2B1-4	0.38	0.26	0.21	1.46	0.049	1.58
2B1-5	0.34	0.28	0.23	1.21	0.048	1.52
2B1-6	0.34	0.23	0.20	1.48	0.039	1.25
2B1-7	0.33	0.29	0.23	1.14	0.048	1.53
2B2-1	0.28	0.27	0.21	1.04	0.038	1.21
2B2-2	0.31	0.25	0.22	1.24	0.039	1.24
2B2-3	0.34	0.27	0.23	1.26	0.046	1.47
2B2-4	0.38	0.27	0.22	1.41	0.051	1.64
2B2-5	0.32	0.26	0.21	1.23	0.042	1.33
2B2-6	0.35	0.21	0.19	1.67	0.037	1.18
2B2-7	0.34	0.28	0.23	1.21	0.048	1.52
2C1-1	0.24	0.32	0.22	0.75	0.038	1.23
2C1-2	0.25	0.26	0.23	0.96	0.033	1.04
2C1-3	0.25	0.26	0.23	0.96	0.033	1.04
2C1-4	0.25	0.26	0.23	0.96	0.033	1.04
2C1-5	0.31	0.30	0.26	1.03	0.047	1.49
2C1-6	0.30	0.23	0.20	1.30	0.035	1.10
2C1-7	0.40	0.26	0.24	1.54	0.052	1.66
2C2-1	0.40	0.24	0.22	1.67	0.048	1.54
2C2-2	0.30	0.25	0.22	1.20	0.038	1.20
2C2-3	0.27	0.28	0.23	0.96	0.038	1.21
2C2-4	0.27	0.28	0.21	0.96	0.038	1.21
2C2-5	0.26	0.28	0.22	0.93	0.036	1.16
2C2-6	0.26	0.24	0.23	1.08	0.031	1.00
2C2-7	0.23	0.30	0.25	0.77	0.035	1.10
3A1-1	0.28	0.26	0.22	1.08	0.036	1.16
3A1-2	0.36	0.25	0.21	1.44	0.045	1.44
3A1-3	0.34	0.28	0.24	1.21	0.048	1.52
3A1-4	0.32	0.28	0.22	1.14	0.045	1.43
3A1-5	0.36	0.30	0.23	1.20	0.054	1.73
3A1-6	0.35	0.28	0.22	1.25	0.049	1.57
3A1-7	0.39	0.23	0.22	1.70	0.045	1.44
3A2-1	0.24	0.27	0.21	0.89	0.032	1.04
3A2-2	0.34	0.26	0.22	1.31	0.044	1.41
3A2-3	0.35	0.29	0.25	1.21	0.051	1.62
3A2-4	0.31	0.25	0.23	1.24	0.039	1.24
3A2-5	0.38	0.29	0.23	1.31	0.055	1.76
3A2-6	0.35	0.22	0.21	1.59	0.039	1.23
3A2-7	0.39	0.24	0.23	1.63	0.047	1.50

3B1-1	0.34	0.30	0.25	1.13	0.051	1.63
3B1-2	0.30	0.28	0.23	1.07	0.042	1.34
3B1-3	0.32	0.29	0.26	1.10	0.046	1.48
3B1-4	0.30	0.31	0.22	0.97	0.047	1.49
3B1-5	0.30	0.32	0.24	0.94	0.048	1.54
3B1-6	0.31	0.29	0.25	1.07	0.045	1.44
3B1-7	0.34	0.27	0.24	1.26	0.046	1.47
3B2-1	0.32	0.29	0.25	1.10	0.046	1.48
3B2-2	0.30	0.31	0.24	0.97	0.047	1.49
3B2-3	0.33	0.28	0.23	1.18	0.046	1.48
3B2-4	0.31	0.30	0.22	1.03	0.047	1.49
3B2-5	0.28	0.31	0.23	0.90	0.043	1.39
3B2-6	0.31	0.31	0.23	1.00	0.048	1.54
3B2-7	0.33	0.27	0.21	1.22	0.045	1.43
3C1-1	0.29	0.26	0.21	1.12	0.038	1.21
3C1-2	0.30	0.29	0.23	1.03	0.044	1.39
3C1-3	0.28	0.28	0.24	1.00	0.039	1.25
3C1-4	0.32	0.31	0.22	1.03	0.050	1.59
3C1-5	0.28	0.29	0.24	0.97	0.041	1.30
3C1-6	0.32	0.28	0.26	1.14	0.045	1.43
3C1-7	0.28	0.31	0.26	0.90	0.043	1.39
3C2-1	0.26	0.26	0.20	1.00	0.034	1.08
3C2-2	0.31	0.30	0.24	1.03	0.047	1.49
3C2-3	0.24	0.30	0.22	0.80	0.036	1.15
3C2-4	0.31	0.30	0.26	1.03	0.047	1.49
3C2-5	0.29	0.30	0.25	0.97	0.044	1.39
3C2-6	0.31	0.30	0.27	1.03	0.047	1.49
3C2-7	0.30	0.32	0.28	0.94	0.048	1.54

Red shaded cells indicate a weld that was rejected by the CWI

Blue shaded cells indicate the measured dimension is less than the nominal dimension

A_m = weld metal area calculated with the measured leg sizes, in.^{2}
A_t = weld metal area calculated with the nominal specified leg size, in.^{2}
E = effective throat, in.
w_1 = fillet weld leg size at the ¼ × 10 in. plate, in.
w_2 = fillet weld leg size at the ¼ × 2 in. plate, in.

APPENDIX C
DOUBLER PLATE WELDS
PHOTOGRAPHS OF SPECIMEN SECTIONS

a. x = 1 ¼ in.

b. x = ⅝ in.

Fig. C-1. ¼ in. doubler plate specimens.

a. x = 1 ¼ in.

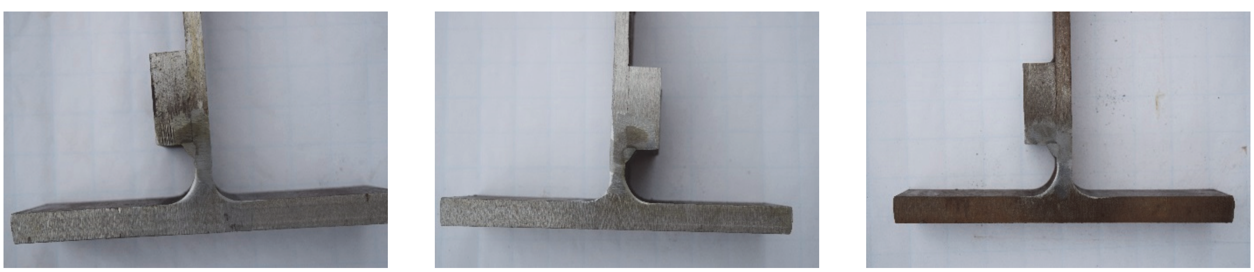
b. x = ⅝ in.

Fig. C-2. ⅜ in. doubler plate specimens.

a. x = 1 ¼ in.

b. x = ⅝ in.

Fig. C-3. ½ in. doubler plate specimens.



a. x = 1 ¼ in.

b. x = ⅝ in.

Fig. C-4. ¾ in. doubler plate specimens.

APPENDIX D1
WELDER QUESTIONNAIRE
FABRICATOR 1

WELDER QUESTIONNAIRE

For AISC Research Project

REQUIRED CLEARANCE FOR WELDED JOINTS

Date: 5/13/2013

Company: Bell Steel Company

Fitter Mike Tanton

Welder Name: Rob Lowe

Inspector: Curtis Smith

WELDING NEAR OBSTRUCTIONS

1) For each of the three welding positions, what is the least clearance that can be provided without affecting the weld quality (See Figure 1)?

   Only on the vertical is weld productivity affected. Lower voltage settings and resulting amperage is lower resulting is a slower weld progression throughout the length of the welds.

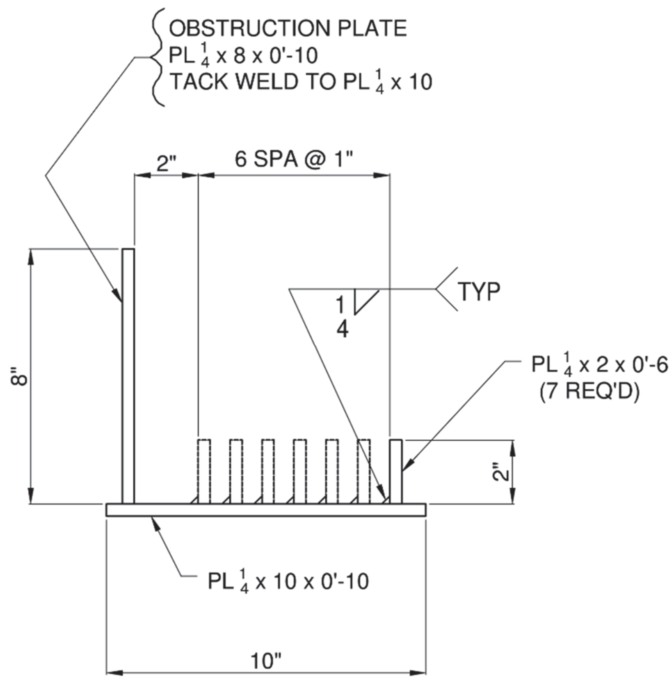


Figure 1

2) For each of the three welding positions, what is the least clearance that can be provided without affecting the production efficiency (See Figure 1)?

   Found no real difference in the productivity in any of the welding on these samples that affected productivity. The vertical as stated above was slower, but because it was vertical and not because of a clearance issue.

3) For small clearances, what changes in your standard welding techniques and equipment would be required?

   No change was required in equipment or technique for any of the clearances provided by the samples.

   How do these changes affect the weld quality and production efficiency?

   N/A

DOUBLER PLATE WELDS

1) What values of *R* would you recommend for each plate thickness (See Figure 2)?

Our standard is to use 0”. The plate is normally located at the intersection of the fillet with the web, or at the tangent point unless a specific weld detail or instruction is supplied by a connection engineer. On the test samples provided varied form approximately 1/8” to 1” depending on whether X was 5/8” or 1 ¼”.

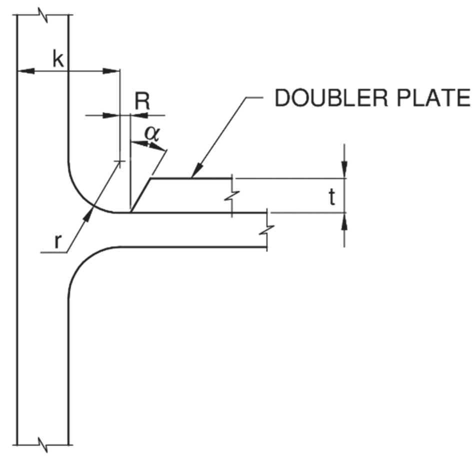


Figure 2.

2) At what doubler-plate thickness would you recommend beveling the edges to provide a groove angle greater than 0°?

On plate thickness ¾” (over 5/8”) a 15 degrees bevel would be recommended to allow access with the standard weld nozzle tip.

For doubler plates of this thickness and greater, what values of *R* and α would you recommend (See Figure 2)?

On thicker samples over 3/4” it might require an increase in the bevel angle from 15 to 30 degrees depending on actual thickness of the plate.

3) Would the answer to Questions 1 and 2 change with the welding process? If so, can you provide estimates for other welding processes (SMAW, GMAW)?

We only use FCAW welding on structural steel in our shop. The only SMAW welding is for tack welding only, and then only in some cases. Most fitters are also using FCAW to make tacks; so therefore in our shop we would not require change any processes.

<u>Off-subject comment</u>: There was one exception to this in the past where welding stiffeners in a cruciform column actually required us to use SMAW because the gun would not fit into the space we had to make the weld. We used a E7018 electrode on these welds and welded the joist using a mirror in a handle to be able to see the weld progression. The welds were not pretty and barely passed inspection, but satisfied the requirements.

4) What changes in your standard welding techniques and equipment would be required? How do changes in variables such as electrode stick-out, contact tip-to-work distance and nozzle width affect the weld quality and production efficiency?

None for the doubler plates; however on the acute angle welds in the next section there are some noted changes.

ACUTE ANGLE WELDS

1) What is the minimum dihedral angle that can be properly welded with standard welding techniques and equipment?

Anything any less than 15 degrees might not be weldable form an access standpoint.

In welding the acute angles on the tube sample welds, the welder had to change the welding tip on his gun form the standard tip to a cone shaped welding tip which narrows down to the tip permitting to have the needed access to the weld, particularly the root passes and back welding.
In fact at all sample angles the cone shaped tip had to be utilized in order to get weldability in the joint. The standard nozzle would not allow access or enough freedom of manipulating the weld gun to properly lay in the weld passes.

For angles less than this, what changes in your standard welding techniques and equipment would be required?

Less than 15 degrees in just not feasible for us from a welding standpoint. We would try to have the design of the joint changed to a configuration we could handle fabrication wise.

How do changes in variables such as electrode stick-out, contact tip-to-work distance and nozzle width affect the weld quality and production efficiency?

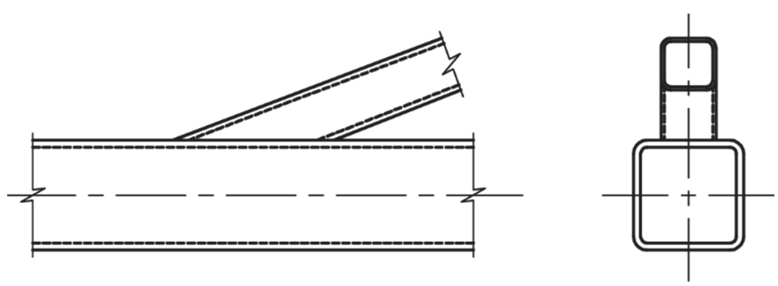
The tight acute angle did require a change in the normal welding technique. It required a longer than normal stick out resulting in a longer arc, increased tip-to-work piece and slower welding travel speeds as a result, which would affect the time required in making the root pass and several of the additional passes of the back weld. Once the weld is layered in and the back weld completed the stick out is reduced some increasing the weld travel speed slightly. The welder just adjusted stick out when completing the passes as was required and did not really kept any accurate measurement of the stick out during the welding of the samples.

2) Will the answer to Question 1 change with welding position?

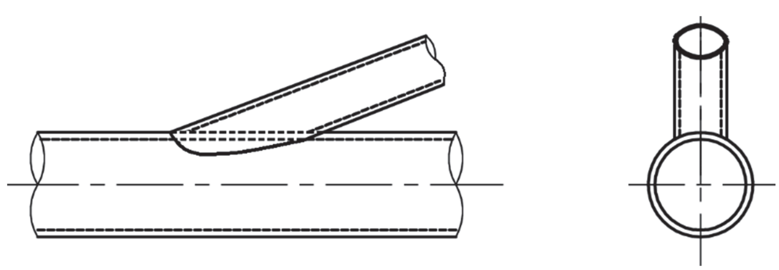
The welding position can be a problem depending on the actual work piece in terms of being able to access the joint in which the acute angle occurs depending on piece geometry. This in itself could dictate a different welding position be used than the one you really would like to use. However, in most circumstances we can manipulate items so as to achieve the best position for the welder prior to starting and completing his welds.

3) For welding the acute angle, are there any differences between rectangular and round HSS (See Figure 3)?

Yes, the round tubing or pipe in general terms is easier to weld as the area where the acute angle occurs is smaller and has better access with some access being form outside the pipe. As you move around the joint once past the small acute angle it becomes easier to weld. There are some special considerations when welding pipe intersections which can require different perpetration on different parts of the pipe to achieve a good weld.



Rectangular HSS Connection



Round HSS Connection

Figure 3.

APPENDIX D2
WELDER QUESTIONNAIRE
FABRICATOR 2

ARC International, LLC

WELDER QUESTIONNAIRE

For AISC Research Project

REQUIRED CLEARANCE FOR WELDED JOINTS

Date: 9/27/16

Company: NAFCO

Welder Name: Joe Pruett

AWS
Patrick J Fulenwider
CWI 16082951
QC1 EXP. 8/1/2019

300 Cahaba Park Circle Suite 116 • Birmingham, AL 35242 • (205) 283-2078 • www.arcstructural.com

WELDING NEAR OBSTRUCTIONS

1) For each of the three welding positions, what is the least clearance that can be provided without affecting the weld quality (See Figure 1)?

Verticle - affected tourch angle on last plate,

Horiz (vert obstruction) - None

Horiz (horiz ob.) - None

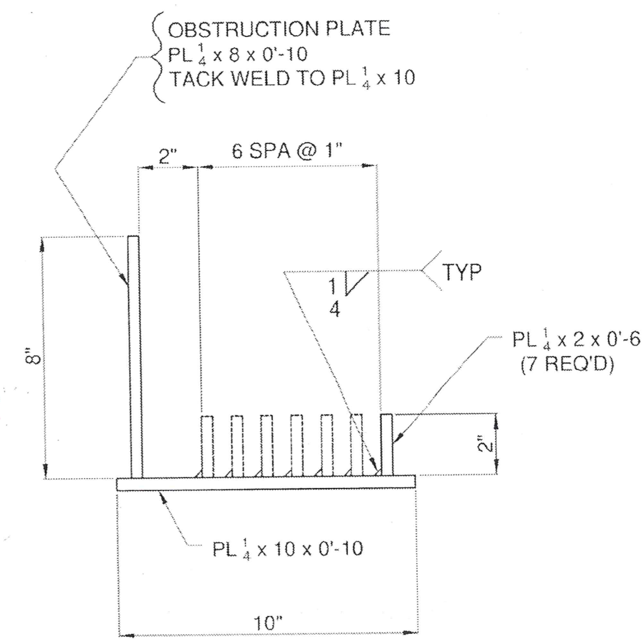


Figure 1

2) For each of the three welding positions, what is the least clearance that can be provided without affecting the production efficiency (See Figure 1)?

No problems

3) For small clearances, what changes in your standard welding techniques and equipment would be required?

None except verticle. The last plate affected the tourch angle somewhat.

How do these changes affect the weld quality and production efficiency?

The change in tourch angle caused the weld to be less uniform and it took a little longer to get in a comfortable welding position.

APPENDIX D3
WELDER QUESTIONNAIRE
FABRICATOR 3

ARC International, LLC

WELDER QUESTIONNAIRE

For AISC Research Project

REQUIRED CLEARANCE FOR WELDED JOINTS

Date: 9-14-16

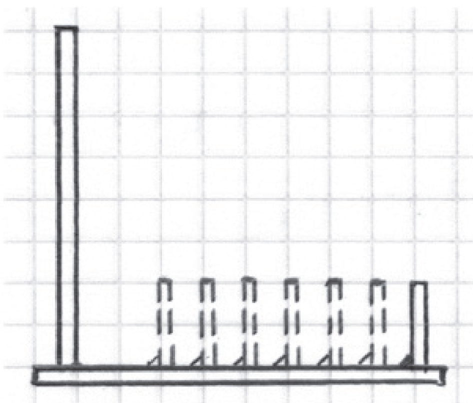
Company: Structural Steel Services, Inc.

Welder Name: Timmy Boles

WELDING NEAR OBSTRUCTIONS

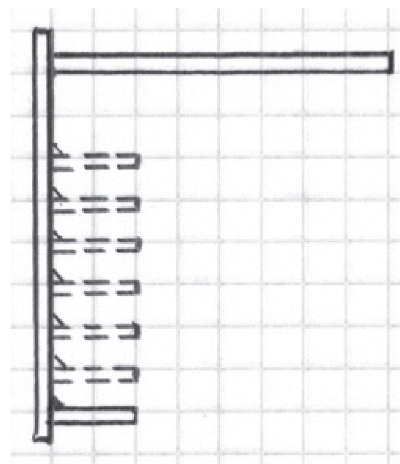
1) For each of the three welding positions, what is the least clearance that can be provided without affecting the weld quality (See Figure 1)?

   For each of the welding samples, issues began at the second last fillet weld location for each of the positions. This location was 3" from the obstruction plate, marked on the sample as position F. All three full samples had this same outcome, fillet welds F & G (measured at 3" & 2" from the obstruction plate, see Figure 1 below).



a. vertical obstruction plate

Samples Marked 1A – 1G



b. horizontal obstruction plate

Samples Marked 2A – 2G

Note: Samples marked 3A – 3G are the samples welded in the vertical position

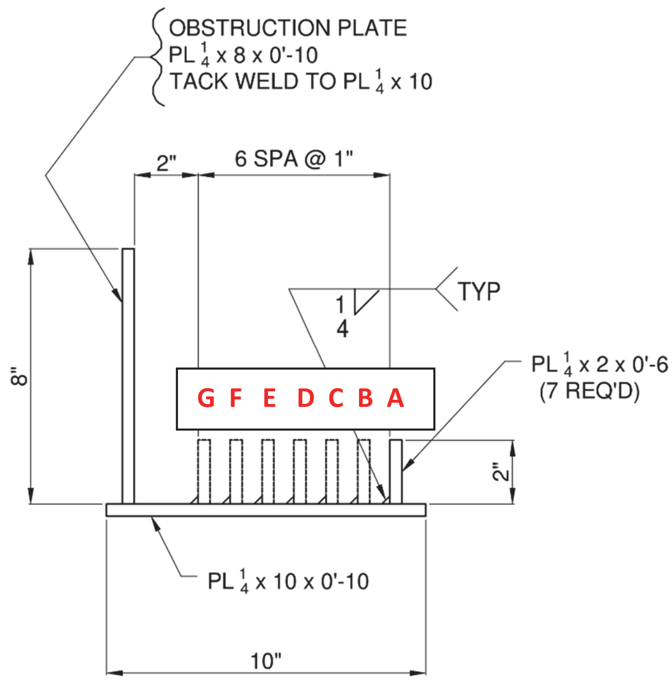


Figure 1

2) For each of the three welding positions, what is the least clearance that can be provided without affecting the production efficiency (See Figure 1)?

At 4" from the obstruction plate (location E), the welds were able to be made without affecting the production efficiency. When the welds were made closer to the obstruction plate, the production efficiency and the quality of the weld appeared to be affected.

3) For small clearances, what changes in your standard welding techniques and equipment would be required?

For the small clearances, we had to adjust the nozzle and our position to accomplish the weld. The obstruction plate forced a limited area for mobility for the welder.

How do these changes affect the weld quality and production efficiency?

The quality of the welds was slightly affected, but the production efficiency was what was affected the most. The welder had to readjust and figure out the best way to make a quality weld for these tight positions. These adjustments were made to hopefully still able to make a quality weld. The size of the welds was able to be achieved, but the penetration and fusion of the weld is what could be affected by these adjustments.

APPENDIX E1
WELDING PROCEDURE SPECIFICATIONS
FABRICATOR 1

Bell Steel

AWS - Prequalified Welding Procedure Specification (pWPS)

WeldOffice WPS

Company name	Bell Steel
Welding process	FCAW
Process type	Semi-automatic

Identification #	Bell Steel WPS 120-1 Rev.
Originated by	Ron Phillips
Date	5/14/2013
Authorized by	Curtis Smith
Date	5/14/2013

Joint design used

Joint type		B - Butt joint
Joint design		Single V groove (2)
Backing		Yes
Backing material		Weld metal
Root opening (R)*	(in.)	1/8, +1/16, -0 (+1/16, -1/8)
Root face (f)*	(in.)	0 to 1/8, +1/16, -0 (Not Limited)
Groove angle (a)*	(deg.)	60, +10, -0 (+10, -5)
Radius (J - U)*	(deg.)	n/a
Back gouging		Yes
Back gouging method		Mechanical or Thermal

* Datum, As Detailed (As Fit-Up)

Base metals

Spec., type or grade		AWS D1.1 Table 3.1 Group II
Thickness: Groove	(in.)	T1:unlimited
Fillet	(in.)	All
Diameter (Pipe)	(in.)	Unlimited

Filler metals

AWS Specification	5.20
AWS Classification	E71T-1C-H8

Shielding

Flux		-
Electrode-flux (class)		-
Gas composition		CO2 (A5.32 SG-C)
Gas flow rate	(cfh)	35-45
Gas cup size	(in.)	3/8-5/8

Position

Welding position: Groove	All
Fillet	All
Vertical progression	Up

Electrical characteristics

Transfer mode (GMAW)	Spray
Current type	DCEP
Other	Constant Voltage (CV) power supply

Technique

Stringer or weave bead		Stringer or Weave
Multi/single pass (per side)		Single or Multiple
Number of electrodes		Single electrode
Spacing: Longitudinal	(in.)	-
Lateral	(in.)	-
Angle	(deg.)	-
Contact tube to work	(in.)	0.5 - 1
Peening		Not permitted
Interpass cleaning		Brushing or grinding

Preheat

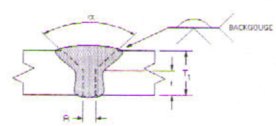
Preheat temp.: Min.	(°F)	See notes
Interpass temp.: Min.	(°F)	See notes
Max.	(°F)	See notes

Post weld heat treatment

Temperature	(°F)	None
Time	(hrs)	-

Welding procedure

Layer	Pass	Process	Filler metal class	Filler metal diameter (in.)	Current type / polarity	Amps	Wire feed speed (in./min)	Volts	Travel speed (in./min)	Joint details
1	All	FCAW	E71T-1C-H8	0.045	DCEP	145-220	200-600	23-28	6-12	
1	All	FCAW	E71T-1C-H8	0.052	DCEP	165-265	200-600	24-29	6-12	
1	All	FCAW	E71T-1C-H8	1/16	DCEP	275-320	200-600	27-31	6-12	



Designation B-U2-GF

Notes

PREHEAT/INTERPASS
For thickness 1/8 to 3/4(in.): 32(°F). Preheat to 70(°F) if the base metal temperature is below 32(°F).
Over 3/4 thru 1-1/2(in.): 50(°F).
Over 1-1/2 thru 2-1/2(in.): 150(°F).
Over 2-1/2(in.): 225(°F).
See additional information page for further limitations

Signature 1

Name	Signature
Ron Phillips	
Date	
5/14/2013	

Ronald M Phillips
CWI 96040091
QC1 EXP. 4/1/2014

Signature 2

Name	Signature
Date	

Signature 3

Name	Signature
Date	

Signature 4

Name	Signature
Date	

Bell Steel Co.

Welding Procedure Specification

WPS No. **Bell Steel WPS 120** Revision **0** Date **7/15/1998** By **Ron Phillips**

Authorized By **Curtis Smith** Date **7/15/1998** Prequalified ☒

Welding Process(es) **FCAW** Type: Manual ☐ Machine ☐ Semi-Auto ☒ Auto ☐

Supporting PQR(s) **AWS D1.1**

JOINT

Type **Butt**

Backing Yes ☐ No ☒ Single Weld ☐ Double Weld ☒

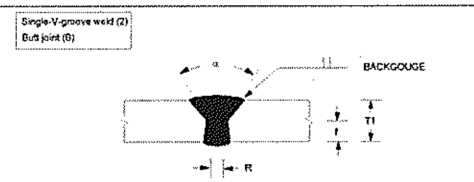
Backing Material **N/A**

Root Opening **1/8"+/-1/16"** Root Face Dimension **1/8"+/-1/16"**

Groove Angle **60°** Radius (J-U) **N/A**

Back Gouge Yes ☒ No ☐

Method **Grind or Gouge**



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T1	T2	Groove Preparation: Root Opening / Root Face / Groove Angle	Tolerances: As Detailed (see 3.13.1)	Tolerances: As Fit Up (see 3.13.1)	Permitted Welding Positions	Gas Shielding for FCAW	Notes
GMAW FCAW	B-U2-GF	U	—	R = 0 to 1/8 f = 0 to 1/8 α = 60°	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°	All	Not required	A, C, N

BASE METALS

Material Spec. **A-36** to **A-36**

Type or Grade **GROUP 1** to **GROUP 1**

Thickness: Groove (in) **1/8** - **Unlimited**

Fillet (in) **Any** - **Any**

Diameter (Pipe, in) **24** - **Unlimited**

FILLER METALS

AWS Specification **A5.20**

AWS Classification **E71T-1**

SHIELDING

Flux **N/A**

Electrode-Flux (Class) **N/A**

Gas **Carbon Dioxide**

Composition **100%**

Flow Rate **35-45 CFH**

Gas Cup Size **10-12**

PREHEAT

Preheat Temp., Min. **SEE MEMO**

Thickness	Temperature
Up to 3/4"	**SEE MEMO**
Over 3/4" to 1-1/2"	**50° F**
Over 1-1/2" to 2-1/2"	**150° F**
Over 2-1/2"	**225° F**

Interpass Temp., Min. **50° F** Max. **350° F**

POSITION

Position of Groove **All** Fillet **All**

Vertical Progression: ☒ Up ☐ Down

ELECTRICAL CHARACTERISTICS

Transfer Mode (GMAW):

Short-Circuiting ☐ Globular ☐ Spray ☐

Current: AC ☐ DCEP ☒ DCEN ☐ Pulsed ☐

Other **N/A**

Tungsten Electrode (GTAW):

Size **N/A** Type **N/A**

TECHNIQUE

Stringer or Weave Bead **Both**

Multi-pass or Single Pass (per side) **Multiple**

Number of Electrodes **1**

Electrode Spacing: Longitudinal **N/A**

Lateral **N/A**

Angle **N/A**

Contact Tube to Work Distance **1/2"-3/4"**

Peening **N/A**

Interpass Cleaning **CHIP OR GRIND/WIRE BRUSH**

POSTWELD HEAT TREATMENT

PWHT Required ☐

Temp. **N/A** Time **N/A**

WELDING PROCEDURE

Layer/Pass	Process	Filler Metal Class	Diameter	Cur. Type	Amps or WFS	Volts	Travel Speed	Other Notes
ALL	FCAW	E71T-1	0.045	DCEP	175-220	23-28	8-10 IPM	
ALL	FCAW	E71T-1	0.052	DCEP	180-250	24-29	8-10 IPM	
ALL	FCAW	E71T-1	1/16"	DCEP	195-300	26-32	8-10 IPM	

AWS
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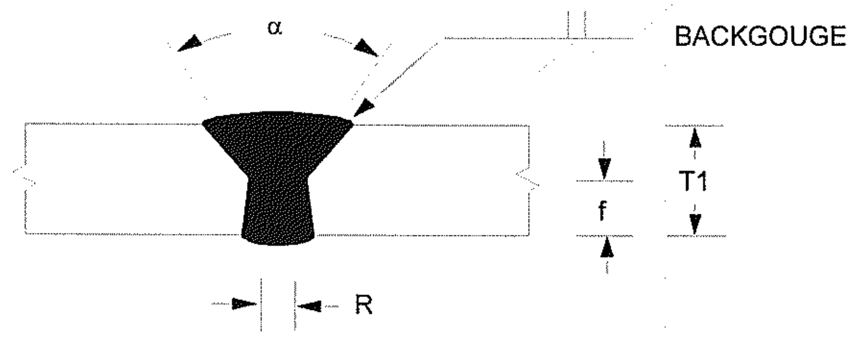
CWI 96040091
QC1 EXP. 04/01/11

Single-V-groove weld (2)
Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (U=unlimited) T1	T2	Groove Preparation: Root Opening / Root Face / Groove Angle	Tolerances: As Detailed (see 3.13.1)	Tolerances: As Fit Up (see 3.13.1)	Permitted Welding Positions	Gas Shielding for FCAW	Notes
GMAW FCAW	B-U2-GF	U	-	R = 0 to 1/8 f = 0 to 1/8 α = 60°	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°	All	Not required	A C N

MEMO

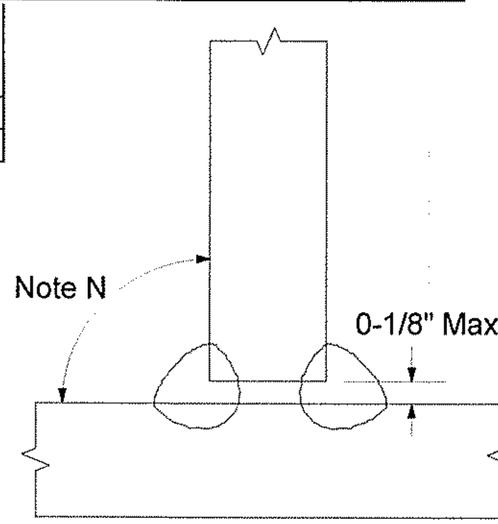
1) When the base metal is below 32 degrees F. (0 Deg. C), the base metal shall be preheated to at least 70 Degrees F (32 Deg. C) and this minimum temprature maintained during welding.

A: Not prequalified for gas metal arc welding using short circuiting transfer nor GTAW. Refer to Annex A.

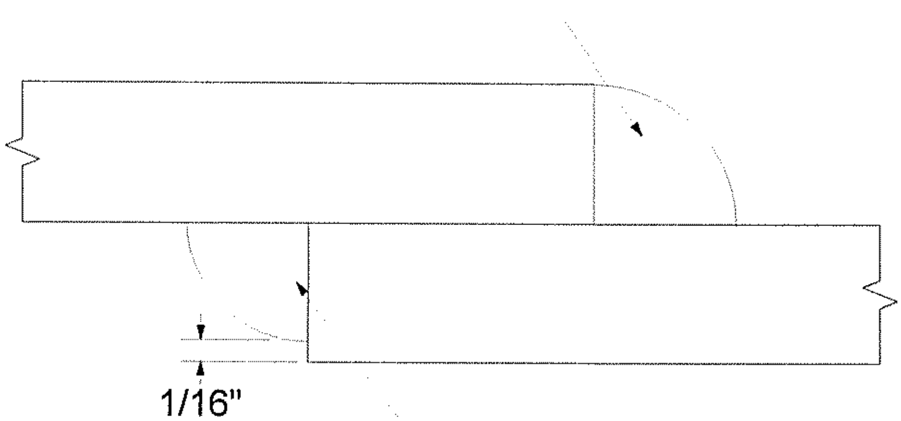
N: The orientation of the two members in the joints may vary from 135° to 180° for butt joints, or 45° to 135° for corner joints, or 45° to 90° for T-joints.

Minimum Fillet Weld Sizes Base-Metal Thickness (T)		Minimum Size of Fillet Weld	
in.	mm	in.	mm
T <1/4	T < 6.4	1/8	3
1/4 < T < 1/2	6.4 < T < 12.7	3/16	5
1/2 < T < 3/4	12.7 < T < 19.0	1/4	6
3/4 < T	19.0 < T	5/16	8

Maximum single pass Fillet Weld Size	
Flat	3/8
Horizontal	5/16



Base Metal Less Than 1/4" Thick



Base Metal Greater Than 1/4" Thick

Maximum Detailed Size of Fillet Weld Along Edges

Bell Steel Co.

Welding Procedure Specification

WPS No. **Bell Steel WPS 121** Revision **0** Date **9/8/2008** By **Ron Phillips**

Authorized By **Curtis Smith** Date **9/8/2008** Prequalified ☒

Welding Process(es) **FCAW** Type: Manual ☐ Machine ☐ Semi-Auto ☒ Auto ☐

Supporting PQR(s) **AWS D1.1**

JOINT

Type **Butt**

Backing Yes ☒ No ☐ Single Weld ☒ Double Weld ☐

Backing Material **STEEL**

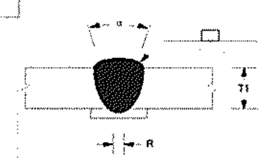
Root Opening **3/16"-3/8"** Root Face Dimension **N/A**

Groove Angle **30°-45°** Radius (J-U) **N/A**

Back Gouge Yes ☐ No ☒

Method **N/A**

Single-V-groove weld (2)
Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (Unlimited) T1	T2	Root Opening	Groove Angle	Tolerances As Detailed (see 3.13.1)	As Fit Up (see 3.13.1)	Permitted Welding Positions	Gas Shielding for FCAW	Notes
GMAW FCAW	B-U2a-GF	U	-	R = 3/16	α = 30°	R = +1/16, -0	+1/4, -1/16	F,V,OH	Required	A
				R = 3/8	α = 30°	α = +10°, -0°	+10°, -5°	F,V,OH	Not req.	N
				R = 1/4	α = 45°			F,V,OH	Not req.	

BASE METALS

Material Spec. **A-36** to **A-36**

Type or Grade **GROUP 1** to **GROUP 1**

Thickness: Groove (in) **1/8** - **Unlimited**

Fillet (in) **Any** - **Any**

Diameter (Pipe, in) **24** - **Unlimited**

FILLER METALS

AWS Specification **A5.20**

AWS Classification **E71T-1**

SHIELDING

Flux **N/A**

Gas **Carbon Dioxide**

Composition **100%**

Electrode-Flux (Class) **N/A**

Flow Rate **35-45 CFH**

Gas Cup Size **10-12**

PREHEAT

Preheat Temp., Min. **SEE MEMO**

Thickness Up to 3/4" Temperature **SEE MEMO**

Over 3/4" to 1-1/2" **50° F**

Over 1-1/2" to 2-1/2" **150° F**

Over 2-1/2" **225° F**

Interpass Temp., Min. **50° F** Max. **350° F**

POSITION

Position of Groove **All** Fillet **All**

Vertical Progression: ☒ Up ☐ Down

ELECTRICAL CHARACTERISTICS

Transfer Mode (GMAW):

Short-Circuiting ☐ Globular ☐ Spray ☐

Current: AC ☐ DCEP ☒ DCEN ☐ Pulsed ☐

Other **N/A**

Tungsten Electrode (GTAW):

Size **N/A** Type **N/A**

TECHNIQUE

Stringer or Weave Bead **Both**

Multi-pass or Single Pass (per side) **Multiple**

Number of Electrodes **1**

Electrode Spacing: Longitudinal **N/A**

Lateral **N/A**

Angle **N/A**

Contact Tube to Work Distance **1/2"-3/4"**

Peening **N/A**

Interpass Cleaning **CHIP OR GRIND/WIRE BRUSH**

POSTWELD HEAT TREATMENT

PWHT Required ☐

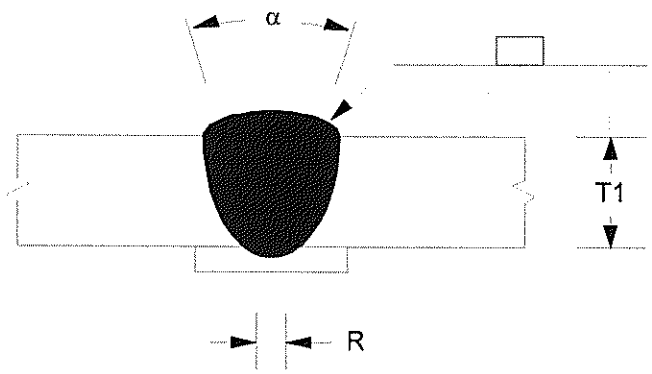
Temp. **N/A** Time **N/A**

WELDING PROCEDURE

Layer/Pass	Process	Filler Metal Class	Diameter	Cur. Type	Amps or WFS	Volts	Travel Speed	Other Notes
ALL	FCAW	E71T-1	0.045	DCEP	175-220	23-28	8-10 IPM	
ALL	FCAW	E71T-1	0.052	DCEP	180-250	24-29	8-10 IPM	
ALL	FCAW	E71T-1	1/16"	DCEP	195-300	26-32	8-10 IPM	

AWS
RONALD M. PHILLIPS
CWI 96040091
QC1 EXP. 04/01/11

Single-V-groove weld (2)
Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (U=unlimited) T1	T 2	Groove Preparation Root Opening	Groove Angle	Tolerances As Detailed (see 3.13.1)	As Fit Up (see 3.13.1)	Permitted Welding Positions	Gas Shielding for FCAW	Notes
GMAW FCAW	B-U2a-GF	U	-	R = 3/16	α = 30°	R = +1/16, -0	+1/4, -1/16	F,V,OH	Required	A
				R = 3/8	α = 30°	α = +10°, -0°	+10°, -5°	F,V,OH	Not req.	N
				R = 1/4	α = 45°			F,V,OH	Not req.	

MEMO

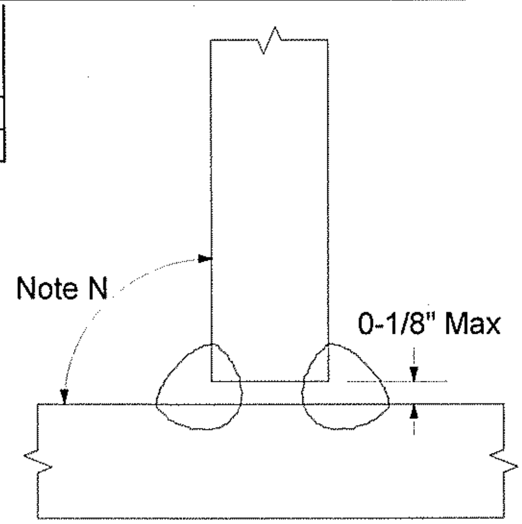
1) When the base metal is below 32 degrees F. (0 Deg. C), the base metal shall be preheated to at least 70 Degrees F (32 Deg. C) and this minimum temprature maintained during welding.

A: Not prequalified for gas metal arc welding using short circuiting transfer nor GTAW. Refer to Annex A.

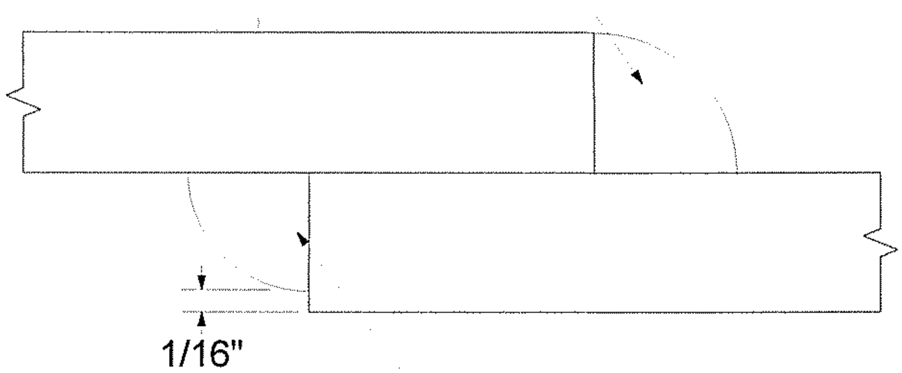
N: The orientation of the two members in the joints may vary from 135° to 180° for butt joints, or 45° to 135° for corner joints, or 45° to 90° for T-joints.

Minimum Fillet Weld Sizes Base-Metal Thickness (T)		Minimum Size of Fillet Weld	
in.	mm	in.	mm
T <1/4	T < 6.4	1/8	3
1/4 < T < 1/2	6.4 < T < 12.7	3/16	5
1/2 < T < 3/4	12.7 < T < 19.0	1/4	6
3/4 < T	19.0 < T	5/16	8

Maximum single pass Fillet Weld Size	
Flat	3/8
Horizontal	5/16



Base Metal Less Than 1/4" Thick



Base Metal Greater Than 1/4" Thick

Maximum Detailed Size of Fillet Weld Along Edges

Bell Steel

AWS - Prequalified Welding Procedure Specification (pWPS)

WeldOffice WPS

Identification #	Bell Steel 130 Rev. 1
Originated by	Ron Phillips
Date	5/21/2010
Authorized by	Curtis Smith
Date	5/21/2010

Company name	Bell Steel
Welding process	FCAW
Process type	Semi-automatic

Joint design used

Joint type		B - Butt joint
Joint design		Single bevel groove (4)
Backing		Yes
Backing material		Weld metal
Root opening (R)*	(in.)	0 to 1/8, +1/16, -0 (+1/16, -1/8)
Root face (f)*	(in.)	0 to 1/8, +1/16, -0 (Not Limited)
Groove angle (a)*	(deg.)	45, +10, -0 (10, -5)
Radius (J - U)*	(deg.)	n/a
Back gouging		Yes
Back gouging method		Mechanical or Thermal

* Datum, As Detailed (As Fit-Up)

Base metals

Spec., type or grade		AWS D1.1 Table 3.1 Group II
Thickness: Groove	(in.)	T1:unlimited
Fillet	(in.)	All
Diameter (Pipe)	(in.)	Unlimited

Filler metals

AWS Specification	5.20
AWS Classification	E71T-1

Shielding

Flux		-
Electrode-flux (class)		-
Gas composition		CO_2 (A5.32 SG-C)
Gas flow rate	(cfh)	35-45
Gas cup size	(in.)	1/2"

Position

Welding position: Groove	All
Fillet	All
Vertical progression	Up

Electrical characteristics

Transfer mode (GMAW)	Spray
Current type	DCEP
Other	Constant Voltage (CV) power supply

Technique

Stringer or weave bead		Stringer or Weave
Multi/single pass (per side)		Single or Multiple
Number of electrodes		Single electrode
Spacing: Longitudinal	(in.)	-
Lateral	(in.)	-
Angle	(deg.)	-
Contact tube to work	(in.)	0.5 - 1
Peening		Not permitted
Interpass cleaning		Brushing or grinding

Preheat

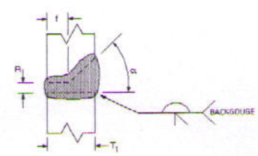
Preheat temp.: Min.	(°F)	See notes
Interpass temp.: Min.	(°F)	See notes
Max.	(°F)	See notes

Post weld heat treatment

Temperature	(°F)	None
Time	(hrs)	-

Welding procedure

Layer	Pass	Process	Filler metal class	Filler metal diameter (in.)	Current type / polarity	Amps	Wire feed speed (in./min)	Volts	Travel speed (in./min)	Joint details
1	All	FCAW	E71T-1	0.045	DCEP	175-200	250-500	23-28	8-10	
1	All	FCAW	E71T-1	0.052	DCEP	180-250	250-500	24-29	8-10	
1	All	FCAW	E71T-1	1/16	DCEP	195-300	250-500	26-32	8-10	



Designation: B-U4b-GF

Notes

PREHEAT/INTERPASS
For thickness 1/8 to 3/4(in.): 32(°F). Preheat to 70(°F) if the base metal temperature is below 32(°F).
Over 3/4 thru 1-1/2(in.): 150(°F).
Over 1-1/2 thru 2-1/2(in.): 225(°F).
Over 2-1/2(in.): 300(°F).
See additional information page for further limitations

Signature 1

Name	Signature
Ron Phillips	
Date	
5/21/2010	

RONALD M. PHILLIPS
CWI 96040091
QC1 EXP. 04/01/11

Signature 2

Name	Signature
Date	

Signature 3

Name	Signature
	Ron Phillips
Date	

Signature 4

Name	Signature
Date	

Identification #	Bell Steel 130	Rev. 1

D1.1 Table 3.7 states:

T37-01.3
Maximum GMAW/FCAW electrode diameter for flat and horizontal position is 1/8 in. (3.2 mm).

Maximum GMAW/FCAW electrode diameter for vertical position is 3/32 in. (2.4 mm).

Maximum GMAW/FCAW electrode diameter for overhead position is 5/64 in. (2.0 mm).

T37-02.1
Maximum current shall be within the range of recommended operation by the filler metal manufacturer.

T37-03.1
Maximum root pass thickness:
3/8 in. (10 mm) for Flat,
5/16 in. (8 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-04.3
Maximum GMAW/FCAW fill pass thickness is 1/4 in. (6 mm).

T37-05.3
Maximum GMAW/FCAW single-pass fillet weld size:
1/2 in. (12 mm) for Flat,
3/8 in. (10 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-06.1
Maximum GMAW/FCAW single-pass layer width:
-Root opening > 1/2 in. (12 mm): Split layers.
-Any layer of width w: In the F, H, or OH positions for nontubulars, split layers when the layer width w > 5/8 in. (16 mm). In the vertical position for nontubulars or the flat, horizontal, vertical, and overhead positions for tubulars, split layers when the width w > 1 in. (25 mm).

D1.1 Table 3.7. end of quote.

Bell Steel Co.

Welding Procedure Specification

WPS No. **Bell Steel WPS 143** Revision **0** Date **4/24/2006** By **Ron Pierce**

Authorized By **Cleveland Rhoades** Date **4/24/2006** Prequalified ☒

Welding Process(es) **FCAW** Type: Manual ☐ Machine ☐ Semi-Auto ☒ Auto ☐

Supporting PQR(s) **AWS D1.1** **B-L1b-GF**

JOINT

Type **Butt**

Backing Yes ☐ No ☒ Single Weld ☐ Double Weld ☒

Backing Material **N/A**

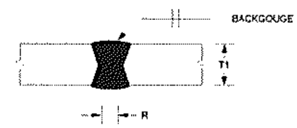
Root Opening **0-1/8"** Root Face Dimension **N/A**

Groove Angle **N/A** Radius (J-U) **N/A**

Back Gouge Yes ☒ No ☐

Method **GRIND OR GOUGE**

Square-groove weld (1)
Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (Unlimited) T1	T2	Groove Preparation: Root Opening	Tolerances: As Detailed (see 3.13.1)	As Fit Up (see 3.13.1)	Permitted Welding Positions	Gas Shielding for FCAW	Notes
GMAW FCAW	B-L1b-GF	3/8 max	-	R=0 to 1/8	+1/16, -0	+1/16, -1/8	All	Not Required	A C N

BASE METALS

Material Spec. **A-36** to **A-36**

Type or Grade **GROUP 1** to **GROUP 1**

Thickness: Groove (in) **1/8** - **3/8"**

Fillet (in) **Any** - **Any**

Diameter (Pipe, in) **24** - **Unlimited**

FILLER METALS

AWS Specification **A5.20**

AWS Classification **E71T-1**

SHIELDING

Flux **N/A**

Electrode-Flux (Class) **N/A**

Gas **Carbon Dioxide**

Composition **100%**

Flow Rate **35-45 CFH**

Gas Cup Size **10-12**

PREHEAT

Preheat Temp., Min. **SEE MEMO**

Thickness	Temperature
Up to 3/4"	**SEE MEMO**
Over 3/4" to 1-1/2"	**50° F**
Over 1-1/2" to 2-1/2"	**150° F**
Over 2-1/2"	**225° F**

Interpass Temp., Min. **50 F** Max. **350 F**

POSITION

Position of Groove **All** Fillet **All**

Vertical Progression: ☒ Up ☐ Down

ELECTRICAL CHARACTERISTICS

Transfer Mode (GMAW):

Short-Circuiting ☐ Globular ☐ Spray ☐

Current: AC ☐ DCEP ☒ DCEN ☐ Pulsed ☐

Other **N/A**

Tungsten Electrode (GTAW):

Size **N/A** Type **N/A**

TECHNIQUE

Stringer or Weave Bead **Both**

Multi-pass or Single Pass (per side) **SEE MEMO**

Number of Electrodes **1**

Electrode Spacing: Longitudinal **N/A**

Lateral **N/A**

Angle **N/A**

Contact Tube to Work Distance **N/A**

Peening **N/A**

Interpass Cleaning **CHIP OR GRIND/WIRE BRUSH**

POSTWELD HEAT TREATMENT

PWHT Required ☐

Temp. **N/A** Time **N/A**

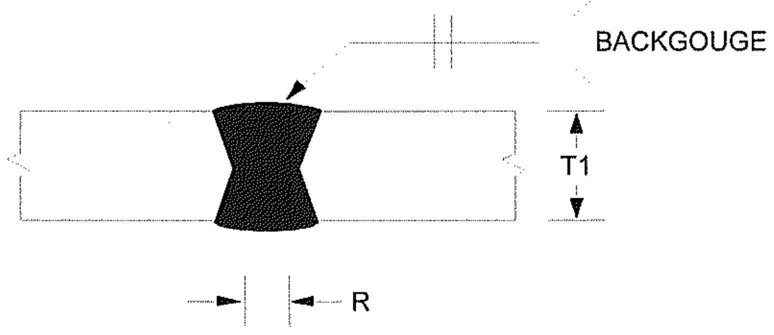
WELDING PROCEDURE

Layer/Pass	Process	Filler Metal Class	Diameter	Cur. Type	Amps or WFS	Volts	Travel Speed	Other Notes
ALL	FCAW	E71T-1	0.045	DCEP	175-220	23-28	8-10 IPM	
ALL	FCAW	E71T-1	0.052	DCEP	180-250	24-29	8-10 IPM	
ALL	FCAW	E71T-1	1/16"	DCEP	195-300	26-32	8-10 IPM	

AWS
RONALD M. PHILLIPS
CWI 96040091
QC1 EXP. 04/01/11

Welding Procedure Specification

Square-groove weld (1)
Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (U=unlimited) T1	T2	Groove Preparation Root Opening	Tolerances As Detailed (see 3.13.1)	As Fit Up (see 3.13.1)	Permitted Welding Positions	Gas Shielding for FCAW	Notes
GMAW FCAW	B-L1b-GF	3/8 max	-	R=0 to 1/8	+1/16, -0	+1/16, -1/8	All	Not Required	A C N

MEMO

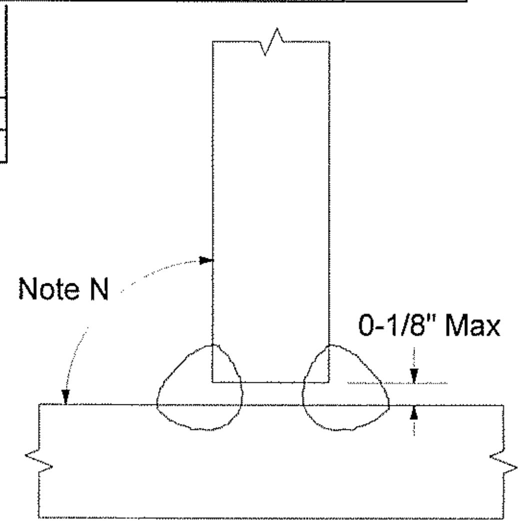
1) When the base metal is below 32 degrees F. (0 Deg. C), the base metal shall be preheated to at least 70 Degrees F (32 Deg. C) and this minimum temprature maintained during welding.

A: Not prequalified for gas metal arc welding using short circuiting transfer nor GTAW. Refer to Annex A.

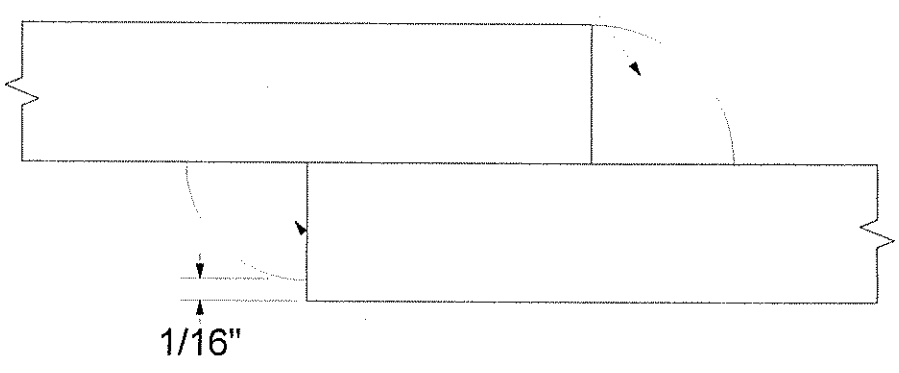
N: The orientation of the two members in the joints may vary from 135° to 180° for butt joints, or 45° to 135° for corner joints, or 45° to 90° for T-joints.

Minimum Fillet Weld Sizes Base-Metal Thickness (T)		Minimum Size of Fillet Weld	
in.	mm	in.	mm
T <1/4	T < 6.4	1/8	3
1/4 < T < 1/2	6.4 < T < 12.7	3/16	5
1/2 < T < 3/4	12.7 < T < 19.0	1/4	6
3/4 < T	19.0 < T	5/16	8

Maximum single pass Fillet Weld Size	
Flat	3/8
Horizontal	5/16



Base Metal Less Than 1/4" Thick



Base Metal Greater Than 1/4" Thick

Maximum Detailed Size of Fillet Weld Along Edges

Bell Steel Co.

Welding Procedure Specification

WPS No. BELL STEEL WPS 144 Revision 0 Date 7/31/2006 By Ron Pierce

Authorized By Cleveland Rhoades Date 7/31/2006 Prequalified ☒

Welding Process(es) FCAW Type: Manual ☐ Machine ☐ Semi-Auto ☒ Auto ☐

Supporting PQR(s) AWS D1.1 BTC-P10-GF

JOINT

Type Butt

Backing Yes ☐ No ☒ Single Weld ☒ Double Weld ☐

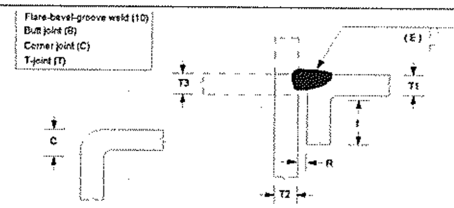
Backing Material N/A

Root Opening 0" Root Face Dimension 0"-3/16" MAX

Groove Angle N/A Radius (J-U) N/A

Back Gouge Yes ☐ No ☒

Method N/A



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T1	T2	T3	Groove Preparation: Root Opening Root Face Bend Radius	Tolerances: As Detailed (see 3.12.3)	As Fit Up (see 3.12.3)	Permitted Welding Positions	Weld Size (E)	Notes
GMAW FCAW	BTC-P10-GF	3/16 min	U	T1 min	R = 0 f = 3/16 min C = 3T1/2 min	+1/16, -0 +U, -0 -0, +Not Limited	+1/8, -1/16 +U, -1/16 -0, +Not Limited	All	5/8 T1	A, J, N, Z

BASE METALS

Material Spec. A-36 to A-500B

Type or Grade GROUP 1 to N/A

Thickness: Groove (in) 3/16 - Unlimited

Fillet (in) Any - Any

Diameter (Pipe, in) 24 - Unlimited

FILLER METALS

AWS Specification A5.20

AWS Classification E71T-1

SHIELDING

Flux N/A

Gas Carbon Dioxide

Composition 100%

Electrode-Flux (Class) N/A

Flow Rate 35-45 CFH

Gas Cup Size 10-12

PREHEAT

Preheat Temp., Min. SEE MEMO

Thickness	Temperature
Up to 3/4"	SEE MEMO
Over 3/4" to 1-1/2"	50° F
Over 1-1/2" to 2-1/2"	150° F
Over 2-1/2"	225° F

Interpass Temp., Min. 50 F Max. 350 F

POSITION

Position of Groove All Fillet All

Vertical Progression: ☒ Up ☐ Down

ELECTRICAL CHARACTERISTICS

Transfer Mode (GMAW):

Short-Circuiting ☐ Globular ☐ Spray ☐

Current: AC ☐ DCEP ☒ DCEN ☐ Pulsed ☐

Other N/A

Tungsten Electrode (GTAW):

Size N/A Type N/A

TECHNIQUE

Stringer or Weave Bead Both

Multi-pass or Single Pass (per side) SEE MEMO

Number of Electrodes 1

Electrode Spacing: Longitudinal N/A

Lateral N/A

Angle N/A

Contact Tube to Work Distance N/A

Peening N/A

Interpass Cleaning CHIP OR GRIND/WIRE BRUSH

POSTWELD HEAT TREATMENT

PWHT Required ☐

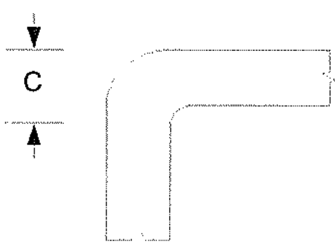
Temp. N/A Time N/A

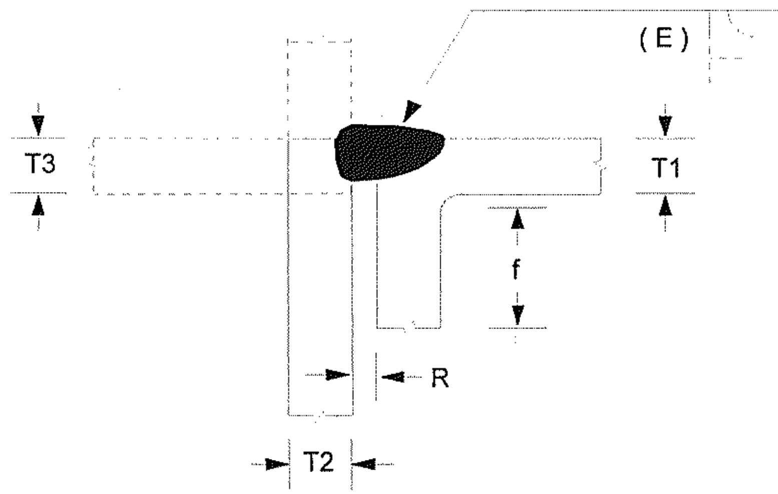
WELDING PROCEDURE

Layer/Pass	Process	Filler Metal Class	Diameter	Cur. Type	Amps or WFS	Volts	Travel Speed	Other Notes
ALL	FCAW	E71T-1	0.045	DCEP	175-220	23-28	8-10 IPM	
ALL	FCAW	E71T-1	0.052	DCEP	180-250	24-29	8-10 IPM	
ALL	FCAW	E71T-1	1/16"	DCEP	195-300	26-32	8-10 IPM	

AWS RONALD M. PHILLIPS CWI 96040091 QC1 EXP. 04/01/11

Flare-bevel-groove weld (10)
Butt joint (B)
Corner joint (C)
T-joint (T)





Welding Process	Joint Designation	Base Metal Thickness (U=unlimited)			Groove Preparation			Permitted Welding Positions	Weld Size (E)	Notes
					Root Opening Root Face Bend Radius	Tolerances				
		T1	T2	T3		As Detailed (see 3.12.3	As Fit Up (see 3.12.3)			
GMAW FCAW	BTC-P10-GF	3/16 min	U	T1 min	R = 0 f =3/16 min C =3T1 / 2 min	+1/16, -0 +U, -0 -0, +Not - Limited	+1/8, -1/16 +U, -1/16 -0, +Not - Limited	All	5/8 T1	A, J N, Z

MEMO

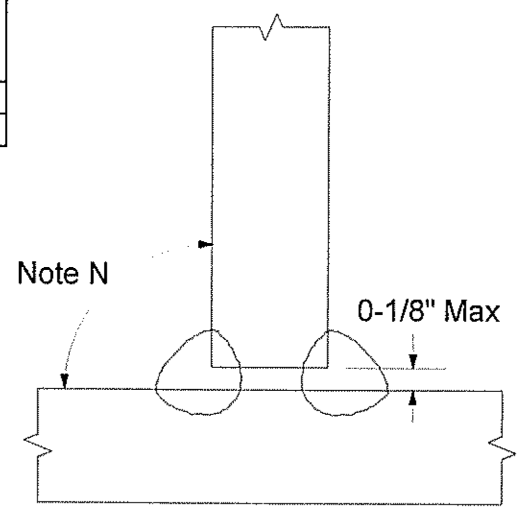
1) When the base metal is below 32 degrees F. (0 Deg. C), the base metal shall be preheated to at least 70 Degrees F (32 Deg. C) and this minimum temprature maintained during welding.
Multiple passes on groove side and single pass on back side.

A: Not prequalified for gas metal arc welding using short circuiting transfer nor GTAW. Refer to Annex A.

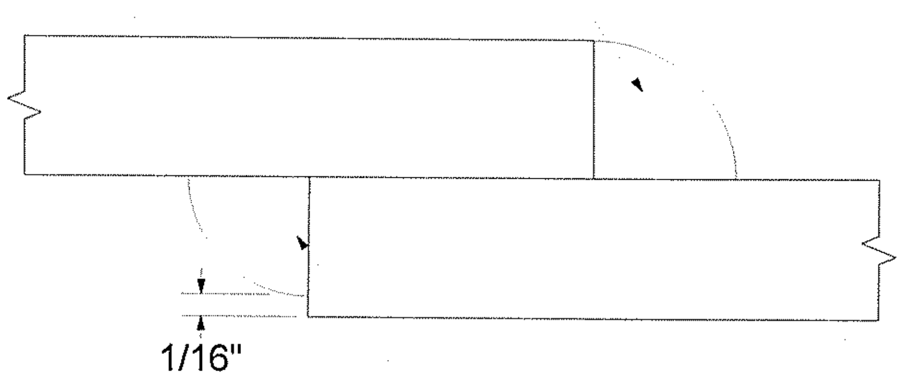
N: The orientation of the two members in the joints may vary from 135° to 180° for butt joints, or 45° to 135° for corner joints, or 45° to 90° for T-joints.

Minimum Fillet Weld Sizes Base-Metal Thickness (T)		Minimum Size of Fillet Weld	
in.	mm	in.	mm
T <1/4	T < 6.4	1/8	3
1/4 < T < 1/2	6.4 < T < 12.7	3/16	5
1/2 < T < 3/4	12.7 < T < 19.0	1/4	6
3/4 < T	19.0 < T	5/16	8

Maximum single pass Fillet Weld Size	
Flat	3/8
Horizontal	5/16



Base Metal Less Than 1/4" Thick



Base Metal Greater Than 1/4" Thick

Maximum Detailed Size of Fillet Weld Along Edges

Bell Steel

AWS - Prequalified Welding Procedure Specification (pWPS)

WeldOffice WPS

Identification #	Bell Steel 160	Rev. 1
Originated by	Ron Phillips	
Date	9/14/2009	
Authorized by	Curtis Smith	
Date	9/14/2009	

Company name	Bell Steel
Welding process	FCAW
Process type	Semi-automatic

Joint design used

Joint type		TC - T or corner joint
Joint design		Single bevel groove (4)
Backing		Yes
Backing material		Weld metal
Root opening (R)*	(in.)	0 to 1/8, +1/16, -0 (+1/16, -1/8)
Root face (f)*	(in.)	0 to 1/8, +1/16, -0 (Not Limited)
Groove angle (a)*	(deg.)	45, +10, -0 (10, -5)
Radius (J - U)*	(deg.)	n/a
Back gouging		Yes
Back gouging method		Mechanical or Thermal

Base metals * Datum, As Detailed (As Fit-Up)

Spec., type or grade		A-992
Thickness: Groove	(in.)	T1:unlimited T2:unlimited
Fillet	(in.)	ALL
Diameter (Pipe)	(in.)	-

Filler metals

AWS Specification	5.20
AWS Classification	E71T-1

Shielding

Flux		-
Electrode-flux (class)		-
Gas composition		CO2 (A5.32 SG-C)
Gas flow rate	(cfh)	25-45
Gas cup size	(in.)	1/2-3/4

Position

Welding position: Groove	All
Fillet	All
Vertical progression	Up

Electrical characteristics

Transfer mode (GMAW)	Spray
Current type	DCEP
Other	Constant Voltage (CV) power supply

Technique

Stringer or weave bead		Stringer or Weave
Multi/single pass (per side)		Single or Multiple
Number of electrodes		Single electrode
Spacing: Longitudinal	(in.)	-
Lateral	(in.)	-
Angle	(deg.)	-
Contact tube to work	(in.)	0.5 - 1
Peening		Not permitted
Interpass cleaning		Brushing or grinding

Preheat

Preheat temp.: Min.	(°F)	See notes
Interpass temp.: Min.	(°F)	See notes
Max.	(°F)	See notes

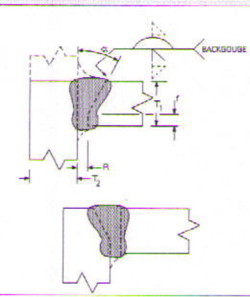
Post weld heat treatment

Temperature	(°F)	None
Time	(hrs)	-

Welding procedure

Layer	Pass	Process	Filler metal class	Filler metal diameter (in.)	Current type / polarity	Amps	Wire feed speed (in./min)	Volts	Travel speed (in./min)
1	All	FCAW	E71T-1	0.045	DCEP	150-290	200-500	25-29	9-15
1	All	FCAW	E71T-1	0.052	DCEP	165-360	150-450	26-31	9-15

Joint details



Designation: TC-U4b-GF

Notes

PREHEAT/INTERPASS
For thickness 1/8 to 3/4(in.): 32(°F). Preheat to 70(°F) if the base metal temperature is below 32(°F).
Over 3/4 thru 1-1/2(in.): 50(°F).
Over 1-1/2 thru 2-1/2(in.): 150(°F).
Over 2-1/2(in.): 225(°F).
See additional information page for further limitations

Signature 1

Name	Signature
Ron Phillips	RONALD M. PHILLIPS CWI 96040091 QC1 EXP. 04/01/11
Date	
9/14/2009	

Signature 2

Name	Signature
Date	

Signature 3

Name	Signature
Date	

Signature 4

Name	Signature
Date	

Identification #	Bell Steel 160	Rev. 1

D1.1 Table 3.7 states:

T37-01.3
Maximum GMAW/FCAW electrode diameter for flat and horizontal position is 1/8 in. (3.2 mm).

Maximum GMAW/FCAW electrode diameter for vertical position is 3/32 in. (2.4 mm).

Maximum GMAW/FCAW electrode diameter for overhead position is 5/64 in. (2.0 mm).

T37-02.1
Maximum current shall be within the range of recommended operation by the filler metal manufacturer.

T37-03.1
Maximum root pass thickness:
3/8 in. (10 mm) for Flat,
5/16 in. (8 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-04.3
Maximum GMAW/FCAW fill pass thickness is 1/4 in. (6 mm).

T37-05.3
Maximum GMAW/FCAW single-pass fillet weld size:
1/2 in. (12 mm) for Flat,
3/8 in. (10 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-06.1
Maximum GMAW/FCAW single-pass layer width:
-Root opening > 1/2 in. (12 mm): Split layers.
-Any layer of width w: In the F, H, or OH positions for nontubulars, split layers when the layer width w > 5/8 in. (16 mm). In the vertical position for nontubulars or the flat, horizontal, vertical, and overhead positions for tubulars, split layers when the width w > 1 in. (25 mm).

D1.1 Table 3.7. end of quote.

Bell Steel

AWS - Prequalified Welding Procedure Specification (pWPS)

WeldOffice WPS

Identification #	Bell Steel WPS 160-1 Rev.
Originated by	Ron Phillips
Date	2/13/2013
Authorized by	Curtis Smith
Date	2/13/2013

Company name	Bell Steel
Welding process	FCAW
Process type	Semi-automatic

Joint design used

Joint type		TC - T or corner joint
Joint design		Single bevel groove (4)
Backing		Yes
Backing material		Steel
Root opening (R)*	(in.)	1/4, +1/16, -0 (+1/4, 1/16)
Root face (f)*	(in.)	n/a
Groove angle (a)*	(deg.)	45, +10, -0 (+10, -5)
Radius (J - U)*	(deg.)	n/a
Back gouging		No
Back gouging method		n/a

* Datum, As Detailed (As Fit-Up)

Base metals

Spec., type or grade			AWS D1.1 Table 3.1 Group II
Thickness:	Groove	(in.)	T1:unlimited T2:unlimited
	Fillet	(in.)	All
Diameter (Pipe)		(in.)	Unlimited

Filler metals

AWS Specification	5.20
AWS Classification	E71T-1C-H8

Shielding

Flux		-
Electrode-flux (class)		-
Gas composition		CO2 (A5.32 SG-C)
Gas flow rate	(cfh)	25-45
Gas cup size	(in.)	1/2-3/4

Position

Welding position:	Groove	All
	Fillet	All
Vertical progression		Up

Electrical characteristics

Transfer mode (GMAW)	Spray
Current type	DCEP
Other	Constant Voltage (CV) power supply

Technique

Stringer or weave bead			Stringer or Weave
Multi/single pass (per side)			Single or Multiple
Number of electrodes			Single electrode
Spacing:	Longitudinal	(in.)	-
	Lateral	(in.)	-
	Angle	(deg.)	-
Contact tube to work		(in.)	0.5 - 1
Peening			Not permitted
Interpass cleaning			Brushing or grinding

Preheat

Preheat temp.:	Min.	(°F)	See notes
Interpass temp.:	Min.	(°F)	See notes
	Max.	(°F)	See notes

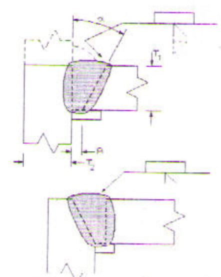
Post weld heat treatment

Temperature	(°F)	None
Time	(hrs)	-

Welding procedure

Layer	Pass	Process	Filler metal class	Filler metal diameter (in.)	Current type / polarity	Amps	Wire feed speed (in./min)	Volts	Travel speed (in./min)
1	All	FCAW	E71T-1C-H8	0.045	DCEP	150-290	200-500	24-29	6-15
1	All	FCAW	E71T-1C-H8	0.052	DCEP	165-300	200-500	25-29	6-15

Joint details



Designation TC-U4a-GF

Notes

PREHEAT/INTERPASS
For thickness 1/8 to 3/4(in.): 32(°F). Preheat to 70(°F) if the base metal temperature is below 32(°F).
Over 3/4 thru 1-1/2(in.): 150(°F).
Over 1-1/2 thru 2-1/2(in.): 225(°F).
Over 2-1/2(in.): 300(°F).
See additional information page for further limitations

Signature 1
Name   Signature
Date

Ronald M Phillips
CWI 96040091
QC1 EXP 4/1/2014

Signature 2
Name   Signature
Date

Signature 3
Name   Signature
Date

Signature 4
Name   Signature
Date

WeldOffice WPS 2012.01.003
Catalog n° PWP00215

D1.1 Table 3.7 states:

T37-01.3
Maximum GMAW/FCAW electrode diameter for flat and horizontal position is 1/8 in. (3.2 mm).

Maximum GMAW/FCAW electrode diameter for vertical position is 3/32 in. (2.4 mm).

Maximum GMAW/FCAW electrode diameter for overhead position is 5/64 in. (2.0 mm).

T37-02.1
Maximum current shall be within the range of recommended operation by the filler metal manufacturer.

T37-03.1
Maximum root pass thickness:
3/8 in. (10 mm) for Flat,
5/16 in. (8 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-04.3
Maximum GMAW/FCAW fill pass thickness is 1/4 in. (6 mm).

T37-05.3
Maximum GMAW/FCAW single-pass fillet weld size:
1/2 in. (12 mm) for Flat,
3/8 in. (10 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-06.1
Maximum GMAW/FCAW single-pass layer width:
-Root opening > 1/2 in. (12 mm): Split layers.
-Any layer of width w: In the F, H, or OH positions for nontubulars, split layers when the layer width w > 5/8 in. (16 mm). In the vertical position for nontubulars or the flat, horizontal, vertical, and overhead positions for tubulars, split layers when the width w > 1 in. (25 mm).

D1.1 Table 3.7. end of quote.

Bell Steel

AWS - Prequalified Welding Procedure Specification (pWPS)

WeldOffice WPS

Identification #	BS 164 Rev.
Originated by	Ron Phillips
Date	11/13/2009
Authorized by	Curtis Smith
Date	11/13/2009

Company name	Bell Steel
Welding process	FCAW
Process type	Semi-automatic

Joint design used

Joint type		BTC - Butt, T or corner joint
Joint design		Single bevel groove (4)
Backing		No
Backing material		n/a
Root opening (R)*	(in.)	0, +1/16, -0 (+1/8, -1/16)
Root face (f)*	(in.)	1/8 min, +U, -0 (+/-1/16)
Groove angle (a)*	(deg.)	45, +10, -0 (+10, -5)
Radius (J - U)*	(deg.)	n/a
Back gouging		No
Back gouging method		n/a

* Datum, As Detailed (As Fit-Up)

Base metals

Spec., type or grade		A572-50 to A500-B
Thickness: Groove	(in.)	T1:1/4 min T2:unlimited
Fillet	(in.)	ALL
Diameter (Pipe)	(in.)	Unlimited

Filler metals

AWS Specification	A5.20
AWS Classification	E71T-1

Shielding

Flux		-
Electrode-flux (class)		-
Gas composition		CO2 (A5.32 SG-C)
Gas flow rate	(cfh)	30
Gas cup size	(in.)	

Position

Welding position: Groove	All
Fillet	All
Vertical progression	Up

Electrical characteristics

Transfer mode (GMAW)	Spray
Current type	DCEP
Other	Constant Voltage (CV) power supply

Technique

Stringer or weave bead		Stringer or Weave
Multi/single pass (per side)		Single or Multiple
Number of electrodes		Single electrode
Spacing: Longitudinal	(in.)	-
Lateral	(in.)	-
Angle	(deg.)	-
Contact tube to work	(in.)	0.5 - 1
Peening		Not permitted
Interpass cleaning		Brushing or grinding

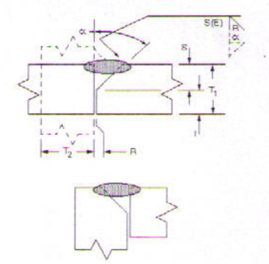
Preheat

Preheat temp.: Min.	(°F)	See notes
Interpass temp.: Min.	(°F)	See notes
Max.	(°F)	See notes

Post weld heat treatment

Temperature	(°F)	None
Time	(hrs)	-

Welding procedure

Layer	Pass	Process	Filler metal class	Filler metal diameter (in.)	Current type / polarity	Amps	Wire feed speed (in./min)	Volts	Travel speed (in./min)	Joint details
1	All	FCAW	E71T-1	0.045	DCEP	175-225		24-26	9-18	
1	All	FCAW	E71T-1	0.052	DCEP	195-275		25-29	9-18	

Designation	BTC-P4-GF

Notes

See additional information page for further limitations

Signature 1

Name	Signature
Ron Phillips	
Date	
11/13/2009	

RONALD M. PHILLIPS
CWI 96040091
QC1 EXP. 04/01/11

Signature 2

Name	Signature
Date	

Signature 3

Name	Signature
Date	

Signature 4

Name	Signature
Date	

Identification #	BS 164	Rev.

D1.1 Table 3.7 states:

T37-01.3
Maximum GMAW/FCAW electrode diameter for flat and horizontal position is 1/8 in. (3.2 mm).

Maximum GMAW/FCAW electrode diameter for vertical position is 3/32 in. (2.4 mm).

Maximum GMAW/FCAW electrode diameter for overhead position is 5/64 in. (2.0 mm).

T37-02.1
Maximum current shall be within the range of recommended operation by the filler metal manufacturer.

T37-03.1
Maximum root pass thickness:
3/8 in. (10 mm) for Flat,
5/16 in. (8 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-04.3
Maximum GMAW/FCAW fill pass thickness is 1/4 in. (6 mm).

T37-05.3
Maximum GMAW/FCAW single-pass fillet weld size:
1/2 in. (12 mm) for Flat,
3/8 in. (10 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-06.1
Maximum GMAW/FCAW single-pass layer width:
-Root opening > 1/2 in. (12 mm): Split layers.
-Any layer of width w: In the F, H, or OH positions for nontubulars, split layers when the layer width w > 5/8 in. (16 mm). In the vertical position for nontubulars or the flat, horizontal, vertical, and overhead positions for tubulars, split layers when the width w > 1 in. (25 mm).

D1.1 Table 3.7. end of quote.

Identification #	Bell Steel WPS 120-1	Rev.

D1.1 Table 3.7 states:

T37-01.3
Maximum GMAW/FCAW electrode diameter for flat and horizontal position is 1/8 in. (3.2 mm).

Maximum GMAW/FCAW electrode diameter for vertical position is 3/32 in. (2.4 mm).

Maximum GMAW/FCAW electrode diameter for overhead position is 5/64 in. (2.0 mm).

T37-02.1
Maximum current shall be within the range of recommended operation by the filler metal manufacturer.

T37-03.1
Maximum root pass thickness:
3/8 in. (10 mm) for Flat,
5/16 in. (8 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-04.3
Maximum GMAW/FCAW fill pass thickness is 1/4 in. (6 mm).

T37-05.3
Maximum GMAW/FCAW single-pass fillet weld size:
1/2 in. (12 mm) for Flat,
3/8 in. (10 mm) for Horizontal,
1/2 in. (12 mm) for Vertical,
5/16 in. (8 mm) for Overhead position.

T37-06.1
Maximum GMAW/FCAW single-pass layer width:
-Root opening > 1/2 in. (12 mm): Split layers.
-Any layer of width w: In the F, H, or OH positions for nontubulars, split layers when the layer width w > 5/8 in. (16 mm). In the vertical position for nontubulars or the flat, horizontal, vertical, and overhead positions for tubulars, split layers when the width w > 1 in. (25 mm).

D1.1 Table 3.7. end of quote.

APPENDIX E2
WELDING PROCEDURE SPECIFICATIONS
FABRICATOR 2

NAFCO
1540 County Road 222
Cullman, AL, 35057

AWS D1.1 Prequalified Welding Procedure Specification (WPS)

WPS No. **TFillet** Date **5/18/2015** Rev. No. **0**

Prepared By: Date 5/18/2015 QA Manager

Welding Process(es)/Type(s) **FCAW / Semiautomatic**

Joint Design Used
Weld Type Fillet welds
Fillet Type T-joint
Double Welded No
Backing Yes Material Base Metal
Root Opening 3/16 in. Root Face N/A
Groove Angle N/A Radius N/A
Back Gouging No Method N/A

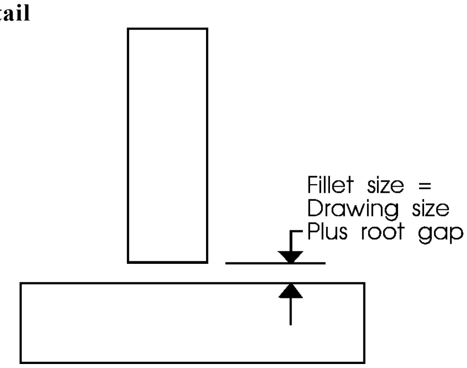
Base Metals
Base Metal ASTM A 572, Grade 50
Thickness: Groove N/A
Thickness: Fillet 1/8 in. min.
Pipe Diameter 3/8 in. min.
Groups I & II

Filler Metals
AWS Specification 5.20
AWS Classification E71T-1
Weld Size 5/16 in.

Shielding
Gas 100% CO2 Flow Rate 32-60 CFH
Gas Cup Size 5/8-3/4
Electrode-Flux (Class) N/A
Flux Trade Name N/A

Preheat
Preheat Temperature, Min. 32°F
Interpass Temperature, Min. 32°F Max. 500°F
Minimum Preheat and Interpass Temperatures for given thickness:
1/8" thru 3/4" incl.: 32°F (70°F if less than 32°F)
Over 3/4" thru 1-1/2" incl.: 50°F
Over 1-1/2" thru 2-1/2" incl.: 150°F
Over 2-1/2": 225°F

Joint Detail



Position
Weld Position: Fillet All Positions
Weld Position: Groove N/A
Vertical Progression Vertical up
5/16

Electrical Characteristics
Power Source
Output Constant Voltage
Current / Polarity DCEP (reverse)
Transfer Mode Globular arc
Tungsten Electrode: Type N/A
Tungsten Electrode: Size N/A

Technique
Stringer or Weave Bead Stringer or weave bead
Multi/Single Pass Single or multipass
Number of Electrodes 1
Electrode Spacing: Longitudinal N/A
Lateral N/A Angle N/A
Contact Tube to Work Distance 3/8 to 3/4
Peening Not allowed.
Interpass Cleaning Chipping hammer, wire brush and grind as needed.

Postweld Heat Treatment
Temperature None
Time (hr.) None

Welding Procedure

Pass or Weld Layer(s)	Process	Filler Metal AWS Classification	Filler Metal Size (in.)	Current Type & Polarity	Current Amps	Volts	Travel Speed (in/min)
ALL	FCAW	E71T-1	0.052	DCEP (reverse)	220 - 270	26-30	12 - 20
ALL	FCAW	E71T-1	0.045	DCEP (reverse)	200 - 240	25-28	9 - 15

APPENDIX F
INSPECTION REPORT
FABRICATOR 1

Test sample weld inspection summary for Obstruction fillet weld test:

Note: Samples were cleaned after all fins were welded; and were inspected after all fins were welded in place on all (3) samples. This posed a small problem with access between fins for cleaning and inspection. During inspection the weld gage could be placed on the actual weld except right at the end of the fin samples and eyeballing from the top. So during inspection, the weld size was eyeballed using the gage from both the top and the ends as best as possible and making the best decision based on what could be determined using this method. It is not uncommon to have a situation occasionally where you have make the best educated guess on the size of the weld when proper access after welding gage becomes an issue. I will usually error on the side of caution and call for another pass if the weld appears close to being small. In the case of the samples below, no extra prep or additional passes for repair were made. The welds from a production standpoint would all be accepted once repairs were made. That said the results of my inspection are as follows:

Sample #1 welded in the flat postion:

- Fin #1- Rejected for a small area of possible lack of fusion or cold lap. In production would be ground and another pass added and the obstruction would not prevent this since the presence of any additional fins would not be present..
- Fin #2- Rejected because there are areas that appear to be undersize in excess of 10% of the weld length. Again these would be ground cleaned and repaired if this were a production weld Fins # 3-7 were accepted as is.

Sample #2 welded in the horizontal position:

- Fin #1 – Rejected because of appearance and cleaning. (Weld would be re-cleaned in an actual production situation and would then be acceptable).
- Fin #2- Rejected due to an area on weld appears to be undersize. Again in a production situation the weld would be properly cleaned and additional weld added to correct the issue. Access would not be a problem in production even with the obstruction present.
- Fins #3 thru 7- All welds accepted.

Sample #3 welded in the 3G vertical up position:

- All fins #1 thru 7 were acceptable as welded with no production repairs to be noted.

Test samples for doubler plates root pass welds:

Two samples created for each respective plate thickness with the X dimension being 5/8" and 1 ¼" and root pass inspected for visual appearance in all cases. *NOTE: In an actual shop inspection of these welds on a couple of the samples I would require the welder to knock off some of the spatter that remained during inspection since addition passes are going to be added to complete the welding to avoid would having to incorporate them in the weld pool upon adding the additional passes.*

Test samples for prequalified tubular heel weld connections:

- Sample 1 with acute angle 15degrees:

AdditionalNotes

Good for any size fillet weld per Clause 3 of AWS D1.1 with a maximum single pass fillet up to and including 5/16”.

JOINT NOTES:

(a)Not Prequalified for GMAW-S nor GTAW. (g) If fillet welds are used in statistically loaded structures to reinforce groove welds in the corner and T-joints, these shall be equal to T1/4, but need need not exceed 3/8in. [10mm]. Groove welds in corner and T-joints of cyclically loaded structures shall be reinforced with fillet welds equal to T1/4, but need not exceed 3/8in. [10 mm]. (j) The orientation of the two members in the joints may vary from 135° to 180° for butt joints, or 45° to 135° for corner joints, or 45° to 90° for T-joints. (K) For corner joints, the outside groove preparation may be in either or both members, provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operations without excessive edge melting.

1. Root pass from the joint side was good & passed inspection.
2. Subsequent passes were made to achieve the required back weld and the final passes looked very good. No defects observed. Back weld passed inspection & size requirements.
3. The final weld out was then completed to achieve the ½" tw. The final weld passed visual inspection.

(NOTE from the back side which would be inside of the tube if this were a real joint which not visible after welding was indeed observed as being a good root pass which would probably pass a pipe weld inspection)

Remaining samples followed the same protocol for inspection. All root passes were acceptable, all back welds were accepted and the size was adequate. The final welds passed visual inspection with no viable defects.