

Welding Fire Protection Piping 101

By

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Part 1 – Welding Procedures and Welder Qualification for Fire Protection Piping

Fire protection piping has an easy life compared to other piping systems. Not much flowing through it. Only occasional pressure changes. Practically no temperature changes, so stresses due to expansion or contraction are not a concern. Fluid being carried is not explosive or flammable. About all it has to do is contain water reliably and provide it to sprinkler heads when it's needed. It's biggest enemy is corrosion.

Like welds in all piping systems, fire protection piping welds need to be adequate for the service. NFPA 13 does not require radiographic examination or other expensive inspection of piping system welds, but it does require that the shop fabricator and installing contractor have Welding Procedure Specifications (WPSs) that provide detailed direction to the welder on how to make welds. It also requires that his welders be qualified. NFPA-13-2007 says:

6.5.2.5.2 Qualification of the welding procedure to be used and the performance of all welders and welding operators shall be required and shall meet or exceed the requirements of AWS B2.1, *Specification for Welding Procedure and Performance Qualification*, ASME Boiler and Pressure Vessel Code, Section IX, *Welding and Brazing Qualifications* or other applicable qualification standard as required by the authority having jurisdiction, except as permitted by 6.5.2.5.3.

When NFPA 13 requires qualification to one of these standards, it means that the WPS has to address certain elements of how to do welding that the codes call “variables;” among these are:

- Welding process or processes (i.e., stick, MIG, flux core, etc.)
- Base metal (i.e., A-53, A-139, etc.)
- Electrode type (i.e., E7018, ER70S-2, E71T-1, etc.)
- Design of the groove (i.e., Single-vee, single-bevel, U-groove, etc.) or fillet
- Position (Most WPSs allow all-position welding, although shop welding may be limited to flat position where the pipe is rotated and the welding torch is held steady at the top of the pipe during welding)
- Progression (when welding with the pipe horizontal and the weld vertical, the welder can start welding at the bottom of the pipe and proceed to the top when welding “uphill” or he can start at the top and proceed to the bottom when welding “downhill.” Contrary to popular opinion, welds made using downhill progression are equal in quality to those made using uphill progression when made by a skilled welder)
- Preheat temperature (The minimum temperature of the pipe before and during welding, typically 50°F.)
- Postweld heat treatment (Typically not done on fire-protection piping)
- Shielding gas (CO₂, Ar-CO₂ mixes, etc.) for gas-shielded processes like MIG or TIG.
- Electrical Characteristics (i.e., current type, polarity, volts, amps and travel speed.) for each welding process and for each electrode type and size..
- Miscellaneous conditions, such as initial and interpass cleaning, peening, repair welding, electrode stick-out, shielding gas flow rate, etc..

See Figure 1 for a typical WPS suitable for welding fire protection piping.

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Not only does the contractor have to address all the variables required by code, but he has to demonstrate by welding test pieces together following the WPS and testing that assembly that the WPS directs the welder to make welds that are of adequate strength and ductility; this process is known as “qualification” of the procedure, and the record documenting the test conditions and test results is known as a Procedure Qualification Record (PQR). See Figure 2 for the PQR that supports the WPS shown in Figure 1.

While the WPS provides the recipe to the welder telling him how to make the weld, the welder himself must also be qualified by welding a test piece and either x-raying or doing bend tests on that piece. Like WPS qualification, there are “variables” that govern welder qualification. Those variables include the welding process, electrode or filler metal type, the pipe diameter, thickness, position, progression and use of backing when the welding process is SMAW (also known as “stick” welding). For GMAW (also known as MIG welding) and GTAW (also known as TIG and HeliArc welding), other variables such as backing gas and transfer mode must also be demonstrated. A typical welder qualification record is shown on Figure 3. Welding operators (such as those who run machines that attach outlet nozzles) also have to be qualified, but the variables are different from those for welders and fewer since the machine is actually doing the welding.

Generally speaking, welders who weld on fire protection piping should be tested:

- 1) by their employer
- 2) on test pieces that are pipe, not plate. (Sometimes shop welder will test on plate.)
- 3) using the welding process and electrode types they will use for installation.

For field work, the test pipe should be inclined at 45° from the horizon (known as the “6G” position) so that the welder is qualified to weld in all positions; for shop work (where most of the pipe is rolled while it is being welded) welder testing may be done with the pipe horizontal and rolled (1GR) while the pipe rotates under the welding torch; this qualifies the welder only for the flat position.

NFPA-13, paragraph 6.5.2.6.1 says that welders or welding machine operators shall, upon completion of each weld, stamp an imprint of their identification into the side of the pipe adjacent to the weld. To comply with this requirement, fabricators and contractors are required to assign an identifying letter, number or symbol to each welder, and that identification must be shown on the qualification records and it must be stamped on that welder’s production welds. The 2007 edition is open-ended on the type of marking, permitting marking other than stamping, such as a paint stick. Welder identification should be visible on the installed pipe.

Purchasers of fire protection piping should specify that the contractor submit copies of their WPSs (including the PQRs that support them) that will be used on their work. Purchasers should also request copies of typical welder qualification records to verify that the contractor knows how to qualify his welders. Smart purchasers review these documents before the fabricator or contractor starts work. WPSs and welder qualification records should be available at the site where the work is being done, and the inspector or Fire Marshal should use them to verify that the welder is doing what the WPS says to do and that the welder is welding within his limits of qualification as shown in the “Range Qualified” column on the welder qualification record. If the inspector or Fire Marshal does not know enough about welding to verify compliance with these documents, a competent contractor’s welding supervisor should be cognizant enough to explain them to him.

NFPA-13, paragraph 6.5.2.6.2, says that contractors or fabricators shall maintain certified records, which shall be available to the authority having jurisdiction, of the procedures used and the welders or welding machine operators employed by them, along with their welder identification. A fabricator or contractor who cannot produce WPSs, PQRs and welder qualification records cannot be in compliance with NFPA 13, and

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any piping fabricated or installed by him would not be legal in any jurisdiction where NFPA 13 is imposed by law and should be rejected by the responsible Fire Marshal.

Part 2 – Examination of Fire Protection Piping during Fabrication and Installation

Once the purchaser has verified that the WPSs are correct and the welders are qualified, the quality of the welds should be checked. This may be done in a fabrication shop, on piping assemblies that have been received at a site but are not yet installed and on welds as they are being made in the field.

Butt Welds and Header Branch Welds¹

All welds should be visually examined externally for general appearance. They should be free of excessive undercut and reinforcement and should show no surface slag or porosity. See Figures 4 and 5. Any butt or header branch welds where the inside surface of the pipe (“root side”) can be seen should exhibit penetration such as shown in Figure 6. For standard weight pipe (see Table 1) where backing rings were not used, a good rule-of-thumb is that there should be at least 1-1/2 inches of obvious root penetration (continuous or discontinuous) in any 6 inches of weld length; for light-weight or schedule 10 pipe, there should be obvious penetration for 3 inches of weld length. Figure 7 shows incomplete penetration. Figure 8 shows additional root side conditions that may be encountered.

For field assembly, similar examinations should be done where one can see the root side of the joint; however, root sides are typically not accessible in field welds, so it is important that the pipe be cut, beveled and assembled properly in accordance with the WPS prior to welding the root pass (Figure 4).

The best way to ensure adequate penetration of a butt weld is to use backing rings. See Figure 9. With a backing ring, adequate root spacing is ensured, and as a bonus, the level of welder skill does not have to be so high.

Without a backing ring, adequate penetration can only be ensured by doing fit-up inspection before welding the root pass. That is, the pipe should be beveled and assembled and tack welded as required by the WPS, then inspected preferably by someone other than the welder before welding the root. A typical fit-up that gives the welder a reasonable opportunity to achieve adequate penetration is shown in Figure 10; if in doubt about the adequacy of a contractor’s root pass welding practices, ask him to fit and weld a joint where the root side is either accessible for visual examination after welding (e.g., a tee) or to weld a mock-up using his standard fit-up practices. To verify that his practices are being followed during installation, purchasers and Fire Marshals should perform fit-up inspection randomly as work progresses.

As welds are being made, welders should clean the root pass and also between passes using a slag hammer, power wire brush or grinder. Some grinding may be needed to ensure that the previously deposited beads have a contour suitable for depositing the next layer. Crevices and excessive roughness should be removed by grinding before making subsequent weld passes.

¹ Header branch welds are connections that are stubbed into or onto a header to carry water to outlet connections. Header branch welds are frequently used in lieu of tees. An outlet connection leading to a spray nozzle (“drop pipe”) is not considered a header branch weld.

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Outlet Connections to Spray Nozzles (i.e., “Drop pipe) and Branch Nozzles

NFPA-13, paragraph 6.5.2.4.1 allows outlet fittings that will go to spray nozzles (commonly referred to as “drop pipe,”) to be fillet welds, partial penetration welds with reinforcing fillet or fully penetrated groove welds. Where partial penetration welds or fillet welds are used, the weld size has to be sufficiently large to withstand the pressure load from the water inside the pipe. The weld should be uniform in size around the fitting except that there may be a larger weld at the point where the ending point of the weld bead overlapped the starting point. For partial penetration welds and fillet welds, paragraph 6.5.2.4.1 requires that the throat of the weld not be less than the thickness of the pipe, the fitting wall or 3/16 inch, whichever is least. This means that the leg length of the fillet around the fitting should be a minimum of 1/4 inch as shown in Figure 11. Where the weld is fully-penetrated, the fillet size is not a concern as long as there is a fillet. Full penetration can be verified by inserting a small mirror into the outlet opening and visually examining the weld.

Welds that attach nozzles that are used to connect a smaller branch pipe to a larger header pipe should be attached the same way that outlet nozzles are attached. Since the throat of a partial-penetration joint is slightly larger than that of a simple fillet weld, partial penetration joint designs are preferred for these nozzles since the nozzle will have external loads imposed on them due to dead weight in addition to pressure-induced loads.

Nozzle welds should be visually examined just like butt welds for surface appearance, contour, porosity, undercut and weld size. In addition, special attention should be paid to threads which should be clean and free of weld spatter or other damage. The holes that are cut in the header should be as large as the opening in the outlet fitting and ground to be free of slag (See paragraph 6.5.2.4.6). Any disks created by cutting the hole shall be removed. The inside surface of the header should be free of slag and dross, and the fitting should not protrude into the header pipe.

Weld Stamping

Finally, all welds should be marked with the stamp assigned to the welder(s) who made the welds. Marking can be by stamping, paint stick or label and should be on or near each weld. Final visual acceptance of welds by the installing contractor should either be documented in an inspection report or recorded with the inspector’s initials and date using a paint stick near the weld itself.

Questions about piping and welding are invited by the author. Readers may contact him at

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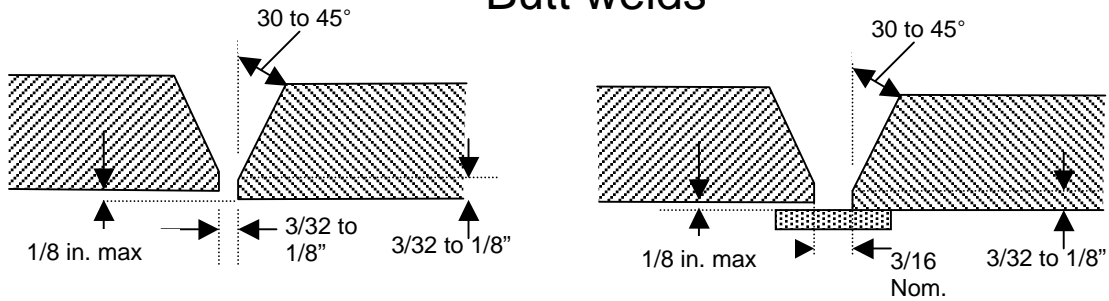
Figure 1 Harry's Rod Burners, Inc. Welding Procedure Specification

WPS Number 1-3-1		Revision 2		Date issued: 2/14/04					
Supporting PQRs: 0123				Mfg. Approval: _____ Date: _____					
Welding Process: Semi-Automatic GMAW-Short Circuiting				QA Approval: _____ Date: _____					
Joints									
Joint Design: Single or Double V, Fillets, repairs, build-up and other grooves shown on engineering drawings.									
Backing: Optional			Backing or Retainer type: Stainless Steel when used.						
Base Metals			Filler Metals and Electrodes						
P/S/M Number 1 Groups No. 1 and 2 P/S/M Number 1 Groups No. 1 and 2 Base Metal Thickness Range Groove Welds: 3/16 to 1.0" Fillet welds: All Minimum Outside Diameter Groove Welds: 2-7/8" and over unless welded in flat position, then all diameters. Fillet Welds: 2-7/8" and over unless rolled in flat or horizontal position, then all			Specification Number: SFA 5.18 AWS Classification: ER70S-2 or -3 F-number: 6 A-Number: 1 Maximum Weld Metal Thickness: Grooves: 1.0" Fillets: All Maximum Bead thickness: 1/8" Supplemental Filler Metal: Not permitted Consumable Insert: Not applicable Pulsed Power Supply: Not permitted						
Postweld Heat Treatment									
Temperature: None Max. Holding Time: N/A									
Preheat		Positions		Gas					
Minimum metal temp: 50 F Interpass Temp. (Max): 400 F Preheat Maintenance: Not required		Positions permitted: All Progression when in Vertical: Uphill		Shielding: 75Ar/25CO ₂ , 25/40CFH Backing: None Trailing Shield: None					
Electrical Characteristics and Related Matters									
Weld Layer	Process	Electrode or Filler		Current				Travel Speed (ipm)	Other
		Class	Diameter	Type	Polarity	Volts	Current/WFS		
All	GMAW	ER70S-2	0.035	DC	EP (rev)	15 to 17	80 to 180	8 to 20	Transfer mode: Short circuiting
		or ER70S-3	0.045	DC	EP (rev)	16 to 21	100 to 350 ipm 110 to 220 100 to 280 ipm	8 to 20	
Technique (QW-410)									
Tungsten Size and Type: Not Applicable Shielding Gas Cup Size: 1/2 to 3/4" ID Single or Multiple Pass per Side: Either Single or Multiple electrodes: Single Contact-tube-to-work distance (stickout): 1/4 to 3/8" Repair Method: Grinding. Backwelding is permitted. Stringer or Weave Bead: Either Peening: Not permitted			Initial Cleaning: Remove grease or oil with solvent. Remove cutting oxide by grinding. Interpass Cleaning: Remove slag with slag hammer, grinder or wire brush. Backgouging: Grinding or carbon arc followed by grinding. Other: Stay at the leading edge of the weld pool to ensure good fusion. Use several thin passes rather than fewer large passes.						
Applicable Code: AWS B2.1-2000 and ASME Section IX									

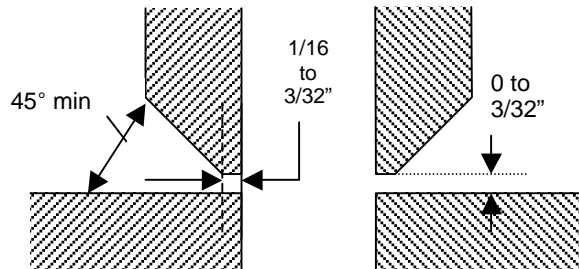
WPS 1-3-1

Typical Joint Designs for Piping Welds

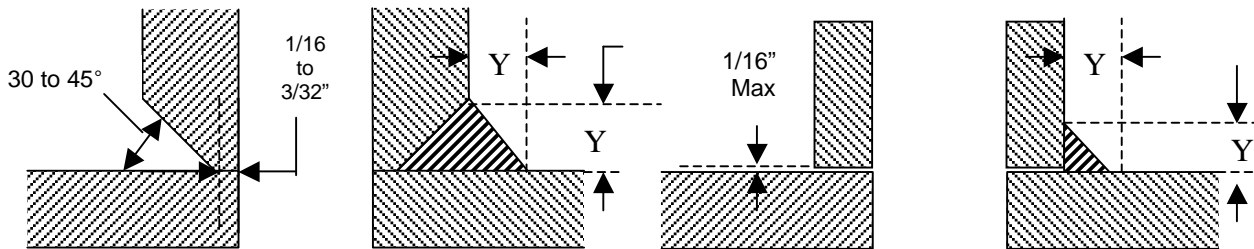
Butt welds



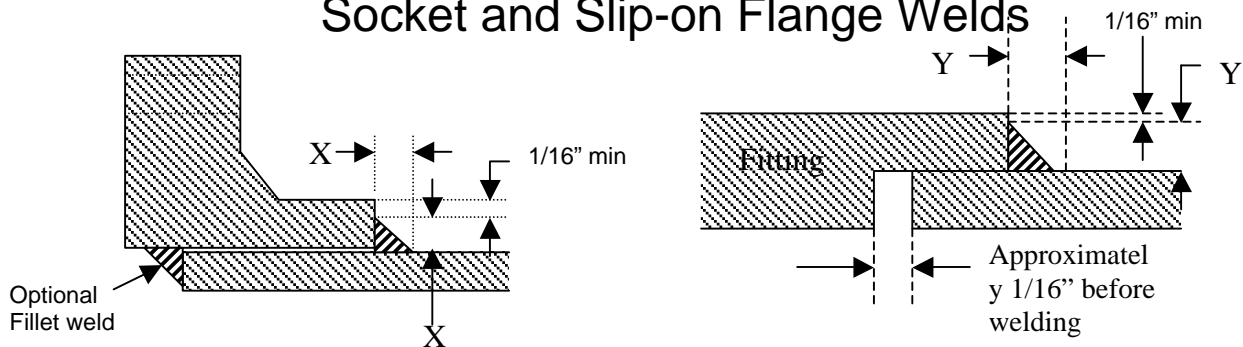
Run-to-Header Branch Connection Welds



Drop Pipe to Header Connections



Socket and Slip-on Flange Welds



The following apply unless another size is shown on the engineering drawings:

T is the nominal header wall thickness.

X = the lesser of 1.4T or the hub thickness

Y = the lesser of 1.1T or 1.1 times the fitting thickness

Z = the lesser of 1.4T or 1.4 times the fitting thickness

Figure 2 Procedure Qualification Record

Identification of WPS followed during welding of test coupon: 1-3-1, Rev 0 dated 11/6/03
 Welding Process(es) used: GMAW-S, Semi-Auto Date coupon was welded: 11-10-03
 Base Metal Specification: SA 516 Grade 70 to Base Metal Specification: SA 516 Gr 70
 P-Number: 1 Group No. 2 to P-Number: 1 Group 2 Plate/Pipe Diameter: Plate
 Base Metal Thickness(in.): 1/2 Joint Type: Double V-groove F-Number: 4
 Filler metal specification: SFA 5.18 AWS Classification: ER70S-2
 A-Number: 1 Weld Deposit Thickness(es)(in.): 1/2 Maximum Pass Thickness: 3/32"
 Filler metal size: 0.035" Supplementary filler metal: None
 Preheat temperature (°F): 60 Interpass temperature (°F) 400 Welding position/progression: 1G
 Current Type and polarity: DCEP Travel speed (ipm): see below
 Shielding gas composition, CFH: 75%Ar/25% CO2, 30 CFH Backing gas, CFH: None
 Tungsten size/type: N/A GMAW transfer mode: Short circuiting
 Postweld Heat treatment (°F): None Postweld heat treatment time (hr.): N/A
 Stringer/Weave bead: Root: String, Fill: Both Oscillation: N/A
 Single/Multi-pass: Multiple Single/Multi-electrode: Single

Weld Layer	Process	Electrode or Filler		Current				Travel Speed (ipm)	Other
		Class	Diameter	Type	Polarity	Volts	Current (a)		
All	GMAW	ER70S-2	0.035	DC	EP (rev.)	17.5 to 18.5	105 to 130 240 to 320 ipm WFS	10	Short Circuiting Transfer

Reduced Section Tensile Tests Rectangular Turned Full Section

Specimen	Width/Dia, in.	Thickness, in.	Area, Sq in.	Ult. Load,Lb	Ult. Stress, psi	Failure Location
1	0.751	0.475	0.358	30,500	85,200	Base Metal
2	0.744	0.478	0.356	29,800	83,700	Base Metal

Bend Tests Transverse Face and Root Side Longitudinal Face and Root

Type	Results	Type	Results
Side	Acceptable	Side	Acceptable
Side	Acceptable	Side	Acceptable

Toughness Tests: Charpy Specimen Size _____ Test Temperature _____

Specimen	Notch Location	Ft-Lbs	Lateral Exp, Mils	% Shear

Fillet weld test macro examination: _____ Fillet weld test leg sizes: _____

Weld deposit analysis: _____

Other tests: _____

Welder's name: Allen Rivers Stamp: Y Welding Supervised by: Joe Watson, QA, Harry's Rod Burners

Tests conducted by: Sam-Bob Urkle, Guaranteed Testing, Inc. Laboratory test number: 56789-1

We hereby certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of AWS B2.1 and Section IX of the ASME Code.

Harry's Rod Burners, Inc.

By: Harry's Rod Burners Date: 12-25-03

Figure 3

Welder Performance Qualification Record

Welder's Name: Jack Jones Social Security No: 123-45-6789 Stamp No: JJ

Testing Conditions and Ranges Qualified

Identification of WPS followed during welding of test coupon: 1-3-1, Rev 2 dated 2/14/04
 Specification of Test Coupon Base Metal: A-106 Grade B or A-53 Grade B Thickness(in.): 0.436

<u>Welding Variables</u>	<u>Actual Values</u>	<u>Range Qualified</u>
Welding Process(es) used:	<u>GMAW</u>	<u>GMAW</u>
Type of welding (manual, semi-automatic):	<u>Semi-automatic</u>	<u>Semi-automatic</u>
Base Metal P or S-Number <u>1</u> to P or S-number:	<u>1</u>	<u>1 through 11</u>
<input type="checkbox"/> Plate <input checked="" type="checkbox"/> Pipe (enter diameter if pipe or tube):	<u>NPS 2, XXS (0.436")</u>	<u>1 in. OD and over</u>
Backing (metal, weld metal, backwelded, etc.):	<u>None</u>	<u>Optional.</u>
Filler Metal (SFA) Specification(s) (info. only):	<u>5.18</u>	
Filler Metal or Electrode Classification(s) (info. only):	<u>ER70S-2</u>	
Filler Metal or Electrode F-Number:	<u>6</u>	<u>6</u>
Solid, Metal Cored or Flux Cored wire for GTAW:	<u>Solid</u>	<u>Solid or Metal Cored</u>
Consumable Insert for GTAW or PAW:	<u>N/A</u>	<u>N/A</u>
Deposit Thickness for each process and variation (in.):	<u>0.436</u>	<u>0.480</u>
Position (2G, 6G, 3F, etc.):	<u>6G</u>	<u>All</u>
Progression (uphill, downhill):	<u>Uphill</u>	<u>Uphill</u>
Fuel Gas for OFW, Backing Gas for GTAW, GMAW:	<u>None</u>	<u>Required</u>
GMAW Transfer Mode (short circuiting, spray, etc.):	<u>Short-circuiting</u>	<u>Short-circuiting</u>
GTAW Current Type/Polarity (AC, DCEP, DCEN):	<u>N/A</u>	<u>N/A</u>

Testing and Results

Visual Examination of Completed Weld: Acceptable Date of Test: _____

Bend Test Transverse Root and Face (QW-462.3(a)) Side (QW-462.2)

Type	Result	Type	Result	Type	Result
Face	Acceptable	Root	Acceptable		
Face	Acceptable	Root	Acceptable		

Radiographic Examination Results: N/A Lab Test No. 04-12536

Film or Specimens Evaluated By: Joe Brown, QC Mgr Company: Harry's Rod Burners

Contractor/Fabricator's Supervisor: Harry Jones, Supt. Company: Harry's Rod Burners

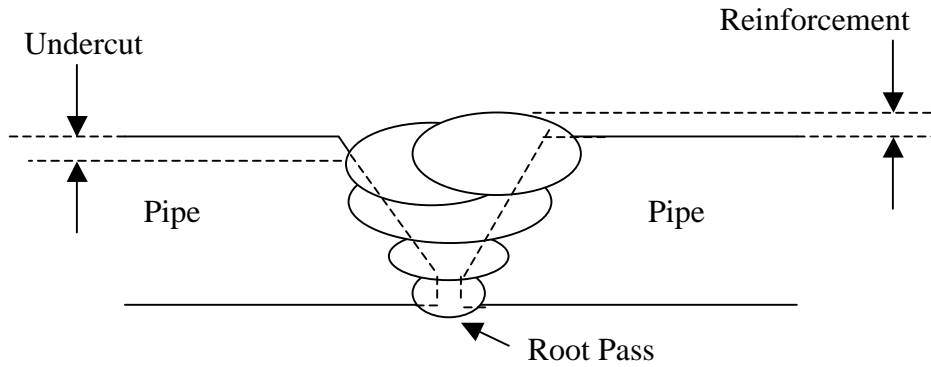
We hereby certify that the statements in this record are correct and that the test weld was prepared, welded and tested in accordance with the requirements of AWS B2.1 and Section IX of the ASME Code.

Harry's Rod Burners, Inc.

By: Harry Jones Date: 3-15-05

Figure 4

Undercut and reinforcement



Undercut occurs along the edge of a weld. It is the result of the arc melting into the pipe wall but the weld metal not filling the groove to flush. Undercut should not exceed 1/32 inches in depth and should not exceed 20% of the pipe circumference in length.

Reinforcement is the extra weld that the welder deposits that is above the surface of the pipe. Reinforcement should not exceed 1/8 inch.

Figure 5

Porosity, Slag and Arc strikes



Photo shows porosity in the weld metal in several locations along the length of the weld, slag on each side of the bead in the center of the weld and an arc strike on the base metal along the top of the weld. This photograph indicates poor workmanship.

Figure 6

Root Side Penetration



Photograph shows root side of a pipe joint exhibiting complete joint penetration over most of the weld length. A short length of incomplete penetration is evident at the arrow. Weld metal clearly visible on the root side of the pipe indicates full penetration.

Figure 7

Root Side Incomplete Penetration



Photo shows root side of a pipe weld exhibiting incomplete penetration except at the very ends of the photo. Note the lack of weld metal on the interior surface of the pipe as compared to Figure 6.

Figure 8

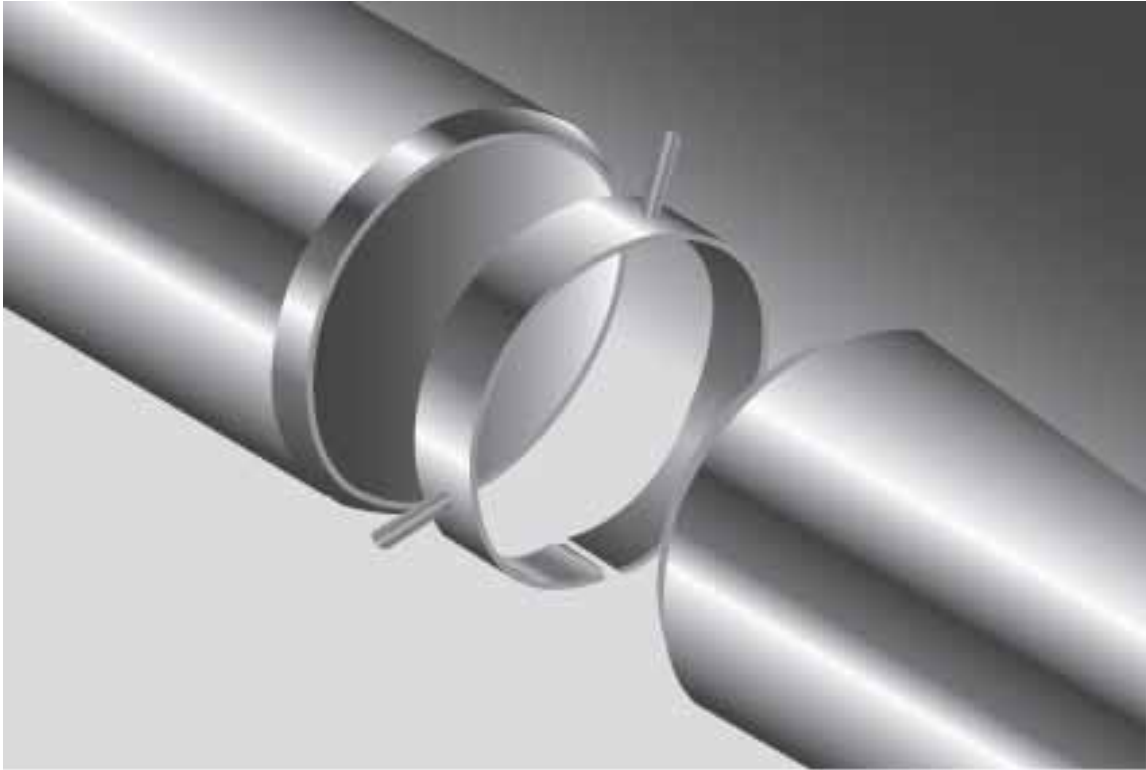
Acceptable Root Side Conditions



The photograph shows the root side of a pipe weld. Note that the weld metal on the right-center protrudes into the pipe somewhat. This is acceptable. Note the short length of wire protruding from the weld metal at the white arrow. An occasional short piece of wire protruding is acceptable. The spatter (small drops of metal on the pipe surface) are acceptable if they do not dislodge when jabbed with a screwdriver or similar hard object. The scale at the yellow arrow should be removed by power wire brushing since that is sufficient scale to clog a nozzle when it comes loose.

Figure 9A

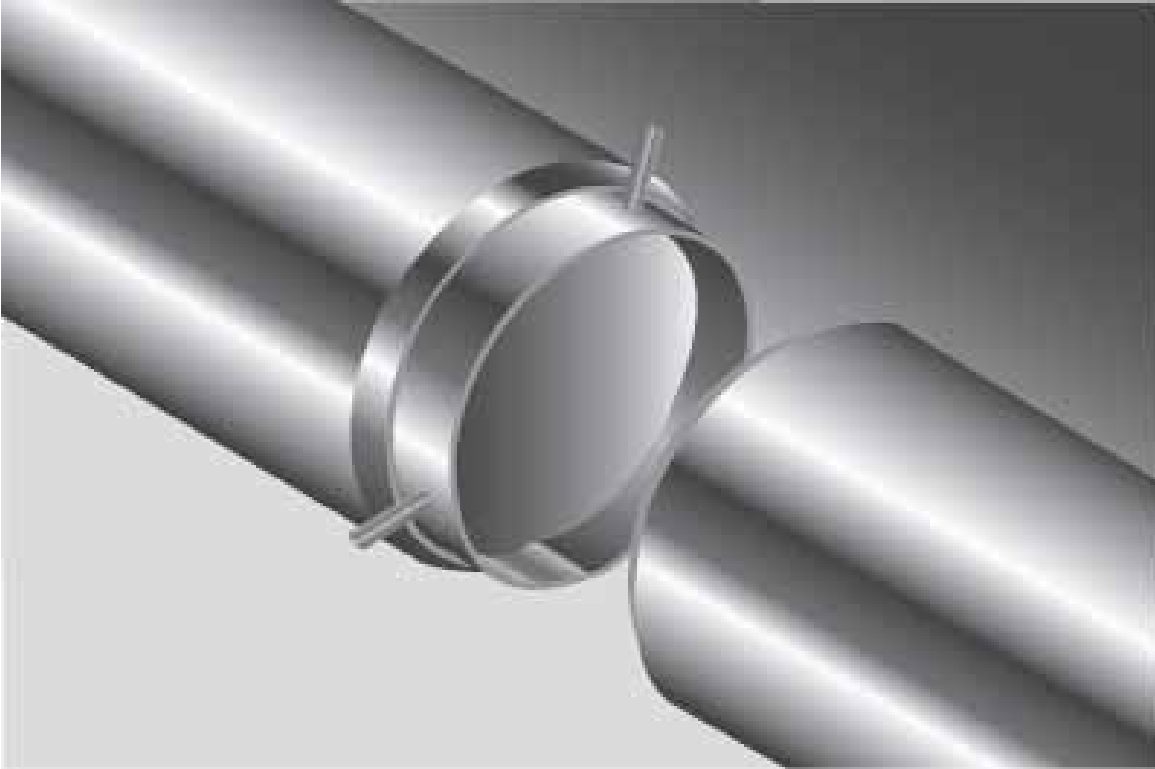
Pipe Butt Weld Made Using a Backing Ring



Pipe and backing ring shown prior to installation

Figure 9B

Pipe Butt Weld Made Using a Backing Ring



Pipe and backing ring shown with backing ring inserted into one member.

Figure 9C

Pipe Butt Weld Made Using a Backing Ring

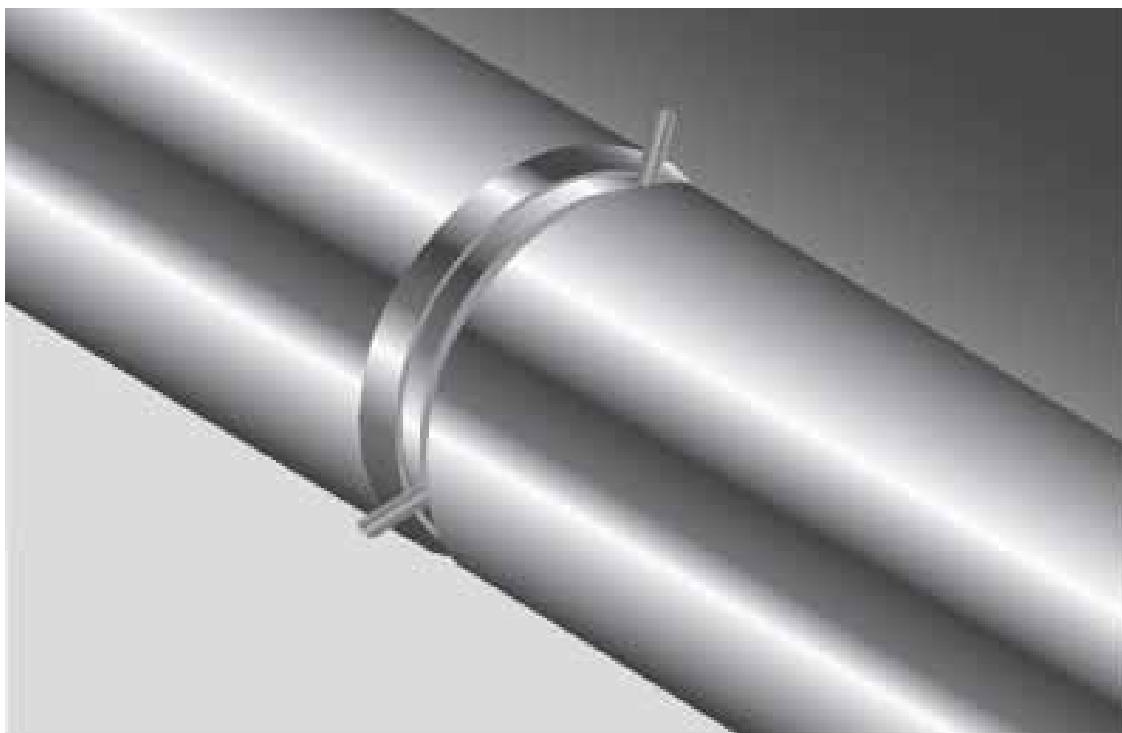


Figure shows the backing ring installed and ready to weld. A backing ring provides support for the weld pool, making welding easier to weld the joint than without one. The spacer pins ensure that there is at least 3/16 inches of root spacing, thereby ensuring a fully penetrated joint.

Figure 10

Recommended Joint Fit-up without a Backing Ring

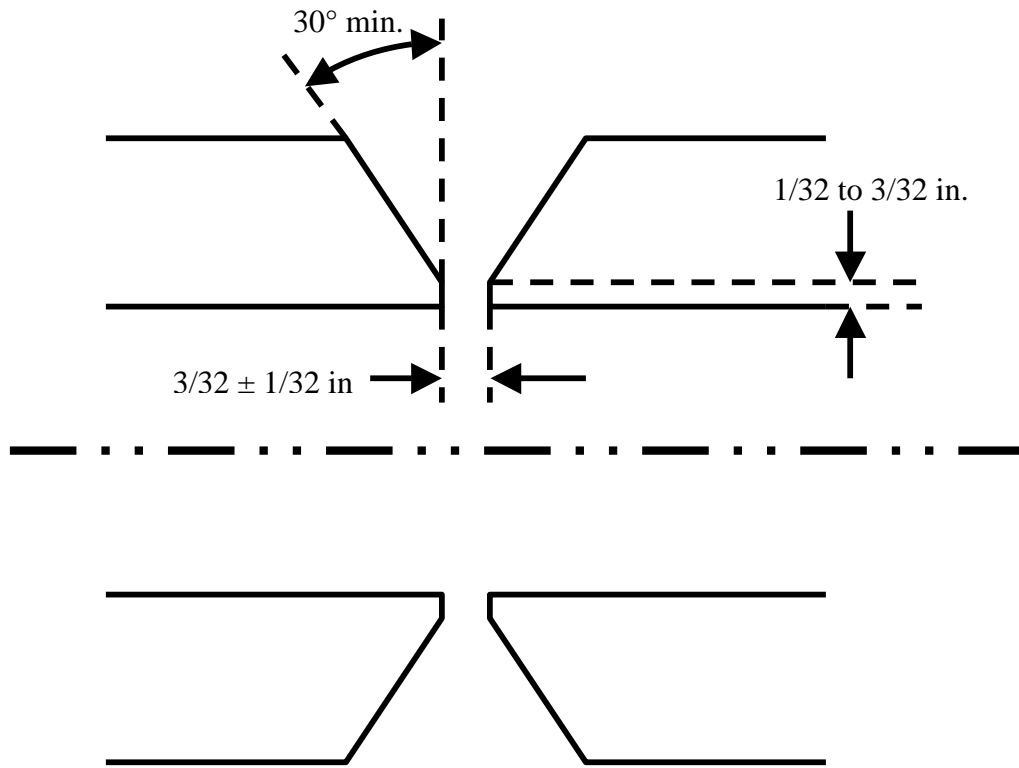


Figure 11

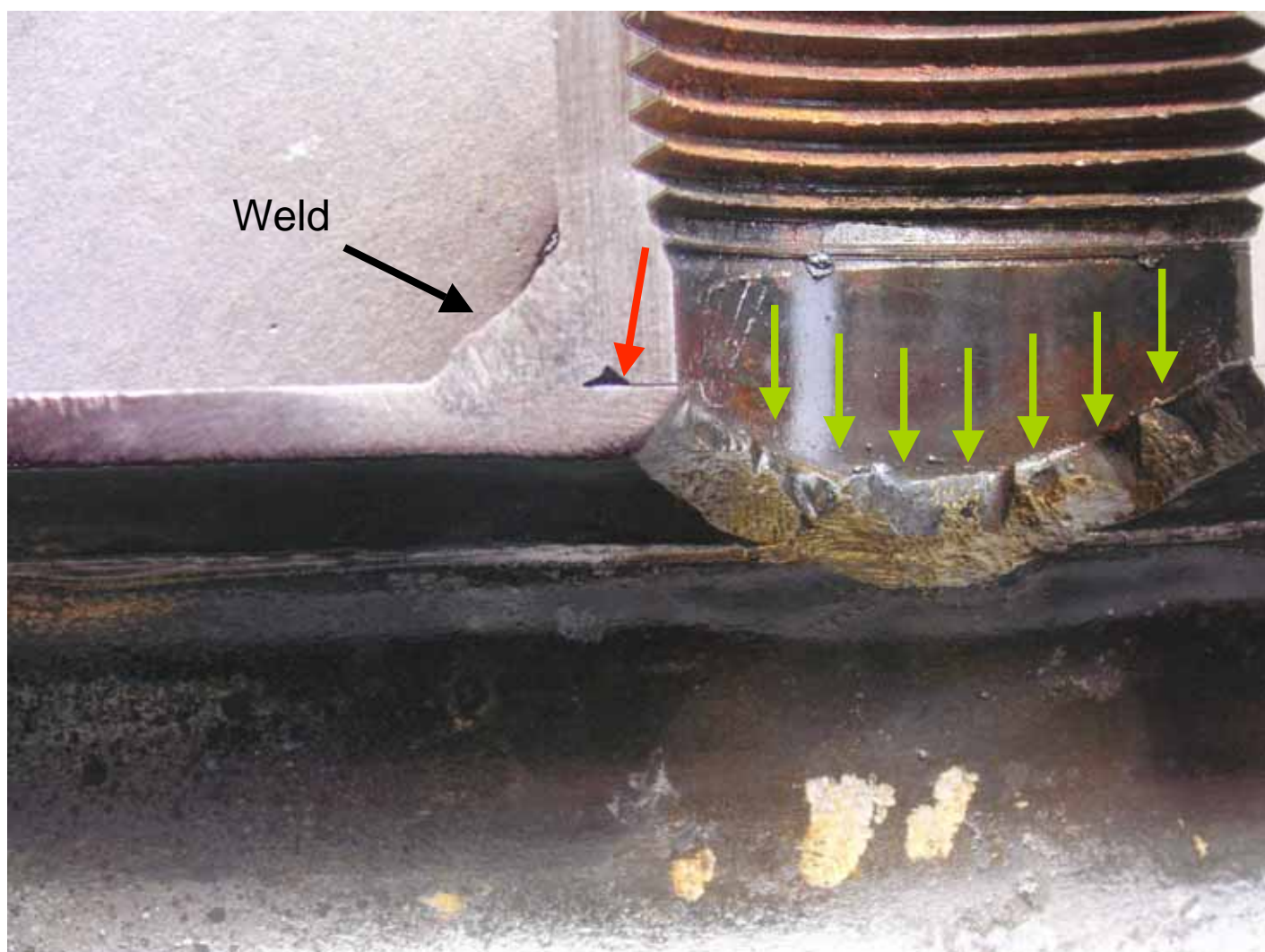
Typical Outlet Fitting



Photograph shows an outlet fitting welded to a header pipe. The weld size is measured at the top center of the header where the centerline of the fitting is located (see Red arrows). The dimension shown should be 1/4 inch or greater unless calculations show that a smaller size is acceptable. The rest of the weld should be the same width or larger as the weld at the measured location. Note the buildup of weld at the yellow arrow. This is an acceptable condition.

Figure 12

Outlet Connection Weld – Interior View



The header pipe and outlet fitting shown in Figure 11 has been split open down their longitudinal axes revealing the inside condition of parts and weld. The weld has been polished and etched to bring out its structure.. The lack of weld metal in the weld cross-section root area (red arrow) and on the inside surface of the joint at the interface between the fitting and the header pipe (green arrows) is an acceptable condition for an outlet nozzle.

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Table 1

Listing of common pipe sizes and schedules

Nominal Pipe size <u>NPS</u>	Outside Diameter <u>(in.)</u>	Schedule 10 <u>(in.)</u>	Schedule 40 <u>(in.)</u>	Schedule 7 <u>(in.)</u>
3/4	1.050	0.083	0.113	-
1	1.315	0.109	0.133	0.059
1-1/2	1.900	0.109	0.145	0.059
2	2.375	0.109	0.154	0.074
2-1/2	2.875	0.120	0.203	0.074
3	3.500	0.120	0.216	0.074
4	4.500	0.120	0.237	0.074
5	5.563	0.134	0.258	-
6	6.625	0.134	0.280	-
8	8.625	0.188	0.322	-
10	8.625	0.250	0.322	-
12	12.75	0.250	0.375	-
14	14.00	0.312	0.375	-

Alternate Figure 9A

Pipe Butt Weld Made Using a Backing Ring



Pipe and backing ring shown prior to installation

Alternate Figure 9B

Pipe Butt Weld Made Using a Backing Ring



Pipe and backing ring shown with backing ring inserted into one member. Note the split in the backing ring. This split allows the ring to be adjusted to fit the inside of the smaller of the members being joined.

Alternate Figure 9C

Pipe Butt Weld Made Using a Backing Ring



Figure shows the backing ring installed and ready to weld. A backing ring provides support for the weld pool, making welding easier to weld the joint than without one. The spacer pin ensures that there is at least 3/16 inches of root spacing, thereby ensuring a fully penetrated joint.