PDHonline Course S150 (2 PDH)

Structural Steel Welding

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Course Outline

This two-hour online course discusses the basic factors every engineer should know about structural steel welding. It is important to understand the potential problems and critical parameters that need to be taken into account in joining steels. This course will enable the designer to become familiar with the typical weld terminology, understand the metallurgical changes that occur during welding, and the precautions to take to avoid situations that can ultimately lead to failures. This course includes a multiple-choice quiz at the end.

Learning Objective

At the conclusion of this course, the student will:

- Become familiar with welding terms and symbols,
- Learn about the various arc welding processes,
- Understand the source of basic weld defects and remedies,
- Develop a basic understanding of code requirements and contents of a welding procedure.

Course Introduction

There are numerous welding processes including arc welding, electron beam welding, friction welding, laser welding, and resistance welding. This course will concentrate on arc welding which is the most common technique used to join structural steels. The factors behind weldability will be discussed and how to avoid common weld defects will be presented.

Course Content

Arc welding requires striking a low-voltage, high-current arc between an electrode and the workpiece (base metal). The intense heat generated with this arc melts the base metal and allows the joining of two components. The characteristic of the metal that is being welded and the joint type (i.e. groove, fillet, etc.) dictates the welding parameters and the procedure that needs to be followed to obtain a sound weld joint.

Typical Arc Welding Processes:

Shielded metal arc welding (SMAW): Shielded metal arc welding, which is also known as stick welding, is the most widely used process. The arc is struck between the metal to be welded and a flux coated consumable electrode. The fluxes are mostly made from mineral components and cover the hot weld deposit and protect it from the environment. The solidified glassy product, slag should be removed by chipping or with a wire brush.

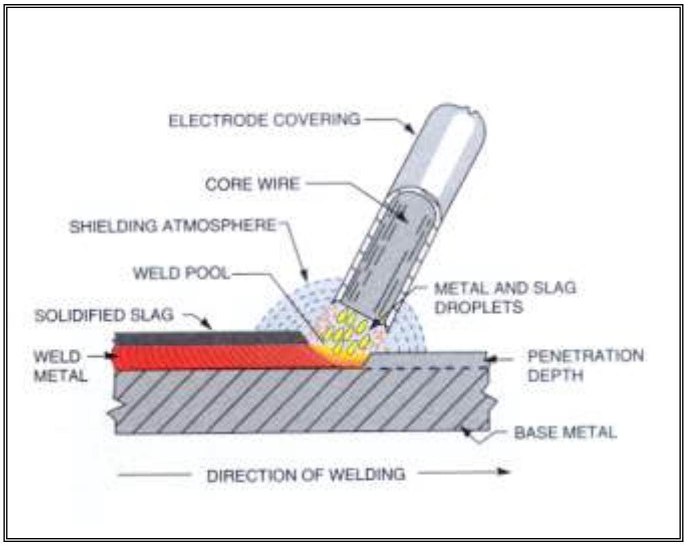

Figure 1. The SMAW Process

Gas metal arc welding (GMAW): This process is also referred to as metal inert-gas (MIG) welding uses an uncoated continuous wire. The weld area is shielded from contamination by the gas that is fed through the welding torch. The mode of metal transfer (spray, globular, short-circuiting, pulsed-arc) is varied by adjusting the amperage and the shielding gases used depending on the welding position and the type of joint. For example, the spray transfer mode requires a higher welding current and often a different shielding gas than the globular transfer mode. Most classifications of the GMAW electrodes are based on the chemical composition and the mechanical properties of the weld deposit.

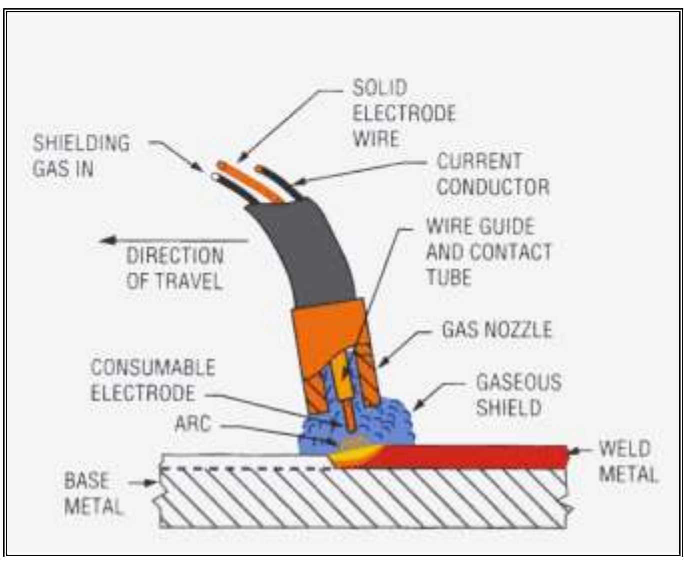

Figure 2. The GMAW Process

Flux-cored arc welding (FCAW): The electrodes for flux cored arc welding consist of a metal sheath surrounding a core of fluxing and/or alloying compounds. The shielding gases and slag are provided by the decomposing flux that is contained within the electrode. Auxiliary shielding is also used in certain instances where deeper penetration is needed.

Gas tungsten arc welding (GTAW): Also known as tungsten inert-gas (TIG), the process uses a non-consumable electrode. The shielding gas is again fed through the welding torch. Welding may be accomplished without the addition of filler metal, which is advantageous especially for thin walled parts.

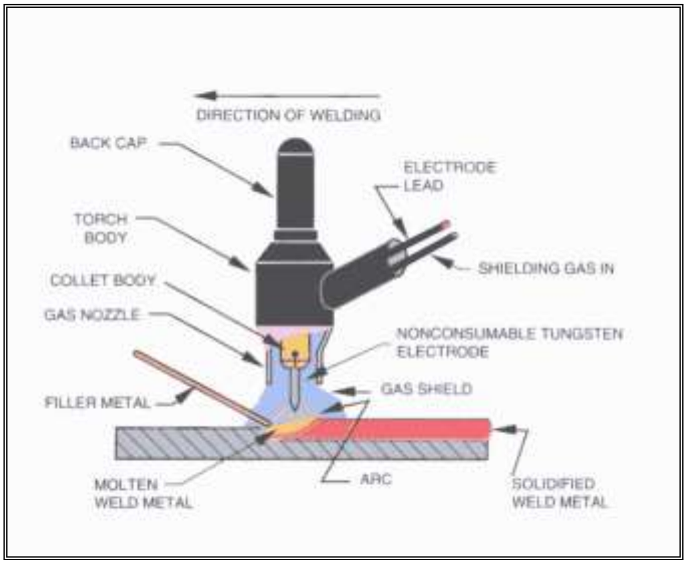

Figure 3. The GTAW Process

Shielding gases:

The primary purpose of the shielding gas is to protect the molten weld from contamination and high temperature oxidation by the surrounding atmosphere. Although plain inert gases may not be suitable for all applications, mixtures with reactive gases (i.e. oxygen, nitrogen, hydrogen and carbon dioxide) in controlled quantities will produce stable and relatively spatter-free metal transfer.

Argon: Argon by itself is frequently used for MIG welding of nonferrous metals. A mixture of argon and oxygen or argon and carbon dioxide is usually preferred for ferrous metals. The high-density arc that is created by argon permits the energy to go into the work piece as heat resulting in a narrow bead width with deep penetration.

Helium: has higher thermal conductivity and arc voltage than argon, which causes it to produce broader weld beads. Because helium is a very light gas, higher flow rates must be used for effective shielding. This characteristic is beneficial in overhead welding.

Carbon dioxide: is widely used for steels. Higher welding speed, better joint penetration and sound deposits with good mechanical properties can be achieved. Carbon dioxide is not an inert gas as the argon and helium and breaks down into carbon monoxide and free oxygen under the heat of the arc. The oxygen is used to superheat the weld metal transferring across the arc.

Arc welding defects:

Most welds contain defects (porosity, cracks, slag inclusions, etc.). The question is to determine if they are significant considering the application. Typically, the applicable codes or standards specify the maximum allowable limits of these types of defects in a weld based on the application. Sometimes discontinuities that may not affect mechanical properties may reduce corrosion performance. The properties of the heat-affected zone (HAZ) are one of the significant factors to consider when evaluating the soundness of the weld joint. The HAZ may be considered as a discontinuity because of the metallurgical alterations as a result of the welding heat, which causes very rapid heating and cooling rates. Grain growth, phase transformations (i.e. brittle untempered martensite which can form depending on the cooling rate and the chemical composition of the base material), formation of precipitates or overaging (loss of strength in precipitation-hardened alloys) all has a drastic effect on the properties of the HAZ. It is possible to improve the weld zone properties by controlling the cooling rate. This may be accomplished by slowing the cooling rate down either by increasing the heat input or preheating (i.e. heating the metal up before welding).

Porosity: Gas pockets are formed in the weld metal when they are entrapped during solidification. Molten steel readily absorbs hydrogen, carbon monoxide and other gases to which it is exposed. Since these are not soluble in solid metal, they are expelled as the metal solidifies. Standard shielded arc electrodes with organic coating such as E6010 produce an atmosphere around the arc that contains hydrogen, a notable contributor to porosity. When using such electrodes, welding should be done slowly to allow the gases time to escape since too high of a travel speed causes rapid solidification of the weld metal leading to porosity. Weld joint cleanliness is also crucial in avoiding porosity since moisture, oil, paint, or rust on the base metal may also cause porosity by introducing oxygen or hydrogen into the weld metal. Employing some minimum preheat temperature is often useful to remove condensation. It is also necessary to maintain the fluxes and the coated electrodes dry to avoid moisture pick-up. They are typically kept in an oven at approximately 250ºF, or if the hermetic seal is broken on the containers then the consumables (e.g. welding rods) should be baked at higher temperatures to drive off the moisture and restore the low hydrogen characteristics. Common causes and remedies of porosity are listed below along with a macrograph of a fillet weld containing porosity (Figure 4). An illustration of a groove weld which exhibits cluster porosity is also included with its corresponding radiograph (Figure 5).

Porosity: gas pockets or voids that are found in welds	
Causes	**Remedies**
Excessive hydrogen, nitrogen or oxygen in welding atmosphere	Use low hydrogen welding process, filler metals high in deoxidizers, increase shielding gas flow
High solidification rate	Use preheat or increase heat input
Dirty base metal	Clean joint faces and adjacent surfaces
Dirty filler wire	Use clean wire and store fillers in a clean area
Improper arc length, welding current or electrode manipulation	Modify welding parameters and techniques
Volatilization of zinc from brass	Use copper-silicon filler, reduce heat input
Galvanized Steel	Use E7010 electrode and manipulate the arc heat to volatilize the galvanizing (zinc) ahead of the molten weld pool
Excessive moisture in electrode covering or on joint surfaces	Use recommended procedures for baking and storing electrodes
High sulfur base metal	Use electrodes with basic slagging reactions

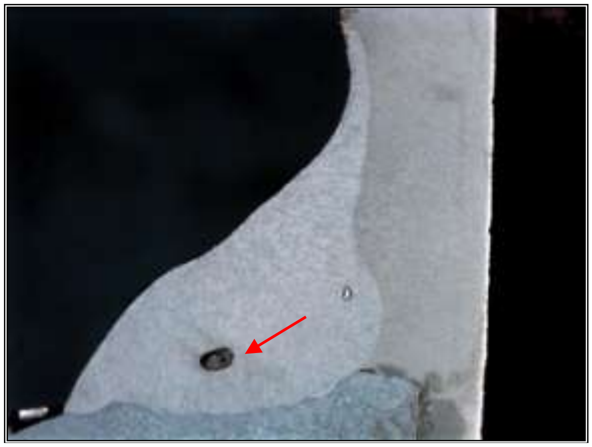

Figure 4. Fillet weld section showing porosity

Figure 5. Cluster porosity observed by radiography

Slag inclusions: This term is used to describe the oxides or other nonmetallic inclusions that become entrapped in the weld metal. They may be caused by contamination or inadequate cleaning between weld passes. The slag derived from fluxes employed during welding needs to be cleaned between weld passes (in multi-pass operations) using a chipping hammer or a wire brush. Slag inclusions are generally linear and may occur either as short particles or as long bands. In Figure 6 below the macrograph on the left illustrates a weld with slag inclusions and the one on the right shows a successfully deposited multi-pass weld joint.

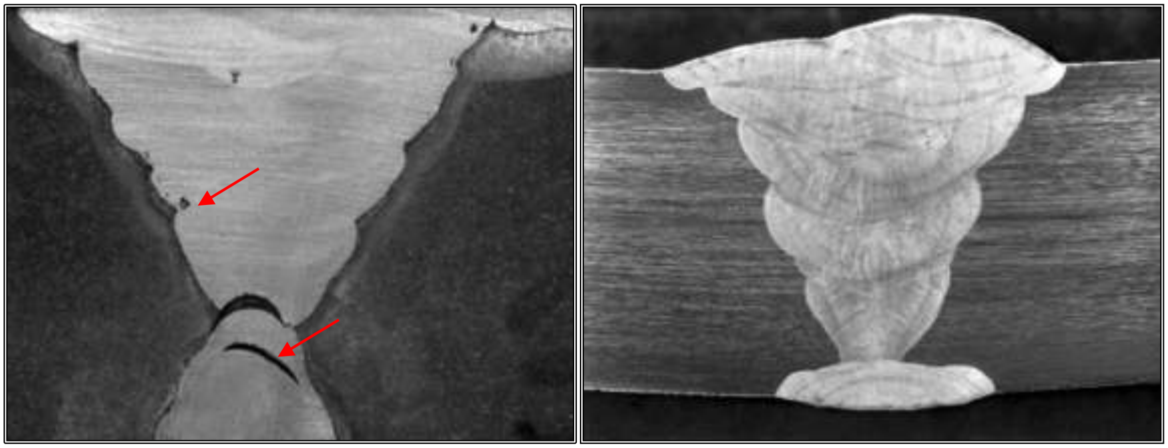

Figure 6. Multi-pass groove welds

Tungsten inclusions: In the TIG process, the touching of the electrode to the weld metal may cause transfer of the tungsten particles into the weld metal. These inclusions are detected by x-ray and show up as bright particles since they are much denser than the steel. An example is shown below (Figure 7) where the x-ray revealed the tungsten inclusions.

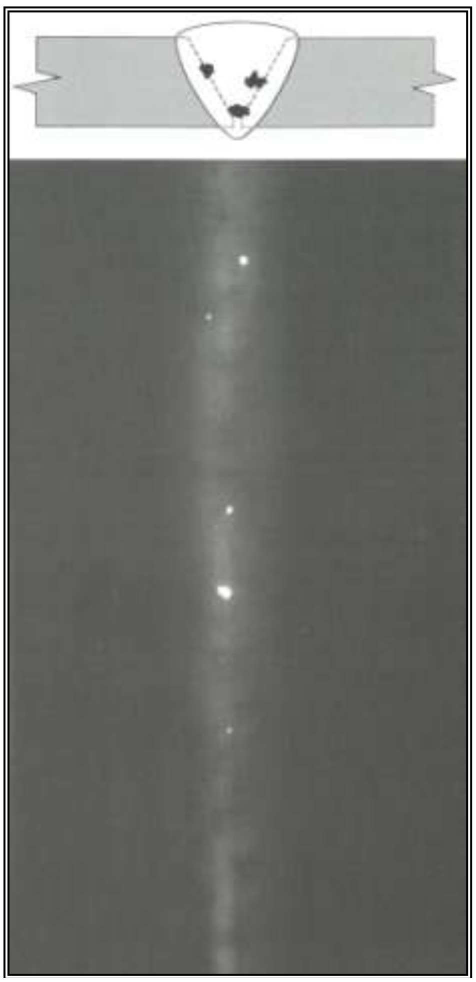

Figure 7. Tungsten inclusions

Incomplete fusion/penetration: Although these terms are sometimes used interchangeably, lack of fusion occurs when the weld and base metal fail to adequately fuse together. It can also be encountered between weld passes. It may be caused by not raising the temperature of the base metal or previously applied weld metal to the melting point or failure to remove the slag or mill scale. Incomplete fusion is usually elongated in the direction of welding and may have either rounded or sharp edges. Inadequate/lack of penetration is typically due to inadequate heat input for the particular joint that is being welded and is usually seen at the sidewalls of a weld joint, between weld passes or at the root of the weld joint. The shielding gas can also influence the penetration (depth of fusion); typically, helium is added for nonferrous metals and carbon dioxide is added for ferrous metals (to argon) to increase penetration. The first macrograph below shows an acceptable single pass fillet weld profile with adequate base metal penetration and root fusion (Figure 8). The second macrograph (Figure 9) shows lack of penetration to the root in a double welded joint, and the third macrograph illustrates lack of penetration to one of the members (Figure 10). The final illustration in Figure 11 shows the sketch of another variation of incomplete root penetration and its appearance on an x-ray film (radiograph). Unsuitable groove design may also result in inadequate joint penetration as shown in Figure 12.

Figure 8. Acceptable fillet weld

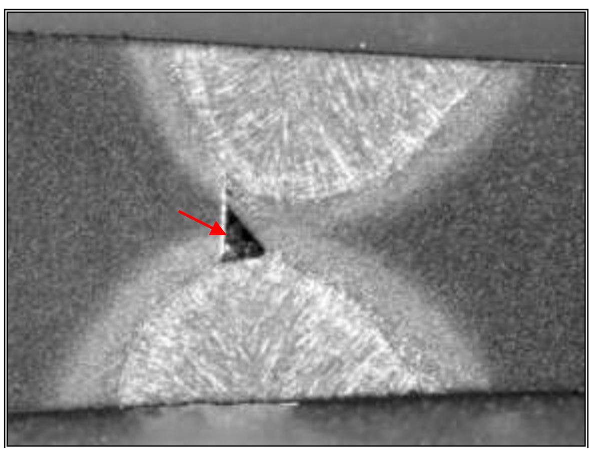

Figure 9. Lack of penetration

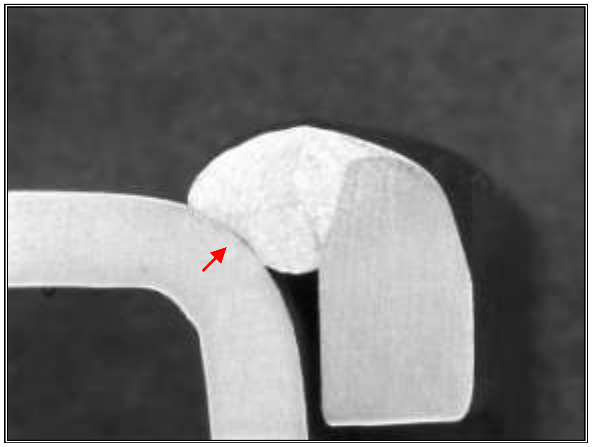

Figure 10. Lack of penetration

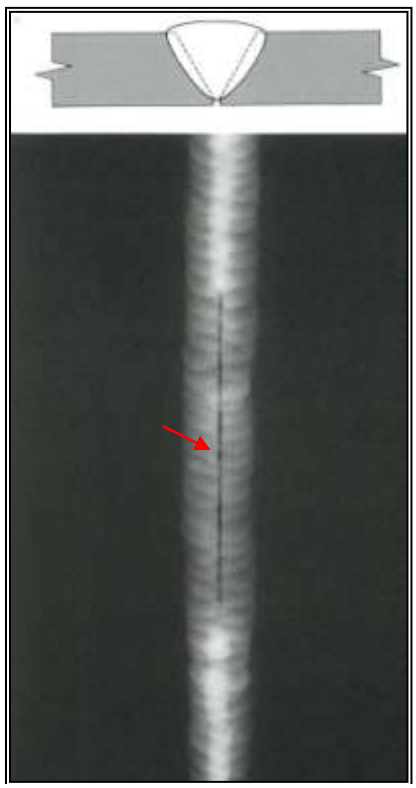

Figure 11. Incomplete root penetration detected on a radiograph

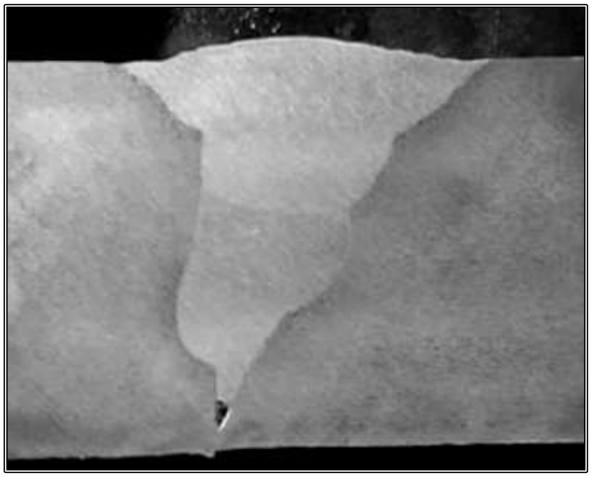

Figure 12. Incomplete root penetration due to insufficient bevel angle and lack of root opening

Undercut: This occurs when a groove that is formed adjacent to the weld as a result of the melting of the base metal remains unfilled. This groove or sharp recess may vary in depth, width and sharpness at its root. An example is shown in the macrograph below (at the toe of the fillet weld) along with the appearance of this type of defect on a radiograph of a groove weld (Figures 13 and 14).

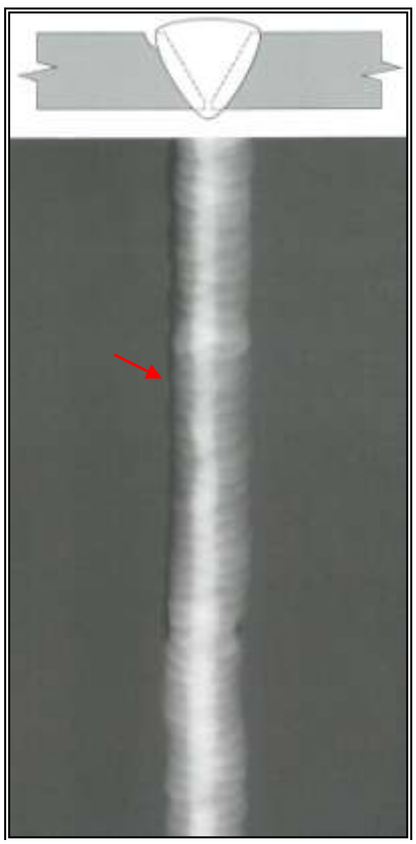

Figure 13. X-ray image of undercut in a groove weld

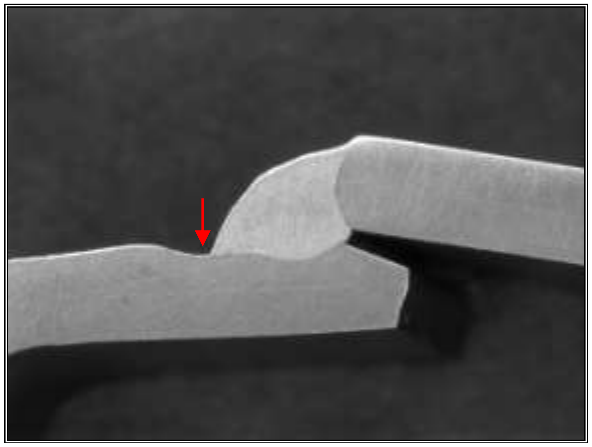

Figure 14. Undercut on a fillet weld

Weld profile: The profile of a finished weld may have a considerable effect on the performance under dynamic loading conditions. Overlap, is usually associated with fillet welding but also can occur at the edge of groove welds. The term describes a protrusion of weld metal beyond the bond at the toe of a weld. Incorrect welding techniques or currents can cause overlap. This condition tends to produce notches that are harmful due to the stress concentration effect (Figure 15). Excessive reinforcement or mismatch can also provide stress concentration points where fatigue cracks can initiate. Typical unacceptable butt and fillet weld profiles are shown below (Figure 16) along with an example of poor fit-up (misalignment) of a butt weld in Figure 17. The proper way of repairing a groove weld by grinding the excessive reinforcement is illustrated in Figure 18.

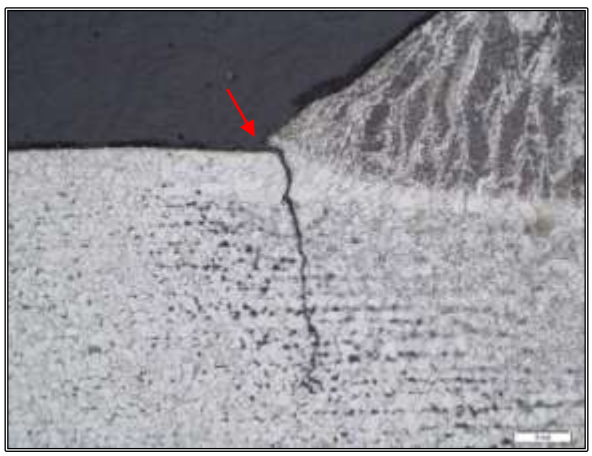

Figure 15. Fatigue crack which initiated at the toe of a weld with overlap

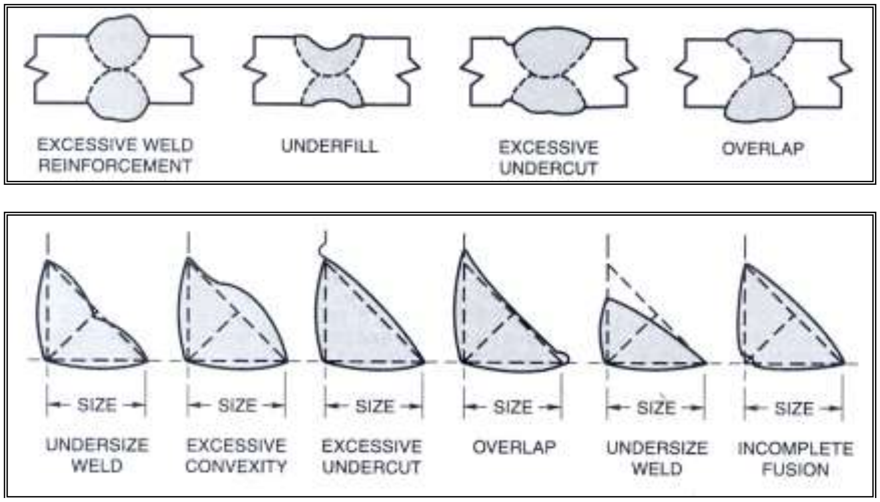

Figure 16. Unacceptable Weld Profiles

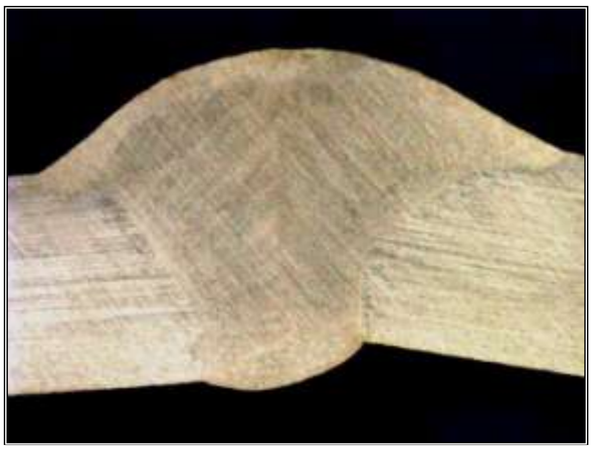

Figure 17. Macrograph showing poor fit-up (butt weld)

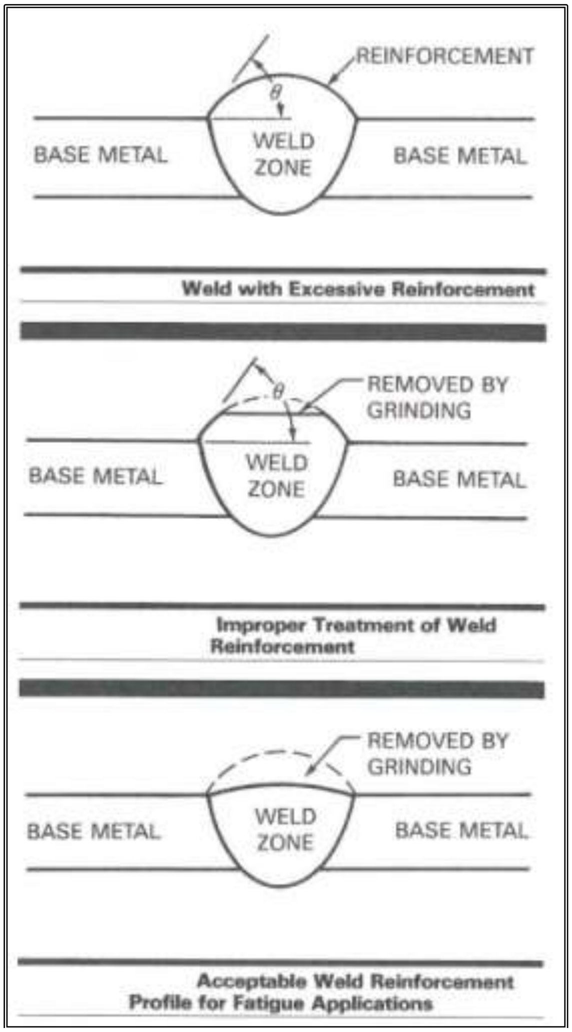

Figure 18. Removal of excess reinforcement

Arc strikes: They are caused by the unintentional melting of the base metal outside the weld deposit area by the welding arc. They can also be produced beneath an improperly secured ground connection. The result is a small remelted area that can lead to localized hard or soft spots, cracking or undercut. Another welder-induced defect is weld spatter. They are small metal particles expelled during welding that do not form a part of the weld. It usually occurs when excessive welding current, long arc or welding voltage is used. Below photographs show arc strikes (Figure 19) and weld spatter (Figure 20) near fillet welds.

Figure 19. Arc Strikes

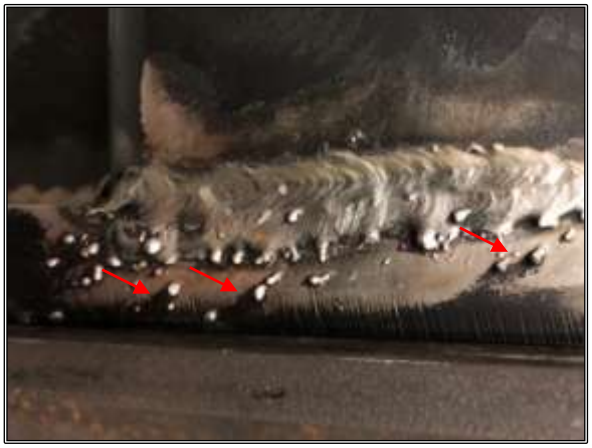

Figure 20. Weld Spatter

Cracks: Cracks are the most serious type of weld defects that can lead to catastrophic failures in service. There are many different types of cracks. One way of categorizing them is as surface or subsurface cracks. Another way would be as hot (which occur during or immediately after the weld is made) or cold (cracks that occur after the weld has cooled to room temperature-sometimes within hours or days). In general, weld or heat- affected zone cracks indicate that the weld or the base metal has low ductility and that there is high joint restraint. Many factors can contribute to this condition such as rapid cooling, high alloy composition, insufficient heat input, poor joint preparation, incorrect electrode type, insufficient weld size or lack of preheat. Some common causes and remedies are given in table below.

Cracks: Hot and cold cracks can form in the weld, HAZ or the base metal	
Causes	**Remedies**
Highly rigid joint	Preheat Relieve residual stresses mechanically Minimize shrinkage stresses using backstep sequence (a longitudinal sequence in which weld passes are made in the direction opposite to the progress of welding)
Excessive dilution (change in chemical composition of a weld deposit caused by the admixture of the base metal)	Change welding current and travel speed Weld with covered electrode negative; butter the joint faces prior to welding (buttering is depositing surfacing metal to provide metallurgically compatible weld metal to the subsequent weld passes)
Poor fit-up	Reduce root opening
Small weld bead	Increase electrode size, raise welding current, reduce travel speed
High sulfur base metal	Use filler metal low in sulfur
Excessive distortion	Change to balanced welding on both sides of joint
Crater cracking (shrinkage cracks which result from sudden stopping of the arc), see Figure 20	Fill crater before extinguishing the arc

High residual stresses	Preheat, redesign weldment, change welding sequence, apply intermediate stress relief
High hardenability	Preheat, increase heat input, heat treat without cooling to room temperature

Figure 20. Photographs illustrating crater cracking resulting from abrupt weld termination in an aluminum weld on left, steel on right (MIG process). These cracks occur due to shrinkage stresses that develop as a result of rapid cooling of the crater compared to the remainder of the weld bead.

Preheat:

Preheating involves heating the material to be welded either locally or in its entirety, to a specified temperature (preheat temperature), before starting the welding operation. Preheat may also be continued during the welding process in multi-pass weld joints but usually the heat from the welding is sufficient to maintain the desired temperature level. In multi-pass welds the interpass temperature should not be allowed to fall below the preheat temperature. The main reasons for preheat are: 1) to lower the cooling rate in the weld and base metal and avoid formation of hard and brittle phases in the heat affected zone, 2) to allow time for any hydrogen present to diffuse out without causing any cracking by slowing the cooling rate, and 3) to reduce the shrinkage stresses that develop in the joint. Not following these guidelines may result in underbead cracking as shown in Figure 21.

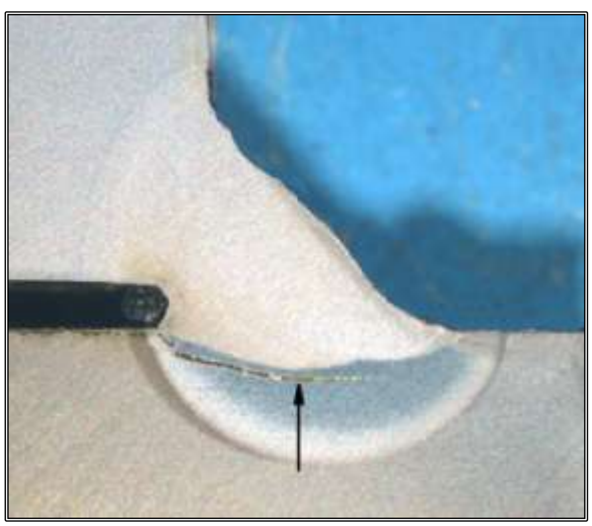

Figure 21. Underbead crack in the HAZ

Underbead cracks are generally cold cracks that form in the HAZ. They may be short and discontinuous, but may also extend to form a continuous crack. When present, they are usually found at regular intervals under the weld metal, and do not necessarily extend to the surface. They cannot be detected by visual inspection, and may also be difficult to detect by nondestructive examination techniques.

Preheat may be applied in various ways depending on the size of the part to be welded. Small assemblies may be heated in a furnace whereas large structures often require heating torches, electrical heating blankets or induction or radiant heaters. Although a high-level accuracy is not generally required for preheating carbon steels and it is acceptable to exceed the minimum preheat temperatures by approximately 100°F, quenched and tempered steels demand better controls as overheating may affect their mechanical properties.

When heating the joint to be welded, AWS Structural Steel Welding Code (D1.1) requires that the minimum preheat temperature be established at a distance that is at least equal to the thickness of the thickest member, but not less than 3 inches in all directions from the point of welding. To ensure that the entire weld joint is heated, it is recommended that the surface temperature adjacent to the joint be measured prior to striking the arc.

The following factors should be considered in determining whether preheat should be employed; welding code requirements (i.e. AWS, ASME, API, etc.), material thickness, chemical composition of the base materials to be welded, joint restraint, ambient temperature, filler metal hydrogen content. If a certain welding code must be followed then it typically will specify the minimum preheat temperature for a given material, welding process and section thickness. If there is not a code governing the welding, then one has to determine whether it is required. Typically, low carbon steels, such as A36 structural steel, do not require preheat when welding less than 1-inch thick sections. The most critical factor in determining preheat need is discussed in the following section.

The effect of carbon equivalent:

Generally, the higher the carbon content of a steel, the lower the critical cooling rate and the greater the necessity for preheating and using low hydrogen electrodes. Carbon, however, is not the only element that influences the critical cooling rate. Other elements in the steel are also responsible for the hardening and loss of ductility that occur with rapid cooling. The carbon equivalent (C.E.) may be one of the most significant factors to be considered when determining preheat need and estimating the preheat temperature. The higher the carbon equivalent of a steel, the greater the tendency to form a hard and brittle heat affected zone (HAZ). One of the various empirical formulas used to determine carbon equivalent that represents the sum of the effects of various elements on hardenability is given in the Structural Steel Welding Code (AWS D1.1) as follows:

$$\%C.E. = \%C + \%\,(Mn+Si)/6 + \%\,(Cr+Mo+V)/5 + \%\,(Ni+Cu)/15$$

The approximate recommended preheat temperatures based on C.E. are:

For up to 0.45%…………preheat is optional

0.45-0.60%………………200-400ºF

Over 0.60%……………....400-700ºF

Usually a steel that requires preheating must also be kept at this temperature between weld passes. The heat input of the welding process is adequate to maintain the required interpass temperature on most weldments. On massive components this may not be the case and torch heating between passes may be required. Since the purpose of preheating is to reduce the quench rate, the same slow cooling rate must be accomplished for all passes.

Besides the widely used carbon equivalent criteria, the following factors should also be considered when determining the need for preheat/post weld heat treat: code requirements, section thickness, restraint, ambient temperature, filler metal hydrogen content and previous cracking problems.

Stress Relief (Post Weld Heat Treatment-PWHT):

Stress relieving is defined as heating to a suitable temperature (for steel, below the critical transformation temperature), holding long enough at that temperature, and then cooling slowly. PWHT is done to accomplish the following: 1) Reduce residual stresses, 2) Improve the microstructure and fracture toughness of the HAZ, and 3) Remove hydrogen from the welded zone and therefore prevent cracking. Heating and cooling should be done slowly and uniformly to avoid additional stresses to develop in the welded component. In general, the greater the difference between the maximum and minimum thickness of the component parts, the slower should be the rate of temperature change. The rates are typically specified in the applicable codes and may be defined as 400°F/hour max. Temperatures may be monitored by thermocouples mounted on the part during the heat treatment. The stress relief range for most carbon steels is 1100-1200°F, and the soak time is usually one hour per inch of thickness. Temperature range is higher for alloyed steels. PWHT may have detrimental effects on low alloy steels since they are susceptible to loss of fracture toughness (temper embrittlement) when heated through certain ranges of temperatures.

AWS Classifications of Filler Metals:

The American Welding Society numbering system tells a lot about the properties and usability of the electrode. Using the stick electrode numbering system as a representative example:

The prefix “E” designates an arc-welding electrode. The first two digits of a four-digit number and the first three digits of a five-digit number indicate tensile strength. For example, E7018 is a 70,000-psi tensile strength electrode while E10018 designates a 100,000-psi one.

The next to last digit indicates the position. 1 is for all position, 2 is for flat and horizontal and 3 is for flat, horizontal, vertical down and overhead. The last two digits together indicate the type of electrode coating and the correct polarity to use. An example would be “18” for iron powder, low hydrogen with AC or DC+.

E6010: May be used for DC current only is designed for putting the root bead since it develops the most penetrating arc of all. It is an all position electrode.

E6011: It is used for all-position AC welding. Its deep and penetrating arc even allows welding on rusty & dirty metal.

E6013: All-position, AC electrode used for welding clean sheet metal. It has as oft arc with minimal spatter, moderate penetration and develops an easy-to-clean slag.

E7018: A low hydrogen, usually DC, all-position electrode typically used when quality is an issue or for hard to weld metals. It is capable of producing more uniform weld metal with better low temperature impact properties.

Weld Symbols:

When welds are specified on fabrication drawings a set of symbols are used to describe the type and size of the weld. They can typically be described as a simplified cross section of the actual weld. Some representative symbols are given in Figures 23-26 below. A complete set of symbols is included in a standard published by the American Welding Society.

The foundation for constructing a welding symbol is the reference line. The reference line is always shown in the horizontal position, and it should be drawn near the weld joint that it is to identify. The other important elements are the arrow and the symbol which indicates the desired type of weld. All welding information should be shown in accordance with the details illustrated in Figure 22.

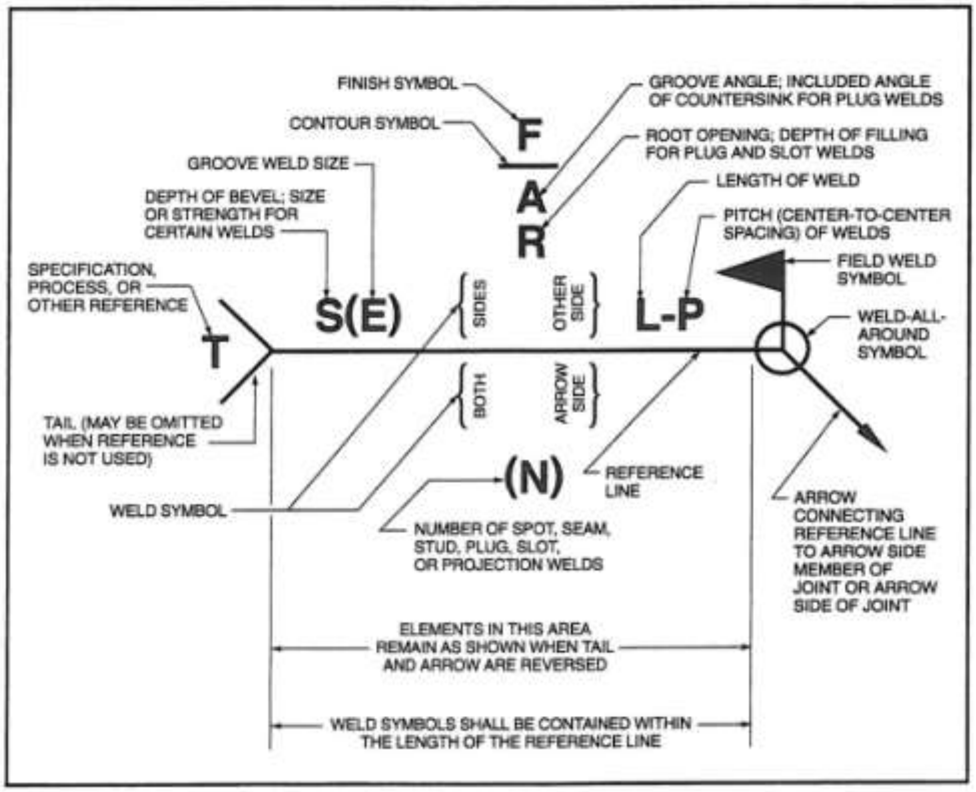

Figure 22. Standard Location of Elements of a Welding Symbol

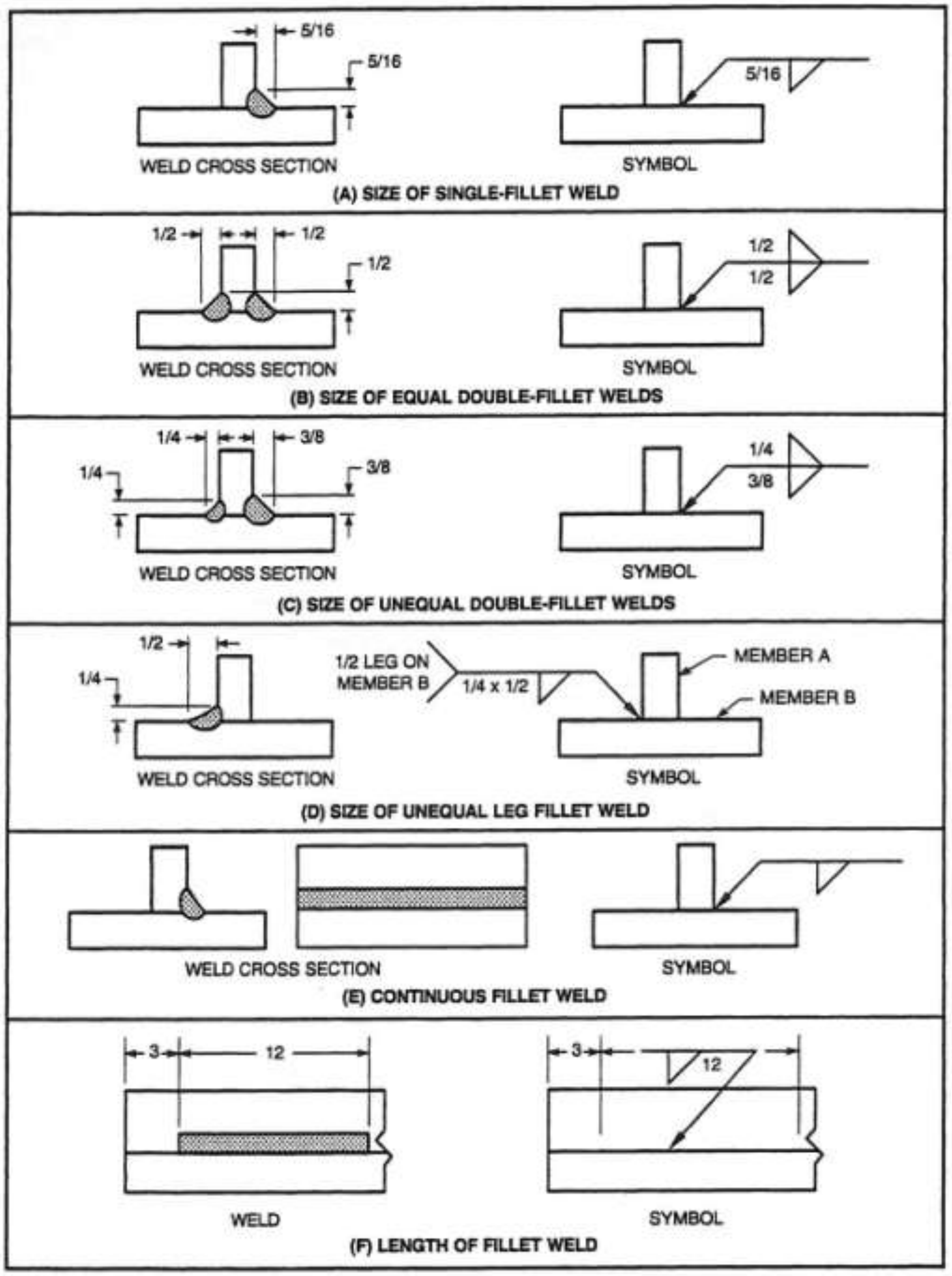

Figure 23. Specification of Size and Length of Fillet Welds

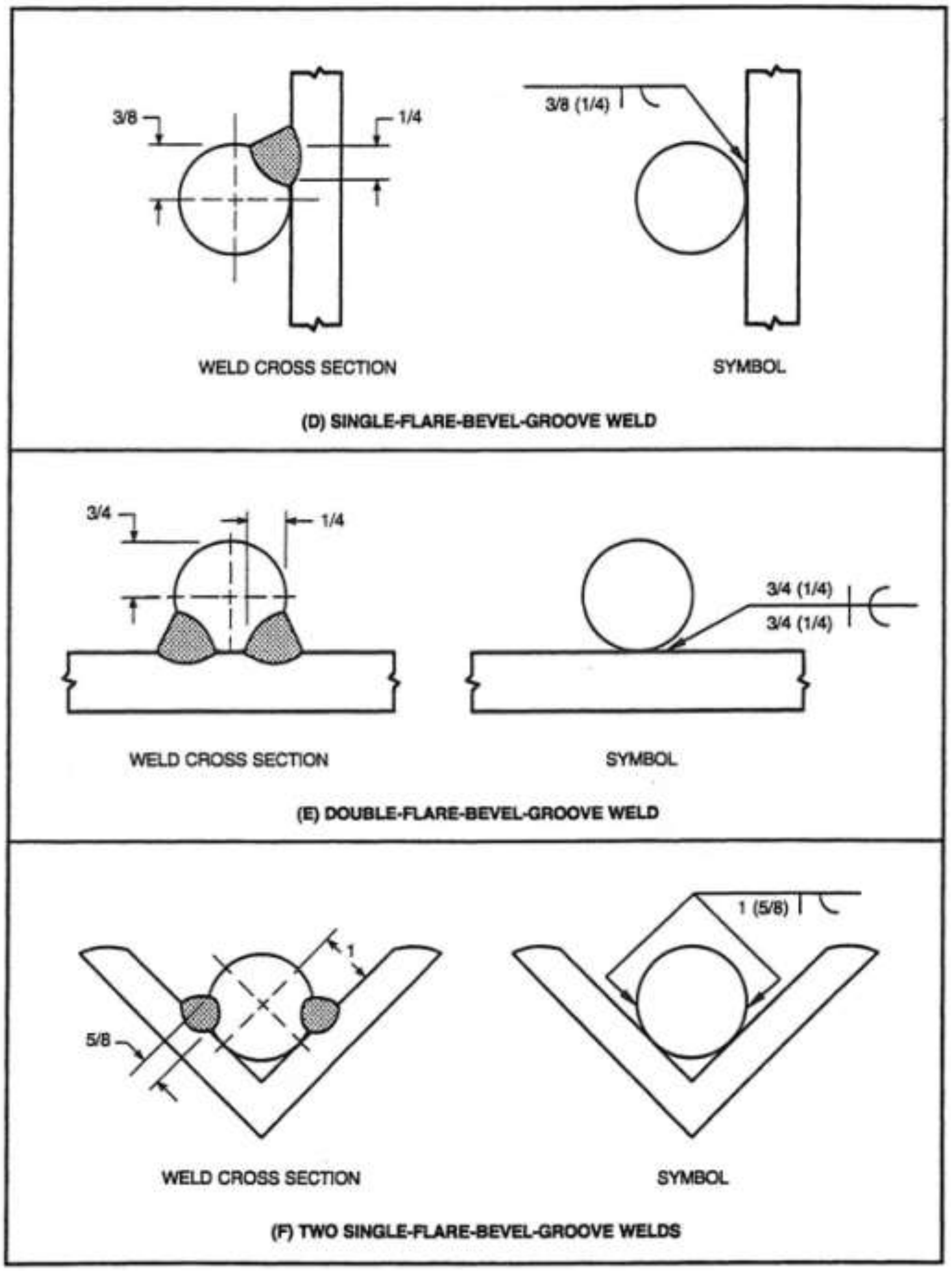

Figure 24. Applications of Flare-Bevel and Flare-V-Groove Weld Symbol-1

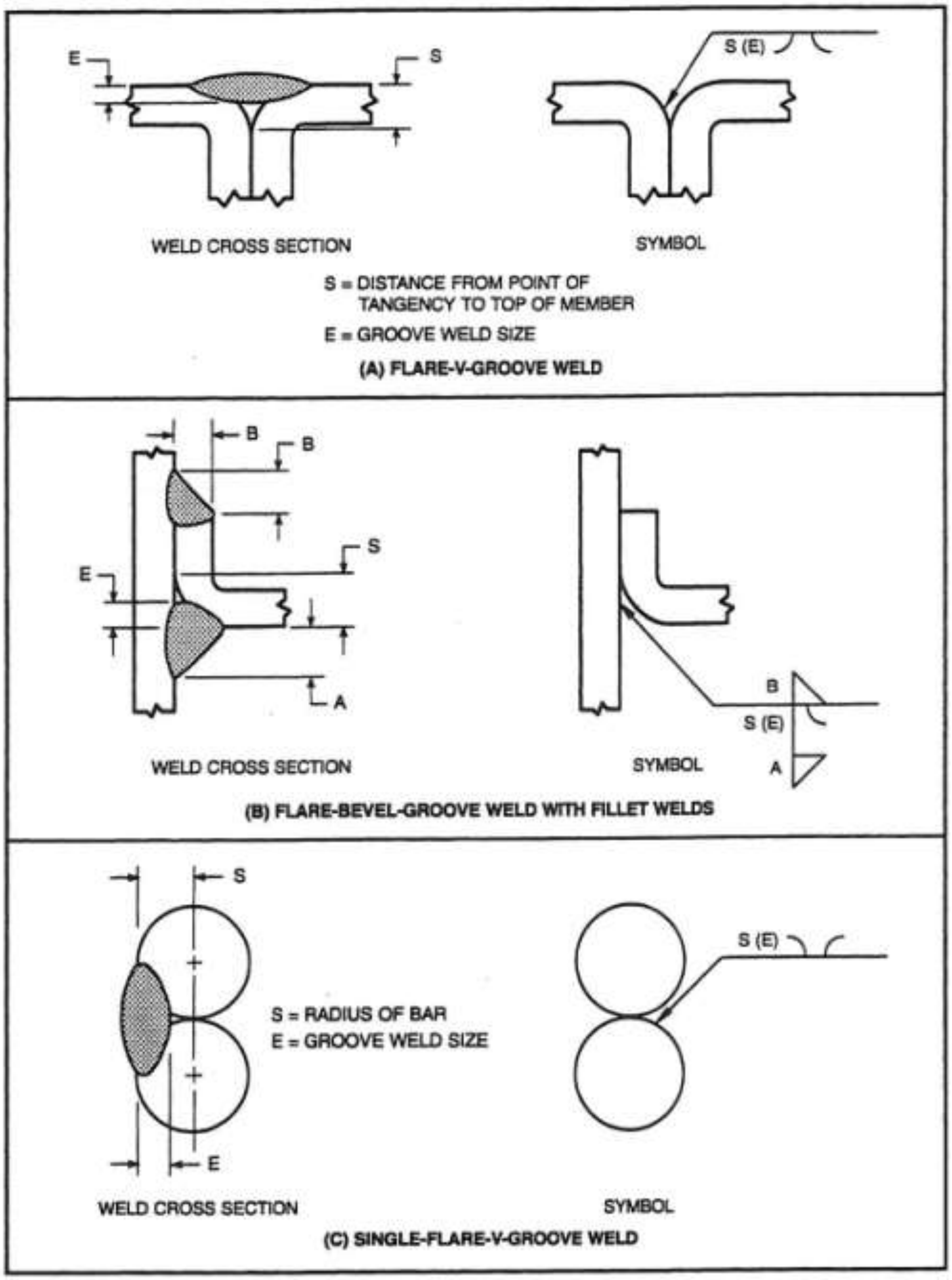

Figure 25. Applications of Flare-Bevel and Flare-V-Groove Weld Symbol-2

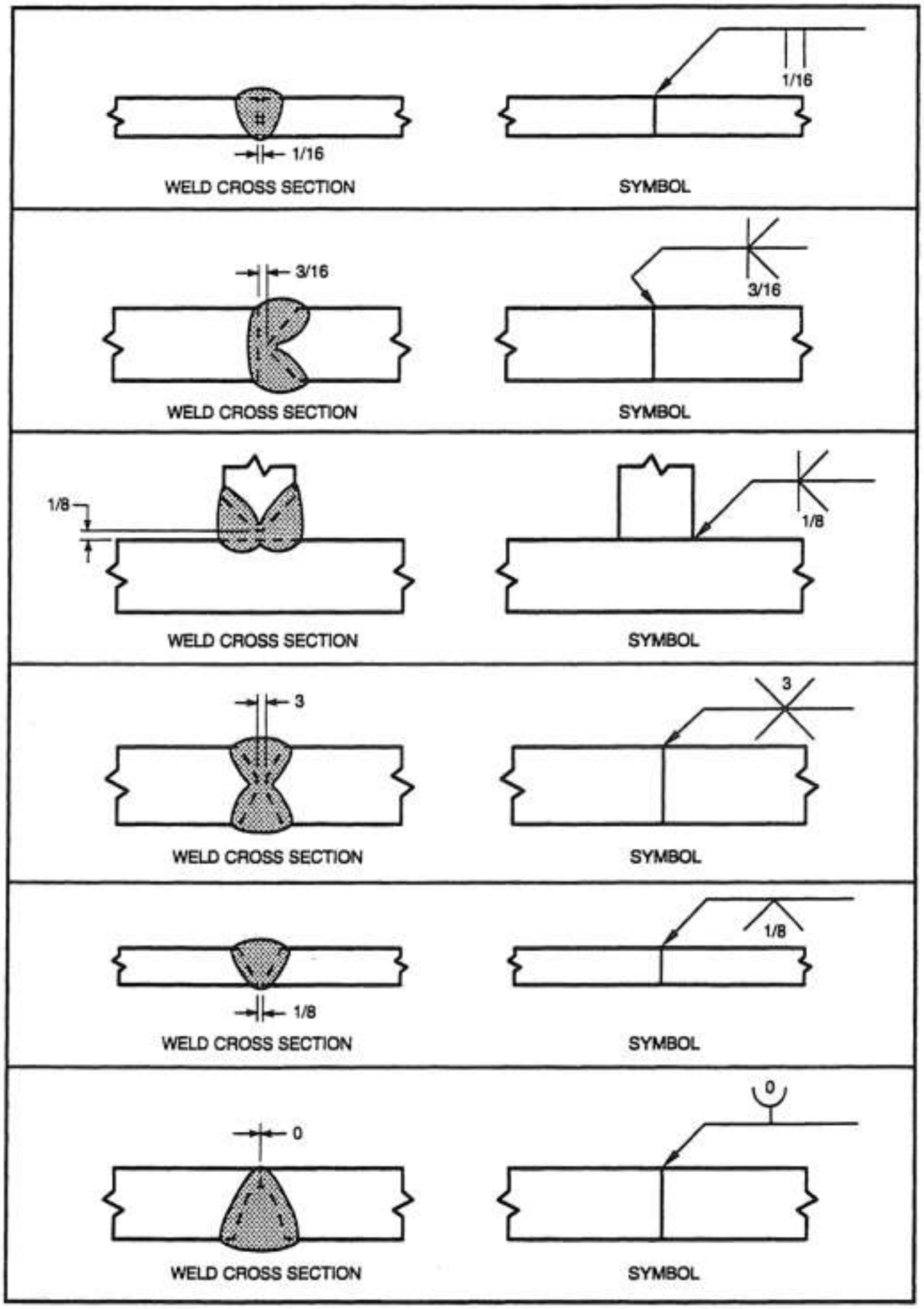

Figure 26. Various Types of Groove Welds with Corresponding Symbols

Weld Qualifications:

Most fabrication documents require qualification of welding procedures and welders. AWS Code D1.1 is the governing document for structural steel welding. A welding procedure specification (WPS) is a formal written instruction that provides the welder with the directions necessary to deposit welds in a consistent manner that meets the project specifications. It includes detail welding conditions for a specific application containing the essential variables that require requalification of procedures when the variables are changed beyond specified limits. Typical weld procedures should, at a minimum, contain information about the base materials that are to be welded, the welding process, the filler metal designation, type of current and range, arc voltage and travel speed, joint design and tolerances, surface preparation, positions of welding, preheat and interpass temperatures, interpass cleaning and post weld heat treat as needed. Each welding document must have a unique identification. The standards do not define a system, it is left up to the manufacturer to devise a suitable system that will meet their needs.

The welding positions as illustrated below in Figure 27 are also important and are considered in certifying welders. Flat (1G/1F), Horizontal (2G/2F), Vertical (3G/3F), Overhead (4G/4F) positions are the most common designations along with 6G (pipe-groove welded in a fixed, 45-degree angle position) - See Figures 28 and 29.

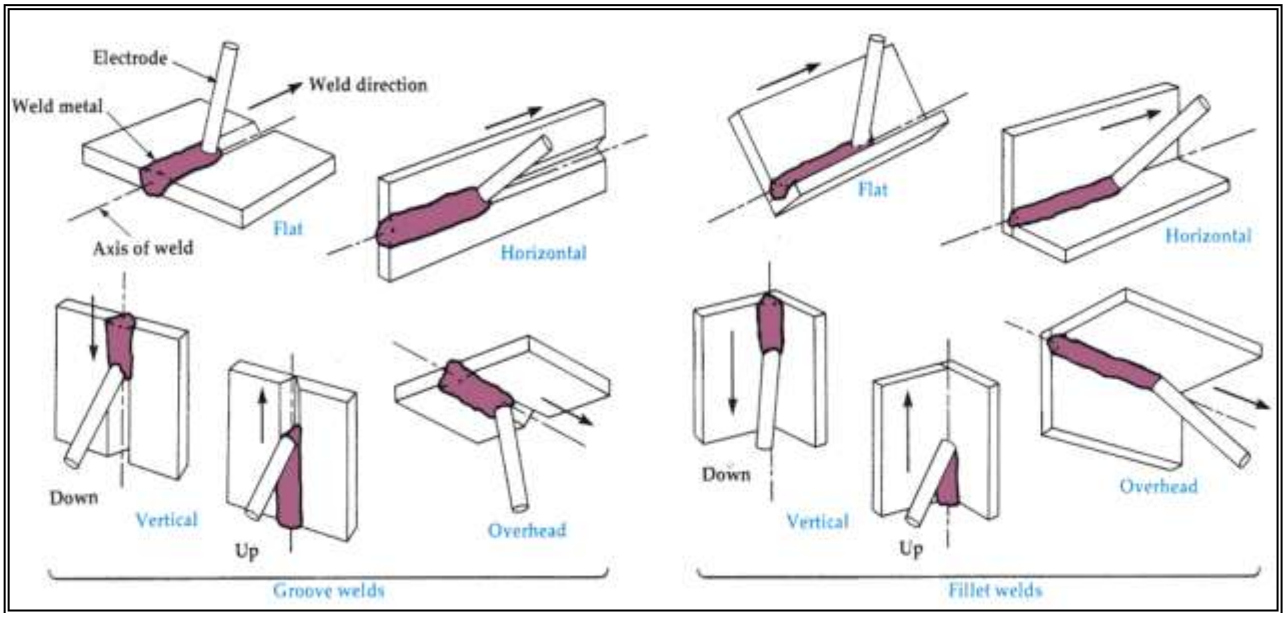

Figure 27. Welding positions for groove and fillet welds

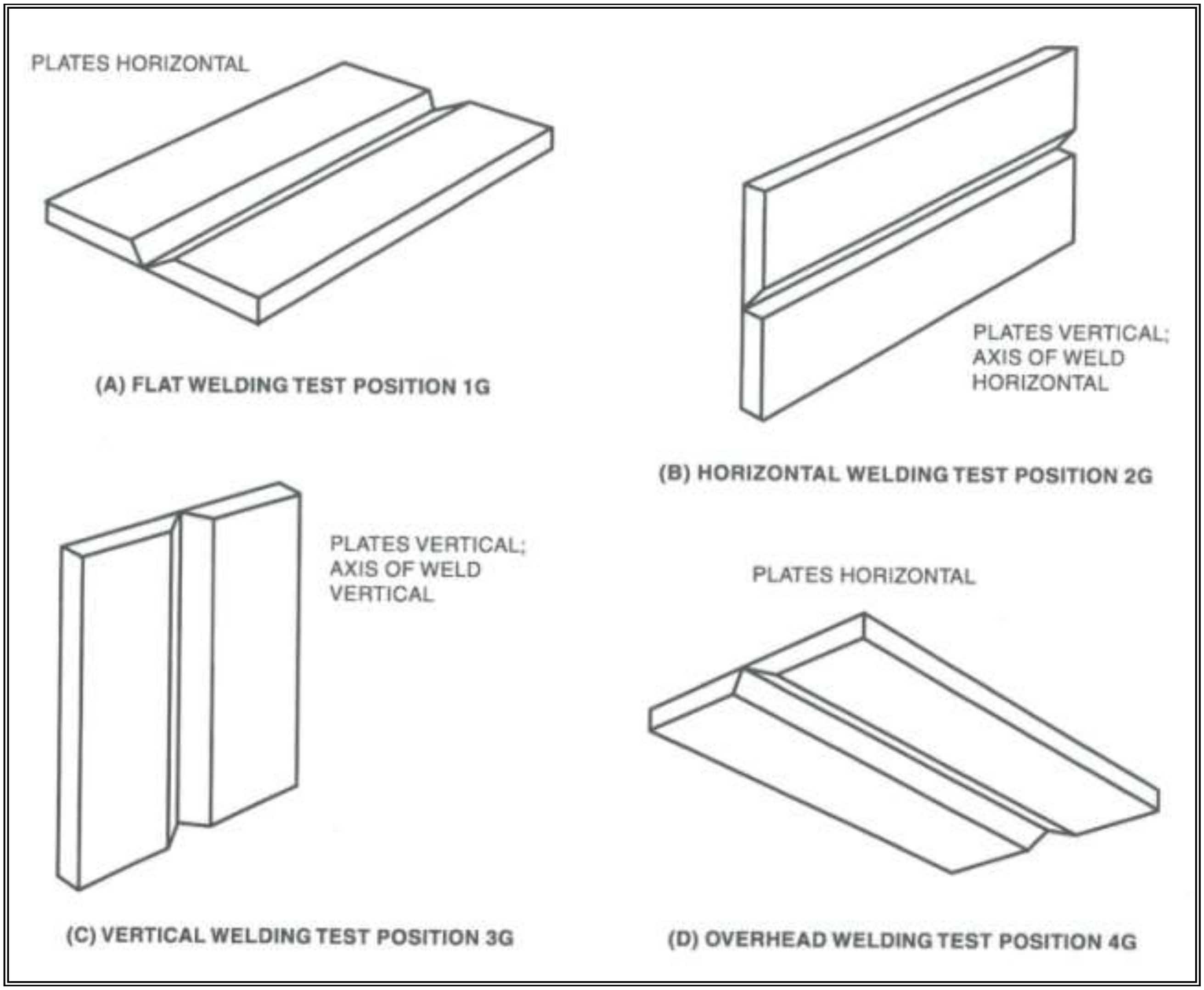

Figure 28. Positions of qualification test plates for groove welds

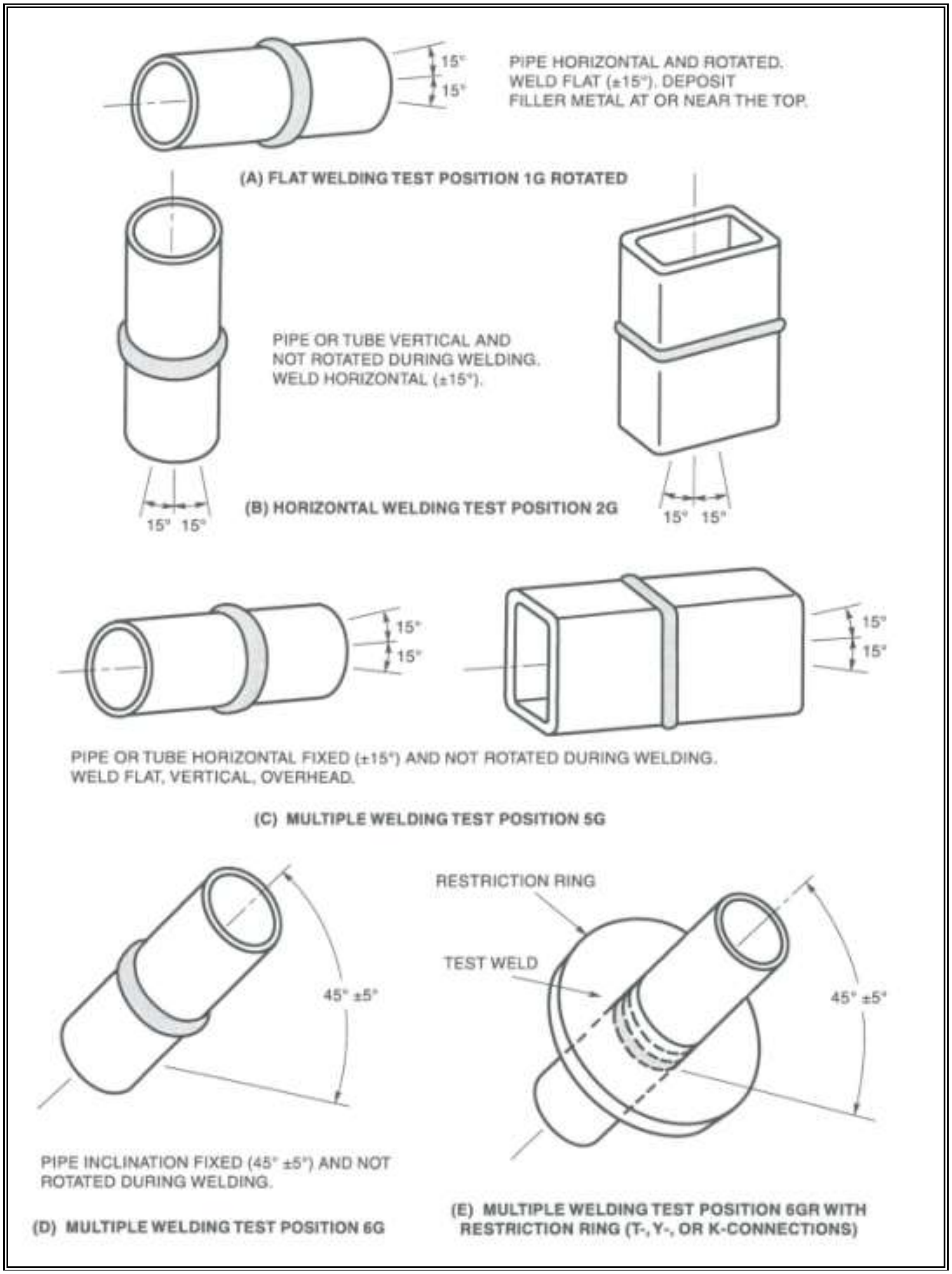

Figure 29. Positions of qualification test pipes/tubes for groove welds

Actual welding parameters used to produce an acceptable test joint and the results of the qualification tests (nondestructive, mechanical, chemical and metallurgical as needed per the applicable codes) are documented in a procedure qualification record (PQR). Welding procedures that are qualified by testing must be supported by one or more PQRs. Some joints are considered prequalified according to the American Welding Society Structural Steel Welding Code, D1.1. In order for a WPS to be prequalified, it must comply with all the criteria in AWS D1.1. Therefore, it is prudent to thoroughly evaluate the code requirements along with contract documents.

Welders are required to take a practical exam to demonstrate their ability to produce sound welds by welding up a plate or a pipe coupon. These samples are then submitted to a test lab for either radiography or mechanical testing to obtain welder performance qualifications (WPQ). Depending on the governing code, nondestructive and/or mechanical tests are performed during qualifications. Typical tests performed for procedure qualifications are bend testing, tensile testing, and charpy impact testing (See Figures 30-32). Chemical analysis and hardness testing may also be required when specified.

Figure 30. Photograph of a side-bend sample, which failed as a result of lack of fusion

Figure 31. Photograph of an acceptable transverse weld tensile specimen that failed in a ductile manner, in the base metal

Figure 32. Photograph showing a notched charpy impact specimen ready for testing

A sample Welding Procedure (WPS), which was qualified by testing and hence became a weld procedure (PQR), is included along with the accompanying Welder Qualification record (WPQ).

WELDING PROCEDURE SPECIFICATION (WPS) Yes ☒
PREQUALIFIED____ QUALIFIED BY TESTING X
or PROCEDURE QUALIFICATION RECORD (PQR) Yes ☒

Identification # TIG CS
Revision 0 Date 1/1/06 By —
Authorized by Semih Genculu Date 1/106
Type Manual X Semi-Automatic ☐
Machine ☐ Automatic ☐

Company Name ABC Company
Welding Process(es) GTAW
Supporting PQR No.(s) TIG CS-1

JOINT DESIGN USED
Type: Double-V
Single ☐ Double Weld ☒
Backing Yes ☒ No ☐
Backing Material Weld Metal
Root Opening 0 - 1/8" Root Face Dimension —
Groove Angle 60° Radius (J-U)
Back Gouging: Yes X No ☐ Method

BASE METALS
Material Spec. SA570
Type or Grade Grade 50
Thickness Groove 3/16" Fillet —
Diameter (Pipe) —

FILLER METALS
AWS Specification SFA5.18
AWS Classification ER70S-6

SHIELDING
Flux N/A Gas Argon
Composition 100
Electrode-Flux (Class) N/A Flow Rate 30 cfh
Gas Cup Size 3/8"

PREHEAT
Preheat Temp., Min. 60°
Interpass Temp., Min. 60° Max. N/A

POSITION
Position of Groove 1G Fillet
Vertical Progression: Up ☐ Down ☐
N/A

ELECTRICAL CHARACTERISTICS
Transfer Mode (GMAW) Short-Circuiting ☐
Globular ☐ Spray ☐
Current: AC ☐ DCEP ☐ DCEN X Pulsed ☐
Other -
Tungsten Electrode (GTAW)
Size: 3/32"
Type: 2% Thoriated

TECHNIQUE
Stringer or Weave Bead Stringer
Multi-pass or Single Pass (per side) Single
Number of Electrodes Single
Electrode Spacing Longitudinal —
Lateral —
Angle —
Contact Tube to Work Distance —
Peening N/A
Interpass Cleaning N/A

POSTWELD HEAT TREATMENT
Temp. No PWHT
Time —

WELDING PROCEDURE

Pass or Weld Layer(s)	Filler Metals			Current		Volts	Travel Speed	Joint Details
	Process	Class	Diam.	Type & Polarity	Amps or Wire Feed Speed			
Single/Side	GTAW	ER70S-6	3/32"	DCSP	110A	24	Manual	Double-V With 60° Groove

Procedure Qualification Record (PQR) # TIG CS-1
Test Results

TENSILE TEST

Specimen No.	Width (in)	Thickness (in)	Area (in^2)	Ultimate Tensile Load, lbs	Ultimate Unit Stress, psi	Character of Failure and Location
Tensile 1	0.750	0.180	0.1350	10,000	74,100	Ductile, B.Metal
Tensiel 2	0.750	0.180	0.1350	10,100	74,800	Ductile, B.Metal

GUIDED BEND TEST

Specimen No.	Type of Bend	Results	Remarks
1	Face	Acceptable	
2	Face	Acceptable	
3	Root	Acceptable	
4	Root	Acceptable	

VISUAL INSPECTION

Appearance Acceptable
Undercut None
Piping Porosity None
Convexity Acceptable
Test Date 1/10/2006
Witnessed by Weld Supervisor

Other Tests N/A

Radiographic-Ultrasonic Examination

RT Report No: ABC123 Result Acceptable
UT Report No: — Result

FILLET WELD TEST RESULTS N/A

Min. size multi. pass ______ Max. size single pass ______
Macroetch
1. ______ 3. ______
2. ______
Macroetch
1. ______ 3. ______
2. ______

All-Weld-Metal Tension Test N/A

Tensile Strength, psi ______
Yield point/strength, psi ______
Elongation in 2 in., % ______

Welder's Name Mr. TIG Welder Clock No. — Stamp No. 1234
Tests conducted by Testing Lab, Inc. Test No. ABC123

We, the undersigned, 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 Section 4 of ANSI/AWS D1.1/D1.1M, (2004) Structural Welding Code – Steel

Signed ABC Company
Manufacturer or Contractor
By ______
Title ______
Date ______

WELDER OR TACK WELDER QUALIFICATION

Name Mr. TIG welder S.S. No. — Identification No. 1234
Welding Procedure Specification No. TIG CS Rev. 0 Date 1/10/2006

VARIABLES	RECORD ACTUAL VALUES USED IN QUALIFICATION	QUALIFICATION RANGE
Process/Type [Table 4.11, Item (1)]	GTAW	
Electrode (single or multiple) [Table 4.11, Item (8)]	Single	GTAW
Current/Polarity	DC SP	
Position [Table 4.11, Item (4)]	1G (Flat)	Flat
Weld Progression [Table 4.11, Item (6)]	N/A	N/A
Backing (YES OR NO)[Table 4.11, Item (7)]	Yes	With
Material/Spec.	SA570, Gr. 50	
Base Metal		
Thickness: (Plate)		
Groove	3/16"	0.125" – 0.375"
Fillet	—	Unlimited
Thickness (Pipe/Tube)		
Groove	—	0.125" – 0.375"
Fillet	—	Unlimited
Diameter: (Pipe)		
Groove	—	Over 24" Diameter w/Backing
Fillet	—	Unlimited
Filler Metal [Table 4.11, Item (3)]		
Spec. No.	SFA 5.18	
Class	ER70S-6	
F-No. Table 4.11, Item (2)]	6	6
Gas/Flux Type [Table 4.11, Item (3)]	100% Argon	100% Argon
Other	—	—

VISUAL INSPECTION (4.8.1)
Acceptable YES or NO Yes

Guided Bend Test Results (4.30.5)

Type	Result	Type	Result
Face	Pass	Root	Pass
Face	Pass	Root	Pass

Fillet Test Results (4.30.2.3 and 4.30.4.1)

Appearance: — Fillet Size: —
Fracture Test Root Penetration: — Macroetch: —

Inspected by Test Technician Test Number ABC123
Organization Testing Lab, Inc. Date 1/10/2006

RADIOGRAPHIC TEST RESULTS (4.30.3.1) N/A

Film Identification Number	Results	Remarks	Film Identification Number	Results	Remarks

Interpreted by Test Number
Organization Date

We, the undersigned, 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 Section 4, of ANSI/AWS D1.1/D1.1M, (2004) Structural Welding Code - Steel.

Manufacturer or Contractor ABC Company Authorized By Welding Supervisor
Date

Course Summary

This course contains detailed information about the various arc-welding processes utilized in welding structural steels. Information about shielding gases is given along with the explanation of the filler metal classification system. Typical weld symbols and unacceptable weld profiles are illustrated. The course describes the sources that are responsible for welding defects and provides solutions on how to avoid them. In addition to the detailed information about weldability, it includes guidelines for following proper procedures in joining materials.

Related Links

For additional technical information related to this subject, please visit the following websites:

aws.org
www.lincolnelectric.com

References

Welding Handbook by AWS
Welding Inspection Technology by AWS