PDHonline Course M381 (5 PDH)

Welding Technology and Inspection Procedures – AWS D1.1

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2020

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Contents

I – INTRODUCTION:

This manual is short and very practical for students, welders, technicians, welding inspectors and engineers the way anyone can research some subject in a timely manner to carry a work without wasting too much his precious time. It covers only the main manufacturing welding processes, materials and inspection procedures according to AWS D1.1 and ASME Section IX, commonly used for field construction projects: SMAW (shielded metal arc), GMAW (gas metal arc), GTAW (gas tungsten arc), FCAW (flux-cored arc), SAW (submerged arc), CAW (carbon arc), PAW (plasma arc) and EGW (electrogas welding). Metallurgy is not the scope and is limited in selecting welding processes, materials, and inspection procedures for the common construction applications.

II – WELDING PROCESSES:

The **five** main **arc welding processes** used in heavy and medium carbon and alloy steel manufacturing are:

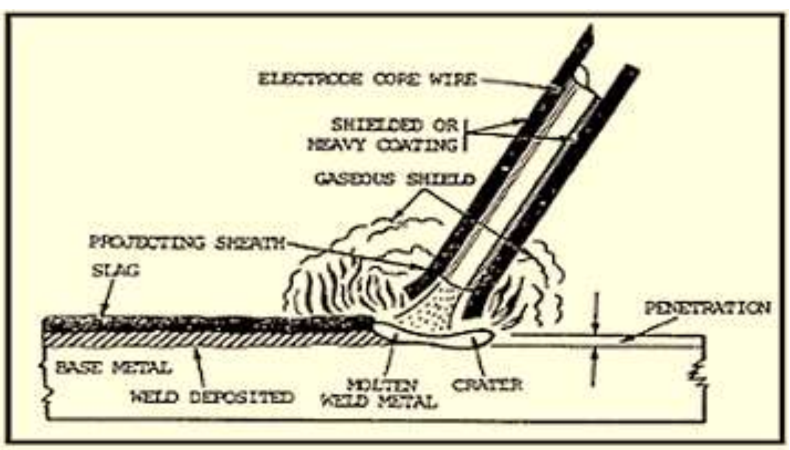
- **SMAW:** Shielded Metal Arc Welding - stick welding electrode;
- **GMAW**: Gas Metal Arc Welding or MIG welding - solid wire or metal cored wire;
- **GTAW**: Gas Tungsten Arc Welding or TIG welding - rod or solid wire.
- **FCAW**: Flux Cored Arc Welding - gas-shielded flux cored wire;
- **SAW**: Submerged Arc Welding - solid or tubular wire;

1) Basic Considerations:

Basically, in the electric welding processes, an arc is produced between an electrode and the work piece (base metal). The **AWS D1.1** describes the welding procedures to be used with the various welding processes. The **main welding processes** are:

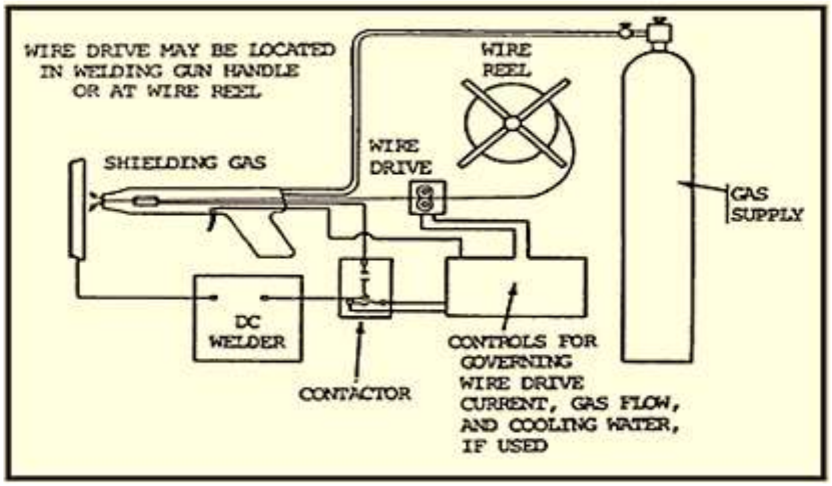
2) SMAW - Shielded Metal Arc Welding:

SMAW - Shielded Metal Arc Welding: Also known as **Manual Metal Arc (MMA)** or **stick welding** is a manual arc welding process that uses a **consumable electrode coated** in flux to lay the weld. An electric current, either alternating current or direct current from a welding power supply, is used to form an **electric arc between the electrode and the metals** to be joined. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a **shielding gas** and providing a layer of slag, both of which protect the weld area from atmospheric contamination.



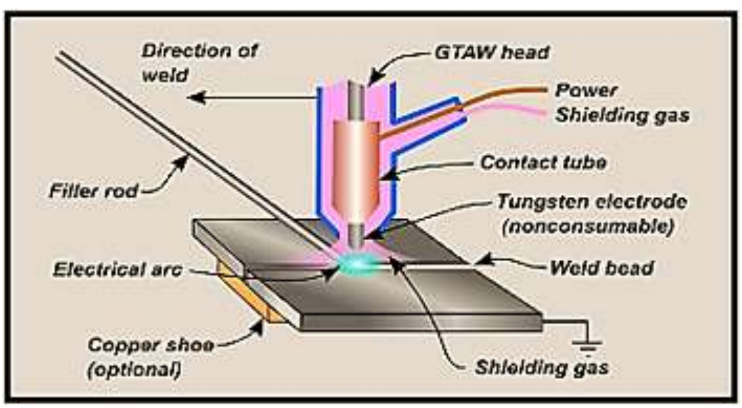
3) GMAW - Gas Metal Arc Welding or MIG Welding:

GMAW - Gas Metal Arc Welding: Sometimes referred to **Metal Inert Gas (MIG)** or **Metal Active Gas (MAG)**, is a **semi-automatic or automatic arc welding** process in which a **continuous and consumable wire electrode** and a **shielding gas** are fed through a welding gun. A constant voltage, direct current power source is used with GMAW, but constant current systems, as well as alternating current, can be used. There are four primary methods of metal transfer in GMAW, called **Globular, Short-Circuiting, Spray, and Pulsed-Spray**, which has distinct properties.



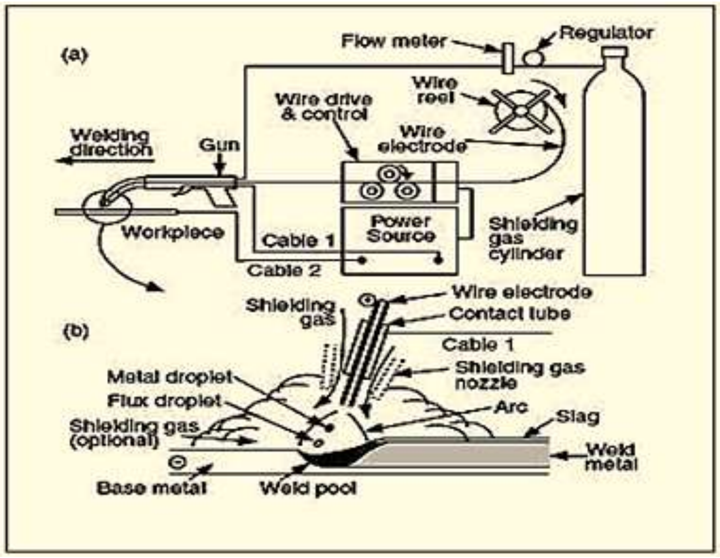
4) GTAW - Gas Tungsten Arc Welding or TIG welding:

GTAW - Gas Tungsten Arc Welding: Also known as **Tungsten Inert Gas (TIG)** is an arc welding process that uses a **non-consumable tungsten electrode.** The weld area is protected from atmospheric contamination by a shielding gas **(usually an inert gas such as argon)**. Normally a filler metal is used, though some welds known as autogenous welds, do not require it. A constant-current welding power supply produces energy through a column of highly **ionized gas and metal vapors known as plasma**.



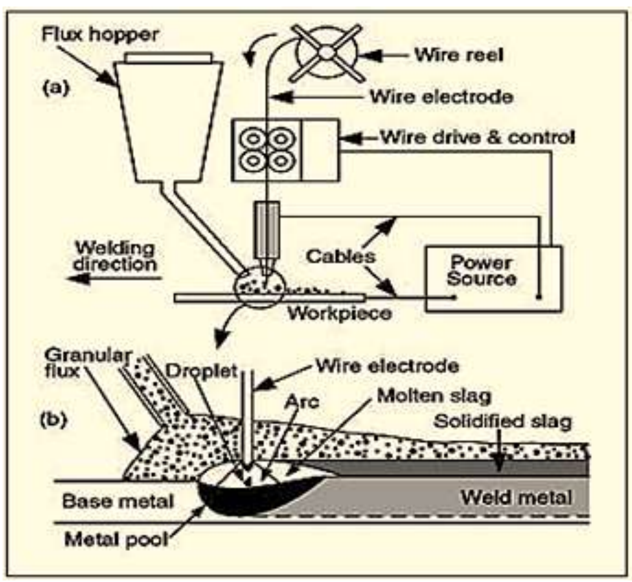
5) FCAW - Flux Cored Arc Welding:

FCAW – Flux Cored Arc Welding: Is a semi-automatic or automatic arc welding process that requires a **continuously-fed consumable tubular electrode containing a flux** core which is filled with a mixture of mineral flux and powder with a constant-current welding power supply. An external shielding gas is sometimes used, but often the flux itself is enough to generate the necessary protection from the atmosphere. The difference **between FCAW and GMAW** is that the **flux cored wire** is hollow and is **filled with a flux** that produces a slag to protect the weld.



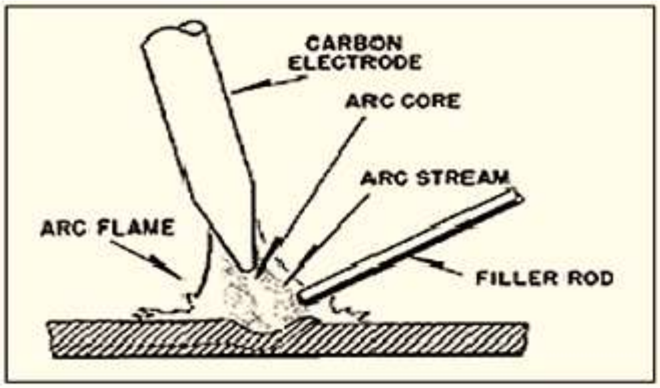
SAW - Submerged Arc Welding:

SAW - Submerged Arc Welding: Is a common arc welding process originally developed by the Linde Union Carbide Company. The process requires a **continuous consumable solid or tubular (flux cored)** electrode. The molten weld and the arc zone are protected from atmospheric contamination by being "submerged" under a **blanket of granular fusible flux consisting of lime, silica, manganese oxide, calcium fluoride**, and other compounds.



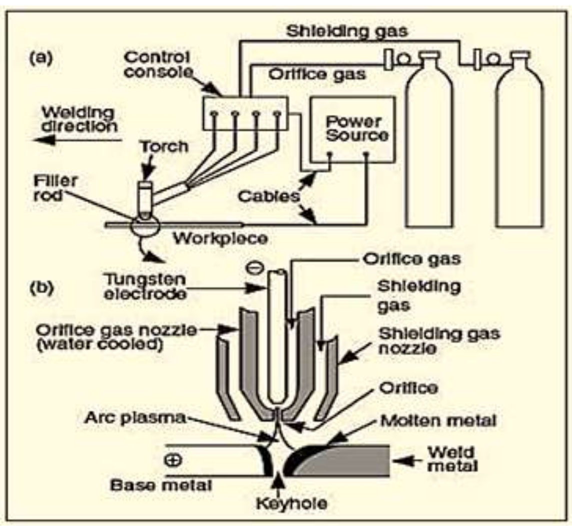
6) CAW - Carbon Arc Welding:

CAW - Carbon Arc Welding: Is a process which produces coalescence of metals by heating them with an **arc between a non-consumable carbon (graphite) electrode and the work-piece**. It was the first arc-welding process ever developed but is not used for many applications today, having been replaced by **Twin Carbon Arc Welding** and other variations. The Carbon Arc Welding electrode is used to produce an electric arc between the electrode and the materials being welded. This arc produces extreme **temperatures in excess of 3,000°C**. At this temperature the separate metals form a bond and become welded together.



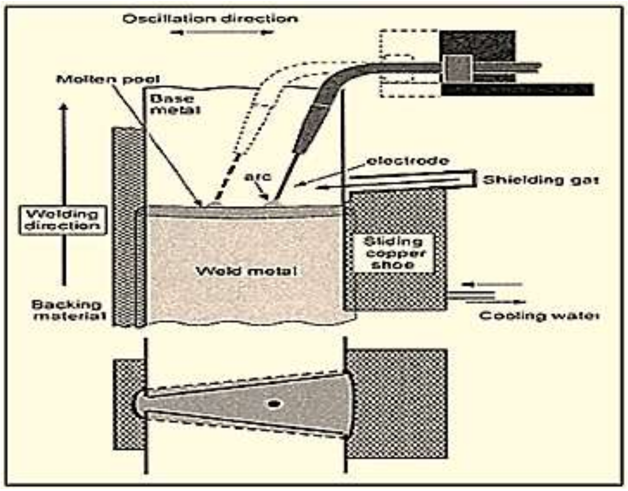
7) PAW - Plasma Arc Welding :

PAW - Plasma Arc Welding: Is an arc welding process **similar to Gas Tungsten Arc Welding (GTAW) (**or **TIG)**, also using a non-consumable tungsten electrode and an arc constricted through a fine-bore copper nozzle. The main **difference from GTAW is that, in PAW**, by positioning the electrode within the body of the torch, the plasma arc can be separated from the shielding gas envelope. The **plasma arc flame is forced** through a fine-bore copper nozzle which constricts the arc and the plasma exits the orifice at high velocities (approaching the speed of sound) and a temperature approaching **20,000 °C**. Plasma Arc Welding is much more advanced in relation to GTAW process.



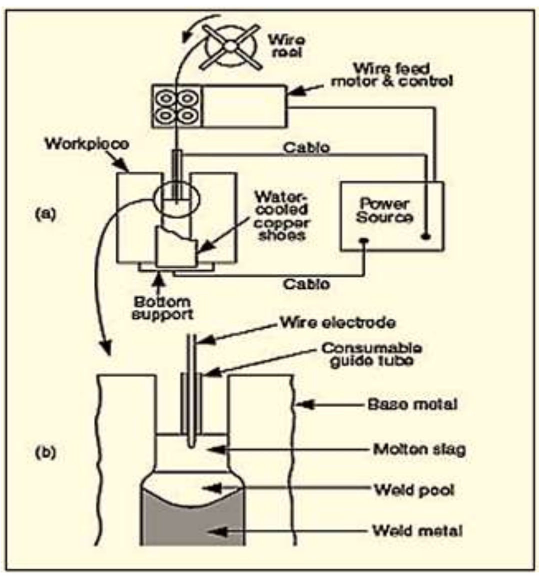
8) EGW - Electrogas Welding:

EGW - Electrogas Welding: Is a continuous vertical position arc welding process developed in 1961, in which an arc is struck between a **consumable electrode and the work piece**. A shielding gas is sometimes used, but pressure is not applied. The main difference between EGW and its cousin Electroslag Welding (ESW) is that the arc in EGW is not extinguished, instead remains struck throughout the welding process. It is **used to make square-groove welds for butt and t-joints**, especially in the shipbuilding industry and in the construction of storage tanks.



9) **ESW - Electroslag Welding**:

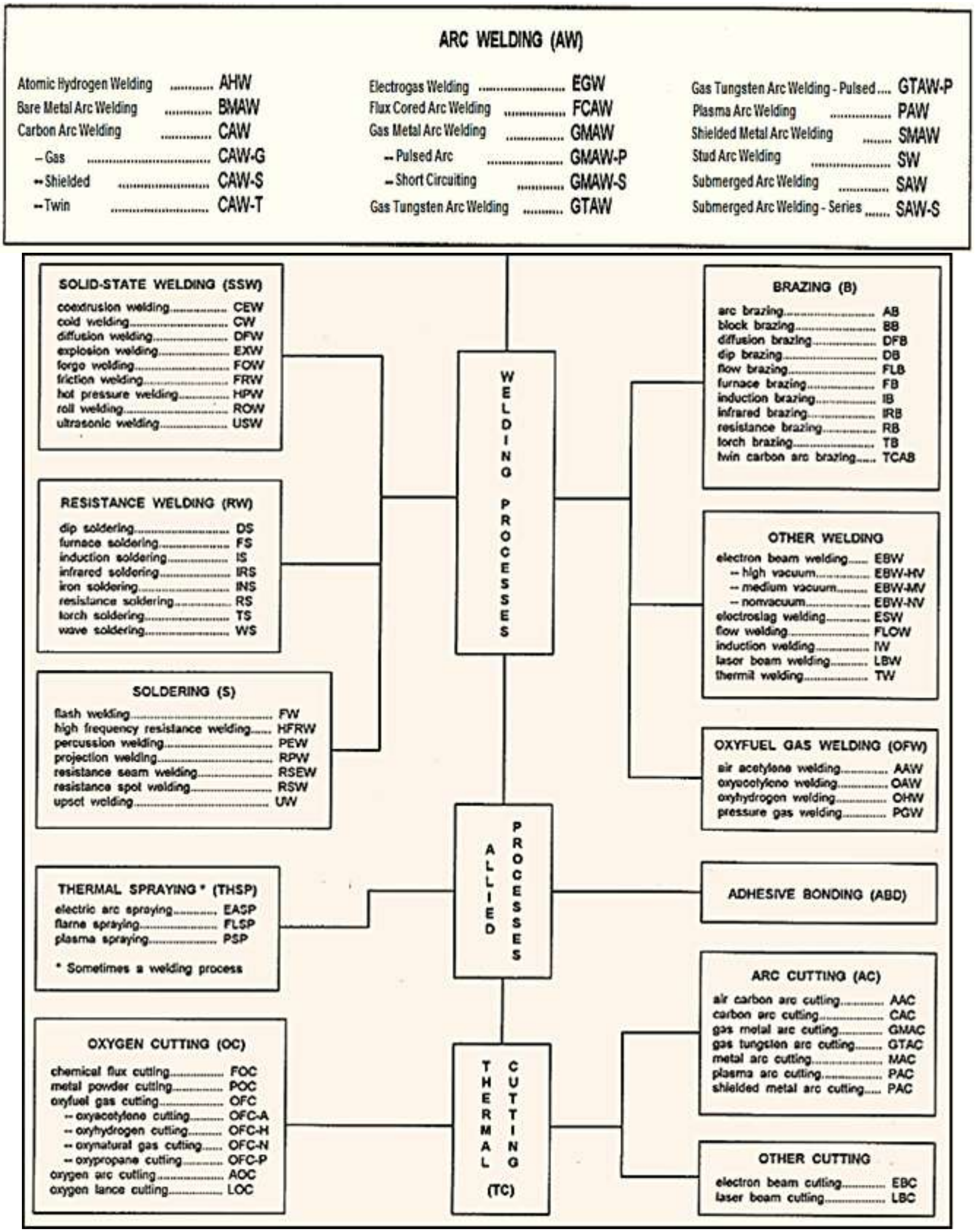
ESW - Electroslag Welding: Is a highly productive welding process **for thick materials** (greater than 25mm up to about 300mm) close to a vertical position similar to ESW Electrogas Welding, but the difference is the arc starts in a different location. In ESW, an electric arc is initially struck by a wire that is fed into the desired weld location, and then flux is added until the molten slag, reaching the tip of the electrode, extinguishes the arc. The electroslag welding is commonly used mainly to join low carbon steel plates and/or sections **that are very thick** using a direct current (DC) voltage ranging from 600A and 40-50V. However, **ESW is not considered an arc welding process**.



10) **AHW - Atomic Hydrogen Welding:**

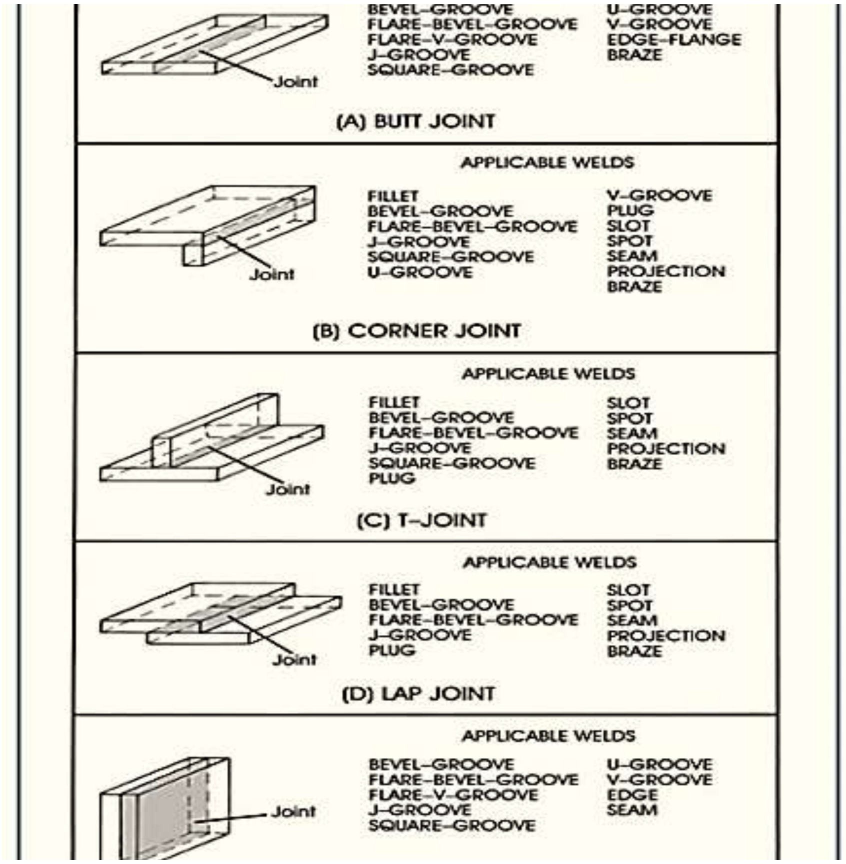
AHW - Atomic Hydrogen Welding: Is an arc welding process, **not common**, which uses an arc **between two metal tungsten electrodes** in a shielding atmosphere of hydrogen. The electric arc breaks up the hydrogen molecules to recombine with a release of heat, reaching temperatures from **3400 to 4000 °C**. The presence of hydrogen also acts as a gas shield and protects metals from contamination. Without the arc, an **oxy-hydrogen torch can only reach 2800 °C**. This is the third hottest flame after cyanogen at 4525 °C and dicyano-acetylene at 4987 °C. An **acetylene torch merely reaches 3300 °C**.

11) General Welding and Allied Processes:



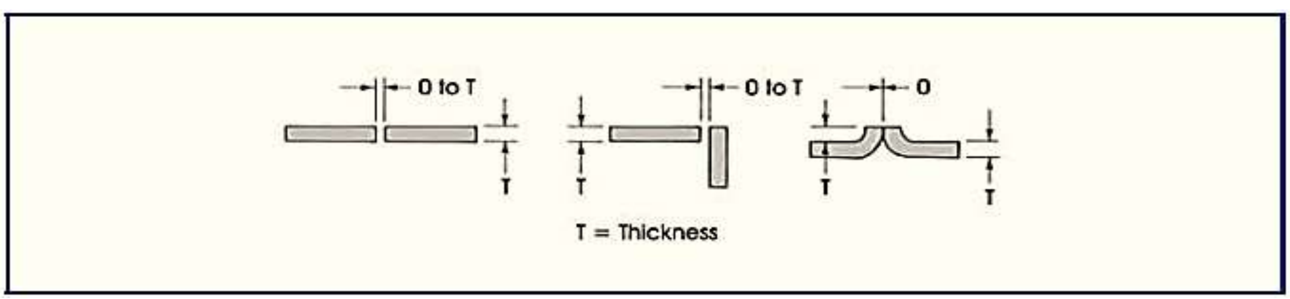
III – MAIN WELDING JOINT TYPES:

The five main types of joints for welding are the **butt joint, lap joint, corner joint, T joint, and edge joint**. Each of these joints can be welded in different ways and with a variety of welding processes.

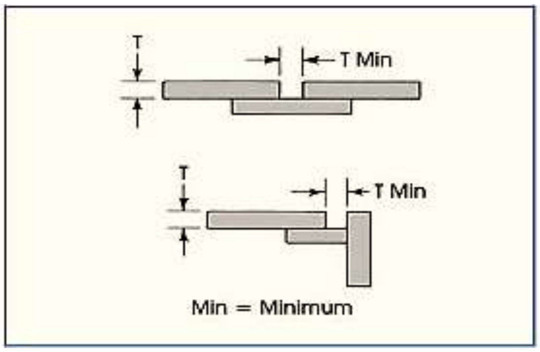


1) Square-Groove Welds:

The square-groove weld on one side of the joint is generally limited to thin sheet-metal sections. The maximum (max) thickness for these welds is 1/16 in. (1.6 mm). Shown here, left to right, are a **butt joint, a corner joint, and an edge-flange type of edge joint**.



A **backing strip** is sometimes used on the opposite side of a square-groove weld. The **backing strip** keeps the molten weld metal from falling through and permits the use of more heat which results in better fusion. The welder can make a strong square-groove weld that completely penetrates the joint.

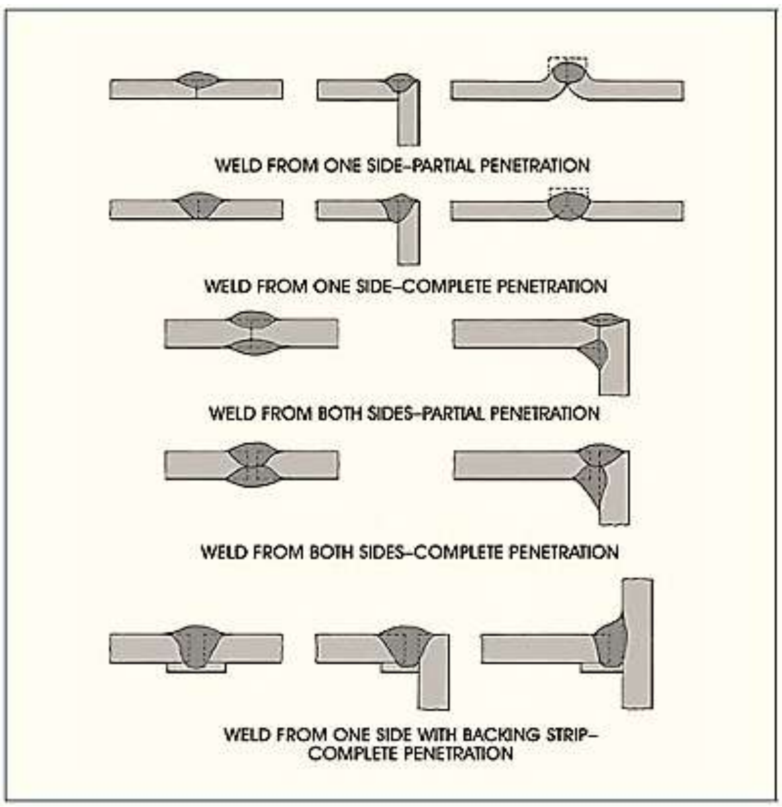


2) Square-Groove Welds Application:

These are some applications of square-groove welds. Where complete joint penetration is required for thicker sections, the weld must be made from both sides. If one side isn't accessible, the weld may be made from the other side with backing.

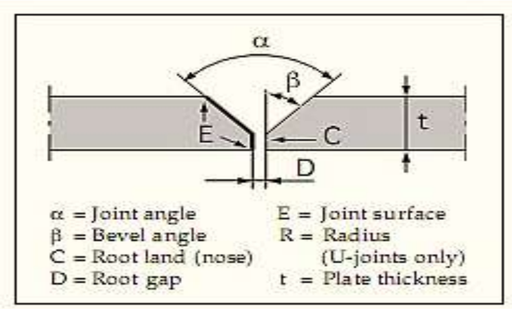
3) Square-groove Weld Examples:

These are some applications of square-groove welds. Where complete joint penetration is required for thicker sections, the weld must be made from both sides. If one side isn't accessible, the weld may be made from the other side with backing.



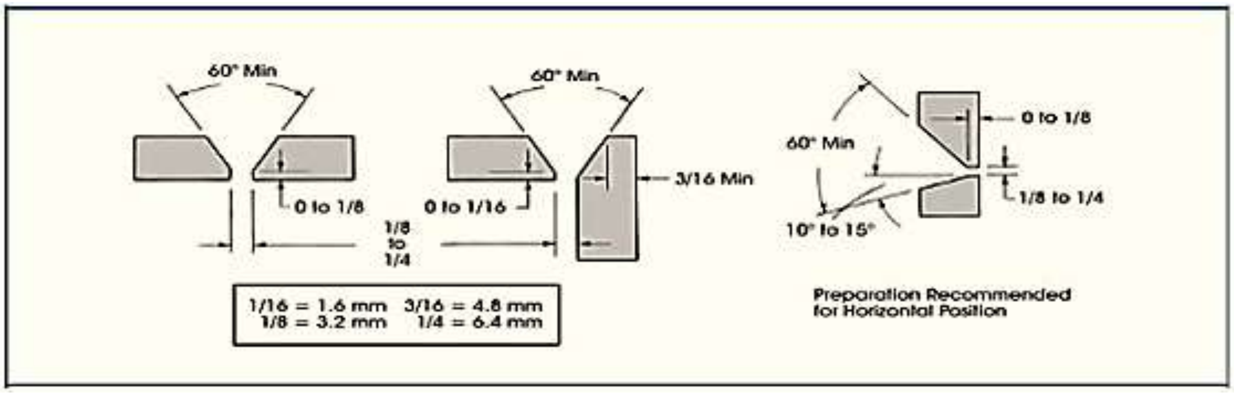
4) Choice of Joint Type:

Welding process, welding position and material thickness are also dependent of a good edge preparation:



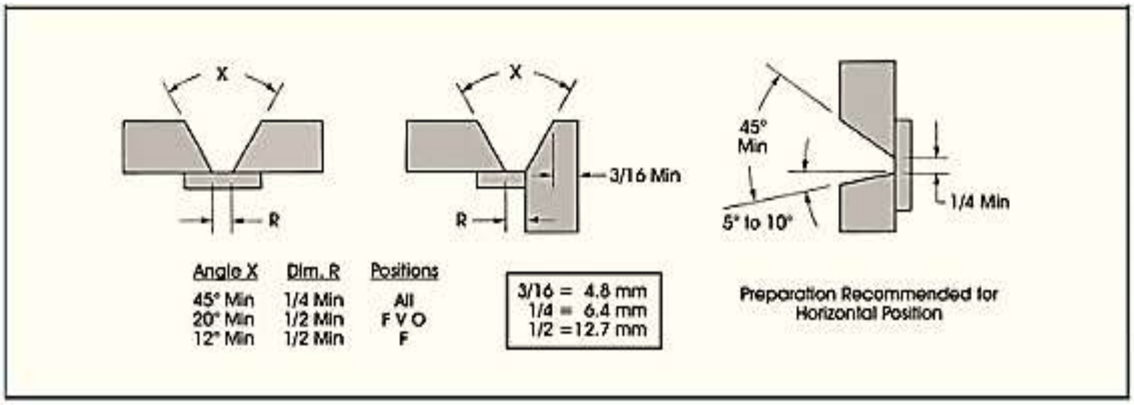
5) Single-V Joints:

Joints for **single-V-groove welds** are prepared as shown below. Generally, the included angle of the **V is about 60 °**. For horizontal welding, the joint is modified to help keep the molten weld metal from running out of the groove.



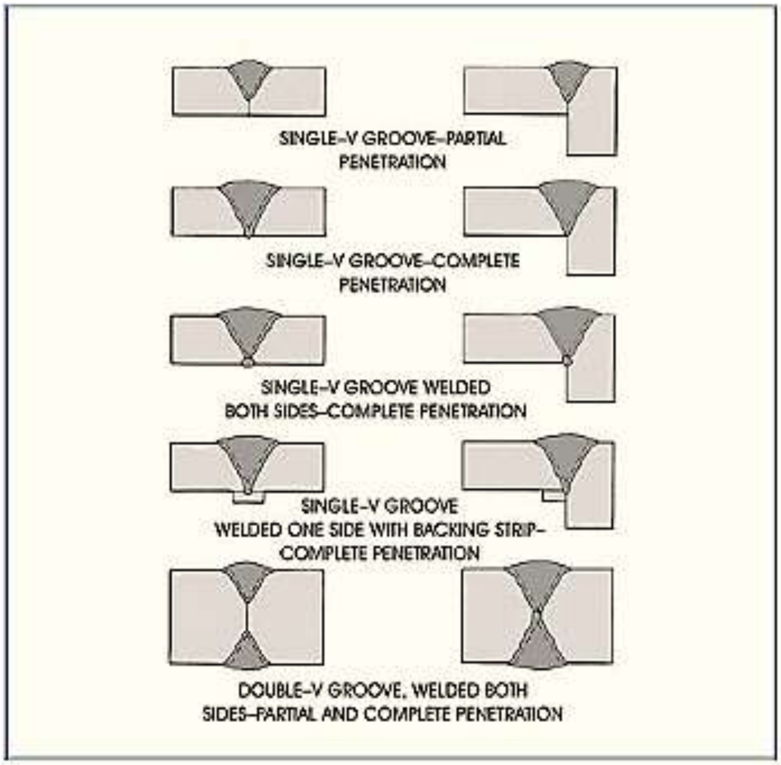
6) Single-V Joints with Backing Strips:

Joints prepared for **single-V-groove welds** with **backing strips** are shown below. Note that if the space between the parts of the joint is increased, a smaller V angle can be used. The **"positions"** listed are various welding positions: **F = flat; V = vertical; and O = overhead**.



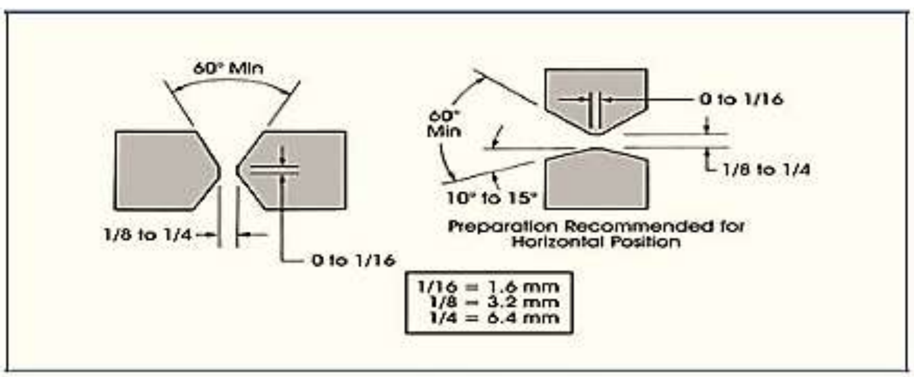
7) V-groove Weld Penetration:

The **V-groove weld** is used on relatively thick metals and becomes difficult to obtain complete joint penetration by welding in only one side. Then, either welding from both sides or welding with a backing strip is usually necessary for thorough penetration.



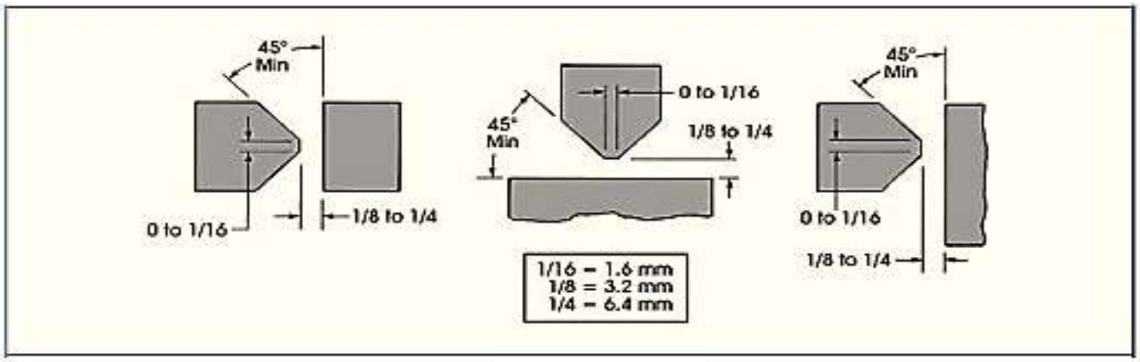
7.1) Double-V Joints:

When the **metal thickness exceeds 3/ 4 in (19.1 mm)**, it's more economical to use the **double-bevel-groove** preparation as shown below. This type of weld requires less weld metal than the single-bevel-groove weld.



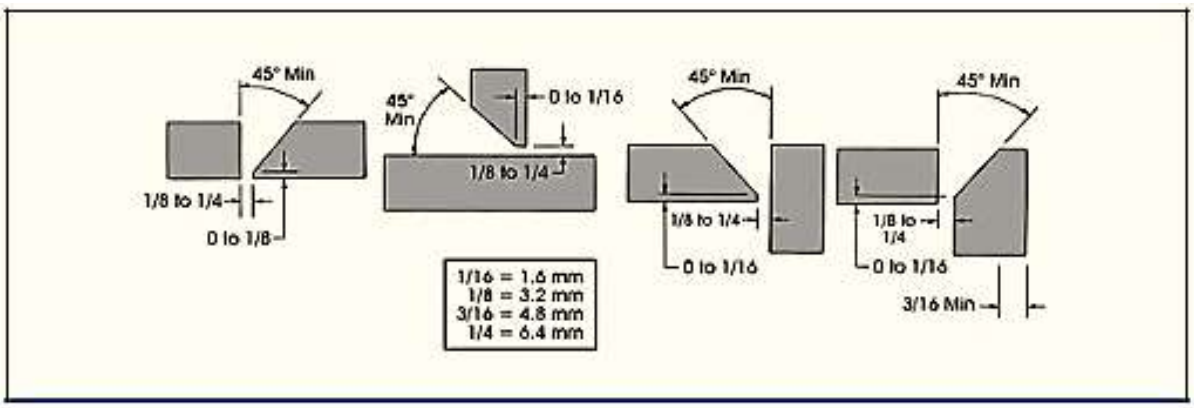
7.2) Double-V-groove Application:

The **Double-V-groove welds** on both sides can be applied only on **butt joints**. Just like the other V-groove welded joints, these joints must be prepared for horizontal welding to keep the molten weld in the groove.



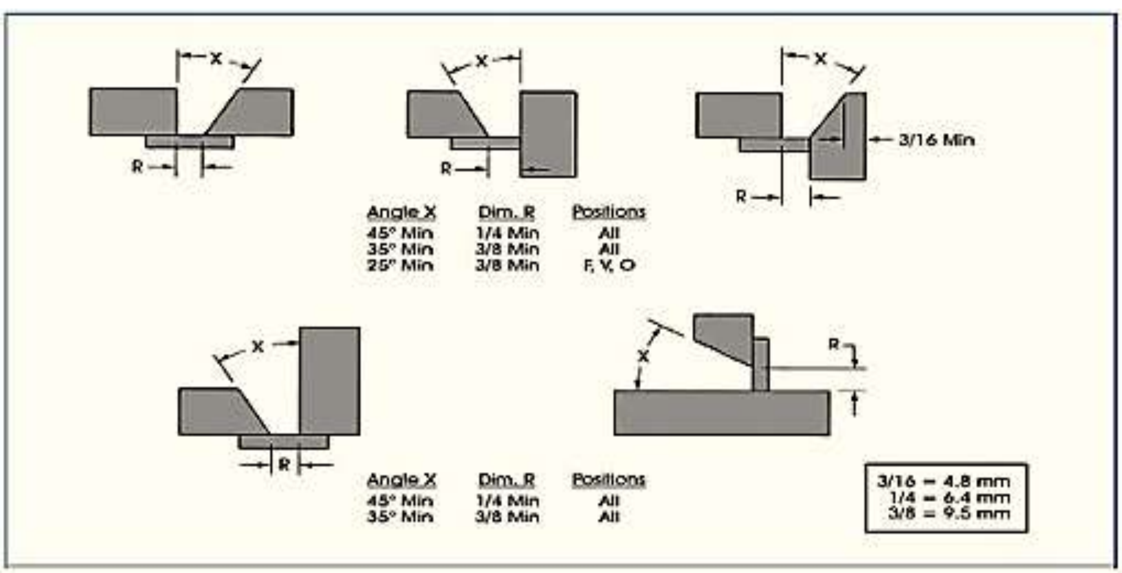
8) Single-Bevel-Groove:

Joints for **single-bevel-groove welds** on one or both sides are easier and more economical to prepare than joints with V-groove welds. Only one of the joint edges has to be beveled in preparation for the weld.



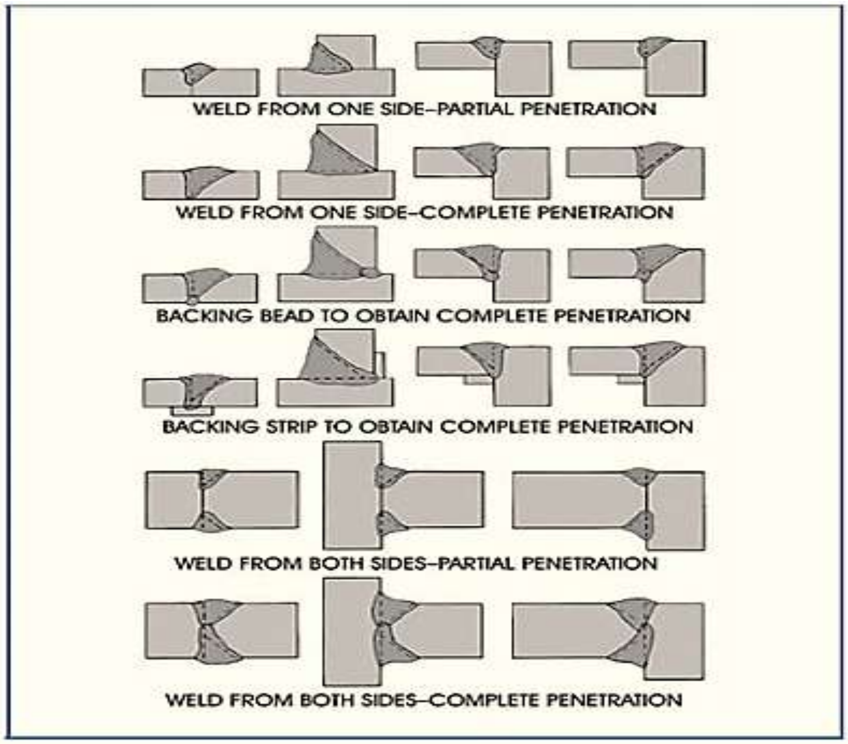
8.1) Single-Bevel-Groove with Backing Strips:

When applying the **single-bevel-groove welds** on one side, **use a backing strip** to help achieve complete joint penetration. Note the **three different methods** of preparing corner joints.



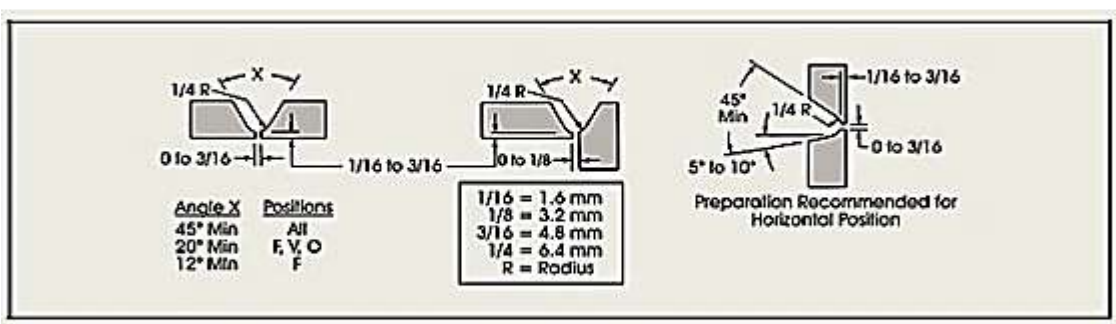
8.2) Single-Bevel-Groove Weld Penetration:

Bevel-groove welds with partial and complete joint penetration are below. Welds can be made from one or both sides, because it's difficult to ensure complete joint penetration from one side only. Consequently, to obtain **complete penetration and maximum strength, backing strips** must be used.



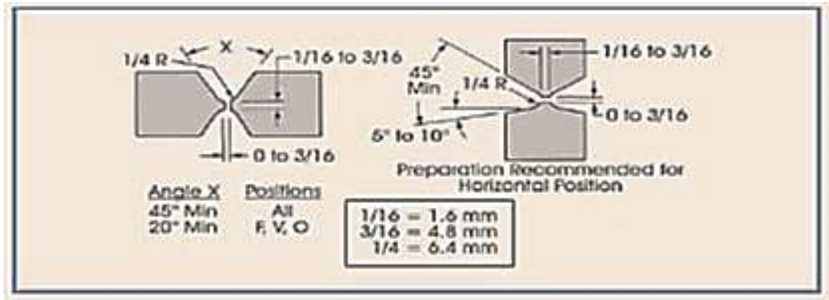
9) Single U-groove Welds:

The single **U-groove welds** are modifications of the single V-groove weld. When it's necessary to weld sections **greater than 3/ 4 in. (19.1 mm) thick** the single U -groove weld with a narrower angle, requires **less weld metal**. It's necessary to provide a **radius (R)** at the narrowest part of the joint root. This radius allows the welder enough space to manipulate the filler metal.



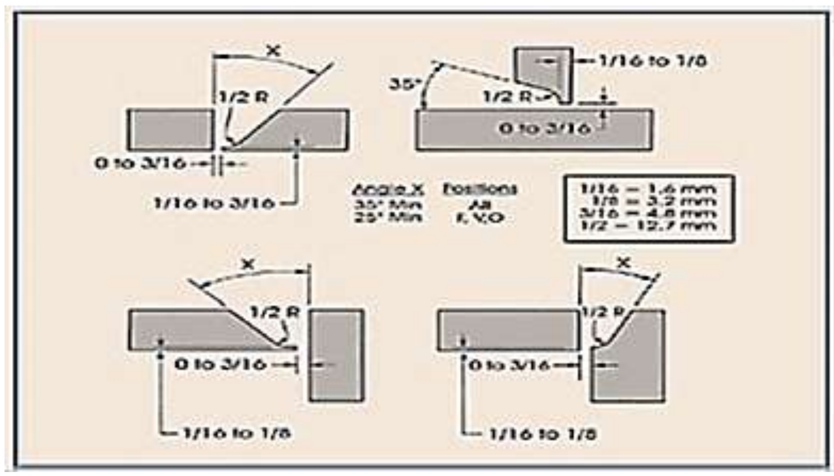
10) Double U-groove Welds:

The joints shown below are prepared for **double-U-groove welds**. This weld is used on metal **thicknesses exceeding 11⁄2 in. (38.1 mm)**. Preparation of the edges is **the same as for the single U-groove** weld except that the grooves are prepared on both sides of the plate edges.



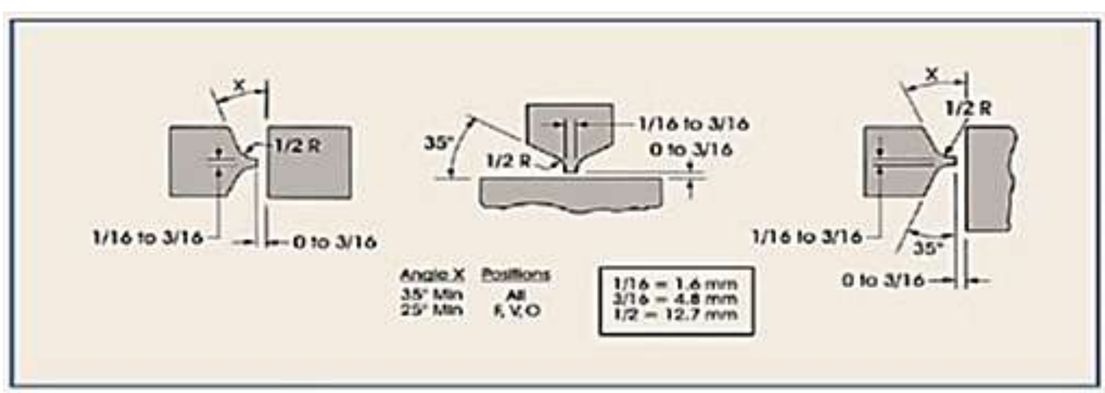
11) Single J-groove Welds:

The **J-groove** is similar in shape to the U-groove but half of its dimension. Just **like the single-U-groove** weld, the single-J-groove weld is used with metal **thicknesses above 3⁄4 in (19.1 mm)**.



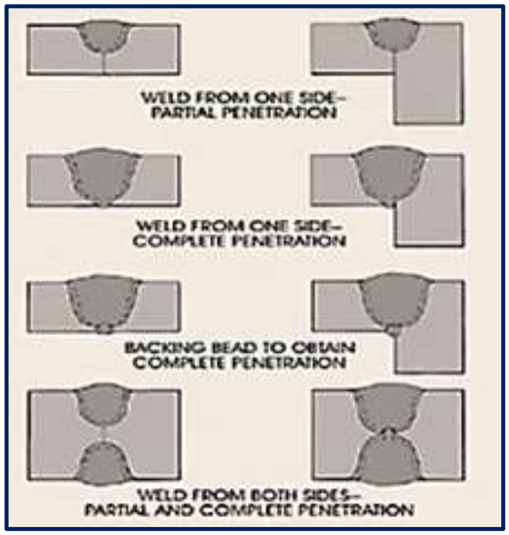
12) Double J-groove Welds:

The **Double-J-groove** welds on both sides have the same basic applications as the double-bevel groove welds. The J-groove welds are used on **thicknesses greater than 1 ½ in. (38.1 mm).**

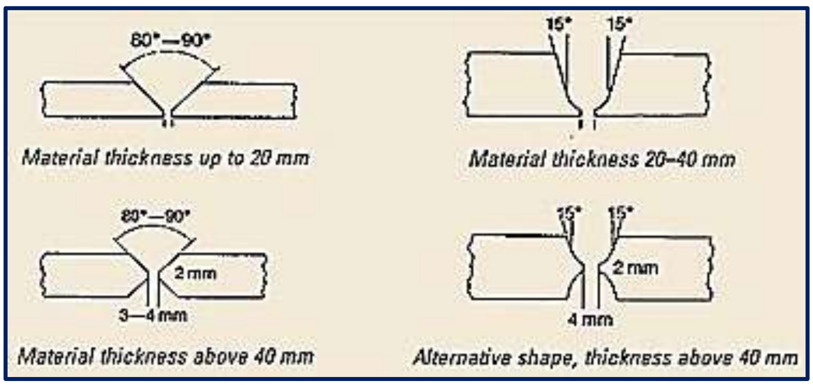


13) U-groove and J-groove Welds Application:

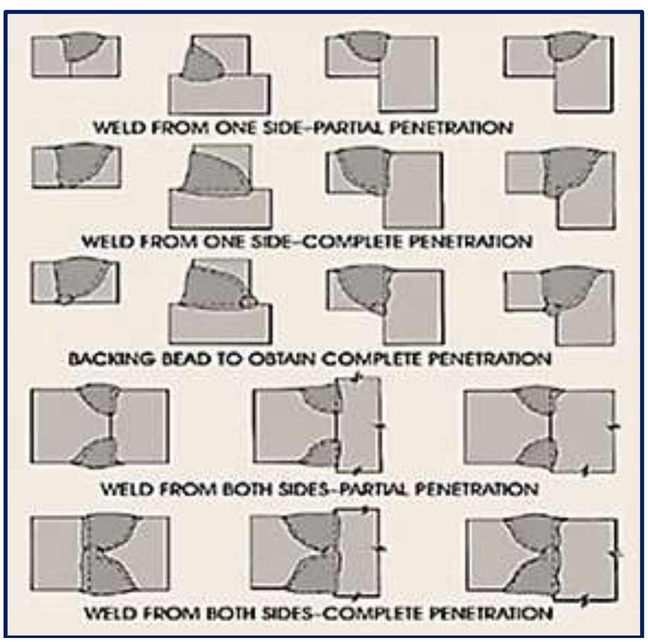
The **U-groove welds** are designed to save filler metal when thick sections are welded **greater than 3/ 4 in. (19.1 mm) thick.** Shown here are typical examples of welded U-grooved butt and corner joints.



13.1) Groove Design According to Metal Thickness:

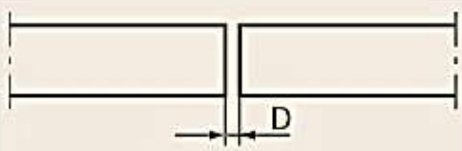
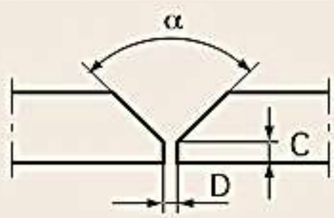
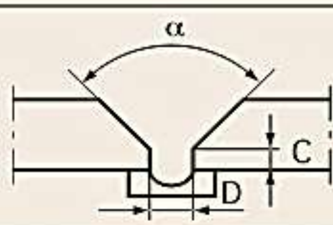
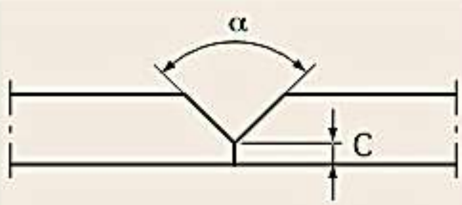


The **J-groove welds** is similar in shape to the U-groove but half of its dimension also used in thick sections **greater than 3/ 4 in. (19.1 mm) thick.** Shown here are typical examples.



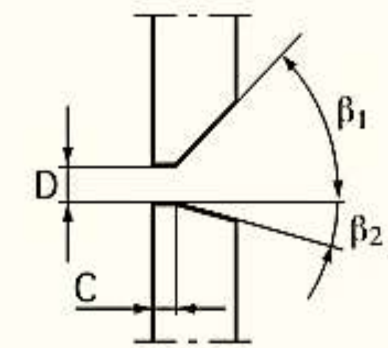
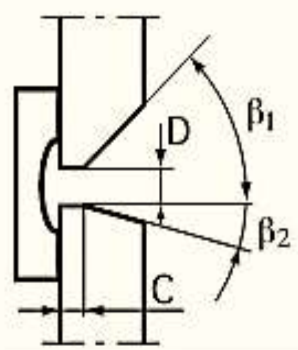
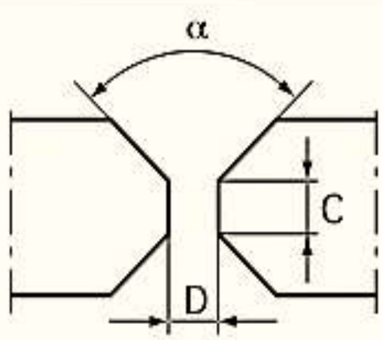
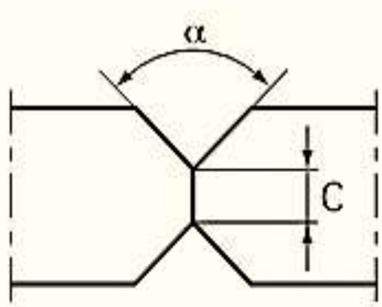
IV - JOINT DESIGN AND WELD PREPARATION:

Weld joints are designed to transfer the stresses between the members of the joint and throughout the welding. Forces and loads are introduced at different points and are transmitted to different areas throughout the welding. All weld joints can be classified into two basic categories: **full penetration joints and partial penetration joints**.

No. and joint type		Sides	Method	Thickness
1. I-joint No root gap[1]		One side	TIG	< 2.5 mm
2. I-joint No root gap[2]		Two sides	SAW	6 – 9 mm
3. I-joint		One side	PAW	1 – 8 mm
4. I-joint D = 1.0 – 2.0 mm		One side	MMA MIG TIG	< 2.5 mm
5. I-joint D = 2.0 – 2.5 mm		Two sides	MMA MIG TIG FCW	< 4 mm
6. V-joint α = 60°[3] C = 0.5 – 1.5 mm D = 2.0 – 4.0 mm		One side	MMA MIG TIG FCW	4 – 16 mm
7. V-joint α = 60°[3] C = 2.0 – 2.5 mm D = 2.5 – 3.5 mm		Two sides	MMA MIG TIG FCW	4 – 16 mm
8. V-joint α = 60°[3] C = 1.5 – 2.5 mm D = 4.0 – 6.0 mm		One side against backing	FCW	4 – 20 mm
9. V-joint α = 80 – 90° C = 1.5 mm No root gap[1]		Two sides	TIG+ SAW	3 – 16 mm
10. V-joint α = 80 – 90° C = 3.0 – 6.0 mm[4] No root gap		Two sides	SAW	8 – 16 mm
11. V-joint α = 80 – 90° C = 3.0 – 4.0 mm No root gap		Two sides	PAW+ SAW	6 – 16 mm

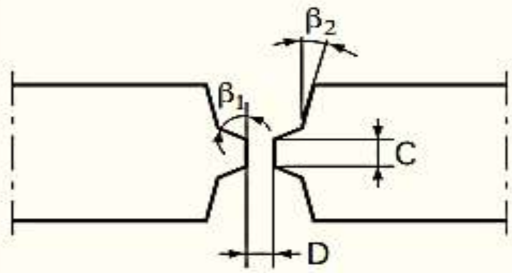
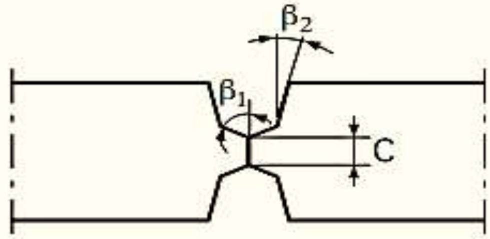
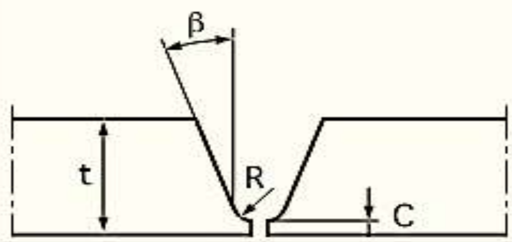
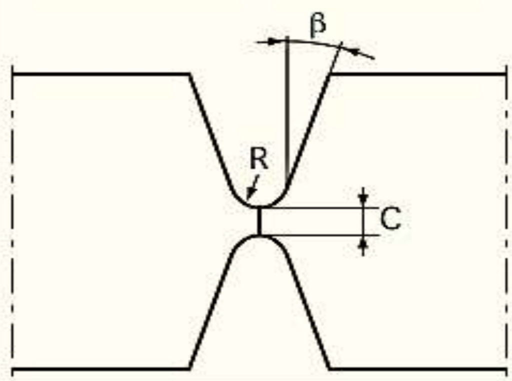
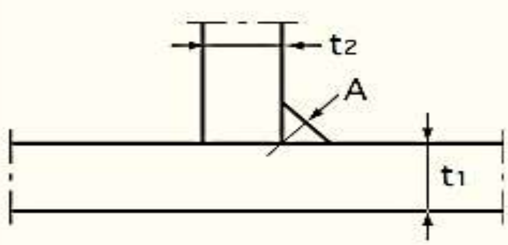
Notes:

[1] There must be a root gap when welding special grades.
[2] A ground groove, 1 – 2 mm deep and wide.
[3] The joint angle for special grades is 60 – 70°.
[4] A root land of 5 mm and above may require the torch to be angled towards the direction of travel

No. and joint type		Sides	Method	Thickness
12. V-joint $\beta_1 = 45°$ $\beta_2 = 15°$ C = 1.0 – 2.0 mm D = 2.0 – 3.0 mm		One side	MMA FCW	4 – 16 mm
13. V-joint $\beta_1 = 45°$ $\beta_2 = 15°$ C = 2.0 – 2.5 mm D = 2.0 – 2.5 mm		Two sides	MMA FCW	4 – 16 mm
14. V-joint $\beta_1 = 45°$ $\beta_2 = 15°$ C = 1.5 – 2.5 mm D = 4.0 – 6.0 mm		One side against backing	FCW	4 – 20 mm
15. X-joint $\alpha = 60°$ [3] C = 2.0 – 3.0 mm D = 2.0 – 2.5 mm		Two sides	MMA MIG TIG [6] FCW	14 – 30 mm [8]
16. X-joint $\alpha = 80°$ C = 3.0 – 8.0 mm [4] No root gap		Two sides	SAW	14 – 30 mm

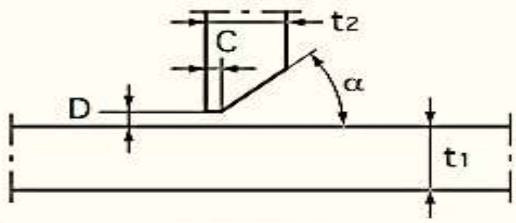
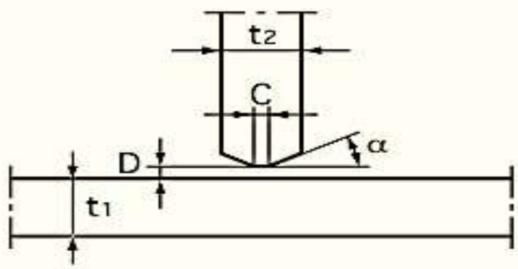
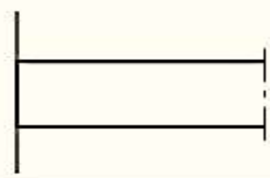
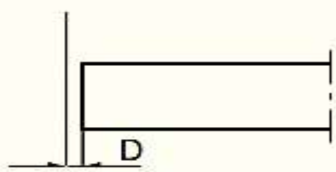
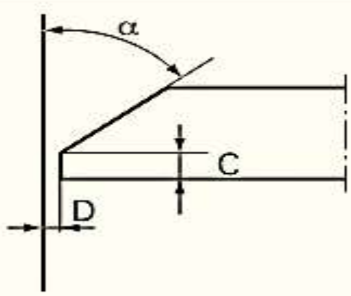
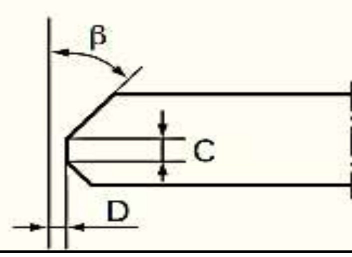
Notes:

[3] The joint angle for special grades is 60 – 70°.
[4] A root land of 5 mm and above may require the torch to be angled towards the direction of travel, see "Width and depth" in chapter 4.
[6] Normally only for the first 1 – 3 runs. Followed by MIG, FCW, MMA or SAW.
[8] A thickness above 20 mm can be prepared as an asymmetrical X-joint.

No. and joint type		Sides	Method	Thickness
17. X-joint $\beta_1 = 45°$ $\beta_2 = 15°$ C = 1.5 – 2.5 mm D = 2.5 – 3.0 mm		Two sides	MMA MIG TIG[5] FCW	14 – 30 mm[8]
18. X-joint $\beta_1 = 45°$ $\beta_2 = 15°$ C = 3.0 – 8.0 mm[4] No root gap		Two sides	SAW[9]	14 – 30 mm
19. U-joint $\beta = 10°$ R = 8.0 mm C = 2.0 – 2.5 mm D = 2.0 – 2.5 mm		Two sides	MMA MIG TIG[5] FCW SAW[10]	< 50 mm
20. Double U-joint $\beta = 15°$ R = 8.0 mm C = 4.0 – 8.0 mm[4]		Two sides	SAW[9]	> 20 mm
21. Fillet weld No root gap A ~ 0.7 x t		One or two sides	MMA MIG TIG FCW	> 2 mm

Notes:

[4] A root land of 5 mm and above may require the torch to be angled towards the direction of travel, see "Width and depth" in chapter 4.
[5] Normally only for the first 1 – 3 runs. Followed by MIG, FCW, MMA or SAW.
[8] A thickness above 20 mm can be prepared as an asymmetrical X-joint.
[9] TIG or MMA can be used for root runs. Grinding from the back. C = 3.0 mm.
[10] SAW can be used for fill and cap passes.

22. Half V-joint α = 50° C = 1.0 – 2.0 mm D = 2.0 – 4.0 mm		One side	MMA MIG TIG[6] FCW	4 – 16 mm
23. Half V-joint α = 50° C = 1.5 – 2.5 mm D = 2.0 – 3.0 mm		Two sides	MMA MIG TIG[6] FCW	4 – 16 mm
24. Half X-joint α = 50° C = 1.0 – 1.5 mm D = 2.0 – 4.0 mm		One side	MMA MIG TIG[6] FCW[5]	14 – 30 mm
25. Half X-joint α = 50° C = 1.5 – 2.5 mm D = 2.0 – 3.0 mm		Two sides	MMA MIG TIG[6] FCW	14 – 30 mm
26. Fillet weld No root gap		Two sides	MMA MIG TIG FCW	< 2 mm
27. Fillet weld D = 2.0 – 2.5 mm		Two sides	MMA MIG TIG FCW	2 – 4 mm
28. Half V-joint α = 50° C = 1.5 – 2.5 mm D = 2.0 – 4.0 mm		One side	MMA MIG TIG[6] FCW[5]	4 – 12 mm
29. Half V-joint α = 50° C = 1.5 – 2.5 mm D = 1.5 – 2.5 mm		Two sides	MMA MIG TIG[6] FCW	4 – 16 mm
30. K-joint β = 50° C = 2.0 – 2.5 mm D = 2.0 – 4.0 mm		Two sides	MMA MIG TIG[6] FCW	14 – 30 mm[8]

Notes:

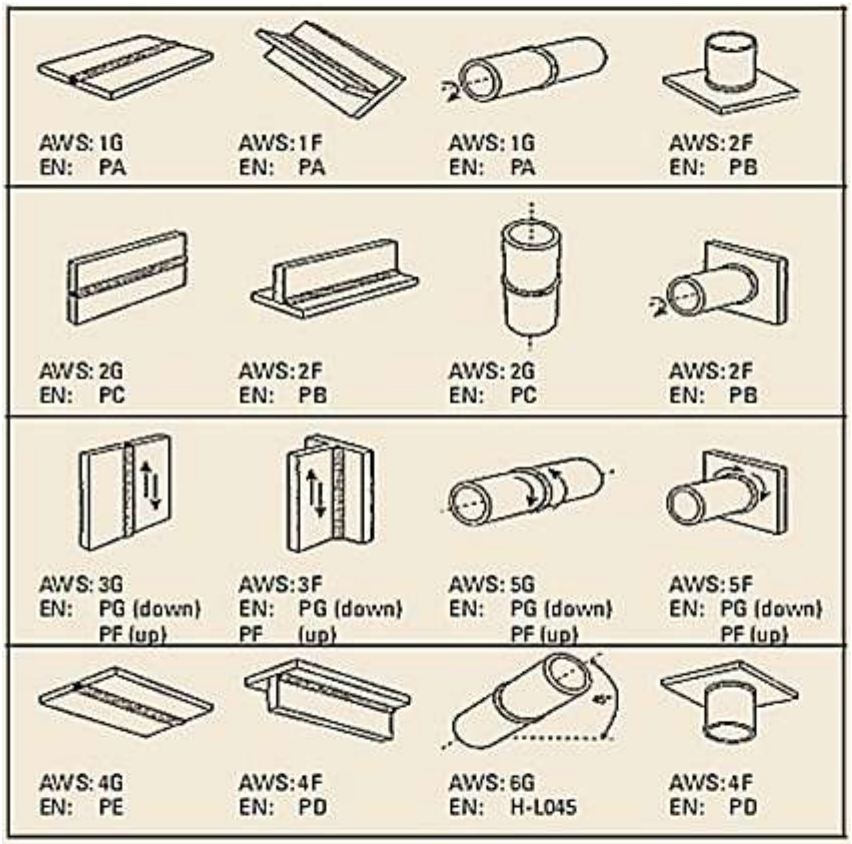
[5] Welding performed against ceramic backing (round type).
[6] Normally only for the first 1 – 3 runs. Followed by MIG, FCW, MMA or SAW.
[7] For openings such as manways, viewports and nozzles.
[8] A thickness above 20 mm can be prepared as an asymmetrical X-joint.

V - STANDARDS FOR WELDING POSITIONS:

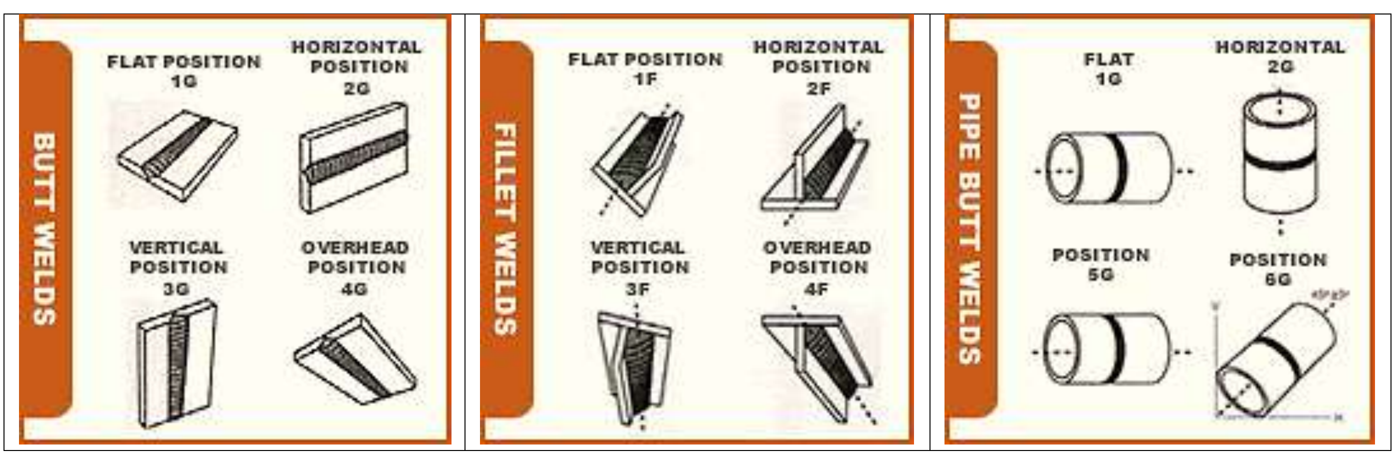
The position, or location, of a joint relative to the horizon is important because it may determine what welding process, methods, and techniques can be used.

Welding is usually easiest when the welder can work on a joint located on a flat, horizontal surface, such as on a table or bench. However, joints in the field may be located in a variety of positions relative to the welder and to the horizon as shown below.

Welding positions according to **AWS D1.1** and European Welding Standard **EN 287 – 1** and **ASME IX**.

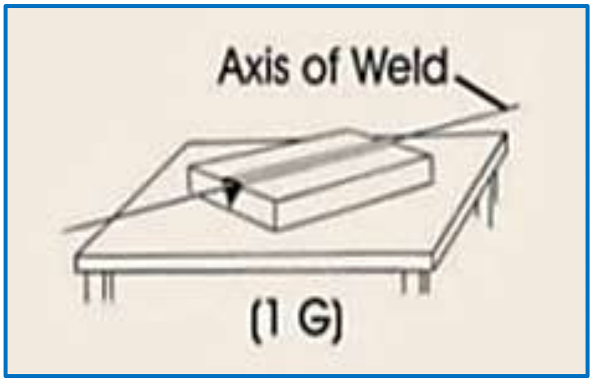


1) Welding Positions for Butt, Fillet and Piping Welds:



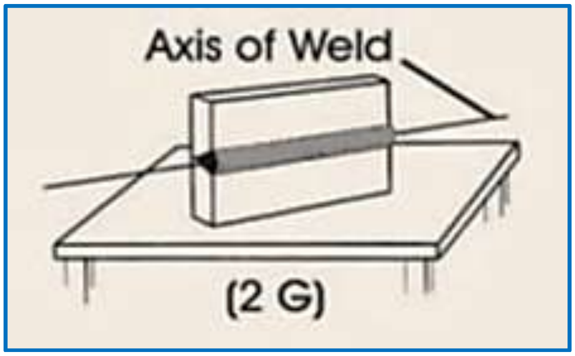
1.1) Flat Butt-Weld Position - 1G:

In this position, the axis line of the weld must **not incline more than 15°** from the horizon and the face of the weld must be on top. Welders often refer to the flat-position welding by the nonstandard term ***downhand welding.***



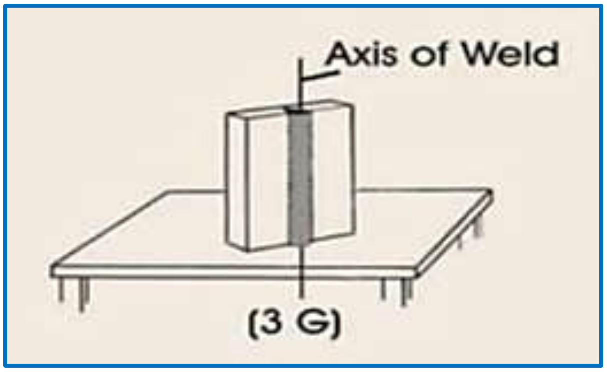
1.2) Horizontal Butt-Weld Position - 2G:

In this position, both plates are perpendicular to the bench top, but the axis of the weld remains horizontal. The lower surface of the groove helps somewhat to hold the molten weld metal in place.



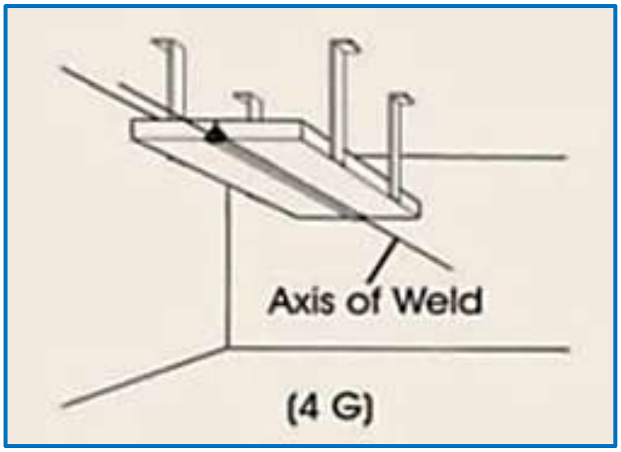
1.3) Vertical Butt-Weld Position - 3G:

In this position, the axis of the weld is perpendicular to the bench top and more difficult than in the flat and horizontal positions. The two plates and the axis of the weld are inclined more than 15° in reference to the horizontal bench top.



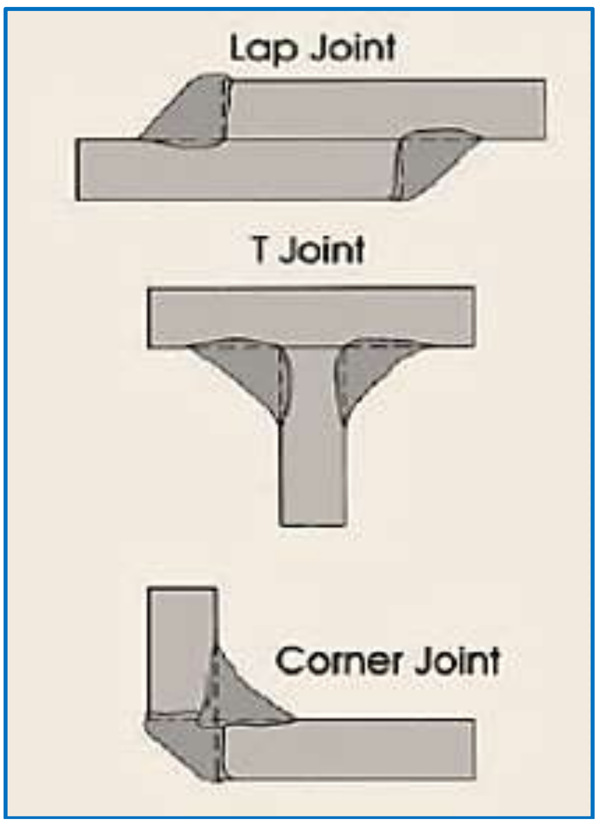
1.4) Overhead Butt-Weld Position - 4G:

In this position, the axis of the weld and the plates are horizontal, but the face for welding is downward. Welding in the overhead position is very difficult because there's nothing to help overcome the force of gravity. A welder must have a high degree of skill to make sound welds consistently in this position.



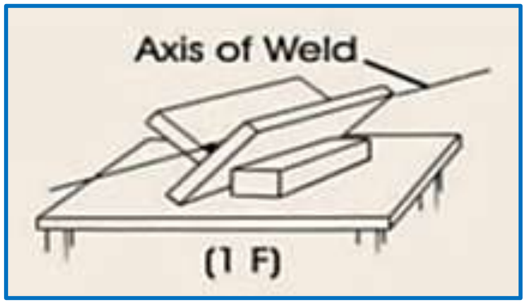
2) Fillet Welds and Their Positions:

The advantage of the fillet-welded joint is **that it's unnecessary to prepare the edges** of the plates or sheets for welding**. Double fillet-welded joints are an improvement** over single-fillet joints because they can withstand loads from more than one direction. During work, **three** of the five basic types of joints - **the lap, the T-joint and the corner joint** - can be joined with fillet welds.



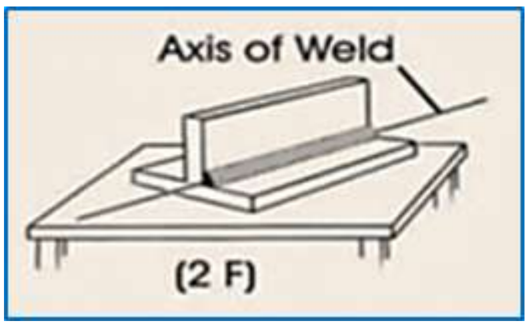
2.1) Flat Fillet Weld Position – 1F:

The **axis of the flat position fillet weld is either horizontal or inclined not more than 15°** to the horizontal. **The surfaces of the plates are each inclined at about 45° to the horizontal**. The typical flat-position fillet weld is similar to the flat-position groove weld. The difference is in the positions of the plates forming the joint.



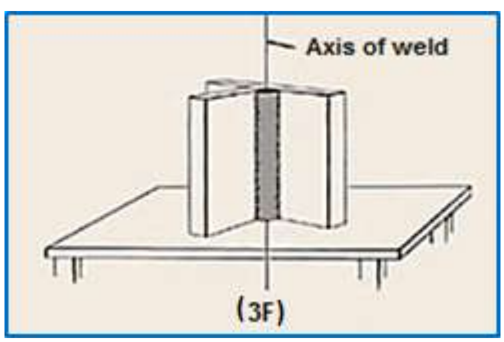
2.2) Horizontal Fillet Weld Position – 2F:

In this position, both the axis of the weld and the lower plate of the joint assembly are horizontal. For the **T-joints and inside corner joints**, the other plate **is vertical**. **For lap and outside corner joints**, only the edge of the other member **is vertical**.



2.3) Vertical Fillet Weld Position – 3F:

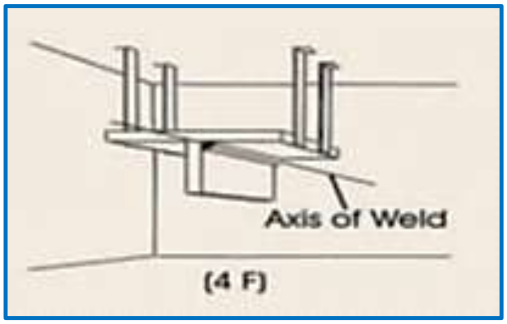
The plates and the axis of the fillet weld are perpendicular to the bench top. Vertical fillet welding is a difficult operation requiring a high degree of skill.



Note: Welders should be tested according to a qualified Weld Procedure Specification (WPS). However, welding vertically in a downward progression does not fit within the guidelines of AWS D1.1-2010, Clause/Sub-section 3.7.1).

2.4) Overhead Fillet Weld Position – 4F:

Overhead position fillet welds are **basically horizontal-position fillet welds** turned upside down. **The axis of the weld is horizontal**, and the plates are usually vertical and horizontal. This is another difficult welding position because there's nothing to hold the molten metal against the force of gravity.

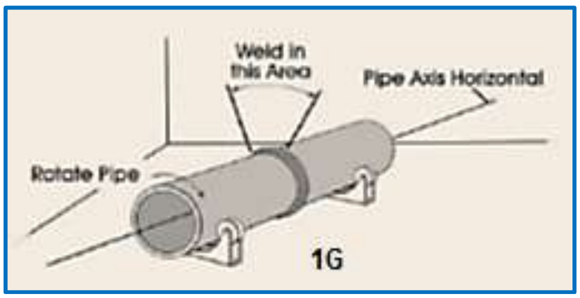


3) Positions for Welding Pipe:

For **welding pipe in shops, power plants, oil refineries, and chemical plants** for crude oil, gasoline, and natural gas, the **same basic welding positions** described previously are used.

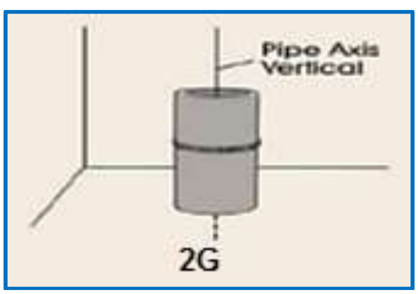
3.1) Flat Butt-Weld Pipe Position – 1G:

A pipe to be welded in the flat position **is usually placed on roller dollies or wooden skids**. As the pipe is welded, it's rotated on the dollies or skids. This procedure **is the same as the flat position plate welding**. The speed of rotation should be the same as the welder's forward welding speed.



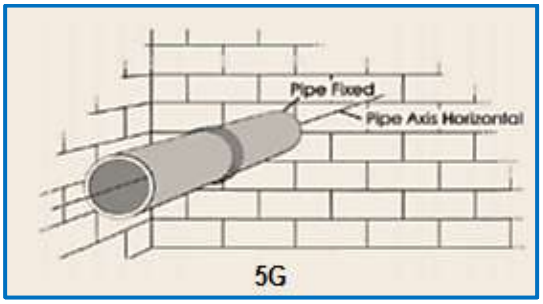
3.2) Horizontal Butt-Weld Pipe Position – 2G:

In this position, the weld around the vertical pipe **is the same of a horizontal position plate welding.** There is little difference whether the pipe is rotated or fixed because the welding is the same. Either the welder will circle around the joint, or the pipe itself can be turned in a circle if it's free to rotate.



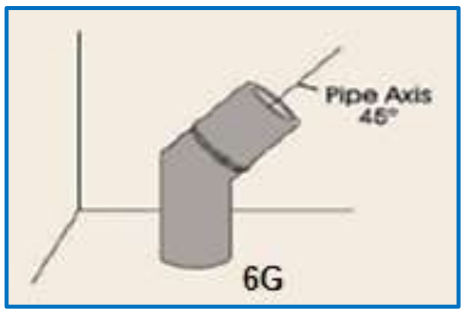
3.3) Multiple Butt-Weld Pipe Position – 5G:

In this position, the axis of the pipe is horizontal, but can’t be rotated. As the welder works around the pipe to make the weld, he or she must weld in a number of different positions.

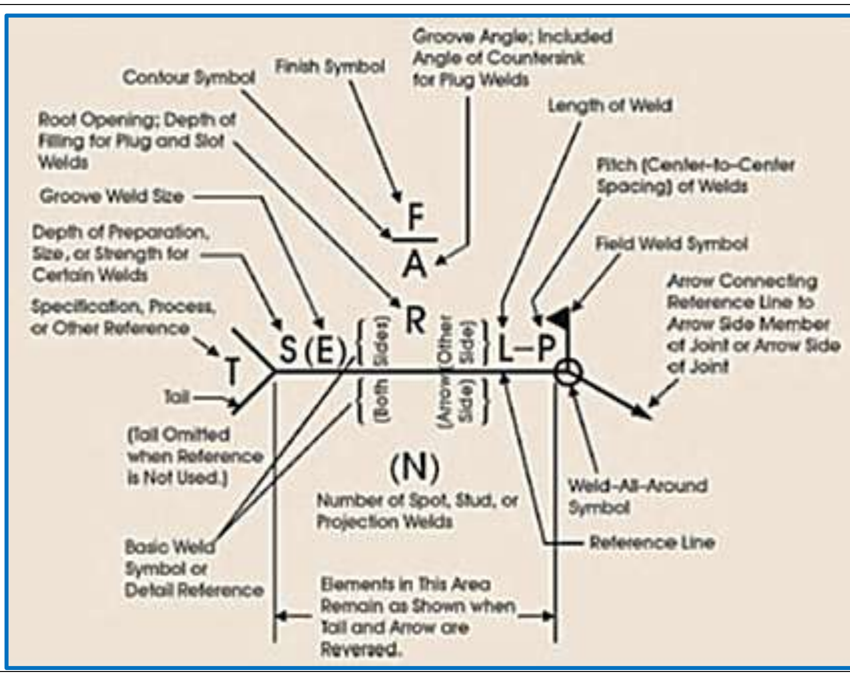


3.4) Multiple Butt Weld in Angled Pipe Position – 6G:

In this position, the axis of the pipe is at a 45° angle to the horizon. This position is used widely in testing welders’ ability. Therefore, it’s used as an all-position qualification test for pipe welders.



VI – WELDING SYMBOLS:



The basic and supplementary symbols are combined with other elements to produce the complete welding symbol as shown aside.

The elements of the symbol are **the *reference line*, an *arrow* on one end of this line, and the *tail of the arrow*** on the opposite end.

The arrow end may be drawn at any angle necessary to connect the reference line to the weld location.

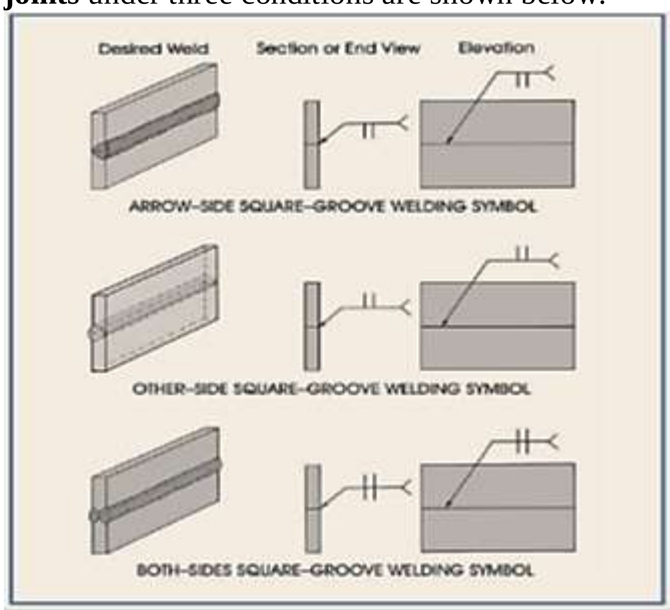
1) Supplementary Symbols for Welds:

The **circle** used as the **weld-all-around symbol** means that welding is to be **all around the joint**. The **small flag, or field weld symbol**, means the weld is to be made in **the field**. The **solid black** semicircle, or **melt-thru symbol**, indicates the weld is made by melting through the top piece into a lower piece.

2) Groove Welding Symbols:

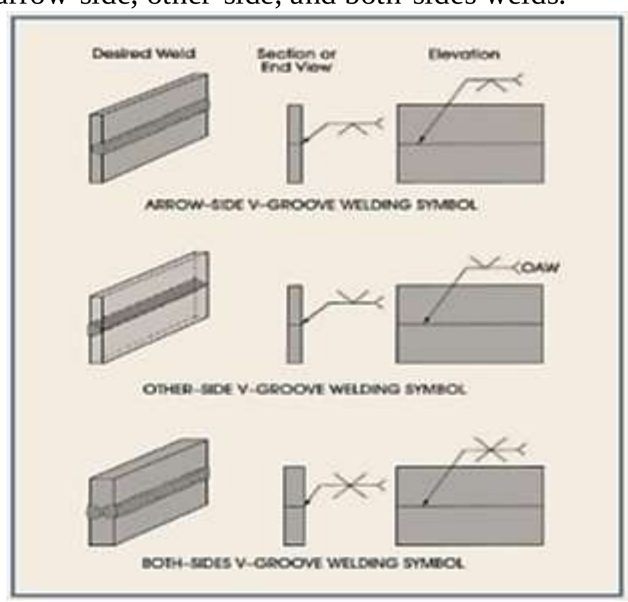
In the following figures, the perspective drawings of welded joints are shown at the left, looking at each joint from the arrow side. The illustrations cover only a small number of all possible symbols. The symbols shown here are those of the most common manufacturing application.

The welding symbols for **square-grooved butt joints** under three conditions are shown below.



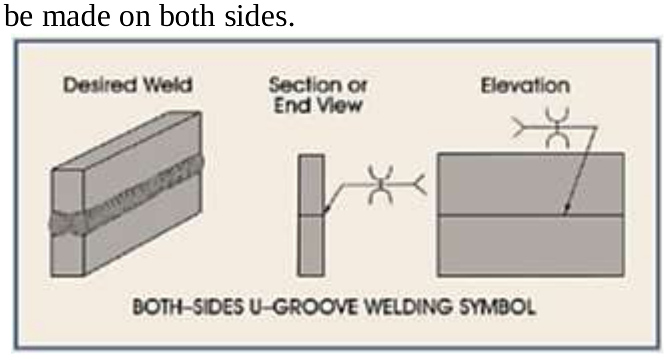
Note that the weld symbol may be placed above, **below, or on both sides** of the reference line.

The **V-groove welding symbol** indicates the arrow-side, other-side, and both-sides welds.

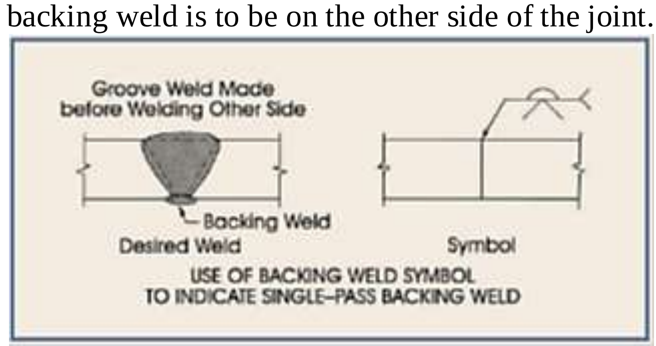


The symbol for the other-side weld, **oxyacetylene welding is indicated** as the process to be used.

The U-groove symbols, means that the weld is to be made on both sides.

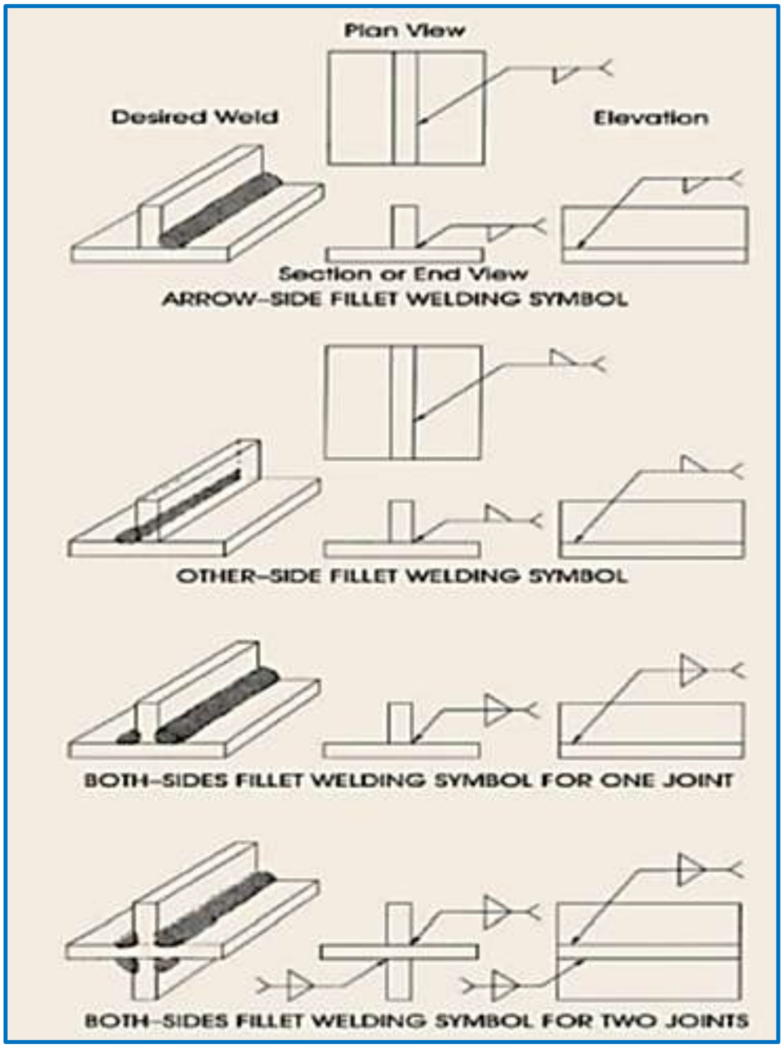


The symbol appears above the line, means the backing weld is to be on the other side of the joint.



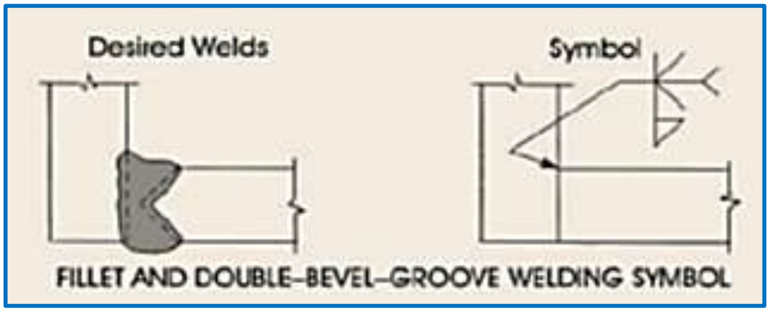
3) Fillet Welding Symbols:

The **single-fillet-welded T-joints** are indicated from both the arrow side and the other side. The symbol for a **double fillet-welded T-joint** is also illustrated. Note that the assembly of two T-joints welded pieces involves **four fillet welds** represented by **two double-fillet-weld** symbols.

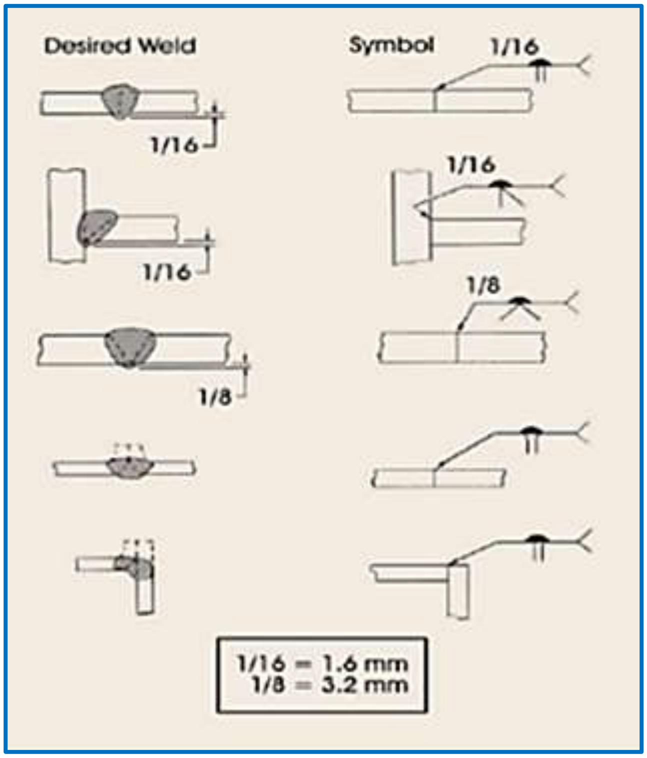


3.1) Fillet Combined Welding:

The most common arrangement uses a **fillet weld** in conjunction with a **bevel- or J-groove weld**. The fillet weld can be added if the **bevel- or J-groove** weld is on a corner or a T-joint.



3.2) Fillet Weld Root Penetration:

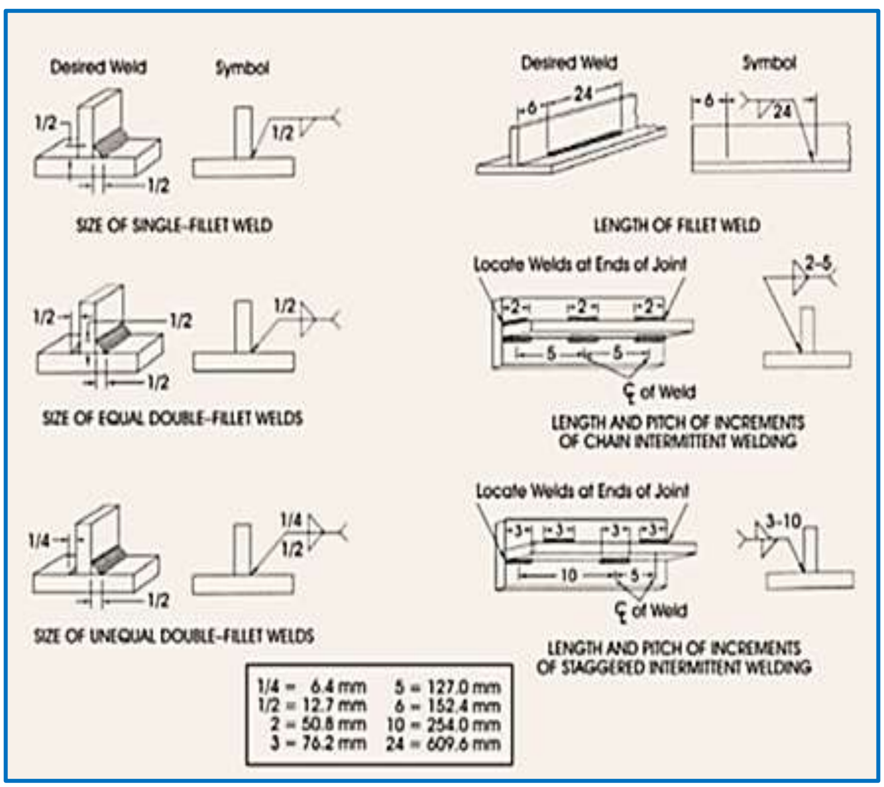


Weld penetration beyond the depth of the groove is indicated aside. The first dimension gives the depth of penetration into the groove; the second dimension gives the additional penetration into the joint root.

Weld penetration beyond the depth of the groove is also indicated aside.

The first dimension gives the depth of penetration into the groove; the second dimension gives the additional penetration into the joint root.

3.2) Dimensioning Fillet Weld Symbols:

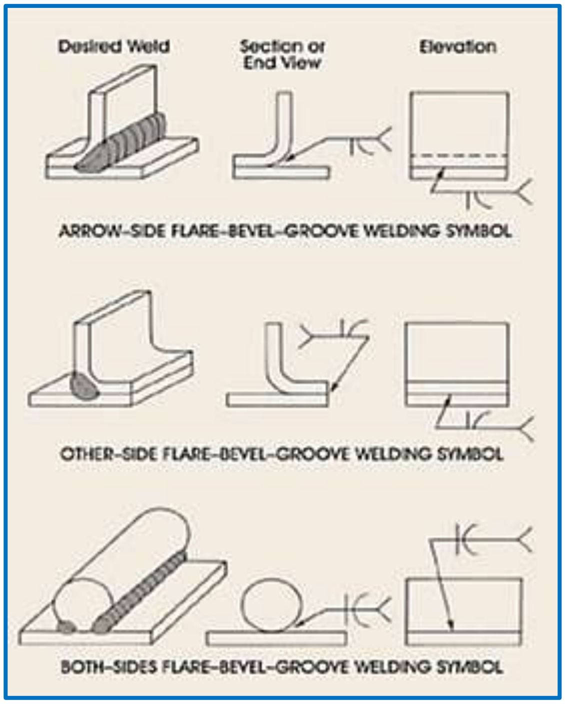
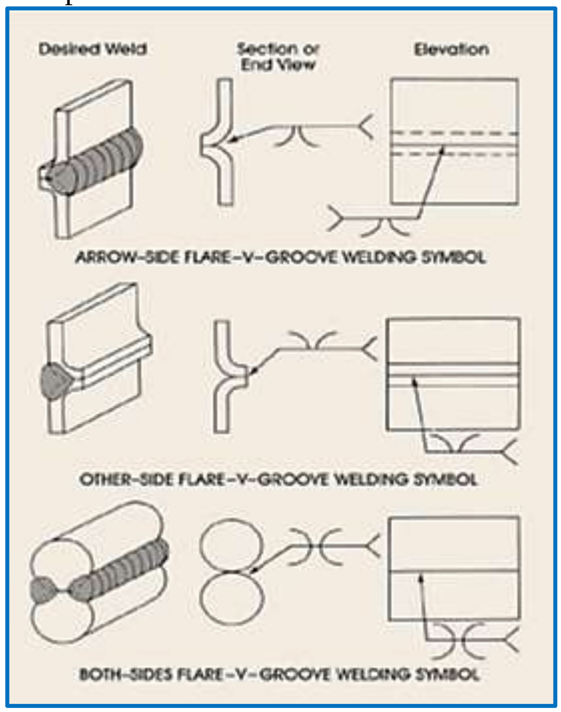


Designers need to specify the desired sizes of fillet welds because welders usually can’t determine the dimensions of the parts to be welded.

The **drawings** of the welded joints are shown **on the left** and the **dimensioned symbol** for each joint **is shown on the right**.

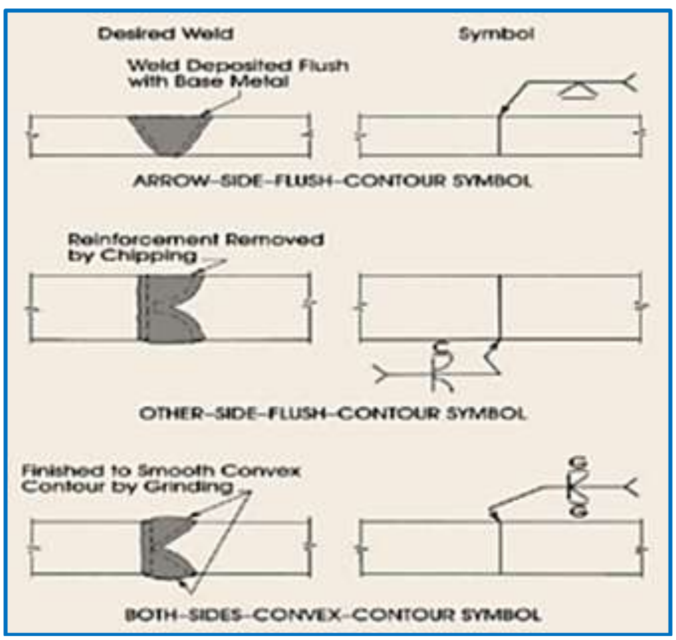
4) Flare V-groove Welding Symbols:

The **flare-V-groove weld** is created when two flanged relatively **thin sheets or plates are joined**. This joint shape is different from the conventional V and so needs a different symbol.

One piece of the joint is rounded while the other member is flat. 	The flanged or flared edge is at a right angle to the sheet or plate. 

5) Contour Symbols for Welding:

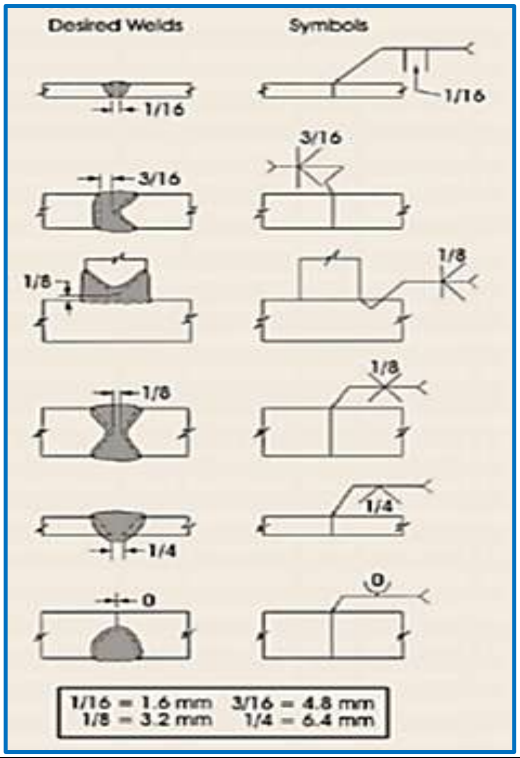
When **weld surface finishing** must be controlled, standard letters are used to indicate finishing operations as, ***C for chipping, G for grinding, M for machining, R for rolling, and H for hammering***.

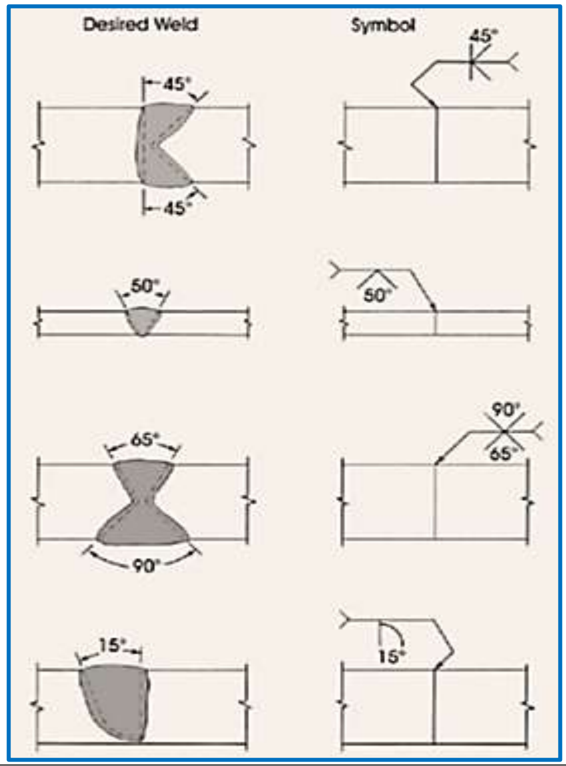


6) Indicating Sizes on Symbols:

The mechanical welding designers can specify to the welders **the sizes of root openings**, **specific groove angles, root penetrations, the lengths of fillet welds, and the spacing** of weld beads.

The root opening, or the minimum spacing between members of a joint, as indicated below.	The angle or angles required for the preparation of joints are placed within the basic weld symbol.





VII. WELDING OF STAINLESS STEELS:

a) General Concepts:

Stainless steels are defined as chrome-nickel steel alloys, where the **chromium content** ranges from **10.5% to 30%.** There are five distinct types of stainless steel:

1) Ferritic Stainless Steel:
Contains **10.5 to 27% chromium**, has low carbon (0.08~0.2%) and some special alloys contain large amounts of molybdenum, niobium and titanium. (Ex. AISI 430/442).

2) Austenitic Stainless Steel:
Contains **16% to 26% chromium**, up to 35% nickel and very low carbon content (0.08 ~0.25%). Some of these steels are also alloyed with a small amount of molybdenum and selenium. (Ex. AISI 304/308/310).

3) Martensitic Alloy Steel:
Contains **12% to 18% chromium**, up to 0.75% nickel and contains low carbon (0.1~0.95%). Some alloys will also have small additions of molybdenum, vanadium, niobium, tungsten, aluminum and copper. (Ex. AISI 410/420).

4) Duplex Stainless Alloys:

Contain **18% to 28% chromium**, 2.0% to 8% nickel and low carbon (0.01~0.05%). Some of the alloys have additions of cobalt, niobium, titanium, molybdenum, tungsten, aluminum and copper. (Ex. S30403/2205/2507).

b) Stainless Steel Welding Processes:

All **stainless steels are commonly weldable by SMAW, GMAW, FCAW, and SAW processes**. **GTAW is also commonly used**, but it is a slow process. The most used process is SMAW because the equipment is portable and easy to use.

Processes by GMAW, FCAW, and SAW are being used more often because they are economical and produce high quality welds. The manufacturers' recommendations for welding stainless steel should be followed including joint designs, preheat temperatures, any associated post-weld heat treatment, and shielding gas.

c) Joint Design:

Weld joints are prepared by plasma-arc cutting, machining or grinding, depending on the alloy as indicated in chapter I. Before welding, the joint surfaces must be cleaned of all foreign material, such as paint, dirt, scale, or oxides. Cleaning may be done with suitable solvents (e. g., acetone or alcohol) or light grinding. Care should be taken to avoid nicking or gouging the joint surface since such flaws can interfere with the welding operation.

(1) A full penetration joint has weld metal throughout the entire cross section of the weld joint.

(2) Partial penetration joint has an unfused area and weld does not completely penetrate the joint.

(3) The rating of the joint is based on the percentage of weld metal depth to the total joint; which is, a 50 percent partial penetration joint would have weld metal halfway through the joint.

Carbon and Low Alloy Joint Design: These weld joints are prepared either by **flame cutting or by machining or grinding**, depending on the joint details. Before welding, the joint surfaces must be cleaned such as paint, dirt, scale, or must. Suitable solvents or light grinding can also be used. **Stainless steel** alloy joint design: These weld joints are prepared either by **plasma arc cutting or by machining or grinding**, depending on the alloy. Before welding, the joint surfaces must be cleaned of all foreign material, such as paint, dirt, scale, or oxides.

VIII. WELDING OF LOW-ALLOY STEEL:

a) General Concepts:

The steels commonly used in plate manufacturing, bridges, and piping systems are covered in specifications of ASTM, AISI, ASME, SAE, and API. These specifications often refer to the same types of steels, although they put different restrictions on the chemical analysis and mechanical properties.
Commonly the most used materials for welded construction meet specifications conform to ASTM A 36, A 203, A 242, A 440, A 441, A 514, A 517, A 572 and A 588. For piping materials the main specifications are ASTM A 53, A 106, A 134, A 139, A 671, A 672 or A 691 or API 5L, 5LX, or 2H.

b) Low Alloy Steel Welding Processes:

All **low alloy steels can be welded by SMAW, GMAW, FCAW, and SAW processes**. **GTAW is also commonly used**, but it is a slow process. The most used process is SMAW because the equipment is portable and easy to use.

AWS D1.1 contains a selection guide to match electrode types with various **ASTM** and **API** steels. The manufacturers' recommendations and normalized procedures should be followed when developing the welding procedures, to avoid welding failures, including heat-treatment and stress-relief for **high strength low alloy steels** conforming to ASTM A 514, A 517, or A 710.

a) Joint Design:

Weld joints are prepared by flame cutting or mechanically by machining or grinding, as indicated in chapter I, depending on the recommended applicable joint details. **AWS** requires the deposited weld metal to have minimum tensile and impact strengths, evaluation of the chemical requirements and preheat treatment to avoid porosity, slag inclusions, incomplete fusion, inadequate joint penetration and cracking.

The detailed requirements for mild steel electrodes are listed in **AWS A5.1**, and for low-alloy steel electrodes in **AWS A5.5**, including other processes. Commonly used ASTM and API steels, and filler metal requirements are listed in **AWS D1.1** in the table "*Matching Filler Metal Requirements*".

IX. WELDING OF RAILS, CAST AND WROUGHT STEELS:

a) Rails Welding:

There are four types of welding methods for rails: **Flash Welding (FW)**, **Gas Pressure Welding (GPW)**, **Enclosed-Arc Welding (EAW)** and **Aluminothermic Welding (ATW)**. The former has high reliability as well as high productivity and the latter has high mobility.

Aluminothermic, **Exothermic or Thermite Welding** is described in the AWS Welding Handbook, Section 2. It is a process that employs a reaction between iron oxide and aluminum producing a red hot iron slag, which is the filler material, through a **chemical reaction called exothermic or aluminothermic.**

Detailed welding procedures must be prepared. After the welds are completed should be visually inspected, but, the **visual inspection must not be used for acceptance**. If there are blowouts or voids, the welded joint should be replaced. Internal defects such as lack of fusion, slag inclusion, porosity, and cracks might not be visible.

Radiographic and Ultrasonic Inspection: Must be included in the welding procedures and specifications. However, since varying thicknesses are still involved, this method is hard to use and results may be inconclusive.

Magnetic Particle Inspection: Is used for gas-pressure welded and flash-welded rail but is not as suitable for rail welds made by the exothermic process. Railroad personnel generally use the **Sperry Rail Detector** cars to inspect the rails when the track is not being used.

b) Cast and Wrought Steels:

Cast Steels and Wrought Steels: Are usually welded to **repair defects** in some damaged manufacturing condition. The welding procedure of steels is primarily a function of mechanical strength, chemical composition and heat treatment. With heat-treatable electrodes, the necessary welding sometimes **can be done before final heat-treating**. After being subjected to an austenitizing treatment (heating above the upper critical temperature), the weld deposits with carbon contents **less than 0.12 percent** usually have lower mechanical properties than they have in the as welded or stress-relieved condition.

Joint designs for cast steel welding are similar to those used for wrought steel. The **AWS D1.1, Section 2** contains design criteria for welded connections and a list of prequalified joint designs. Any other type of joint design must be qualified before being used in the structure.

The choice of **electrode filler metal** is based on the **type of cast steel being used**, the strength needs of the joint, and the post-weld heat treatment. When welding carbon or low-alloy cast steels, the **same electrodes recommended for steel plates should be used**.

When **cast austenitic stainless steels are welded** to either cast or wrought ferritic materials, the proper filler metal depends on the service conditions. If the application service temperature is low (below 600°F) and the stresses are moderate, a **high-alloy austenitic stainless steel filler metal**, such as **AISI 309 or 310**, is generally used. For application conditions under higher temperatures and stress, the high-nickel welding materials **(70% Nickel, 15% Chromium)** are better because their thermal expansion is closer to that of the ferritic materials.

High-nickel weld metal retards carbon migration and this weld metal should be used with a technique to reduce nickel's dilution of the ferritic material.

X. INSPECTION PROCEDURES:

1) General Conditions:

Weld inspection serves as a quality control on the welding operators and welding procedures. **Records of how often various types of defects** occur can show when changes in welding procedures are needed, detecting poor welding practices or when the welders or welding operators should be re-qualified.

The quality criteria as defined in applicable specifications and standards, must judge whether the inspected welding is conform in all respects to the specifications. The inspector must know the limitations of the testing methods, the material, and the welding process.

Personnel doing nondestructive testing must be qualified according to **ASME** or **ASNT (American Society for Nondestructive Testing)** using the current requirements of the **ASME IX** and **ASNT SNT-TC-1A**. A responsible manufacturer **depends entirely on inspection records** to correct problems soon enough to prevent the lost time, high costs of frequent repairs.

2) Inspection Duties:

- Understand shop drawings, erection drawings, referenced codes and standards.
- Review the manufacturer's **Material Test Report (MTR)**. Verify all materials properties and that all materials are readily identifiable and traceable to an MTR.
- Conduct a complete visual examination of the welding area for visible discontinuities. Visual examination should include, as a minimum, the finished conditions of the seam weld.
- For visual examination, the only equipment commonly used is a **magnifying glass** (10x or less) and a **flashlight**. Other tools, such as a **borescope and dental mirrors**, are useful for inspection inside vessels, pipe, or confined areas.
- For structural plates, piping, wrought and cast steel, conduct a complete visual examination of surfaces for visible fabrication defects or discontinuities.
- Verify that all applicable welders, welding operators or tack welders are **qualified for the job** and the qualifications reports are available, current, and accurate.
- Verify that a written **Welding Procedure Specification (WPS)** is available for each type of weld, in compliance with all requirements, and that the WPS has been approved as required.
- Evaluate all **Procedure Inspection Tests (PIT)** and verify that the **Procedure Qualification Records (PQR)** are compliant with all applicable requirements.
- Verify that all welding consumables comply with the quality approved documents and the **Welding Procedure Specification (WPS)**. Verify that all **electrodes are properly stored**.
- Verify that the welding current and voltage are within the **WPS parameters** by using a **calibrated hand-held volt/amp meter**. Readings should be taken as near the arc as possible.

- Verify that joint preparation, assembly practice, preheat temperatures, interpass temperatures, welding techniques, welder performance, and **Post-Weld Heat Treatment (PWHT)** meet the requirements of the quality approved documents, WPS, and applicable AWS code.

- Verify size, length, and location of all welds. Verify that all welds conform to the requirements of the AWS code. Weld size and contour **shall be measured with suitable gauges**.

- Execute a distinguishing mark in completed welds and joints just inspected and accepted using a tag or a dye stamp. The mark shall include; inspector's initials, inspection date and status.

- Schedule or notify those responsible for the **Nondestructive Testing (NDT) technicians** in a timely manner, after visual inspection and acceptance is complete, and the assembly has cooled.

3) Inspection Reporting Duties:

- Daily inspection reports must describe the inspection process and document all inspection duties as above. Reports shall include a systematic list of accepted and rejected welds, parts, or joints.

- Reports shall reference the details on the quality approved documents and the **Procedure Inspection Tests (PIT)** used as basis for inspection.

- Inspection reports must state that the work was inspected and met the requirements of the approved documents. Reports indicating non-compliance shall be submitted immediately.

- At the conclusion of the work, the welding inspector is required to sign and submit a clear report.

4) Inspection Documentation Experience:

- Experience in documentation with a direct relationship to weldments fabrication according to American or European standards.

- Experience in the development of plans, drawings, procedures, inspection requirements, acceptance criteria, and specifications for weldments.

- Experience in planning, control, supervision, and application of base metals and filler metals in the preparation and completion of production weldments.

- Experience in fabrication, construction, and supervision of personnel in erection of welded assemblies or subassemblies.

- Experience in the detection and measurement of weld discontinuities by application of visual or other nondestructive evaluation processes to a written procedure.

- Experience in supervision of personnel engaged in material and weld examination.

- Experience in repair welding, or supervision of personnel performing weld repairs, preparation of written procedures for welding, nondestructive evaluation, or destructive tests.

- Experience in the qualification of welders or welding procedures, welding design functions as specified in the applicable codes, standards or specification.

- Experience in operational techniques and activities used to fulfill quality control requirements for welding and using a quality system.

5) Inspection Procedures:

The quality, integrity, properties, and dimensions of materials and components can be inspected with methods that do not cause damage. The main **NDT (nondestructive tests) methods** are:

- Visual Inspection - VT
- Liquid Penetrant Testing - LT
- Magnetic Particle Testing - MT
- Radiographic Testing - RT
- Ultrasonic Testing – UT
- Eddy Current Testing – ET (not used in field inspection)
- Acoustic Emission Testing – AET (not used in field inspection)

It is very important to inspect the finishing of seam welds and root passes before more weld is deposited. If there is a crack, it may propagate with subsequent passes and if this happens, the entire weld must be removed and the joint re-welded.

Follow-up inspection of root passes is important because subsequent passes may seal a crack so tightly that it cannot be detected by visual inspection

When a defective weld is removed and the joint is re-welded, the repaired weld should be inspected all over again and cracks should be checked very carefully.

It is less expensive and quicker to replace defective tack welds and root passes before more weld metal is added. Thus, these welds should be inspected as soon as they are made.

5.1) Visual Inspection – VT:

Visual inspection after welding is very useful in evaluating quality, even if other testing methods are to be employed. There is no good sense in submitting an obvious visual bad weld to subsequent sophisticated inspection methods. As welding progresses, surface flaws such as cracks, porosity, and unfilled craters can be detected, leading to repairs or rejection of the work.

Welds must be cleaned from slag to make inspection for surface flaws possible. A **10x magnifying glass** is helpful in detecting fine cracks and other faults. As indicated before, a **borescope and dental mirrors** are useful for inspection inside vessels, pipe, or confined areas.

The objective of visual inspection at this stage is not only to **detect non permissible faults**, but also to give clues to what may be wrong in the entire repair /fabrication process. If the inspector **has a sound knowledge of welding**, he can read much from what he sees.

Thus, the presence of excessive porosity and slag inclusions may be an indication of insufficient current even if the dial readings on the machine tell otherwise.

Shot blasting should not be used prior to examination, since the peening action may seal fine cracks and make them invisible.

Inspector visual requirements: Shall be performed the eyes examination, with or without corrective lenses, to prove near vision acuity on **Jaeger J2 at not less than 12 inches** and a color perception test.

5.2) Liquid Penetrant Testing – LT:

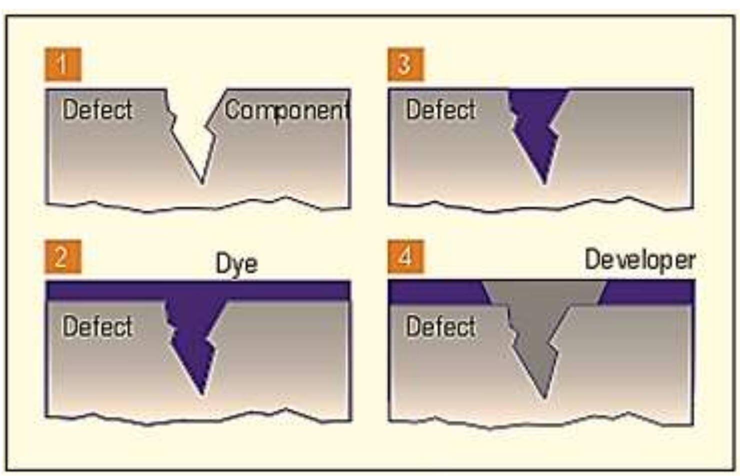
Liquid Penetrant inspection methods are used to check nonporous materials for defects open to the surface and surface defects can be found with penetrant inspection. Several types of cracks connected with seam welding, grinding, porosity or lack of bond between metals, this method can locate.

The equipment used in Liquid Penetrant Testing is portable: aerosol cans of cleaner, dye, and a developer. When fluorescent penetrant is used, a black light source in the 36-angstrom unit range and a hood or dark area are required. Portable inspection kits for field use are commercially available.

The procedure conforms to **ASTM E 165**. There are three types of penetrant: water washable, post emulsifying, and solvent removable. Inter-mixing these materials is not permitted.

Liquid Penetrant Testing can be done quickly and easily; it costs less per foot of weld inspected than any other nondestructive method except visual inspection. However, surface porosity and improper surface cleanliness reduce the sensitivity of the inspection technique and contaminants such as water, oil, and grease can cover or fill discontinuities so the penetrant does not enter.

In Liquid Penetrant inspection, both visible and fluorescent, the surface of a material is **coated with a film of penetrating liquid**. The liquid is allowed to **seep into any flaws that are open to the surface**, and the **excess surface film is removed**. A **developer** is then applied; **it draws the penetrant** from a discontinuity to the surface **so the inspector can see the flaw**.



In **petrochemical plants, pressure vessels and piping**, which are often made of nonmagnetic materials, can be inspected for surface shallow cracks and porosity by this method. The indications for cracks and porosity bleed out rapidly upon application of the dry developer.

5.3) Magnetic Particle Testing – MT:

Magnetic Particle inspection is a nondestructive method of detecting cracks, seams, inclusions, segregations, porosity, lack of fusion, and similar flaws in ferromagnetic materials such as steels and some stainless steel alloys.

The main disadvantage is that it applies **only to magnetic materials** and is not suited for very small, deep-seated defects. The deeper the defect is, the larger it must be for detection. Subsurface **defects** are easier to find **when they have a crack-like shape**, such as **lack of fusion** in welds.

The part to be **inspected is magnetized by passing through it a low-voltage, high-amperage electric current**, or by placing it in a magnetic field. Electrical poles form at the ends of the flaws. The fine magnetic particles applied to the surface of the part **are attracted to these electrical poles**. The **concentration of particles** can be seen and the flaw located.

The magnetic particles applied to the weld can be as a **dry powder** or as **a suspension** in light oil. The particles used are **iron oxide particles** with a proper size, shape, magnetic permeability and retentivity. They can be applied by from.

Dry particles are in **powder form** and may be obtained in gray, red, or black for contrast. **Wet particles** consist of particles suspended in a light petroleum oil or kerosene. These particles are applied using aerosol cans, dipping, immersing, hand shakers, spraying and screens.

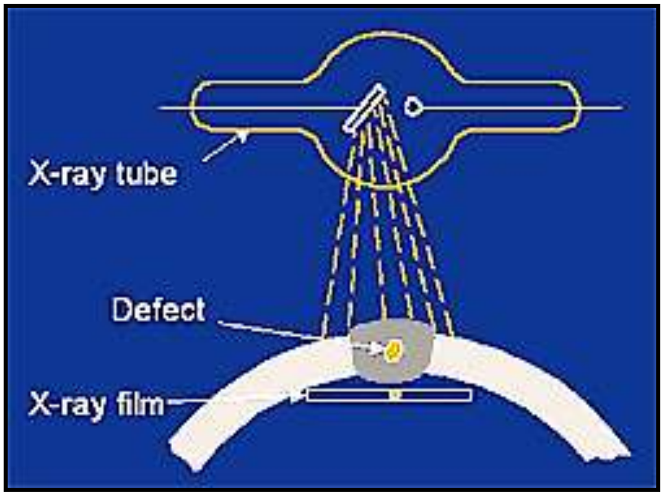
The property of any magnetic material is to keep or retain a magnetic field after the magnetizing current is removed. Usually a magnetized metal **that has high permeability** has **low retentivity**, while a metal with a low permeability has high retentivity. Construction steels generally have low retentivity.

The particles **can be colored** and have a fluorescent coating for viewing with ultraviolet light. **Wet particles provide better control** of magnetic particles through the concentration of suspension. The wet procedure is more sensitive for the detection of extremely small discontinuities.

The procedure conforms to **ASTM E 138, ASTM E 709, MIL-I-6868** and the ASME Boiler and Pressure Vessel Code, Section V.

The surface should be cleaned of all grease, oil, loose rust or water because such materials interfere with the particles which indicate defects.

5.4) Radiographic Testing – RT:



Radiographic inspection is a nondestructive inspection technique which involves **taking a picture** of the internal condition of a material. This picture is produced by **directing a beam of short wave-length radiation (X-rays or gamma rays)** through a material that would be opaque to ordinary light.

The radioactive isotopes most widely used are Cobalt 60 and Iridium 192. Gamma rays emitted from these isotopes are similar to X-rays, except the wavelengths are usually shorter. The gamma rays penetrate to greater depths than X-rays of the same power; however, exposure times are considerably longer due to the lower intensity.

This radiation **exposes a film** which is placed on the opposite side of the material. When **developed**, the film (called a radiograph), shows the presence or absence of internal defects. Different types of internal defects and flaws can be identified such as cracks, porosity, lack of fusion and entrapped slag.

Radiography uses the penetrating power of radiation to reveal the interior of a material. Radiation from a source passes through an object and causes a change in the film emulsion when the film is developed.

The limitations, however, include **high initial cost**, **radiation hazards**, **trained technicians** and be aware that certain defects, particularly cracks and lack of fusion, **be correctly oriented** with respect to the beam of radiation (if the orientation is incorrect, the defects will not be recorded on the film).

Not all of the **radiation penetrates the weld**. Some is absorbed, the amount depending on the density and thickness of the weld and on the material being inspected. Inadequate technique can result in poor sensitivity, irrelevant indications, or other problems.

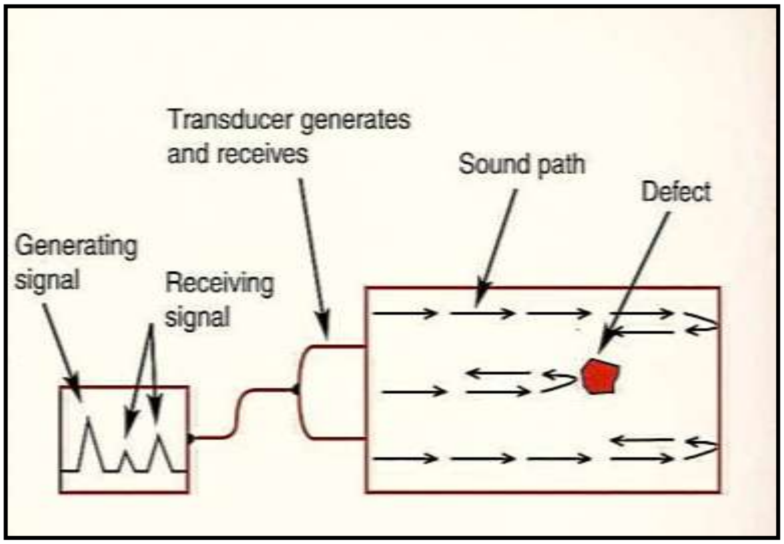
A cavity, such as a blowhole in the weld interior, leaves less metal for the radiation to pass through, so that the amount absorbed by the weld will vary in the defective region. These variations recorded on a radiation-sensitive film, produce an image that will indicate the presence of the defect.

The procedure conforms to **ASTM E 94, ASTM E 142**, and AWS D1.1. Procedures are also outlined in **MIL-R-11470, MIL-STD-453**, and the ASME Boiler and Pressure Vessel Code, Section V.

5.5) Ultrasonic Testing – RT:

Ultrasonic inspection is an energy wave form with frequencies above 20,000 Hertz. The **ultrasonic wave is introduced** into the material being tested **by a piezoelectric transducer** placed in contact with the test specimen. The ultrasound enters the specimen and is **reflected back to the transducer** when it encounters an **interface that could be a flaw** or the back surface of the material.

The transducers consist of a **straight beam and an angle beam** in the frequency range of 0.1 to 15.0 MHz. The angle beam transducers that can be used are of 70°, 60° and 45°.



The ultrasonic vibrations are converted to electric signals, amplified, and **displayed on a Cathode Ray Tube (CRT)** screen. Because of the high frequency (above the range for the human ear), the short wave-length **allows small flaws** to be detected.

Ultrasonic reference blocks are usually needed to check the sensitivity and performance of ultrasonic instrumentation and transducers for inspecting critical welds. AWS D1.1 recommends several standards, the most common being the International Institute of Welding (IIW) reference blocks.

By using **calibrated standards blocks** and a few calculations, the inspector can classify the indications as irrelevant, acceptable, or unacceptable. Ultrasonic inspection has a higher sensitivity level than radiographic inspection.

Ultrasonic inspection detects both **internal and surface flaws** in all types of welded joints. Defects such as slag inclusions, porosity, lack of fusion, lack of penetration (root defects), longitudinal and transverse cracks can be detected.

Indications of defects **can be seen immediately on the CRT**. Both internal and surface flaws can be detected, though shallow surface cracks are more easily and reliably detected with Magnetic Particle or Liquid Penetrant.

Ultrasonic inspection has many advantages over other methods. It is fast, and the equipment is compact and portable. Unlike radiographic inspection, it involves **no time delay** while film is being processed and poses no radiation hazard to persons working in the inspection area.

The limitations to restrict its use are the difficulty in **interpreting the oscilloscope patterns and the need for standards to calibrate the instrument**. This procedure produces no permanent records showing flaws and their location. A high degree of operator skill and training is required to interpret the oscilloscope patterns reliably.

The procedure conforms to **ASTM E 164** and AWS D1.1.

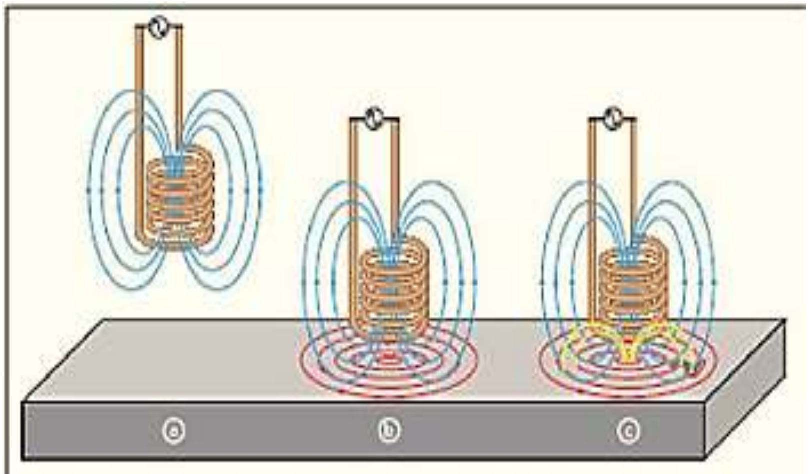
The procedures are also outlined in Appendix U to the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, and in Section V, Article 5.

5.5) Eddy Current Testing – RT:

Eddy-current inspection uses electromagnetic induction to detect flaws in conductive materials. A circular coil carrying current is placed in proximity to the test specimen (electrically conductive). The alternating current in the coil generates changing magnetic field which interacts with test specimen and generates eddy current.

The **term eddy current** (also called Foucault currents) comes from analogous currents seen in water where localized areas of turbulence **known as eddies** give rise to persistent vortices.

Variations in the electrical conductivity or magnetic permeability of the test object, or the presence of any flaws, will cause a change in eddy current and a corresponding change in the phase and amplitude of the measured current. This is the basis of standard (flat coil) eddy current inspection, the most widely used technique.



a—The alternating current flowing through the coil at a chosen frequency generates a magnetic field around the coil.

b—When the coil is placed close to an electrically conductive material, eddy current is induced in the material.

c—If a flaw in the conductive material disturbs the eddy current circulation, the magnetic coupling with the probe is changed and a defect signal can be read by measuring the coil impedance variation.

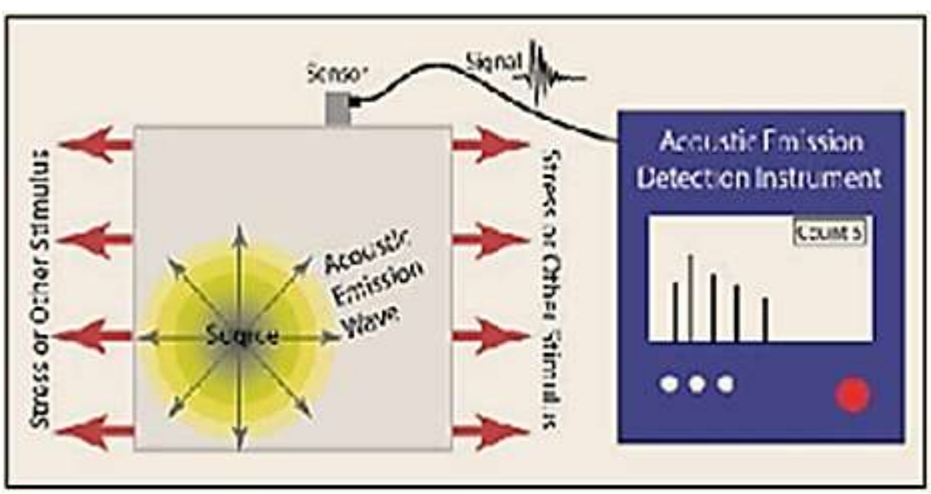
There are several limitations to Eddy Current testing, as described below:

Only conductive materials can be tested, the surface of the material must be accessible, the finish of the material may cause bad readings, the depth of penetration into the material is limited, and flaws that lie parallel to the probe may be undetectable.

The testing devices are portable, provide immediate feedback, and do not need to contact the item in question.

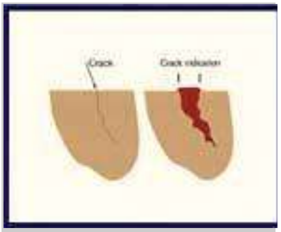
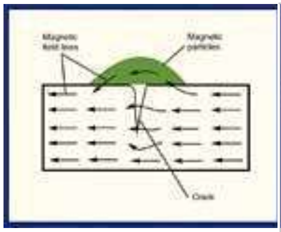
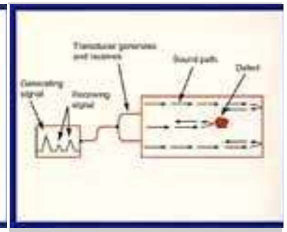
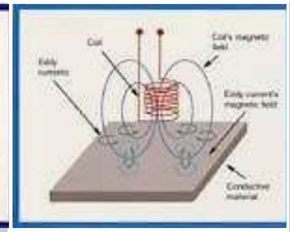
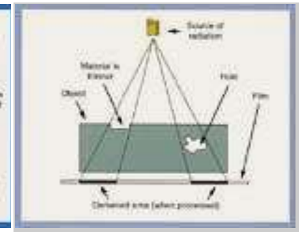
5.5) Acoustic Emission Testing – AET:

Acoustic Emission Testing (AET) unlike most other nondestructive testing (NDT) is not used commonly. Instead of supplying energy to the object under examination, AET simply listens for the energy released by the object. AE tests are often performed on structures while in operation, as this provides adequate loading for propagating defects and triggering acoustic emissions.



5.6) NDT Method Summary:

No single NDT method will work for all flaw detection or measurement applications. Each of the methods has **advantages and disadvantages** when compared to other methods. The table below summarizes the scientific principles for some of the **most often used NDT methods**:

Penetrant Testing	Magnetic Particle Testing	Ultrasonic Testing	Eddy Current Testing	Radiographic Testing
				
Scientific Principles				
Penetrant solution is applied to the surface of a pre-cleaned component. The liquid is pulled into surface-breaking defects by capillary action. Excess penetrant material is carefully cleaned from the surface. A developer is applied to pull the trapped penetrant back to the surface where it is spread out and forms an indication. The indication is much easier to see than the actual defect.	A magnetic field is established in a component made from ferromagnetic material. The magnetic lines of force travel through the material and exit and reenter the material at the poles. Defects such as crack or voids cannot support as much flux, and force some of the flux outside of the part. Magnetic particles distributed over the component will be attracted to areas of flux leakage and produce a visible indication.	High frequency sound waves are sent into a material by use of a transducer. The sound waves travel through the material and are received by the same transducer or a second transducer. The amount of energy transmitted or received and the time the energy is received are analyzed to determine the presence of flaws. Changes in material thickness and changes in material properties can also be measured.	AC is passed through a coil producing a magnetic field. When the coil is placed near a conductive material, the changing magnetic field induces current flow in the material. These currents travel in closed loops and are called eddy currents. Eddy currents produce their own magnetic field that can be measured and used to find flaws and characterize conductivity, permeability, and dimensional features.	X-rays are used to produce images of objects using film or other detector that is sensitive to radiation. The test object is placed between the radiation source and detector. The thickness and the density of the material that X-rays must penetrate and affects the amount of radiation reaching the detector. This variation in radiation produces an image on the detector that often shows internal features of the test object.
Main Uses				
Used to locate cracks, porosity, and other defects that break the surface of a material and have enough volume to trap and hold the penetrant material. Liquid penetrant testing is used to inspect large areas very efficiently and will work on most nonporous materials.	Used to inspect ferromagnetic materials (those that can be magnetized) for defects that result in a transition in the magnetic permeability of a material. Magnetic particle inspection can detect surface and near surface defects.	Used to locate surface and subsurface defects in many materials including metals, plastics, and wood. Ultrasonic inspection is also used to measure the thickness of materials and otherwise characterize properties of material based on sound velocity and attenuation measurements.	Used to detect surface and near-surface flaws in conductive materials, such as the metals. Eddy current inspection is also used to sort materials based on electrical conductivity and magnetic permeability, and measures the thickness of thin sheets of metal and nonconductive coatings such as paint.	Used to inspect almost any material for surface and subsurface defects. X-rays can also be used to locates and measures internal features, confirm the location of hidden parts in an assembly, and to measure thickness of materials.

Main Advantages				
Large surface areas or large volumes of parts/materials can be inspected rapidly and at low cost. Parts with complex geometry are routinely inspected. Indications are produced directly on surface of the part providing a visual image of the discontinuity. Equipment investment is minimal.	Large surface areas of complex parts can be inspected rapidly. Can detect surface and subsurface flaws. Surface preparation is less critical than it is in penetrant inspection. Magnetic particle indications are produced directly on the surface of the part and form an image of the discontinuity. Equipment costs are relatively low.	Depth of penetration for flaw detection or measurement is superior to other methods. Only single sided access is required. Provides distance information. Minimum part preparation is required. Method can be used for much more than just flaw detection.	Detects surface and near surface defects. Test probe does not need to contact the part. Method can be used for more than flaw detection. Minimum part preparation is required.	Can be used to inspect virtually all materials. Detects surface and subsurface defects. Ability to inspect complex shapes and multi-layered structures without disassembly. Minimum part preparation is required.
Disadvantages				
Detects only surface breaking defects. Surface preparation is critical as contaminants can mask defects. Requires a relatively smooth and nonporous surface. Post cleaning is necessary to remove chemicals. Requires multiple operations under controlled conditions. Chemical handling precautions are necessary (toxicity, fire, waste).	Only ferromagnetic materials can be inspected. Proper alignment of magnetic field and defect is critical. Large currents are needed for very large parts. Requires relatively smooth surface. Paint or other nonmagnetic coverings adversely affect sensitivity. Demagnetization and post cleaning is usually necessary.	Surface must be accessible to probe and couplant. Skill and training required is more extensive than other technique. Surface finish and roughness can interfere with inspection. Thin parts may be difficult to inspect. Linear defects oriented parallel to the sound beam can go undetected. Reference standards are often needed.	Only conductive materials can be inspected. Ferromagnetic materials require special treatment to address magnetic permeability. Depth of penetration is limited. Flaws that lie parallel to the inspection probe coil winding direction can go undetected. Training required is more extensive than other techniques. Surface finish and roughness may interfere. Reference standards are needed for setup.	Extensive operator training and skill required. Access to both sides of the structure is usually required. Orientation of the radiation beam to non-volumetric defects is critical. Field inspection of thick section can be time consuming. Relatively expensive equipment investment is required. Possible radiation hazard for personnel.

5.6) Choices Control Quality:

A good **NDT inspection program** must recognize the inherent limitations of each process. For example, both radiography and ultrasound have distinct orientation factors that may guide the choice of which process to use for a particular job. Their strengths and weaknesses tend to complement each other.

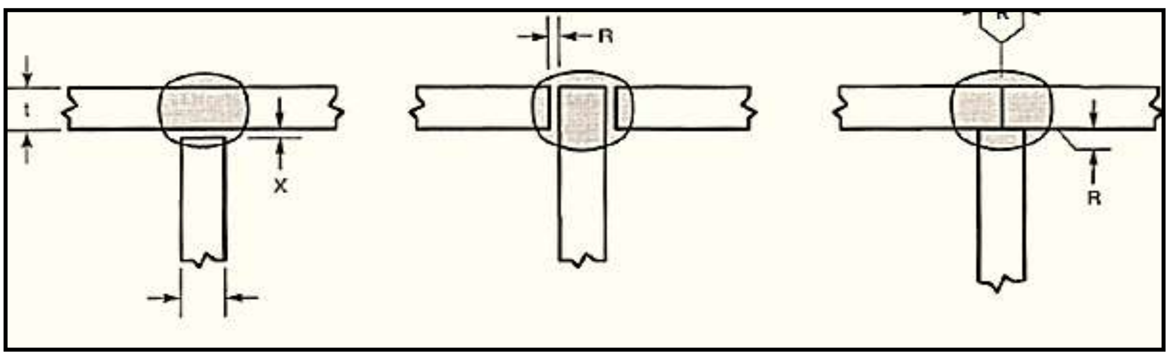
While **radiography is unable** to reliably detect lamination-like defects, **ultrasound is much better** at it. However, **ultrasound is poorly suited to detecting scattered porosity**, while radiography is very good.

Whatever inspection techniques are used, paying attention to the **"Five P's" of weld quality** will help reduce subsequent inspection to a routine checking activity as shown below:

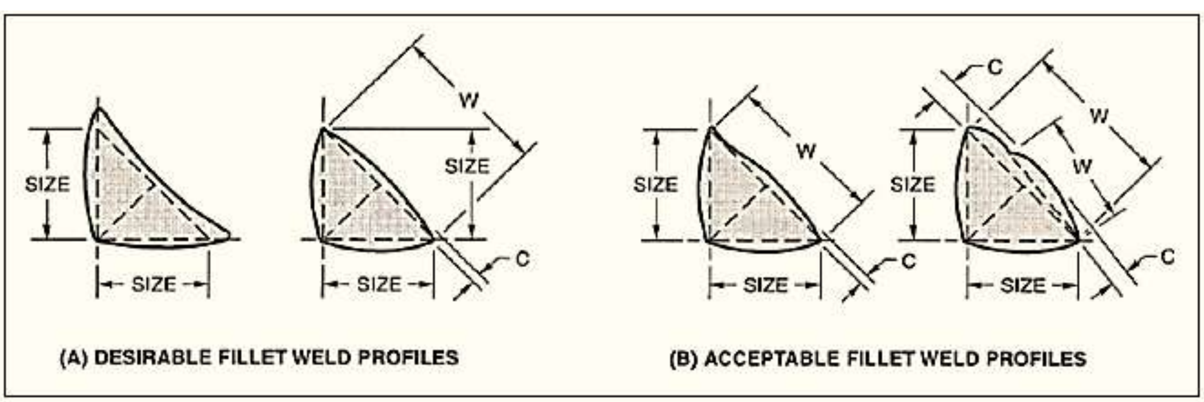
The Five P's:

1) Process Selection. The process must be right for the job.
2) Preparation. The joint configuration must be right and compatible with the welding process.
3) Procedures. The procedures must be spelled out in detail and followed religiously during welding.
4) Pre-testing. Full-scale mockups or simulated specimens should be used to prove that the process and procedures give the desired standard of quality.
5) Personnel. Qualified people must be assigned to the job.

5.7) Inspection of Weld Profiles:

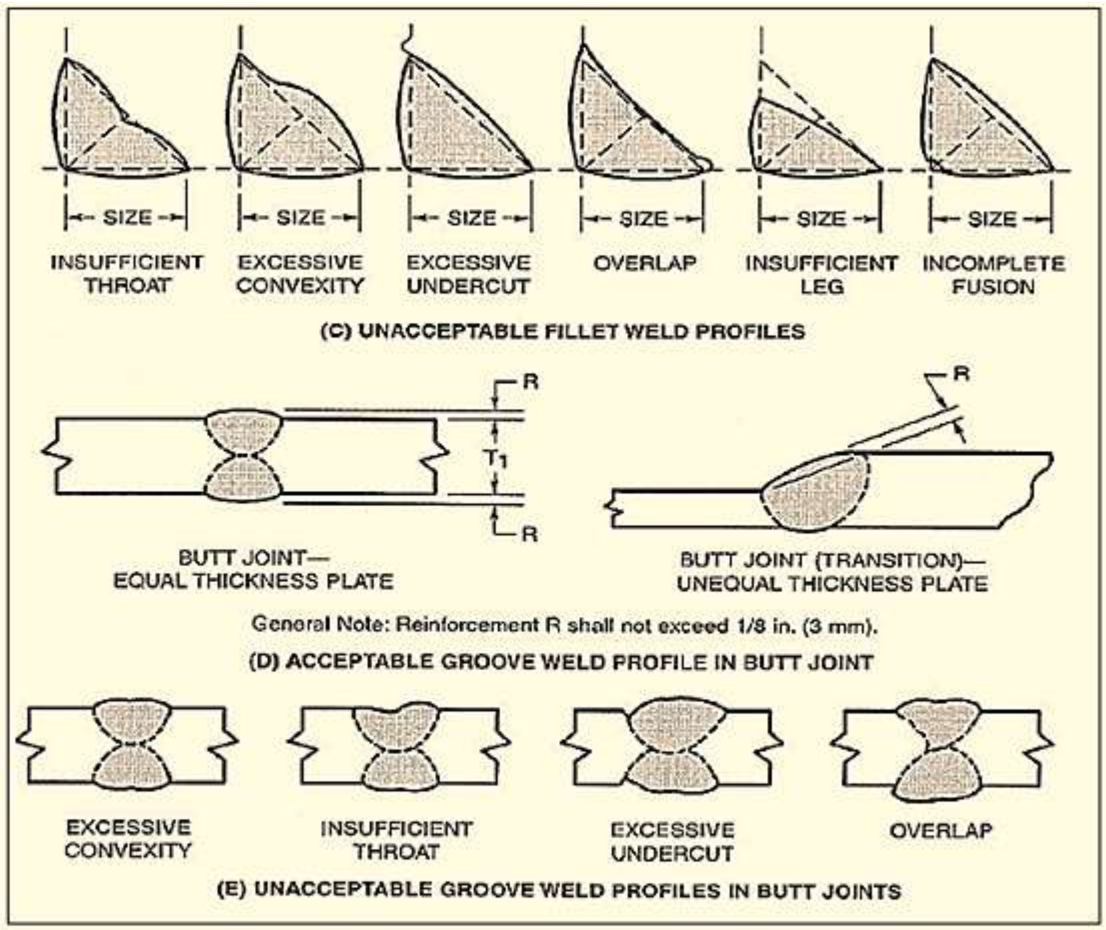


Legend:
t = Thickness of thinner member
R = Root opening ≤.010” for t <.100”, ≤.030” for t ≥.100”
X = Weld penetration Min = 1/2t or .015”, whichever is greater
Max = 2-1/2t or .187”, whichever is less



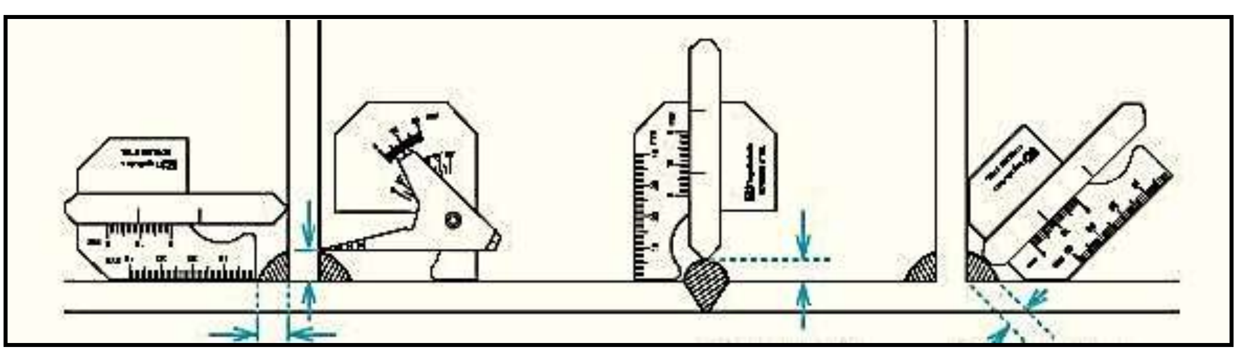
Note: Convexity, C, of a weld or individual surface bead with dimension W shall not exceed the value of the following table.

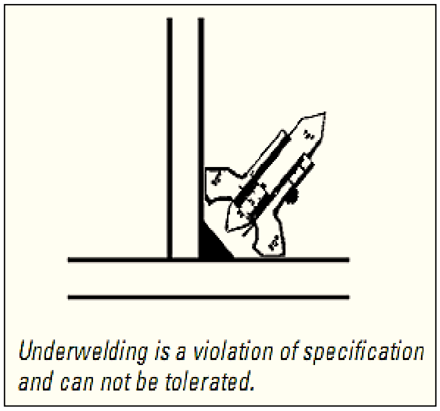
Width of weld face or individual surface bead, W	Max Convexity, C
W ≤ 5/16 in.	1/16 in.
W > 5/16 in.	1/8 in.
W ≥ 1 in.	3/16 in.

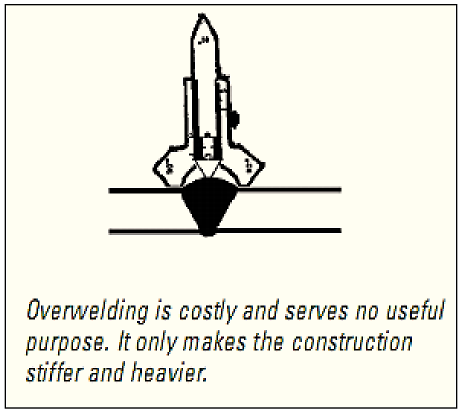


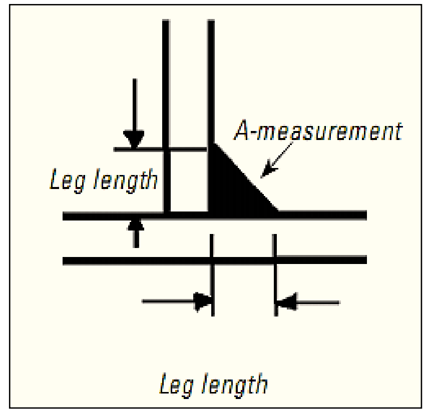
5.8) Welding Measurements:

The methods for using the **welding gauges for measuring** the dimensions of weld profiles are:









NOTE: For **supplemental information** and **safe welding procedures** consult the American Welding Society (AWS) *Welding Handbook* and AWS D l.1. Joint design practices for vessels see Section VIII of the ASME Boiler and Pressure Vessel Code, ANSI B31.1 for piping and the AISC (American Institute of Steel Construction) for steel construction.

6) Hydrostatic and Pneumatic Tests.

a) Hydrostatic Test for Vessels and Piping:

A hydrostatic test is a way in which leaks through the weld or bolting can be inspected and repaired in tanks, pressure vessels, pipelines and valves. The **ASME VIII Div. 1, UG-99** - Standard Hydrostatic Test - defines the conditions to carry on the procedures.

The **Inspector shall reserve the right to require** the manufacturer or the designer to furnish the calculations used for determining the **Hydrostatic Test Pressure** for any part of the vessel.

The Hydrostatic Test Pressure Gage shall be equal **at least one 1.5 times the Maximum Allowable Working Pressure** (MAWP), **multiplied** by the ratio of the stress value **''S''** (materials of which the vessel is constructed) at the **Test Temperature** to the stress value **''S''** at the **Design Temperature** for the materials of which the pressure vessel is constructed.

A hydrostatic test based on a calculated pressure may be used by **agreement between the user and the manufacturer**. For the basis for calculating test pressures, see **UA–60(e)** of the **ASME Code**.

The descriptive **paragraphs** according to **ASME B31.3** for Hydrostatic Test Pressure are:

Paragraph: 345.4 Hydrostatic Leak Test:

345.4.1 Test Fluid. The **fluid shall be water** unless there is the possibility of damage due to freezing or to adverse effects of water on the piping or the process.

In this case another **suitable nontoxic liquid** may be used.

If the liquid is flammable, its flash point shall be at least **49°C (120°F)**, and consideration shall be given to the test environment.

Paragraph: 345.4.2 Test Pressure. The hydrostatic test pressure at any point in a metallic piping system shall be as follows:

(a) Not less than **1.5 times** the design pressure;
(b) For design temperature **above the test temperature**, the minimum test pressure shall be calculated by the same equation as indicated below, except that the value of ***ST /S* shall not exceed 6.5**:

$$P_T = \frac{1.5.P.S_T}{S_D}$$

Where:

P_T = Minimum Hydrostatic Test Pressure Gauge
P = Internal design gage pressure (MAWP)
S_T = Stress value of material at test temperature
S_D = Stress value of material at design temperature (See Table A-1- ASME B31.3 Material Stresses).

(c) If the test pressure as defined above would produce a nominal pressure stress or longitudinal stress in **excess of the yield strength** at test temperature, **the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at test temperature**.

(d) The stress resulting from the hydrostatic test **shall not exceed 90%** of the **yield stress** of the material at the test temperature.

The **Hydrostatic Test Pressure** shall be applied for a **sufficient period of time** to permit a thorough examination of all joints and connections. The test shall not be conducted until the vessel and liquid are at approximately the same temperature.

Defects detected during the Hydrostatic Test or subsequent examination shall be completely removed and then inspected. Provided the marine inspector gives his approval, they may then be repaired

The vessels requiring **Stress Relieving** after any welding repairs **shall be stress relieved** conforms to **UW–40 of the ASME Code**.

After repairs have been made the vessel shall be hydro tested again in the regular way, and if it passes the test, the Inspector and the Quality Engineer may accept it. If it does not pass the test they can order supplementary repairs, or, if in his judgment the vessel is not suitable for service, they may permanently reject it.

The **fluid for the hydrostatic test shall be water**, unless there is a possibility of damage due to freezing or to adverse effects of water on the piping or the process. In that case, another suitable non-toxic liquid may be used. So **glycol/water** is allowed.

b) Hydrostatic Test for Valves – API 598:

1. Hydrostatic Body Test:

Every valve shall be subjected to a hydrostatic test of the body shell at **1.5 times** the **Maximum Allowable Working Pressure(MAWP)** at 100°F (38°C), see Table 1.

The test shall show no leakage, no wetting of the external surfaces, and no permanent distortion under the full test pressure. No device shall be used in testing the valve that will reduce the stress in the body.

Gate Valve & Screw Down Non-Return Globe Valve: The pressure shall be applied successively to **each side** of the closed valve with the other side open to the atmosphere to check for leakage at the atmospheric side of the closure.

Globe Valve: The pressure shall be applied **in one direction** with the pressure applied under the disc (upstream side) of the closed valve with the other side open to the atmosphere to check for leakage at the atmospheric side of the closure.

Check valve: The pressure shall be applied **in one direction** with the pressure applied behind the disc (downstream side) of the closed valve with the other side open to the atmosphere to check for leakage at the atmospheric side of the closure.

2. Hydrostatic Seat Test:

When applicable or specified, every valve shall be subjected to a hydrostatic seat test to **1.1 times the Maximum Allowable Working Pressure(MAWP)** at 100°F (38°C), see Table 1. The valve shall be set in the partially open position for this test, and completely filled with test fluid. Any entrapped air should be vented from both ends and the body cavity via either. **If a leakage** is found in any valve part, **corrective action** may be taken and the test shall be repeated.

3. Liquid Test:

Water is used, unless the use of another liquid is agreed between the purchaser and the manufacturer. It will contain a **rust inhibitor**. Potable water used for pressure test of **austenitic stainless steel valves** shall have chloride content less than 30 ppm and for **carbon steel valves** shall be less than 200 ppm.

Table 1 – Test Pressure (ASME B 16.34 & API Std. 602 for Class 800 Valves):

Class	150#			300#		
Description / Material	CWP	Shell	Seat	CWP	Shell	Seat
	psig	Kg/cm²	Kg/cm²	psig	Kg/cm²	Kg/cm²
A105, A350-LF2	285	32	23	740	80	59
A182-F5,F9,F11,F22	290	32	23	750	80	59
A182-F304,F316	275	30	23	720	78	57
A182-F304L, F316L	230	25	20	600	64	48
Class	**600#**			**800#**		
Description / Material	CWP	Shell	Seat	CWP	Shell	Seat
	psig	Kg/cm²	Kg/cm²	psig	Kg/cm²	Kg/cm²
A105, A350-LF2	1480	157	117	1975	210	153
A182-F5,F9,F11,F22	1500	159	117	2000	211	155
A182-F304,F316	1440	153	113	1920	204	150
A182-F304L, F316L	1200	127	94	1600	169	125

Obs.: CWP means Cold Working Pressure.

Table 2 – Test Duration:

NOMINAL SIZE (NPS)	MINIMUM TEST DURATIONS (Seconds)			
	Hydro Shell Test	Backseat Test	Hydro Seat Test	Air Seat Test
≤ 2"	15	15	15	15
2 ½" – 6"	60	60	60	60
8" – 12"	120	60	120	120
≥ 14"	300	60	120	120

Table 3 – Maximum Allowable Leakage Rates:

NOMINAL SIZE (NPS)	Gate & Globe Valves		Check Valves	
	Liquid Test[(a)] (Drops Per Minute)	Gas Test (Bubbles Per Minute)	Liquid Test	Gas Test
≤ 2"	0 [(b)]	0 [(c)]	3 scc x NPS / minute.	700 scc x NPS / minute
2 ½" – 6"	12	24		
8" – 12"	20	40		
≥ 14"	d	e		

Notes:
(a) For the liquid test, **1 milliliter is considered equivalent to 16 drops**.
(b) For the liquid test, **0 drops means no visible leakage** per minimum specified duration of the test.
(c) For valves greater than or equal to 14" (NPS 14), the **maximum permissible leakage** rate shall be **2 drops** per minute per inch NPS size.
(d) For valves greater than or equal to 14" (NPS 14), the **maximum permissible leakage** rate shall be **4 bubbles** per minute per inch NPS size.

c) Pneumatic Test for Vessels and Piping:

Pneumatic testing of **welded pressure vessels shall be permitted** only for those specially designed that cannot be **safely filled with water**, or for those which **cannot be dried** and are to be used in a service where **traces of the testing content** cannot be tolerated.

The Pneumatic Test Pressure shall be **at least equal to 1.25 times the Maximum Allowable Working Pressure (MAWP) multiplied** by the ratio of the stress value **"S"** (materials of which the vessel is constructed) at the **Test Temperature** to the stress value **"S"** at the **Design Temperature** for the materials of which the pressure vessel is constructed (see UG–21 of the ASME Code).

$$P_T = \frac{1.25 . P . S_T}{S_D}$$

Where:

P_T = Minimum Pneumatic Test Pressure Gauge
P = Internal design gage pressure (MAWP)
S_T = Stress value of material at test temperature
S_D = Stress value of material at design temperature (See Table A-1- ASME B31.3 Material Stresses).

And as **per UG-100**, a pneumatic test shall be at least **equal to 1.1 times the MAWP multiplied** by the lowest ratio for the materials of the stress value **"S"** (materials of which the vessel is constructed) at the **Test Temperature** on the vessel to the stress value **"S"**.

The **Design Temperature may be used in lieu of the standard hydrostatic test** prescribed in **UG-99** for vessels under certain conditions:

1) For vessels that **cannot safely be filled** with water;

2) For vessels that **cannot be dried** and are to be used in a service where **traces of the testing content** cannot be tolerated and previously tested by hydrostatic pressure as required in UG-99.

Then, the formula becomes:

$$P_T = \frac{1.1.P.S_T}{S_D}$$

As a general method, the pneumatic test pressure is **1.25 MAWP** for materials ASME Section VIII - Division 1 and **1.1 MAWP** for materials ASME Section VIII - Division 2.

The pneumatic test of pressure vessels **shall be accomplished** as follows:

The pressure on the vessel **shall be gradually increased to not more than half the test pressure**. After, the pressure will then be **increased at steps of approximately 1/10 the test pressures** until the test pressure has been reached.

In order to permit examination, **the pressure will then be reduced to the Maximum Allowable Working Pressure** of the vessel. The tank supports and saddles, connecting piping, and insulation if provided shall be examined to determine if they are satisfactory and that no leaks are evident.

The pneumatic test is inherently **very dangerous and more hazardous than a hydrostatic test**, and **suitable precautions** shall be taken to protect personnel and adjacent property.

XI. APPENDIX:

1) Levels of Certification AWS B5.1:

The **levels of qualifications** for welding inspection personnel according to **AWS B5.1** are:

AWI - Associate Welding Inspector;
WI - Welding Inspector;
SWI - Senior Welding Inspector.

1.1) Associate Welding Inspector (AWI):

Shall be a **high school graduate**, or hold a military **approved high school equivalency** with a **minimum of 2 years' experience** in a function with a direct relationship to weldments fabrication to national or international standards and directly involved in one or more of the areas.

1.2) Welding Inspector (WI):

Shall be a **high school graduate**, or hold a state or military **approved high school** equivalency diploma with a **minimum of 5 years' experience** in an occupational function with a direct relationship to weldments fabrication to national or international standards and be directly involved in one or more of the areas.

1.3) Senior Welding Inspector (SWI):

Shall be a **high school graduate**, or hold a state or military **approved high school equivalency** diploma with a **minimum of 15 years' experience** in a function with a direct relationship to welded assemblies fabrication to national or international standards and be directly involved in one or more of the areas.

2) Written Test Requirements:

Shall be performed an applicable **AWI, WI, or SWI** examination. Individuals failing one Part of the examination shall have to retest on all Parts. The examination includes the following Parts:

1) A test on the requirements of a code, standard or specification.

2) A test on fundamental principles including, but not limited to: welding processes, nondestructive examination, safety, quality assurance, inspector's duties, weld discontinuities, welding symbols, joint design, mechanical properties of metals, and basic on-the-job mathematics.

3) A test on practical application of welding inspection knowledge including, but not limited to: welding procedure qualification, welder qualification, mechanical testing, drawing and specification compliance, welding examination, and nondestructive testing processes.

1) Welding Inspection Capabilities Based on Qualification Level:

3.1) Knowledge and Skills:

- Prepare reports and understand what is SMAW, SAW, OFW, RW, GTAW, FCAW, GMAW, PAW, SW, ESW, Thermal Spraying, Soldering, Mechanical Cutting, Thermal Cutting/Gouging, Brazing/Braze Welding, etc.
- Understand VT, MT, AET, UT, PT, ET, RT, LT, quality procedures and quality audits/surveillance, understand the fundamentals of welding metallurgy understand welding symbols and drawings.

3.2) Standards:

Verify base material, verify filler metal, verify filler metal storage/handling, verify inspection records, verify proper documentation, verify base material and filler metal compatibility, certify documented results, verify procedure qualification records, verify welding procedure and verify NDT procedures.

3.3) Procedure Qualification:

Verify welding equipment appropriateness, verify edge preparation, verify joint geometry, witness procedure qualification, verify welding procedure qualification, (review and approve welding procedures, develop welding procedures.

3.4) Performance Qualification:

Witness welder performance qualification, verify welder qualification, verify welder qualification records and request welder performance requalification.

3.5) Inspection Duties:

Perform visual examinations, verify examination procedure, review examination results, develop visual inspection procedures (before, during, and after welding), provide NDT inspection planning and scheduling, review welding inspection reports, verify implementation of nondestructive and destructive evaluation methods, prepare visual inspection requirements, prepare NDT requirements, report investigation results of quality inspection disputes, prepare destructive testing requirements.

3.6) Safety:

Verify safety requirements compliance, develop safety procedures and policies.

3.7) Quality Assurance:

Perform audits and surveillance, develop quality assurance plans, prepare base material control requirements, prepare weld consumable control requirements, prepare audit and surveillance plans, prepare documentation control requirements.

3.8) Project Management:

Review contract requirements, review vendor proposal compliance, prepare weld inspection bid specifications, prepare purchase specifications, determine vendor capacity and capability, select vendor.

3.9) Training:

Develop and provide a training program as, visual inspection training, technical leadership for welding inspectors, manufacturing quality assurance, verify implementation of quality assurance training, guidance to inspectors for maintaining their individual qualifications.

2) Welding Procedure and Qualification Evaluation:

4.1) Boiler and Pressure Vessel Code, Section IX :

The inspector should have the skills required to review a **Procedure Qualification Record (PQR)** and a **Welding Procedure Specification (WPS)** and to be able to determine the following:

a) Determine if procedure and qualification records are in compliance with applicable **ASME Boiler and Pressure Vessel Code** and any additional requirements of **API570**.

b) The weld procedure review will include a **Weld Procedure Specification (WPS)** and a **Procedure Qualification Record (PQR).**

c) Determine if all required essential and nonessential variables have been properly addressed. (Supplemental essential variables will not be a part of the WPS/PQR)

d) Determine that the number and type of mechanical tests that are listed on PQR are the proper tests, and whether the results are acceptable.

e) Weld Procedure Specification (WPS) evaluation for SMAW, GTAW, GMAW, and SAW:

- The **WPS should be reviewed and supported** by a single **PQR**;
- Filler metals will be limited **to one per process** for SMAW, GTAW, GMAW, or SAW;
- Special weld processes such as corrosion resistant weld metal overlay, hard facing overlay and dissimilar metal welds with buttering of ferritic member will be excluded;
- For the purpose of the examination the lower transition temperature will be 13300ºF and the upper transformation temperature will be 16000°F.

4.2) Nondestructive Examination - ASME Section V:

A. Article 1, General Requirements:

The inspector should be familiar with and understand;

a) The Scope of Section V;
b) Rules for use of Section V as a referenced Code;
c) Responsibilities of the Owner / User, and of subcontractors;
d) Calibration, definitions of "inspection" and examination";
e) Record keeping requirements;

B. Article 2, Radiographic Examination:

The inspector should be familiar with and understand;
a) The **Scope of Article 2** and general requirements;
b) The rules for radiography as typically applied on butt welded seams such as, but not limited to:

- Required marking
- Type, selection, number, and placement of IQI's,
- Allowable density and density ranges
- Control of backscatter radiation

c) Welding records.

C. Article 6, Liquid Penetrant Examination (Mandatory Appendices II and III):

The inspector should be familiar with the general rules for using the Liquid Penetrant method, including:

a) The Scope of Article 6;
b) General requirements such as but not limited to:

- Procedures
- Contaminants
- Techniques
- Examination
- Interpretation
- Documentation and record keeping.

D. Article 7, Magnetic Particle Examination (Yoke and Prod Techniques):

The inspector should be familiar with the general rules for using the Magnetic Particle method:

a) The Scope of Article 7;
b) General requirements such as but not limited to:

- Procedures
- Techniques (Yoke and Prod only)
- Calibration
- Examination
- Interpretation

c) Documentation and record keeping.

E. Article 9, Visual Examination:

The inspector should be familiar with the general rules for applying the Visual Examination method:

a) The scope of Article 9;
b) General requirements such as but not limited to:

- Procedures
- Physical requirements
- Procedure/technique
- Evaluation

c) Documentation and record keeping.

F. Article 10, Leak Testing (Mandatory Appendix I Bubble Test –Direct Pressure Technique):

The inspector should be familiar with the general rules for applying the **Leak Testing** method including:

a) The scope of Article 10;
b) General requirements such as but not limited to:

- Procedures
- Equipment
- Calibration
- Test
- Evaluation

c) Documentation and record keeping.

G. Article 23, Manual Ultrasonic Pulse Echo Method, Section SE–797:

The inspector should be familiar with and understand;

a) The Scope of Article 23, Section SE797,
b) The general rules for applying and using the Ultrasonic Method;
c) The specific procedures for Ultrasonic thickness measurement as contained in paragraph 7.

H. ASME B31.3 and API570: General Nondestructive Examination Requirements:

The inspector should have a **general knowledge** of the following principles described below:

a) General rules for **NDT in ASME B31.3**, **NDT in API570** and examination methods by **API** and **ASME Body of Knowledge:**

API 510 - Maintenance inspections, repair, alteration, and re-rating procedures for pressure vessels.
API 570 - Performs visual, baseline and in-service corrosion inspections on piping systems.
API 653 - Specific inspection requirements and techniques that apply to above ground storage tanks.
API570 - Piping inspection code;
API RP 571 - Damage mechanisms affecting fixed equipment in the refining industry;
API RP 574 - Inspection practices for piping system components;
API RP 577 - Welding and metallurgy;
API RP 578 - Material verification program for new and existing alloy piping systems;
ASME V - Non-destructive examination;
ASME IX - Welding qualifications;
ASME B16.5 - Pipe flanges and flanged fittings
ASME B 31.3 - Process piping.

b) Types and Definitions of Maintenance Inspection:

a) Thickness Measurement Inspection (API 570, 5.4.2)
b) Inspection of Flanged Joints (API570, 5.11)
c) Inspection of Valves (API570, 5.9)
d) Inspection of Buried Piping (API 570, 9.0)
e) Inspection for Specific Types of Corrosion and Cracking (API570, 5.3)
f) Visual External Inspection (API570, 5.4.3 & 6.4)
g) Thickness Measurements (API570, 5.5 & 5.6)
h) Nondestructive Examination (API570, 5.10 & 8.2.5)
i) Risk Based Inspection (API 570, 5.1)

c) Piping:

a) Welding Inspection Requirements (API570, 5.10)
b) Corrosion Rate Determination (API 570, 7.1)
c) Maximum Allowable Working Pressure Determination (API 570, 7.2)
d) Minimum Required Thickness Determination (API 570, 7.3)

d) Repairs and Alterations to Piping:

a) Authorization (API 570, 8.1.1)
b) Approval (API 570, 8.1.2)
c) Design Requirements (API 570, 8.2.3)
d) Materials Requirements (API 570, 8.2.4)
e) Welding Repairs (API 570, 8.1.3, 8.2 & Appendix C)
f) Non welding Repairs (8.1.4)
g) Hot Tapping (8.2)
h) Heat Treating Requirements, including:

- Preheating (API 570, 8.2.2.1)
- Post Weld Heat Treating (API 570, 8.2.2.2)

i) Rerating of Piping (API 570, 8.3)
j) Pressure Testing After Repairs, Alterations or Rerating (API570, 8.2.6)

e) Inspection of Piping, Tubing, Valves, and Fittings:

a) Piping Components (API RP574, Section 4)
b) Reasons for Inspection (API RP574, Section 5)
c) Inspecting for Deterioration in Piping (API RP574, Section 6)
d) Frequency and Time of Inspection (API RP574, Section 7)
e) Inspection, Tools (API RP574, Section 9)
f) Inspection Procedures (APIRP574, Section 10)
g) Determination of Retirement Thickness (API RP574, Section 11)
h) Maintenance Inspection Safety Practices - Piping Inspection (API RP574, Section 8)
i) Inspection Records and Reports (API RP574, Section 12)

I. API RP 577, Welding Inspection and Metallurgy:

The inspector should have a general knowledge of **API RP 577** with the following principles here described: Definitions, Welding Inspection, Welding Processes, Welding Procedure, Welding Materials, Welder Qualifications, Nondestructive Examination, Metallurgy, Refinery and Petrochemical Plant Welding Issues, Terminology and Symbols, Welding Procedure Review, Guide to Common Filler Metal Selection, Example Report of RT Results.

J. ASME B16.5, Pipe Flanges and Flanged Fittings:

The inspector should have a general knowledge of **ASME B16.5** with the following principles: Pressure Temperature Ratings, Markings, Materials, Dimensions, Test, Limiting Dimensions of Gaskets, Methods for Establishing Pressure-Temperature Ratings.

4.3) General Knowledge for Welding Specification:

- AWS A3.0 - 2001 - Standard Welding Terms and Definitions
- AWS A5.32/A5.32M- 97 - Specification for Welding Shielding Gases
- AWS A5.4- 92 – Specific. for Stainless Steel Electrodes for Shielded Metal Arc Welding
- AWS A5.6- 84 – Spec. for Covered Copper and Copper Alloy Arc Welding Electrodes
- AWS 5.9- 93 - Specification for Bare Stainless Steel Welding Electrodes and Rods
- AWS 5.8- 92 - Specification for Filler Metals for Brazing and Braze Welding
- AWS A1.1 - Metric Practice Guide for the Welding Industry
- AWS A2.4 - Standard Symbols for Welding, Brazing, and Nondestructive Examination
- AWS A3.0 - Standard Welding Terms and Definitions
- AWS B1.10 - Guide for the Nondestructive Examination of Welds
- AWS B1.11 - Guide for the Visual Inspection of Welds
- AWS B2.1 - Specification for Welding Procedure and Performance Qualification
- AWS B4.0 - Standard Methods for Mechanical Testing of Welds
- AWS B5.1 - Specification for the Qualification of Welding Inspectors
- AWS QC1 - Standard for AWS Certification of Welding Inspectors

- AWS - Certification Manual for Welding Inspection
- AWS - Welding Inspection Handbook
- ASME Section IX - Welding and Brazing Qualifications – Boiler and Pressure Vessel Code
- ASME Z49.1 - Safety in Welding, Cutting, and Allied Products

4.4) General Knowledge for Specific Standards:

- AWS D1.1 (2006 or 2008) -Steel
- AWS D1.3 (1998 or 2007) - Sheet Steel
- AWS D1.4 (1998 or 2005) - Reinforcing Steel
- AWS A2.4-98 or A2.4-2007 Symbols for Welding, Brazing, and Nondestructive Examination
- API 1104 - Welding of Pipelines and Related Facilities
- API 6A - Specification for Wellhead Equipment
- API 6D - Pipeline Valves
- API 599 - Steel Plug Valves
- API 600 - Steel Gate Valves
- API 602 - Compact Carbon Steel Gate Valves
- API 603-1 50 - Pound Light Wall Corrosion Resistant Gate Valves
- ISO 9001 - Quality Management Systems—Requirements SWI
- ASNT SNT-TC-1A - Personnel Qualification and Certification in Nondestructive Testing
- ANSI/ASME B16.5 - Steel Pipes, Flanges and Flanged Valves and Fittings.
- ANSI/ASME B16.34 - Steel Butt-Welding End Valves

4.5) Classification of Electrodes:

Classification consists of a **prefix letter E** specifying an electrode, a group of **two or three digits** specifying **weld metal strength in ksi** in the "*as-weld*" or stress relieved condition, and a final **two digits** specifying **type of covering**, **weld position** and current **characteristics**.

a) Nomenclature of electrode specification:

E60xx - 60ksi (420MPa)
E70xx - 70ksi (490 MPa)
E80xx - 80ksi (560 MPa)
E90xx - 90ksi (630 MPa)
E100xx - 100 ksi (700 MPa)

Typical electrodes (those in **brackets** are widely used) are given in the following:

Exx10 - Cellulosic covering for the use with DC reversed polarity
(E6010) - Deep penetration and all positions electrode for general purpose.
Exx11 - Cellulosic covering for AC or DC., all position.
(E6011) - Deep Penetration and thin slag, X-ray quality weld.
Exx12 - Rutile covering AC or DC, all positions.
(E6012) - Medium penetration, good choice for fit-up work.
Exx13 - Rutile electrode, AC or DC, all position.
(E6013) - Good performance in sheet metal welding.

Exx14 - Iron powder rutile same characteristic as Exx 13, but with a higher welding speed.
Exx15 - Basic low hydrogen covering requiring use of DC only, all positions for steel welds.
(E7015) - Good for high sulfur steels.
Exx16 - Basic low hydrogen covering as Exx15 but with addition of potassium
(E7016) - Salts to allow operation with AC.
Exx18 - Low hydrogen electrode as Exx 16, but with 30% iron powder to give (E7018)
Exx20 - Typical mineral (iron oxide/silicate) covering for use in flat and (E6020)
Exx24 - Rutile and 50 per cent iron powder covering similar to Exx12, with (E7024)
Exx27 - Mineral plus 50 iron powder covering with similar (E6027) characteristics to Exx20.
Exx28 - Low hydrogen basic plus 50 per cent iron powder covering with high (E7028) deposition rate
Exx30 - Mineral covering similar to Exx20 but high deposition rates. F position only.

Note:
The use of mineral or iron oxide/silicate covered electrodes is decreasing in the USA and UK.

b) Electrodes - IS and AWS Classifications and Codes.

The classification of electrode by letter and numerical are given below:
Ex xxxx
ER 4211

The first letter **"E" indicates a covered electrode for SMAW**, manufactured by extrusion process, the second letter **"R" indicates type of covering** e.g.:

R = Rutile, **A** = Acid, **B** = Basic, **C** = Cellulosic, **RR** = Rutile Heavy Coated, **S** = any other type not mentioned here.

The first numerical **"4" indicates strength** (UTS = 410-510 MPa) in combination with the yield strength of the weld metal deposit YS = 330 MPa.

The **second numerical digit** indicates **percentage elongation** in combination with the impact value of the weld metal deposited. Thus **"2" means 22 % minimum** elongation with impact **47 J at zero °C**.

The **third digit "1"** shows **welding position** in which the electrode may be used:

"**I**" means all positions.
2 = all position except vertical
3 = flat butt weld horizontal/vertical fillet weld
4 = flat butt and fillet weld
5 = vertical down and flat butt
6 = any position not mentioned here.

3) Welding Procedures:

Welding procedures include **standard designation of materials and filler metals**, thickness and form of joints, cleaning procedures, welding jigs and fixtures, tack welds, welding position. A **Welding Procedure Specification** (**WPS)** is developed for each material carbon, alloy, stainless or aluminum and for each welding type used. A **WPS is supported** by a **Procedure Qualification Record (PQR)**. A PQR is a record of a **test weld performed** and tested (more rigorously) to ensure that the procedure will produce a good weld. The welders are certified with a qualification test documented in a **Welder Qualification Test Record (WQTR)** that shows they have the understanding of a specific welding condition and demonstrate ability to work within the specified WPS. The basic examples for **WPS and PQR** found in various codes and standards are the following:

Welding Procedure Specification (WPS)

Code: AWS D1.1

Company Name: AWS America

Address: info@WPSAmerica.com,

Identification #: GMAW

WPS Prequalified: Yes

Welding Process:	Process Type:	Position(s):	Supporting PQR No.(s):
GMAW	Semi-Automatic	Flat	N/A

Base Metal Part I (Material Spec., type or grade):	Base Metal Part II (Material Spec., type or grade):
Steels in Group I and II of Table 3.1-AWS D1.1	Steels in Group I and II of Table 3.1-AWS D1.1

Qualified Thickness and Diameter Range:	Filler Metals:
Groove (Fillet): mm (in) T >= 6 mm (1/4 in)	AWS Classification/AWS Specification: E70C-6M H4 A5.18

Joint Details/Sketch:

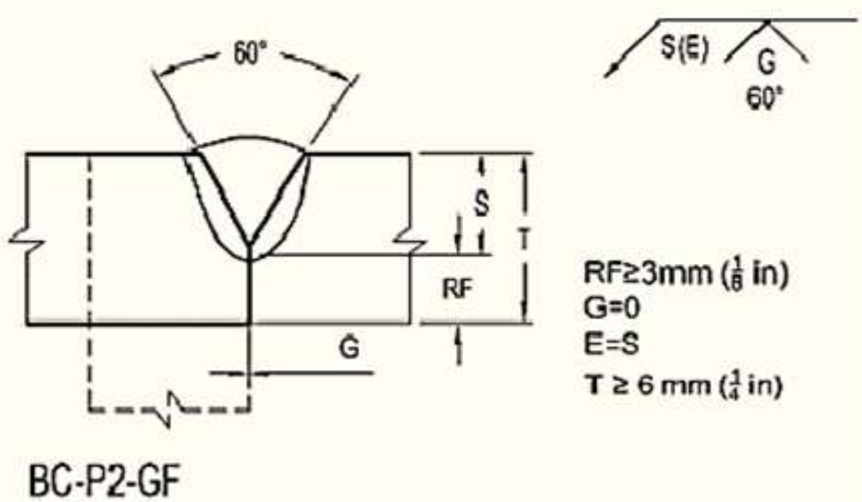


Table 3.4 of AWS D1.1		
T	S	E min
in	in	in
T = 1/4	As specified in the drawing	1/8
T ≤ 1/2		3/16
T ≤ 3/4		1/4
T ≤ 1-1/2		5/16
T ≤ 2-1/4		3/8

Joint Design Used: mm (in)

Root Opening G: 0 | Root Face RF: >= 3 mm (1/8 in.) | Groove Angle: 60° | Radius (J-U): N/A

Weld Type:	Joint Type:
Partial Joint Penetration Groove Weld	Butt Joint Corner Joint

Backing Option:	Backing Material:	Back Gouging Method:
Welded without backing	N/A	N/A

Sheet 1 of 4

Procedure Qualification Record (PQR)

Code: AWS D1.1

Company Name: WPS America

Address: info@WPSAmerica.com,

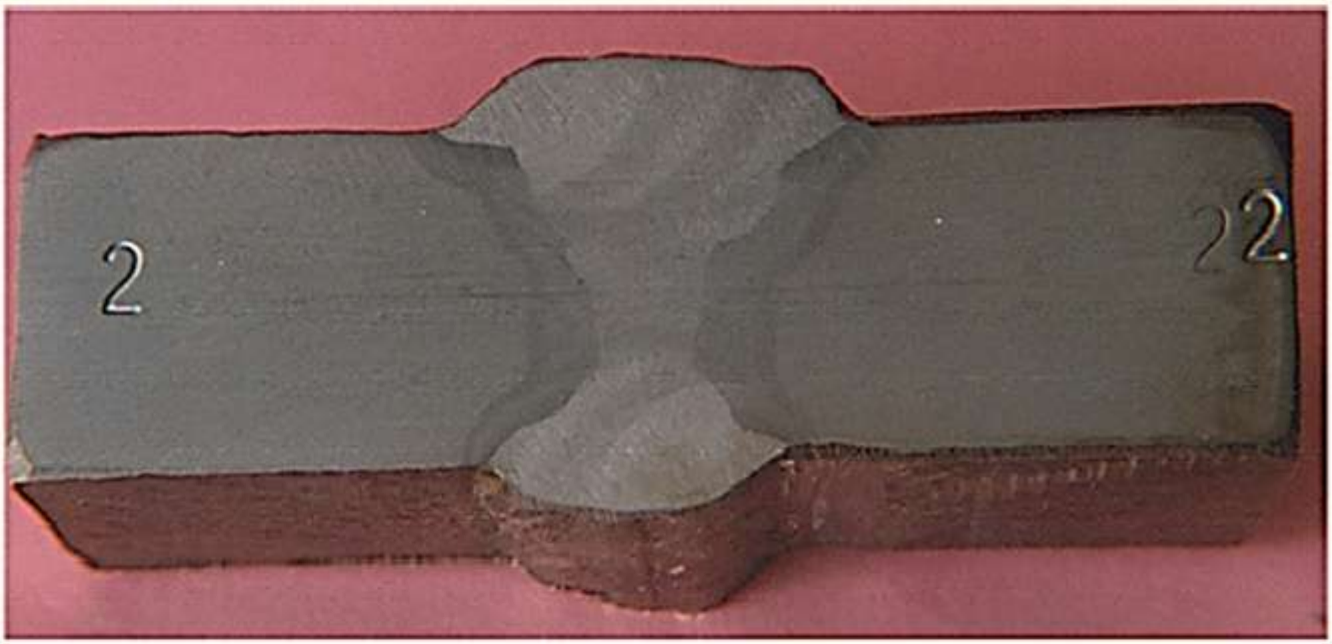
PQR No.: 123 - PQR

Welding Process:	Process Type:	Position:	WPS No.:
SMAW	Manual	Flat	

Base Metal Part I (Material Spec., type or grade):	Base Metal Part II (Material Spec., type or grade):
ASTM A 516 Grade 60	ASTM A 516 Grade 60

Thickness and Diameter (Pipe): mm (in)	Filler Metals: AWS Classification/AWS Specification:
Thickness of Test Coupon: 60 mm (2.36 in.), Plates Diameter of Test Coupon: N/A	E7018 A5.1

Joint Details/Sketch:



Joint Design Used: mm (in)

Root Opening G: *0 to 1/8 in.* Root Face RF : *3 mm (1/8 in.)* Groove Angle: *60° (both sides)* Radius (J-U): *N/A*

Weld Type:	Joint Type:
Complete Joint Penetration Groove Weld	Butt Joint

Backing Option:	Backing Material:	Back Gouging Method:
Back-gouge to sound metal	N/A	Mechanical (Grinding)

Electrical Characteristics:

Current Type/Polarity: DCEP

Transfer Mode (GMAW): N/A

Tungsten Electrode (GTAW):

Type: N/A

Size: mm (in) N/A

Shielding:

Gas Composition (Flux for SAW): N/A

Gas Flow Rate: lt/min. (CFH) N/A

Gas Cup Size: N/A

Welding Procedure

Weld Layers	Pass No.	Process	Filler Metal Classification	Filler Metal Diameter mm (in)	Current Amps	Current Type & Polarity	Wire Feed Speed (in/min)	Volts	Travel Speed (in/min)	Remarks [Heat Input] J/mm (J/in)
1 to 2	1 to 3	SMAW	E7018	4.0 mm (5/32)	160-200	DCEP	N/A	24-26	5-10 (in/min)	Root Pass
2 to n	4 to n	SMAW	E7018	4.8 mm (3/16)	220-250	DCEP	N/A	24-26	5-10 (in/min)	Fill and Cap
Side 2										Backgouged
1 to n	1 to n	SMAW	E7018	4.8 mm (3/16)	220-250	DCEP	N/A	24-26	5-10 (in/min)	Fill and Cap

Technique:

Stringer or Weave Bead: *Stringer and Weave Bead*

Contact Tube to Work Distance: *N/A*

Initial/Interpass Cleaning: *Wire Brush, Grinding*

Peening: *Not Required*

Number of Electrodes: *Single*

Electrodes Spacing: *Longitudinal: N/A* *Lateral: N/A* *Angle: N/A*

Heat Treatment:

Preheat Temp. Min °C (°F): *150 °C*

Interpass Temp. Min/Max °C (°F): *150 °C*

Postweld Heat Treatment: Temp. °C (°F): *600 to 620 °C*

Time: *1 Hour per in.*

Additional Notes:

See Postweld Heat Treatment (PWHT) Specification No. PWHT-SMAW-01

Manufacturer/ Contractor Welding Engineer :

Name: *Jim Clark*

Title: *Welding Engineer*

Date: *12,12,2005*

Authorized by:

Name: *John Smith*

Title: *QA Manager*

Date: *12,13, 2005*

Heat Treatment (AWS Code's Guideline):

PREHEAT TABLE:
AWS D1.1, Table 3.2 Prequalified Minimum Preheat and Interpass Temperature °F (°C):
Thickness 3 to 20 mm (1/8 to 3/4 in.) incl.: 32°F (0°C)
Over 20 thru 38 mm (3/4 to 1-1/2 in.) incl.: 50°F (10°C)
Over 38 thru 65 mm (1-1/2 to 2-1/2 in.) incl.: 150°F (65°C)
Over 65 mm (2-1/2 in): 225°F (110°C)
For SMAW process, above preheat data is with low hydrogen electrodes.
When the base metal temperature is below 32°F (0°C), preheated to a minimum of 70°F (20°C)
Preheat and interpass temperature shall be sufficient to prevent cold cracking.
Guideline on Alternative Methods for Determining Preheat/Interpass: See Annex XI of AWS D1.1

POSTWELD HEAT TREATMENT:
PWHT requirements shall be based on Welding Procedure Specification (WPS).
AWS D1.1, 5.8 Stress-Relief Heat Treatment: Where required by the contract drawings or specifications, welded assemblies shall be stress relieved by heat treating.
(See AWS D1.1, 5.8.1, Requirements for stress-relief treatment;
Table 5.2, Minimum Holding Time; Table 5.3, Alternate Stress-Relief Heat Treatment)
See AWS D1.1, 5.8.3, Steels Not Recommended for PWHT

PQR Qualified Range (AWS Code's Guideline):

Qualified Position: F (CJP/PJP Groove, Fillet) on Plate, Pipe, Box Tube (Table 4.1 AWS D1.1)

Qualified Thicknesses (CJP Groove): 1/8 in. (3 mm) Min., Unlimited
Plus any size of fillet or PJP groove weld for any thicknesses or diameter (Table 4.2 AWS D1.1)

WPS Base Metal Group Allowed by PQR: Any Steels in Group I to Any Steels in Group I of Table 3.1 of AWS D1.1 (Table 4.8 AWS D1.1)

Qualified WPS Filler Metal Allowed by PQR: For SMAW process, only same electrode type (change from low hydrogen to non-low hydrogen is not allowed) and same flux-electrode classification for SAW process. Also same (or lower) strength electrode tested in PQR for SMAW, GMAW and FCAW processes. [No increase in diameter from size tested in PQR is allowed, except that an increase on electrode size of only 1/32 in. (0.8 mm) in SMAW and increase up to 1/16 in. (1.6 mm) in GTAW is acceptable for use in WPS. For GMAW, only same electrode diameter size tested in PQR is allowed in WPS (Table 4.5 AWS D1.1).]

Note: Accessories like special holders, specific welding equipment, welding consumables, welding parameters, welding sequence, number of passes and sequences, possible interpass cleaning and grinding stages, all these and more items of information should be clearly prescribed.

PROCEDURE QUALIFICATION RECORDS

Test Results

TENSILE TEST

Specimen No.	Width mm (in)	Thickness mm (in)	Area sq. mm (in)	Ultimate Tensile Load kg (lb)	Ultimate Unit Stress MPa (psi)	Character of Failure and Location
TA1	25,1	30	753	36212 Kg	471 (MPa)	Ductile out Weld
TA2	25,1	30	753	36712 Kg	477 (Mpa)	Ductile out Weld
TB1	25	30	750	35712 Kg	466 (MPa)	Ductile out Weld
TB2	25,1	30	753	35612 Kg	463 (MPa)	Ductile out Weld

GUIDED BEND TEST

Specimen No.	Type of Bend	Results	Remarks
T1	Side bend	Satisfactory	Ductile
T2	Side bend	Satisfactory	Ductile
T3	Side bend	Satisfactory	Ductile
T4	Side bend	Satisfactory	Ductile

VISUAL INSPECTION:

Appearence: Good appearance

Undercut: No

Piping porosity: No

Convexity: Acceptable

Test Date: 11,11, 2005

Witnessed By: Jim Clark

Other Tests (Notes):

Radiographic-ultrasonic examination:

RT report no: 1230-RT Result: O.K.

UT report no: 2310-UT Result: O.K.

FILLET WELD TEST RESULTS:

Max. size single pass: Macrotech	Min. size multiple pass: Macrotech
1: N/A	1: N/A
2: _	2: _
3: _	3: _

All-weld-metal tension test:

Tensile strength, MPa (psi): N/A

Yield point/strength, MPa (psi): _

Elongation in 2 in.,%: _

Laboratory test no.: _

Welder's name: Welder Guy

Clock No.: 123-12-1234 Stamp No.: JS-02

Tests conducted by: Quality Weld Lab, Inc.

Laboratory Tests Number: TN-46547

Per: WPSAmerica.com

We, the undersigned, certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in conformance with the requirements of Section 4 of AWS D1.1, (Year:2004) Structural Welding Code Steel.

Signed (Manufacturer):

Name: John Smith

Title: QA Manager

Date: 12,12,2005

WELDER PERFORMANCE QUALIFICATION RECORD

Welder's Name C. W. Practical ID No. 222-33-4444 Date 11-08-00

WPS No. D1.1-3G-U-CJP-B-307

Welding Process FCAW Type Manual

Specification or Code AWS D1.1:2000, Structural Welding Code–Steel

Base Metal

Material Spec/Type/Grade A 36 To: Material Spec/Type/Grade A 36

Thickness 1 in Thickness Range Qualified 1/8 in-Unlimited

Base Metal Preparation Base metal shall be clean and free of moisture, oil, dirt, paint, coatings, rust, scale. etc. Cleaning shall leave no residue.

Joint Welded Single V-Groove with steel backing

Type of Weld Joint (See Figure 4.21, Test Plate for Unlimited Thickness)

Bevel Angle 22.5° Root Face 0 Root Opening 1/4 in

Backing Yes [X] No [ ] Backing Type 1/4 x 1 in Steel Strap

Electrode

F No. 4 Specification A 5.18 Classification E71T-1 Size Range 1/16th

Filler Metal

F No. 4 Specification A 5.18 Classification E71T-1 Size Range 1/16th

Preheat

Preheat 50°F min. Interpass Temperature Max. 400°F

Position

Position 3G Progression Up

TEST RESULTS

Visual	Bends	Radiographic	Metallographic
Pass [X] Fail [ ]	N/A [ ] Pass [X] Fail [ ]	N/A [X] Pass [ ] Fail [ ]	N/A [X] Pass [ ] Fail [ ]

Test conducted by ______ Laboratory test no. ______

per ______ Test date ______

QUALIFIED FOR

Base Metal Group No.	Type Weld	Current	Backing	Penetration	Vertical
I(a) (Carbon and Low-Alloy Steel)	Single Side [X] Double Side [ ]	AC [ ] DCEN [ ] DCEP [X]	With [X] Type Steel Open Root [ ]	Complete [X] Partial [ ]	Down [ ] Up [X]

	Position				t, in Min.	t, in Max.	OD, in Min.	OD, in Max.
Plate—Groove	1G [X]	2G [X]	3G [X]	4G [ ]	1/8	Unlimited		
Pipe/Tube—Groove	1G [X]	2G [X]	5G [ ]	6G [ ]	1/8	Unlimited	Over 24	Unlimited
Plate—Fillet	1F [X]	2F [X]	3F [X]	4F [ ]	1/8	Unlimited		
Pipe/Tube—Fillet	1F [X]	2F [X]	5F [ ]	6F [ ]	1/8	Unlimited		

The above individual is qualified to the above limits in accordance with AWS D1.1:2000, *Structural Welding Code—Steel*.

Qualified By *John Smith* (signature) Position Weld Supervisor Date 11-10-00

Welding Performance Qualification Record (WPQR)
Welding Code: AWS D1.1

Company Name: WPSAmerica.com

Company Address: info@WPSAmerica.com, 1 (877) 977-9353

Welder's Name: Elvis Tom Jones	Identification No: ETJ-2005	Type of welder: Welder
Welding Performance Qualification Record WPQR No. DEMO-SMAW-WPQR		Qualification Date: 12, 12, 2005
Welding Procedure Specification WPS No. DEMO-SMAW-WPS		Rev. 0

BASE METALS USED

Material Specification, Type or Grade: ASTM A 36 — ☑ Plate ☐ Pipe ☐ Box Tube ☐ Sheet

Welded to

Material Specification, Type or Grade: ASTM A 36 — ☑ Plate ☐ Pipe ☐ Box Tube ☐ Sheet

Variables	Actual Values Used	Qualification Range
Welding Process	SMAW	SMAW
Process Type	Manual	Manual
Electrode (Single o r Multiple)	Single	Single
Current Type/Pola rity	DCEP	
Backing (Yes or No)	Without backing	With or without
Welding Position :		
Groove	2G	F, H (Plate, Pipe, Box T ube)
Fillet		F, H (Plate, Pipe, Box T ube)
Vertical Progression	n/a	n/a
Plug or Slot Welds	n/a	2G (Plate)
Base Metals Thickness:		
Groove	3/8 in. (10 mm)	/8 in. (mm) to 3/4 in. (20 mm)
Fillet	n/a	any thickness
Plug or Slot Welds	n/a	any thickness
Base Metals Diameter (Pipe or Tube):		
Groove	n/a	24 in. (600 mm) OD and over
Fillet	n/a	24 in. (600 mm) OD and over
Filler Metal Specification (SFA)	A5.1	
Filler Metal Classification (AWS Classified	E7018	Any AWS A5 Class Approved
Filler Metal F-Number	4	4, 3, 2, 1
Gas/Flux (SAW)	n/a	n/a
Other Variable (coating type/thickness, etc)	n/a	n/a

Results

Visual Inspection of Completed Weld (D1.1, 4.8.1): Acceptable ☑ YES ☐ NO

Guided Bend Test Type and Results (D1.1, 4.30.5): One Root and One Face Bend Specimens

Result and Comments: Acceptable criteria based on AWS D1.1, Clause 4.8.3.3 measured values

Fillet-Weld Test Results (D1.1, 430.2.3 and 4.30.4.1):

Appearance: n/a	Fillet Size in (mm): n/a
Fracture Test Root Penetration: n/a	Macroetch: n/a
(Describe the location, nature, and size of any crack or tearing of the specimen.)	
Result and Comments: Groove weld test qualifies fillet weld test as well	
Inspected by: Tom Jones, AWS Certified Welding Inspector	Test Number: 1012-G
Organization: Testing Lab Data, Inc.	Date: 12, 12, 2005

Alternative * Radiographic Test Results (D1.1, 4.30.3.1) : * In lieu of Guided Bend Test, except for GMAW-S

Film Identification No.	Results	Remarks	Film Identification No.	Results	Remarks
n/a	n/a	n/a	n/a	n/a	n/a
n/a	n/a	n/a	n/a	n/a	n/a

Film interpreted by: n/a	Test Number: n/a
Organization: n/a	Date: n/a

Other information: Guide bend test conducted instead of RT. This WPQR demo form has been created by WPSAmerica.com Online Welding Software

We, the undersigned, certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in conformance with the requirements of Section 4 of AWS D1.1/D1.1M, (2008) Structural Welding Code-Steel.

Manufacturer/ Contractor Welding Engineer	Authorized By:
Name: Joe Smith Title: Welding Engineer Signature: J. S. Date: 14, 12, 2005	Name: James Bond Title: QA Manager Signature: J. B. Date: 14, 12, 2005

XII – REFERENCES:

AWS D1.1 – Structural Welding Code
AWS A2.4 - Standard Symbols for Welding, Brazing, and Nondestructive Examination;
AWS A3.0 - Standard Welding Terms and Definitions;
AWS B1.10 - Guide for the Nondestructive Examination of Welds;
AWS B1.11 - Guide for the Visual Inspection of Welds;
AWS B2.1 - Specification for Welding Procedure and Performance Qualification;
AWS B4.0 - Standard Methods for Mechanical Testing of Welds;
AWS B5.1 - Specification for the Qualification of Welding Inspectors;
AWS QC1 - Standard for AWS Certification of Welding Inspectors;
ANSI/ASME B31.1 - Power Piping;
ASME VIII - Pressure Vessels, Division 1, Division 2 and Division 3;
ASME V - Non-destructive examination;
ASME B16.5 - Pipe flanges and flanged fittings.
ASME IX - Welding and Brazing Qualifications;
API 510 - Maintenance inspections, repair, alteration, and re-rating procedures for pressure vessels;
API 570 - Performs visual, baseline and in-service corrosion inspections on piping systems;
API 653 - Specific inspection requirements and techniques that apply to above ground storage tanks;
API570 - Piping inspection code;
API RP 574 - Inspection practices for piping system components;
API RP 577 - Welding and metallurgy;
API RP 578 - Material verification program for new and existing alloy piping systems;