

# Introduction to Welding Technology

Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding, the pieces to be joined (*the workpieces*) are melted at the joining interface and usually a filler material is added to form a pool of molten material (*the weld pool*) that solidifies to become a strong joint.

In contrast, *Soldering and Brazing* do not involve melting the workpiece but rather a lower-melting-point material is melted between the workpieces to bond them together.

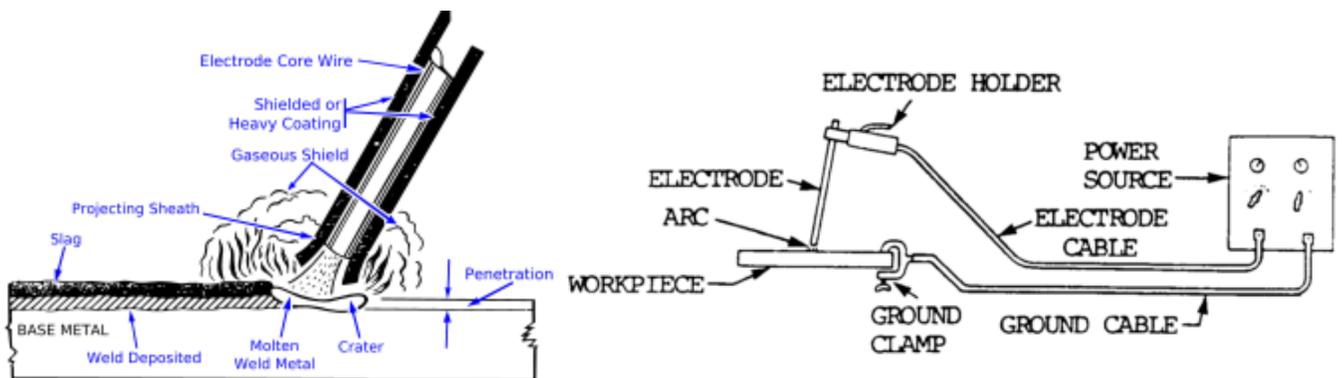
## Types of Welding

There are many different types of welding processes and in general they can be categorized as:

**Arc Welding:** A welding power supply is used to create and maintain an electric arc between an electrode and the base material to melt metals at the welding point. In such welding processes the power supply could be AC or DC, the electrode could be consumable or non-consumable and a filler material may or may not be added.

The most common types of arc welding are:

- Shielded Metal Arc Welding (SMAW): A process that uses a coated consumable electrode to lay the weld. As the electrode melts, the (flux) coating disintegrates, giving off shielding gases that protect the weld area from atmospheric gases and provides molten slag which covers the filler metal as it travels from the electrode to the weld pool. Once part of the weld pool, the slag floats to the surface and protects the weld from contamination as it solidifies. Once hardened, the slag must be chipped away to reveal the finished weld.



- Gas Metal Arc Welding (GMAW): A process in which a continuous and consumable wire electrode and a shielding gas (*usually an argon and carbon dioxide mixture*) are fed through a welding gun.
- Gas Tungsten Arc Welding (GTAW): A process that uses a nonconsumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by a shielding gas, and a filler metal that is fed manually is usually used.

**Gas Welding:** In this method a focused high temperature flame generated by gas combustion is used to melt the workpieces (and filler) together. The most common type of gas welding is Oxy-fuel welding where acetylene is combusted in oxygen.

**Resistance Welding:** Resistance welding involves the generation of heat by passing a high current (1000–100,000 A) through the resistance caused by the contact between two or more metal surfaces where that causes pools of molten metal to be formed at the weld area. The most common types of resistance welding are Spot-welding (using pointed electrodes) and Seam-welding (using wheel-shaped electrodes).

**Energy Beam Welding:** In this method a focused high-energy beam (Laser beam or electron beam) is used to melt the workpieces and thus join them together.

**Solid-State Welding:** In contrast to other welding methods, solid-state welding processes do not involve the melting of the materials being joined. Common types of solid-state welding include; ultrasonic welding, explosion welding, electromagnetic pulse welding, roll welding, friction welding (including friction-stir-welding), etc.

## Welding Terminology

There is some special technical vocabulary (or language) that is used in welding. The basic terms of the welding language include:

**Filler Material:** When welding two pieces of metal together, we often have to leave a space between the joint. The material that is added to fill this space during the welding process is known as the filler material (or filler metal).

**Welding Rod:** The term welding rod refers to a form of filler metal that does not conduct an electric current during the welding process. The only purpose of a

welding rod is to supply filler metal to the joint. This type of filler metal is often used for gas welding.

**Electrode:** In electric-arc welding, the term electrode refers to the component that conducts the current from the electrode holder to the metal being welded. Electrodes are classified into two groups: consumable and non-consumable.

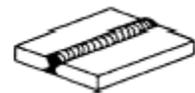
- Consumable electrodes not only provide a path for the current but they also supply filler metal to the joint. An example is the electrode used in shielded metal-arc welding.
- Non-consumable electrodes are only used as a conductor for the electrical current, such as in gas tungsten arc welding. The filler metal for gas tungsten arc welding is a hand fed consumable welding rod.

**Flux:** Before performing any welding process, the base metal must be cleaned from impurities such as oxides (rust). Unless these oxides are removed by using a proper flux, a faulty weld may result. The term flux refers to a material used to dissolve oxides and release trapped gases and slag (impurities) from the base metal such that the filler metal and the base metal can be fused together. Fluxes come in the form of a paste, powder, or liquid. Different types of fluxes are available and the selection of appropriate flux is usually based on the type of welding and the type of the base metal.

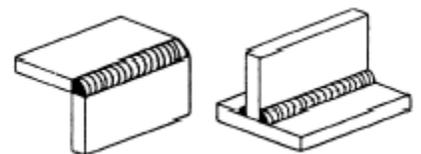
### Types of Welded Joints

The weld joint is where two or more metal parts are joined by welding. The five basic types of weld joints are the butt, corner, tee, lap, and edge.

**Butt Joint:** it is used to join two members aligned in the same plane. This joint is frequently used in plate, sheet metal, and pipe work.



**Corner and Tee Joints:** these joints are used to join two members located at right angles to each other. In cross section, the corner joint forms an L-shape, and the tee joint has the shape of the letter T.

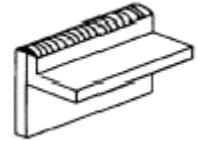


**Lap Joint:** this joint is made by lapping one piece of metal over another. This is one of the strongest types of joints available; however, for maximum joint efficiency, the overlap should be at



least three times the thickness of the thinnest member of the joint.

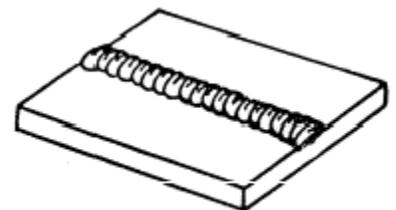
**Edge Joint:** it is used to join the edges of two or more members lying in the same plane. In most cases, one of the members is flanged, as seen in the figure. This type is frequently used in sheet metal work for joining metals 1/4 inch or less in thickness that are not subjected to heavy loads.



### Types of Welds

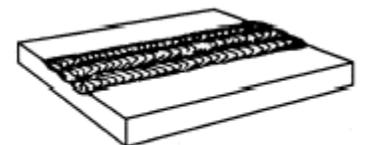
There are many types of welds. The most common types are the bead, surfacing, plug, slot, fillet, and groove.

- A weld **Bead** is a weld deposit produced by a single pass with one of the welding processes. A weld bead may be either *narrow or wide*, depending on the amount of transverse oscillation (side-to-side movement) used by the welder. A weld bead made without much weaving motion is often referred to as a stringer bead. On the other hand, a weld bead made with side-to-side oscillation is called a weave bead.



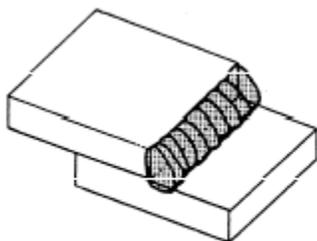
Simple weld bead.

- Several weld beads applied side-by-side are usually used in **Surfacing** which is a welding process used to apply a hard, wear-resistant layer of metal to surfaces or edges of worn-out parts.

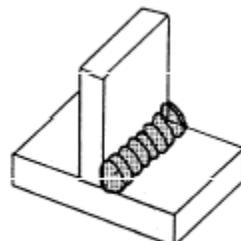


Surfacing welds.

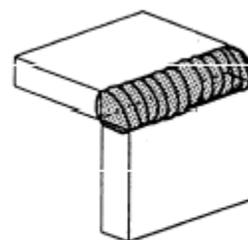
- A **Fillet** weld is triangular in shape and this weld is used to join two surfaces that are at approximately right angles to each other in a lap, tee, or corner joint.



LAP FILLET

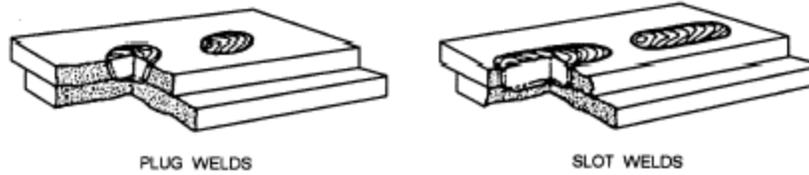


TEE FILLET

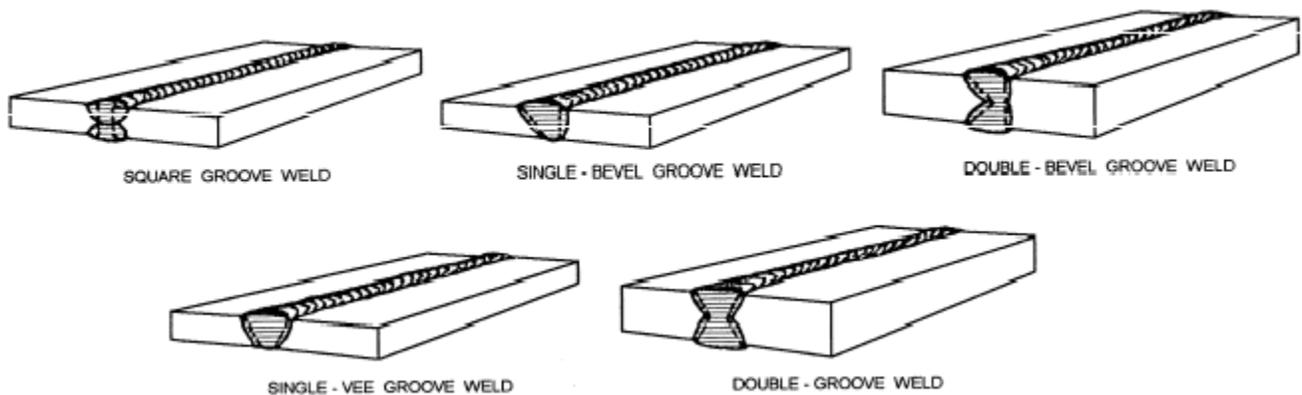


CORNER FILLET

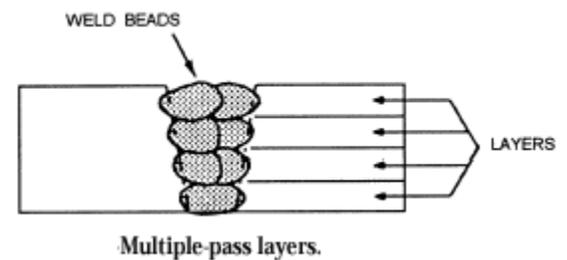
- **Plug** and **Slot** welds are welds made through holes or slots in one member of a lap joint. These welds are used to join that member to the surface of another member that has been exposed through the hole.



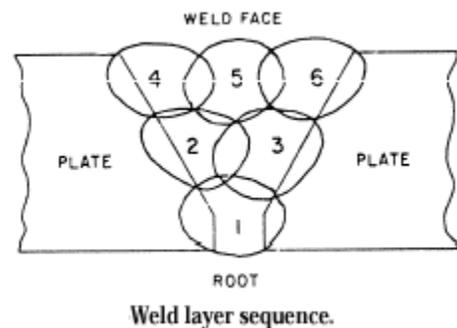
- **Groove** welds (also may be referred to as Butt welds) are simply welds made in the groove between two members to be joined. The weld is adaptable to a variety of butt joints, as seen in the figure.



- Groove welds may be joined with one or more weld beads, depending on the thickness of the metal. If two or more beads are deposited in the groove, the weld is made with multiple-pass layers, as shown in the figure. As a rule, a multiple-pass layer is made with stringer beads in manual operations.



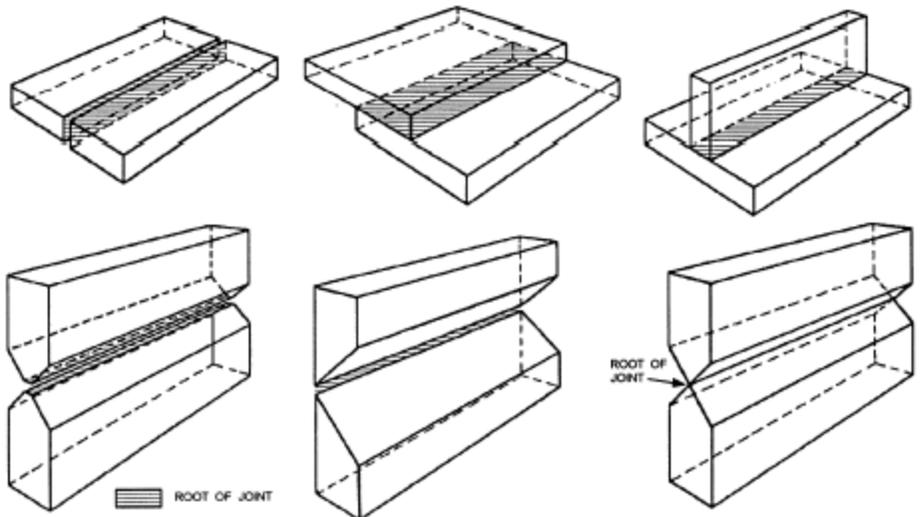
- The buildup sequence refers to the order in which the beads of a multiple-pass weld are deposited in the joint. Usually, before adding the next pass, the previous pass needs to cool down to a certain temperature which is called the inter-pass temperature. Also, before adding the next pass, the surface of the previous pass needs to be cleaned from slag, especially with SMAW, using a wire brush or other appropriate method.



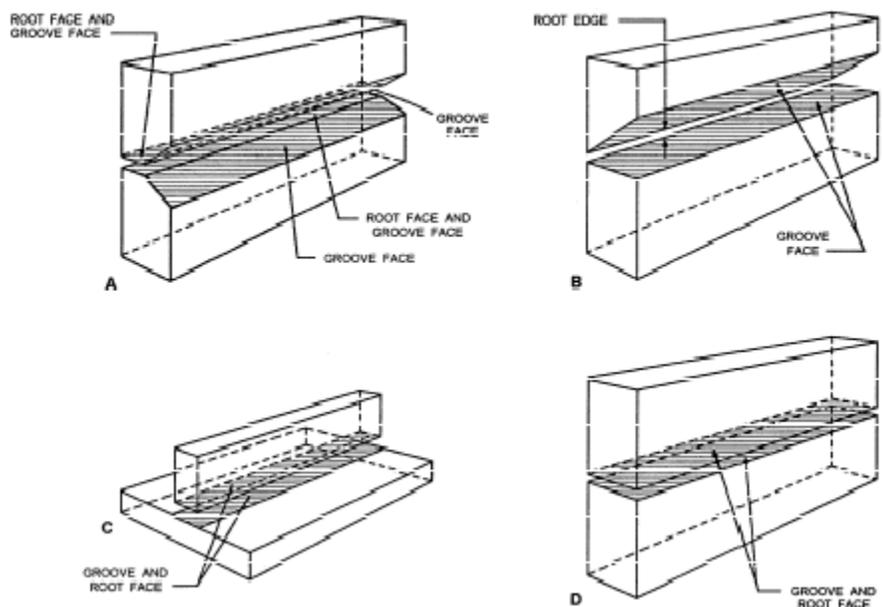
## Parts of Welded Joints

While there are many variations of joints, the parts of the joint are described by standard terms.

- The **root** of a joint is that portion of the joint where the metals are closest to each other. As shown in the figure, the root may be a point, a line, or an area, when viewed in cross section.

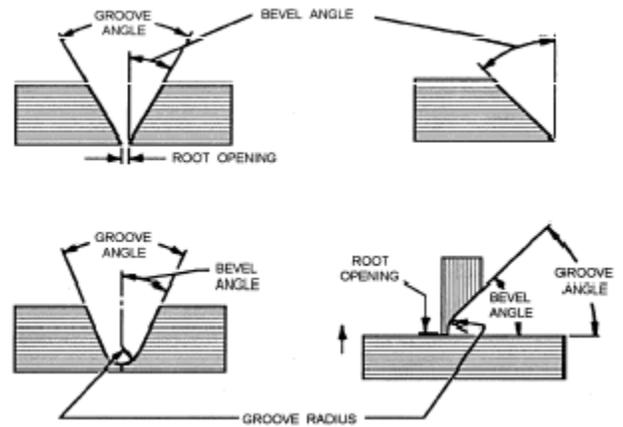


- A **groove** is an opening or space provided between the edges of the metal parts to be welded.
  - The **groove face** is that surface of a metal part included in the groove, as shown in view A.
- A given joint may have a **root face or a root edge**.
  - The **root face**, also shown in view A, is the portion of the prepared edge of a part to be joined by a groove weld that has not been grooved. As you can see, the root face has relatively small dimensions.
  - The **root edge** is basically a root face of zero width, as shown in view B. As you can see in views C and D of the illustration, the groove face and the root face are the same metal surfaces in some joints.

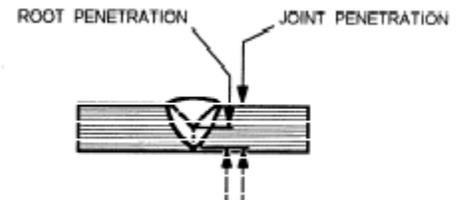


- The specified requirements for a particular joint are expressed in terms such as *bevel angle*, *groove angle*, *groove radius*, and *root opening* which are illustrated in the figure.

- The *bevel angle* is the angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member.
- The *groove angle* is the total angle of the groove between the parts to be joined. For example, if the edge of each of two plates were beveled to an angle of 30 degrees, the groove angle would be 60 degrees.
- The *groove radius* is the radius used to form the shape of a J- or U-groove weld joint. It is used only for special groove joint designs.
- The *root opening* refers to the separation between the parts to be joined at the root of the joint. It is sometimes called the “*root gap*”.

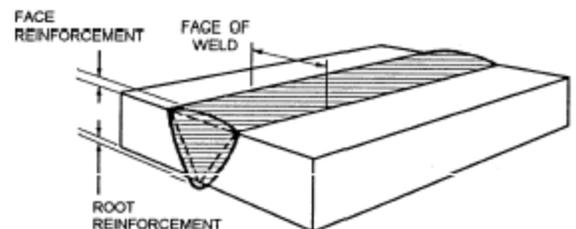


- *Root penetration* refers to the depth that a weld extends into the root of the joint. Root penetration is measured on the center line of the root cross section.
- *Joint penetration* refers to the minimum depth that a groove weld extends from its face into a joint, exclusive of weld reinforcement.



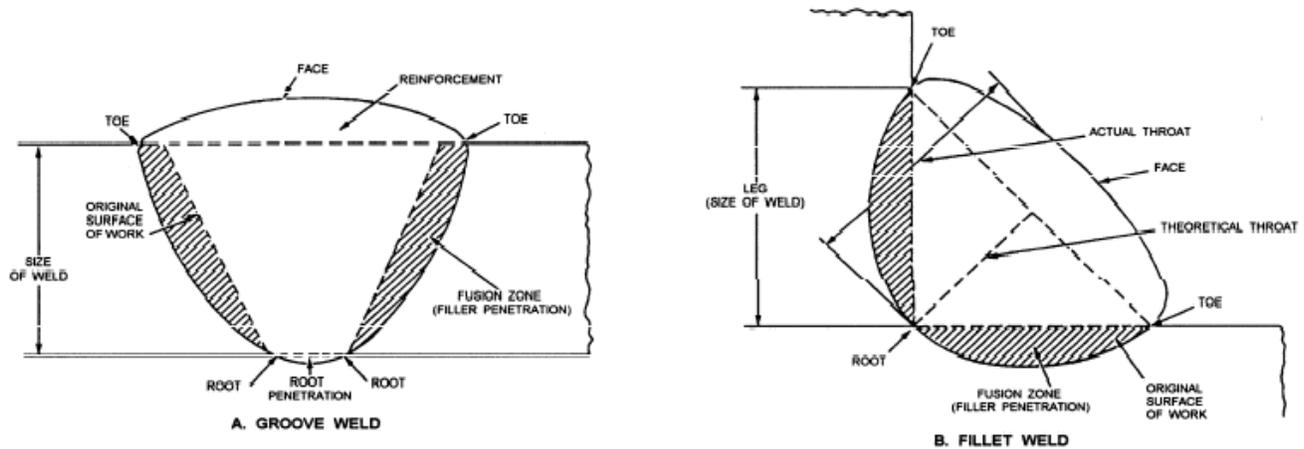
➤ In some cases, root penetration and joint penetration, can refer to the same dimension.

- *Weld reinforcement* is a term used to describe weld metal in excess of the metal necessary to fill a joint. The reinforcement needs to be grinded in some cases depending on the intended use of the joint.



## Parts of Welds

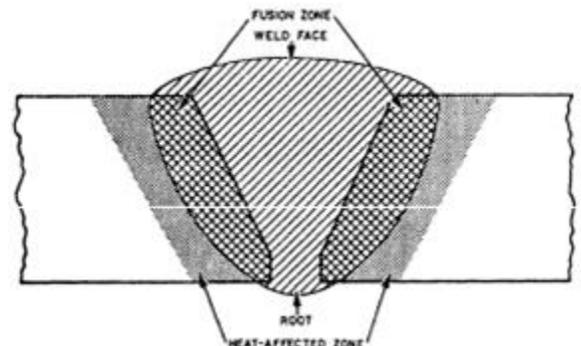
It is important to be familiar with the terms used to describe a weld. The figure shows the parts of groove weld and fillet welds.



- The face is the exposed surface of a weld on the side from which the weld was made.
- The toe is the junction between the face of the weld and the base metal.
- The root of a weld includes the points at which the back of the weld intersects the base metal surfaces.
- In a fillet weld, the leg is the portion of the weld from the toe to the root.
- In a fillet weld, the throat is the distance from the root to a point on the face of the weld along a line perpendicular to the face of the weld. Theoretically, the face forms a straight line between the toes.
- The size of a fillet weld refers to the length of the legs of the weld. The two legs are assumed to be equal in size unless otherwise specified.

Some other terms which are used to describe areas or zones of welds are:

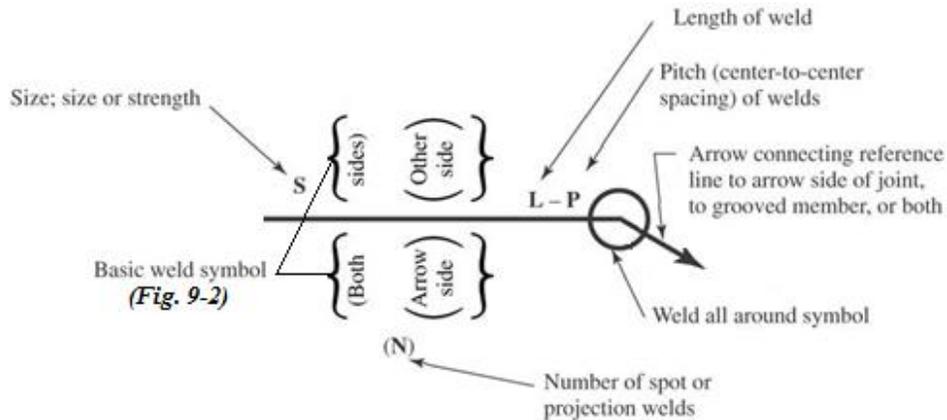
- The fusion zone is the region of the base metal that is actually melted. The depth of fusion is the distance that fusion extends into the base metal or previous welding pass.
- The heat-affected zone (HAZ) refers to that portion of the base metal that has not been melted; however, the structural or mechanical properties of the metal have been altered by the welding heat.



## Welding Symbols

Welding symbols are used on drawings to indicate the type and specifications of the weld.

- The figure shows the *American Welding Society (AWS)* standard welding symbol. The most important features of the welding symbol are illustrated below:



- The table shows the *Basic weld symbol* for the different types of welds.

Type of weld							
Bead	Fillet	Plug or slot	Groove				
			Square	V	Bevel	U	J

- The figures below show some examples for the use of welding symbols.

