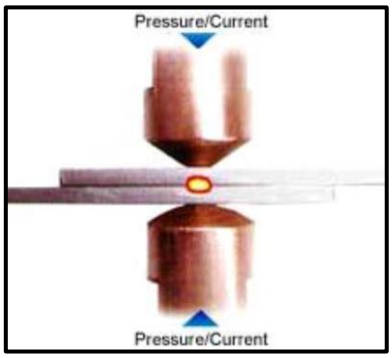
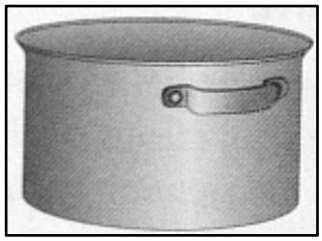
1-4 Resistance welding (RW)

Resistance welding process makes use of the electrical resistance for generating heat required for melting the workpiece. It is generally used for joining thin plates and structures. It has different variants such as Spot welding, Seam welding and Projection welding.

Here, metal strips are welded by holding them together by a force, and raising their temperature by passing a current through the interface. Resistance welding is commonly used in several applications, to make butt joints, lap joints, seam joints etc. Examples include pan-handle welding, automobile mufflers, band-saw blades, seam-joints in automobile bodies and automobile components, etc. Some examples are shown in figure (1) and (2) below.



Spot welding



Spot welding of a pan

Robotic Spot welding on auto body

Figure (1): (a) Spot welding (b) and (c) Examples of resistance welding

Advantages of Resistance Welding:

There are a number of distinct advantages that account for wide use of the resistance welding processes, particularly in mass production. These advantages include:

- Very rapid and economical process, widely used in mass production.
- The equipment can be fully automated.
- They conserve materials as no filler material, shielding gas or flux is required.

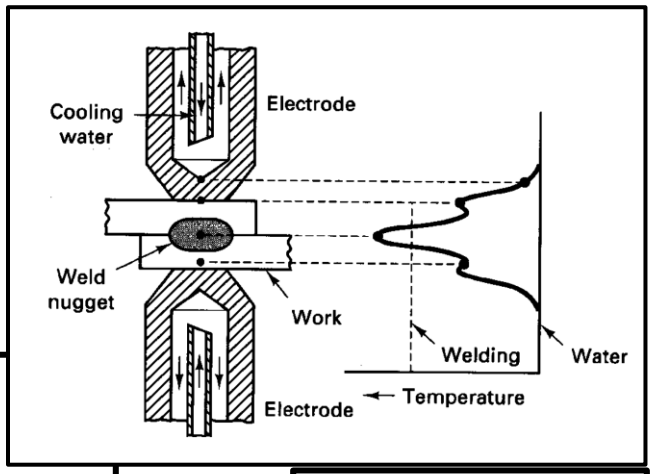
- Skilled operators are not required.
- Dissimilar metals can be easily joined.
- A high degree of reliability and reproducibility can be achieved.

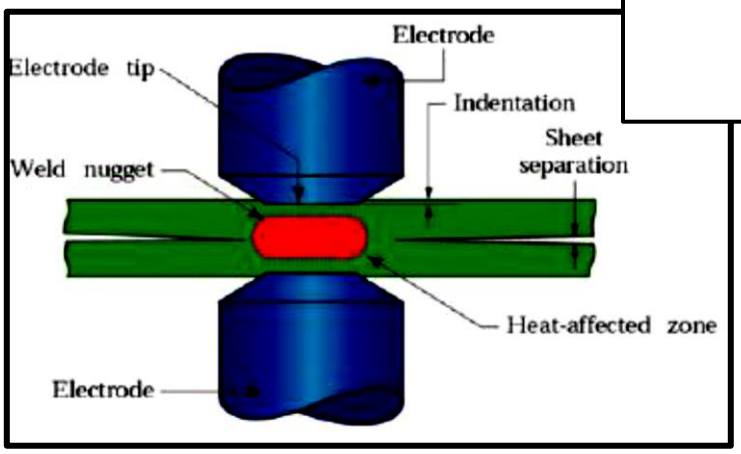
Resistance Welding has some limitations, the principal ones being:

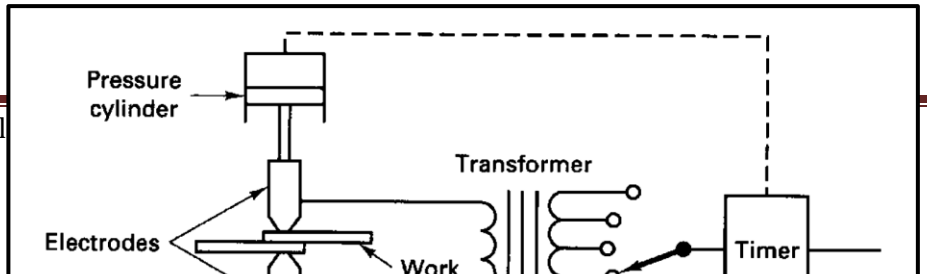
- The equipment has a high initial cost.
- There are limitations to the type of joints that can be made (mostly suitable for lap joints).
- Skilled maintenance persons are required to service the control equipment.
- Some materials require special surface preparations prior to welding.

1-4-1 Resistance Spot Welding (RSW)

Two or more sheets of metal are held between metal, water cooled electrodes of spot-welding machines, or portable spot welding guns.

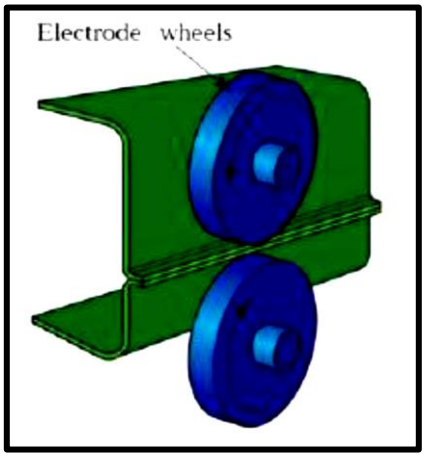


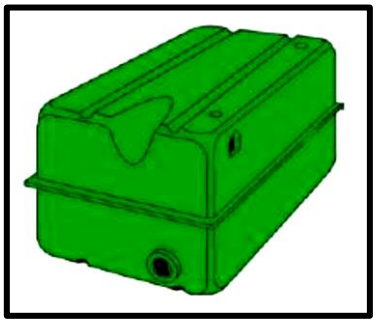


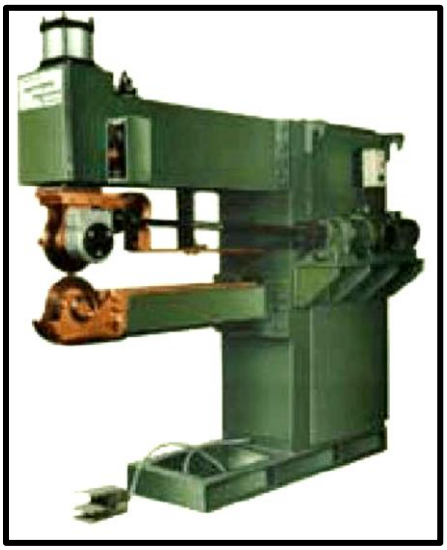


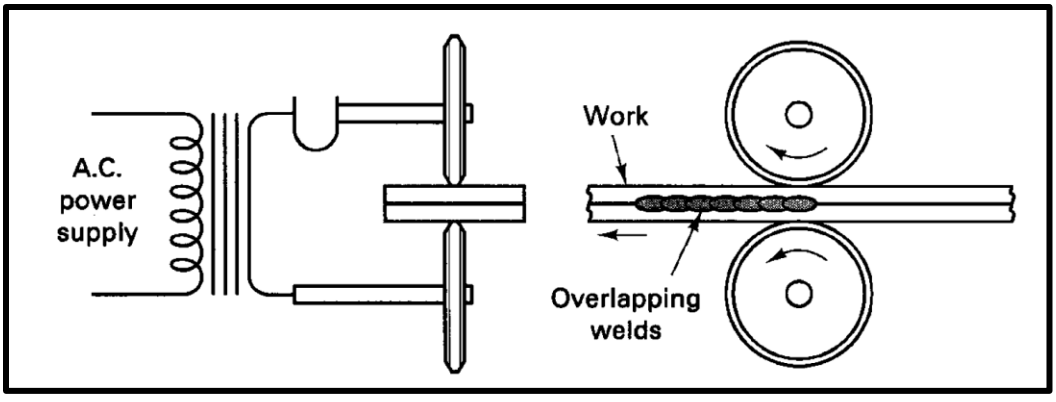
1-4-2 Resistance Seam Welding (RSEW)

In most cases, where the weld is between two sheets of metal, the seam is actually is a series of overlapping spot welds. The basic equipment is the same as for spot welds, except that two rotating disks are used as electrodes.









As the metal passes between the electrodes, timed pulses of current pass through it to form the overlapping welds. The timing of the welds and the movement of the works is controlled to assure that the welds overlap and the workpiece do not get too hot. The welding current is usually higher than the conventional spot welding. In order to compensate for the short circuit of the adjacent welds, external cooling of the work by air or water is often employed. In a variation process, a continuous seam is produced by passing a continuous current through the rotating electrodes. The typical welding speed is about 60 in/ min for thin sheets. Some variants of

The second type of resistance seam welding is used to make butt welds between thicker metal plate. In this process, the electrical resistance of the abutting metal is used to generate heat and a high frequency current (up to 450 kHz) is employed to restrict the flow of current to the surfaces

to be joined and to their intermediate surroundings. The most extensively used resistance butt welding is in the manufacturing of pipes and tubes and simple structural shapes which can be produced from plates.

Applications:

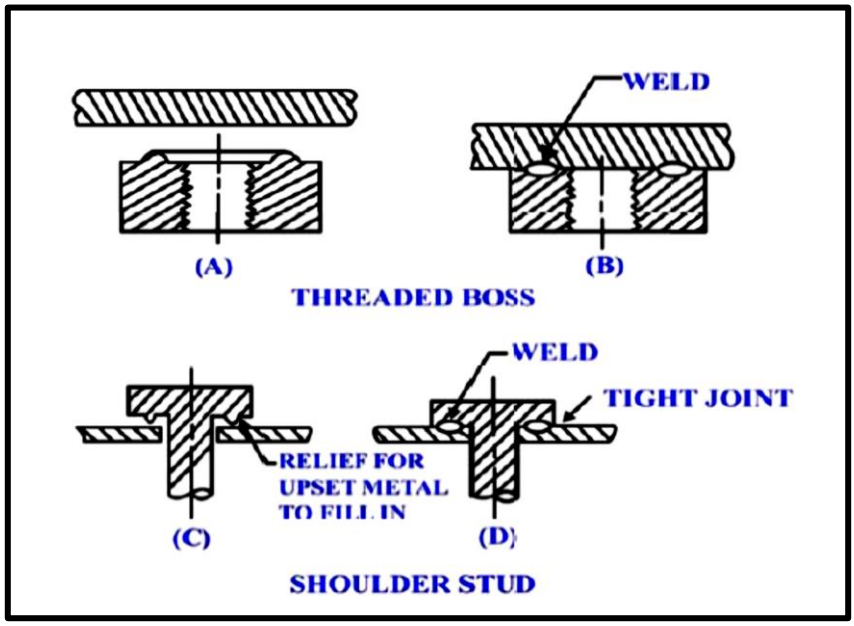
- Materials from 0.13 mm thickness to more than 19 mm thickness can be welded up to 82 meter /min.
- The combination of high frequency current and high welding speed produces a very narrow heat affected zone.
- Almost all types of materials can be welded, including dissimilar metals and high conductivity metals, such as aluminium and copper.

1-4-3 Projection Welding:

Principles

A dimple is embossed into one of the workpieces at the locations where the weld is desired as shown in the Figs. 4.2.4 & 4.2.5. The work-pieces are then placed between large area electrodes. Pressure and current are applied as in the spot welding process. Since the current must flow through the points of contact, namely the dimples, the heating is concentrated where the weld is desired. As the metal

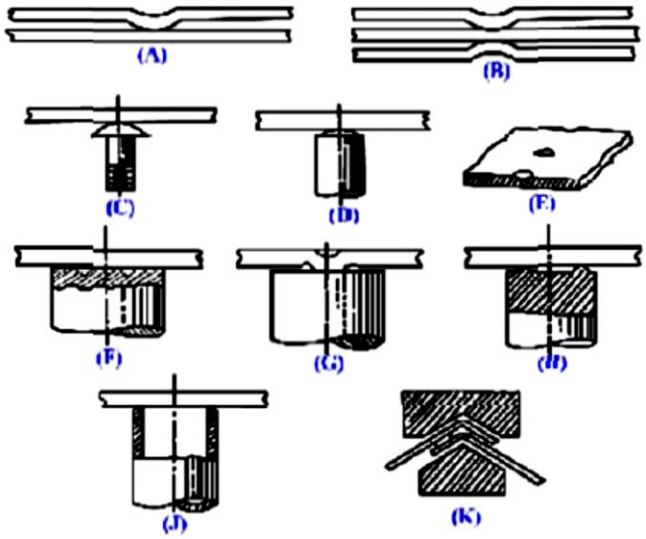
heats and becomes plastic, pressure causes the dimple to flatten and form a weld. Since the projections are press formed, they can often be produced during other blanking and forming operations with virtually no additional cost.



Projection Welding Design example

Advantages:

- Dimples and projections can be made in almost any shapes such as round, oval or circular in order to produce the welds of shapes to suit various design purposes.
- Several dimples can be incorporated into the sheet and multiple welds can be made at a given time.
- A conventional spot welding machine can be changed into a projection welding machine by changing the size and shape of the electrode.
- Projection welding leaves no indentation mark on the free surface, a distinct advantage over spot welding when good appearance is required (Fig. 4.2.6).



Applications:

- Several joints can be made with multiple spots as per required applications.
- Nuts, bolts can be attached to other metal parts by projection welding. Contact is made at a projection that has been machined or forged onto the bolt or nut, current is applied and the pieces are pressed together to form a weld.
- It is an attractive means of mass production. Multiple welds can be made with additional strength thereby improving the short comings of a conventional spot welding where one spot is made at a time.

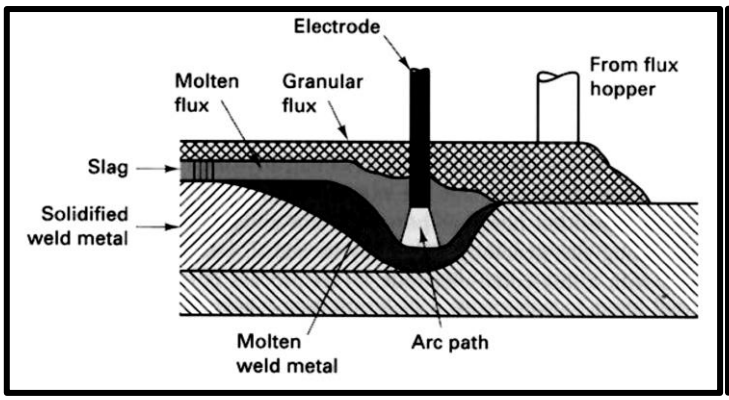
1-5 Submerged Arc Welding (SAW)

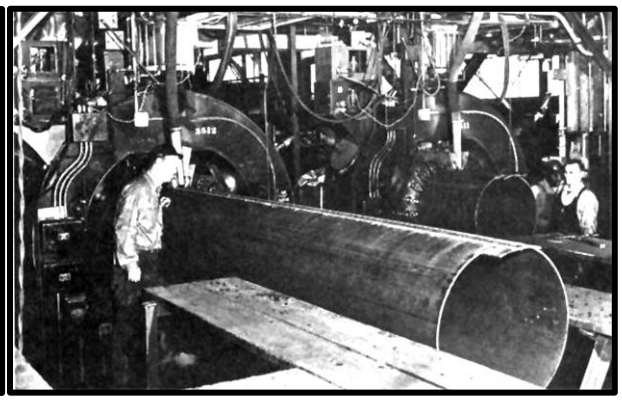
The conventional welding processes like arc welding and gas welding, although serve variety of purposes, look inadequate while catering to some specific requirements. The need for advanced / newer welding techniques frequently arises in the following situations.

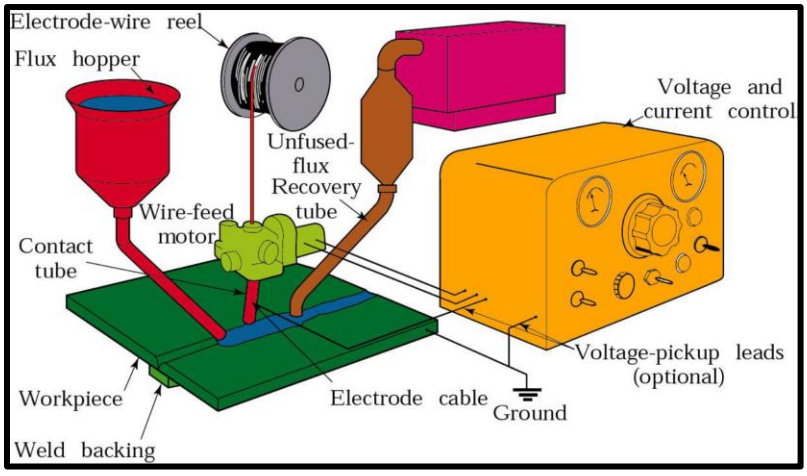
- Joining of thick plates, structures and large joints are required.
- Joining of very thin plates usually cause large heat affected zones and undesired warpages.
- Joining of different metals can cause uneven fusion due to different range in melting points.

- Requirements of good finish, low heat affected zones and high quality welds demand the use of advanced or non-conventional welding methods.

The Submerged Arc Welding (SAW) process was invented in the U.S.A and U.S.S.R. around 1930's. The process contributes to approximately 10% of the total welding activities carried out today. In this process, the arc, is kept submerged under a blanket of granular fusible flux. The flux is deposited just ahead of the electrode, which is in the form of coiled wire. The granular flux provides excellent shielding of the molten metal and, because the pool of molten metal is relatively large, good fluxing action occurs, so as to remove impurities. Consequently very high quality welds are obtained.







Principles of Operation:

In submerged arc welding, the end of a continuous bare wire electrode is inserted into a mould of flux that covers the area or joint to be welded. An arc is initiated using some of the common arc starting methods. A wire feed mechanism further begins to feed the electrode wire towards the joint at a controlled rate and the feeder is moved manually or automatically along the weld seam. For machine welding or automatic welding, the work may be moved beneath a stationary wire feeder.

Additional flux is continually fed in front of and around the electrode and it is continually distributed over the joint through the hopper. Heat evolved by the electric arc then progressively melts some part of the flux, the end of the wire and the adjacent edges of the base metal, creating a pool of molten metal beneath a layer of liquid slag. The melted bath near the arc is in a highly turbulent state. Gas bubbles are quickly swept to the surface of the pool. The flux floats on the molten metal and completely shields the welding zone from the atmosphere.

The flux blanket on the top surface of the weld pool prevents atmospheric gases from contaminating the weld metal, dissolves impurities in the base metal and electrode, and floats them to the surface. The flux can also add or remove certain alloying elements to or from the weld metal. As the welding zone progresses along the seam, the weld metal and then the liquid flux gets cooled and subsequently solidified, forming a weld bead and a protective slag over it. It is important that the slag is completely removed before making another weld pass.

Factors which determine the usage of SAW include:

1. The chemical composition and mechanical properties required of the final deposit.
2. Thickness of base metal to be welded.
3. Joint accessibility.
4. Position in which the weld is to be made.
5. Frequency and/or volume of welding to be performed.

Characteristics of SAW:

The significant characteristics of the SAW process are:

- Higher metal depositing rate,
- Higher welding speed,
- Higher process efficiency,
- Lower nitrogen and hydrogen content in the weld metal,
- Cleaner weld metal,
- Better control over the chemical composition,
- Better control over on the mechanical and metallurgical properties.

General Methods:

The SAW can be applied in 3 different modes: Semi-automatic, Automatic and Machine. Each method requires the work be positioned so that flux and the molten weld pool will remain in place until they have solidified. Fixtures and positioning equipment can be used for typical requirements.

Semiautomatic Welding:

This welding is done with a gun held in hand, which delivers both flux and the electrode. The electrode is further driven by a wire feeder. The flux may be supplied by a gravity hopper

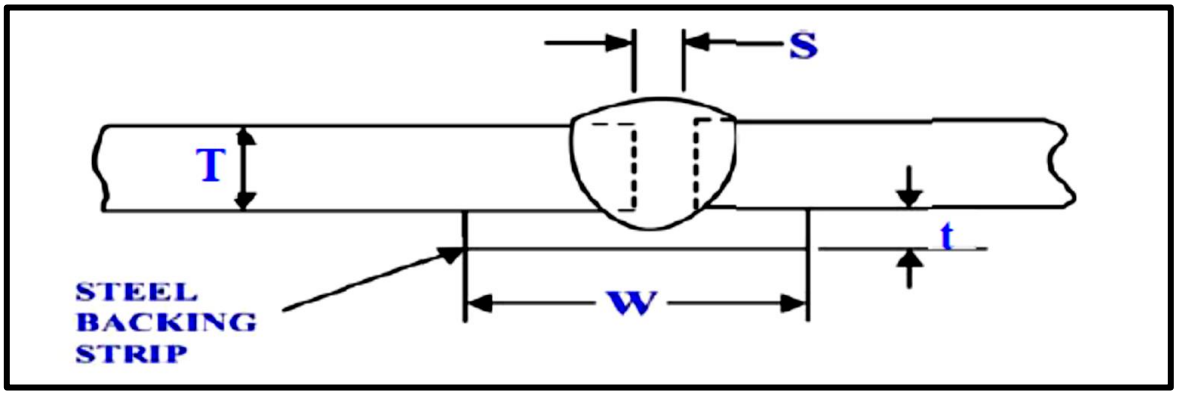
mounted on the gun or it is pressure fed through a hose. This welding method involves some manual assistance wherein the electrodes used are relatively smaller in diameter and travel speeds are also not high. Further the travel can be partially automated using a driving motor and a small gun.

Automatic Welding:

In this process, a welding operator is not required for continuous monitoring and controlling of the process. Self-regulating equipment are used in order to achieve high production rates.

Machine Welding:

It employs equipment which perform complete welding operations and needs monitoring to position the work, start and stop welding, adjust the controls and speeds of weld. Figure 4.1.2 shows the back strip and gap details. Typical welding conditions for single Machine-weld SAW (using one pass square groove) are indicated in Table 4.1



Backing strip and gap details in SAW

Table 4.1 Typical welding conditions in SAW

Plate Thickness, T	Root Opening S	Current	DCEP Voltage	Travel Speed	Electrode Diameter	Electrode consumption	t	W
mm	mm	A	V	mm/s	Mm	kg/m	mm	mm
3.6	1.6	650	28	20	3.2	0.11	3.2	15.0
4.8	1.6	850	32	15	4.8	0.19	4.8	19
6.4	3.2	900	33	11	4.8	0.25	6.4	25.4
9.5	3.2	950	33	10	5.6	0.36	6.4	25.4
12.7	4.8	1100	34	8	5.6	0.69	9.5	25.4

Flux:

It is a material used to prevent, dissolve or facilitate the removal of oxides and other undesirable substances. It helps the process in the following ways:

- In protecting the weld pool and stabilizing the arc,
- Providing appropriate chemical composition as desired,

- Improving the properties by alloying materials appropriately,
- Deoxidizing the weld metal,
- Improving weld bead shape parameters,
- Improving the efficiency of metal deposition.

Power Sources:

These play a major operating role. A DC power supply may be a transformer-rectifier, a motor or engine generator, which provides a constant voltage (CV), constant current (CC) or a selectable CV/CC output. The AC power supplies are generally transformer types and may provide either a CC output or a CV square wave output. Since SAW is generally a high current with a high duty cycle, a power supply capable of providing high amperage at 100 percent duty cycle is recommended.

DC Constant Voltage Power Sources:

These are available in both transformer-rectifier and motor generator models. They range in size from 400-1500A models. These power sources are used for semi-automatic SAW at currents ranging from 300 to 600A recommended for 1.6 to 2.4 mm diameter electrodes. Automatic welding is done with currents ranging from 300 to over 1000A, with wires generally ranging from 2.4-6.4 mm.

Applications for DC welding at over 1000 A are limited since severe arc blow can occur at such high currents. New generation power suppliers provide more stable arc and can be maintained at lower current densities.

A constant voltage power supply is self-regulating, so it can be used with a constant speed wire feeder. Constant current DC power sources are available in both transformer rectifier and motor generator models, with rated outputs up-to 1500 A.

Alternating Current Power Sources:

Transformers are the most commonly used power sources in AC welding. Sources rated for 800 to 1500 A at 100 percent duty cycle are available. If higher amperages are required, these machines can be connected in parallel. Conventional AC power courses are the constant current type.

Effect on Polarity:

- Direct Current Electrode Negative (DCEN): It gives higher deposition rates, higher yield strength and higher hardness.
- Direct Current Electrode Positive (DCEP): It gives lower deposition rates and lower yield strengths.

Accessory and Equipment:

The commonly used accessories in SAW are: travel equipment, flux recovery units, fixturing equipment and positioning equipment.

Flux Recovery Units:

Flux recovery units are frequently used to maximize flux utilization and minimize manual cleanup activities. Pneumatic flux feeding is commonly used in semi-automatic SAW and frequently in automatic SAW. Flux recovery units may help in the following:

1. Remove un-fused flux and fused slag behind the weld head.
2. Screen out fused slag and other oversized material.
3. Remove magnetic particles and fines.
4. Recirculate flux back to a hopper for reuse.
5. Flow heat inside the hopper to keep it dry.

Positioners and Fixtures:

Since SAW is limited to flat position welding, positioners and related fixturing equipment find widespread use for it. Commonly used positioners include:

1. Head-tailstock units, turning rolls, or both, to rotate cylindrical parts under the weldhead,
2. Tilting rotating positioners, to bring the weldable areas of irregular parts into flat position.

Custom fixturing often includes positioners to aid in setting up, positioning and holding the workpiece together. Turnkey systems are available depending on the requirements.

Testing requirements for SAW welds:

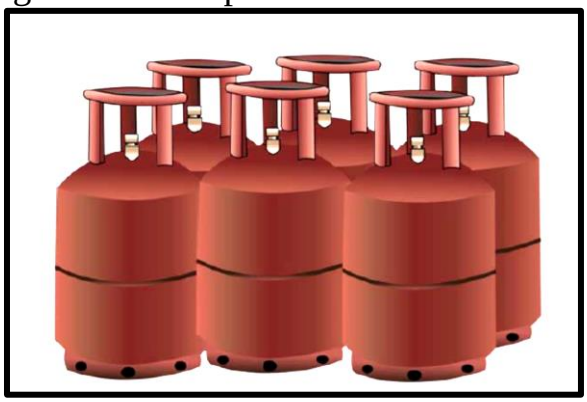
• Destructive: Tensile Testing and Impact testing.

• Non Destructive Testing (NDT): Surface Inspection: Dye Penetration and Magnetic Particle

• Internal Inspection: Ultrasonic Inspection, Radiographic Inspection.

SAW Applications:

The process is very commonly used in joining the two deep drawn vessels of the liquified gas cylinder bodies as indicated in the figure. Some other applications of SAW are in the welding of:



Application of SAW in Joining LPG Cylinders

- High strength low alloy steels
- Low carbon steels, Stainless steels, Aluminum and Titanium alloys
- Other non-ferrous alloys
- Fabrication of thick plates and thick pipes
- Pressure vessels and heat exchangers,
- Rail road tanks and ship body fabrication