# Welding of aluminium and its alloys

**Objectives:** At the end of this lesson you shall be able to
- **explain the properties of aluminium and its alloys**
- **state the difficulties in welding of aluminium by oxy-acetylene process**
- **describe the joint design, importance of flux and welding procedure**
- **state the various process of welding aluminium**
- **explain the advantages and disadvantages of welding of aluminium by oxy-acetylene process.**

**Properties of aluminium and its alloys**

Silvery white in colour.

Weighs only about one third as much as the commonly used low carbon steel.

Highly resistant to corrosion.

Possesses great electrical and thermal conductivity.

Very ductile, adaptable for forming and pressing operations.

Non-magnetic.

Melting point of pure aluminium is 659°C

Aluminium oxide has a higher melting point (1930°C) than aluminium.

**Types**

Aluminium is classified into three main groups.

– Commercially pure aluminium

– Wrought alloys

– Aluminium cast alloys

Commercially pure aluminium has a purity of at least 99% the remaining 1% consisting of iron and silicon.

**Difficulties in welding of aluminium by gas:** Aluminium does not change in colour before it reaches the melting temperature. When the metal begins to melt, it collapses suddenly.

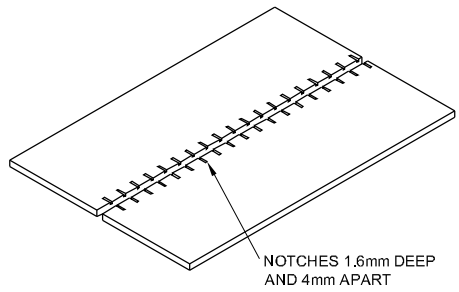
Molten aluminium oxidizes very rapidly form a heavy coating of aluminium oxide on the surface of the seam which has a higher melting point - 1930°C. This oxide must be thoroughly removed by using a good quality flux.

Aluminium, when hot, is very flimsy and weak. Care must be taken to support it adequately during the welding operation.

**Joint design:** Up to 1.6 mm, the edges should be formed to a 90° flange at a height equal to the thickness of the material.

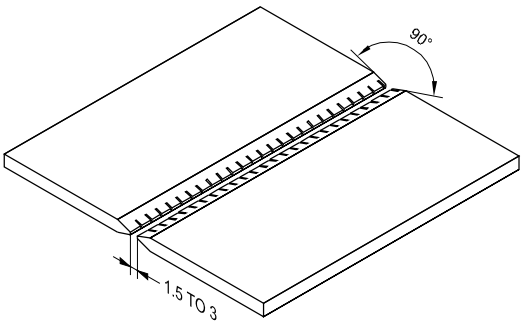
From 1.6 to 4 mm it can be butt-welded provided the edges are notched with a saw or cold chisel. (Fig 1)

Fig 1




For welding heavy aluminium plates, 4 mm or more in thickness, the edges should be beveled to form 90° included angle with a root gap of 1.6 mm to 3 mm. (Fig 2)

Fig 2




Preparation, pitch of tack, nozzle, size, filler rod etc. are given in Table 1 for butt joints.

**Importance of flux:** Since aluminium oxidizes very rapidly, a layer of flux must be used to ensure a sound weld.

Aluminium flux powder is to be mixed with water (two parts of flux to one part of water).

The flux is applied to the joint by means of a brush. When a filler rod is used, the rod is also coated with flux.

On heavy sections, it is advisable to coat the metal as well as the rod for greater ease in securing better fusion.

**Necessity of preheat:** Aluminium and its alloys possess high thermal conductivity and high specific and latent heat. For this reason, a large amount of heat is required for fusion welding.

To ensure fusion and complete penetration to avoid cracking, and to reduce gas consumption, aluminium castings and assemblies in wrought alloys of above 0.8 mm are to be preheated.

Preheating temperature varies from 250°C to 400°C according to the size of the work, and can be done by using a torch or by keeping the job in the furnace where preheating is done.

**Welding procedure:** Please refer to Working Steps and Skill Information of Ex. No. 2.28/G-55.

Various processes of welding of aluminium

– Oxy-acetylene welding
– Manual metal arc welding
– TIG welding
– MIG welding
– Resistance welding
– Carbon arc welding
– Solid state welding:
– cold welding
– diffusion welding
– explosive welding
– ultrasonic welding.

**Advantages of adopting oxy-acetylene process for welding of aluminium**

Simple and low cost equipment

For welding thinner sheets, gas welding may prove to be economical.

**Disadvantages**

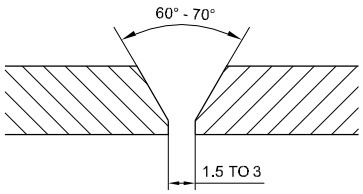
The flux residue, if not properly removed, may result in corrosion.

Distortion is greater than in arc welding.

Heat-affected zone is wider than in arc welding.

Welding speed is lower.

**Table 1**

| Metal thickness | Preparation | Joint assembly | Pitch of tacks (mm) | Nozzle size | Filler rod |
|---|---|---|---|---|---|
| 1 | Square | No gap | 25 | 1 | 2.5 mm |
| 1.2 | Square | No gap | 40 | 2 | 2.5 mm |
| 1.5 | Square | No gap | 40 | 2 | 2.5 mm |
| 3 |  | 1.5 - 3 mm gap | 75 | 5 | 3.15 mm |

# Metallic arc cutting and gouging

**Objectives:** At the end of this lesson you shall be able to
- **state the different arc cutting and gouging processes**
- **state the equipment and accessories**
- **explain the different electrodes and their properties**
- **describe the current setting for different size electrodes**
- **describe the arc cutting and gouging procedures**
- **explain the advantages and applications.**

### Different arc cutting and gouging processes

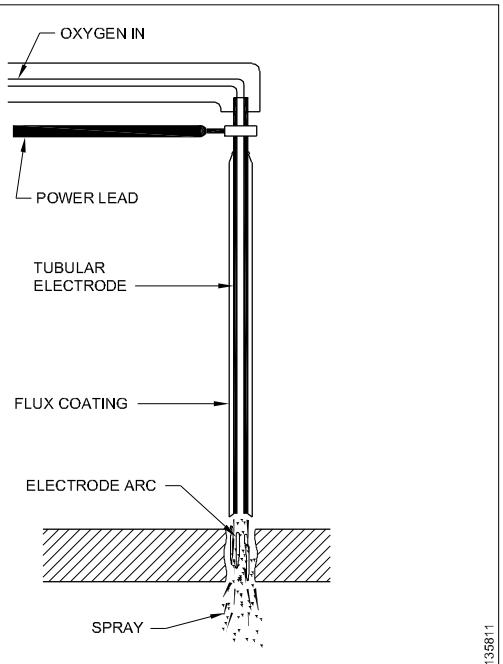
– Metallic arc cutting gouging process
– Carbon arc cutting process
– Air arc cutting process
– Plasma arc cutting process
– Oxy-arc cutting process
– Carbon arc gouging process

### Metallic arc cutting - equipment and accessories

They are:

– AC or DC machines
– cables with lugs and earth clamp
– electrode holders
– shield or helmet with suitable glasses (Shade No. 14)
– chipper or chipping hammer
– apron, gloves, safety boots and white goggles.

Fig 1



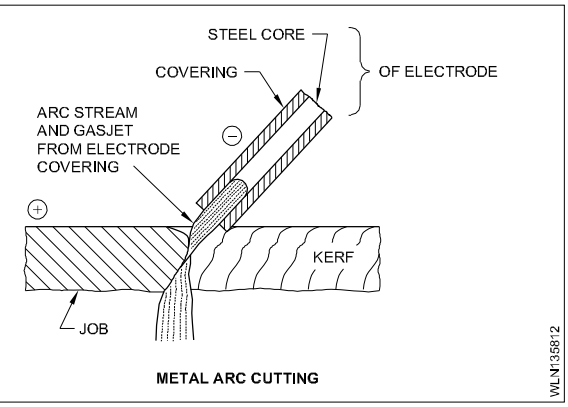

SCHEMATIC OF OXYGEN ARC CUTTING ELECTRODE IN OPERATION

### Electrodes and their properties

**Oxy-arc cutting electrode:** This electrode is similar to the manual arc welding electrode and is coated with a flux, whose function is to provide an insulated sleeve to stabilise the arc and to make the products of combustion more fluid. The core wire, however, is in the form of a hollow tube through which a stream of oxygen is passed and designed holder, capable of conveying electric current to the electrode as well as oxygen to the arc, is used. (Fig 1)

**Metallic arc cutting and gouging electrodes:** These electrodes are normally the same as welding electrodes or are sometime specially designed as cutting electrodes (Fig 2) at a current setting which is 20 to 50% higher than that normally used for a given size for welding. Although AC can be used, DC with electrode negative is preferred. Sometimes it helps to make the electrode slightly wet. Water in the coating reduces overheating of the electrode to some extent and disassociates in the arc to render it more penetrating.

Fig 2




METAL ARC CUTTING

**Tungsten arc cutting electrode:** This is an arc cutting electrode, which is used in TIG and plasma arc cutting processes.

**CURRENT SETTING FOR DIFFERENT SIZE ELECTRODES**

| Metal thickness | | Electrode diameter | | AC Range amps | DC (DCEN) amps |
|---|---|---|---|---|---|
| in. | mm | in. | mm | | |
| 1/8 | 3.2 | 3/32 | 2.4 | 40-150 | 75 - 115 |
| 1/8 - 1 | 3.2 - 25.4 | 1/8 | 3.2 | 125-300 | 150 - 175 |
| 3/4 - 2 | 19.1 - 50.8 | 5/32 | 4.00 | 250-375 | 170 - 500 |
| 1 - 3 | 25.8 - 76.2 | 3/16 | 4.8 | 300-450 | — |
| 3 and over | 76.2 and over | 1/4 | 6.4 | 400-650 | — |

**Arc cutting and gouging procedure**

**Arc cutting procedure:** Prepare the piece as per the requirements. Clean the surface to be cut. Mark and punch the line. Position the job in flat.

Choose the welding machine and set the polarity DCEN, if DC is used.

Select the electrode size according to the thickness of the material.

Set the current as per the requirements for the selected electrodes.

Strike the arc and move the electrodes up and down on the edge of the plate. As the metal melts brush it downwards with the arc. Feed the electrodes into the slot and make the molten metal to run away underneath. Use only half the electrode and keep it away to cool for use again.

Check the cut surface for its smoothness and uniformity.

**Arc gouging procedure:** Prepare the piece as per the requirements. Clean the surface to be gouged. Mark and punch the line. Position the job in flat.

Choose the machine and set the polarity DCEN if DC is used.

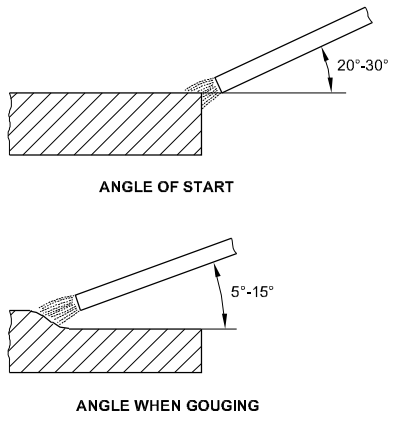
Select suitable sizes of electrodes and set the required current.

Strike the arc and as a molten pools is established, lower the electrode holder and reduce the angle between 5°-15° from 20°-30°. (Fig 3)

Move the electrode along the line of marking from the right to the left side of the plates and push the molten pool and slag away from the gouged groove.

Because of the rapid fusion due to the arc heat, move the electrode fast and control the gouging operation. Ensure that the angle of slope is not too steep, and avoid grooving too deeply. Maintain the angle of the electrode constant and the rate of travel uniform to obtain a groove of uniform width and depth.

Fig 3




Clean the surfaces.

Check the smoothness, depth and uniformity.

**Advantages:** Arc gouging procedure can be used when other cutting and gouging processes are not available.

In emergency it is more useful.

It can be used on metals which are difficult to cut by the oxy-acetylene cutting process.

(Cast iron, stainless steel, wrought iron, manganese steel and non-ferrous metals etc.)

**Applications:** Metallic arc cutting and gouging are used:

- to remove weld defects
- to make the groove on the root penetration for depositing sealing run
- to cut the scarp
- to remove rivets
- to pierce holes
- to remove casting defects and make grooves.

## Carbon arc cutting and gouging

**Objectives:** At the end of this lesson you shall be able to
- **describe the machine used for carbon arc cutting**
- **explain the different sizes of electrodes and current setting**
- **describe the method of carbon arc cutting**
- **state the applications of this process**
- **explain the method of gouging by air carbon arc process**
- **explain the safety points to be observed while cutting.**

Carbon arc cutting is a process of cutting metals by melting with the heat of a carbon arc. It is melting process and as such does not produce smooth even edges. The actual cutting process is similar to that of metallic arc cutting.

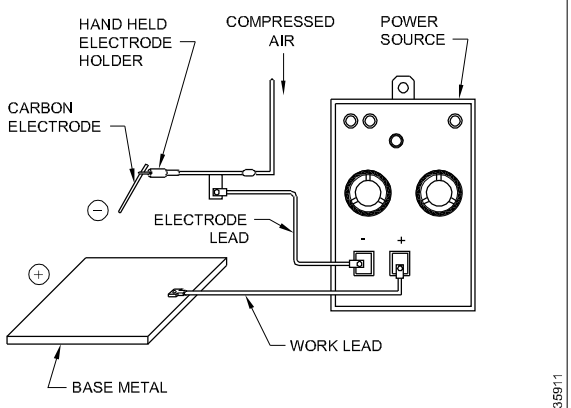
The equipment consists of:

– an AC, DC or AC/DC (rectifier) welding machine (Fig 1)

– a special carbon electrode holder (Fig 2)

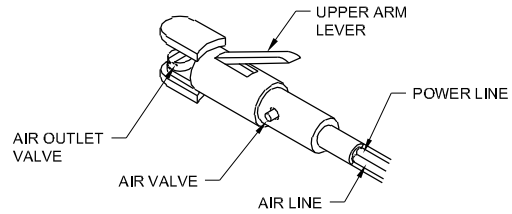
– heavy duty gloves (asbestos).

Fig 1




CIRCUIT BLOCK DIAGRAM OF CARBON ARC CUTTING

Fig 2




ELECTRODE HOLDER FOR CARBON ARC CUTTING

Two types of electrodes are available i.e. AC electrodes (copper added electrodes) and DC electrodes. An AC machine is used when AC electrodes are used, and the DC electrodes (plain carbon electrodes) are connected to the negative side of the DC machine.

Carbon electrodes, used for cutting, come in sizes ranging from 12.2 mm to 25.4 mm. Rods are available in different lengths i.e. 305,457 and 610 mm (12, 18 and 24 inches).

A table of recommended electrode sizes, current settings, and speeds for carbon arc cutting various thickness of steel is given. (Table 1)

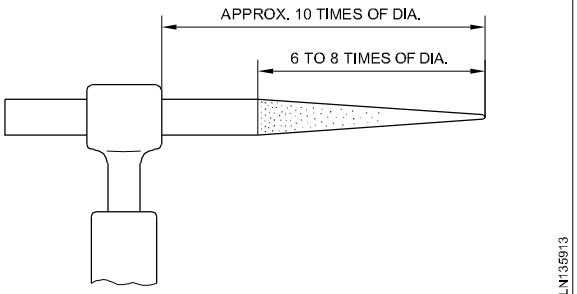
**Table 1**

**Recommended electrode sizes, current settings, and speeds for carbon arc cutting of various thickness of steel**

| Thickness of plate | | Current setting and carbon electrode diameter | | | |
|---|---|---|---|---|---|
| in. | mm | 300 amps 1/2 in. dia. (12.2 mm) | 500 amps 5/8 in. dia. (15.9 mm) | 700 amps 3/4 in. dia. (19.1 mm) | 1000 amps 1 in. dia. (25.4 mm) |
| | | SPEED OF CUTTING IN MINUTES PER FOOT | | | |
| 1/2 | 12.7 | 3.5 | 3.5 | 1.5 | 1.0 |
| 3/4 | 19.1 | 4.7 | 4.7 | 2.0 | 1.4 |
| 1 | 25.4 | 6.8 | 6.8 | 2.9 | 2.0 |
| 1 1/4 | 31.8 | 9.8 | 9.8 | 4.0 | 2.9 |
| 1 1/2 | 38.1 | - | - | 5.8 | 4.0 |
| 1 3/4 | 44.5 | - | - | 8.0 | 5.3 |
| 2 | 50.8 | - | - | - | 7.0 |

Prior to cutting, the carbon electrodes should be ground to a very sharp point. The length of taper should be 6-8 times the electrode diameter. (Fig 3)

Fig 3

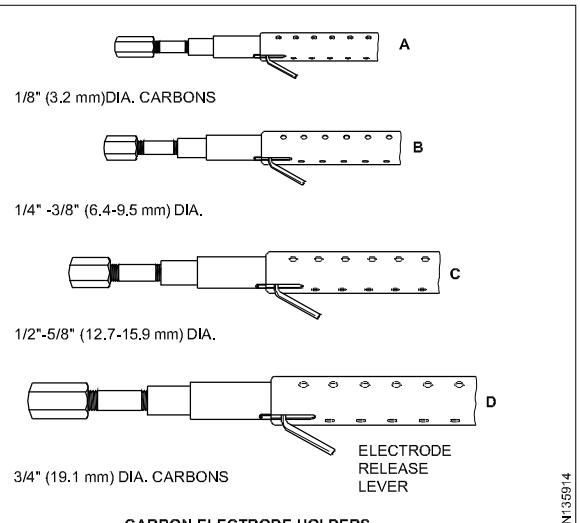



The electrode should stick out from the electrode holder to a distance equal to 10 times the electrode diameter.

(This is necessary to reduce electrical resistance and the heating effect on the electrodes. If carbon wears away too fast, shorten the electrode extension out of the electrode holder to as little as 7 cm).

Carbon electrodes holders are designed for: A-3.2 mm (1/8 in.) carbon electrode B - 6.4 - 9.5 mm carbon electrode, C - 12.7 - 15.9 mm carbon electrode and D - 19.1 mm carbon electrode. (Fig 4)

Fig 4

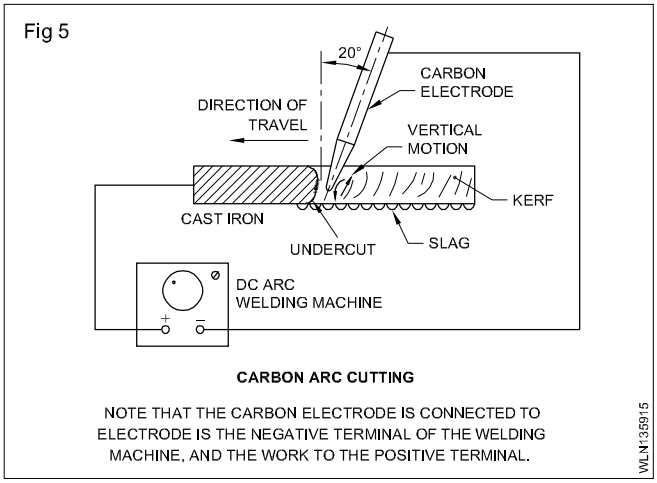



**Procedure:** Start the cutting at the bottom right hand edge of the plate and proceed towards the left end of the plate.

During the actual cutting, the carbon electrode should be manipulated in a vertical elliptical movement to cut the metal. This motion facilitates the removal of the molten metal. In addition to the vertical motion, a side-to-side crescent motion is recommended along the line of cut. For heavy plates the electrode angle is about 20° off from the vertical. (Fig 5)

**Applications:** The carbon arc method of cutting may be used successfully on cast iron because the temperature of the arc is sufficient to melt the iron oxides formed.

Fig 5




This method is used to cut:

– almost all types of steels
– light gauge to heavy gauges of metals.
– non-ferrous metals.

**Safety precautions:** In cutting operations a large amount of metal always falls on the floor. Therefore be sure there are no combustible materials nearby when excessive amount of cutting is to be done. It is a good idea to sprinkle sand over the concrete floor. This prevents the molten metal from heating the concrete and thus avoid cracks and particles to fly upward. Alternatively provide water/sand tray on the floor where cutting is to be done.

**Differences between metal arc cutting and carbon arc cutting**

**Metal arc cutting:** The arc is struck between the consumable steel electrode and base.

AC and DC machines can be used.

The electrode used are of smaller diameters, say 4 mm ø.

Sheets and plates can be cut.

The cut face is not as fine when compared to the face produced by carbon arc cutting.

This process is more suitable for cutting scarps, rivets and for piercing holes.

Ordinary electrode holder is used.

**Carbon arc cutting:** A carbon arc is struck between the consumable carbon electrode and base metal.

Generally a DC machine is used.

A special type of holder is used.

The electrodes used are of a bigger diameter i.e. above 12 mm

A water cooling type holder is used when cutting with a higher current.

Generally heavy sections are cut by this process.

The cut face is more hard.

Good for cast iron and non-ferrous metal cuttings.

**Gouging: Air-carbon arc method**

**Equipment:** The equipment used for air-carbon arc cutting (ARC) consists of the following.

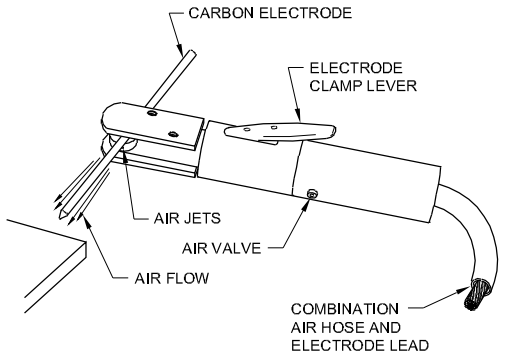
AC, DC or AC/DC welding machine.

An air compressor or compressed air cylinders.

A compressed air hose.

An air carbon arc torch equipment with an air jet device. (Fig 6)

Fig 6




AN AIR CARBON ARC ELECTRODE HOLDER WITH A CARBON ELECTRODE INSTALLED. NOTE THE AIR JET ORIFICES BEHIND THE ELECTRODE.

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**Electrodes:** Electrodes may be of carbon form or graphite form or a mixture of carbon and graphite.

There are 3 basic types of air-carbon arc cutting electrodes. They are:

– CDEP, plain
– DCEP, copper coated
– AC, copper coated

The copper coating helps to reduce the oxidation of the electrode body. It also helps to keep the electrode cool.

Carbon electrodes for gouging come in sizes from 4 mm to 25.4 mm.

A table suggesting current settings for various diameters and types of air carbon arc electrodes is given. (Table 2)

**Gouging procedure:** In gouging, the amperage and electrode diameter are selected according to the width and depth of the desired groove.

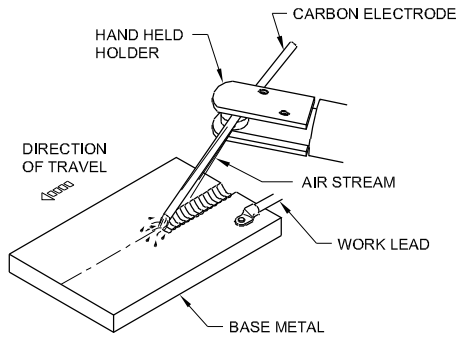
**Table 2**

**Suggested current setting for various diameters and types of air carbon arc electrodes**

| Electrode diameter | | Amperage with DCEP ($D_{CRP}$) electrode | | Amperage with Ac electrode | |
|---|---|---|---|---|---|
| in. | mm | Min. | Max. | Min. | Max. |
| 5/32 | 4.0 | 90 | 150 | — | — |
| 3/16 | 4.8 | 150 | 200 | 150 | 200 |
| 1/4 | 6.4 | 200 | 400 | 200 | 300 |
| 5/16 | 7.9 | 250 | 450 | — | — |
| 3/8 | 9.5 | 350 | 600 | 300 | 500 |
| 1/2 | 12.7 | 600 | 1000 | 400 | 600 |
| 5/8 | 15.9 | 800 | 1200 | - | - |
| 3/4 | 19.1 | 1200 | 1600 | - | - |
| 1 | 25.4 | 1800 | 2200 | - | - |

When gouging, the air stream must be turned on prior to striking the arc. The air stream must be directed from behind the carbon electrode. (Fig 7)

Fig 7




PROCESS DIAGRAM FOR AIR-CARBON ARC CUTTING OR GOUGING

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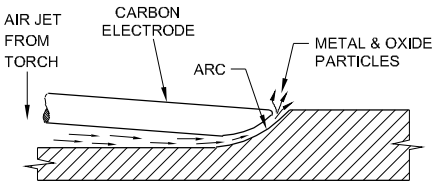
This permits the metal to be blown out of the arc pool as shown in the Fig 8.

Fig 8




A SCHEMATIC DIAGRAM OF AN AIR-CARBON ARC GOUGING OPERATION IN PROGRESS. NOTE HOW THE COMPRESSED AIR BLOWS UNDER THE CARBON ELECTRODE TO REMOVE THE MOLTEN METAL.

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In the vertical position, gouging should be done from the top to downwards. This permits gravity to help remove the molten metal from the arc groove. Gouging in horizontal position may be done from the right to the left.

When gouging overhead, the electrode should be placed in the electrode holder so that it is nearly parallel to the center line of the holder.