MANUFACTURING PROCESSES

WELDING INTRO

JOINING PROCESS

- Welding is a ***joining process***.
- Joining may be preferred for one or more of the following reasons:-
  - ***Product is impossible or uneconomical to manufacture as a single piece.***
  - ***The product is easier to manufacture in individual components, which are then assembled, then as a single piece.***

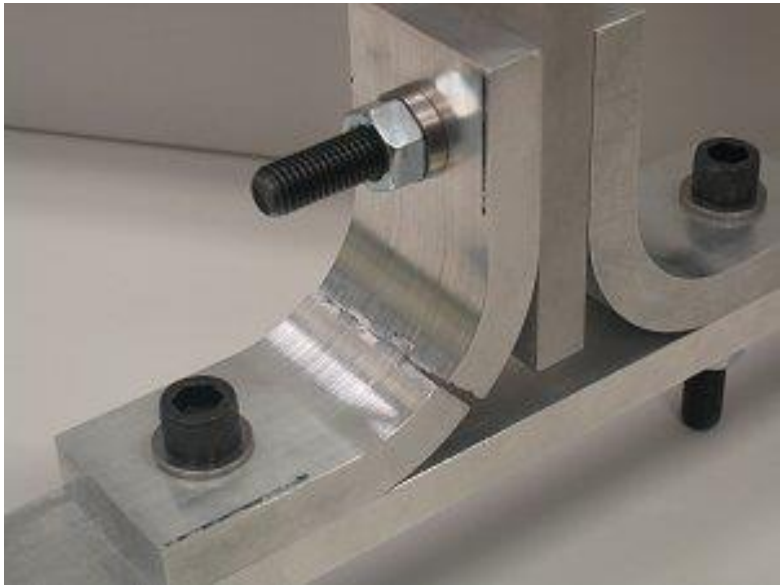
NEED FOR JOINING

- ***Different properties may be desirable for functional purpose of the product.***
- ***Transportation of the product in individual components are more economical than transporting it as a single piece***

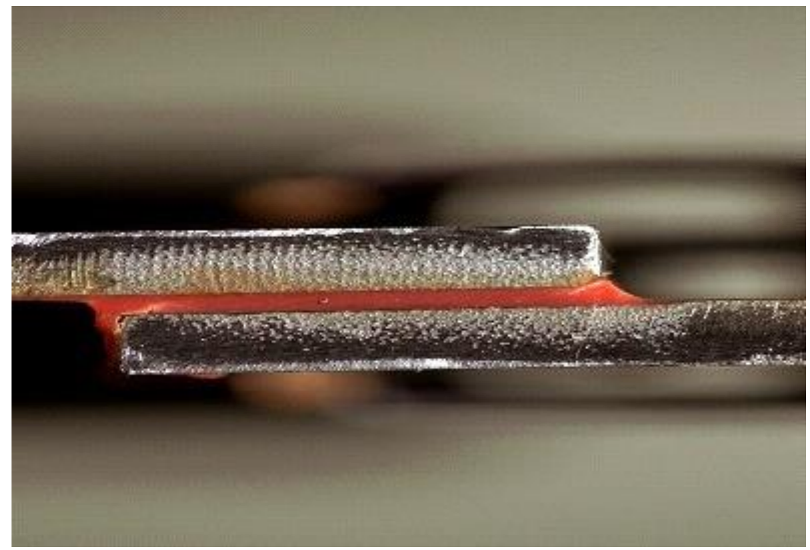
JOINING PROCESS

- Three joining techniques are commonly used.
  - ***Mechanical joints***
  - ***Adhesives***
  - ***Welding and allied processes***

MECHANICAL JOINTS



ADHESIVES



WELDING JOINTS

WELDING DEFINATION

- Welding is a process of ***permanent joining*** two materials (usually metals) through localised coalescence resulting from a suitable combination of ***temperature, pressure and metallurgical conditions.***
- Depending upon the combination of temperature and pressure from a high temperature with no pressure to a high pressure with low temperature, ***a wide range of welding processes has been developed.***

WELDING DEFINATION

- Welding is a fabrication process that joins materials, usually metals, by causing coalescence.
- This is often done by ***melting*** the workpieces and ***adding a filler*** material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld.

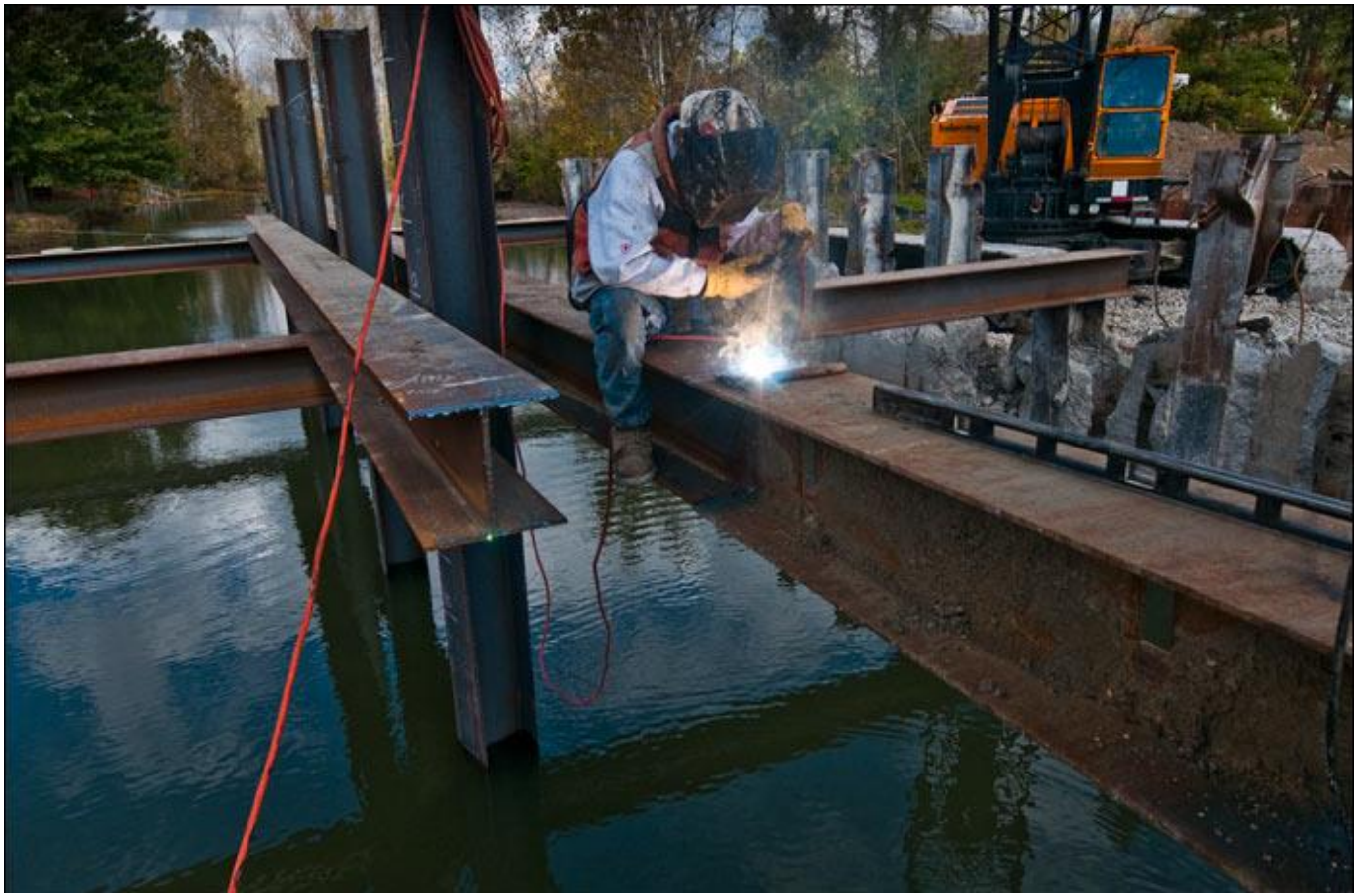
ADVANTAGES

- ***Strong*** and tight joining.
- ***Cost*** effectiveness.
- ***Simplicity*** of welded structures design.
- Welding processes may be mechanized and ***automated***.

DISADVANTAGES

- Internal stresses, distortions and changes of micro-structure in the weld region.
- Harmful effects: light, ultra violate radiation, fumes, high temperature.

BUILDINGS AND BRIDGES STRUCTURES



AUTOMOTIVE, SHIP AND AIRCRAFT CONSTRUCTIONS

PIPE LINES

TANKS AND VESSELS

RAILROADS

MACHINERY ELEMENTS

CLASSIFICATION

- There are two groups of welding processes according to the state of the base material during the welding process:
  a) Liquid-state welding (fusion welding)
  b) Solid-state welding.

a. Liquid-state (fusion welding)

- ***Fusion welding*** is defined as the ***melting*** together and joining of materials by means of ***heat***, usually supplied by ***chemical or electrical*** means; ***filler*** metals ***may or may not*** be used.
- Fusion welding is composed of ***consumable and non consumable-electrode*** arc welding and high-energy-beam welding processes.
- Fusion welding is by far the more ***important category.***

a. Liquid-state (fusion welding)

- The fusion category includes the most widely used welding processes, which can be organized into the following general groups
  - ***Arc welding***
  - ***Resistance Welding (also Solid-state welding)***
  - ***Oxyfuel gas welding***
  - ***Other fusion welding (Electron beam & Laser beam)***

b. Solid-state welding

- ***Solid-state*** welding refers to joining processes in which joining results from application of ***pressure*** alone ***or a combination*** of ***heat*** and pressure.
- Joining takes place ***without fusion***; consequently, there is ***no liquid*** (molten) ***phase*** in the joint.
- If heat is used, the temperature in the process is below the melting point of the metals being welded.
- ***No filler*** metal is utilized.

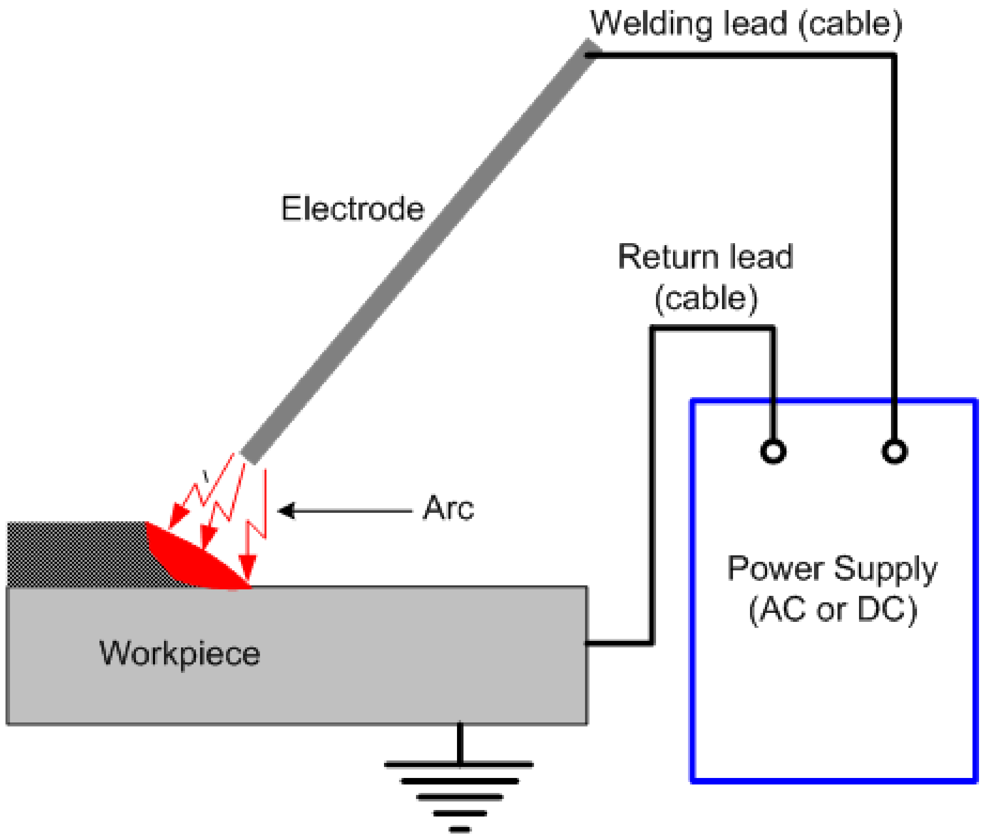
b. Solid-state welding

- Representative welding processes in this group include:
  - ***Friction welding***
  - ***Diffusion welding***
  - ***Ultrasonic welding***
  - ***Resistance Welding (also fusion welding)***

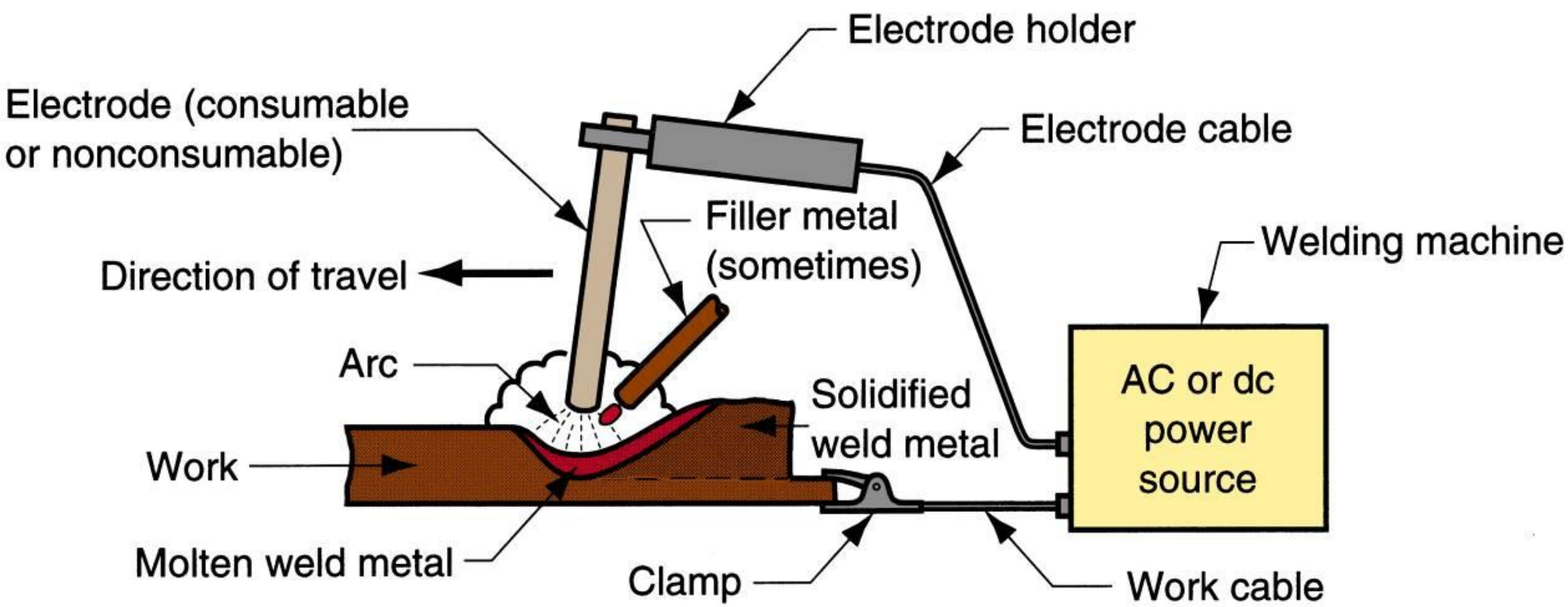
1. Arc Welding

- **Arc welding** is a fusion-welding process, in which heat is generated by an **electric arc** struck between an electrode and the work piece.
- Any arc welding method is based on an electric circuit consisting of the following parts:
  - *Power supply (AC or DC);*
  - *Welding electrode;*
  - *Work piece;*
  - *Welding leads (electric cables) connecting the electrode and work piece to the power supply.*

1. Arc Welding



1. Arc Welding



The basic configuration and electrical circuit of an arc-welding process.

1. Arc Welding

- ***Electric arc*** between the electrode and work piece closes the electric circuit.
- An ***electric arc*** is a discharge of electric current across a gap in a circuit.
- It is sustained by the presence of a thermally ionized column of gas (called a ***plasma***) through which current flows.
- The arc temperature may reach ***5500°C***, which is sufficient for fusion the work piece edges and joining them.

1. Arc Welding

- A ***pool*** of molten metal, consisting of base metal(s) and filler metal (if one is used) is formed near the tip of the electrode.
- In most arc-welding processes, ***filler metal*** is added during the operation to increase the volume and strength of the weld joint.
- Chemical compositions of filler metal is ***similar*** to that of work piece.

1. Arc Welding - ELECTRODES

- ***CONSUMABLE*** electrodes - are used in SMAW, SAW & GMAW or TIG.

- ***NON-CONSUMABLE*** electrodes – are used in GTAW.

1. Arc Welding - ELECTRODES

- ***CONSUMABLE*** electrodes provide the source of the filler metal in arc welding.
- These electrodes are available in two principal forms:
  - **rods (also called sticks) and**
  - **wire.**
- Welding ***rods*** are typically 225 to 450 long and 9.5 mm or less in diameter.

1. Arc Welding - ELECTRODES

- The ***problem*** with consumable welding ***RODS***, at least in production welding operations, is that they must be ***changed periodically***, reducing arc time of the welder.
- Consumable weld ***WIRE*** has the ***advantage*** that it can be ***continuously fed*** into the weld pool from spools containing long lengths of wire, thus avoiding the frequent interruptions that occur when using welding sticks.

1. Arc Welding - ELECTRODES

- ***Non-consumable*** electrodes are made of tungsten (or carbon, rarely), which resists melting by the arc.
- Despite its name, a ***non-consumable*** electrode is gradually depleted during the welding process (vaporization is the principal mechanism), analogous to the gradual wearing of a cutting tool in a machining operation.

1. Arc Welding - ELECTRODES

- For arc welding processes that utilize ***non-consumable*** electrodes, any filler metal used in the operation must be supplied by means of a separate wire that is fed into the weld pool.
- If no filler rod is used with non-consumable electrode then the process is called ***Autogenous***.

1. Arc Welding - ARC SHIELDING

- At the high temperatures in arc welding, the metals being joined are ***chemically reactive*** to ***oxygen , nitrogen , and hydrogen*** in the air.
- The mechanical properties of the weld joint can be seriously ***degraded*** by these reactions.
- Thus, some means to ***shield*** the arc from the surrounding air is provided in nearly all arc welding processes.

1. Arc Welding - ARC SHIELDING

- Arc shielding is accomplished by covering the electrode tip, arc, and molten weld pool with a blanket of ***gas or flux***, or both, which inhibit exposure of the weld metal to air.
- Common shielding gases include ***argon*** and ***helium***, both of which are inert.
- In the welding of ferrous metals with certain Arc Welding processes, ***oxygen*** and ***carbon dioxide*** are used, usually in combination with Ar and/or He.

1. Arc Welding - FLUX

- A ***flux*** is a substance used to ***prevent*** the formation of oxides and other unwanted contaminants, or to dissolve them and facilitate removal.
- During welding, the flux melts and becomes a liquid ***slag***, covering the operation and protecting the molten weld metal.
- The slag hardens upon cooling and ***must be removed*** later by chipping or brushing.

1. Arc Welding - FLUX

- Flux is usually formulated to serve several additional functions:
  - *provide a **protective atmosphere** for welding,*
  - ***stabilize** the arc,*
  - *provide a **protective slag** coating to accumulate impurities, prevent oxidation, and slow the cooling of the weld metal,*
  - *affect **arc penetration** (the depth of melting in the workpiece)*
  - *add **alloying elements** to the weld,*
  - *to **reduce spatter**.*

1. Arc Welding - FLUX

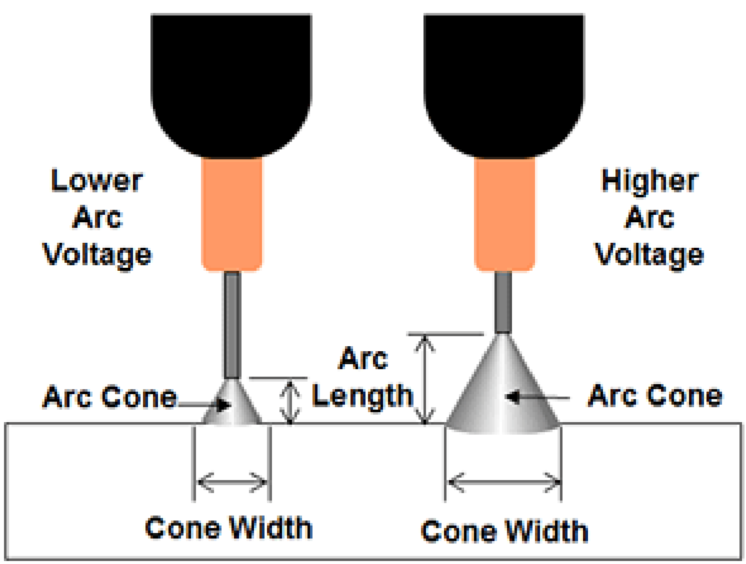
- The method of flux application differs for each process. The delivery techniques include

1. pouring ***granular flux*** onto the welding operation,
2. using a stick electrode ***coated*** with flux material in which the coating melts during welding to cover the operation, and
3. using ***tubular electrodes (flux cored)*** in which flux is contained in the core and released as the electrode is consumed.

1. Arc Welding – POWER SOURCES

- Two types:
    a) ***Constant Current (Drooping)***
    b) ***Constant Voltage***

- Before discussing the question of CC vs. CV, we must first understand the effects of both current and voltage with arc welding. Current effects the melt-off rate or consumption rate of the electrode, whether it be a stick electrode or wire electrode. The higher the current level, the faster the electrode melts or the higher the melt-off rate, measured in pounds per hour (lbs/hr) or kilograms per hour (kg/hr). The lower the current, the lower the electrode's melt-off rate becomes. Voltage controls the length of the welding arc, and resulting width and volume of the arc cone. As voltage increases, the arc length gets longer (and arc cone broader), while as it decreases, the arc length gets shorter (and arc cone narrower). **Figure 2** illustrates the effect of voltage in the arc.



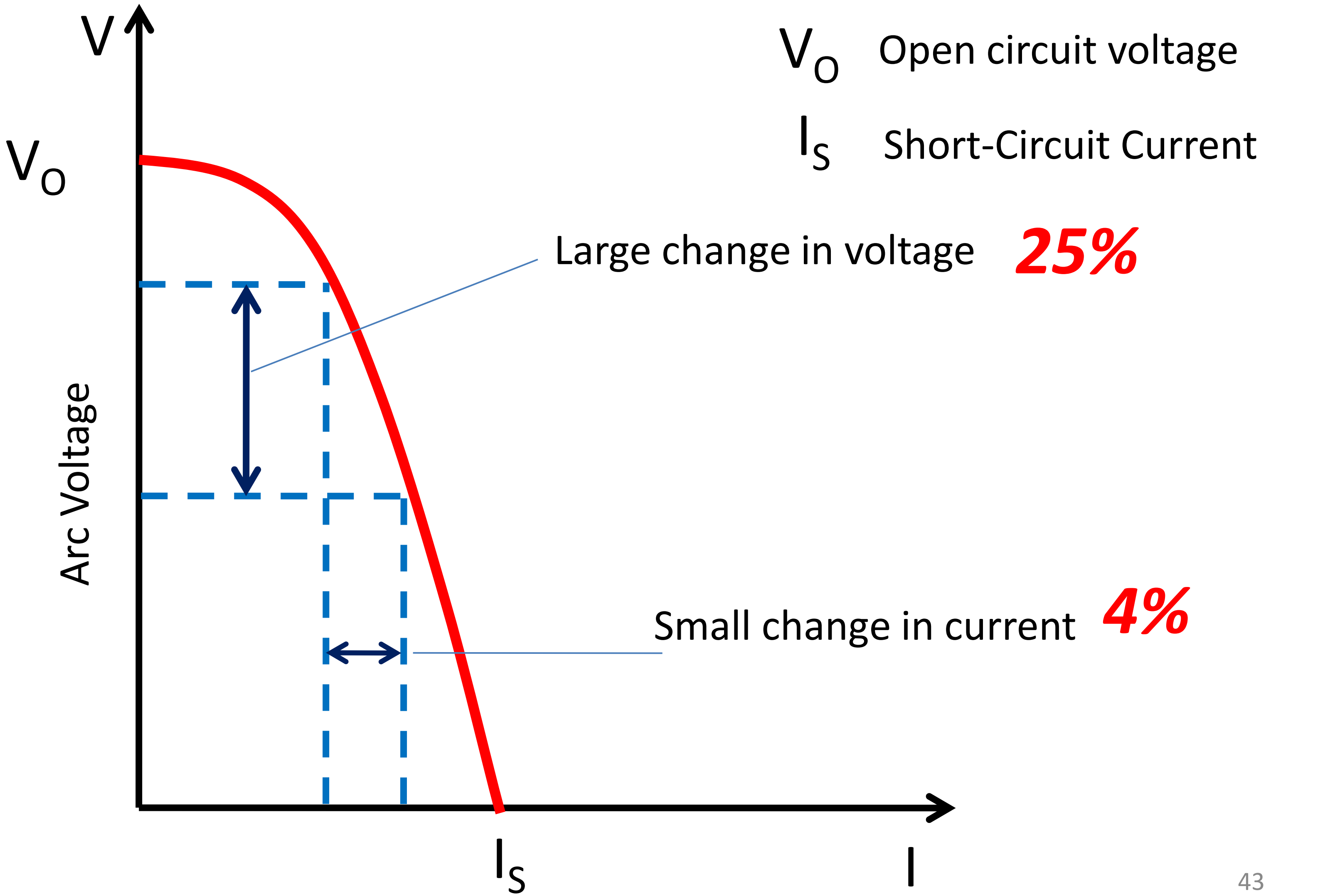
- Now the type of welding process you are using, and its associated level of automation, determines which type of welding output is most stable and thus preferred. The Shielded Metal Arc Welding (SMAW) process (aka MMAW or stick) and the Gas Tungsten Arc Welding (GTAW) process (aka TIG) are both generally considered manual processes. This means you control all welding variables by hand. You hold the electrode holder or TIG torch in your hand and control travel angle, work angle, travel speed, arc length and the rate in which the electrode is fed into the joint all by hand. With the SMAW and GTAW processes (i.e. the manual processes), CC is the preferred type of output from the power source.
- conversely, the Gas Metal Arc Welding (GMAW) process (aka MIG) and the Flux Cored Arc Welding (FCAW) process (aka flux core) are both generally considered semi-automatic processes. This means that you still hold the welding gun in your hand and control travel angle, work angle, travel speed and contact tip to work distance (CTWD)) by hand. However, the rate in which the electrode is fed into the joint (known as wire feed speed (WFS)) is controlled automatically with a constant speed wire feeder. With the GMAW and FCAW processes (i.e. the semi-automatic processes), CV is the preferred output.

- With the two manual processes, SMAW and GTAW, you are controlling all variables by hand (which is why they are the two most operator skill intensive processes). You need to have the electrode melt at a consistent rate, so that you can feed it into the joint at a consistent rate. To do this, the welding output needs to maintain current at a constant level (i.e., CC), so that the resulting melt-off rate is consistent. Voltage is a less controlling variable. With manual processes, it is very difficult to consistently maintain the same arc length because you are also constantly feeding the electrode into the joint. Voltage varies as a result of changes in arc length. With CC output, current is your preset, controlling variable and voltage is simply measured (typically as an average value) while welding.
- If you tried to weld with the SMAW process for example using CV output, current, and the resulting melt-off rate, would vary too much. As you were traveling along the joint (trying to be consistent with all other welding variables), the electrode would melt at a faster rate, then a slower rate, then a faster rate, etc. You would constantly need to change the rate in which you fed the electrode into the joint. This is an impracticable condition, thus making CV output undesirable.
- When you switch to a semi-automatic process, such as GMAW or FCAW, something changes. While you are still controlling many of the welding variables by hand, the electrode is being fed into the joint at a constant speed (based on the particular WFS you have set on the wire feeder). Now you want the arc length to be consistent. To do this, the welding output needs to maintain voltage at a constant level (i.e., CV), so that the resulting arc length is consistent. Current is a less controlling variable. It is proportional to, or a result of, the WFS. As WFS increases, so does current and vice versa. With CV output, voltage and WFS are your preset, controlling variables and current is simply measured while welding.
- If you tried to weld with the GMAW or FCAW processes using CC output, voltage, and the resulting arc length, would vary too much. As voltage decreased, arc length would become very short and the electrode would stub into the plate. Then as voltage increased, arc length would become very long and the electrode would burn back towards the contact tip. The electrode would be constantly stubbing into the plate, then burning back towards the tip, then stubbing into the plate, etc. This is an impracticable condition, thus making CC output undesirable

a). CONSTANT CURRENT POWER SOURCE

- In ***Constant Current*** [***CC***] power source, variation in welding current with arc voltage (due to fluctuations in arc length) is very small.
- ***welding current*** remains more or less ***constant*** in spite of fluctuations in arc voltage/length.
- ***suitable for*** those welding processes where large fluctuation in arc length is observed like in *Manual Metal Arc Welding* (***MMAW***) ***and*** *Tungsten Inert Gas* ***TIG welding***.

a). CONSTANT CURRENT POWER SOURCE



a). CONSTANT CURRENT POWER SOURCE

- The constant current (CC) welding machine is called a ***drooper*** because of this curve.
- A ***25%*** change in voltage results in only a ***4%*** change in amperage.
- The current change is so ***slight*** that the current is considered constant.

a). CONSTANT CURRENT POWER SOURCE

- Following points should be kept in mind regarding CC power source:
  - It has ***high OCV*** (open circuit voltage:- the voltage when the welding is not being performed).
  - High OCV ensure ***easy initiation*** and ***maintenance of arc.***
  - ***Low short circuit current.***

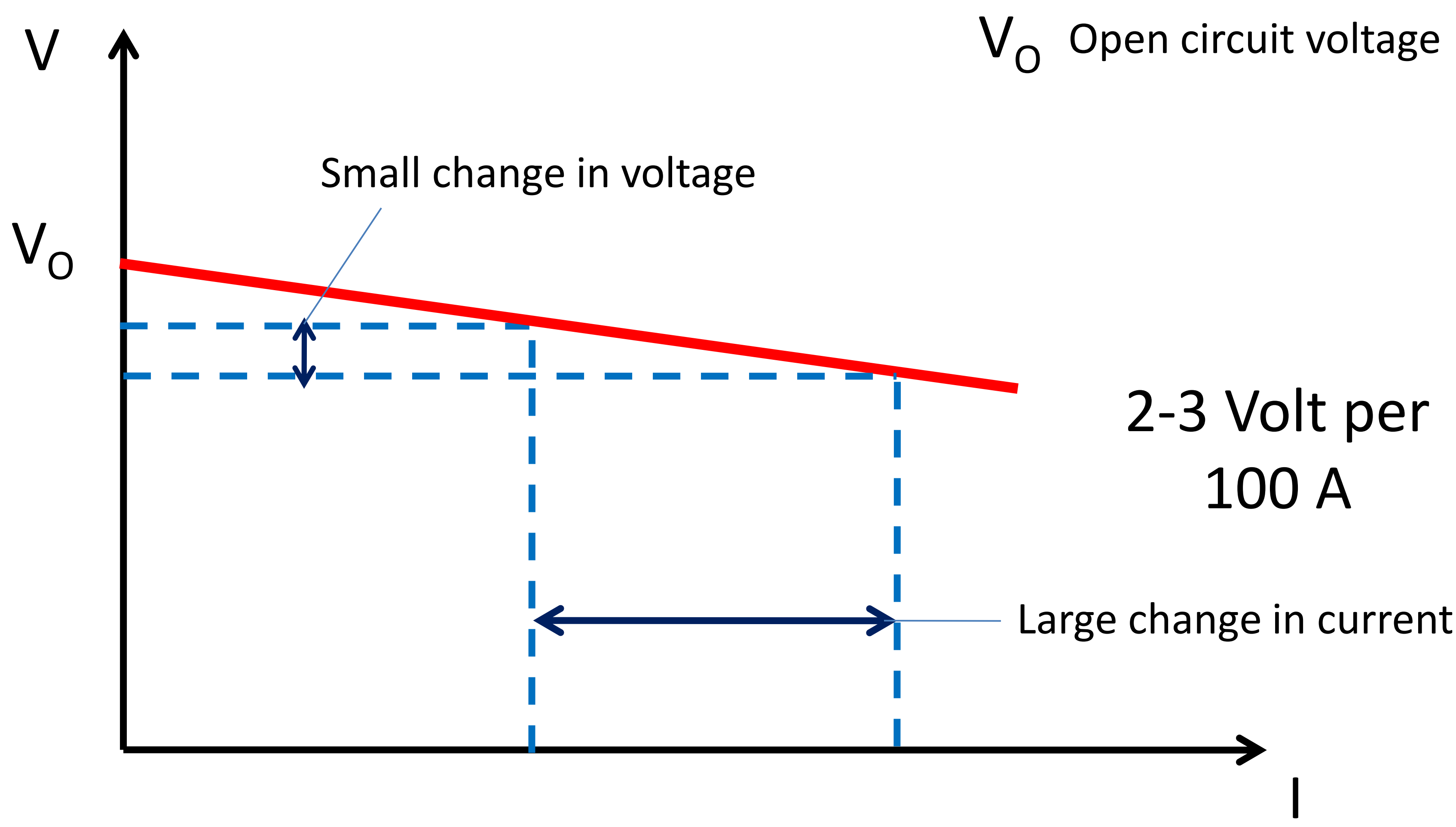
b). CONSTANT VOLTAGE POWER SOURCE

- In CV power source, very small variation in arc voltage (due to fluctuation in arc length) causes significant change in welding current.
- Since ***arc voltage*** remains almost ***constant*** therefore this type of power sources are called constant voltage power source.
- Constant voltage power source does not have true constant voltage output. It has ***slightly*** downward or ***negative slope***.

b). CONSTANT VOLTAGE POWER SOURCE

- ***suitable for*** all those welding processes where small fluctuations in arc length can take place, like in semiautomatic welding processes ***MIG & SAW*** .

b). CONSTANT VOLTAGE POWER SOURCE



b). CONSTANT CURRENT POWER SOURCE

- Following points should be kept in mind regarding CV power source:
  - It has slightly ***low OCV*** as compared to CC power source.
  - ***High short circuit current.***

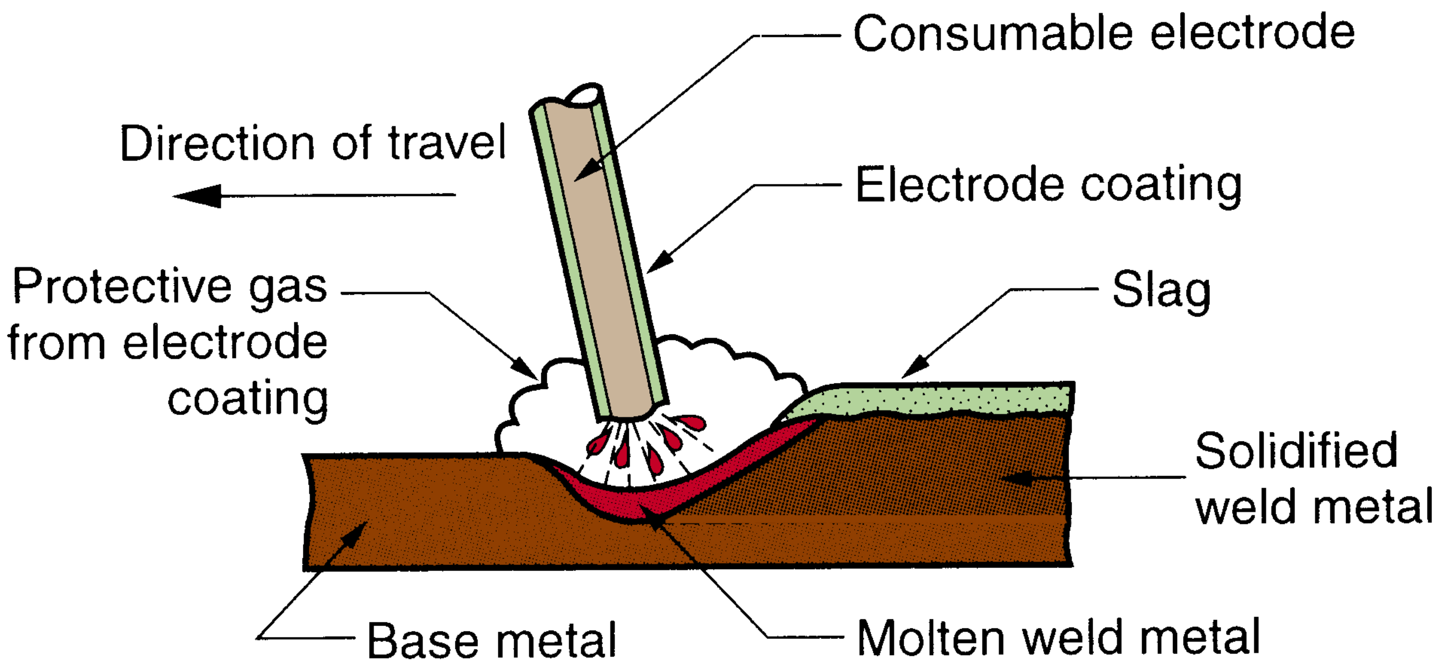
1. Arc Welding- TYPES

A. Shielded/Manual Metal Arc Welding ***(SMAW)(MMAW)***
B. Submerged Arc Welding ***(SAW)***
C. Tungsten Inert Gas Arc Welding ***(TIG, GTAW)***
D. Metal Inert Gas Welding ***(MIG, GMAW)***

MANUFACTURING PROCESSES

MMAW or SMAW

1.A. Shielded/Manual Metal Arc Welding



1.A. Shielded/Manual Metal Arc Welding

- Shielded metal arc welding (SMAW) is an AW process that uses a ***consumable electrode*** consisting of a ***filler metal*** rod coated with ***chemicals*** that provide ***flux*** and ***shielding***.

1.A. Shielded/Manual Metal Arc Welding

- The ***filler*** metal used in the rod must be ***compatible*** with the ***metal to be welded***, the composition usually being very close to that of the base metal.
- The coating consists of powdered ***cellulose*** (i.e., cotton and wood powders) mixed with ***oxides, carbonates***, and other ingredients, held together by a ***silicate binder***.
- ***Metal powders*** are also sometimes included in the coating to ***increase*** the ***amount of filler metal*** and to ***add alloying elements***.

1.A. Shielded/Manual Metal Arc Welding

- The heat of the welding process melts the coating to provide a protective atmosphere and slag for the welding operation.
- It also helps to stabilize the arc and regulate the rate at which the electrode melts.
- Currents typically used in SMAW range between ***30 and 300 A*** at voltages from ***15 to 45 V.***

1.A. Shielded/Manual Metal Arc Welding

- Selection of the proper ***power parameters*** depends on the metals being welded, electrode type and length, and depth of weld penetration required.
- Shielded metal arc welding is usually performed ***manually***.
- Common ***applications*** include construction, pipelines, machinery structures, shipbuilding, job shop fabrication, and repair work.

1.A. Shielded/Manual Metal Arc Welding

- It is preferred over oxyfuel welding for thicker sections—above 5 mm—because of its higher power density.
- The equipment is portable and low cost, making SMAW highly versatile and probably the most widely used of the AW processes.
- Base metals include steels, stainless steels, cast irons, and certain nonferrous alloys.

1.A. Shielded/Manual Metal Arc Welding

- It is not used or seldom used for aluminum and its alloys, copper alloys, and titanium.

POLARITY

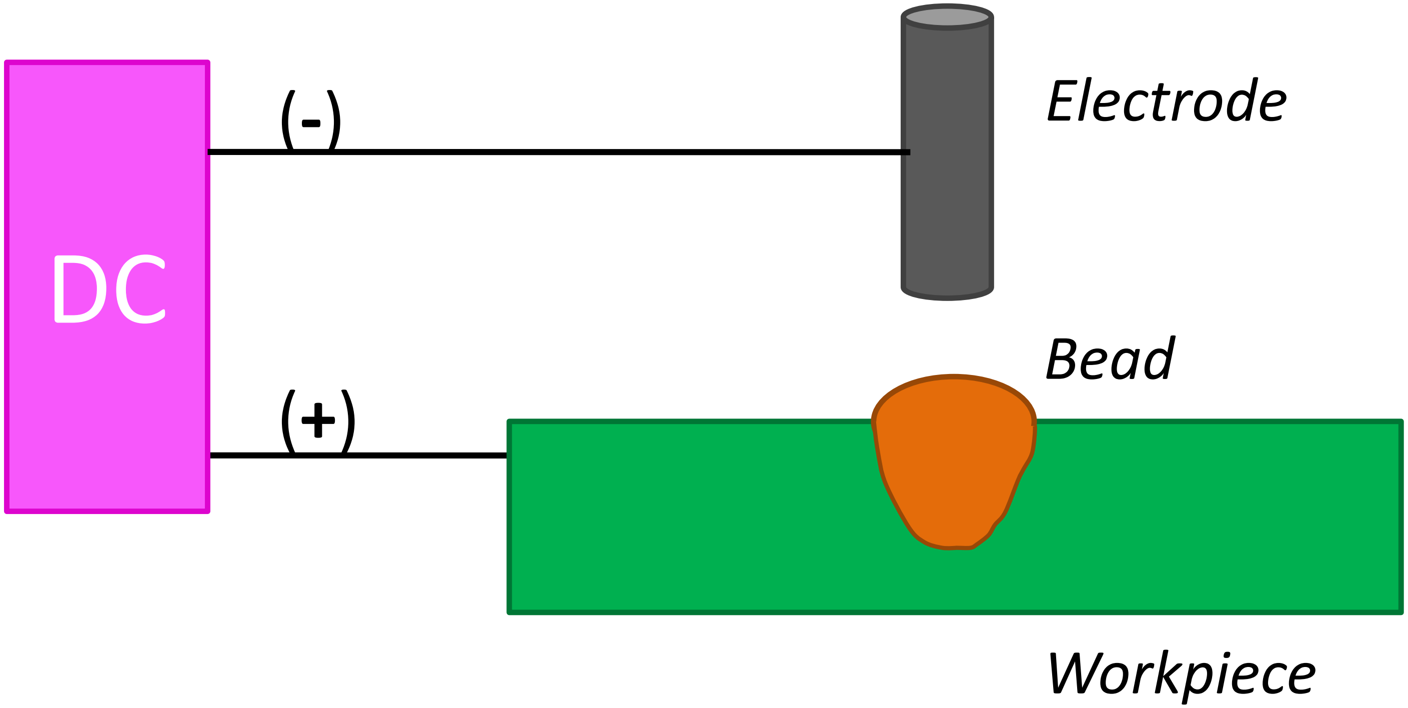
- When using a DC power source, the question of whether to use electrode negative or positive polarity arises.
- Some electrodes operate on both DC straight and reverse polarity, and others on DC negative or DC positive polarity only.
- Direct current flows in one direction in an electrical circuit and the direction of current flow and the composition of the electrode coating will have a definite effect on the welding arc and weld bead.

POLARITY

- Figure shows the connections and effects of straight and reverse polarity.

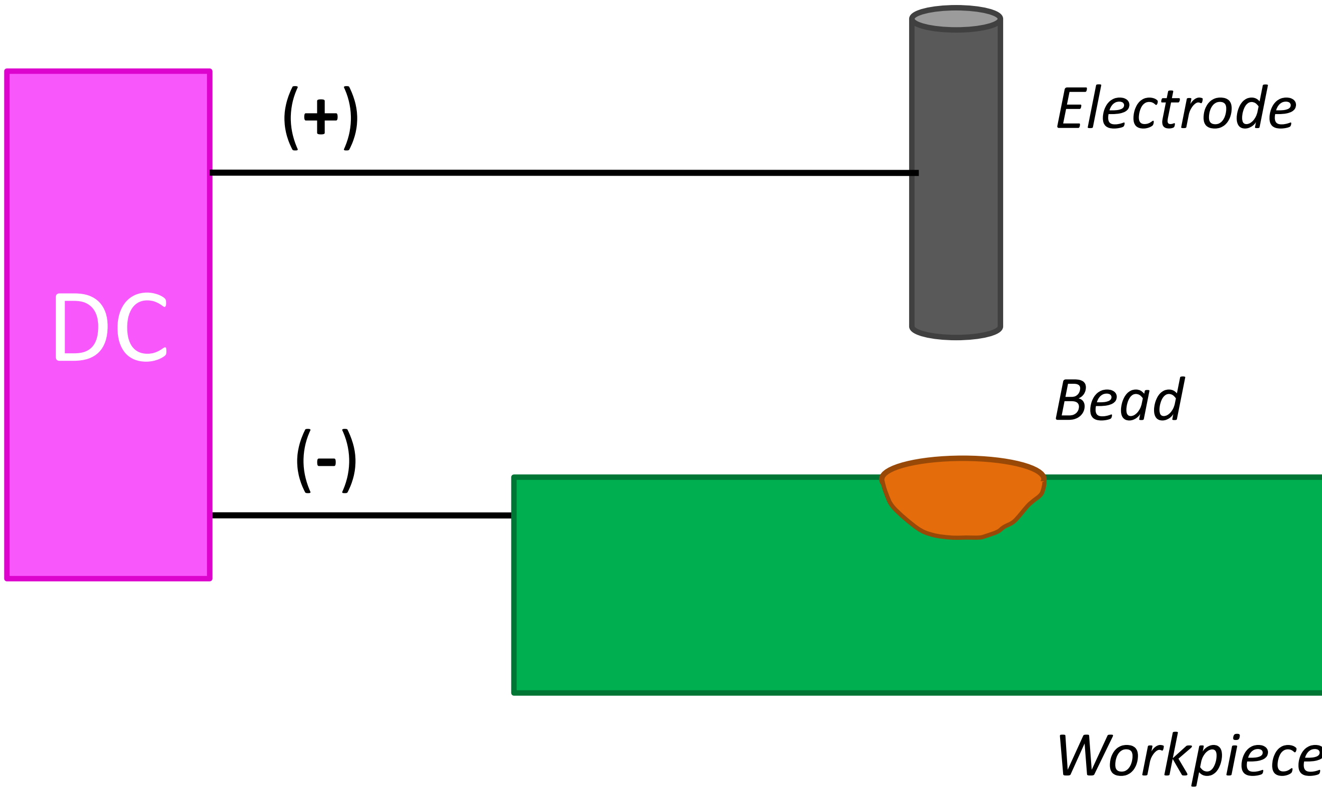
DC Electrode Negative (DCEN) or Straight Polarity

- **DC Electrode Negative (DCEN)** or **Straight Polarity** causes heat to build up on the workpiece, thereby increases the weld penetration.



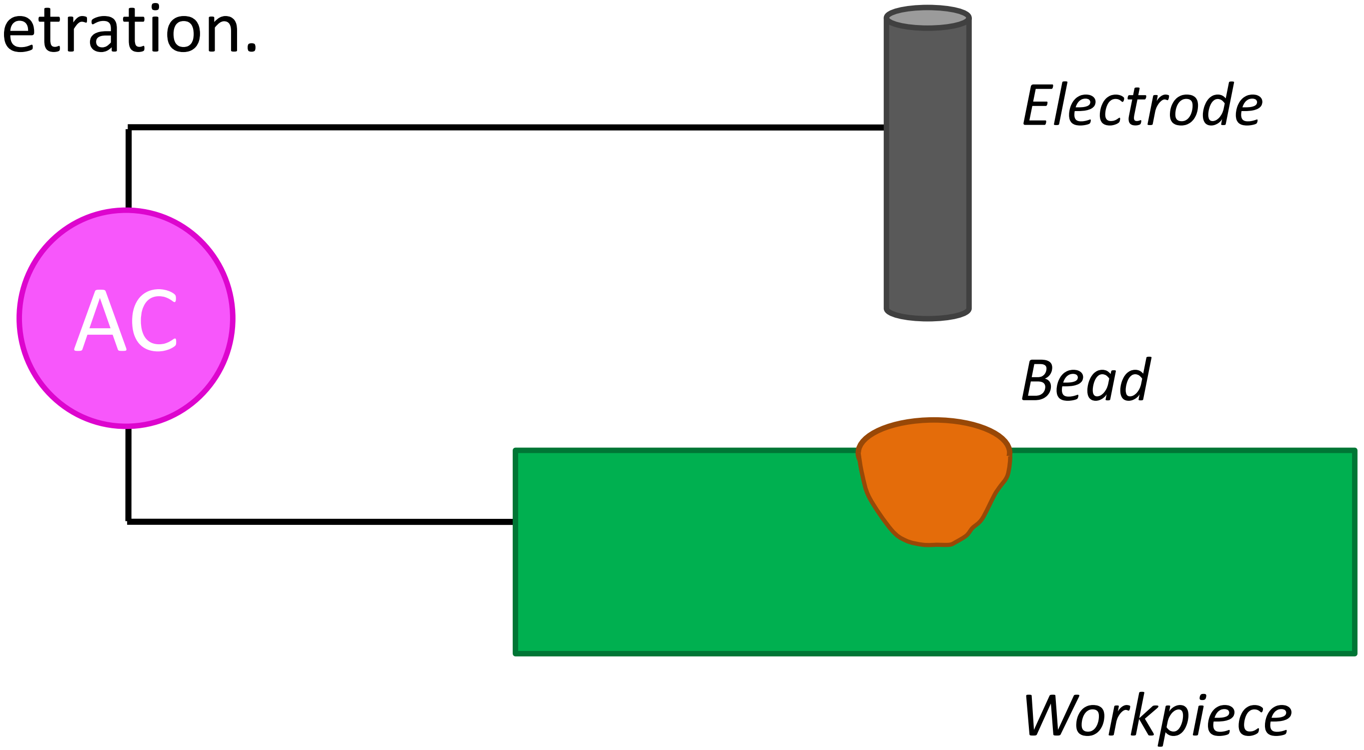
DC Electrode Positive (DCEP) or Reverse Polarity

- Reversing the polarity ie. **DC electrode positive** **(DCEP)** increase the electrode melting rate and decrease the depth of the weld.



AC

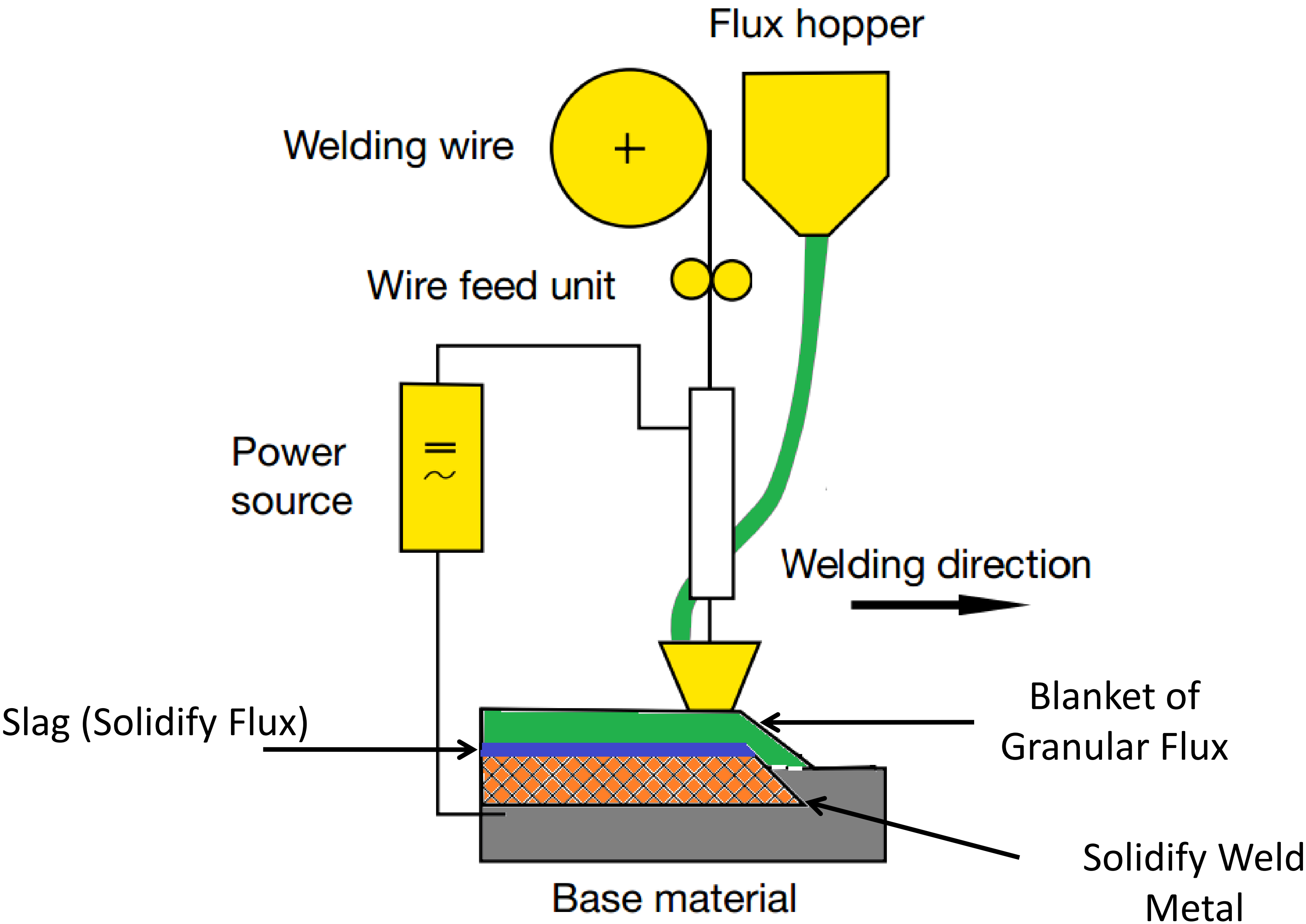
- With alternating current the polarity changes over 100 times per second, creating an even heat distribution and providing a balance between electrode melting rate and penetration.



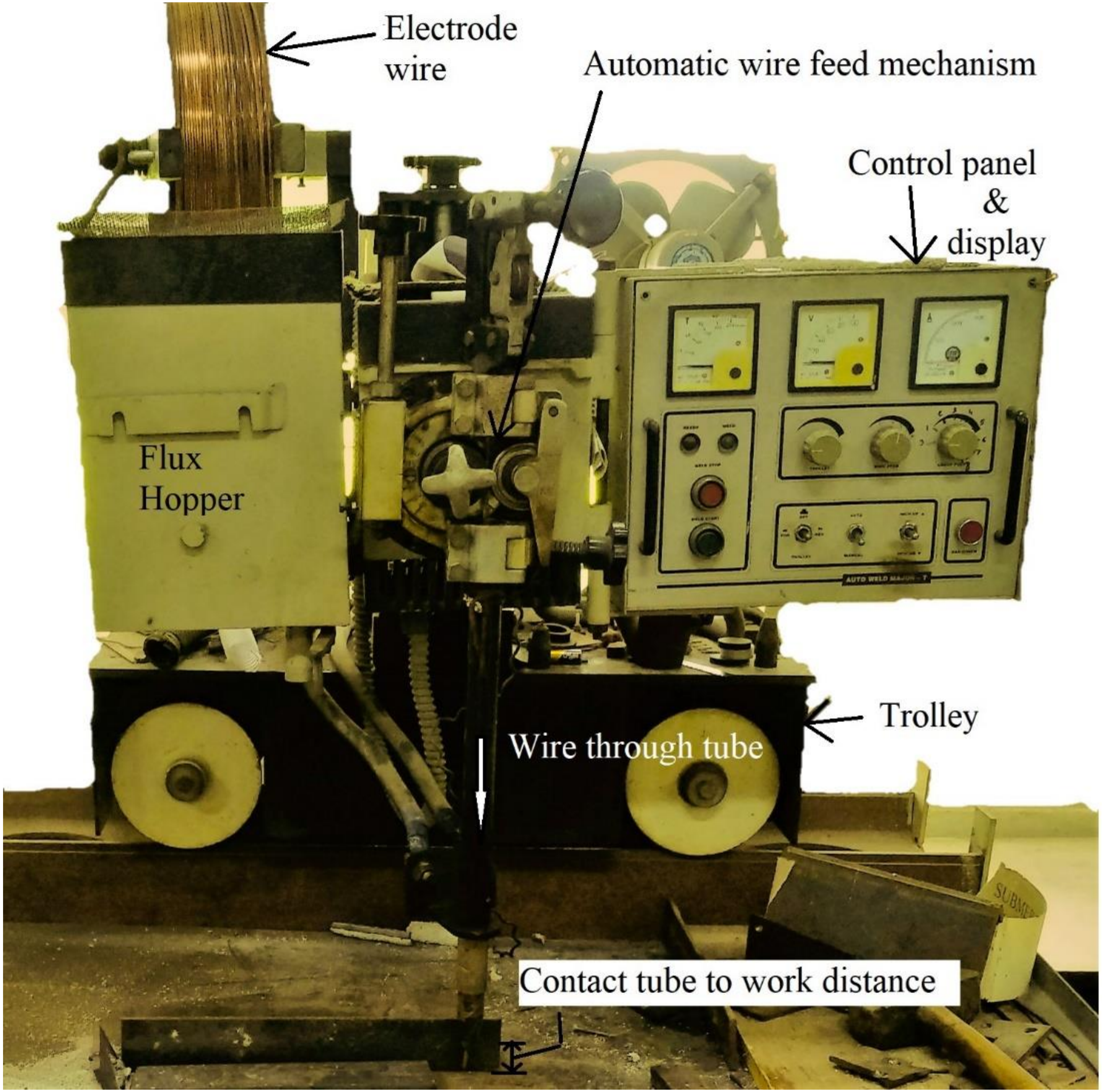
Submerged arc welding(SAW)

Submerged arc welding(SAW)

- Submerged arc welding(SAW) is an arc-welding process that uses a continuous, consumable bare wire electrode, and arc shielding is provided by a cover of ***granular flux***.
- ***No shielding gas*** is used in the submerged arc welding (SAW) process.
- The arc is maintained beneath the blanket of flux therefore ***no arc is visible*** (only a few small flames being visible sometimes).



Flux hopper
Welding wire
+
Wire feed unit
Power
source
Welding direction
Slag (Solidify Flux)
Blanket of
Granular Flux
Solidify Weld
Metal
Base material


Electrode wire
Automatic wire feed mechanism
Control panel & display
Flux Hopper
Trolley
Wire through tube
Contact tube to work distance

Submerged arc welding(SAW)

- The portion of the flux closest to the arc is melted, mixing with the molten weld metal to remove impurities and then solidifying on top of the weld joint to form a ***glass-like slag***.
- The slag and unfused flux granules on top provide good ***protection from the atmosphere*** and good ***thermal insulation*** for the weld area, resulting in relatively slow cooling and a ***high-quality weld joint***, noted for ***toughness and ductility.***

Submerged arc welding(SAW)

- The unfused flux remaining after welding can be recovered and ***reused***.
- The solid slag covering the weld must be chipped away, usually by manual means.

APPLICATIONS

- Submerged arc welding is widely used in steel fabrication for structural shapes (e.g., welded I-beams); longitudinal and circumferential seams for
  - ***large diameter pipes,***
  - ***tanks,***
  - ***pressure vessels,***
  - ***welded components for heavy machinery,***
  - ***thick sheets for shipbuilding etc.***

Shipbuilding often requires long welded seams for joining **thick plates**, and process like Submerged Arc Welding is the preferred choice for this task

Image source: https://www.motorship.com/news101/ships-and-shipyards/system-solutions-for-economical-welding

Video Link

https://www.youtube.com/watch?v=H6QGLGJ-BOE

APPLICATIONS

- In these kinds of applications, steel plates of ***25-mm thickness and heavier*** are routinely welded by this process.
- The process is ***not recommended*** for high-carbon steels, tool steels, aluminum, magnesium, titanium, lead, or zinc.
- Low-carbon, low-alloy, and stainless steels can be readily welded by SAW.
- The process is ***not recommended*** for high-carbon steels, tool steels, aluminum, magnesium, titanium, lead, or zinc.

Characteristics/ Advantages

- ***High welding speeds***,
- ***high deposition rates***,
- ***deep penetration***, and
- ***high cleanliness*** (due to the flux action) are all characteristic of submerged arc welding.

- Because the arc is totally submerged, ***high welding currents can be used*** (600 to 2000 A) (5 to 10 times higher than MMAW).
- A welding speed of 0.75 m/min in 2.5-cm-thick steel plate is typical.

Characteristics/ Advantages

- Single-pass welds can be made with penetrations up to 25 mm, and greater thicknesses can be joined by multiple passes.
- Because the metal is deposited in fewer passes than with alternative processes, there is ***less possibility of entrapped slag*** or voids, and weld quality is further enhanced.
- For even higher deposition rates, multiple electrode wires can be employed.

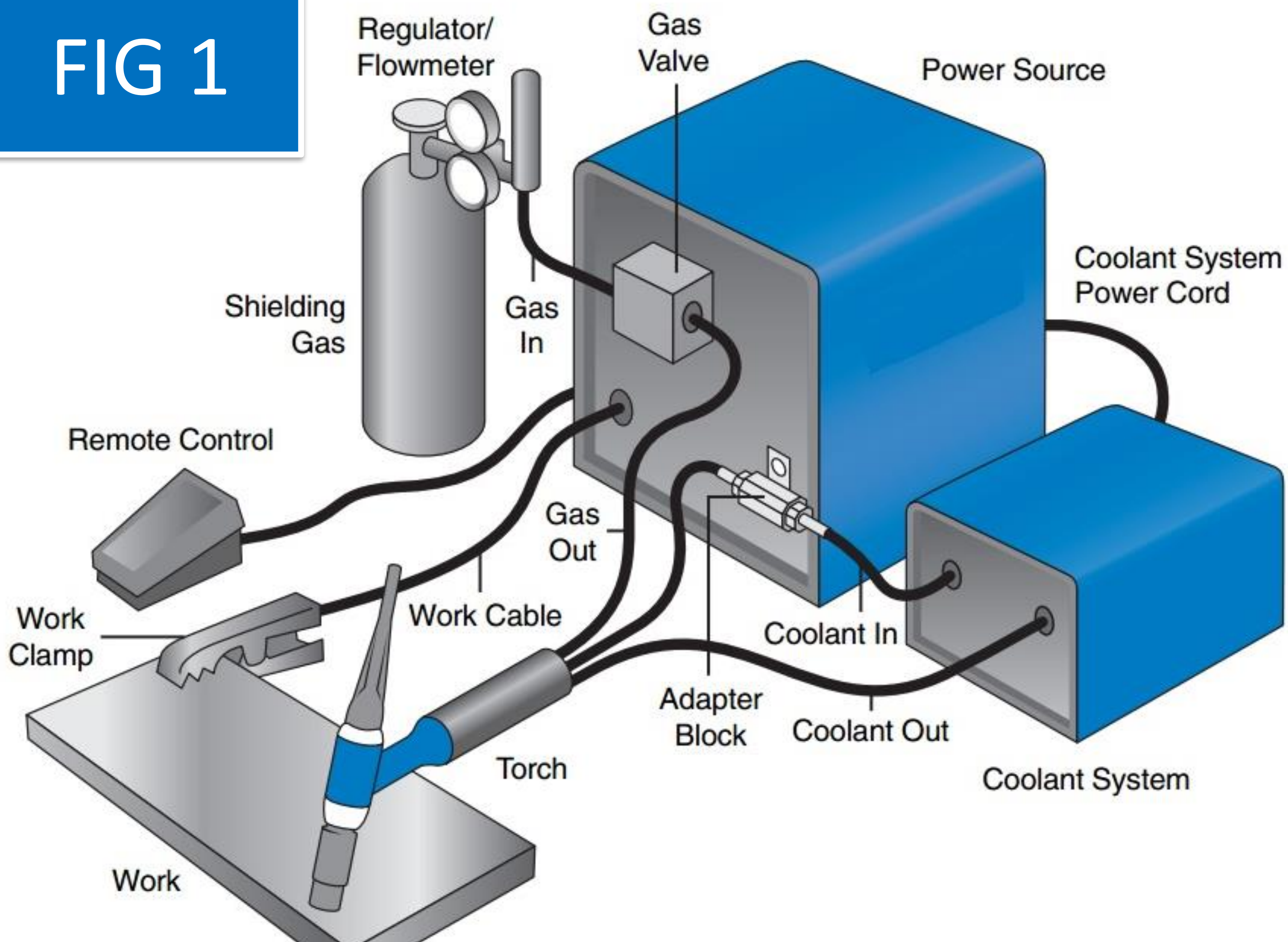
LIMITATIONS

- Limitations to the process include the
  - ***need for extensive flux handling***,
  - ***possible contamination of the flux by moisture*** (leading to porosity in the weld),
  - ***the large volume of slag that must be removed***, and
  - ***shrinkage problems due to the large weld pool.***
- The high heat inputs can produce large grain size structures, and the slow cooling rate may enable segregation and possible hydrogen or hot cracking.
- Welding is restricted to the horizontal position, since the flux and slag are held in place by gravity.

WELDING PROCESSES

TIG or GTAW

FIG 1



Regulator/ Flowmeter
Gas Valve
Power Source
Shielding Gas
Gas In
Coolant System Power Cord
Remote Control
Gas Out
Work Clamp
Work Cable
Coolant In
Adapter Block
Coolant Out
Torch
Coolant System
Work

Gas Tungsten Arc Welding (GTAW)

- The ***heat*** for ***Gas Tungsten Arc Welding*** (GTAW) is produced by an electric arc maintained between a ***non-consumable tungsten electrode*** and the ***part to be welded***.
- The heat-affected zone, the molten metal, and the tungsten electrode are all shielded from the atmosphere by a ***blanket of inert gas*** fed through the ***GTAW torch***.

Gas Tungsten Arc Welding (GTAW)

- ***Inert gas*** is that which is ***inactive***, or deficient in active chemical properties.
- It ***does not burn***, and ***adds nothing*** to or ***takes anything*** from the metal.
- Inert gases such as ***argon and helium*** do not chemically react or combine with other gases.

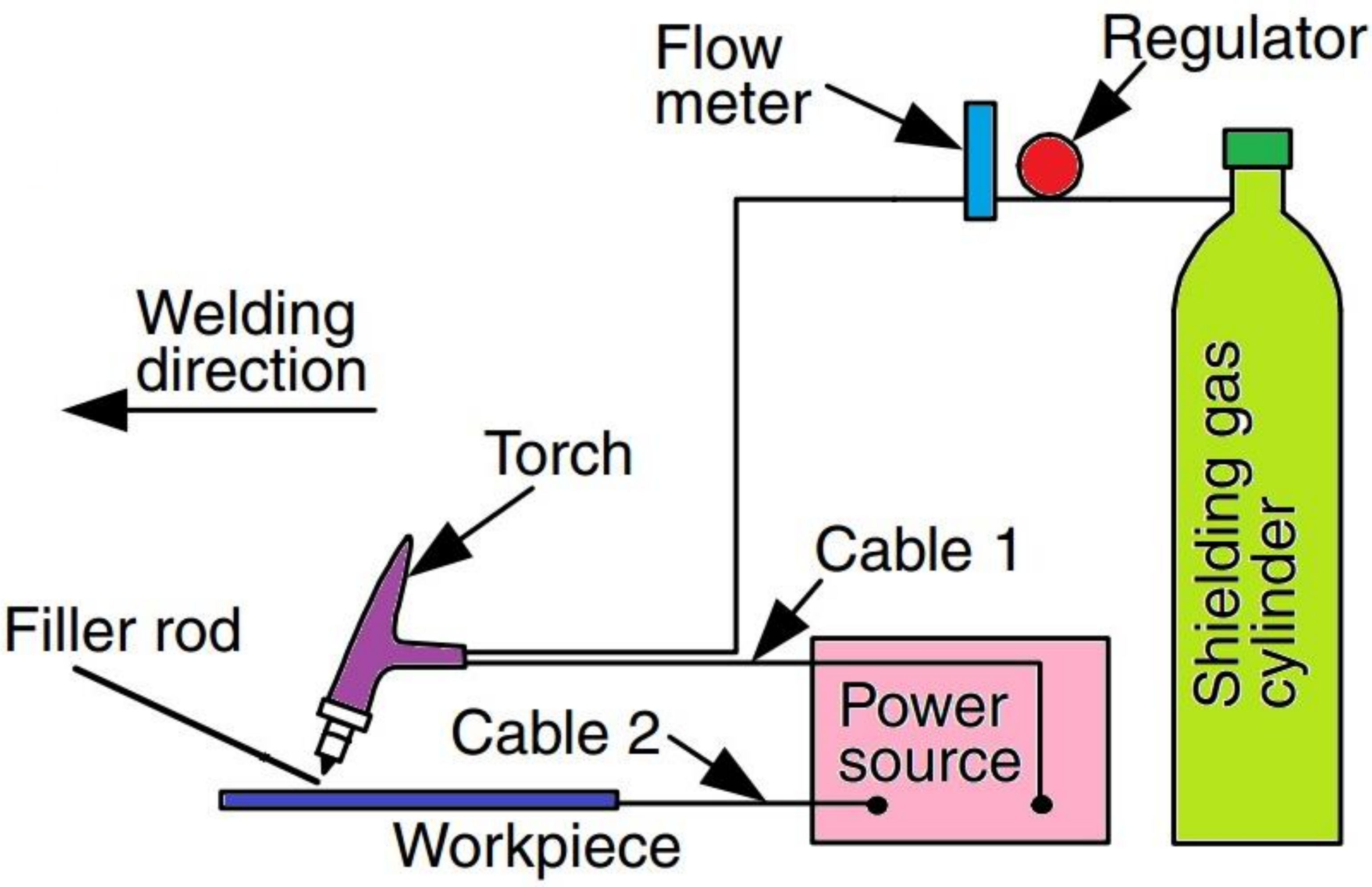
Gas Tungsten Arc Welding (GTAW)

- They possess ***no odour*** and are ***transparent***, permitting the welder ***maximum visibility*** of the ***arc***.
- ***In some instances a small amount of reactive gas such as hydrogen can be added to enhance travel speeds.***

Gas Tungsten Arc Welding (GTAW)

- The torch holding the tungsten electrode is connected to a shielding gas cylinder as well as one terminal of the power source, as shown in Figure 2.

FIG 2


Flow meter
Regulator
Welding direction
Torch
Cable 1
Filler rod
Cable 2
Power source
Workpiece
Shielding gas cylinder

Gas Tungsten Arc Welding (GTAW)

- The tungsten ***electrode*** is usually in contact with a ***water-cooled copper tube***, called the ***contact tube***, which is connected to the welding cable (***cable 1***) from the terminal.
- The ***workpiece*** is connected to the other terminal of the power source through a different cable (***cable 2***).

Gas Tungsten Arc Welding (GTAW)

- The shielding gas goes through the torch body and is directed by a nozzle toward the weld pool to protect it from the air.
- ***Protection*** from the air is ***much better*** in ***GTAW than in SMAW.***

Gas Tungsten Arc Welding (GTAW)

- ***Autogenous*** GTAW welding (***without filler metal***) is used in ***thin square edged sections*** (2mm), while ***V*** and ***X*** type edge preparations are needed in ***thicker sections***.
- A ***filler rod*** is needed for joining thicker materials.
- The autogeneous process is readily used in robotics and automation techniques.

Gas Tungsten Arc Welding (GTAW)

- This process is extensively used for welding thin components of ***stainless steel***, ***aluminum***, ***magnesium*** or ***titanium alloys*** as well pieces of ***carbon*** and ***low alloy steels***.

ELECTRODE

- ***Tungsten*** is preferred for this process because it has the ***highest melting point of all metals***.
- The tungsten electrode establishes and maintains the arc.
- It is said to be a "***nonconsumable***" in that the electrode is not melted and included in the weld pool.
- In fact, great care must be taken so that the tungsten does not contact the weld pool in any way, thereby causing a ***contaminated***, faulty weld.

SHIELDING GAS

- Primarily two inert gases are used for shielding purposes for TIG.
- They are ***argon and helium***.
- ***Argon***, with an atomic ***weight of 40***, is about ***one and a half*** times ***heavier than air*** and ***ten times heavier than helium*** which has an atomic weight of 4.

AR & HELIUM

- Argon and helium are the major shielding gases used in gas tungsten arc welding.
- In some applications, mixtures of the two gases prove advantageous.
- To a lesser extent, hydrogen is mixed with argon or helium for special applications.
- ***Note:*** CO2 cannot be used in this process since it provides inadequate protection for the hot tungsten electrode as it tends to oxides the electrode.

Advantages of the GTAW Process

1. ***Wide range of metal*** can be welded.
2. ***Dissimilar metals*** can also be joined such as copper to brass and stainless to mild steel.
3. ***Narrow heat-affected zone*** (compared to other processes like SMAW, GMAW and SAW)
4. ***Less distortion***
5. ***No Slag:*** There is no requirement for flux with this process; therefore, there is no slag to obscure the welder's vision of the molten weld pool.

Advantages of the GTAW Process

6. ***No Sparks or Spatter, No Smoke or Fumes:***
7. ***Improved metallurgical properties*** stronger, more ductile and more corrosion resistant joints.
8. ***Very thin metals can be welded*** due to the ease of controlling the current.

GTAW Disadvantages

- The main disadvantage of the GTAW process is the ***low filler metal deposition rate***.
- Another disadvantage is that the ***hand-eye coordination*** necessary to accomplish the weld is ***difficult to learn***, and requires a great deal of practice to become proficient.
- The ***arc rays*** produced by the process tend to be ***brighter*** than those produced by SMAW and GMAW. This is primarily due to the absence of visible fumes and smoke.

GTAW Disadvantages

- The ***increased*** amounts of ***ultraviolet rays*** from the arc also cause the ***formation*** of ***ozone and nitrous oxides.***
- Therefore, care should be taken to protect ***skin*** with the proper clothing and protect ***eyes*** with the correct shade lens in the welding hood.
- Metal thickness of upto 7 mm can be welded only.
- Contamination of tungsten can cause discontinuities in welding.

(Ozone is formed by the irradiation of the oxygen in the air surrounding and in the immediate vicinity of the arc with ultraviolet light. Ozone results from the action of ultraviolet radiation, which "breaks" the surrounding oxygen molecules. The single oxygen atoms thus formed (O) will be able to react with other oxygen molecules O_2 and form ozone molecules O_3)

APPLICATIONS

- Aerospace application.
- Welding of aluminium alloys, steel, copper, nickel, tin & Zr.
- Aircraft frames, Jet engine castings, Rocket motor cases etc.
- Precision welding of parts in atomic industry.
- Pipe works required for high pressure steam lines, chemical and petroleum industries.

APPLICATIONS

- Stainless steel, nickel and its alloys – Ar + 5% H(increase the arc heating efficiency)
- Aluminium alloys –Ar and He

Welding Processes

MIG or GMAW

Metal Inert Gas Welding (MIG, GMAW)

- **Metal Inert Gas Welding** (Gas Metal Arc Welding) is a arc welding process, in which the weld is shielded by an external gas (Argon, helium, CO2, argon + Oxygen or other gas mixtures).
- Consumable electrode wire, having chemical composition similar to that of the parent material, is continuously fed from a spool to the arc zone.

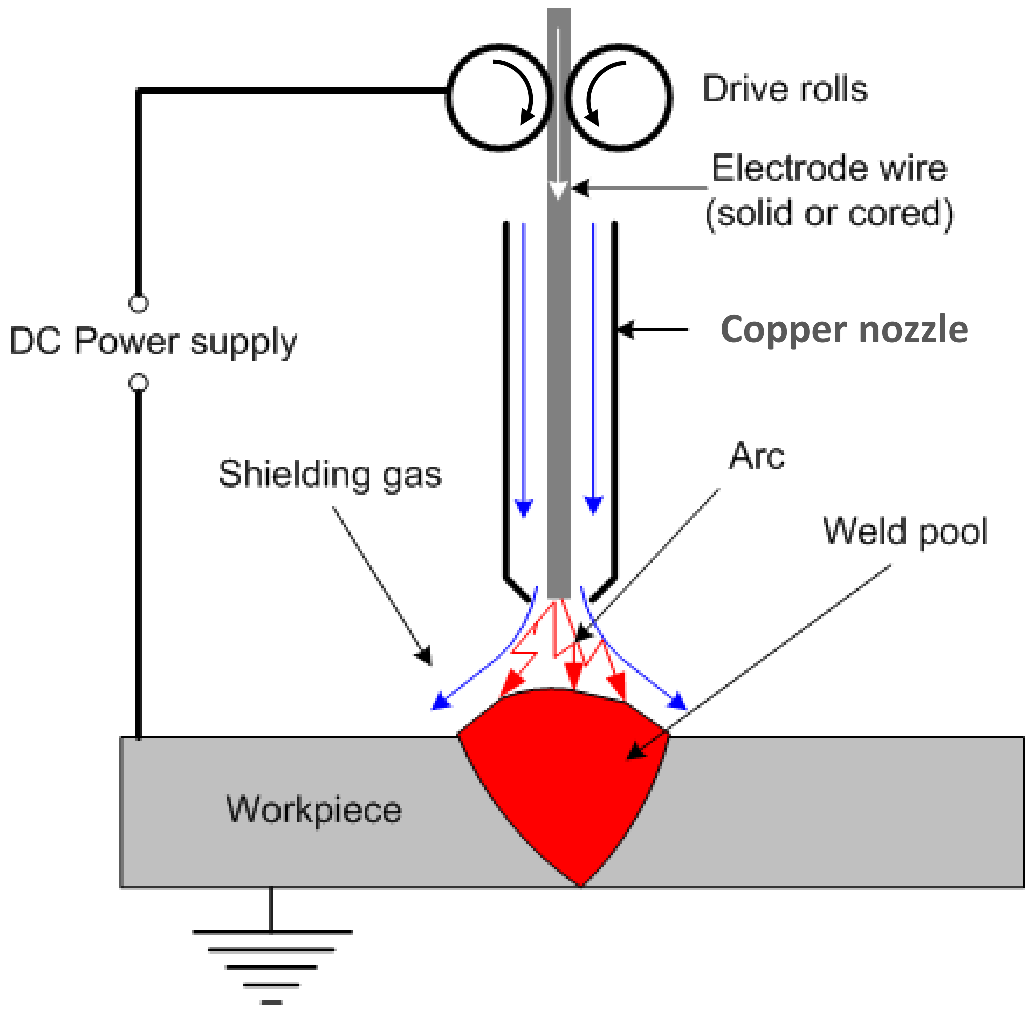
Metal Inert Gas Welding (MIG, GMAW)

- The arc heats and melts both the work pieces edges and the electrode wire. The fused electrode material is supplied to the surfaces of the work pieces, fills the weld pool and forms joint.
- Due to automatic feeding of the filling wire (electrode) the process is referred to as a semi-automatic. The operator controls only the torch positioning and speed.

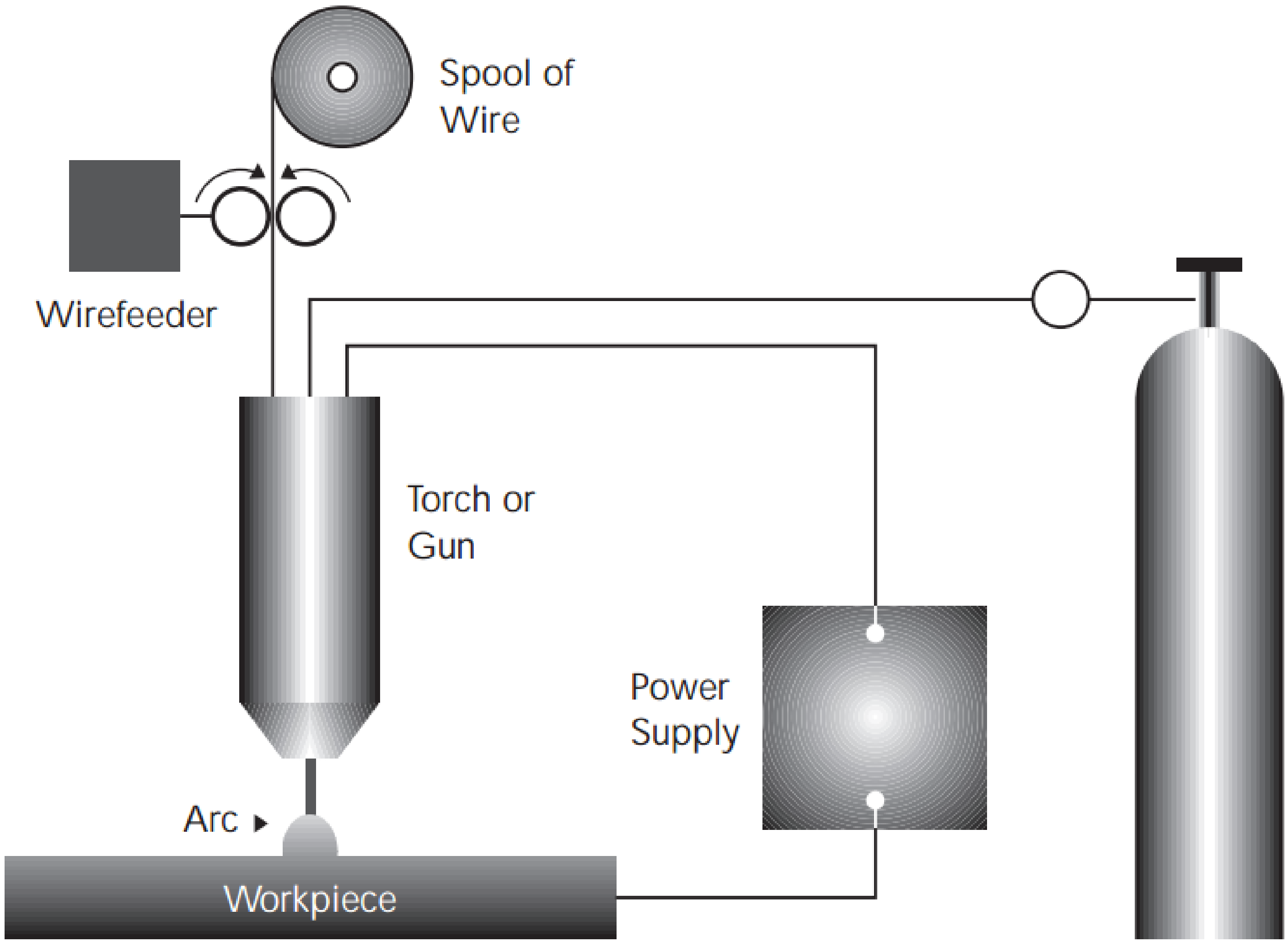
Metal Inert Gas Welding (MIG, GMAW)

- Gas metal arc welding(GMAW) is an AW process in which the electrode is a consumable bare metal wire, and shielding is accomplished by flooding the arc with a gas.
- The bare wire is fed continuously and automatically from a spool through the welding gun, as illustrated in Figure.

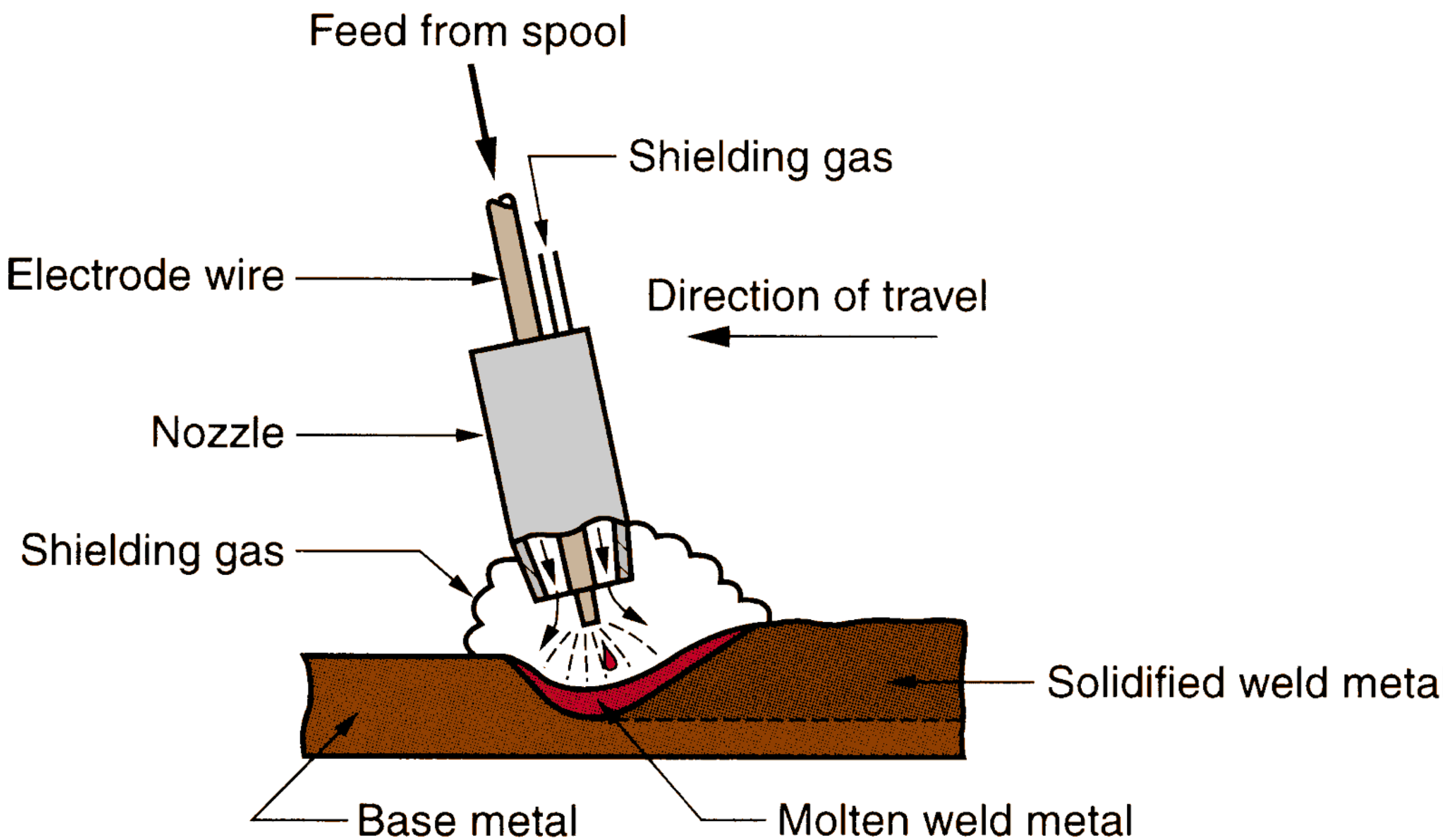
Metal Inert Gas Welding (MIG, GMAW)



Metal Inert Gas Welding (MIG, GMAW)



Metal Inert Gas Welding (MIG, GMAW)



Metal Inert Gas Welding (MIG, GMAW)

- Wire diameters ranging from 0.8 to 6.5 mm (1/32–1/4 in) are used in GMAW, the size depending on the thickness of the parts being joined and the desired deposition rate.
- Gases used for shielding include inert gases such as argon and helium, and active gases such as carbon dioxide.
- Selection of gases (and mixtures of gases) depends on the metal being welded, as well as other factors.

Metal Inert Gas Welding (MIG, GMAW)

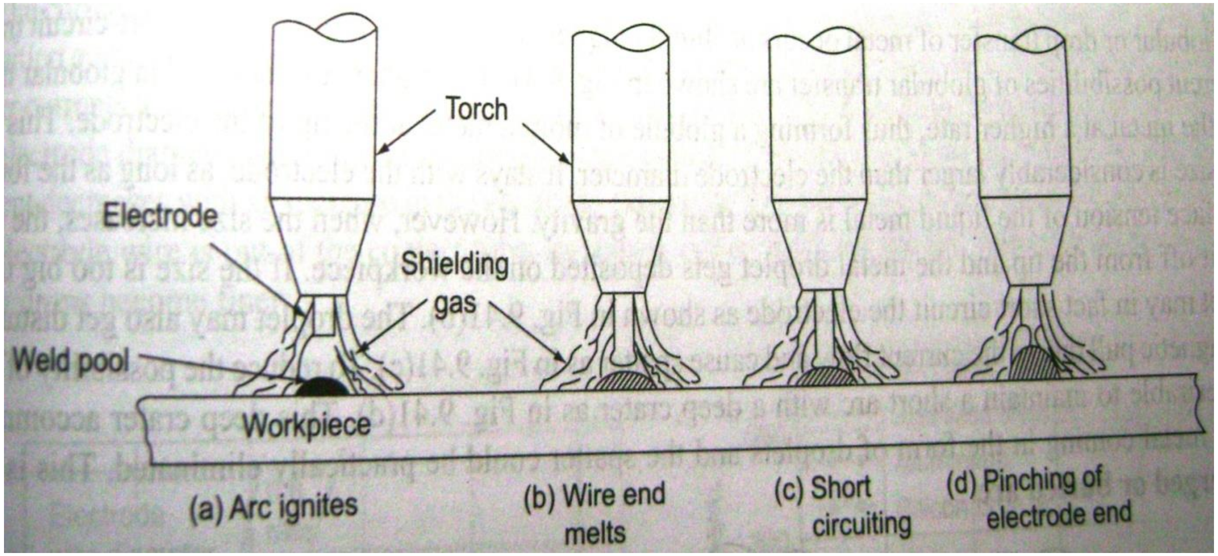
- Inert gases are used for welding aluminum alloys and stainless steels, while CO2 is commonly used for welding low and medium carbon steels.
- As there is no electrode flux used therefore there is no slag covering on the weld bead and thus no need for manual grinding and cleaning of slag.
- The GMAW process is therefore ideal for making multiple welding passes on the same joint.

GMAW – Metal Transfer modes

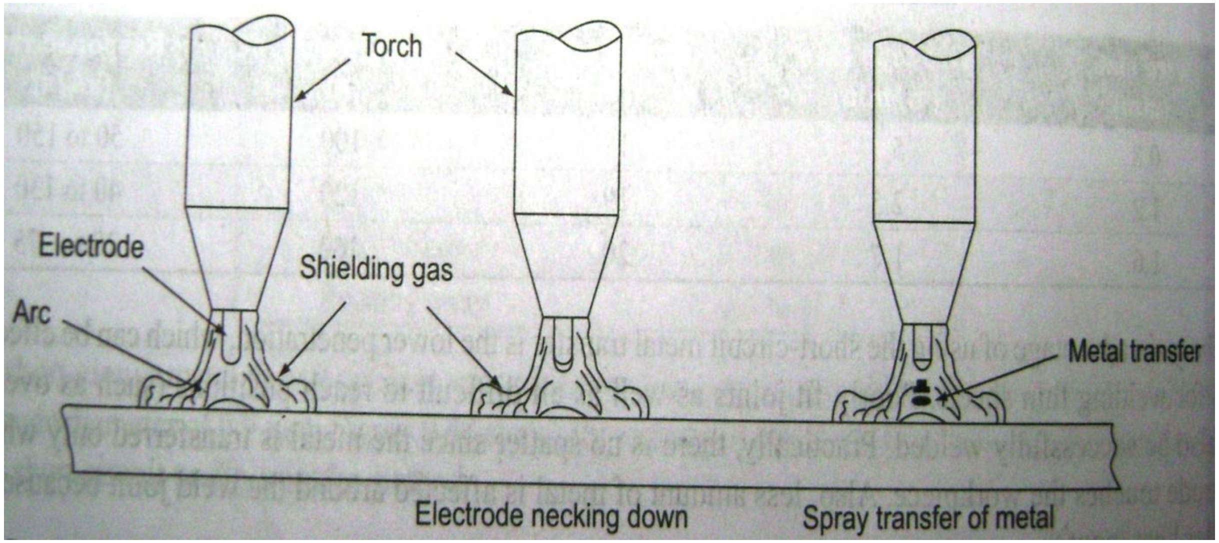
In the GMAW process, the filler metal is transferred from the electrode to the joint. Depending upon the current, voltage and the wire feed rate used for given electrode, the metal transfer is done in different ways. They are

- **Short circuit** (low voltage – lowest amperage, incomplete fusion could cause)
- **Dip transfer** (Like short-circuiting - low voltage – lowest amperage with high wire feed rate)
- **Globular transfer** (high voltage-high amperage, high deposition with high spattering)
- **Spray transfer** (axial & pulsed) – very high voltage and amperage (highest), good deposition, high heat produced, pulsed spray with high to low amperage cycles due to pulsing cycles)

GMAW – Metal Transfer modes



SHORT CIRCUIT & Dip METAL TRANSFER



SPRAY TRANSFER

Metal Inert Gas Welding (MIG, GMAW)

ADVANTAGES

- Continuous weld may be produced (no interruptions)
- High level of operators skill is not required
- Slag removal is not required (no slag)

Metal Inert Gas Welding (MIG, GMAW)

DISADVANTAGES

- Expensive and non-portable equipment is required
- Outdoor application are limited because of effect of wind, dispersing the shielding gas

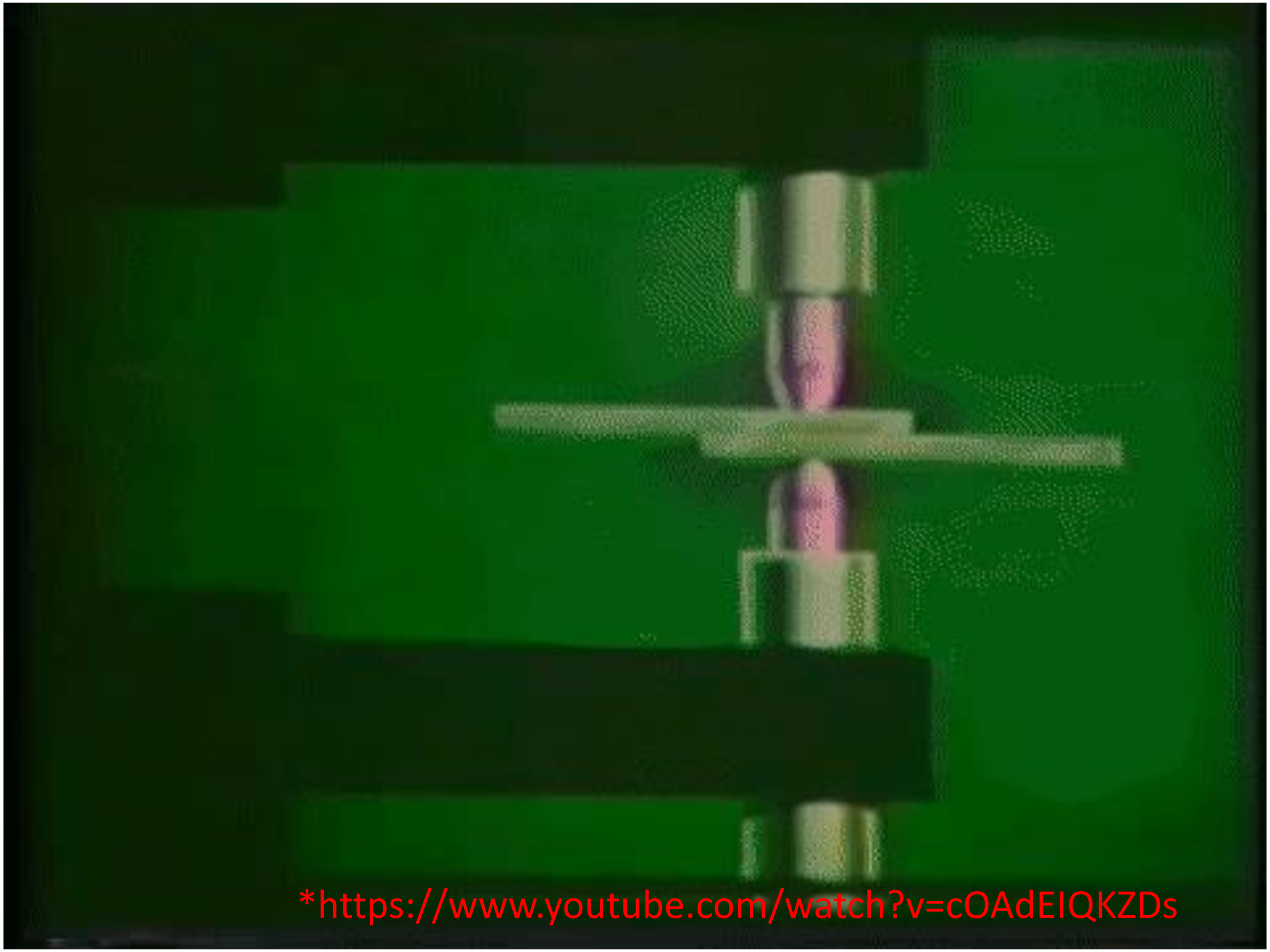
Resistance Welding (RW)

- **Resistance Welding** is a welding process, in which work pieces are welded due to a **combination** of a **pressure** applied to them and a localized **heat** generated by a high electric **current** flowing through the contact area of the weld.

- The weld is made by a combination of ***HEAT***, ***PRESSURE***, and ***TIME***.

- ***Resistance*** of the material is used for welding by current flow which causes a ***localized heating*** in the part.

Resistance Welding (RW)



*https://www.youtube.com/watch?v=cOAdEIQKZDs

Resistance Welding (RW)

- The heat generated in resistance welding

$$\boxed{H = I^2 R\, t} \qquad (1)$$

H_w

Heat used to form weld Nugget

say 60%

H_L

Heat lost into the work metal, electrodes, and surrounding air

say 40%

Resistance Welding (RW)

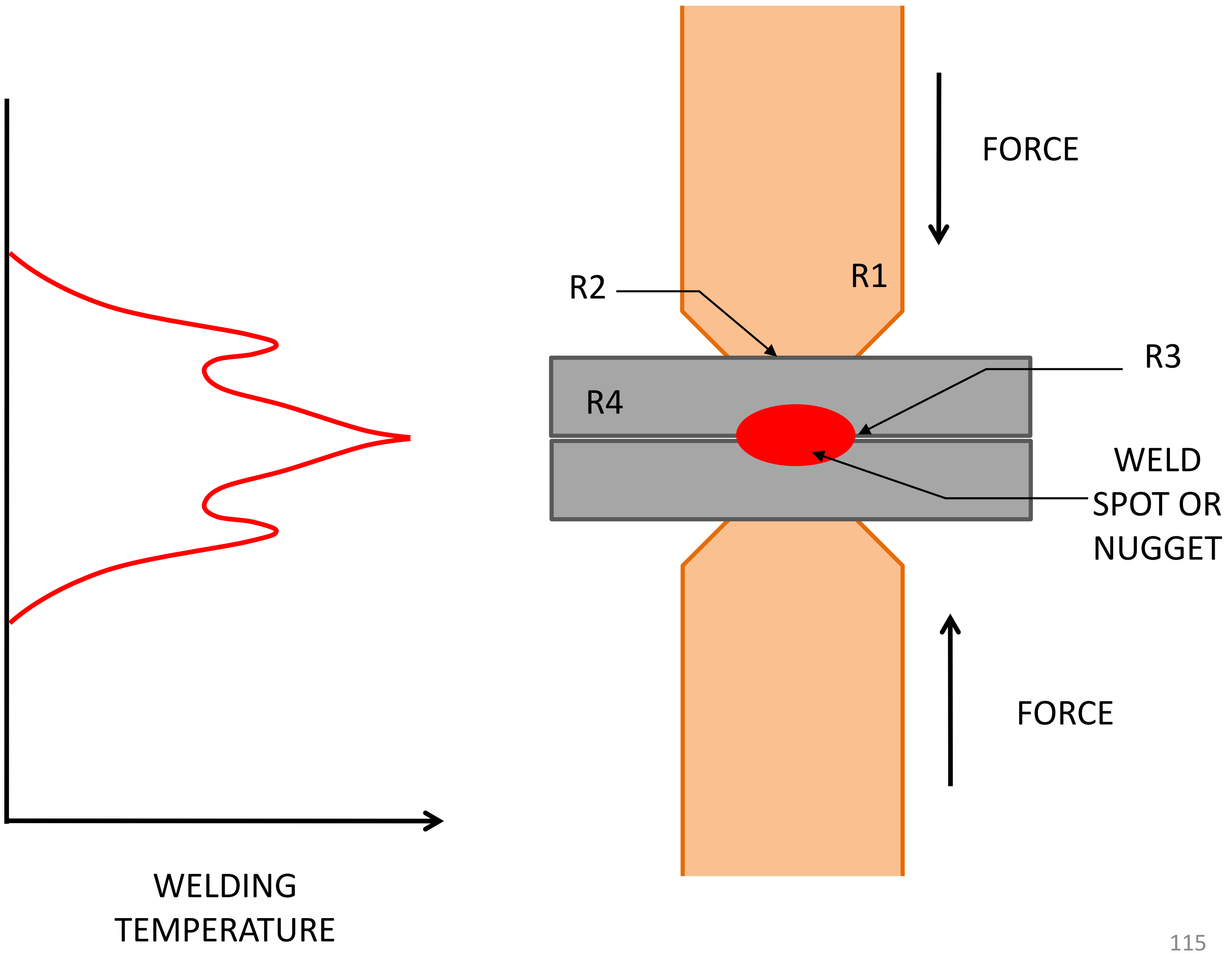
- Therefore the heat generated in resistance welding ***which is used to form the weld nugget*** can be expressed as

$$H = k\, I^2 R\, t \qquad (2)$$

  - ***H*** = the total heat generated in the work, J
  - ***I*** = electric current, A
  - ***t*** = time for which the electric current is passing through the joint
  - ***R*** = the resistance of the joint, ohms
  - ***k***= a constant to account for the heat losses from the welded joint. (if ***k=0.6***, that means ***40%*** of the heat is lost into the work metal, electrodes, and surrounding air.)

4 Major Points of Resistance

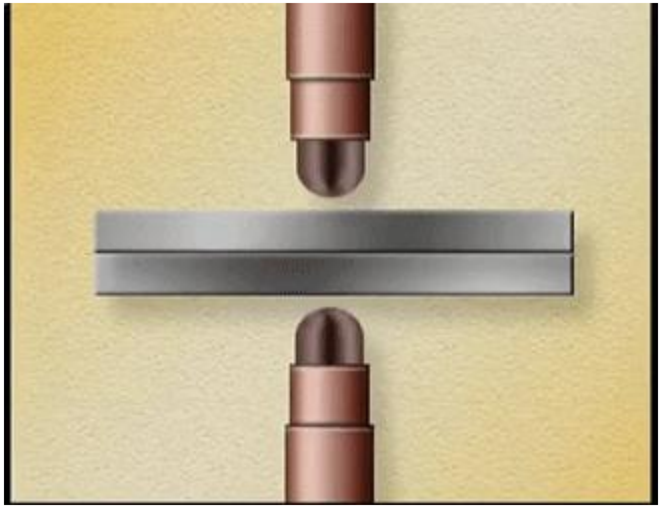
- There are 4 major points of resistance in the work area. They are as follows:
  - ***(R1)*** Resistance of the electrodes.
  - ***(R2)*** The contact resistance between the electrode and the workpiece.
  - ***(R3)*** The contact resistance between the two workpiece plates.
  - ***(R4)*** The workpiece resistance.



FORCE
R1
R2
R3
R4
WELD
SPOT OR
NUGGET
FORCE
WELDING
TEMPERATURE

Current Voltage

- AC low volt (typically 1 to 30 V) electric current (1000–100,000 A) is supplied through **copper electrodes** connected to the secondary coil of a welding transformer.



https://gfycat.com/tattereddownrightbutterfly

APPLICATIONS

- Resistance Welding (RW) is used for joining
  - **vehicle body parts,**
  - **fuel tanks,**
  - **domestic radiators,**
  - **pipes of gas oil and water pipelines,**
  - **wire ends,**
  - **turbine blades etc.**

SHEET METAL PRODUCTS

Metals Welded

- The following metals may be welded by Resistance Welding:
  - ***Low carbon steels*** - the widest application of Resistance Welding
  - ***Aluminum alloys***
  - ***Medium carbon steels, high carbon steels and Alloy steels***

ADVANTAGES

- High welding rates
- Low fumes
- Cost effectiveness
- Easy automation
- No filler materials are required
- Low distortions
- Good repeatability and reliability

Types of Resistance Welding (RW)

The most popular methods of Resistance Welding are:

1. Spot Welding (RSW)

2. Seam Welding (RSEW)

3. Resistance Projection Welding (RPW)

1. Spot Welding (RSW)

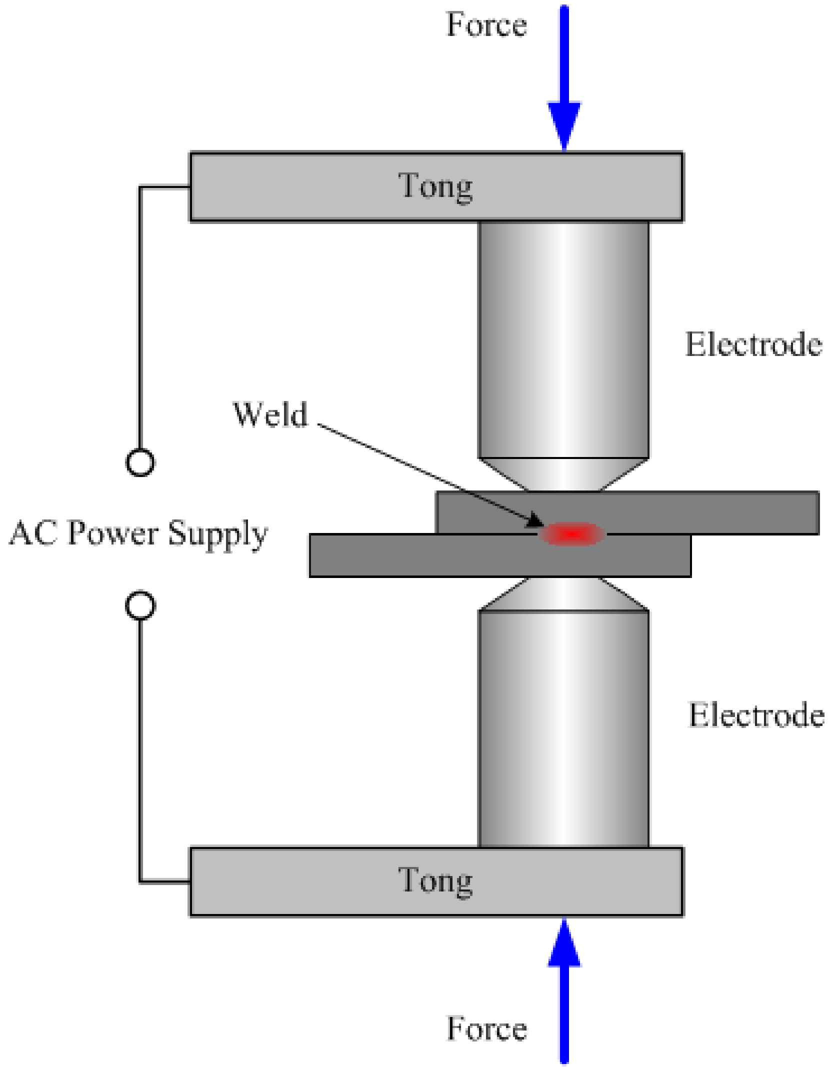
- **Spot Welding** is a Resistance Welding (RW) process, in which two or more overlapped metal sheets are joined by spot welds.

- The method uses pointed copper electrodes providing passage of electric current. The electrodes also transmit pressure required for formation of strong weld.

- ***Diameter*** of the weld spot is in the range - ***(3 - 12 mm).***

- Spot welding is widely used in ***automotive industry*** for joining vehicle body parts.

1. Spot Welding (RSW)

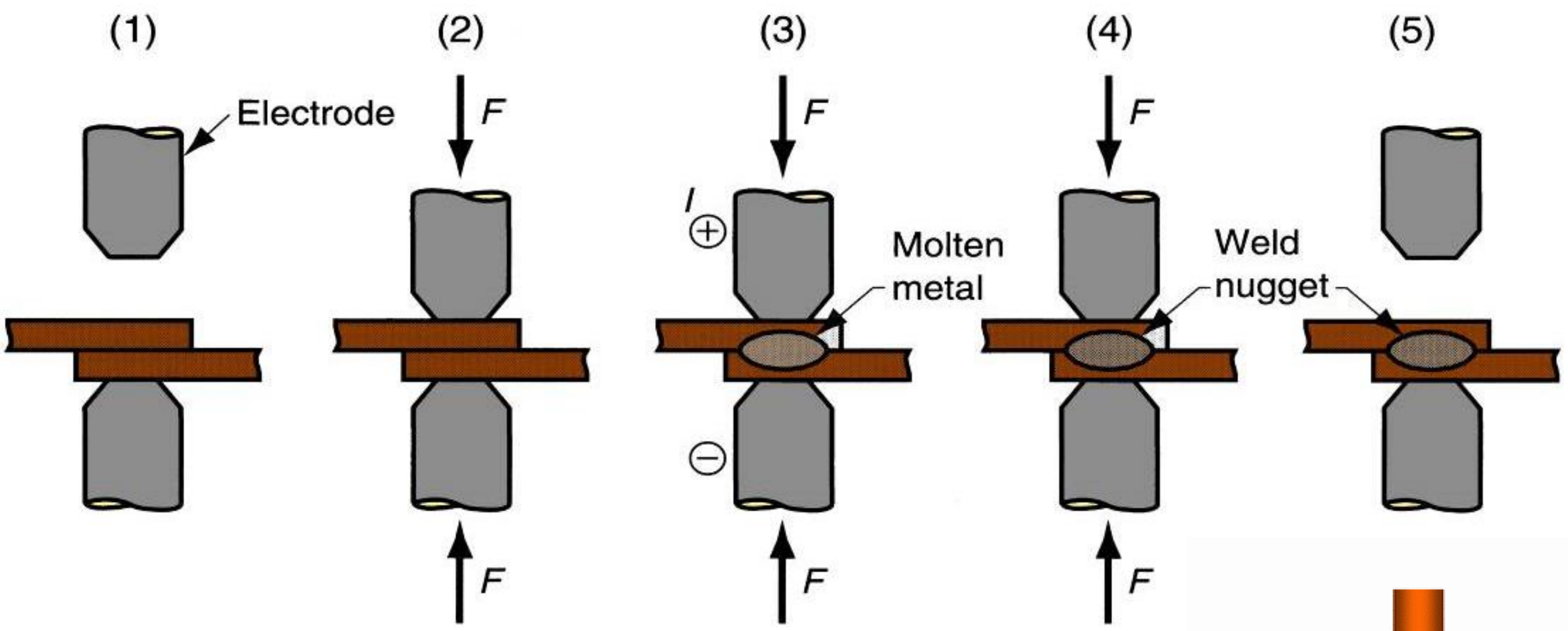


1. Spot Welding (RSW) - STEPS

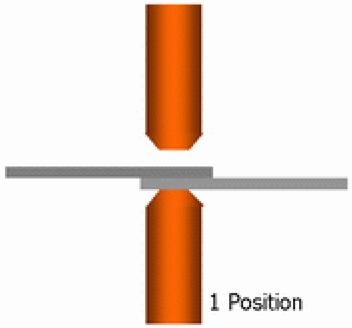
- The sequence is as follows:

1. ***parts inserted*** between open electrodes,
2. ***electrodes close*** and force is applied,
3. ***weld time—*** current is switched on,
4. ***current is turned off*** but force is maintained or increased (a reduced current is sometimes applied near the end of this step for stress relief in the weld region), and
5. ***electrodes are opened***, and the welded assembly is removed.

1. Spot Welding (RSW) - STEPS



(1) parts inserted between electrodes, (2) electrodes close, force applied, (3) current on, (4) current off, (5) electrodes opened.

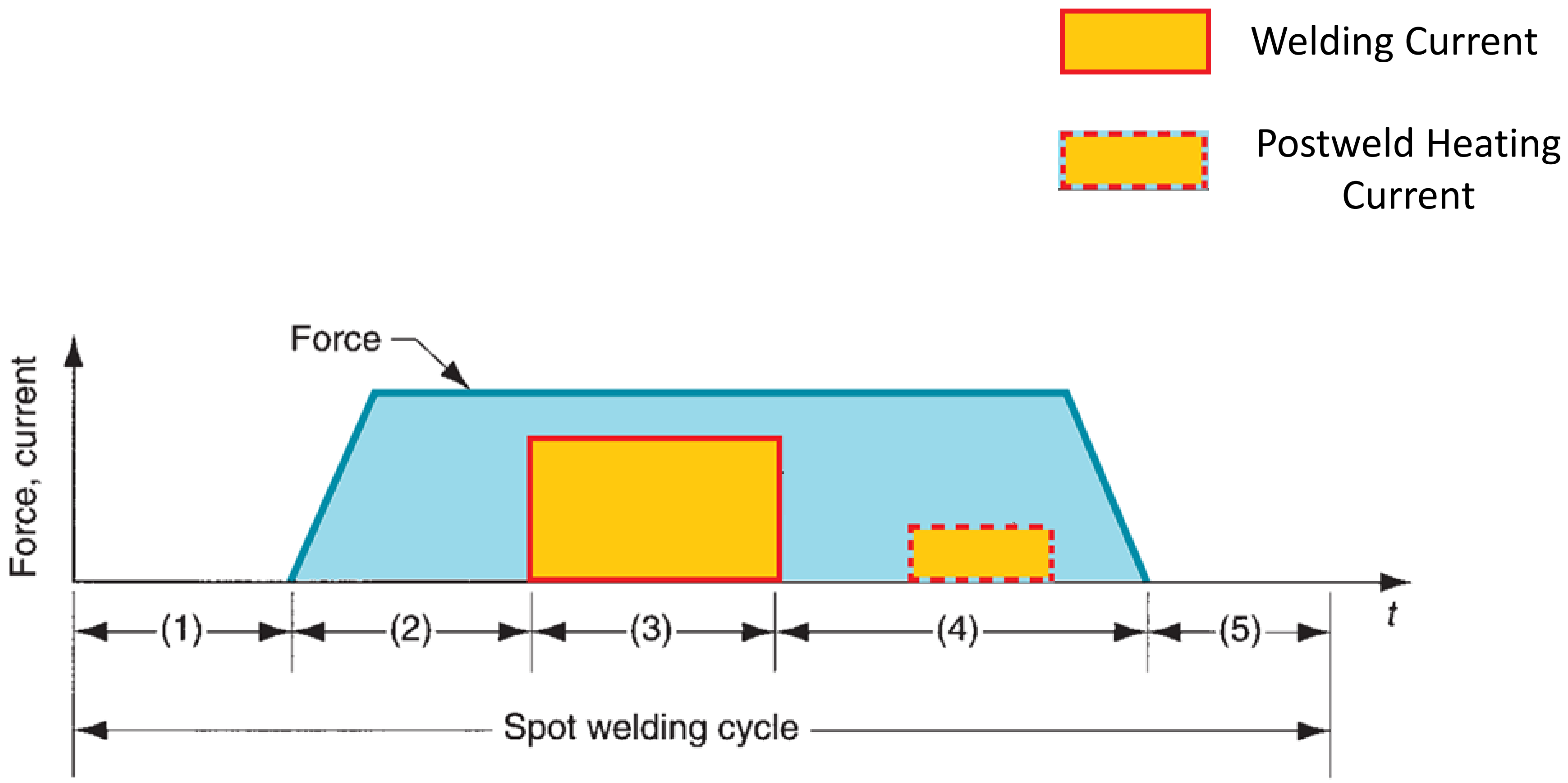


Resistance spot weld sequence

© David Page Associates Limited

http://www.davidpageassociates.co.uk/spotweld.htm

1. Force, Current vs Time



(1) parts inserted between electrodes, (2) electrodes close, force applied, (3) current on, (4) current off, (5) electrodes opened.

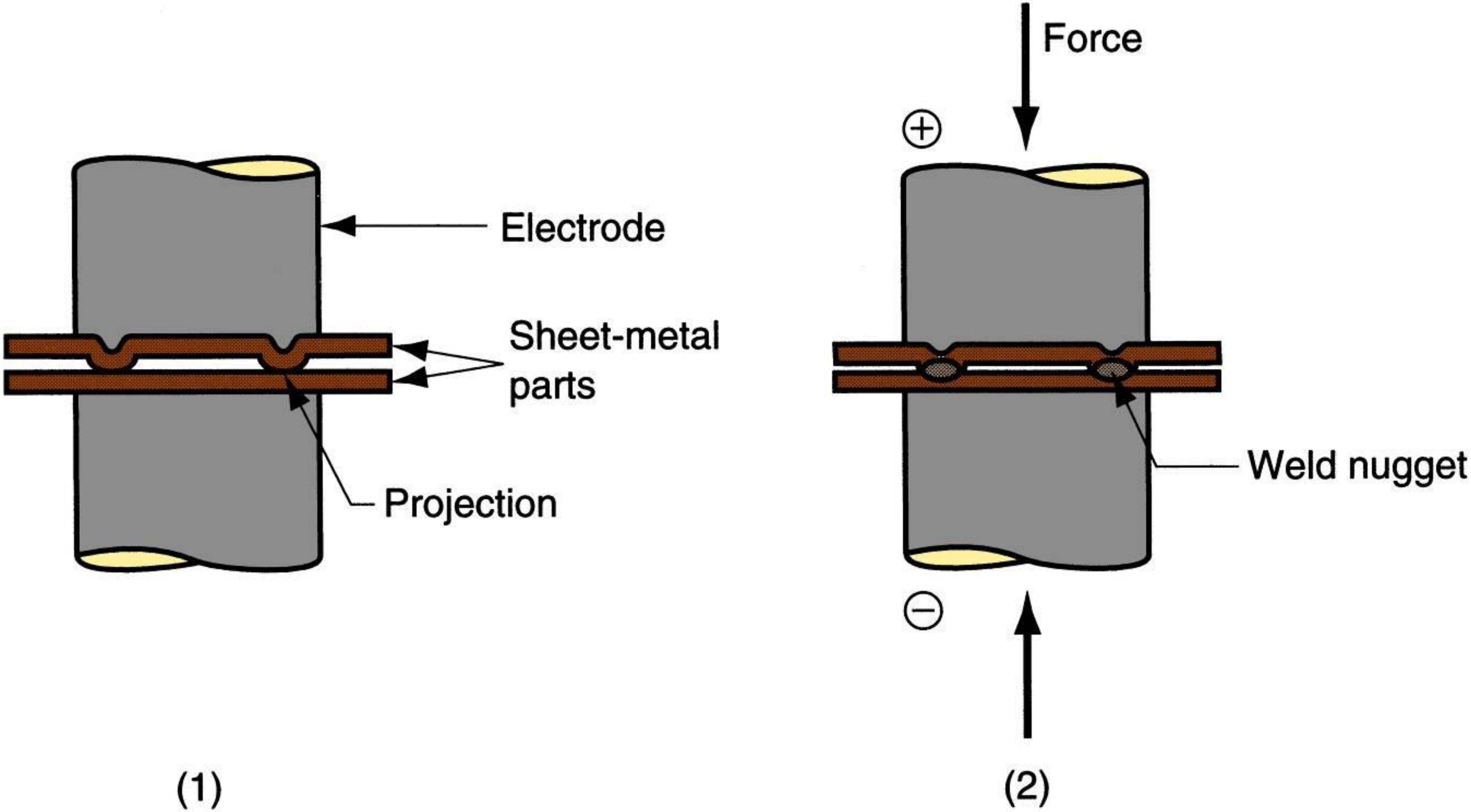
1. Spot Welding (RSW) - POSTWELD

- It has been observed that ***steels*** containing more than ***0.15% carbon*** may result into ***brittle weld joint*** during resistance welding.

- Therefore ***post-weld heating*** is sometimes applied to ***eliminate possible brittleness***.

2. Resistance Projection Welding (RPW)

- When **increased strength** is required, **multiple welds** are often needed, and this means multiple operations.
- Dimples are embossed into one of the workpieces at the location where a weld is desired.
- The two workpieces are then placed between large-area electrodes in a press machine, and pressure and current are applied as in spot welding.
- Since the current must flow through the points of contact (i.e., the dimples), the heating is concentrated where the weld is desired.

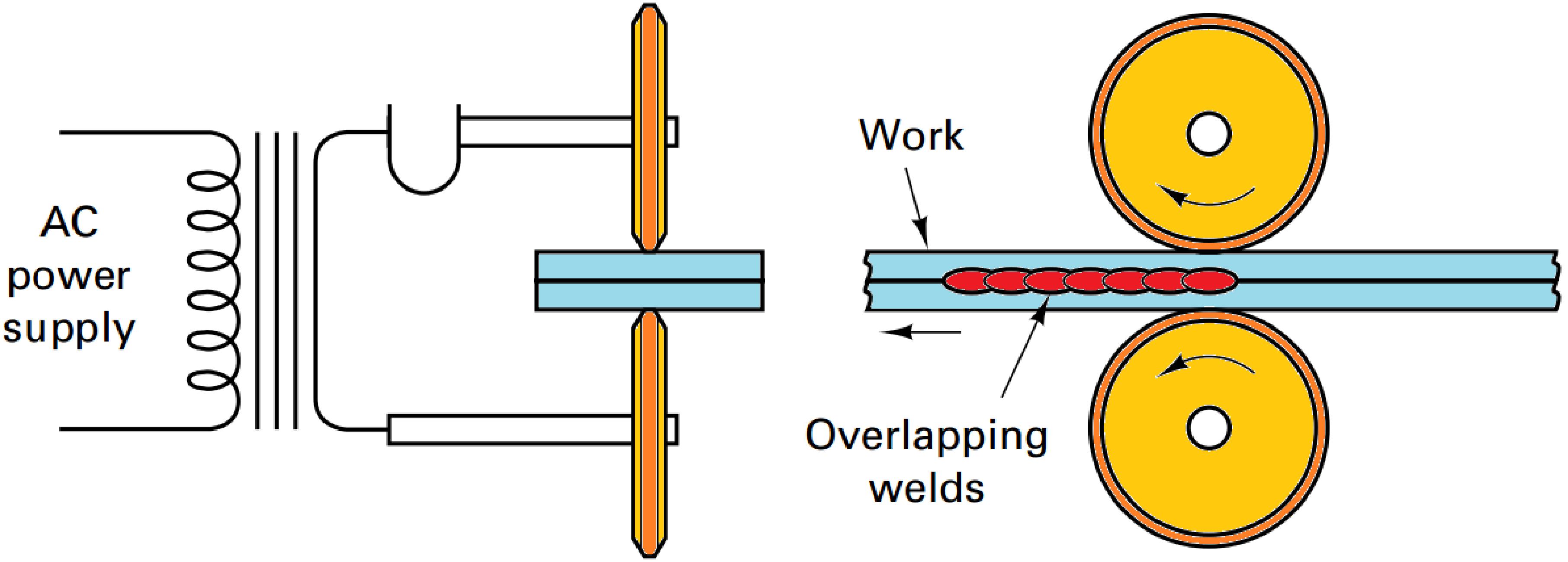


- Resistance projection welding (RPW): (1) start of operation, contact between parts is at projections; (2) when current is applied, weld nuggets similar to spot welding are formed at the projections.

3. Seam Welding (RSEW)

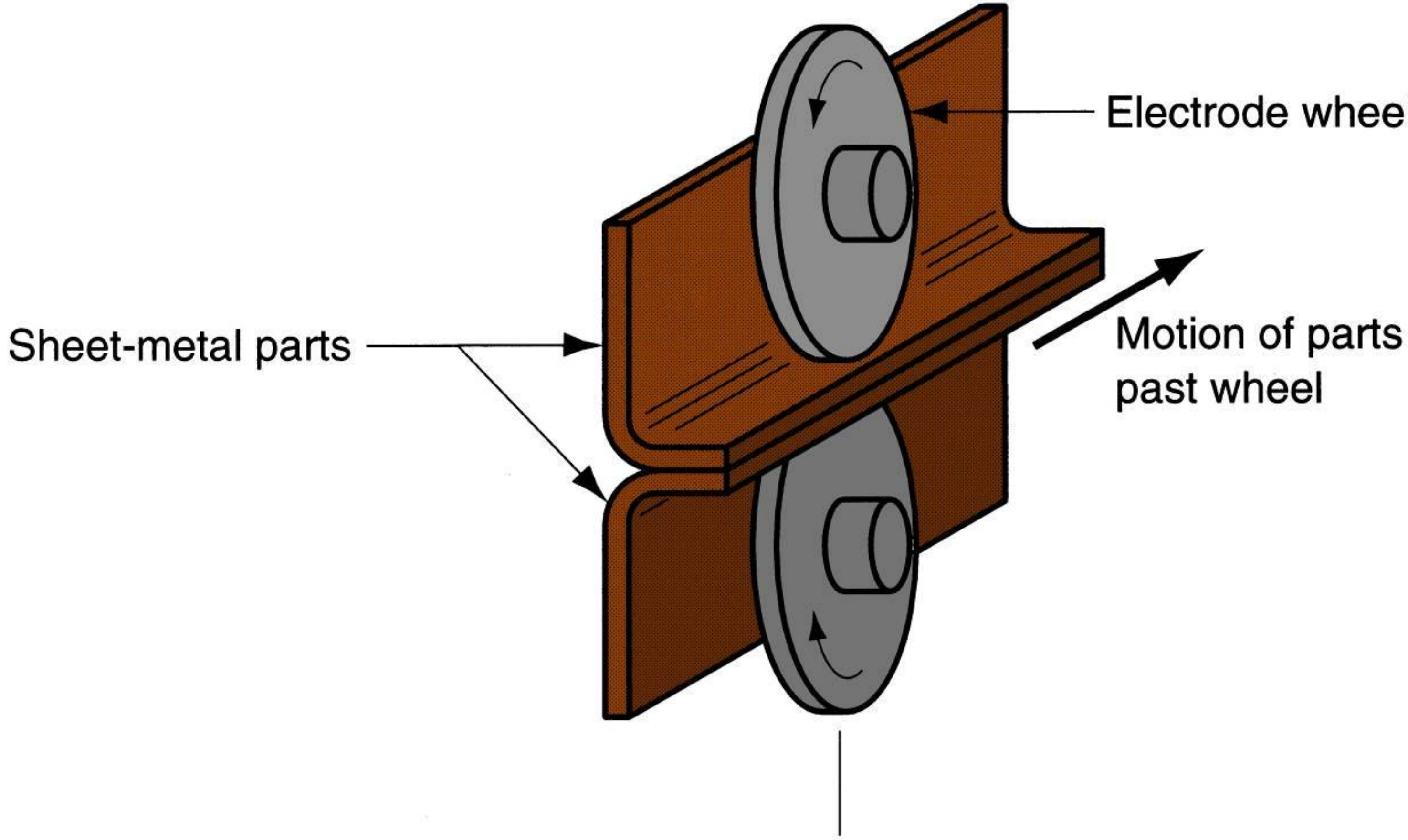
- **Seam Welding** is a Resistance Welding (RW) process of continuous joining of overlapping sheets by passing them between two rotating electrode wheels.
- Heat generated by the electric current flowing through the contact area and pressure provided by the wheels are sufficient to produce a **leak-tight weld**.
- Resistance seam welds (RSEW) can be made by ***two distinctly different processes***.

3. Seam Welding (RSEW)



https://gfycat.com/gifs/search/resistance+welding

3. Seam Welding (RSEW)



3. Seam Welding (RSEW)

- Seam Welding is high speed and clean process, which is used when continuous tight weld is required .
- Can produce air-tight joints
- ***Applications:***
  - ***Gasoline tanks***
  - ***Automobile mufflers***
  - ***Various other sheet metal containers***

Resistance Welding Numerical (RW)

- The heat generated in resistance welding

$$\boxed{H = I^2 R\, t} \qquad (1)$$

H_w

Heat used to form weld Nugget

say 60%

H_L

Heat lost into the work metal, electrodes, and surrounding air

say 40%

Resistance Welding (RW)

- Therefore the heat generated in resistance welding ***which is used to form the weld nugget*** can be expressed as

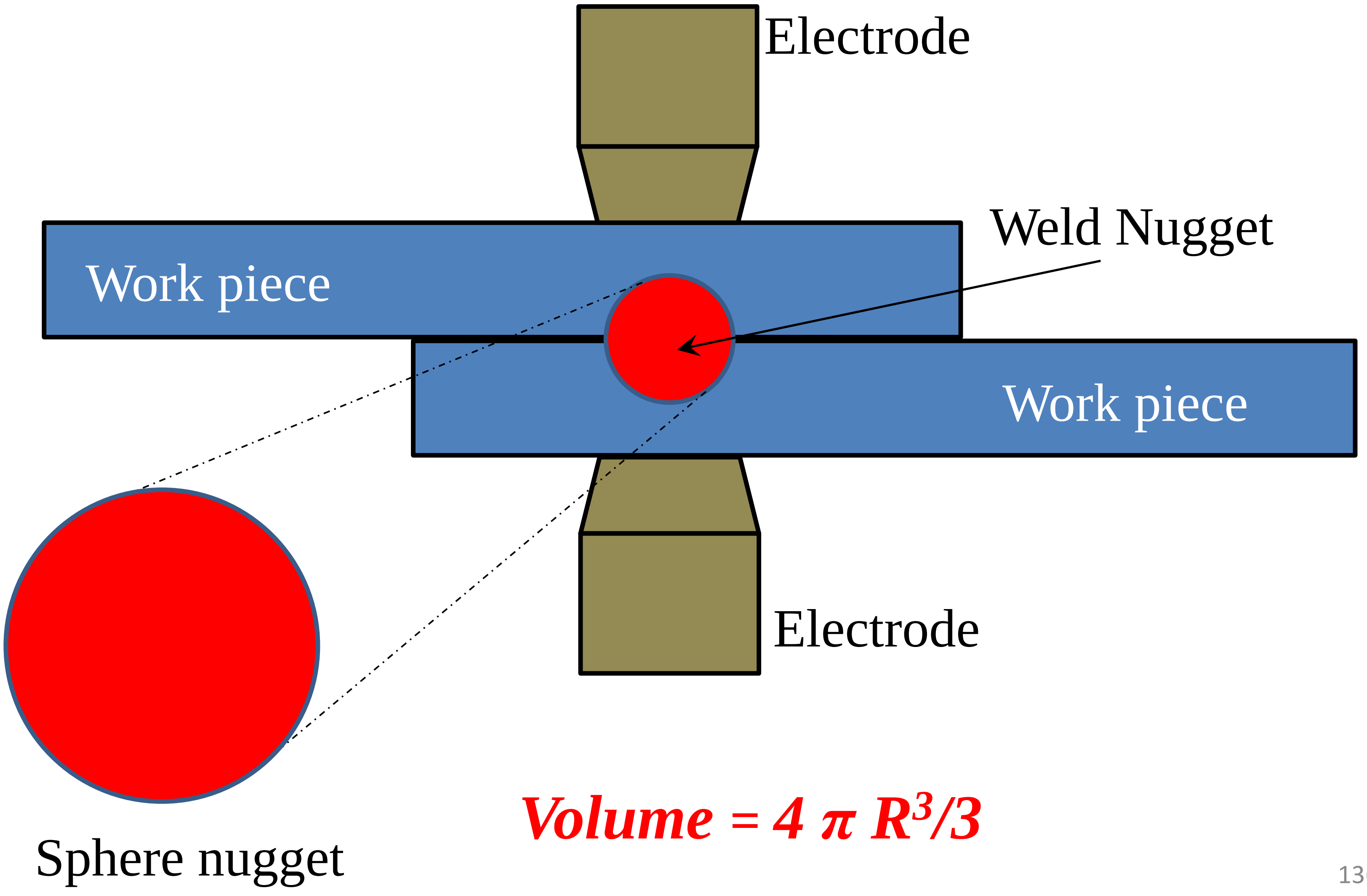
$$H = k\, I^2 R\, t \qquad (2)$$

  - ***H*** = the total heat generated in the work, J
  - ***I*** = electric current, A
  - ***t*** = time for which the electric current is passing through the joint
  - ***R*** = the resistance of the joint, ohms
  - ***k***= a constant to account for the heat losses from the welded joint. (if ***k=0.6***, that means ***40%*** of the heat is lost into the work metal, electrodes, and surrounding air.)

NUMERICAL- Q

- A resistance spot-welding operation is performed on two pieces of 3.5-mm-thick sheet steel using ***12,000A*** for a ***0.20 s*** duration. The electrodes are 7 mm in diameter at the contacting surfaces. Resistance is assumed to be ***0.0001 Ω*** , and the resulting weld nugget is a ***sphere*** of ***6 mm*** in diameter. The unit melting energy for the metal ***U=12.0 J/ mm³***. What portion of the heat generated was used to form the weld nugget, and what portion was dissipated into the work metal, electrodes, and surrounding air?

NUMERICAL- Ans



Volume = 4 π R³/3

NUMERICAL- Ans

- The heat generated in the operation ***(H)***

$$H = I^2R\,t$$

$$H = (12000)^2 \times 0.0001 \times 0.20$$

$$H = 2880\ J$$

NUMERICAL- Ans

- Volume of weld nugget = vol of sphere with a diameter of 6 mm

$$= \frac{4}{3}\pi R^3$$

$$= 4/3 \times 3.14 \times (3)^3$$

$$= 113.04\ mm^3$$

NUMERICAL- Ans

- Heat required to weld the nugget ***(H$_W$)*** ***= vol X U***

$$= 113.04 \times 12$$

$$= 1356.48\ J$$

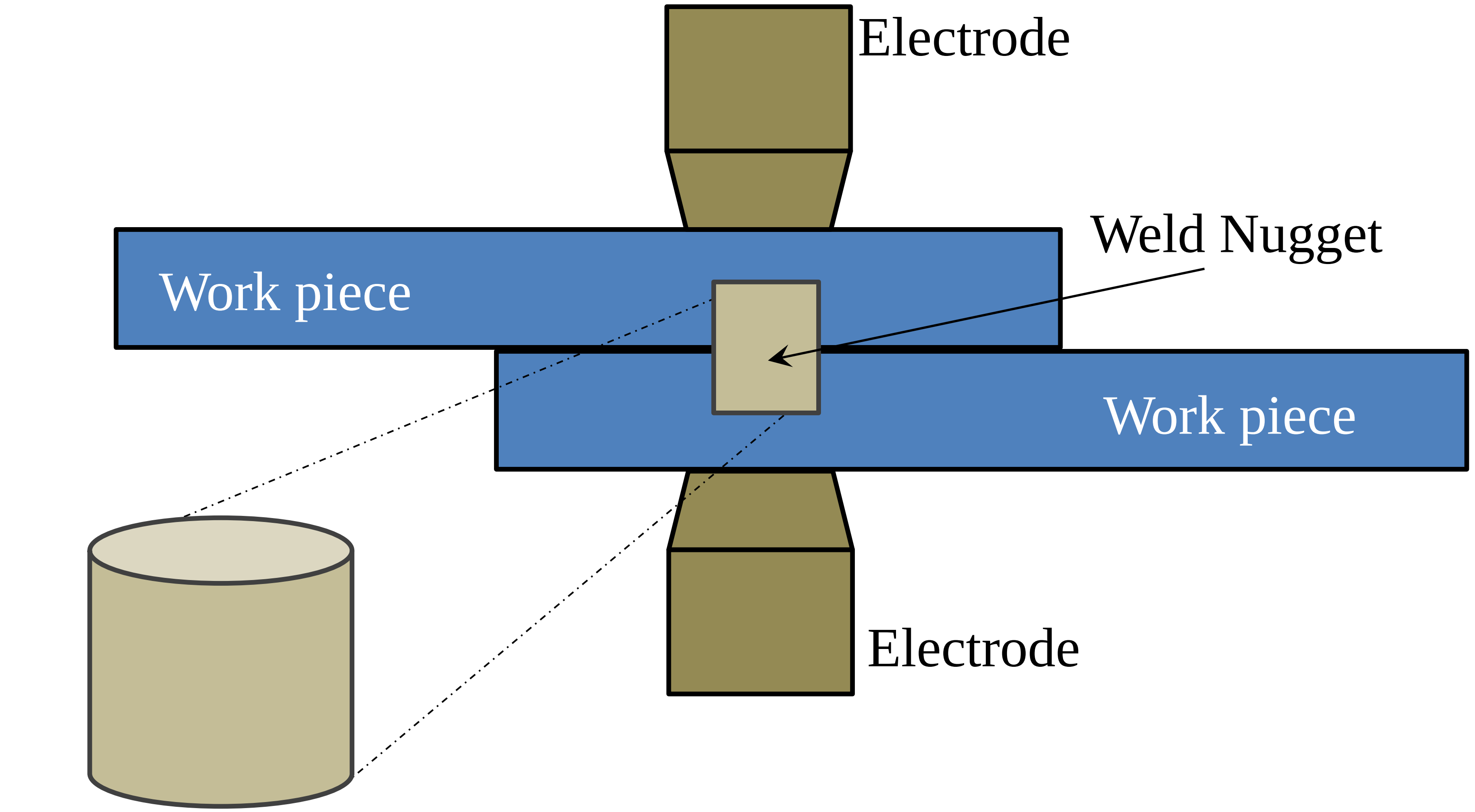
NUMERICAL- Ans

- Heat Lost ***(H_L)*** $=$ ***(H)*** $-$ ***(H_W)***

$$= 2880 - 1356.48$$

$$= 1523.52\ J$$

NUMERICAL-



$$Volume = \pi R^2 h$$

Gas Flame Processes: Welding, Cutting and Straightening

- **Oxy-fuel gas Welding** (OFW): Heat source is the flame produced by the combustion of a fuel gas and oxygen.
- OFW has largely been replaced by other processes but it is still popular because of its portability and the low capital investment.
- Acetylene is the principal fuel gas employed.

- Combustion of oxygen and acetylene (C_2H_2) in a welding torch produces a temp. in a two stage reaction.
- In the first stage

$$C_2H_2 + O_2 \rightarrow 2CO + H_2 + \text{Heat}$$

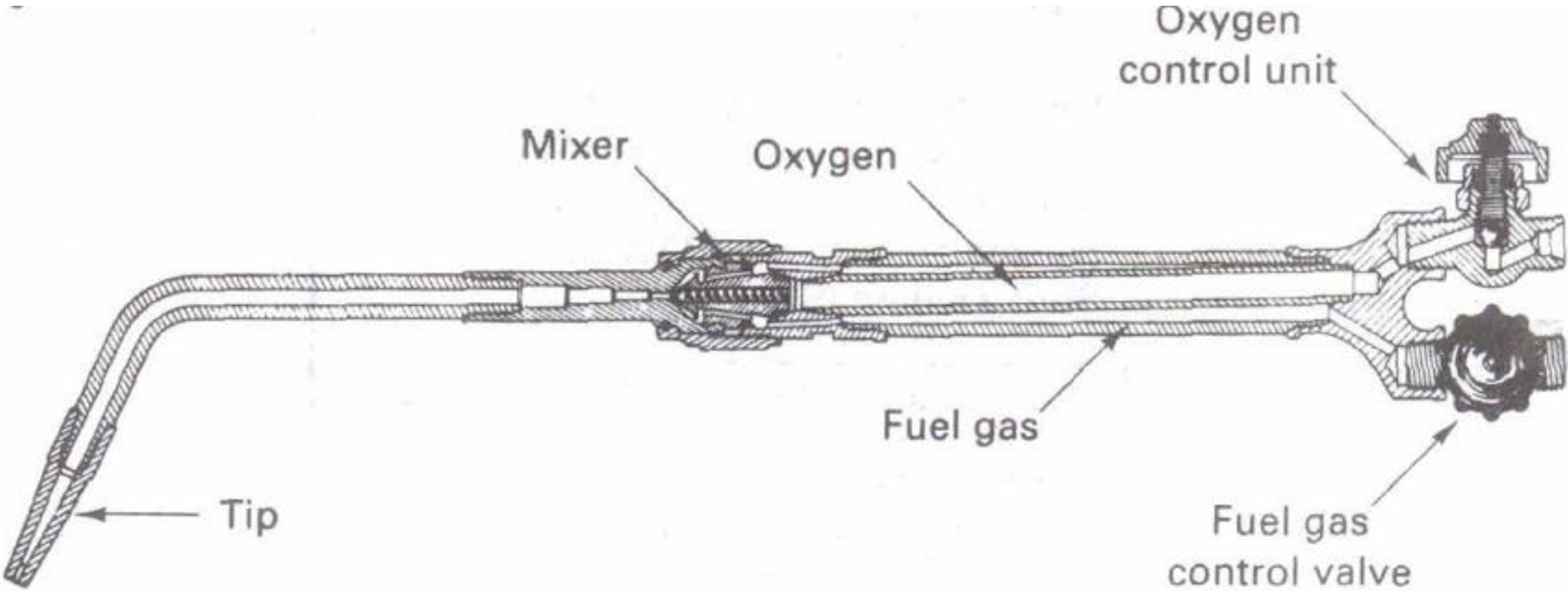
This reaction occurs near the tip of the torch.

- In the second stage combustion of the CO and H_2 and occurs just beyond the first combustion zone.

$$2CO + O_2 \rightarrow 2CO_2 + \text{Heat}$$

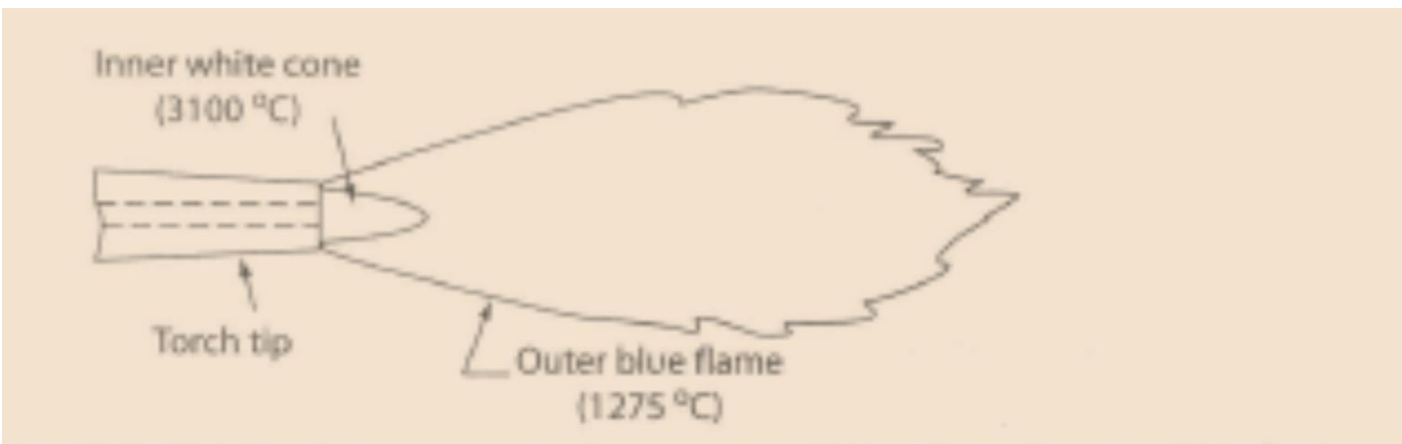
$$H_2 + \frac{1}{2} O_2 \rightarrow H_2O + \text{Heat}$$

Oxygen for secondary reactions is obtained from the atmosphere.


Oxygen
control unit
Mixer
Oxygen
Fuel gas
Tip
Fuel gas
control valve

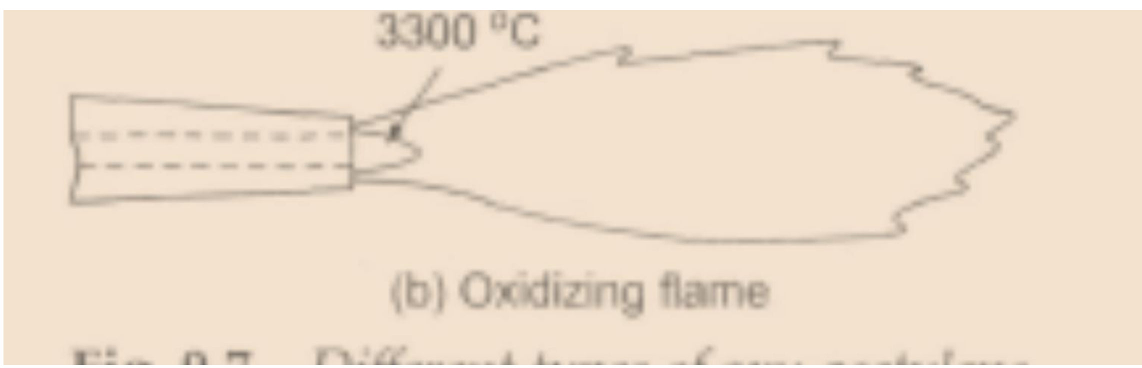
Three types of flames can be obtained by varying the oxygen/acetylene (or oxygen/fuel gas) ratio.

- If the ratio is about 1 : 1 to 1.15 : 1, all reactions are carried to completion and a neutral flame is produced.
- Most welding is done with a neutral flame. It is chemically neutral and neither oxidizes or carburizes the metal being welded.



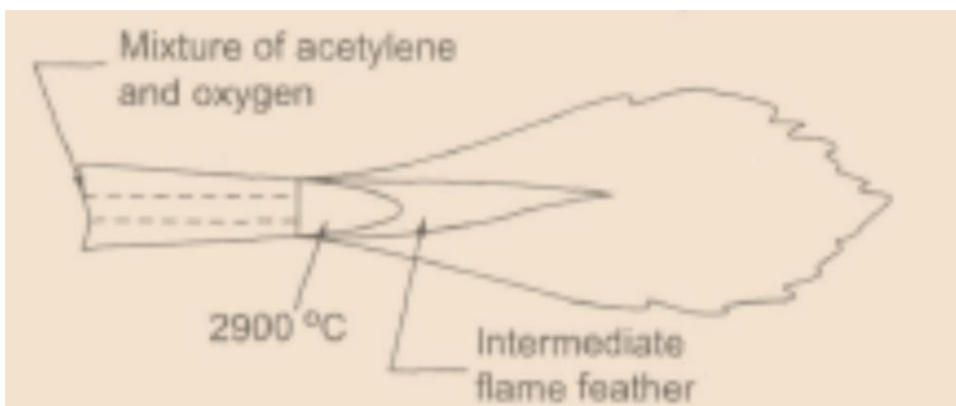
Oxy-acetylene gas welding neutral flame

- A higher ratio, such as 1.5 : 1, produces an oxidizing flame, hotter than the neutral flame (about 3300ºC) but similar in appearance.
- Used when welding copper and copper alloys but harmful when welding steel because the excess oxygen reacts with the carbon, decarburizing the region around the weld.



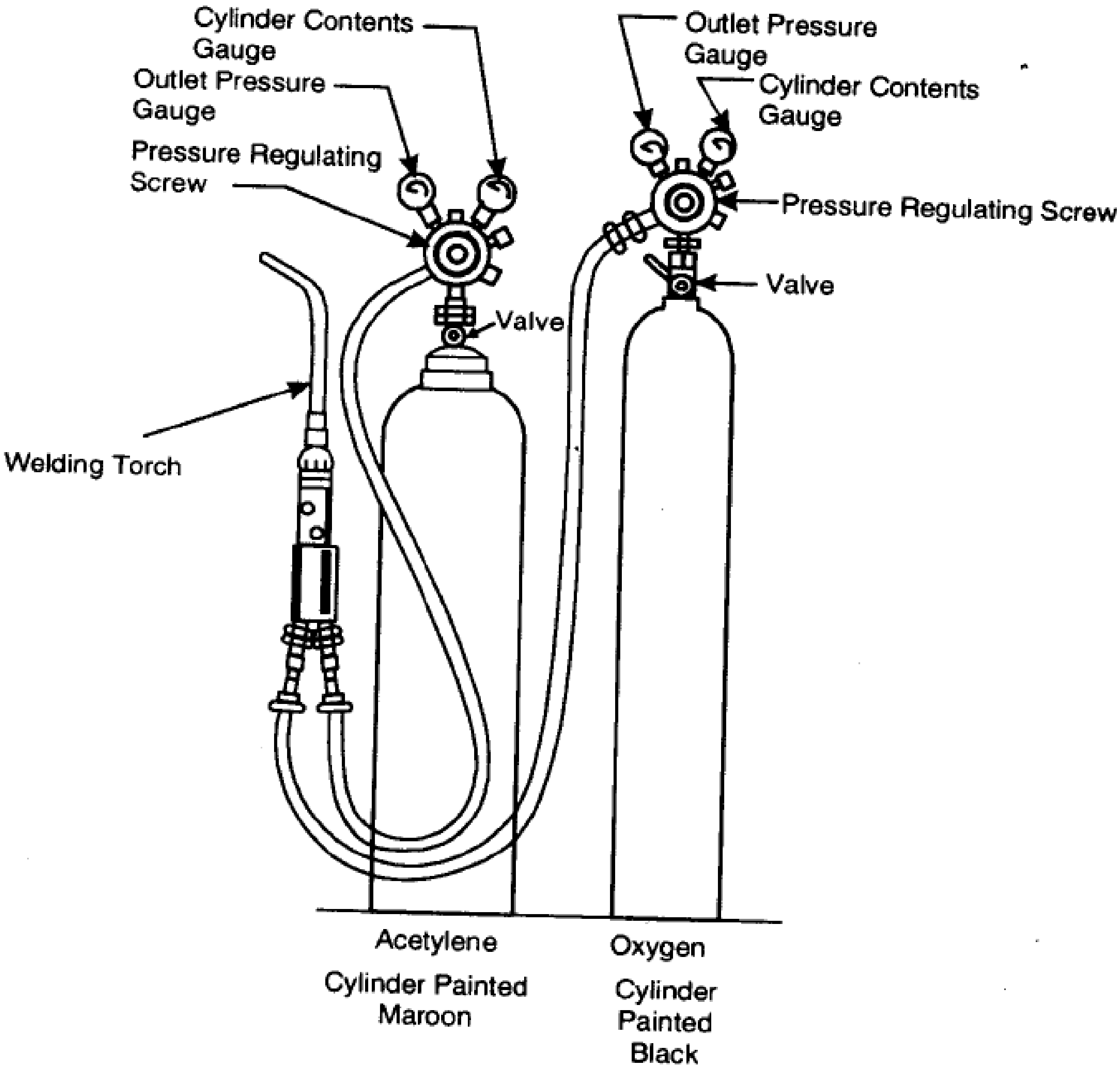
Oxy-acetylene gas welding Oxidising flame

- Excess fuel, on the other hand, produces a carburizing flame. Carburizing flame can carburize metal also.
- The excess fuel decomposes to carbon and hydrogen, and the flame temperature is not as great (about 3000°C).
- Flames of this type are used in welding Monel (a nickel-copper alloy), high-carbon steels, and some alloy steels, and for applying some types of hard-facing material.



Oxy-acetylene gas welding Carburizing flame

Metal	**Flame**
M S	N
High carbon steel	R
Grey cast iron	N, slightly oxidizing
Alloy steel	N
Aluminium	Slightly carburizing
Brass	Slightly oxidizing
Copper, Bronze	N, slightly oxidizing
Nickel alloys	Slightly carburizing
Lead	N


Cylinder Contents Gauge
Outlet Pressure Gauge
Pressure Regulating Screw
Valve
Welding Torch
Outlet Pressure Gauge
Cylinder Contents Gauge
Pressure Regulating Screw
Valve
Acetylene
Cylinder Painted Maroon
Oxygen
Cylinder Painted Black

Uses, Advantages, and Limitations

- OFW is **fusion welding**.
- **No pressure is involved**.
- Filler metal can be added in the form of a wire or rod.
- Fluxes may be used to clean the surfaces and remove contaminating oxide. The gaseous shield produced by vaporizing flux can prevent oxidation during welding, and the slag produced by solidifying flux can protect the weld pool. Flux can be added as a powder, the welding rod can be dipped in a flux paste, or the rods can be pre-coated.

Contd…

- Exposer of the heated and molten metal to the various gases in the flame and atmosphere makes it difficult to prevent contamination.
- Heat source is not concentrated, a large area of the metal is heated and distortion is likely to occur.
- Flame welding is still quite common in field work, in maintenance and repairs, and in fabricating small quantities of specialized products.

Oxy acetylene welding equipment

- Oxygen is stored in a cylinder at a pressure ranging from 13.8 MPa to 18.2 MPa .
- Due to high explosiveness of free acetylene it is stored in a cylinder with 80-85% porous calcium silicate and then filled with acetone which absorb upto 420 times by its volume at a pressure 1.75 MPa .
- At the time of acetylene release if acetone comes with acetylene the flame would give a purple colour.
- Another option is acetylene generator.

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$$

Pressure Gas Welding

- Pressure gas welding (PGW) or Oxyacetylene Pressure Welding is a process used to make butt joints between the ends of objects such as pipe and-railroad rail.
- The ends are heated with a gas flame to a temperature below the melting point, and the soft metal is then forced together under considerable pressure.
- This process, therefore, is actually a 'form of solid-state welding.

Oxygen Torch Cutting (Gas Cutting)

- Iron and steel oxidize (burn) when heated to a temperature between 800^{0}C to 1000^{0}C.
- High-pressure oxygen jet (300 KPa) is directed against a heated steel plate, the oxygen jet burns the metal and blows it away causing the cut (kerf).
- For cutting metallic plates shears are used. These are useful for straight-line cuts and also for cuts up to 40 mm thickness.

Contd…

- For thicker plates with specified contour, shearing cannot be used and oxy-fuel gas cutting (OFC) is useful.
- Gas-cutting is similar to gas welding except torch tip.

Fig- differences in torch tips for gas welding and gas cutting

Contd...

- Larger size orifice produces kerf width wider and larger oxygen consumed.
- At kindling temperature (about 870^{o}C), iron form iron oxide.
- Reaction:

$$3Fe + 2O_2 \rightarrow Fe_3O_4 + 6.67 \text{ MJ/kg of iron}$$

The other reactions:

$$2Fe + O_2 \rightarrow 2FeO + 3.18 \text{ MJ/kg of iron}$$

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3 + 4.9 \text{ MJ/kg of iron}$$

- All exothermic reactions preheat the steel.

Contd…

- For complete oxidation 0.287 m^3 oxygen/kg of iron is required
- Due to unoxidized metal blown away the actual requirement is much less.
- Torch tip held vertically or slightly inclined in the direction of travel.
- Torch position is about 1.5 to 3 mm vertical from plate.

Contd…

- The drag lines shows the characteristics of the movement of the oxygen stream.

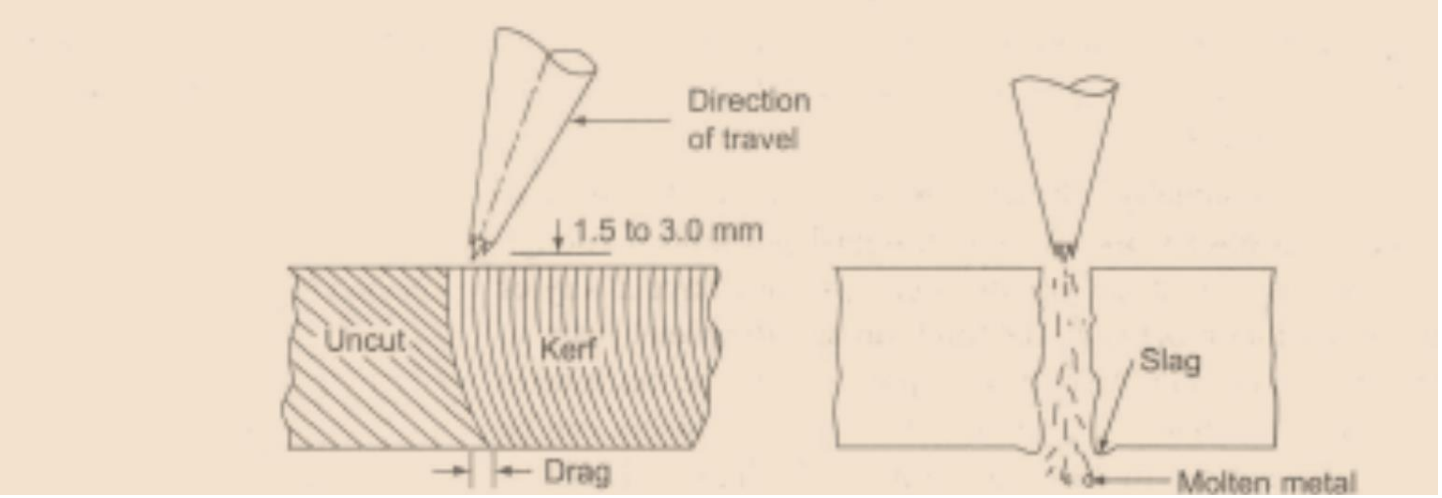


Fig- positioning of cutting torch in oxy- fuel gas cutting

- Drag is the amount by which the lower edge of the drag line trails from the top edge.
- Good cut means negligible drag.

Contd…

- If torch moved **too rapidly**, the bottom does not get sufficient heat and produces large drag so very rough and irregular-shaped-cut edges.
- If torch **moved slowly** a large amount of slag is generated and produces irregular cut.

Contd…

- Gas cutting is more useful with thick plates.
- For thin sheets (less than 3 mm thick) tip size should be small. If small tips are not available then the tip is inclined at an angle of 15 to 20 degrees.

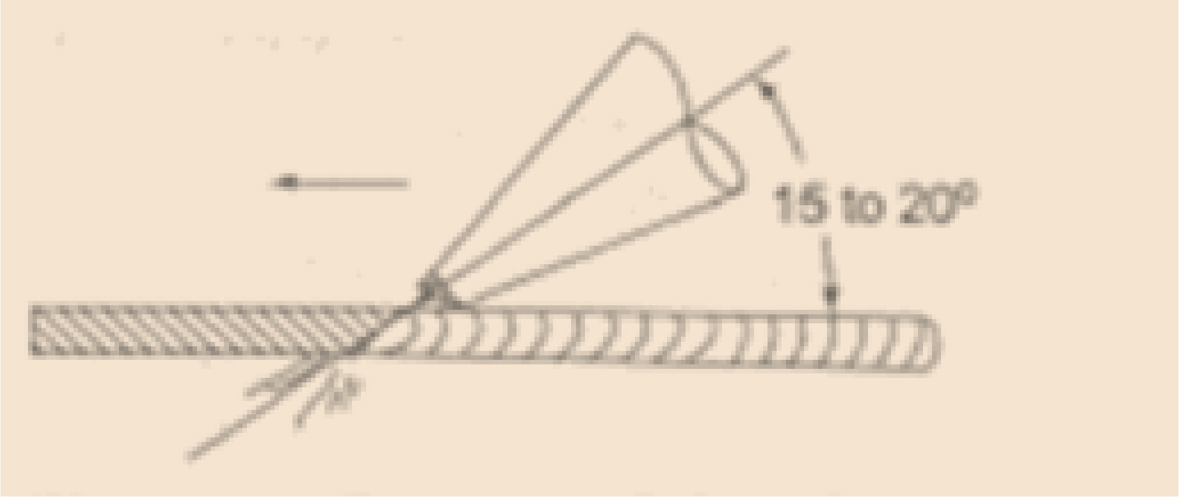


Fig. Recommended torch position for cutting thin steel

Application

- Useful only for materials which readily get oxidized and the oxides have lower melting points than the metals.
- Widely used for ferrous materials.
- Cannot be used for aluminum, bronze, stainless steel and like metals since they resist oxidation.

Difficulties

- Metal temperature goes beyond lower critical temperature and structural transformations occur.
- Final microstructure depends on cooling rate.
- Steels with less than 0.3 % carbon cause no problem.

Contd…

- For high carbon steel material around the cut should be preheated (about 250 to 300^{o}C) and may post heat also necessary.
- Cutting CI is difficult, since its melting temp. is lower than iron oxide.
- If chromium and nickel etc are present in ferrous alloys oxidation and cutting is difficult.

Soldering & Brazing

- In brazing and soldering, the surfaces to be joined are first cleaned, the components assembled or fixtured, and a **low-melting-point *nonferrous metal [Aluminum-silicon, Copper, Copper-silver, Copper-zinc (brass), Copper-tin (bronze), Gold-silver]*** is then melted, drawn into the space between the two solids by ***capillary action***, and allowed to solidify.

Brazing

Source: https://qphs.fs.quoracdn.net/main-qimg-9fcaa4b47839d57b306a2613972ada02.webp

Brazing

- Brazing is the ***permanent joining*** of ***similar or dissimilar metals*** or ceramics (or composites based on those two materials) through the use of heat and a filler metal whose melting temperature (actually, liquidus temperature) ***is above 450°C but below the melting point*** (or solidus temperature) of the materials being joined.

Brazing Advantages

1. A wide range of metallic and non-metallic materials can be brazed. The process is ideally suited for ***joining dissimilar*** materials, such as ***ferrous metal to nonferrous metal***, cast metal to wrought metal, metals with widely different melting points, or even metal to ceramic.
2. Since ***less heating*** is required than for welding, the process can be performed quickly and economically.

Brazing Advantages

3. The lower temperatures ***reduce problems*** associated with ***heat-affected zones*** (or other material property alteration), warping, and distortion.
4. Assembly tolerances are closer than for most welding processes, and joint appearance is usually quite neat.

Brazing Advantages

5. Brazing is highly adaptable to automation and performs well when mass-producing complex or delicate assemblies. Complex products can also be brazed in several steps using filler metals with progressively lower melting temperatures.
6. A strong permanent joint is formed.

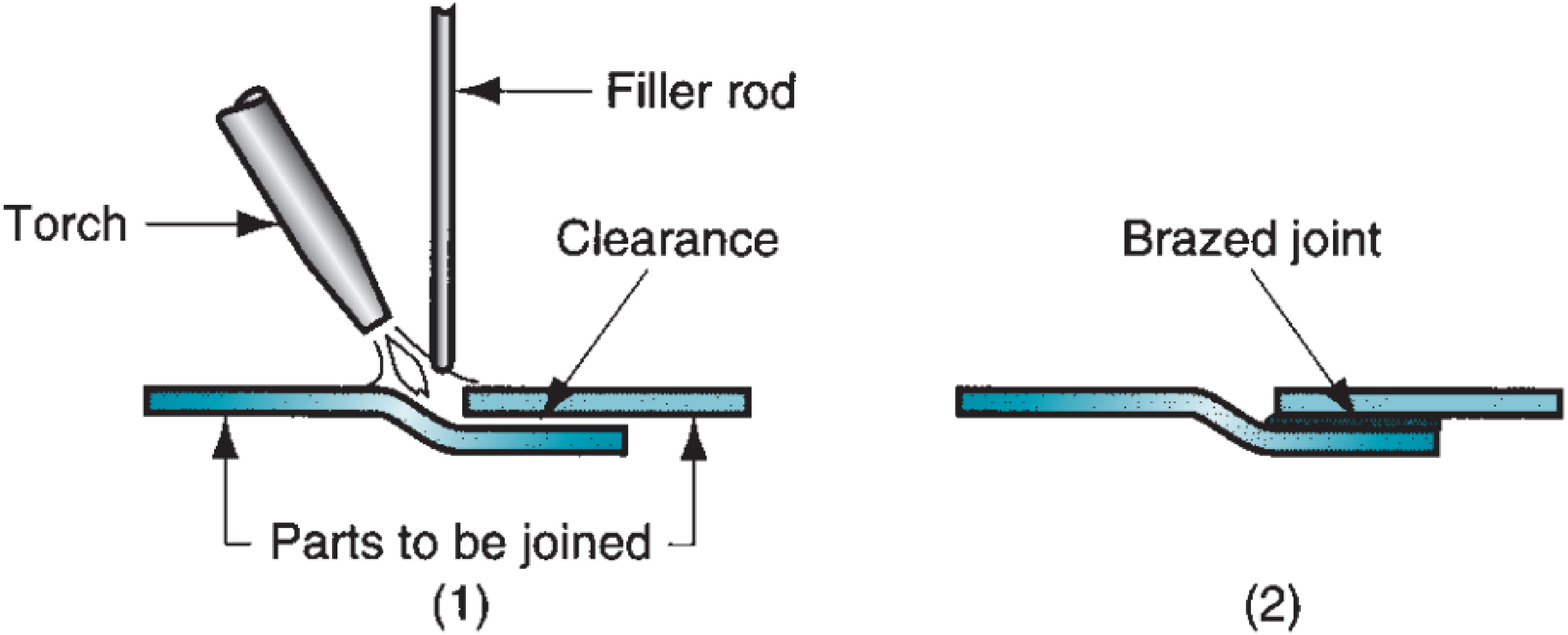
Brazing Disadvantages

- Joint ***strength*** is generally ***less*** than that of a welded joint;
- Although strength of a good brazed joint is greater than that of the filler metal, it is likely to be less than that of the base metals;
- High service temperatures may weaken a brazed joint; and
- The colour of the metal in the brazed joint may not match the colour of the base metal parts, a possible aesthetic disadvantage.

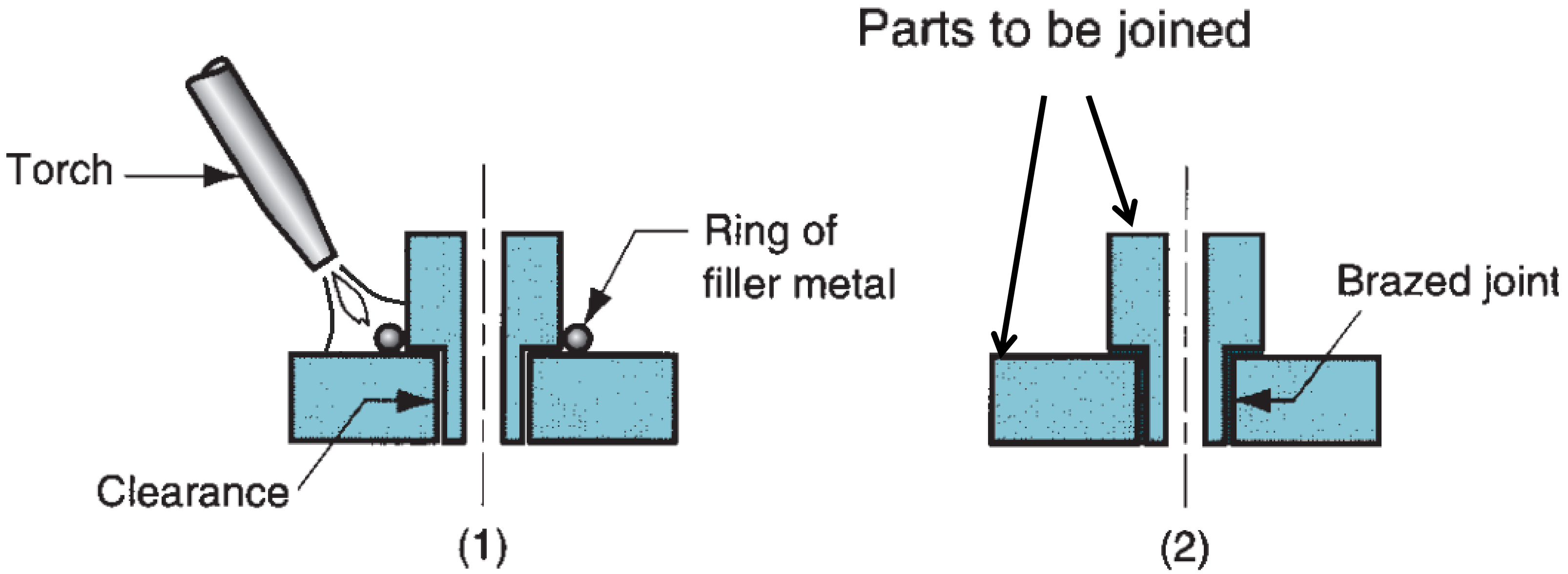
Brazing Applications

- Brazing as a production process is widely used in a variety of industries, including
  - automotive (e.g., joining tubes and pipes),
  - electrical equipment (e.g., joining wires and cables),
  - cutting tools (e.g., brazing cemented carbide inserts to shanks), and
  - Jewellry making.
- In addition, the chemical processing industry and plumbing and heating contractors join metal pipes and tubes by brazing.
- The process is used extensively for repair and maintenance work in nearly all industries

Brazing FILLER METALS



Brazing FILLER METALS



SOLDERING

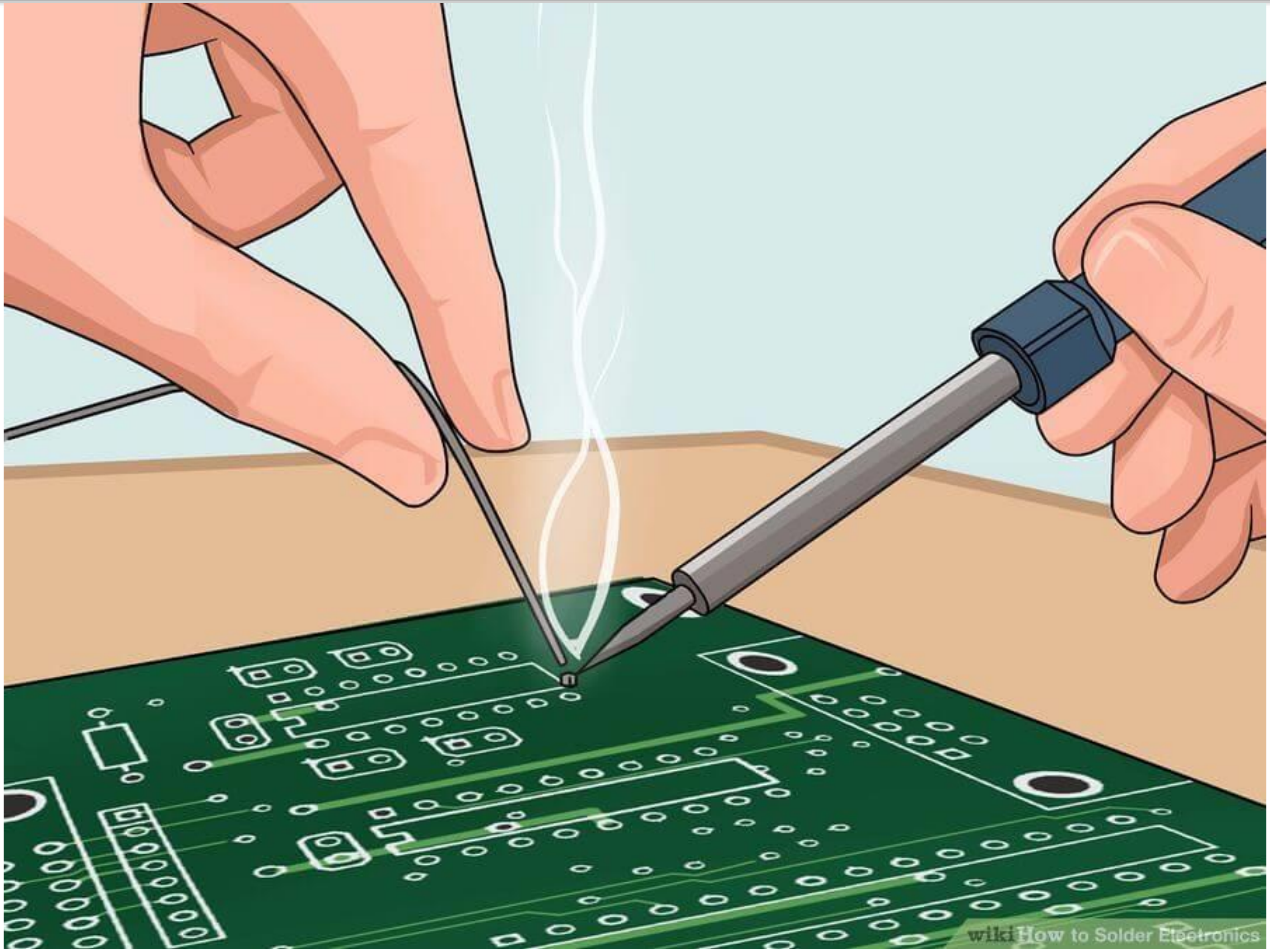


Image source: http://epcb2016.blogspot.com/2017/01/common-soldering-mistakes.html

SOLDERING

- Soldering is a brazing-type operation where the filler metal has a melting temperature (or liquidus temperature if the alloy has a freezing range) ***below 450°C.***
- It is typically used for joining thin metals, connecting electronic components, joining metals while avoiding exposure to high elevated temperatures, and filling surface flaws and defects.
- Details of soldering are similar to those of brazing, and many of the heating methods are the same.

SOLDERING

- Surfaces to be soldered must be pre-cleaned so they are free of oxides, oils, and so on.
- An appropriate flux must be applied to the faying surfaces, and the surfaces are heated.
- Filler metal, called solder, is added to the joint, which distributes itself between the closely fitting parts.

SOLDERING

- As an industrial process, soldering is most closely associated with electronics assembly.
- It is also used for mechanical joints, but not for joints subjected to elevated stresses or temperatures.

ADVANTAGES

- Advantages attributed to soldering include
  - (1) low energy input relative to brazing and fusion welding,
  - (2) variety of heating methods available,
  - (3) good electrical and thermal conductivity in the joint,
  - (4) capability to make air-tight and liquid-tight seams for containers, and
  - (5) easy to repair and rework.

DISADVANTAGES

- The biggest disadvantages of soldering are
  - (1) low joint strength unless reinforced by mechanically means and
  - (2) possible weakening or melting of the joint in elevated temperature service.

ELECTRONICS APPLICATIONS

- Principal function of the soldered joint is to provide an electrically conductive path between two parts being joined.
- Other design considerations include heat generation (from the electrical resistance of the joint) and vibration.
- Mechanical strength in a soldered electrical connection is often achieved by deforming one or both of the metal parts to accomplish a mechanical joint between them,
- or By making the surface area larger to provide maximum support by the solder.

COMMONLY USED SOLDERING ALLOY

Some common solder alloy compositions with their melting temperatures and applications.

Filler Metal	Approximate Melting Temperature °C	Approximate Melting Temperature °F	Principal Applications
Lead–silver	305	580	Elevated temperature joints
Tin–antimony	238	460	Plumbing and heating
Tin–lead	183	361	Electrical/electronics
	188	370	Electrical/electronics
	199	390	General purpose
	207	405	Automobile radiators
Tin–silver	221	430	Food containers
Tin–zinc	199	390	Aluminum joining
Tin–silver–copper	217	423	Electronics: surface mount technology

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