HANDOUT FOR
MECHANICAL ENGINEERING DEPARTMENT

TIG WELDING

Presented By
STC/NBQ/NFR

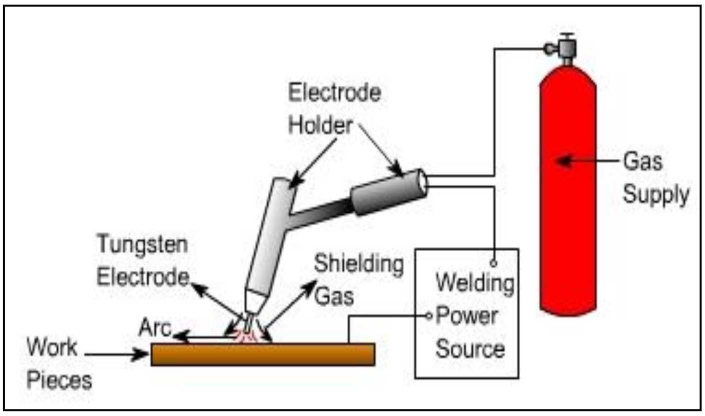
INTRODUCTION:

Gas Tungsten Arc Welding (**GTAW**) also known as Tungsten Inert Gas welding (**TIG**) is an electric arc welding process that produces an arc between a non-consumable electrode (tungsten which does not melt due to its high melting point) and the work piece to be welded. The weld is shielded from the atmosphere by a shielding gas that forms an envelope around the weld area. However, a filler metal is usually used in the process . The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used.

- A **constant-current** welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a **Plasma**(1) .

  Plasma(1) is an electrically neutral medium of unbound positive and negative particles (i.e. the overall charge of a plasma is roughly zero). Although these particles are unbound, they are not 'free' in the sense of not experiencing forces. Moving charged particles generates an electric current within a magnetic field; and any movement of a charged plasma particle affects and is affected by the general field created by the motion of other charges .

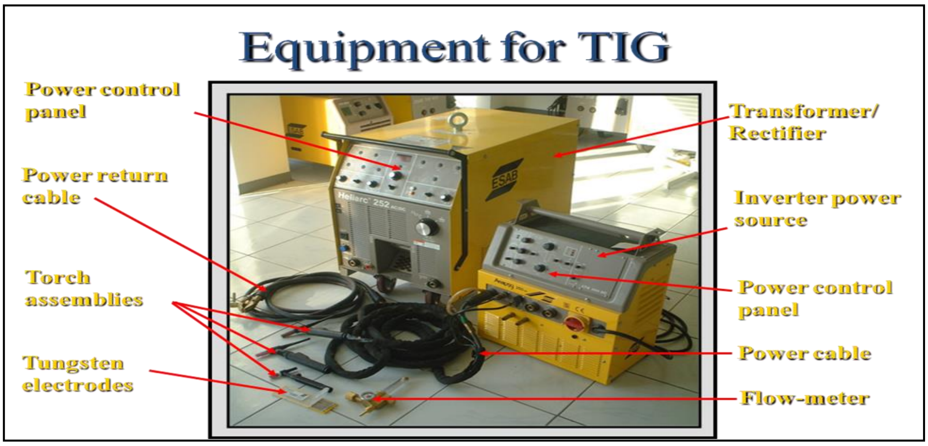
- Manual gas tungsten arc welding is often considered the most difficult of all the welding processes commonly used in industry. Because the welder must maintain a short arc length, great care and skill are required to prevent contact between the electrode and the workpiece. hand while manipulating the welding torch in the other .
- Similar to torch welding, TIG normally requires two hands, since most applications require that the welder manually feed a filler metal into the weld area with one .
- TIG is most commonly used to **weld thin sections of stainless steel** and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds.
- Gas Tungsten Arc Welding(GTAW) is most commonly used to weld stainless steel and nonferrous materials, such as aluminum and magnesium, but it can be applied to nearly all metals, with a notable exception being zinc and its alloys. Its applications involving carbon steels are limited not because of process restrictions, but because of the existence of more economical steel welding techniques, such as gas metal arc welding and shielded metal arc welding. Furthermore, GTAW can be performed in a variety of other-than-flat positions, depending on the skill of the welder and the materials being welded



Working principle:

- An arc is established between the end of a tungsten electrode and the parent metal at the joint line. The electrode is not melted and the welder keeps the arc gap constant. The current is controlled by the power-supply unit.
- A filler metal, usually available in 1 m lengths of wire, can be added to the leading edge of the pool as required. The molten pool is shielded by an inert gas which replaces the air in the arc area.
- Argon and helium are the most commonly used shielding gases.
- The process may use direct current electrode positive, direct current electrode negative or alternating current. The chart above indicates the operating characteristics of each of these current types.
- DCEN or "**straight polarity**" is used for welding most materials other than aluminium. The electrode tip geometry is generally a sharp point with a small blunted end since most of heat balance is on melting of the base material.
- DCEP or "**reverse polarity**" is rarely used since it results in low penetration. Also the constant bombardment of the tungsten electrode by electrons in the DCEP mode degrades the electrode.
- Alternating current(AC) is used primarily to weld aluminium, which has a tenacious oxide surface layer. Although the diagram above states that there is a 50% cycle from DCEN to DCEP, it is possible through solid state electronics to vary the amount of time at each polarity and also the current at each polarity.
- High-quality welds in metals such as aluminium, stainless steels, **Nimonic alloys**[2] and copper in chemical plants; sheet work in aircraft engines and structures; Mainly thin sheets.

Nimonic[2] is a registered trademark of Special Metals Corporation that refers to a family of nickel-based high-temperature low creep super alloys. **Nimonic alloys** typically consist of more than 50% nickel and 20% chromium with additives such as titanium and aluminium.

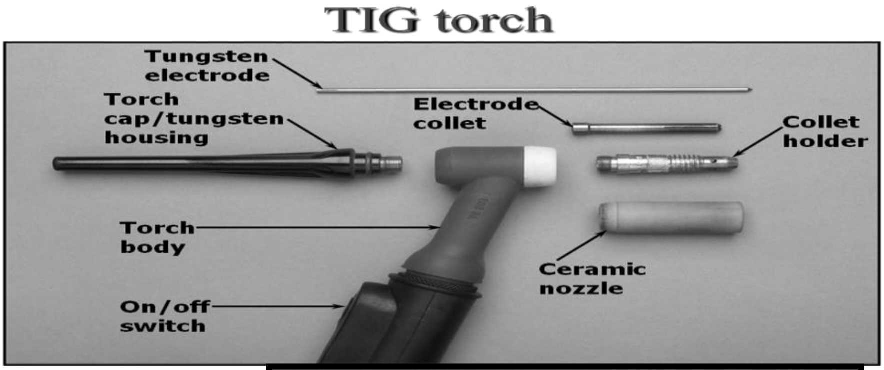


Equipments:

The equipment required for the gas tungsten arc welding operation includes a welding torch utilizing a non-consumable tungsten electrode, a constant-current welding power supply, and a shielding gas source.

1. Welding torch
2. Power supply
3. Electrode
4. Shielding gas
5. Filler Rod

1. **Welding torch**:



GTAW welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. The automatic and manual torches are similar in construction, but the manual torch has a handle while the automatic torch normally comes with a mounting rack. The angle between the centerline of the handle and the centerline of the tungsten electrode, known as the head angle, can be varied on some manual torches according to the preference of the operator. Air cooling systems are most often used for low-current operations (up to about 200 A), while water cooling is required for high-current welding (up to about 600 A). The torches are connected with cables to the power supply and with hoses to the shielding gas source and where used, the water supply.

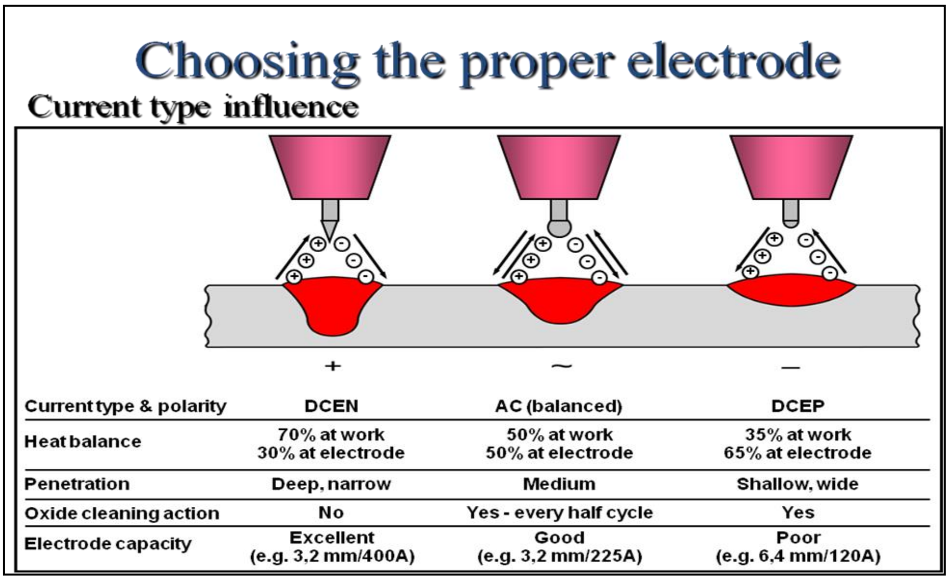
The internal metal parts of a torch are made of hard alloys of copper or brass so it can transmit current and heat effectively. The tungsten electrode must be held firmly in the center of the torch with an appropriately sized collet, and ports around the electrode provide a constant flow of shielding gas. Collets are sized according to the diameter of the tungsten electrode they hold. The body of the torch is made of heat-resistant, insulating plastics covering the metal components, providing insulation from heat and electricity to protect the welder.

The size of the welding torch nozzle depends on the amount of shielded area desired. The size of the gas nozzle depends upon the diameter of the electrode, the joint configuration, and the availability of access to the joint by the welder. The inside diameter of the nozzle is preferably at least three times the diameter of the electrode, but there are no hard rules. The welder judges the effectiveness of the shielding and increases the nozzle size to increase the area protected by the external gas shield as needed. The nozzle must be heat resistant and thus is normally made of alumina or a ceramic material, but fused quartz, a high purity glass, offers greater visibility. Devices can be inserted into the nozzle for special applications, such as gas lenses or valves to improve the control shielding gas flow to reduce turbulence and introduction of contaminated atmosphere into the shielded area. Hand switches to control welding current can be added to the manual GTAW torches.

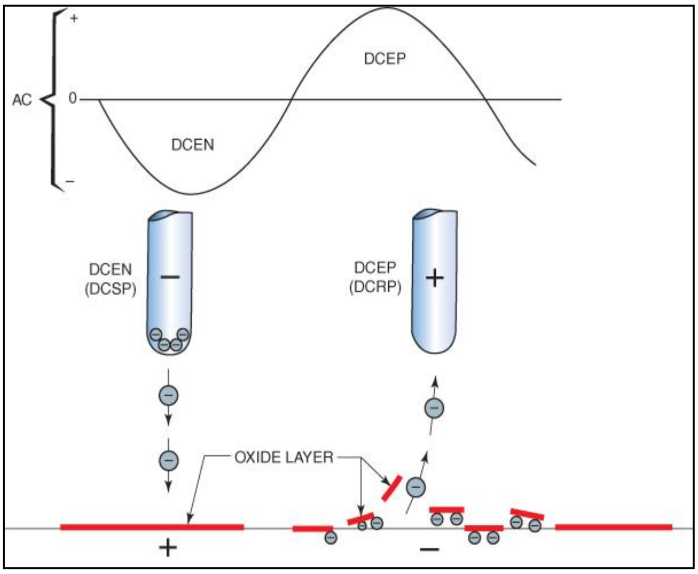
2. **Power supply**:

Gas tungsten arc welding (GTAW) uses a constant current power source, meaning that the current (and thus the heat) remains relatively constant, even if the arc distance and voltage change. This is important because most applications of GTAW are manual or semiautomatic, requiring that an operator hold the torch.

Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead, since it can cause dramatic heat variations and make welding more difficult. The preferred polarity of the GTAW system depends largely on the type of metal being welded.



Direct current with a negatively charged electrode (**DCEN**) is often employed when welding steels, nickel, titanium, and other metals. It can also be used in automatic GTAW of aluminum or magnesium when helium is used as a shielding gas. The negatively charged electrode generates heat by emitting electrons, which travel across the arc, causing thermal ionization of the shielding gas and increasing the temperature of the base material. The ionized shielding gas flows toward the electrode, not the base material, and this can allow oxides to build on the surface of the weld.



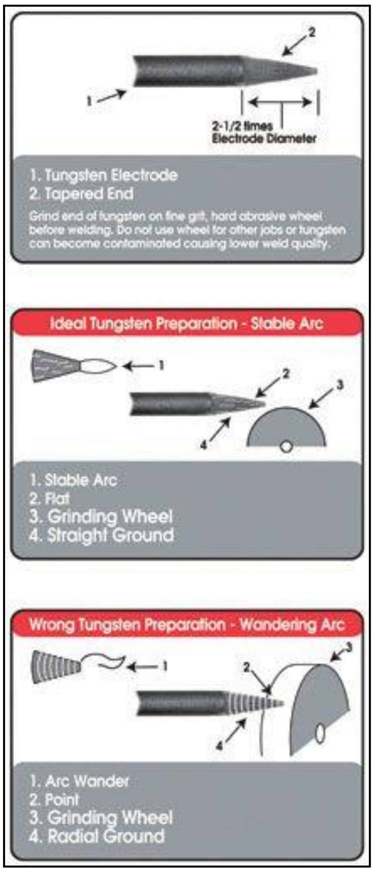
Direct current with a positively charged electrode (**DCEP**) is less common, and is used primarily for shallow welds since less heat is generated in the base material. Instead of flowing from the electrode to the base material, as in DCEN, electrons go the other direction, causing the electrode to reach very high temperatures. To help it maintain its shape and prevent softening, a larger electrode is often used. As the electrons flow toward the electrode, ionized shielding gas flows back toward the base material, cleaning the weld by removing oxides and other impurities and thereby improving its quality and appearance. Alternating current, commonly used when welding aluminum and magnesium manually or semi-automatically, combines the two direct currents by making the electrode and base material alternate between positive and negative charge. This causes the electron flow to switch directions constantly, preventing the tungsten electrode from overheating while maintaining the heat in the base material. Surface oxides are still removed during the electrode-positive portion of the cycle and the base metal is heated more deeply during the electrode-negative portion of the cycle. Some power supplies enable operators to use an unbalanced alternating current wave by modifying the exact percentage of time that the current spends in each state of polarity, giving them more control over the amount of heat and cleaning action supplied by the power source. In addition, operators must be wary of rectification, in which the arc fails to reignite as it passes from straight polarity (negative electrode) to reverse polarity (positive electrode). To remedy the problem, a square wave power supply can be used, as can high-frequency voltage to encourage ignition.

3. Electrode:

TYPE OF TUNGSTEN	COLOR	USES AND PREFORMANCE
Pure	Green	Provides good arc stability for AC welding. Reasonably good resistance to contamination. Lowest current carrying capacity. Least expensive. Maintains a balled end.
Ceriated CeO2 1.8% to 2.2%	Orange	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life. Possible replacement for thoriated.
Thoriated ThO2 1.7% to 2.2%	Red	Easier arc starting. Higher current capacity. Greater arc stability. High resistance to weld pool contamination. Difficult to maintain balled end on AC.
Lanthanated La2O3 1.3% to 1.7%	Gold	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life, high current capacity. Possible replacement for thoriated.
Zirconiated ZrO2 0.15% to 0.40%	Brown	Excellent for AC welding due to favorable retention of balled end, high resistance to contamination, and good arc starting. Preferred when tungsten contamination of weld is intolerable.

The electrode used in GTAW is made of tungsten or a tungsten alloy, because tungsten has the highest melting temperature among pure metals, at 3,422 °C (6,192 °F). As a result, the electrode is not consumed during welding, though some erosion (called burn-off) can occur. Electrodes can have either a clean finish or a ground finish—clean finish electrodes have been chemically cleaned, while ground finish electrodes have been ground to a uniform size and have a polished surface, making them optimal for heat conduction. The diameter of the electrode can vary between 0.5 and 6.4 millimetres (0.02 and 0.25 in), and their length can range from 75 to 610 millimetres (3.0 to 24.0 in).

A number of tungsten alloys have been standardized by the International Organization for Standardization and the American Welding Society in ISO 6848 and AWS A5.12, respectively, for use in GTAW electrodes, and are summarized .



Tungsten electrode types:

1. Pure tungsten electrodes -GREEN
2. Thoriated tungsten electrodes - RED
3. Ceriated tungsten electrodes - ORANGE
4. Lanthaniated tungsten electrodes – GOLD
5. Zirconiated tungsten electrodes – BROWN

- **Pure tungsten electrodes** (classified as WP or EWP) are general purpose and low cost electrodes. They have poor heat resistance and electron emission. They find limited use in AC welding of e.g. magnesium and aluminum.
- **Cerium oxide** (or ceria) as an alloying element improves arc stability and ease of starting while decreasing burn-off. Cerium addition is not as effective as thorium but works well, and cerium is not radioactive.
- An alloy of **lanthanum oxide** (or lanthana) has a similar effect as cerium, and is also not radioactive.
- **Thorium oxide** (or thoria) alloy electrodes offer excellent arc performance and starting, making them popular general purpose electrodes. However, it is somewhat radioactive, making inhalation of thorium vapors and dust a health risk, and disposal an environmental risk.
- Electrodes containing **zirconium oxide** (or zirconia) increase the current capacity while improving arc stability and starting and increasing electrode life.

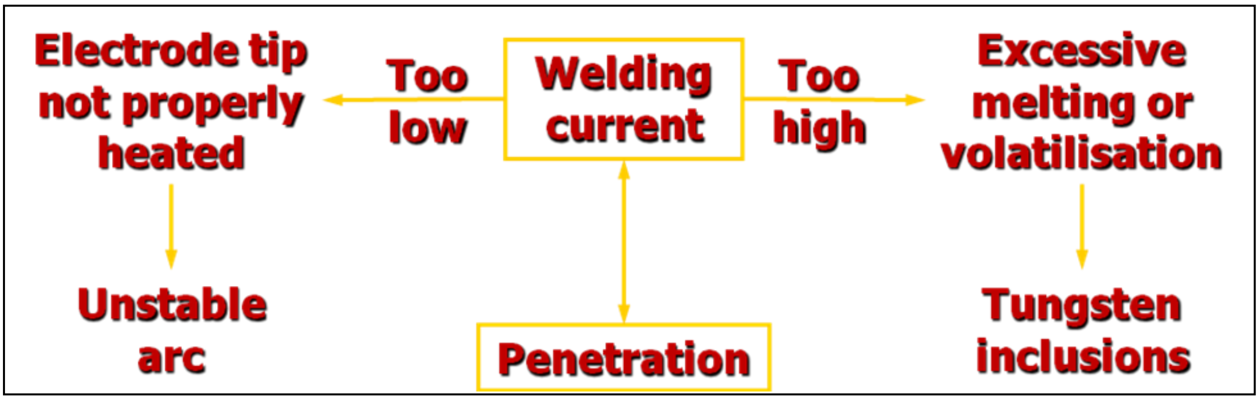
Choosing the proper electrode:

Factors to be considered:

- ◆ Type of welding current
- ◆ Type and thickness of parent metal
- ◆ Type of torch (gas/water cooled)
- ◆ Electrode extension
- ◆ Welding position

Tungsten Electrode Specifications

Diameter		Diameter Tolerance	Length	Length Tolerance
mm	inch	mm	mm	mm
1.0	0.040	(+/-)0.05	50,75,150,175	(+/-)1.0
1.6	1/16(0.0625)	(+/-)0.05	50,75,150,175	(+/-)1.0
2.0	5/64(0.0781)	(+/-)0.05	50,75,150,175	(+/-)1.0
2.4	3/32(0.0938)	(+/-)0.05	50,75,150,175	(+/-)1.0
3.2	1/8(0.125)	(+/-)0.1	50,75,150,175	(+/-)1.0
4.0	5/32(0.156)	(+/-)0.1	50,75,150,175	(+/-)1.0
4.8	3/16(0.187)	(+/-)0.1	50,75,150,175	(+/-)1.0
6.4	1/4(0.250)	(+/-)0.1	50,75,150,175	(+/-)1.0
8.0	5/16(0.312)	(+/-)0.1	50,75,150,175	(+/-)1.0
10.0	25/64(0.391)	(+/-)0.1	50,75,150,175	(+/-)1.0



Electrode diameter (mm)	Gas nozzle ID (mm)	Welding current			
		DCEN (WTh20 electrode)	DCEP (WTh20 electrode)	AC (balanced wave)	
				WP electrode	Alloyed electrode
0.5	6.4	5-20	N/A	5-15	5-20
1.0	9.5	15-80	N/A	10-30	20-60
1.6	9.5	70-150	10-20	30-80	60-120
2.4	12.7	150-250	15-30	60-130	100-180
3.2	12.7	250-400	25-40	100-180	160-250
4.0	12.7	400-500	40-55	160-240	200-320

4. Shielding gas:

As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc.

The selection of a shielding gas depends on several factors, including the type of material being welded, joint design, and desired final weld appearance. Argon is the most commonly used shielding gas for GTAW, since it helps prevent defects due to a varying arc length. When used with alternating current, argon shielding results in high weld quality and good appearance. Another common shielding gas, helium, is most often used to increase the weld penetration in a joint, to increase the welding speed, and to weld metals with high heat conductivity, such as copper and aluminum. A significant disadvantage is the difficulty of striking an arc with helium gas, and the decreased weld quality associated with a varying arc length.

Argon-helium mixtures are also frequently utilized in GTAW, since they can increase control of the heat input while maintaining the benefits of using argon. Normally, the mixtures are made with primarily helium (often about 75% or higher) and a balance of argon. These mixtures increase the speed and quality of the AC welding of aluminum, and also make it easier to strike an arc. Another shielding gas mixture, argon-hydrogen, is used in the mechanized welding of light gauge stainless steel, but because hydrogen can cause porosity, its uses are limited. Similarly, nitrogen can sometimes be added to argon to help stabilize the austenite in austenitic stainless steels and increase penetration when welding copper. Due to porosity problems in ferritic steels and limited benefits, however, it is not a popular shielding gas additive.

5. **Filler Rod:**

Filler metals are also used in nearly all applications of GTAW, the major exception being the welding of thin materials. Filler metals are available with different diameters and are made of a variety of materials. In most cases, the filler metal in the form of a rod is added to the weld pool manually, but some applications call for an automatically fed filler metal, which often is stored on spools or coils