WELD TECH NEWS is a newsletter for welders working primarily in maintenance and repair. Each issue contains useful information on materials (cast irons, steels, aluminum, copper alloys, etc.), welding products and welding techniques. By collecting each issue, the reader will soon have a handy reference manual covering all aspects of welding, brazing and soldering for maintenance repair.

**GAS TUNGSTEN ARC WELDING (GTAW)**

The Gas Tungsten Arc Welding Process evolved during World War II as a means to join aluminum and magnesium that were becoming more and more prevalent in aircraft. These metals were being joined by riveting. Aluminum and magnesium are reactive metals and could not be effectively welded with the common processes of the time. The Linde Division of the Union Carbide Corporation introduced the process commercially as the Heliarc process in 1946 and it is referred to today as Tungsten Inert Gas (TIG) or the A.W.S. standard term of Gas Tungsten Arc Welding (GTAW) as per the ANSI/AWS A3.0:2001 Standard Definitions.

"Gas Tungsten Arc Welding (GTAW) – an arc welding process that uses an arc between a tungsten electrode (nonconsumable) and the weld pool. The process is used with shielding gas and without the application of pressure."

The main element that distinguishes this process from the other common arc welding processes of stick welding (SMAW) or wire feed welding (GMAW-FCAW) is the use of a nonconsumable tungsten electrode. With stick welding, the rod acts as the electrode and the heat of the arc melts the rod and the molten metal transfers across the arc into the molten weld puddle. We are, in effect, "burning rod". With wire feed, the wire acts as the electrode and the heat of the arc melts the wire which then transfers across the arc into the weld. We are, in effect, "burning wire".

With GTAW or TIG welding, we use a nonconsumable tungsten electrode to conduct the current and establish an arc. The heat of the arc melts the base metal, and the filler metal when it is introduced into the arc, melts and flows into the molten weld puddle. The tungsten, acting as the electrode, is not supposed to be consumed in the arc and the filler metal is not transferred across an arc as with stick or wire feed. In some ways, TIG welding is a lot like brazing except we are using an electric arc for heat instead of an oxy-acetylene flame. And as we know, electric currents can be manipulated and controlled in many ways thus enabling control of welding heat. The key to this process though is the nonconsumable electrode and no metal transfer across an arc.
The TIG process can be used to join all metals but it works exceptionally well with highly reactive metals such as aluminum and magnesium. It is the most practical way to join titanium. It is excellent for thinner stainless welding, as well as tool steels, brass, bronze and dissimilar metals.

This process produces superior welds with excellent corrosion resistance and x-ray quality. There is no flux or slag which allows the welder to see the molten weld pool while welding. Since there is no metal transfer across an arc there are no sparks or spatter. The process itself produces no smoke or fumes on clean base metal. The concentrated arc allows pinpoint heat control which results in a narrow heat affected zone. The arc can produce heats up to 35,000 degrees fahrenheit. A concentrated high heat arc is an advantage when welding metals with high heat conductivity such as aluminum and copper. The narrow heat affected zone minimizes molecular changes in the base metal such as in stainless, lessening the effect on corrosion resistance.

Since the arc is simply an electric current with no metal transfer, it can be manipulated in many ways depending on the abilities of the power source. The welding variables can be precisely controlled. The use of a remote amperage control, for example, allows the welder to control heat input into the weld while welding. As heat builds up in the base metal, the welder can ease off on the amperage while welding and therefore lower the heat input.

There are disadvantages to the process. Rates of deposition are lower than with the consumable electrodes. There is low tolerance for contaminants. The process takes greater eye-hand coordination to become skillful. The gas shield must be maintained in drafty environments. For weld joints thicker than 3/8 inches (10mm) TIG welding becomes less economical than stick or wire feed welding.

GASES

Whenever we heat metals up, we must protect them from the atmosphere. With the TIG process, both the base metal and the tungsten electrode are protected from the atmosphere by the use of inert gases. When the process was first developed, the inert gas used for shielding was helium because it was readily available from deposits in the ground in Texas. Thus, the process was first referred to as Heliarc welding. Argon gas has certain advantages over helium and when it became available it became the generally preferred gas shield making the term Heliarc improper.

**Inert gas**- a gas that does not normally combine chemically with materials. (ANSI/AWS A3.0:2001)

Inert means no chemically reactive properties. The gas won't burn or combine with anything changing the composition. The inert gas flows from the TIG torch cooling and shielding the tungsten electrode and then it flows over the weld zone blanketing the weld and keeping the atmosphere away. This is especially important for reactive metals such as aluminum, magnesium and titanium. Gas mixes are typically used for wire feed welding and in most cases are not inert. The key difference with the wire feed process is that there is a metal transfer across the arc with wire feed welding and the shielding gas can have great effect on that metal transfer.
Argon- an inert gas that is colorless, odorless, tasteless, nontoxic and nonflammable. The most commonly used shielding gas is obtained from the atmosphere by separating it from liquefied air, of which 0.8% is argon. Welding grade is 99.995% pure. Argon is an effective weld shield because it is dense, 1.3 times heavier than air and 10 times heavier than helium, which means it will blanket the weld area. Remember, helium is lighter than air and tends to flow away. Besides being heavier, argon is better than helium due to its easier arc initiation, smoother arc action, reduced penetration, lower cost and cleaning action on reactive metals such as aluminum. This cleaning action will be discussed later.

Helium- colorless, odorless, tasteless and lighter than air, helium is also more expensive than argon. It also requires two to three times the flow rates of argon to properly blanket the weld area. Welding grade is 99.99% pure. Helium has greater thermal conductivity than argon, so it can transfer more heat into the metal, which can be an advantage on metals of high thermal conductivity, thick plates or high speed mechanized applications. Helium is sometimes added to argon making an inert gas mix that combines the features of both gases, this being an advantage on some applications such as thicker aluminum or copper alloys.

Some TIG welding applications such as titanium may require special gas shielding measures due to the reactivity of the heated metal to such elements as oxygen. An enclosed gas chamber, trailing gas shield or backup shielding or purging may be necessary for optimum welds.

AC/DC

Both alternating current and direct current are used for TIG welding, the deciding factor being the base metal to be welded. Basically, if you are welding aluminum you need AC (with hi-freq) and other metals are done with DC straight polarity (DCEN).

Direct current electrode negative (DCEN) provides deep penetration, fast welding speeds and minimal electrode overheating. Remember that electricity flows from negative to positive. With DCEN, the electricity flows from the negative tungsten into the positive workpiece. The positive end of the arc is about 70% hotter than the negative end so with DCEN more heat is put into the base metal than into the tungsten. Remember that with TIG welding you do not want to melt the tungsten but you want to melt the base metal to form a weld puddle.

With DCEN at 125 amps we can use a 1/16 inch (1.6mm) diameter electrode, which will give us a narrow heat zone and good penetration. Using electrode positive (DCEP) at 125 amps would require a 1/4 inch (6.4mm) diameter electrode to handle the heat at the electrode end of the arc and not melt the electrode. This would result in a wide heat zone and minimal weld penetration.

Alternating current is used for TIG welding metals such as aluminum and magnesium that form refractory oxide surfaces. Aluminum is difficult to weld for two basic reasons. An aluminum oxide film is constantly forming on the surface of the base metal. Even when scraped off this film will instantly reform. Aluminum oxide is rated right below diamonds in hardness and has a melting temperature about three times higher than that of aluminum itself. Though aluminum has a relatively low melting temperature it can actually take
more heat to weld because it is a big time heat conductor, three to five times that of steel. As fast as we are putting heat into the weld zone, it is flowing away.

So the two problems with welding aluminum are cleaning (aluminum oxide) and heating (heat conductor). Using alternating current works to solve both these issues. Alternating current (AC) is in effect both DC straight polarity (DCEN) and DC reverse polarity (DCEP) at the same time. Remember direct current flows in one direction only. Alternating current changes the direction of flow, first it flows one way then it alternates and flows the other way and is commonly diagramed with a sine wave. AC in a full cycle is in effect both DCEN and DCEP at the same time.

Theoretically, there is one half of the full cycle where the electrode is negative and the work is positive which would be the straight polarity phase of the cycle. The other half cycle, the electrode would be positively charged and the work would be negatively charged, which is the reverse polarity phase of the cycle. Each one of these cycles helps with the two problems of welding aluminum, heating and cleaning. During the straight polarity phase, the hot end of the arc is at the base metal providing heat and penetration to the high conductivity metal. During the reverse polarity phase, the electrode end of the arc is positively charged and this positively charges the gas ions flowing from the torch. Opposites attract and the positive gas ions are attracted to the negatively charged base metal and they chip away the aluminum oxide film providing a cleaning action. Thus we have heating and cleaning.

Electricity can be manipulated, so some TIG welding machines are capable of controlling the amount of time each phase (or wave) of the AC current occurs and how fast the change happens. These are called square wave power sources. If the base metal is thick, then more of the DCEN phase would be better and less of the DCEP (cleaning phase) may be necessary or vice versa. This can be controlled by the power source.

AC does provide an erratic arc due to arc reignition during the change between half cycles. High frequency is used to stabilize the arc and must be used with AC. It can also be used to allow "non-strike starts" with DC current. Inverter type power sources may accomplish the same tasks through different electronic circuitry.

**TUNGSTEN ELECTRODES**

Tungsten is used as a non-consumable electrode for TIG welding because of its hardness and high melting temperature. It has the highest melting point of all metals, 6,170°F (3,410°C). It does not melt or vaporize in the heat of the arc when used properly and maintains its hardness at high heats. A "pure tungsten" electrode is a minimum 99.5% tungsten with no elements intentionally added. Different types of tungsten electrodes have small additions, 1% to 2%, of other elements added to the tungsten to improve certain arc characteristics. This primarily effects how the electrode conducts either AC or DC current. The different types of electrodes are color coded for identification.

Pure tungsten electrodes are used for welding aluminum and magnesium because they provide good arc stability with AC current and work well with both argon and helium shielding gas. Zirconium oxide is
added to pure tungsten to make an electrode that is even more stable with AC current for the highest quality welds. When heated these electrodes form a ball end. These electrodes do not work well with DC current.

Thorium oxide is added to tungsten to make thoriated electrodes. These are used with DC because of better arc starting, longer life and better resistance to tungsten contamination. Ceriated and lanthanated electrodes are similar to thoriated. These electrodes avoid the low level radioactivity of the thoriated types. These electrodes can be used with AC current. With DC current the electrodes are ground to a point and will retain that shape.

**GAS TUNGSTEN ARC WELDING (GTAW) ALLOYS**

**Brutus-TIG** (130,000 p.s.i.) is ideal for welding high carbon, stainless, tool steel and dissimilar steels. Suitable for buildup on shafts and 400 series stainless. Deposits are machinable and corrosion resistant.

**Gemini-TIG/A** (85,000 p.s.i.) and **Gemini-TIG/B** (83,000 p.s.i.) are suitable for the 300 series stainless and provide ultra low carbon content for superior corrosion resistance. **Gemini-TIG/B** contains molybdenum.

**Gemini-TIG/C** (86,000 p.s.i.) provides excellent joining and overlay results on stainless exposed to severe corrosion. Suitable for the Carpenter type stainless, it is superior for high temperature corrosive exposure.

**Gemini-TIG/E** (85,000 p.s.i.) has more chromium and nickel than any type of stainless. Perfect for unknown stainless and high heat types such as 309,310 and 314. Good strength at high heats and high elongation.

**Tartan-TIG** (95,000 p.s.i.) is for a wide variety of mild and medium alloy steels providing deposits that can be flame hardened, heat treated and will respond to bluing and plating. Also suitable for 4130 and 4140 alloys.
Tartan-TIG/B (80,000 p.s.i.) can be used for mild and medium carbon steels and provides deposits with superior machinability. Deposits are crack free.

Neptune-TIG (34,000 p.s.i.) is suitable for a wide range of aluminum alloys. Deposits exhibit minimum crack sensitivity and can be anodized. Excellent color match.

Neptune-TIG/M (37,000 p.s.i.) is for the welder who must weld a variety of magnesium components such as dock plate and tool housings. It is best used for cast, sheet and tubing.

Midas-M2/TIG (64RC) and Midas-H12/TIG (59RC) are tool steel alloys for cutting edges and abrasion resistant surfaces. Deposits are hardenable and are suitable for a range of tool steel base metals.

Midas-H72/TIG (32-47RC) provides heat treatable deposits on low alloy and medium carbon steels. Machinable deposits can be heat treated to provide increased hardness. Ideal for joining or buildup.

Jupiter-TIG/B (60,000 p.s.i.) is a high nickel alloy for buildup and joining of cast iron or for joining cast iron to steel. Deposits are machinable and porosity free.

Venus-TIG (60,000 p.s.i.) and Venus-TIG/C (106,000 p.s.i.) are bronze alloys for joining and buildup. Deposits are corrosion resistant and machinable. Also suitable for joining dissimilar combinations and wear surfaces.

Please consult ROCKMOUNT WELDING MANUAL for more specific information on these or other products.
RECOMMENDED TUNGSTEN ELECTRODES AND GAS CUPS FOR VARIOUS WELDING CURRENTS (ARGON GAS)

<table>
<thead>
<tr>
<th>Electrode Diameter Inches (mm)</th>
<th>Gas cup size I.D.— inches</th>
<th>Amps - DCEN Straight polarity Th-2 tungsten</th>
<th>Amps - AC Unbalanced Wave Pure tungsten</th>
<th>Amps - AC Balanced Wave Pure tungsten</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.010 (0.25)</td>
<td>1/4</td>
<td>Up to 15</td>
<td>Up to 15</td>
<td>Up to 15</td>
</tr>
<tr>
<td>0.020 (0.50)</td>
<td>1/4</td>
<td>5-20</td>
<td>5-15</td>
<td>10-20</td>
</tr>
<tr>
<td>0.040 (1.00)</td>
<td>3/8</td>
<td>15-80</td>
<td>10-60</td>
<td>20-30</td>
</tr>
<tr>
<td>1/16 (1.60)</td>
<td>3/8</td>
<td>70-150</td>
<td>50-100</td>
<td>30-80</td>
</tr>
<tr>
<td>3/32 (2/40)</td>
<td>1/2</td>
<td>150-250</td>
<td>100-160</td>
<td>60-130</td>
</tr>
<tr>
<td>1/8 (3.20)</td>
<td>1/2</td>
<td>250-400</td>
<td>150-210</td>
<td>100-180</td>
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<tr>
<td>5/32 (4.00)</td>
<td>1/2</td>
<td>400-500</td>
<td>200-275</td>
<td>160-240</td>
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<td>3/16 (4.80)</td>
<td>5/8</td>
<td>500-750</td>
<td>250-350</td>
<td>190-300</td>
</tr>
<tr>
<td>1/4 (6.40)</td>
<td>3/4</td>
<td>750-1100</td>
<td>325-450</td>
<td>325-450</td>
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</tbody>
</table>

Note: Ceriated & Lanthanated electrodes may be substituted for Thoriated tungsten (Th-2) Zirconiated electrodes may be substituted for Pure tungsten.

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