

## Gas Tungsten Arc Welding (GTAW / “TIG”)

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The gas tungsten arc welding (GTAW) process is a very versatile, all-position welding process that is widely used to join Ni-/Co-base alloys. In GTAW, the heat for welding is generated from an electric arc established between a non-consumable tungsten electrode and the workpiece. GTAW can be performed manually or adapted to automatic equipment, and can be used in production as well as repair welding situations. It is a process that offers precise control of welding heat, and is therefore routinely used for welding thin base metal and depositing root passes of thicker section welds. The major drawback of the GTAW process is productivity, as weld metal deposition rates during manual welding are low.

Two percent thoriated tungsten electrodes (AWS A5.12 EWTh-2) have been traditionally used for GTAW of Ni-/Co-base alloys, but now other compositions are becoming more common due to possible health concerns associated with EWTh-2 and other thoriated tungsten electrodes. The thorium oxide contained in the EWTh-2 electrode is a low-level radioactive material that presents a small external radiation hazard and an internal hazard from ingestion or inhalation. The greatest risk for a welder is associated with the inhalation of radioactive dust while grinding the tungsten electrode tip to maintain the desired conical shape. Consequently, it is necessary to use local exhaust ventilation to control the dust at the source, complemented if necessary by respiratory protective equipment, and precautions must be taken in order to control any risks of exposure during the disposal of dust from grinding devices. As a result of these health concerns, thoriated tungsten electrodes are being phased out by certain governing bodies and organizations. Fortunately, there are alternatives that provide comparable performance to EWTh-2, including two percent ceriated (AWS A5.12 EWCe-2) and lanthanated (AWS A5.12 EWLa-2) electrodes. For further information on the different types of tungsten electrodes, the reader is referred to: *AWS A5.12/A5.12M, Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting, American Welding Society.*

The diameter of the tungsten electrode should be selected according to weld joint thickness and filler wire diameter. It is suggested that the electrode be ground to a cone shape (included angle of 30 to 60 degrees) with a small flat of 0.040 to 0.060 in (1.0 to 1.5 mm) ground at the point. See Figure 4 for the suggested tungsten electrode geometry.

Welding-grade argon shielding gas with a 99.996% minimum purity is suggested for most welding situations. Helium, or mixtures of argon/helium or argon/hydrogen may be advantageous in certain situations, such as high travel speed, highly mechanized welding operations, in order to increase weld penetration. Shielding gas flow rates are critical; too low of a rate will not provide adequate protection of the weld pool, while too high of a rate can increase turbulence and aspirate air. Typically, flow rates for 100%Ar shielding gas are in the 20 to 30 cubic feet per hour (CFH) (9 to 14 L/min) range. Generally, the shielding gas cup should be as large as practical so that the shielding gas can be delivered at lower velocity. It is also recommended that the welding torch be equipped with a gas lens in order to stabilize the gas flow and provide optimum shielding gas coverage. While welding-grade shielding gases are of a very high purity, even a small amount of air can compromise the protective shielding and cause weld metal oxidation/discoloration and porosity. This can be caused by air movement from fans,

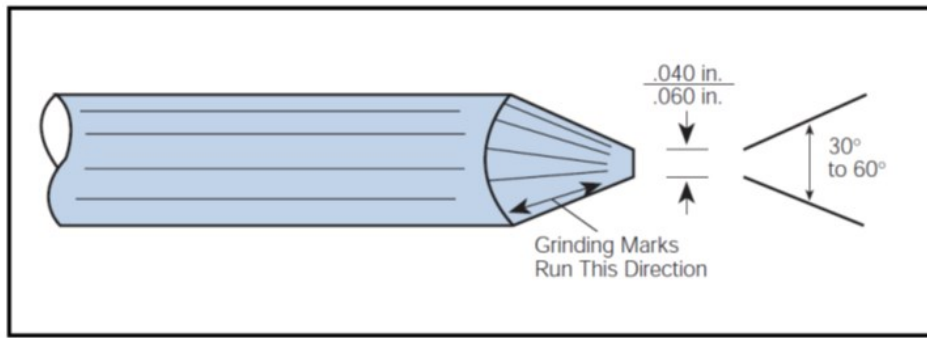
cooling systems, drafts, etc., or from leakage of air into the shielding due to a loose gas cup or other welding torch components. When proper shielding is achieved, the as-deposited weld metal should typically have a bright-shiny appearance and require only minor wire brushing between passes.

In addition to welding torch shielding gas, a back-purge at the root side of the weld joint with welding-grade argon is suggested. The flow rates are normally in the range of 5 to 10 CFH (2 to 5 L/min). Copper backing bars are often used to assist in weld bead shape on the root side of the weld. Backing gas is often introduced through small holes along the length of the backing bar. There are situations where backing bars cannot be used. Under these conditions, open-butt welding is often performed. Such welding conditions are often encountered during pipe or tube circumferential butt welding. Under these conditions where access to the root side of the joint is not possible, special gas flow conditions have been established. Under these open-butt welding conditions, the torch flow rates are reduced to approximately 10 CFH (5 L/min) and the back purge flow rates are increased to about 40 CFH (19 L/min). Detailed information concerning back-purging during pipe welding is available from Haynes International upon request.

It is recommended that the welding torch be held essentially perpendicular to the work-piece, with the work angle at 90° from the horizontal and only a slight travel angle of 0° to 5°. If a large drag angle is utilized, air may be drawn into the shielding gas and contaminate the weld. The arc length should be maintained as short as possible, especially during autogenous welding. Stringer bead techniques, or narrow weave techniques, using only enough current to melt the base material and allow proper fusion of the filler, are recommended. Filler metal should be added carefully at the leading edge of the weld pool to avoid contact with the tungsten electrode. During welding, the tip of the welding filler metal should always be held under the shielding gas to prevent oxidation. Pausing or “puddling” the weld pool adds to the weld heat input and is not recommended.

Electrical polarity for the GTAW process should be direct current electrode negative (DCEN / “straight polarity”). Typical manual GTAW parameters for welding HASTELLOY® and HAYNES® alloys are provided in Table 1. The parameters should be viewed as approximate values that are ultimately dependent on many other factors, including the particular welding power source, weld joint geometry, and welder skill level. Thus, it is suggested that the parameters be used as a guideline for developing a specific welding procedure. Smaller diameter filler wire is suggested for depositing root passes. A power source equipped with high-frequency start, pre-purge/post-purge and up-slope/down-slope (or foot peddle) controls is highly recommended. Weld travel speed has a significant influence on the quality of Ni-/Co-base welds, and is typically lower than for carbon and stainless steel. The suggested travel speed for manual GTAW is 4 to 6 inches per minute (ipm) / 100 to 150 mm/min.

#### **Figure 4: Tungsten Electrode Geometry**



**Table 1: Typical Manual Gas Tungsten Arc Welding Parameters (Flat Position)**

| Joint Thickness |         | Tungsten Electrode Diameter |         | Filler Wire Diameter |         | Welding Current | Arc Voltage |
|-----------------|---------|-----------------------------|---------|----------------------|---------|-----------------|-------------|
| in              | mm      | in                          | mm      | in                   | mm      | Amps            | Volts       |
| 0.030-0.062     | 0.8-1.6 | 0.062                       | 1.6     | 0.062                | 1.6     | 15-75           | 9-15        |
| 0.062-0.125     | 1.6-3.2 | 0.062/0.093                 | 1.6/2.4 | 0.062/0.093          | 1.6/2.4 | 50-125          | 9-15        |
| 0.125-0.250     | 3.2-6.4 | 0.093/0.125                 | 2.4/3.2 | 0.093/0.125          | 2.4/3.2 | 100-175         | 12-18       |
| > 0.250         | >6.4    | 0.093/0.125                 | 2.4/3.2 | 0.093/0.125          | 2.4/3.2 | 125-200         | 12-18       |

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