# White Paper: High Amperage Gas Tungsten Arc Welding

## Background

High amperage gas tungsten arc welding (HA-GTAW) is the term given, by Orano, to the welding process commercially known as keyhole tungsten inert gas (K-TIG). The term HA-GTAW will be used to avoid integrating an external commercial brand into the application of a common process. The K-TIG is a commercial brand of the applied keyhole GTAW process that has improved the welding equipment design to perform beyond historic keyhole GTAW thickness limits. To achieve single pass keyhole welds in plates greater than 0.250 inch thick, a number of equipment improvements are required. However, the primary developments are in handling and controlling higher amperages. Therefore, for licensing purposes, Orano has given the term HA-GTAW to all GTAW welding process designed to join materials with a thickness greater than 0.250 in a single pass.

## Application

Orano will apply an HA-GTAW process to weld the corner joint between the outer top cover plate (OTCP) and the dry storage canister (DSC) (see Figure 1). For purposes of installation, the OTCP will always be slightly smaller in diameter than the inside diameter of the shell. This will require an amount of filler metal to be added during welding. The filler metal feed rate will be proportional to the gap between the OTCP and the DSC. The HA-GTAW process will be capable of welding a joint with a gap range from 0.000 to 0.200 inch. Though the possible joint designs are numerous and may be further developed over time, Orano will use a square edge with a relief cut at the bottom side of the joint. The relief cut is to allow plasma gas to escape when the joint gap is tight.

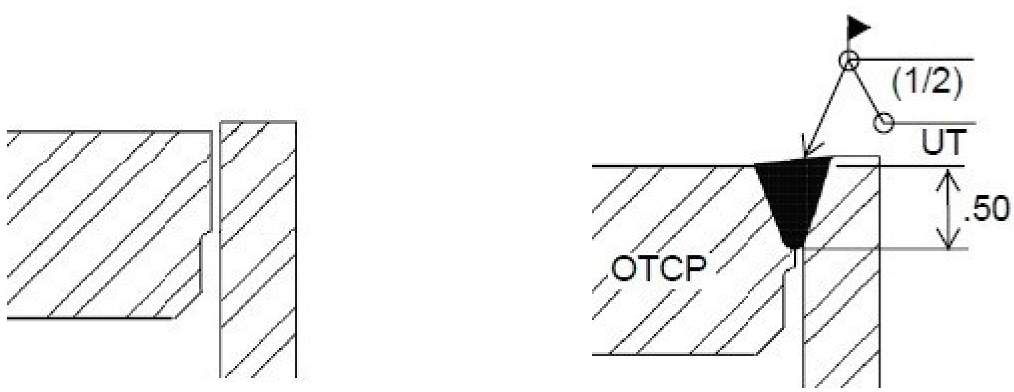
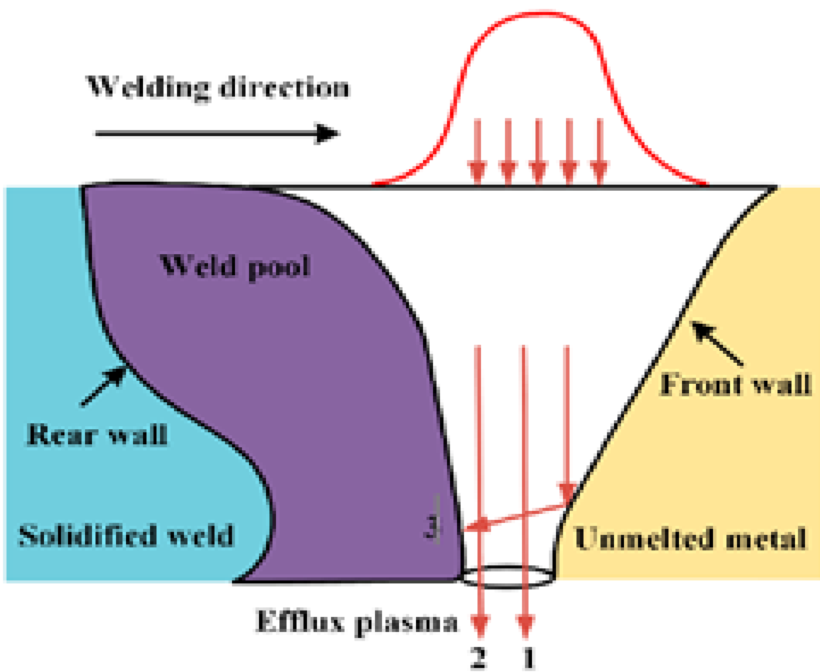



**Figure 1**

Historically, common GTAW processes have been limited in pass thickness by solidification issues in which welds approaching a 1:1 depth to width ratio have a strong tendency to hot-crack.  This is generally caused by the outer solidus weld metal shrinking in size while the center of the weld is still liquidus.  Another limitation to thick weld passes is the change in mechanical properties due to extended solidification times and lower cooling rates.  Utilization of a HA-GTAW process allows for the desired effective weld cross-sectional thickness of 0.500 inch while maintaining a relatively narrow width of less than 0.500 inch in the lower sections of the weld pass.  This is achieved by changing the direction of solidification to a more vertical advancing face as in Figure 2 (see Reference 1).  The solidification in a vertically advancing weld pool resembles multiple thin layers deposited vertically where they solidify against the advancing rear wall of the solidified weld metal.  This vertical solidification promotes the desired solidification profile and cooling rates that will produce the appropriate mechanical properties (see Figure 3 and Reference 2).




(a)

Figure 6. *Cont.*

**Figure 2**

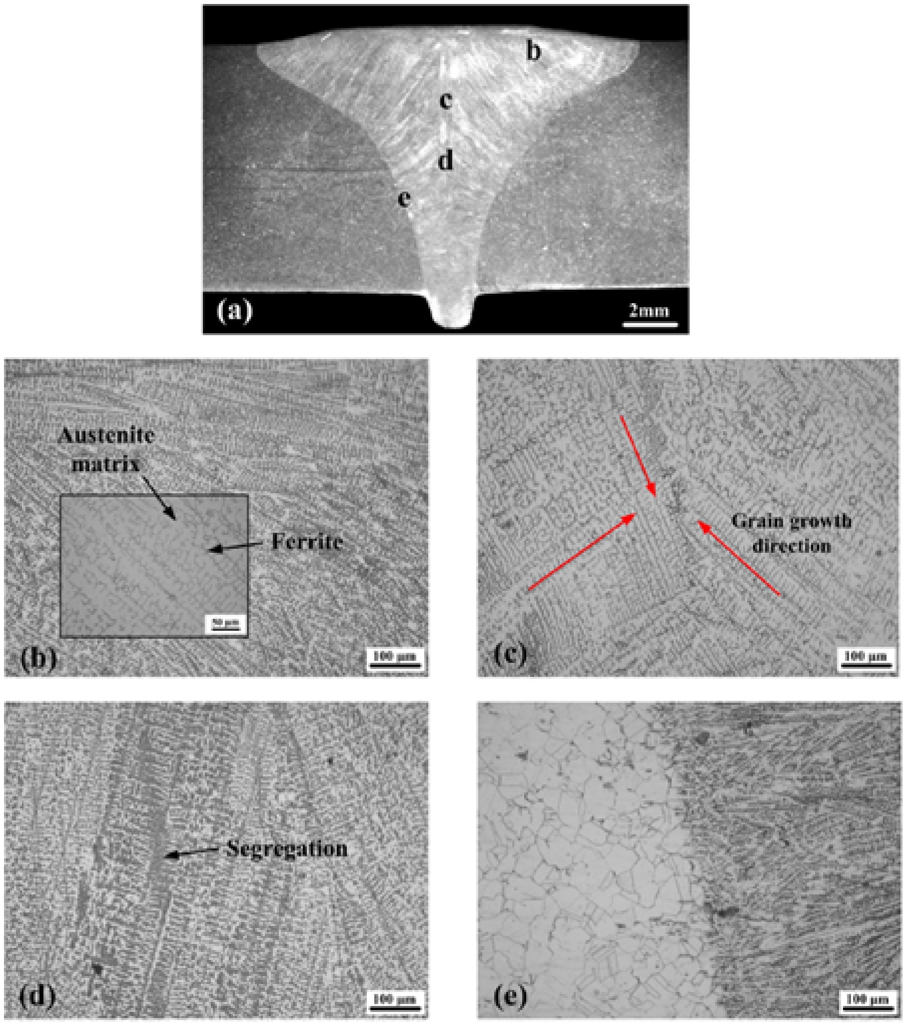



**Figure 3**

In order to maintain performance consistency and enhance the level of quality control, the application of HA-GTAW will be performed by mechanized and robotic type controls. Such control will enable the welding operator to make adjustments to various controls, such as wire feed speed, while other controls remain constant. Commercially available equipment developed for HA-GTAW is conducive to robotic controls and interfacing with camera/remote viewing systems.

**Qualification**

The OTCP will be comprised of a plate-to-plate butt joint, and the HA-GTAW welding will be qualified per ASME IX. Additionally, a production-type joint mockup will be produced for cross-sectional analysis to demonstrate weld soundness and to validate the phased array ultrasonic testing that will be applied to the inspection of production welds.

**References:**

1. Fei, Zhenyu; Pan, Zengxi Stephen; Cuiuri, Dominic; Li, Hui Jun; Wu, Bintao; Ding, Donghong; and Su, Lihong, “Effect of Heat Input on Weld Formation and Tensile Properties in Keyhole Mode TIG Welding Process,” (2019). Faculty of Engineering and Information Sciences - Papers: Part B. 3475. https://ro.uow.edu.au/eispapers1/3475

2. Yueqiao Feng, Zhen Luo, Zuming Liu, Yang Li, Yucan Luo, Yongxian Huang, “Keyhole Gas Tungsten Arc Welding of AISI 316L Stainless Steel,” Materials & Design, Volume 85, 2015, Pages 24-31, ISSN 0264-1275, https://doi.org/10.1016/j.matdes.2015.07.011