

AUTOMATIC ORBITAL GTA WELDING:
HIGHEST QUALITY WELDS FOR
TOMORROW'S HIGH-PERFORMANCE SYSTEMS

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ABSTRACT

Automatic orbital GTAW (TIG) welding is certain to play an increasingly prominent role in tomorrow's technology. The welds are of the highest quality and the repeatability of automatic weldings is vastly superior to that of manual welding. Since less heat is applied to the weld during automatic welding than manual welding, there is less change in the metallurgical properties of the parent material. In stainless steel pipe and tube, this process can eliminate carbide precipitation and reduce the tendency towards IGSCC.

The possibility of accurate control and the cleanliness of the automatic GTAW welding process make it highly suitable to the welding of the more exotic and expensive materials which are now widely used in the aerospace and hydrospace industries. Titanium, stainless steel, Inconel, and Incoloy as well as aluminum can all be welded to the highest quality specifications automatically.

Automatic orbital GTAW equipment is available for the fusion butt welding of tube-to-tube as well as tube to autobutt weld fittings. The same equipment can also be used for the fusion butt welding of up to 6-inch pipe with a wall thickness of up to 0.154 inches. To weld pipe from 1-1/2 inches and up with heavier wall thicknesses requiring the use of filler wire, automatic orbital GTAW pipe welding systems with remote welding capabilities are available.

These technologies have already been widely used in various aerospace applications such as: aircraft fuel and hydraulic lines, space shuttle module lines and aircraft drop tanks. Applications for hydrospace include underwater hyperbaric welding in high pressure, mixed gas atmospheres using both semiautomated and automated processes. Undoubtedly, automatic orbital GTAW will find a wider application in future systems.

Introduction and Point of View

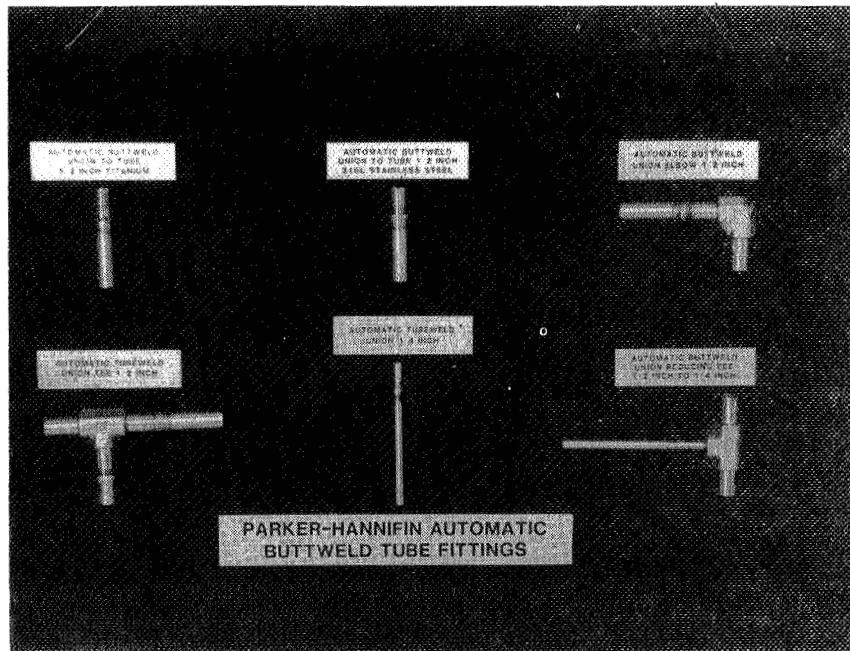
We intend to present Automatic Orbital GTAW (TIG) welding from the point of view of a manufacturer of this type of equipment. At this time we see a tremendous broadening of the application base for automatic orbital in-place welding. There are a number of reasons for the increase in the use of automated processes. To understand these reasons it is useful to look at the origins of the applications, what the current uses for this kind of equipment are, and then to discuss how we expect this technology to be used in the 1990's.

Automatic orbital TIG welding has found a niche in certain key industries. It began in the aerospace industry in the early 1960's at Rockwell (Rocketdyne) in Los Angeles. At that time the power supplies were very large, unreliable and difficult to use. Any kind of serious welding required an engineer, a welding technician, and an electronic technician. Even then, when a good weld was achieved, there were advantages over either compression fittings or manual welding techniques. There was an increase in the strength of the weld, an improvement in the consistency of penetration, and (particularly compared to compression fittings) a decrease in the likelihood of a leak. Using autogenous welding techniques also eliminated the necessity of using a compression fitting resulting in a savings in weight which was critical for aerospace applications.

In the mid 60's, companies such as Astro-Arc and Dimentrics produced production equipment to do this type of welding. The major users were Lockheed on the C-5A and L-1011 and Bell Aerosystems on the Minuteman missile.

The next major application for automatic orbital tube welding occurred in the early 1970's. This was the welding of instrumentation tubing in nuclear plants. At this time, the Parker-Hannifin Corporation developed the autobuttweld fitting for use with 1/4, 3/8, and 1/2-inch instrumentation tubing. These fittings featured a patented locator rib which automatically aligns the joint to the tungsten. A lip on the end of the fitting helps

to align the tube to the fitting, as well as provide filler metal for the weld.



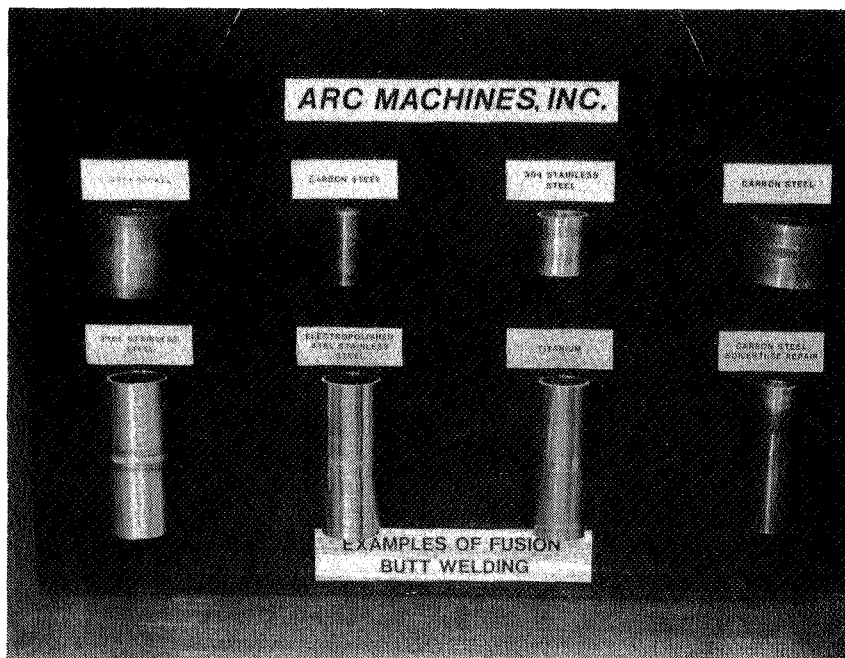
Description of Equipment and Process

Arc Machines, Inc., manufactures automatic orbital pipe welding systems, tube-to-tube sheet systems as well as orbital tube-to-tube welding equipment. The power supplies used for this type of automated welding are all transistorized and programmable to the extent that the weld, from pre-purge through post-purge, is made automatically, without operator control.



As you can see, the power supply is considerably more compact and portable than earlier models. The weld heads for fusion welding contain an internal rotor which holds the tungsten and rotates around the work. The tube, or pipe, therefore remains in place and the weld can be placed close to a wall, ceiling or bulkhead as the internal rotor is the means of moving the arc around the joint. The weld heads must provide gas shielding of the entire weld zone, and a motor to give precise rotational control. The power supply for tube-to-tube welding controls the following welding parameters automatically: pre-purge time, controlled arc strike with no overshoot, pulsation, rotation delay, four timed levels of current control, downslope and post-purge. The pipe welding equipment adds arc voltage control, oscillation and cold wire feed. All these controls must be extremely accurate and a general industry standard is that accuracy of 1% of dial reading is necessary for high-quality repeatable welds.

The process used is TIG, or more properly, GTAW. In the tube welding equipment, the weld head forms a purge chamber which is filled with the shield gas prior to, during, and after the welding operation. The most common shield gas is Argon, but for some stainless steel welds Argon/Hydrogen in the ratio of 95% Argon, 5% Hydrogen is used; for carbon steel or some relatively thick wall stainless applications, 75% Helium/25% Argon can be utilized. The tungsten is fixed to the rotor and the welding current is developed in the power supply, transmitted via cables to the weld head and finally to the rotor, the tungsten and across the arc gap to the work. Pulsation is used both to reduce the heat input into the material and to permit welding in the 5-G position. Essentially, the fusion weld consists of a series of spot welds in which the main welding current penetrates the material and the background current chills the puddle. Metallurgically, the results are excellent welds. If there are no impurities in the base metal, there are none in the weld. The heat input to the material is low, the heat affected zone is small, and the strength of the weld is greater than the tube. With this welding technique, problems common to manual welding techniques, such as overheating of the weld, are not a factor. While the fusion technique is most commonly used on thin-wall tubes of 0.035", 0.065" and 0.095" wall thickness, one of our customers is performing satisfactory production welds on 2" Schedule 40 pipe, with a 0.154" thick wall. Those welds have been extensively tested, and according to the customer, "pass with flying colors!" However, as a company policy, you should be advised that we do not recommend the use of fusion techniques, that is without filler wire, beyond 6" Schedule 10 pipe, which is 0.134" wall thickness.



The present uses of orbital tube welding have grown beyond the initial aerospace and nuclear applications. The largest single use of orbital tube welding equipment today is in process lines for the semiconductor industry. Parker-Hannifin, Cajon and Valex fittings are used to join and terminate the process lines for the hazardous gasses (such as Arsene and Silene) and the de-ionized water used in wafer fabrication. The Cajon fitting is similar to the Parker, but lacks the locator rib for alignment. Cajon uses a shoulder which butts up against the outside of the tube clamp insert to align the tungsten to the joint on tee and elbow fittings. Pharmaceutical and bio-technology plants also commonly specify automatic orbital welding to ensure the cleanliness of their process lines for biological or pharmaceutical components and water for injection into the human body. Ladish Tri-Clover and Valex are fitting manufacturers who adapted their fittings to the requirements of automatic welding. Lastly, the final ingredient necessary to make in-place fusion butt welding really field-practical is the ready availability of portable, in-place tube prepping equipment. This is now readily available and produces the kind of machined finished square joint that is absolutely necessary for repeatable orbital fusion butt welding.

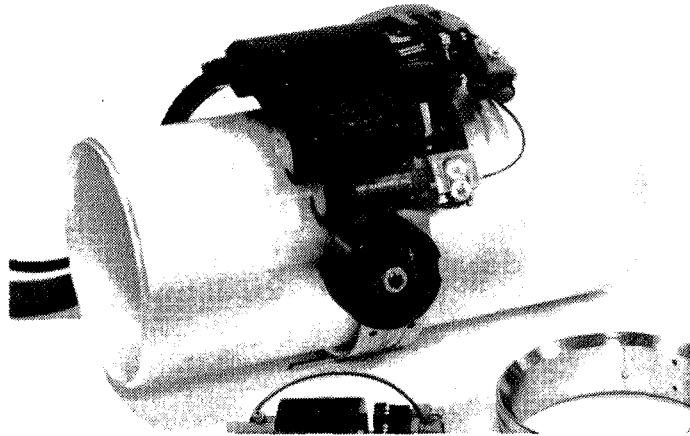
From this base, we see a general broadening of the application. Many of our mechanical contractor customers who purchased fusion butt welding equipment for semiconductor use are using the equipment on more mundane jobs - paint thinner plants and a chocolate factory are two that come to mind. In aerospace and hydrospace, the applications are also broadening. Fusion butt welding is relatively common in many aircraft, missiles, and spacecraft. Now we find that the fuel-handling facilities and many lines associated with hazardous, high-pressure or cryogenic gasses are being welded with orbital equipment. Recently we demonstrated to a manufacturer of jet engine test panels and discovered a whole new application area that could make excellent use of existing, proven fusion butt welding techniques and available fittings.

For hydrospace, we also see a broadening of the application. To date, fusion butt welding has not been accepted as readily for marine use as has been the case with aerospace. In 1984, the U.S. Navy seriously tested fusion butt weld fittings. The lip on the fitting produces a weld that is thicker than the tube wall, with both full penetration on the inside and reinforcement on the outside of the tube. These welds may well meet Navy specifications for crown, in which case their use could multiply in ship construction. Another factor is the increase in size that we have seen in autobutt weld fittings. From the initial 1/4", 3/8" and 1/2" sizes,

3/4" and 1" are now commonly used in semiconductor plants. The semiconductor plants are requesting the fitting manufacturers to produce even larger fittings and I can now show a prototype 2" O.D. auto butt weld fitting. If this weld becomes approved, the increase in size means that more and more tubes on board ship could be fusion butt welded. Aside from ship applications, shore facilities could benefit from fusion butt welding. It has long been the belief of our company that there is a lot of process pipe installed that could be thin wall tubing. The theoretical internal burst pressure of thin wall tubing is higher than generally realized: 1/2" 0.049" wall theoretical burst pressure is 14,700 p.s.i.; 1-1/2" 0.065 wall theoretical burst pressure is 5,800 p.s.i.; 30" 0.083" wall is 4,150 p.s.i. Many applications for fuel, oil or water are at 400 p.s.i. or less. If a facility were built using thin-wall tubing where it is appropriate, instead of thick-wall pipe, the savings could be quite large. The material is very easy to handle and prepare for welding. The welds are top quality, repeatable and are made very quickly, particularly when compared to manual thick-wall pipe welding. The support structure for tube could be lighter and possibly use smaller material than would be required for pipe. The foundations could be designed to carry less load. We are not mechanical engineers, but it would be an interesting exercise to calculate how much could be saved by using this approach.

Orbital Pipe Welding

Orbital pipe welding requires more complex equipment than the fusion tube welding equipment just described.



The pipe joint configurations, with a groove which must be filled with weld metal provided by filler wire, require additional electronic functions, and their mechanical equivalents. The filler wire addition requires accurate wire feed motors and mechanisms. The necessity to move the torch across the groove requires accurate control of both the rate of movement, the distance moved and the dwell on the sidewall. Accurate rotational movement around the pipe must also be provided, together with current pulsation and the ability to change parameters as this becomes necessary. Weld head radial clearance poses a real challenge for the designers, as the heads must be as small as possible, yet sturdy enough to meet their real-world requirements found on the job site. The result of this design effort is a level of control of the weld puddle that results in welds that are metallurgically and physically excellent, as well as aesthetically attractive.

Most recently, remote operation of this equipment has come into its own. Several nuclear plants have been repaired in 1983 and 1984 with remotely operable pipe welding equipment. Our system uses fiber optics to view the leading and trailing edges of the puddle and may be operated up to 200 feet from the weld joint. This remote ability can also be used on weld heads which mount inside a pipe and weld or clad the I.D.

The aerospace applications of this equipment are, to date, limited to fuel handling facilities. Little or no additional applications are expected in the future. Marine applications, however, are greater. Several constructors in the United States have very strong orbital pipe welding programs. Newport News Shipyard and General Dynamics Electric Boat are two that come immediately to mind. Developments of weld heads such as our miniature pipe weld head with very minimum radial clearance of 1-3/8" will no doubt increase the applications for ship construction. We expect the experience in on-board construction to carry over to the shore based support facilities involved in direct ship servicing, as well as to the refineries that produce fuel. Another application is that demonstrated by the recent completion of the first stainless steel pipeline. The cost of the material, and metallurgical considerations, dictated the use of orbital welding equipment.

A fascinating application of orbital pipe welding is the use of orbital equipment to weld pipelines under water. Not a "pipe dream", this is now a field-proven technique used by Subsea International at their base in Aberdeen, Scotland, that uses a micro-processor controlled welding power supply and programmer topside, which operates an orbital pipe welding head in a habitat up to 300 M (1,000 feet) below the surface. The current application is in the repair of underwater pipelines. In operation, the habitat, on the ocean floor, is placed over the broken or ruptured pipe and this is brought up into the habitat. The pipe is cut and prepped in place, and the repair section tacked into position. The technician doing this work need not be a skilled welder - tacking is easier than pipe welding. The welding head is placed on its guide ring and the entire weld is then performed on command from the surface. In this way, for the first time, nuclear quality repair welds can be made in place, on the ocean bottom.

CONCLUDING REMARKS

In summation, we believe that orbital in-place welding, particularly tube welding, will see a great expansion of applications in the near future, and will become, in time, a very common joining technique.