Welding reactive metals WP-307

The reactive metals by classification are zirconium, titanium and beryllium. We also include here tantalum and columbium (niobium), being from the refractory class and which also present similar challenges to the welding engineer.

Aerospace, automotive, medical and military industries are increasingly using all these materials. They have many technological attractions being durable, low density, bio-compatible and offering high corrosion resistance but they are expensive. Welding procedures need to be carefully developed and stringently applied to avoid expensive waste, rework or risk of service failure.

Successful fusion joining techniques have evolved[1] since the alloys were first used in engineering applications. The majority of metallurgical problems, even considering dissimilar metal welding, have been resolved and filler materials are readily available. However, their reactive nature make it essential to continue to address the requirement for thorough pre-cleaning and particularly oxidation at the high temperatures involved in arc welding.

Cleanliness

Weld repair of plant that has been in service presents the most difficult situation for welding reactive and refractory alloys. The equipment is usually dirty and may have process scale on the surface. In most cases, the repairs must be done outdoors where the work area and conditions are not optimal for welding reactive metals - the environment usually is dirty. High humidity and wind also interfere with the welding process.

Furthermore, plant shutdowns that require equipment repair usually result in pressure to complete the work quickly. There is little merit however in cutting corners. Repairs that must be made to partial-penetration welds or where crevices exist pose a special problem because of contaminants in crevices.

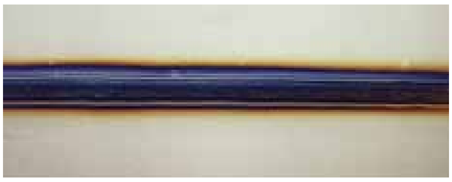
Poorly prepared surfaces can result in weld contamination and lead to a premature failure and a repeat of the weld repair. Overall, expect to spend more time preparing to weld than actually welding when work is undertaken on site.

Even under the cleaner conditions prevailing in most factory environments however there is still a need to prepare surfaces by removing all contamination prior to welding. Published information on cleaning techniques is available [2-8] but the basic principles are to abrade surfaces to remove any corrosion products and other debris then degrease and finally dry. Prepared surfaces should then be protected by covering until any joints are to be made.

by Dr M J Fletcher, Delta Consultants

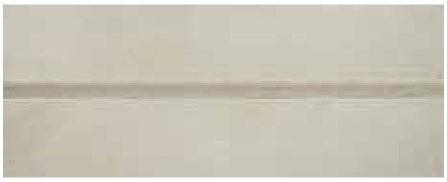
Protection Against Oxidation

Reactive metals have a strong affinity for oxygen at the temperatures prevailing in fusion welding and when combined form very stable compounds. Refractory metals exhibit many of the same characteristics. Oxidation will be evident visually as discolouration as may be seen from Figure 1.



Weld made with 500 ppm oxygen in purge gas

Weld made with 70 ppm oxygen in purge gas



Weld made with 12 ppm oxygen in purge gas

It can be generally assumed that for titanium and other refractory and reactive alloys a 20 ppm level is necessary if oxidation is to be avoided.

Discolouration itself may be acceptable and may be removed mechanically after welding but a more significant result of oxygen contamination is the effect on mechanical properties. Tensile strength is often increased but at the expense of loss of ductility. There can also be a dramatic reduction in corrosion resistance. Since the primary uses of these alloys are in applications where strength and corrosion resistance are mandatory, oxidation is clearly unacceptable.

Protection is thus essential and this is achieved by surrounding the joint with an inert gas such as argon or helium. However, the gas shield associated with a standard GTAW torch is inadequate, offering insufficient cover. Specialised purging equipment has evolved over the past 25 years.

Trailing Shields®

The extra coverage provided by trailing shields not only protects the fusion zone, it also provides inert gas protection to all the hot adjacent metal. Figure 2.

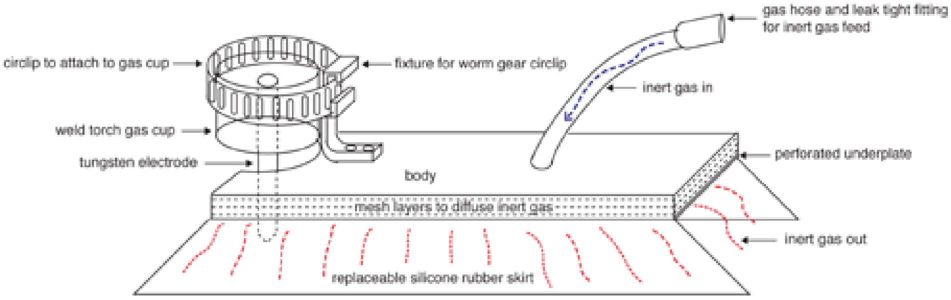


Fig 2 The welding torch is mounted on the leading end of the shield and inert gas fed through one or more ports behind the fusion zone. A seal between the shield and the work is ensured through the use of a flexible, pre-formed and easily replaceable silicone skirt. Turbulence inside the cavity is avoided by passing the gas through a series of mesh filters above the fusion zone.

Custom made trailing shields are available commercially, but these are inevitably expensive and have limited use. The shields manufactured under the Argweld®[11] name have in-built flexibility.

For curved shapes, eg pipes, tubes and cylindrical vessels, trailing shields are available to suit a specific diameter. They can be configured for either internal or external welding and there are versions for mechanised welding.

Flat trailing shields for plate, sheet and rectangular tanks are available in small lightweight versions for manual welders or, like the radiused versions, larger, more robust, versions for attaching to automatic/mechanised welding systems.

Argweld® Trailing Shields® have been designed specifically for use with GTAW (TIG) or PAW (plasma) welding torches and provide a high level of additional inert gas shielding to supplement that supplied by the basic torch.

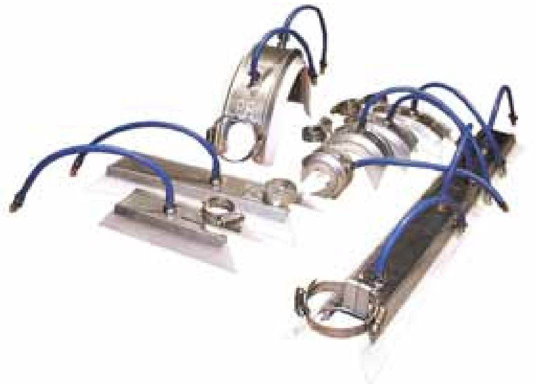
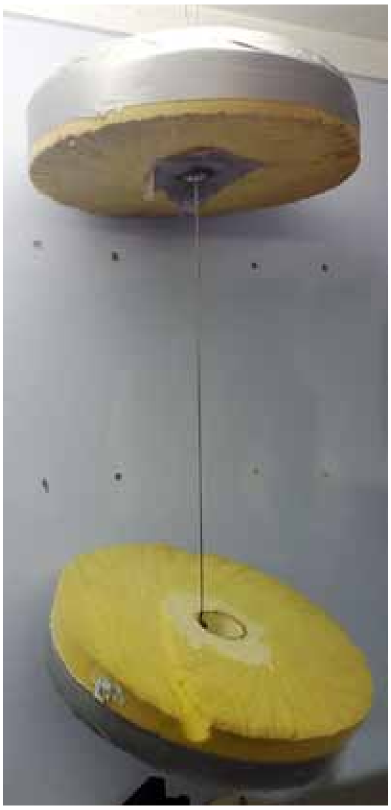


Fig 3. Standard Argweld® radiused and flat Trailing Shield®.



Pipe and tube purging

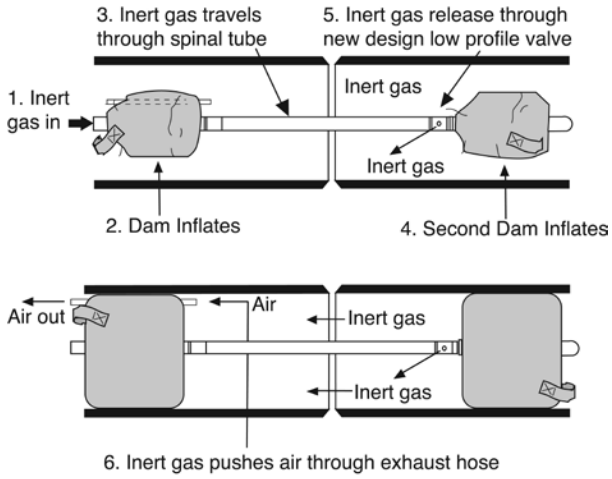
Systems for weld root protection are based on sealing the inside of a pipe on either side of the weld zone then displacing air with an inert gas. The seals must be reliable and leak tight, effective and easy to insert and remove. The inert gas must be of a quality commensurate with the need to protect the molten metal.

Gas flow should be laminar to maintain a high level of protection and pressure controlled to offer adequate coverage but without expelling molten metal from the joint. Early, and with hindsight, primitive systems, mostly home made and individually fashioned at great expense, involved the use of paper, card, wood and polystyrene discs. Often these provided at best poor sealing and on occasions burst into flames – satisfactory removal after welding presented challenges.

Ensuring that all oxygen had been removed during purging was left entirely to the skill and experience of the operator.

There were regular incidences where protection proved to be inadequate and the joint had to be re-made with consequent expense and loss of time. It comes as a surprise that these practices are still used, even by prominent fabrication companies across the world.

Fig 4 Pipe and tube purging concept.



Argweld® systems have been developed to help speed up the welding of pipes. This has been realised using a design which allows for easy and positive insertion into position and by limiting the purge volume.

The product range, which includes QuickPurge® and PurgElite® (Figures 5 and 6), has been used successfully and internationally during the welding of reactive and refractory alloys for the nuclear, liquid natural gas LNG, aerospace and process industries.

Flexible Enclosures

The highest level of protection is afforded by undertaking welding in a vacuum as in, for example, the electron beam process. A less effective process uses a metal enclosure, the 'glove box', which can be filled with inert gas. Both these techniques are relatively expensive to manufacture and only justified by companies involved in high volume production where the cost can be easily amortised.

Ultra violet stabilized engineering polymers are used throughout during manufacture of Flexible Enclosures. Material thickness is nominally 480 microns.

A large principle access leak-tight zip is fitted. Additional entry points provide for operators gloves access ports for welding torches, electrical supplies and cooling water along with purge gas entry and exhaust ports are incorporated into each enclosure.

Fig 7. Glands for electrical, weld torch and water feed through.

Fig 8. Medium size standard enclosure showing large entry zip, two sets of glove ports and a posting port.

Residual oxygen measurement instruments

Any effective weld purge process needs to be supported by suitable oxygen detecting equipment. Weld Purge Monitors® have now been developed to meet the need for reliable, robust and sensitive measurements. For reactive and refractory alloy welding these must be capable of measuring oxygen levels down to 10 ppm.

As an example, the PurgEye® 300 Plus instrument manufactured by Huntingdon Fusion Techniques HFT® reads down to 10 ppm with extreme accuracy and has a display range from 1,000 to 10 ppm.

Mains driven, the instrument has integral switching software to control external devices like power supplies or alarms and software to give QC analysis when connected to a PC.

Fig 9. An alternative version to this model is the PurgEye®500 Desk, see below, which has an integral pump to extract samples on a timed basis when no regular free flow of gas is available.

The entire Argweld® product range is supported by an extensive technical library of publications including Technical Notes, White Papers, Conference Proceedings and peer-reviewed International Articles. These are available on-line by application to Huntingdon Fusion Techniques HFT®.

References

1. ASME International, Three Park Avenue, NY 10016, USA
2. TWI Job Knowledge Pt II , The Welding Institute, Cambridge CB21 6AL, UK
3. J Watson, Welding Industry News, September 2013
4. American Welding Society, 8669 NW 36 Street, Miami, FL 33166-6672
5. ATI Wah Chang, P.O. Box 460, Albany, OR 97321
6. D Haas, The Fabricator, April 2004
7. Arc-Zone, Las Palmas Drive, Carlsbad CA 92011-1551
8. Specifications for cleaning, fusion welding …., NASA technical memorandum TM 67879, Lewis Research Center July 1971
9. Welding of Titanium and its Alloys - Pt I, The Welding Institute, Cambridge CB21 6AL, UK
10. Miller Electric Manufacturing Co., Appleton, WI 54912-1079 USA
11. Argweld® is a registered range of products from Huntingdon Fusion Techniques in the UK. www.huntingdonfusion.com