Stainless Steel Pipe Fabrication

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We are now all too familiar with demands to reduce manufacturing costs. Fabrication of stainless steel poses particular problems.

This review examines recent developments in inert gas purging and demonstrates where significant cost savings can accrue through the use of specialist contemporary purging equipment when welding pipes and tubes.

Good Practice

Joints of high quality between stainless steel cylindrical sections such as tubes, pipes and containers can only be made by ensuring that atmospheric gases are eliminated.

The presence of oxygen, and to a lesser extent nitrogen, around the molten weld can lead to wide-ranging defects. Discoloration is unsightly and in some instances might produce metallurgical imbalance, especially with some stainless steels. Gross oxidation inevitably results in reduction in mechanical properties and can cause catastrophic loss of corrosion resistance. Nitrogen contamination can result in brittleness. Gases in the weld may give rise to cracking during or after cooling.

Basic Principles

Weld root quality when making tubular joints can be ensured by applying appropriate safeguards that are based on removal of air from the fusion zone and the provision of inert gas. This is achieved by *gas purging.*

Purging Gases

The most commonly used purging gas in Europe is commercial quality argon; in the USA helium is in more general use, being less expensive. For specialised applications purging techniques using argon/hydrogen and helium argon mixtures and nitrogen have been developed.

Selection of the optimum gas or gas mixture will depend upon many factors but not least the materials being joined and the welding process used. Purge gas flow rate and pressure also need to be established and once selected they should be included in the formal welding procedure.

Variation in purge gas quality may arise during welding and it may be desirable to apply continuous gas monitoring, especially to control oxygen and moisture content. For this purpose dedicated oxygen analysers and dew point meters are available commercially.

Purging Procedure

The first requirement is to provide gas entry and exit points. Gas is fed through one

end seal with an exit hole at the other end to prevent an undesirable build-up of pressure. Argon has a greater density than air and the gas inlet should be at a lower elevation than the bleed end so that air is expelled effectively from the pipe bore.

Total purging

On small pipes and tubes, where the internal volume is small, the cost of continuous total purging may not be significant. Under these circumstances wooden or plastic discs simply taped to the tube ends will be adequate. Plastic caps employed for example to protect pipe ends and threads during transit are commonly used. It is most important that potential leak paths are eliminated and that any branch pipes are vented to ensure complete removal of air.

When total purging is impractical, perhaps because the pipe volume is large or because access is difficult, alternative containment techniques are available.

Water soluble papers and pastes

A low cost and effective solution to providing gas coverage is to make discs from water-soluble paper and tape them inside the pipes to be joined. They should not be placed in position until after any pre-weld heat treatment and be far enough apart, typically 500 mm, to avoid thermal damage during welding. Purge gas is introduced into the area between the soluble dams by means of a hypodermic tube through the weld joint line.

On small diameter pipes an effective dam can be produced simply by crumpling the paper and pushing it into the pipe bore. Soluble pastes are also available and can be convenient for small diameters.

On completion of the welding operation the paper or paste can be removed by passing water into the pipe and allowing time for it to dissolve the barrier medium.

Thermally disposable barriers

Water-soluble products are not always acceptable and an alternative method is to use cardboard discs. These are simply cut to fit the internal diameter of the pipe and, if necessary, taped in position to provide a gas seal. Distance between discs should be typically 500 mm to avoid thermal damage during welding.

The thermally disposable disc solution is convenient if welding is to be followed by a post-weld heat treatment cycle since the card is removed effectively by incineration. Otherwise general heating by torch is a sound method of removal.

The water soluble and thermally disposable barriers are expedient solutions where access to the tube or pipe bore is impractical after welding. If access can be gained, several alternative purge gas damming techniques, which include collapsible discs, rubber gasket discs and inflatable bladders, can be considered.

These dams are normally placed in the pipe at the time of joint assembly, the recovery cord or rod projecting down the access route. A spacing of 150 to 200 mm will usually prevent thermal damage during welding but it should be noted that greater spacing is prudent if pre-weld heat treatment is to be applied.

Collapsible disc barriers

Discs can be made from any readily available rigid sheet material; plywood is a good medium if in-house manufacture is planned. The discs are split across the diameter and hinged and a sealing pad of synthetic foam bonded to the periphery. Cords attached to the discs are used to collapse the dam after welding and to remove the discs from the pipe.

Rubber gasket dam

A rubber disc can be sandwiched between a pair of wooden or metal discs and some adjustment to diameter can be effected by applying axial pressure. This gasket technique is not collapsible and after welding the discs must be pulled out past the weld root, an operation that may cause difficulties.

Inflatable bladder dam

By far the most efficient purge gas containment method is to use inflatable dams such as the *Argweld*™ system[1]. This has been developed specifically to provide a re-usable solution to gas purging which is easy to use and economical when several similar joints need to be produced.

The bladder, which has sufficient length to ensure sound sealing, is manufactured from rubber with a protective canvas cover. One is placed on each side of the joint and inflated using either compressed air or the purge gas itself. The latter is much preferred since it overcomes any problems that might arise from leakage of the bladder. Variations on the basic equipment are commercially available;

Purge inlet and outlet pipes can be incorporated in the bladder to allow the full circumference to seal against the pipe wall.
High temperature covers can be provided to afford protection during weld pre-heat cycles.
Single bladders can be used for closed-end joints
Inflation and purging gas pressures can be separately controlled
Longer or shorter spinal connecting tubes are available
Provision can be made for continuous alteration in gas flow rate up to 20 l/min

The Pre-Purge Process

A pre-purge is used to displace air present in the pipework system or dam volume. Numerous factors control the pre-purge time such as pipe diameter, purge volume and maximum permitted oxygen level. A common misconception is that increasing the purge flow rate will reduce the purge time. This is fallacious. Increase in flow rate increases turbulence and results in unwanted mixing of purge gas and air and can actually extend the purge time. As a general rule the pre-purge flow rate and time should allow for about five volume changes in the pipe system or dam volume but a typical gas flow rate will be in the region of 20 l/min.

Weld joints which require a root gap or which exhibit bad end matching, both of which characteristics provide an unwanted leak path for the purge gas, can be sealed by taping.

Oxygen and moisture levels in the purge gas should be checked using appropriate equipment with checking taking place at the outlet point. Where dam inserts are being used the outlet point needs to be extended with a flexible pipe to a convenient access position. If this is impractical a system that has the purge inlet and outlet in

the same dam unit should be used.

Whilst 1% residual oxygen is a suitable working level for most stainless steels, the level needs to be as low as 0.1% (20 ppm) when welding the more sensitive alloys and those based on titanium and other reactive metals.

The Weld Purge Process

Once the quality of the gas in the dammed volume has reached the required level, gas flow can be reduced to about 5l/min for the welding operation. On a more practical level it should just be possible to feel the gas flow from the exit point. Excessive flow can cause the internal pressure in the pipe to rise and create concavity in the weld root geometry and in more extreme cases can cause complete ejection of the molten weld pool.

On joints that are not fully sealed a higher flow rate mayl be necessary to avoid contamination. Towards the end of the weld run however, as the joint becomes permanently sealed, the gas flow rate will need to be reduced to avoid over-pressurisation.

Process Costs

It is impractical to be specific across the entire spectrum of diameters and welding procedures other than to say that savings are very significant. As an example, users report that a 900 mm diameter pipe can be fully purged to less than 0.1% oxygen in under 10 minutes. There are reported savings in excess of 80% on purge time compared with alterative purging systems so that inert gas usage can be reduced dramatically as a result.

Typical analysis has been made on however on pipe diameters between 100 and 300 mm and these are presented in Table 1. An example from the *Argweld*™ range of equipment (Figure 1) is a proprietary product that uses the inflatable bladder principle.

It is clear from this basic analysis that where several welds have to be made on similar pipe diameters there can be genuine cost savings when using inflatable bladders as the sealing medium. Add this to the technical advantages of reliable sealing and ease of use and the inflatable purge bladder concept can be seen to offer significant attractions.

References

1. Argweld™ is a registered trading name of Huntingdon Fusion Techniques Ltd

2. Gas Purging Optimises Root Welds
American Welding Journal 2006

3. Gas Purging for Pipe Welding
Welding & Metal fabrication 1989

4. Innovation in Weld Protection
AWS Sheet Metal Welding Conference. Michigan May 2010

5. Effective Inert Gas Purging for Pipe Welding
International Pipeline Technology Conference. Kuwait October 2010

Table 1 Indicative times to reduce oxygen to 1% in pipes with and without the use of gas dams.

Pipe Length (m)	Pipe Diameter (mm)	Undammed Pipe (min)	Dammed using Argweld™ system (min)
10	100	26	1.5
10	200	83	4
10	300	173	8

Figure 1 Argweld *Quick-Purge*™ system