Stainless pipe welding - optimum purging for economy with efficiency

When welding stainless steel pipes, selecting the optimum pre-welding purge gas flow rate and duration is essential to minimise purging costs and achieve acceptable corrosion performance. *Paul Anderson* and *Richard Wiktorowicz* explain how welding engineers can select appropriate purge gas flow rates and times for purging for a range of pipe diameters.

Welding procedure specifications for. high quality welding of stainless steel tube and pipe require gas purging of the pipe bore, this prevents oxidation of the weld bead inside the pipe.[1] Use of an appropriate gas purge will give-e a smooth, oxide-free penetration bead with good wetting to the parent material. This will generallv provide a better contact angle with the parent material, which is preferable during service from the viewpoints of stress reduction and smoother flow within the pipe. Unsatisfactorv purging procedures result in oxidation of the penetration bead, which leads to a reduction in resistance to pitting corrosion and possible premature failure of the welded joint clue to cracking.

By using the correct equipment, effective purging and good welding procedures, it is possible to achieve corrosion resistance in the weld material similar to that of the parent material. It has been reported that, compared to inadequate purging, the expected life of an installation can increase fivefold, providing large reductions in maintcnance costs, whilst ensuring safer operating conditions.[2]

EFFECTIVENESS OF PURGING

The aim of pipe purging is to shield the rear. of the joint from atmospheric contamination. It is a two stage operation, involving pre-purge and purging during welding. The pre-purge displaces air inside a pipe with an inert or, if appropriate, reducing gas; the purge during welding maintains the low oxygen content achieved bv the pre-purge and prevents air ingress into the system.

Effectiveness of purging depends upon:

- an oxygen content inside the pipe which can be tolerated bv the material during welding, without detrimentally affecting joint performance.
- the purge gas containment system.
- pipe diameter, pre-purge gas flow rate and the pre-purge time.

Maximum oxygen content

Typicallv, the oxygen content inside a stainless steel pipe at the start of welding is limited to a widely applied maximum value of 1000ppm (0.1%).

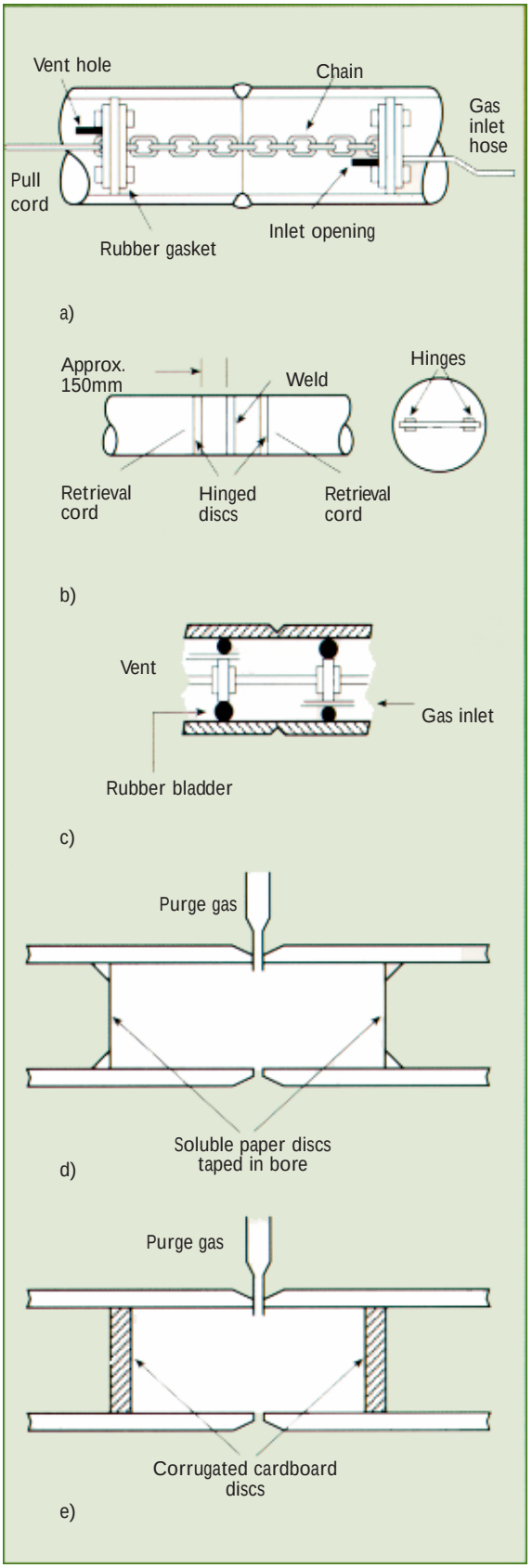

Fig.1 Examples of different types of purge dam:
a) Removable, rubber gasket;
b) Removable, hinged discs;
c) Removable, expansion bags,.
d) Thermally disposable, cardboard discs;
e) Water soluble, paper.

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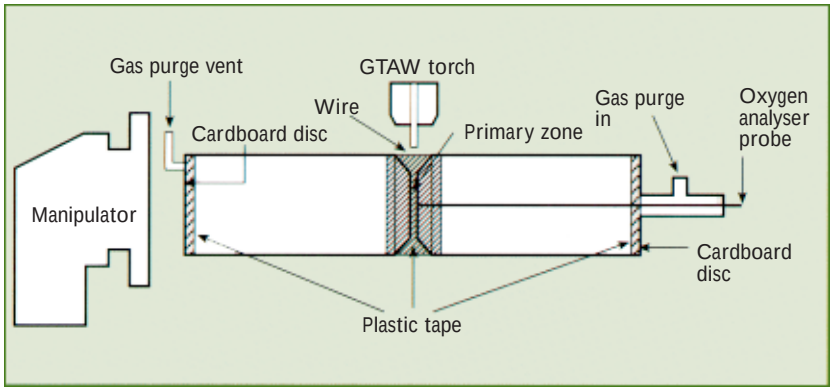

Top

Fig.2 Test assembly.

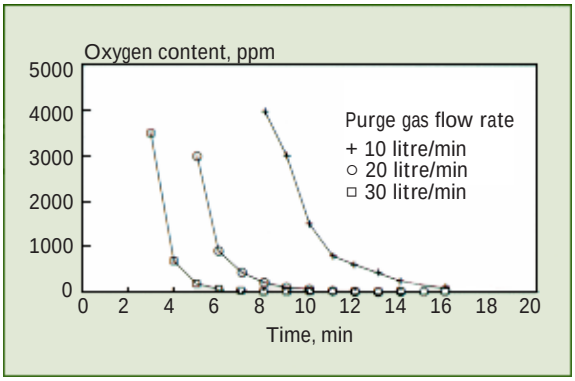

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Fig.3 Variation in oxygen content with pre-weld purge time: argon purge gas, stainless steel pipe of 240mm internal diameter, length purged 420mm.

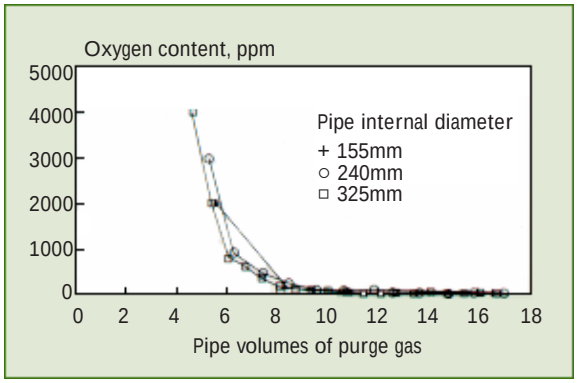

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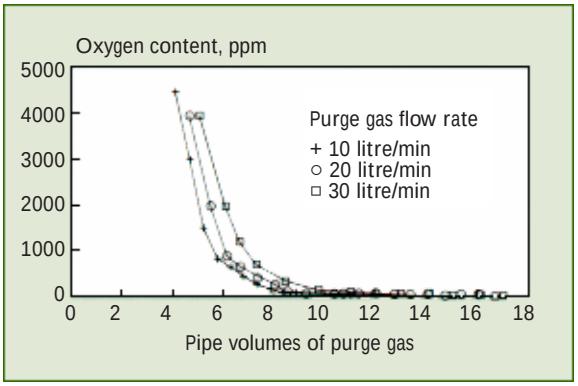
Fig.4 Relationship between oxygen content and pipe volumes of purge gas for three pipe diameters: argon purge gas, flow rate 20 litre/min.



Bottom

Fig.5 Relationship between average oxygen content and pipe volumes of purge gas for four pipe internal diameters: 62.5, 155, 240 and 325mm argon purge gas.

This is based on observations that the corrosion resistance of stainless steel weld metals is significantly lower than the parent material where the oxygen content of the purge gas exceeds this figure.[2] Reductions in the oxygen content below 1000ppm lead to further improvement in the corrosion resistance.[3] With an oxygen content of below 150ppm (0.015%), it has been reported that the corrosion resistance of the weld metal is similar to that of the parent metal;[2] but achieving this level during fabrication may not always be practical.

Purge gas containment

Two approaches can be applied to purging pipes: purging the entire system, or rising localised purge dams. The most suitable approach depends on access, pipe diameter, available equipment, joint configuration and economic factors.

Total purging of the pipe system is normally only applied to small diameter pipes, where the volume inside the pipes is not considered a significant gas cost factor, or where there are access restrictions preventing rise of localised systems. The purge gas is fed through a hole in a dam at one end of the system, and escapes through a bleed hole in the dam at the other end of the pipe system, thus preventing gas pressure build-up. With argon purge gas, which is denser than air, normal practice is for the purge gas inlet to be at a lower level than the bleed hole. It is important that any leak paths are sealed and that an. is vented from any branch pipes with blind endings.

Localised purging is used where system purging is impractical due to large volumes or excessive costs. This normally involves use of purge dams, which are placed in the pipe during joint assembly. There are several different types of dam which may be used, ***Fig.l,*** these include:

- Removable dams, such as hinged collapsible, expansion bags (inflatable bladder dams) arid rubber gasket discs. These are retrieved following welding by using attached pull cords or rods.
- Thermally disposable dams, such as cardboard discs. These are normally reduced to ash during post weld heat treatment, and subsequently washed away.
- Water soluble paper, in the form of discs which are taped or glued (using a water soluble paste) inside the pipe. After, welding, these are dissolved by water flowing through the pipe.

It is necessary to place the dams at a sufficient distance from the joint to prevent thermal damage during the welding process.

Pre-weld purging

To demonstrate the relationship between pipe diameter, pre-purge gas flow rate, and pre-purge time, a series of trials was carried out using argon purge gas. This involved the purging of four stainless steel pipe assemblies with close-fit joints, of internal diameters 62.5, 155, 240 and 350mm. The joint was subsequently welded rising the TIG process, arid the pipe ends were sealed using wooden dams arid plastic tape. The oxygen contents were measured at the mid-point inside the pipe using a Dansensor SGI analogue sensing device, ***Fig.2.***

Results showed that, for a given pipe diameter, as the purge gas flow rate increases, there is a reduction in the purge time required to achieve a given oxygen level, ***Fig.3.***

For a given flow rate, the number of pipe volume changes of purge gas required to achieve a given oxygen content was shown to be largely independent of the pipe diameter, ***Fig.4.*** This can be attributed to laminar gas flow in the pipe, where the (inert) purge gas is simply displacing the pipe atmosphere in similar proportions. This relationship has been shown to be valid for, different gas flow rates tip to 30 litre/min, ***Fig.5.***

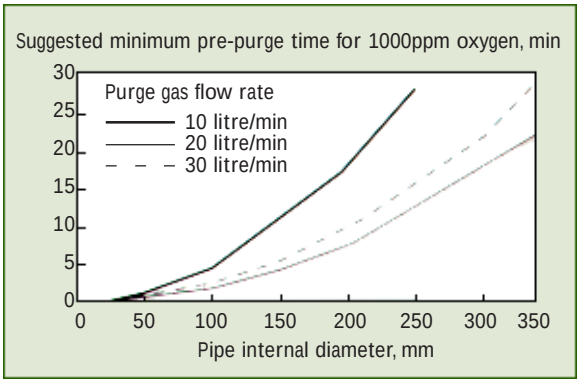


Fig.6 Suggested minimum purge times to achieve 1000ppm oxygen in one metre length purged pipes, argon purge gas.

From the data generated it is possible to plot suggested minimum pre-purge times to achieve an oxygen level of 1000ppm in a one metre long pipe, for various pipe diameters, with three different gas flow rates. This allows a minimum pre-purge time for pipe sizes up to 350mm diameter to be quickly assessed, ***Fig.6.*** It must be noted that these results apply to an 'ideal' case with a closed joint, ie zero root gap and effective purge gas containment. In practice, presence of a root gap can allow additional air ingress into the purge, and longer pair times will be required to achieve the same reduction in oxygen content. Adhesive tape is frequently used to seal the root gap and prevent air ingress which is removed progressively during welding.

It should be noted that the cost of gas used typically represents only a small proportion of the total welding costs for a particular fabrication, and the purge gas consumption can be a significant proportion of the total gas used. Selection of an appropriate flow rate should consider labour costs for the time to purge to the required oxygen level plus the costs of the purge gas used.

Purging during welding

When the atmosphere within the pipe has reached the required quality level, the gas flow should be reduced to maintain only a slight positive pressure, (so that the gas flow is just discernible at the outlet port). An excessive flow rate will cause internal pressure in the pipe system, which may result in a concave root weld bead profile and possible weld blow out on completion of' the joint. A typical purge gas flow rate during TIG root welding of 150mm internal diameter stainless steel pipe would be 4-6 litre/min.

IMPLICATIONS WHEN USING BS 4677: 1984

This recommends that the volume of purging gas should be at least six times the volume of air displaced. However, using a six-volume change rule ma not always be sufficient to achieve the required reduction in oxygen content (see Fig.1) when the decrease in the efficiency of purging with increasing flow rate is considered. To ensure satisfactory joint performance it is therefore recommended that the oxygen level in the purge gas should always be monitored to ensure that it is below the required value. This could be carried out using one of the commercially available hand-held meters.

SUMMARY

- For high quality pipe welds, effective purging of the pipe bore is a prerequisite.
- Oxygen content inside the pipe will depend upon the purge gas flow rate and the duration of purging. As the purge gas flow rate increases, there is a reduction in purge time needed to achieve a given oxygen level, although the volume of gas used increases.
- Applying the six-volume change gas purging rule may not necessarily lead to an oxygen level in the pipe of 0.1% or less. To ensure satisfactory joint performance it is recommended that the oxygen level inside the pipe should always be monitored to ensure-e that it is below the required value.

References

1 BS 4677: 1984: 'Arc welding of austenitic stainless steel pipework for carrying fluids.'
2 Tapp J et al: 'Lower oxygen levels when welding improve corrosion resistance.' *Tube International* 1994 March, 131-133.
3 Odegard L. and Fager S-A: 'The root side pitting resistance of stainless steel welds.' *Sandvik Welding Reporter* l990 (1).
4 Sewell R A: 'Gas purging for pipe welding.' *Welding & Metal Fabrication* 1989 (1) 20-22. ✤

TWI has several projects relevant to this subject: working confidentially for individual clients or for groups of companies, and as part of' its core research programme. For example, work is being carried out on the development of shielding gases; on penetration control in TIG and A-TIG welding; and to develop mechanisms for understanding how A-TIG fluxes work.