GAS PURGING FOR WELD ROOT CONTROL IN PIPE WELDING

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For many pipe welding applications the physical characteristics of welds may not be important. Fillet and non fully penetrating welds have inherent crack like defects but these are seldom of any consequence.

In circumstances where joints have to be designed to withstand stress in service or they need to be free from the risk of product entrapment or they need to be able to offer good flow characteristics, however, special consideration needs to be given to metallurgical aspects and to weld profile.

The mechanical properties of welds, particularly their fatigue properties, can be influenced significantly by their shape and composition. In particular, at the weld root, a positive reinforcement combined with smooth transition from weld to parent material are pre-requisites if optimum mechanical strength, flow characteristics and lack of product entrapment are to be realised.

Guidance on weld root profile control for linear butt welds is provided elsewhere. Here we examine solutions when making tubular butt welds.

GOOD PRACTICE

Joints of high quality between cylindrical sections such as tubes, vessels and pipes can only be made by ensuring that :

a) Atmospheric gases are eliminated and

b) Positive, smooth weld reinforcement is provided

1) The presence of oxygen and to a lesser extent, nitrogen, around the molten weld can lead to wide ranging defects.

Discolouration 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. Furthemore, product entrapment and contamination by such oxidations is unacceptable in most cases.

Nitrogen contamination can result in brittleness. Gases in the weld may give rise to cracking during or after cooling.

2) It is clear that a reduction in weld section at the root, as evidenced by a concave geometry will reduce the joint strength. Perhaps not so evident but in many applications of crucial importance is the presence of notches or cracks which tend to appear at the weld/parent material interface. These can propagate in service and cause failure.

BASIC PRINCIPLES

Weld root quality when making tubular joints can be ensured by applying appropriate safeguards which are based on removal of air from the fusion zone and the provision of inert gas. This is achieved by gas purging and the general principles are shown in Figure 1.

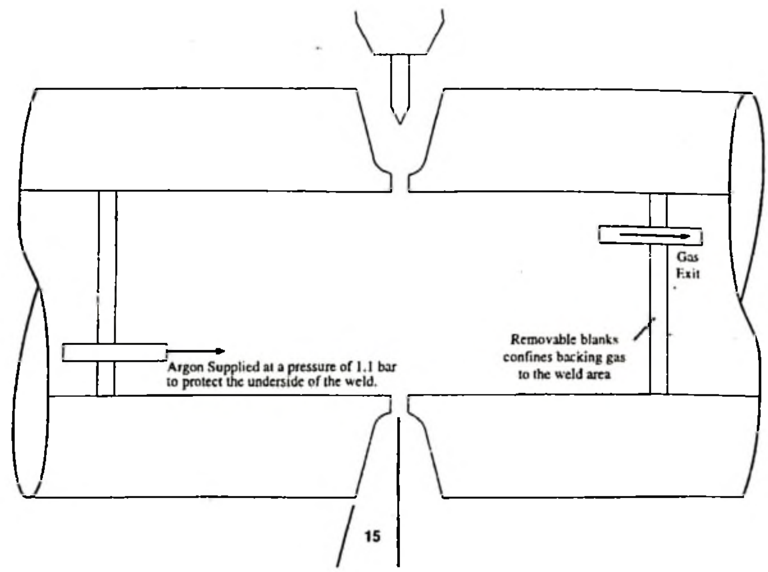

Fig. 1 : Principles of Gas Purging.

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 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 dewpoint 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 or foam bungs inserted in the pipe, are commonly used to contain the purge. 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.

There is always a danger however that wooden, foam or plastic discs will outgas during the weld cycle and cause air or moisture to enter the weld space leading to porosity, coking or oxidation of the weld root. This can be prevented by the use of a quality nylon purge plug as shown in Figure 14.

When total purging is impractical, perhaps because the pipe volume is large and it would be too costly with gas and waiting time, alternative containment techniques are available.

WATER SOLUBLE FILM

A low cost and effective solution to providing gas coverage is to make discs from water soluble film and glue them inside the pipes to be joined using water soluble adhesive. They should not be placed in position until after any pre-weld heat

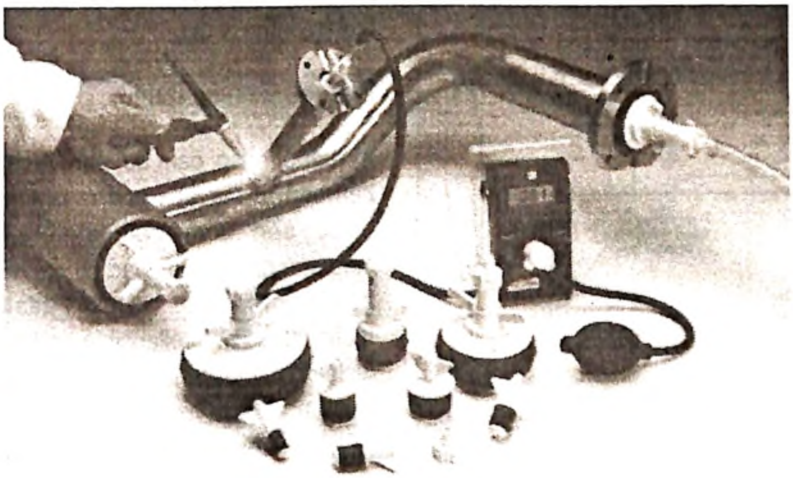

Fig. 14 : ARGWELD Nylon Purge Plugs.

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 as shown in Figure 2.

On small diameter pipes an effective dam can be produced simply by crumpling the film and pushing it into the pipe bore.

On completion of the welding operation the film is removed by passing water into the pipe and allowing time for it to dissolve the barrier medium.

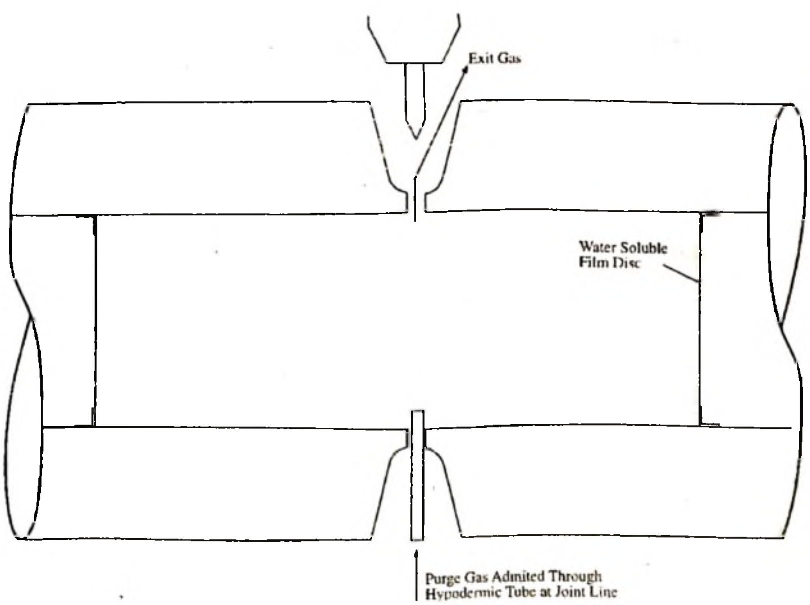

Fig. 2 : Use of Water Soluble Paper.

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 taped in position to provide a gas seal. Distance between discs should be typically 500 mm to avoid thermal damage during welding The principle is shown in Figure 3.

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.

Again, as mentioned previously, tape, wood and paper will outgas during the welding cycle and there is a risk of water vapour and oxygen contacting the hot metal and causing porosity, coking and oxidation.

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

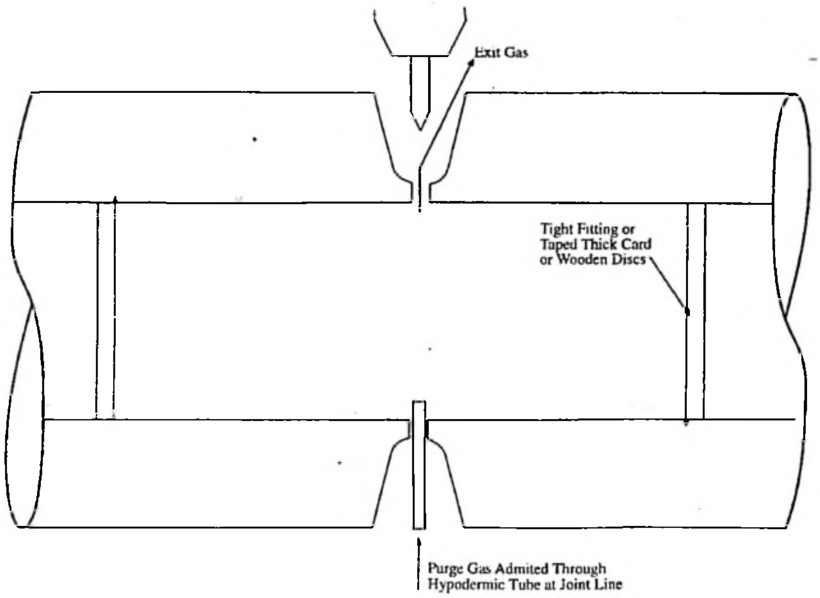

Fig. 3 : Thermally Disposable Barriers.

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. Heat resisting covers are also available for instances where greater spacing may not be possible or desirable.

Collapsible Disc Barriers

Discs are 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. Figure 4 shows the principle of operation.

Again, as mentioned previously, such materials contain air and water vapour and may outgas into the purge stream during welding and damage the weld.

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 which may cause difficulties. Figure 5 is representative.

A disadvantage with this technique is that discs need to be available for every tube or pipe internal diameter otherwise loose discs will leak air and tight discs will not be easily pulled into position or removed.

Inflatable Bladder Dam

By far the most efficient and versatile purge gas containment method is to

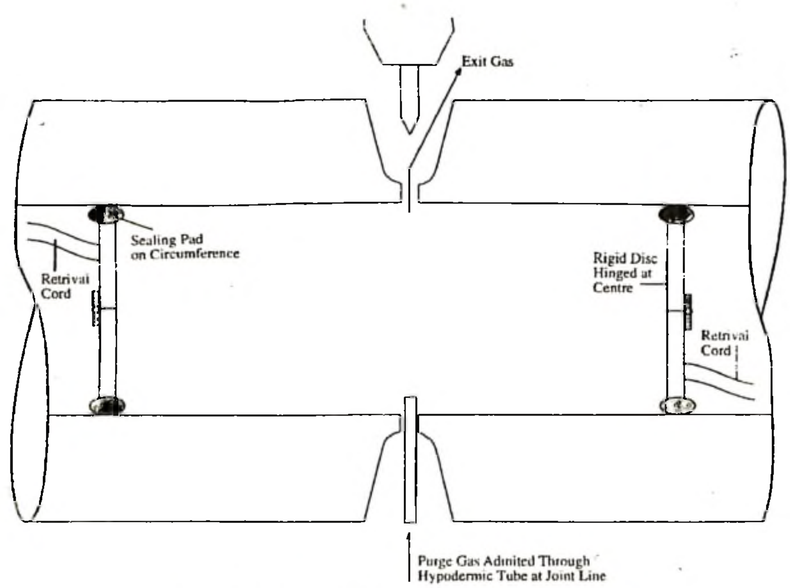

Fig. 4 : Use of Collapsible Disc Barriers.

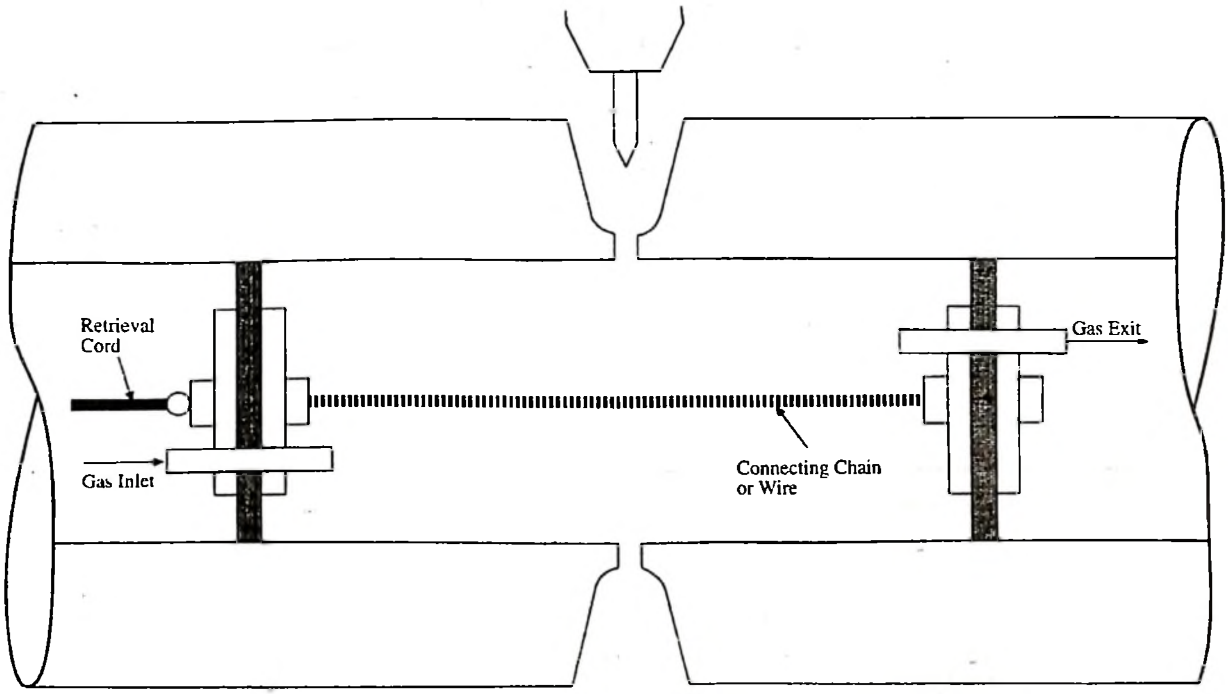

Fig. 5 : Use of Rubber Gasket Barriers

use inflatable bladders such as the **Argweld®** system. This system 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 the purge gas itself.

Figures 6 to 10 illustrate the bladder concept and Figure 11 shows typical products. Variations on the basic equipment are commercially available;

Purge inlet and outlet pipes are incorporated in the bladder to allow the full circumference to seal against the pipe wall.

High temperature covers are provided to afford protection during weld preheat 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.

THE PRE-PURGE PROCESS

A pre-purge is used to displace air present in the pipework system or contained 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 falacious. 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

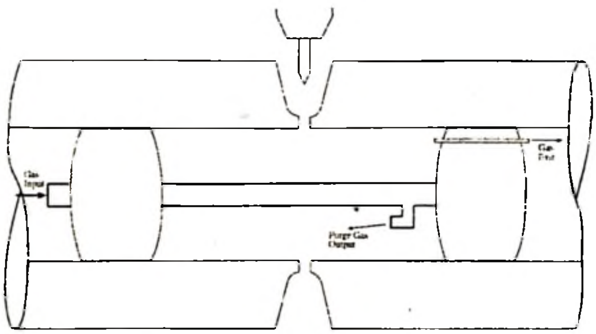

Fig. 6 : Use of Inflatable Purge Bladders

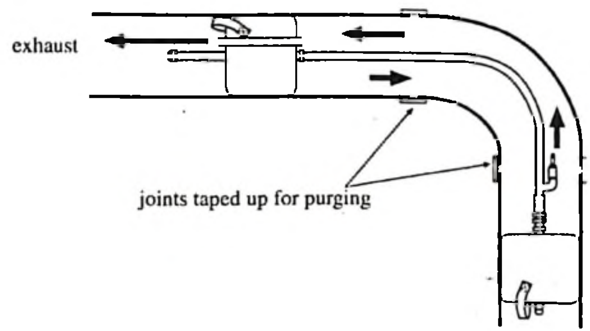

Fig. 7 : 90° Blend

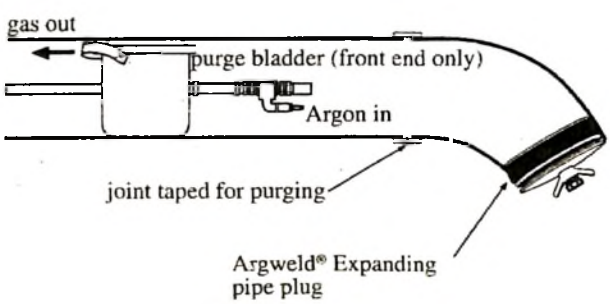

Fig. 8 : Same with expanding plug

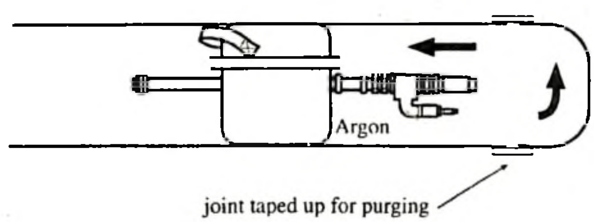

Fig. 9 : Dome end

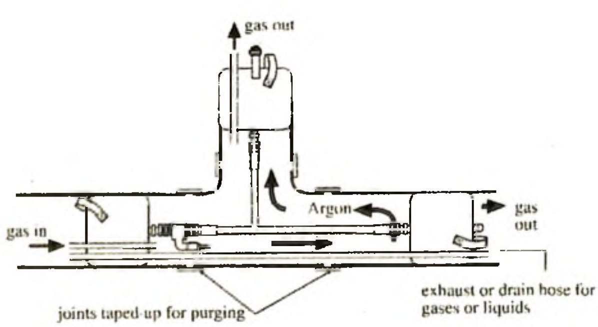

Fig. 10 : Tee Piece

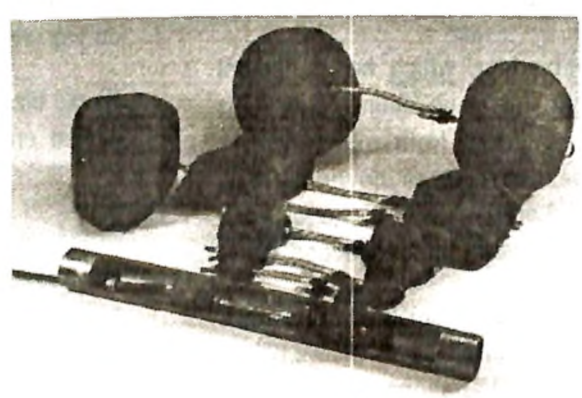

Fig. 11 : ARGWELD MKIII Purge Bladders

the region of 20 l/min. Figure 12 is an illustration of the relationship between pre-purge time and pipe diameter based on a pipe purge length of 300 mm.

For different purge lengths it is reasonable to use a pro-rata calculation. Table 1 presents examples of purge times for different pipe diameters and flow rates.

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.

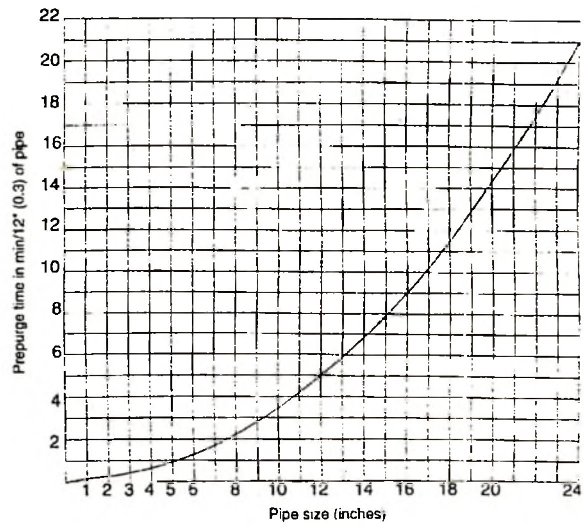

Fig. 12 : Pre purge time Vs pipe diameter

Prepurge time for 12" of pipe at a flow rate of 50ft³/hr (23.5 ltrs/min)

To calculate the prepurge time for any length of pipe, multiply the value obtained from the chart by the length of pipe.

Example : Find the time required for prepurging 200' (60m) of 5" (127mm) pipe. From the chart at 5" pipe size, get 1 minute/12" (0.3m) of pipe, hence 200' (60m) = 200 mins or 3hrs & 20 mins.

TABLE 1

Purge times for different pipe diameters and flow rates

Purge times for TIG welding of steel pipe

Pipe Diameter in	Pipe Diameter mm	Flow Rate ft3/hr	Flow Rate ltrs/m	Purge time min	Vent diameter in	Vent diameter mm
3	75	20	10	3	1/16	1.5
4	100	20	10	3	1/16	1.5
5	125	20	10	5	1/8	3
6	150	20	10	6	1/8	3
8	200	25	12	8	1/8	3
10	250	25	12	13	1/8	3
12	300	30	15	13	1/8	3
14	350	30	15	16	—	—
20	500	35	17	25	—	—

Upon completion of purging cycle, reduce flow rate to maintain slight positive pressure during welding.

Note : Purge time and flow rates were those required to reduce the oxygen to 1% or less, based on enclosure of 12" (300 mm) in length. When enclosures exceed 12" length, increase flow time proportionally.

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 which has the purge inlet and outlet in the same dam unit should be used.

Figure 13 gives times to reduce the dam volume oxygen content to below 1 % using inflatable bladders. Whilst 1 % residual oxygen is a suitable working level for materials such as stainless steels, the levels need to be as low as 20 ppm when welding the more sensitive alloys based on titanium and other reactive metals.

THE WELD PURGE PROCESS

Once the quality of the gas in the dammed volume has reached the

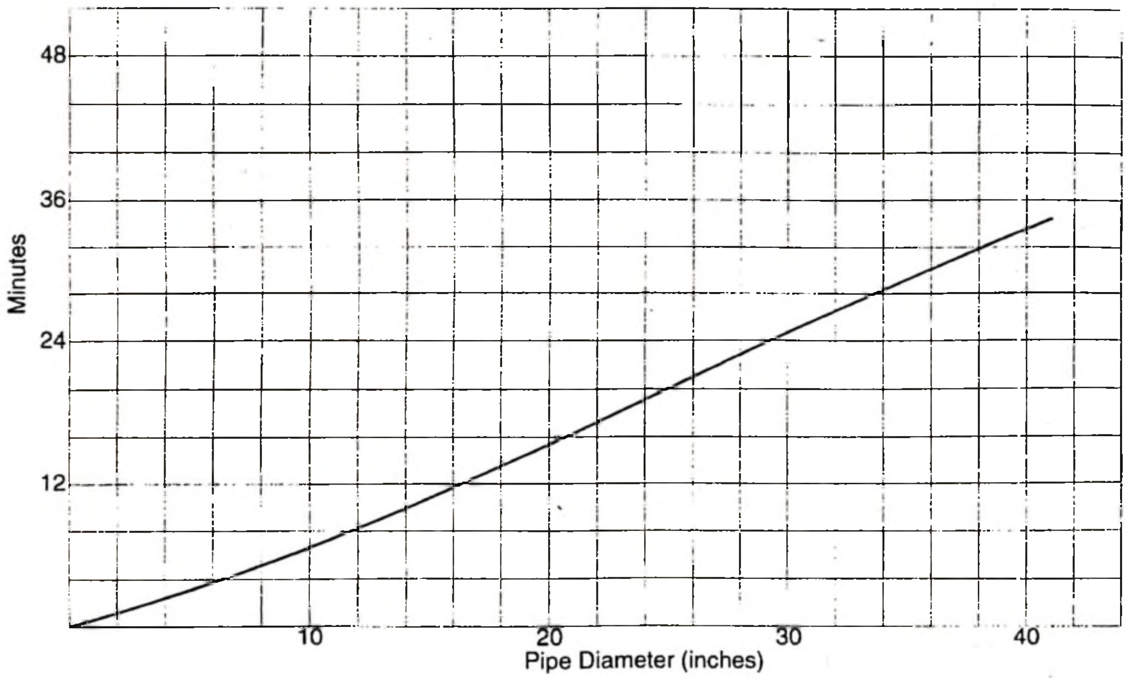

Fig. 13 : Times to reduce oxygen to 1%

required level, gas flow can be reduced to about 15 l/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 which are not fully sealed to restrict leakage high flow rate will 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

Providing precise data on cost comparisons between the different purging techniques is difficult not least because the pipe diameter and wall thickness have a profound influence on the cost. Furthermore it is impractical to use removable inserts in sealed pipes or in pipes and tubes with diameters much below 75 mm. Typical comparisons have been made however, on pipe diameters between 100 and 600 mm and these are presented in Table 2. The **Argweld®** System is a proprietary product which uses the inflatable bladder principle and the costs of applying this are compared with the cost of continuous purging on a 10 metre long pipe.

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.

NOTE

Argweld® Purge Bladders is a registered trademark of Huntingdon Fusion Techniques Limited, Cambridgeshire, United Kingdom.

TABLE - 2 : COST COMPARISONS				
Pipe Diameter mm (in)	100 (4)	200 (8)	300 (12)	600 (24)
Time saved - minutes				
Purge time for conventionally purging the pipe to 1 % oxygen	26	83	173	706
Purge time with Argweld to 1 % oxygen	1 .5	4	8	19
Time saving with Argweld	24.5	79	165	687
Gas Savings - ltrs (cu ft)				
Gas used for purging the complete pipe conventionally	624 (21.66)	1992 (69.14)	4152 (144)	16940 (588)
Gas used for purging with Argweld at 10 ltrs/mm	15 (0.53)	40 (1.41)	80 (2.83)	190 (6.71)
Gas saved with Argweld	609 (21.13)	1952 (67,73)	4072 (77.17)	16750 (183.29)
Money Saved				
Assume one person per hour cost £15 whilst waiting	£6.12	£19.75	£41 .25	£171.75
Assume one bottle Argon 8500 ltrs (300 cu ft) cost £30	£2.16	£6.90	£14.37	£59.13
Total savings per weld	£8.28	£26.65	£55.62	£230.88
Typical cost of Argweld system	£110.00	£120.00	£140.00	£210.00
Number of welds for payback	14	5	3	2

Notes

1. Each gas user in each country will pay different price for gas.
2. Waiting time will be changed differently for each job and will vary from country to country.
3. This chart is merely intended as a guide only to show that **Argweld Purge System will pay for itself in only a few welds**