RESEARCH SHOWS THAT X80 PIPE CAN BE ECONOMICALLY AND SAFELY WELDED BY CONVENTIONAL METHODS

Ken Bilston, Leigh Fletcher, Max Kimber and Phil Venton
APIA/WTIA/CRC for Welded Structures Pipelines Research Program
Management Committee

An incorrect perception has developed that X80 pipe in typical Australian pipelines cannot be welded by conventional stovepipe welding using cellulosic electrodes. This is not the case as is shown in this article.

Any procedure for welding a natural gas pipeline constructed to the Australian Pipeline Code AS2885 must result in the following minimum outcomes:

(1) Freedom from cracking

The joints must be free from cracks over the range of essential variables. This is absolutely critical due to the difficulties in finding planar defects with conventional NDT, and because hydrogen cracking may occur after NDT has been carried out. In short, the prospect of cracking must be designed out of the welding procedure. The key parameter to be addressed is the hot pass delay time, and in extreme circumstances, preheat may be necessary to extend the window of available hot pass delay time.

(2) Resistance to brittle fracture

The joints must have sufficient fracture toughness so that in the presence of planar defects at the limit permitted in the defect acceptance criteria, failure will occur in a ductile manner. That is: brittle fracture must not be possible.

(3) Sufficient strength

The joints should have sufficient strength so that there is a high probability that when a joint containing planar defects at the permitted limit is overloaded in axial tension or bending in special locations in the pipeline, the weldment will be strong enough to cause significant plastic strain in one of the pipes each side of the joint before fracture occurs. That is, the strength of the joint should exceed that of the parent metal. As a result, failure can only occur by gross section yielding (of the parent metal) rather than by yielding of the nett section of the weld. There is no universal agreement on the actual minimum acceptable value of strain which must occur in the base metal prior to fracture. However there is general agreement that a level of 0.5% is sufficient. 0.5% strain in a 15m length of pipe represents a displacement of 75mm and is sufficient to accommodate the displacements that might occur in special locations in a petroleum pipeline, such as in areas of land slip, in highly erodable valleys, or in river crossings.

In the remainder of the pipeline, where there is not a significant threat of high axial tension or bending forces, it is not essential that the strength of the joint be sufficiently strong to overmatch the strength of the strongest pipes in the statistical population of the order. A good example of this is given by the fact that it is accepted practice at present to weld X70 pipelines with a combination of E6010 and E8010 cellulosic electrodes. This combination is undermatched by any definition, and would be likely to fail by nett section yielding if overloaded in tension in the presence of weld defects at the limit of AS2885.2 Tier 2.

All these issues of welding thin walled high strength pipelines have been under investigation for the last three years within the CRC for Welded Structures with sponsorship from a large number of companies in the pipeline industry in Australia and overseas. An abbreviated summary of the findings of the research is set out in the following table. The table shows that in addition to the obvious choice of GMAW, there are clear alternative options available for field welding X80 pipe. This includes the very definite option of using a conventional cellulosic electrode stovepipe welding procedure for thicknesses in the range 8-9.5mm. The information in the table for thicknesses up to 9.5mm is based upon preheat-free welding.

These comments and recommendations are qualified by the observation that a good deal more care and attention needs to be given to the specification and quality assurance of welding consumables than is usual at present. The research has shown that the quality and variability of the weld metal produced by some of the consumables which were considered was inadequate, especially in the achievement of strength and toughness.

Any person or company interested in the detailed results of the research work should contact the CRC for Welded Structures to inquire about participation in the on-going research work and thereby obtain the outcomes and conclusions of the work done so far on welding X80 thin-walled pipe.

Welding Methods for Thin-Walled X80 Pipelines

Pipe Thickness (Range)	Welding Method	Potential for Hydrogen Cracking Note 1	Potential for Brittle Fracture	Potential for Nett Section Yielding		Overall Rating	
				Tier 1 Defects (Workmanship)	**Tier 2 Defects (Fitness for Purpose)**	**Other Locations**	**Special Locations**
4-7	Gas Metal Arc GMAW	Not so far encountered	Very low. Excellent weld metal properties	Very low. Overmatching easily achievable	Very low. Overmatching easily achievable	Accept-able	Accept-able
	Hybrid: E8010 root E10018 hot pass, fill and cap	Possible. Control of hot-pass delay required	Very low. Excellent weld metal properties	Low. Note 2	Significant. Note 2	Accept-able	Not recomm-ended
	Hybrid E6010 root E91T8 FCAW hot pass, fill and cap	Significant. Control of hot-pass delay required Note 3	Significant. Note 4	Low. Note 5	Significant. Note 5	Not recomm-ended	Not recomm-ended
	E9010 throughout	Significant. Control of hot-pass delay required	Very low. Adequate weld metal properties	Significant. Note 6	Substantial. Note 6	Accept-able	Not recomm-ended
8-9.5	Gas Metal Arc GMAW	Not so far encountered	Very low. Excellent weld metal properties	Very low. Overmatching easily achievable	Very low. Overmatching easily achievable	Accept-able	Accept-able
	E6010 root E9010 hot pass, fill and cap	Significant. Control of hot-pass delay required	Low. Adequate weld metal properties Note 7	Low. Note 8	Significant. Note 8	Accept-able	Not recomm-ended
	Hybrid E8010 root and E10018 hot pass, fill and cap	Possible. Control of hot-pass delay required	Very low. Excellent weld metal properties Note 7	Very low.	Very low.	Accept-able	Accept-able
	Hybrid E6010 root and E91T8 FCAW hot pass, fill and cap	Significant. Control of hot-pass delay required Note 3	Substantial. Note 4	Very low.	Significant.	Not recomm-ended	Not recomm-ended
Greater than 9.5	Not considered; in general very low hydrogen processes such as GMAW and/or preheat should be employed. Special attention needs to be given to the avoidance of hydrogen cracking. Preheat may be essential.						

Notes to the table

1. Comments indicating the likelihood of hydrogen cracking are based upon preheat-free welding up to 9.5mm thickness. The terms 'possible' and 'significant' are intended to indicate that hydrogen cracking may occur unless care and controls are exercised. Readers are referred to the Proceedings of the recent Hydrogen Cracking Conference which are available from WTIA.
2. Low penetration characteristic of EXX18 electrodes makes it difficult to achieve a high enough proportion of cross sectional thickness to be made up of the high strength component of the weld metal.
3. E91T8 consumables may contain around 10ml/100g H_2 and so should not be regarded as immune to hydrogen cracking.
4. Self shielded FCAW weld metal in the as-deposited condition may sometimes exhibit low toughness.
5. The achievement of matching strength will depend upon the degree of penetration of the E91T8 weld metal into the E6010 root pass.
6. When assessed using all methods other than full scale (entire pipe circumference) tension tests the weld is undermatching. Limited full scale test evidence indicates satisfactory performance. Procedure qualification would need to include such testing.
7. Adequate weld toughness needs to be demonstrated.
8. When assessed using conventional methods such as hardness and joint tensiles the weld is undermatching. Wide plate tests show that Tier 1 defect acceptance criteria can be met. Full scale (entire pipe circumference) tension tests are believed likely to show that Tier 2 defect acceptance criteria would be met. Such tests could be included in procedure qualification if Tier 2 was considered essential.