Energy Networks Australia

Distribution Networks Steel Pipe In-Service Welding Guideline

ENA DOC 053-2024

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Contents

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Tables

Key Information

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Acknowledgements

This is a Reference Group project of Energy Networks Australia Gas Technical Reference Group (GTRG).

The Energy Networks Australia Gas Technical Reference Group has broad national representation from a number of industry representatives and has access to a large database of industry guidelines, policies, reference standards and design manuals.

Energy Networks Australia has Members across Australia’s electricity distribution and transmission and gas distribution companies. For the development of this guideline the following industry organisations were represented on the Reference Group:

» AGIG, APA, Atco, AusNet, Jemena, Multinet Gas, Tas Gas

The remaining companies represented by Energy Networks Australia, but not on the Reference Group, were actively engaged throughout the preparation, review and comment stages of the draft document.

In addition, a number of technical experts and stakeholder groups have also been consulted during the development of this document.

The Reference Group would like to acknowledge the assistance of all these parties and specifically:

» Jeff Jones (Project Delivery Assurance)

Documents of Energy Networks Australia

History of Energy Networks Australia

Energy Networks Australia is the peak national body representing Australia's gas distribution and electricity transmission and distribution companies. Established in its current form in 2004 it has a long history of industry representation, operating under different names over the years to reflect the sector transformation.

With more than 16 million customer connections across the nation, Australia's energy networks provide the final step in the safe, reliable delivery of gas and electricity to virtually every home, business and industry in the country.

Documents

Part of Energy Networks Australia's role is the development and management of support material such as codes, specifications, guidelines and handbooks to support the energy industry and members of the public in the interpretation and application of legislation and standards. All documents are written in collaboration with the industry through reference groups and general consultation with Energy Networks Australia's members.

This guideline is just one document in a framework of information designed to support the energy sector. Network Operators and Service Providers should refer to all current Energy Networks Australia Guidelines. A full list of documents can be obtained from Energy Networks Australia at http://www.energynetworks.com.au/industry-guidelines.

Definitions and Abbreviations

Below are the definitions of terms and abbreviations used in this guideline and in the Industry Risk Assessment:

Table 1 - Definitions and Abbreviations

Abb'n	Term	Definition
Threat Description		
	Carrier Pipe	Distribution pipeline being welded onto
DN	Diameter Nominal	Inside pipe diameter in mm. This Guideline assumes pipes with a diameter between DN40 and DN450
	Grade	Material grade e.g. API 5L Grade X42
WT	Wall Thickness	Thin, Standard, Thick
	Thin Wall Pipe	Wall thickness under 4.8mm. The risk of burn through is considered significate.
	Standard Wall Pipe	Wall thickness equal to 4.8mm, and up to 6.4mm. The risk of burn through is considered likely and is certainly possible.
	Thick Wall Pipe	Wall thickness equal to and above 6.4mm. The risk of burn through is considered unlikely.
	Flow Rate	Flow rate of gas through the live pipe to be welded on. A critical factor in the planning and outcome of an in-service weld
	Low Flow Rate	low or no (such as dead end mains) flow reduces the cooling rate produced by the gas, which resultantly increases the risk of burn through. As a general rule, a flowrate below 1m/s may be considered as adding little cooling effects.
	Normal Flow Rate	Normal flow rate has the ability to give a good balance of high enough cooling to reducing burn through risk but low enough cooling effect limit the HACC threat. These flow rates are between the low and high velocities.
	High Flow Rate	High flowrates may add cooling effects to the pipe, weld metal and HAZ. As a result, the risk of burn through should generally decrease, however resultant hardness will increase. Typically these flow rate are above 6m/s, dependant on pressure.
	Type	Type of fitting
	Size	Size of fitting
	Grade	Grade of fitting
	Operating Pressure	Normal operating pressure of the live gas main expected at the time of in-service welding.
	SMYS %	Max 20% for steel gas distribution pipes complying with AS/NZS 4645.2.
	Network Operator	In this Guideline is defined as the entity responsible for managing the risk, planning and undertaking the in-service welding operation.
Threat Consequences		
	Weld Strength	Refers to the ability of the completed weld to be able to withstand design loading including pressure containment, external impacts, fatigue stress etc.
	Burn-Through	Where too much heat energy is applied during an in-service weld, reducing the pipe strength to below its pressure containing minimum, leading to loss of containment of the carrier pipe in the localised area of the welding arc.

HACC	Hydrogen Assisted Cold Cracking	Where the presence of hydrogen in welding electrodes leads to entrapment of hydrogen in the weld, resulting in cracking of the completed weld.
	HACC risk and wall thickness relationship	Whilst HACC relies on several factors, an increase in cooling rate is a direct impact to increase of HAZ and weld metal hardness. As wall thickness increases, so does the cooling rate during welding. This is to include a combination of the pipe and fitting wall thickness. Pre-heat and higher heat input will aid in mitigating the effects of high cooling rates from high wall thickness.
	Credible	The threat is considered credible with the application of initial controls.
	Hole Size	Size of the hole created in the live pipe either due to burn through or HACC.
	Flow	Flow of gas through a hole created by either burn through or HACC. Considered to be either Zero, Low, Medium or High for risk assessment purposes
	Energy Rate	The resultant energy rate of the gas flow from the hole created either due to burn through or HACC. Considered to be ether Low, Medium or High for risk assessment purposes.
Design / Operating Controls		
	Welding Supervisor/Inspector	Person who has the qualifications as detailed in section 3.3 AS/NZS 2885.2 – 2020, to witness all welding operations and undertake an examination of the weld including visual inspection.
	Confirm Fit-up	Prior to commencing the in-service weld, the welding surfaces preparation and position of the fitting on the pipe is confirmed to comply with the requirements of the WPS.
	Code	AS/NZS 4645.2 or AS/NZS 2885.2
	CE Limit	Ensuring that the CE values of the pipe and fitting are with the limits of the essential variables of the WPS
	Low Hydrogen Electrode	Consumables which have a “hydrogen controlled” designation as per AS/NZS 2885.2 – 2020 Table 4.2.1 or AS/NZS 4645.2 – 2018 Table 4.3.1.
WPS	Weld Procedure Specification	To meet the requirements of AS/NZS 4645.2 or AS/NZS 2885.2
WPQR	Weld Procedure Qualification Record	To meet the requirements of AS/NZS 4645.2 or AS/NZS 2885.2
	Weld-log/Inspector	The presence of a welding supervisor/ inspector, monitoring and logging the weld during welding, and providing feedback to the welding on their heat inputs.
NDT	Non Destructive Testing	Testing conducted to determine presence of defects that does not physically impact or destroy the weld under test. Typical industry methods include visual, radiography, ultrasonic, magnetic particle and dye penetrant.
	Pre-weld NDT	Non Destructive Testing undertaken prior to in-service welding to determine specifications and condition of the of the live gas pipe at the location of the weld.
	Post-weld NDT	Non Destructive Testing undertaken post weld to confirm the soundness of the completed weld.
V	Visual Examination	Visual inspection of the completed on the live gas pipe prior to welding confirm external surface of pipe is free from defects. Visual inspection undertaken on the completed weld to confirm weld is free from defects. Refer to section 4.10 AS/NZS 4645.2:2018
UT	Ultrasonic Testing	Generally used in the pipeline industry to identify defects in the pipe or weld metal.

UTT	Ultrasonic Thickness Test	Used to return a wall thickness the material under test.
Lam	Lamination Inspection	Used to check for planer tears in a material.
MPI	Magnetic Particle Inspection	Used to identify sub-surface and surface breaking defects.
DPI	Dye Penetrant Inspection	Used to identify surface breaking defects.
CE	Carbon Equivalent	Used to predict the hardness of materials subject to heating and cooling. Typically IIW formula is used in Australia.
	Lower Pressure	Lowering of the operating pressure of the live gas pipe for the duration of the in-service weld as a control that would reduce the consequence level if a blow through was to occur. It is also considered to affect the cooling rate during the weld.
HAZ	Heat Affected Zone	A non-melted area of metal that has undergone changes in material properties as a result of being exposed to high temperatures.
IIW	International Institute of Welding	The International Institute of Welding is an international scientific and engineering body for welding, brazing and related technologies.

Objective

The objective of this guideline is to provide:

a. Industry risk-based suggestions for managing in-service welding on distribution networks
b. Alignment with the relevant Australian Standards
c. Nationally consistent approaches for in-service welding.

This document aims to assist Network Service Providers/Network Operators and Service Providers in developing appropriate and fit-for-purpose design solutions to be applied to in-service welding.

This document is intended to complement, but not substitute or override, a number of regulations and Australian Standards. The aim is to provide additional information to guide the development of appropriate, fit-for-purpose and consistent design solutions for in-service welding.

This document does not stipulate prescriptive details in designing, planning and undertaking in-service welding. Consistency of approach in the detail will be delivered by way of this document together with the relevant legislation, codes and standards. Individual organisations will then establish their own safety management systems together with the attendant design standards and detailed manuals for in-service welding.

Application

This document applies to members of the industry engaged in distribution network steel pipe in-service welding activities.

Scope

This Guideline sets out an industry agreed risk-based approach to in-service welding operations on distribution network steel pipelines. The Guideline is intended to supplement the requirements currently contained in AS/NZS 4645.2-2018 Clause 4.12 (In-Service Welding). This Guideline provides a suggestion of appropriate controls to be applied under different general gas distribution network in-service welding operations. These controls were established by a panel of industry experts through a risk assessment process.

Referenced Documents

The following documents are referred to in this document:

Table 2 - Referenced Documents

Document Code	Title
AS/NZS 4645.2:2018	Gas Distribution Networks Steel Pipe Systems
AS/NZS 2885.2:2020	Pipelines – Gas and Liquid Petroleum Welding
API 5L: 46th Edition	Line Pipe

1 Background

In-service welding on steel gas distribution pipelines carries some inherent risks including blow through of the pipe or producing a weld with insufficient strength including the effects of HACC. Both these risks lead to pipeline failure with potential consequences of injury to personnel, damage to property and significant interruptions to gas supply.

In-service welding on steel pipelines is a technically complex operation as there are many variables that can affect the quality of the weld that vary from weld to weld. These variables include:

- Operating pressure within the pipeline at time of completing the weld
- Flow through the pipeline at the time of completing the weld
- Size and type of the fitting
- Ambient weather conditions
- Diameter of the pipe
- Condition of the pipe – corrosion, age, subsurface cracks etc.
- Grade of the pipe material
- Pipe parameters: wall thickness, carbon content
- Experience of the Welder

For transmission pipelines, there is a detailed industry accepted process for managing these variables as outlined in AS/NZS 2885.2. For distribution networks, however, the effect of these variables and the level of the risk can vary greatly depending on the operating conditions of the asset. To apply the transmission pipeline in-service welding process on all occasions would be considered onerous and inefficient from a time and cost perspective. It should be noted that the volumes of in-service welds completed on some distribution networks are significantly greater than those completed on transmission pipelines.

This Guideline is aimed at identifying the risk levels of different in-service welding operations undertaken on gas distribution networks and suggesting appropriate controls to be put in place to effectively manage the risk.

2 Disclaimer

The application of this Guideline by Gas Network Operators shall be undertaken by experienced Engineering and welding operating personnel. These personnel shall have good knowledge of the gas network.

This Guideline assumes that the pipeline physical and operational parameters are well understood by the network operators and that all personnel involved in the welding process are experienced in network operations and in-service welding.

The Network Operator shall use their discretion to apply this Guideline. The Network Operator shall be completely satisfied that the risks associated with in-service welding in general or for an application are managed in line with their organisations' risk framework. This may require the application of further controls than are suggested by this guideline.

3 Industry Risk Assessment

An industry risk assessment was completed in order to establish the suggested in-service welding controls detailed in this Guideline.

Six (6) in-service welding categories were developed to cover all in-service welding operations completed on distribution networks. Each of these categories carry different levels of risk and were assessed by the group individually. During the risk assessment workshop, a number of sub-categories where created as it was identified that the change in a single variable alters the risk outcome. The in-service welding categories and sub-categories are described in section 5 below.

The methodology applied for the industry risk assessment was derived from the Formal Safety Assessment (FSA) approach described in AS4645.1-2018 Clause 2.3, including use of the Severity & Likelihood Classes contained in Appendix B. The analysis of consequences and likelihood was used to determine a risk ranking per the Risk Matrix in Appendix A.

The FSA identified hazards, determined the threats from these hazards, assessed the risk of these threats and determined the level of controls to remove the threats or reduce the risk to an acceptable level. The risk assessment determined the risk of burn-through and hydrogen-assisted cold cracking.

As per the requirements in AS4645.2-2018 Clause 4.12.2, the risk assessment considered the following aspects of the in-service welding operation:

a) Operating pressure of the live steel pipe
b) Percentage of SMYS the live steel pipe is operating at
c) Condition of live steel distribution pipes including age, quality of material and levels of corrosion
d) Wall thickness of live steel pipes operating in the distribution networks
e) Experience and competencies of personnel undertaking welding, inspection and testing on live steel gas distribution pipes

This risk assessment may be applicable for Gas Network Operators to use as a generic in-service welding risk assessment as outlined in Section 4.12 AS/NZS 4645.2 for common in-service welding activities. The Network Operator shall review the risk assessment and ensure the processes and controls are relevant to their operations before adopting.

4 Baseline Controls

This Guideline assumes the following minimum controls are being implemented by the Network Operator as standard for all in-service welding operations. These controls are to be in addition to any further controls suggested in this guideline:

- Welding is being completed by a Welder with a trade qualification in welding and has reasonable experience welding in the gas industry
- The welding is being undertaken in accordance with a qualified weld procedure that complies with AS/NZS 4645.2 or AS/NZS 2885.2
- The Welder has been qualified for the specific welding procedure in accordance with AS/NZS 4645.2 or AS/NZS 2885.2
- Welding operations are not exposed to adverse weather conditions. Appropriate shelters are provided where required
- Welding equipment is compatible with welding procedure and is in good working order
- Welder is wearing all required welding-specific personal protective equipment (PPE)

- A post weld visual examination is completed as per the requirements of AS/NZS 4645.2 or AS/NZS 2885.2 to confirm soundness of the completed weld

5 In-Service Welding Categories

This in-service welding guideline has considered a series of welding scenarios based on the fittings regularly used by gas network operators. These scenarios were developed on the six (6) categories assessed in the Risk Assessment workshop. Further sub-categories were established to allow the risk of certain variables within the main category to be assessed. In some instances, further controls were deemed necessary for certain sub-categories.

For all categories (and sub-categories), the pipe diameters considered range between, and include, DN40 to DN450, for all grades up to and including API 5L X52, operating at a maximum stress of 20% SMYS.

Fitting diameters and grades are not limited, respective to the fitting type in each category, provided they meet the material requirements of AS/NZS 4645.2. It's assumed that fittings are prepared either at the site or in the workshop to ensure WPS joint tolerances are met.

The sub-categories selected represent the generalised worst-case scenarios that gas distribution networks in Australia are subjected to. Gas Network Operators need to remain aware that sub-categories may not consider every conceivable scenario possible, and they are to assess their unique situations with local knowledge of their network.

Weld types assessed include the standard industry best practice configuration of full encirclement and full penetration sit-on style joints, however given the thin wall nature of pipelines in Australia, especially amongst distribution, an acceptable practice of partial penetration joints has also been assessed, as used only in the AS/NZS 4645 coded mains and services.

5.1 Category 1 - In-Service welds on pipelines with an operating pressure >550kPa

Considers welds occurring on pipelines operating with pressures above 550kPag. Welds may meet the requirements of either AS/NZS 2885.2 or AS/NZS 4645.2, however given the higher pressures and often associated high importance of the pipe, welding and inspection will meet the higher requirements of AS/NZS 2885.2.

All joint configurations are considered. Note that categories 5 and 6 specifically cover full encirclement and spherical fittings configurations on main <550kPa.

Sub-Category 1a – Considers the burn-through risk for full penetration style sit-on fittings, welded to thin wall thickness pipe. The operating pressure would typically be above 550 kPag, and often these welds also meet AS/NZS 2885.2 requirements.

- The flowrate is normal.
- The pipe weld zone is to be inspected using NDT techniques as per AS/NZS 4645.2 – 2018 clause 4.12.3.3, to be deemed defect-free.
- HACC is addressed in Item 1c.

Sub-Category 1b – Considers the burn through risk for partial penetration style sit-on fittings, welded to standard wall thickness pipe. The operating pressure would typically be above 550 kPag, however being a partial penetration weld, it does not meet the requirements of AS/NZS 2885.2 and is considered an AS/NZS 4645.2 weld.

- The flowrate is normal.

- The pipe weld zone is to be inspected using NDT techniques as per AS/NZS 4645.2 – 2018 clause 4.12.3.3, to be deemed defect-free.
- This item considers burn through as the risk however, the increase in wall thickness and typical reduction in root gap will reduce the risk of burn through when compared to Item 1a.
- HACC is addressed in Item 1c.

Sub-Category 1c - Considers the risk of HACC for any joint type and fitting type, used on thick wall thickness pipe operating above 550 kPag. The joint may meet the requirements of either AS/NZS 2885.2 or AS/NZS 4645.2.

- The flowrate is normal.
- The pipe weld zone is to be inspected using NDT techniques as per AS/NZS 4645.2 – 2018 clause 4.12.3.3, to be deemed defect free.
- Burn through is address for different joint types in Items 1a and 1b.

5.2 Category 2 - Full penetration weld - sit on branch fittings

Considers sit-on branch style fittings using a full penetration joint type, as common with AS/NZS 2885.2. Also used with AS/NZS 4645, this joint type can elevate the risk to burn though (BT) when coupled with mains and pipelines that exhibit low cooling effects.

Sub-Category 2a - Considers the burn through risk for full penetration style sit-on fittings, welded to standard wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is normal.
- The pipe weld zone is inspected visually and does not utilise any NDT techniques however shall still be deemed defect free prior to welding. An additional spot thickness check is conducted.
- HACC is addressed in Items 2d and 2e.

Sub-Category 2b - Considers the burn through risk for full penetration style sit-on fittings, welded to thin wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is normal.
- The pipe weld zone is inspected visually and does not utilise any NDT techniques however shall still be deemed defect free prior to welding. No thickness check is conducted.
- HACC is addressed in Items 2d and 2e.

Sub-Category 2c - Considers the burn through risk for full penetration style sit-on fittings, welded to standard wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is low to no flow, resulting in poor cooling effects.
- The pipe weld zone is inspected visually and does not utilise any NDT techniques however shall still be deemed defect free prior to welding. An additional spot thickness check is conducted.
- HACC is addressed in Items 2d and 2e.

Sub-Category 2d - Considers the HACC risk for full penetration style sit-on fittings, welded to standard wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is normal.
- The pipe weld zone is inspected visually and does not utilise any NDT techniques however shall still be deemed defect free prior to welding.
- Burn through is addressed in Items 2a, 2b and 2c.

Sub-Category 2e - Considers the HACC risk for full penetration style sit-on fittings, welded to standard wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is high, resulting in elevated cooling effects.
- The pipe weld zone is inspected visually and does not utilise any NDT techniques however shall still be deemed defect free prior to welding.
- Burn through is addressed in Items 2a, 2b and 2c.

5.3 Category 3 - Partial penetration weld on a thin wall main

Considers sit-on branch style fittings using a partial penetration joint type. Often these will have low to no root gaps, and the fitting will be prepared to meet the pipe curvature on site to ensure good fit-up.
Category 3 considers installation specifically on thin wall mains, recognising burn thought (BT) as a major threat.

Sub-Category 3a - Considers the burn through risk for a partial penetration style sit-on fittings, welded to thin wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is normal.
- The pipe weld zone is inspected visually and does not utilise any NDT techniques however shall still be deemed defect free prior to welding. An additional spot thickness check is conducted.
- HACC was not deemed a major threat in this category however it should be considered if pressures and flows are high.

5.4 Category 4 - Partial penetration weld on standard wall main

Similar to category 3, category 4 considers the same sit-on branch style fittings using a partial penetration joint type but as placed on thicker wall mains and pipelines. The intent is to assess if hydrogen-assisted cold cracking (HACC) becomes an issue on the thicker mains with a greater thermal mass.
Sub-Category 4a - Considers the burn through risk for a partial penetration style sit-on fittings, welded to standard wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is normal.
- The pipe weld zone is inspected visually and does not utilise any NDT techniques however shall still be deemed defect free prior to welding. An additional spot thickness check is conducted.

HACC was not deemed a major threat in this category however it should be considered if pressures and flows are high.

5.5 Category 5 - Full encirclement sleeve

Considers full encirclement fittings installed on mains and pipeline operating <550kPa. This category only reviews the circumferential fillet weld, as the longitudinal weld is typically considered a non-in-service weld due to the presence of a backing bar.

Sub-Category 5a - Considers both the burn through and HACC risk for a fillet weld conducted on a full encirclement style fitting, welded to thin wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is normal.
- The pipe weld zone is to be inspected using NDT techniques as per AS/NZS 4645.2 – 2018 clause 4.12.3.3, to be deemed defect free.

Sub-Category 5b - Considers both the burn through and HACC risk for a fillet weld conducted on a full encirclement style fitting, welded to standard wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is normal.
- The pipe weld zone is to be inspected using NDT techniques as per AS/NZS 4645.2 – 2018 clause 4.12.3.3, to be deemed defect free.

5.6 Category 6 - Spherical Tee - Branch connection

Considers the circumferential tee-butt weld of a spherical tee style fitting. Similarly to category 5, the longitudinal welds on a spherical tee are not affected by cooling effects and as such are considered non-in-service welds.

Sub-Category 6a - Considers both the burn through and HACC risk for a full penetration tee butt weld conducted on a spherical style fitting, welded to thin wall thickness pipe. The operating pressure would typically be below 550 kPag.

- The flowrate is normal.
- The pipe weld zone is to be inspected using NDT techniques as per AS/NZS 4645.2 – 2018 clause 4.12.3.3, to be deemed defect free.

6 Suggested In-Service Welding Controls

Whilst individual risk assessment of specific welding scenario is advised, the industrial risk assessment determined a minimum set of controls for the six (6) categories and associated sub-categories, which when applied, resulted in the threat being controlled, or the resultant risk being either low or negligible. The controls for each sub-category are per Table 3 - Suggested In-Service Welding Controls.

Table 3 - Suggested In-Service Welding Controls

Item	***Prevention / Protection / Mitigation***							
	Pre-weld NDT (Visual / UTT / Lam / MPI)[1]	WPS (Specific / Generic)[2]	Heat Sink[3]	Thermal Modelling (PRCI, Battelle)[4]	CE Checked (Material Cert / Chem analysis)[5]	Low Hydrogen Electrodes[6]	Welding Supervisor[7]	Post-weld NDT (As applicable) (RT / UT / MPI / DPI)[8]
Category 1 - In-Service welds on pipelines with an operating pressure >550kPa								
1a	V, UTT, Lam, MPI	Specific	X	X			X	RT, UT, MPI, DPI
1b	V, UTT, Lam, MPI	Specific	X	X			X	RT, UT, MPI, DPI
1c	V, UTT, Lam, MPI	Specific	X	X	X	X	X	RT, UT, MPI, DPI
Category 2 – Full Penetration weld – Sit-on Branch Fitting								
2a	V, UTT	Generic	As defined in WPS					
2b	V	Generic	As defined in WPS					
2c	V, UTT	Generic	As defined in WPS	Pending WPS Basis				

2d	V	Generic	As defined in WPS		X			
2e	V	Generic	As defined in WPS	Pending WPS Basis	X			
Category 3 – Partial Penetration Weld on Thin Wall Main								
3a	V, UTT	Generic						
Category 4 – Partial Penetration Weld on Standard Wall Main								
4a	V, UTT	Generic						
Category 5 – Full Encirclement Sleeve								
5a	V, UTT, Lam, MPI	Specific	As defined in WPS	As needs basis			X	RT, UT, MPI, DPI
5b	V, UTT, Lam, MPI	Specific	As defined in WPS	As needs basis			X	RT, UT, MPI, DPI
Category 6 – Spherical Tee – Branch Connection								
6a	V, UTT, Lam, MPI	Specific	As defined in WPS	X	X	X	X	RT, UT, MPI, DPI

Notes:
"X" is used to indicate suggested additional controls to be applied for each of the weld sub-categories.

1. Pre-weld NDT describes the level of inspection required on the in-service pipe at the location of the weld prior to welding. Where V and UTT only is listed, this may be able to be undertaken by the welder with basic ultrasonic equipment. Lamination and MPI is usually undertaken by a specialist NDT company, however with appropriate training, welders may also be capable of this inspection. Refer to AS/NZS 4645.2 or AS/NZS 2885.2 for instruction of how to undertake these inspections.
2. WPS - Specific refers to a WPS being created specifically for a single in-service weld application. Data gathered from Pre-weld NDT, Heat Sink Test and fitting data shall be used to qualify the WPS under simulated conditions to represent condition equal to or worse than site. The WPS shall pass all Destructive testing and NDT as required by AS/NZS 4645.2 or AS/NZS 2885.2.

WPS – Generic refers to a WPS that has been created for in-service welding under general conditions. This WPS can be used for any in-service weld that meets the parameters stated or has the parameters extended with use of Thermal Modelling.

3. Heat Sink Test – is a test that is undertaken on the in-service pipe prior to welding to establish a measurable cooling rate. The pipe is heated up externally and the time taken for the temperature to fall is measured. This data is then used to simulate cooling conditions for the WPS qualification testing. Refer to Section 16.9 AS/NZS 2885.2 - 2020 for further details.
4. Thermal Modelling – is a computer aided simulation using Finite Element Analysis (FEA) software, to determine predicted inner wall temperature and predicted hardness from its input variables.
5. CE Check – requires that the CE of the steel pipe and the fitting are known and confirmed to be within the limits of the essential variables of the WPS. This is usually obtained from pipe and fitting heat certificates, where these are not available, metal samples can be shaved from the pipe and fitting and the CE value determined from laboratory analysis.
6. Low Hydrogen Electrodes – Using welding consumables which have a "hydrogen controlled" designation as per AS/NZS 2885.2 – 2020 Table 4.2.1 or AS/NZS 4645.2 – 2018 Table 4.3.1.
7. Welding Supervisor – Requires a Welding Supervisor with the qualifications as detailed in section 3.3 AS/NZS 2885.2 – 2020, to witness all welding operations and undertake an examination of the weld including visual inspection.
8. Post Weld NDT – Undertaking of NDT on the completed weld. Post weld NDT is usually completed by a Specialist NDT company as per the requirements of AS/NZS 4645.2 or AS/NZS2885.2,

Appendix A

Table 4 - Industry Risk Assessment Matrix

THREAT DESCRIPTION

ITEM	THREAT CAUSE	THREAT DETAILS	Carrier Pipe: NB	Carrier Pipe: Grade	Carrier Pipe: WT	Carrier Pipe: Condition	Fitting: Type	Fitting: Size	Fitting: Grade	Operating Conditions: Network Flow	Operating Conditions: Operating Pressure	Operating Conditions: SMYS %
1	**In-Service welds on pipelines with an operating pressure >550kPa**											
1a	Operational	In-service welding on live network (operating >550 kPa) - more likely resulting in burn-through	40mm-450mm	All	Thin	Defect-free (per AS4645 Clause 4.12.3.3)	Any sit-on fittings with full-pen welds	Any	Any	Normal	Normal	Max 20%
1b	Operational	In-service welding on live network (operating >550 kPa) - more likely resulting in burn-through	40mm-450mm	All	Standard	Defect-free (per AS4645 Clause 4.12.3.4)	Any sit-on fittings with partial-pen welds	Any	Any	Normal	Normal	Max 20%
1c	Operational	In-service welding on live network (operating >550 kPa) - more likely resulting in HACC	40mm-450mm	All	Thick	Defect-free (per AS4645 Clause 4.12.3.4)	Any	Any	Any	Normal	Normal	Max 20%
2	**Full penetration weld - sit on branch fittings**											
2a	Operational	In-service welding of sit on branch - resulting in burn-through - standard conditions	40mm-450mm	All	Standard	Defect-free (external visual)	Williamson Tee, TOR, Weldolet etc	Any	Any	Normal	Normal	Max 20%
2b	Operational	In-service welding of sit on branch - resulting in burn-through - Thin Wall	40mm-450mm	All	Light	Defect-free (external visual)	Williamson Tee, TOR, Weldolet etc	Any	Any	Normal	Normal	Max 20%
2c	Operational	In-service welding of sit on branch - resulting in burn-through - low/zero flow	40mm-450mm	All	Standard	Defect-free (external visual)	Williamson Tee, TOR, Weldolet etc	Any	Any	Low	Normal	Max 20%
2d	Operational	In-service welding of sit on branch - resulting in delayed failure (HACC) - standard conditions	40mm-450mm	All	Standard	Defect-free (external visual)	Williamson Tee, TOR, Weldolet etc	Any	Any	Normal	Normal	Max 20%
2e	Operational	In-service welding of sit on branch - resulting in delayed failure (HACC) - high flow	40mm-450mm	All	Standard	Defect-free (external visual)	Williamson Tee, TOR, Weldolet etc	Any	Any	Low	Normal	Max 20%
3	**Partial penetration weld (e.g. skinner tee) on a thin wall main**											
3a	Operational	In-service partial penetration welding of sit on fitting - leading to possible burn-through	40mm-450mm	All	Light	Defect-free (external visual)	Williamson Tee, TOR, Weldolet, Tapping / Skinner Tee etc	Any	Any	Normal	Normal	Max 20%
4	**Partial penetration weld (e.g. skinner tee) on standard wall main**											
4a	Operational	In-service partial penetration welding of sit on fitting - leading to a possible burn-through	40mm-450mm	All	Light	Defect-free (external visual)	Williamson Tee, TOR, Weldolet, Tapping / Skinner Tee etc	Any	Any	Normal	Normal	Max 20%
5	**Full encirclement sleeve**											
5a	Operational	In-service fillet welding on live network (<550 kPa) on thin wall pipe for full-encirclement fitting	40mm-450mm	All	Thin	Defect-free (per AS4645 Clause 4.12.3.3)	Any full-encirclement fittings with circumferential fillet weld Note - longitudinal weld considered non-service due to backing bar etc	Any	Any	Normal	Normal	Max 20%
5b	Operational	In-service fillet welding on live network (<550 kPa) on standard wall pipe for full-encirclement fitting	40mm-450mm	All	Standard	Defect-free (per AS4645 Clause 4.12.3.4)	Any full-encirclement fittings with circumferential fillet weld Note - longitudinal weld considered non-service due to backing bar etc	Any	Any	Normal	Normal	Max 20%
6	**Spherical Tee - Branch connection**											
6a	Operational	In-service full-penetration butt weld of connecion onto live pipe	40mm-450mm	All	Thin	Defect-free (per AS4645 Clause 4.12.3.3)	Spherical Tee with butt weld Note - longitudinal weld considered non-service	Any	Any	Normal	Normal	Max 20%

POTENTIAL CONSEQUENCES / CONSEQUENCE ANALYSIS

ITEM	Weld Strength	Burn-Through	HACC (Delayed)	Uncontrolled Release: Credible?	Uncontrolled Release: Operating Pressure	Uncontrolled Release: Hole Size	Uncontrolled Release: Flow	Entry of gas into external confined space	Possible ignition of explosive mixtures: Credible?	Possible ignition of explosive mixtures: Energy Rate	People	Supply	Env	Property
1a	Yes	Yes		Yes	delete	Small hole	Low		Yes	Medium	Yes	Yes		Yes
1b	Yes	Yes		Yes	delete	Small hole	Low		Yes	Medium	Yes	Yes		Yes
1c	Yes		Yes	Yes		Weld crack (up to loss of fitting)	High		Yes	High	Yes	Yes		Yes
2a	Yes	Yes		Yes		Small hole	Low		Yes	Low	Yes	Yes		Yes
2b	Yes	Yes		Yes		Small hole	Low		Yes	Low	Yes	Yes		Yes
2c	Yes	Yes		Yes		Small hole	Low		Yes	Low	Yes	Yes		Yes
2d	Yes		Yes	Yes		Weld crack (up to loss of fitting)	High		Yes	High	Yes	Yes		Yes
2e	Yes		Yes	Yes		Weld crack (up to loss of fitting)	High		Yes	High	Yes	Yes		Yes
3a	Yes	Yes		Yes		Small hole	Low		Yes	Low	Yes	Yes		Yes
4a	Yes	Yes		Yes		Small hole	Low		Yes	Low	Yes	Yes		Yes
5a	Yes	Yes	Yes	Yes	delete	Small hole	Low		Yes	Medium	Yes	Yes		Yes
5b	Yes	Yes	Yes	Yes	delete	Burn-through - Small hole. HACC - annulus leak	Low		Yes	Medium	Yes	Yes		Yes
6a	Yes	Yes	Yes	Yes		Burn-through - Small hole. HACC - annulus leak	Low		Yes	Medium	Yes	Yes		Yes

DESIGN / OPERATING CONTROLS (Proposed Industry Standard) – PREVENTION / PROTECTION / MITIGATION; THREAT ANALYSIS

ITEM	Welder Training	Welder Competence	Pipe Inspection	Confirm Fit-up	Specific WPS	Generic WPS	Code	Heat-Sink	Thermal Modelling	CE Limit	Low-Hydrogen Electrodes	WPQR	Weld-log/ Inspector	Wall Thickness	Pre-weld NDT	Post-weld NDT	Lower Pressure	Threat Controlled
1a	Yes	Yes	Yes	Field based to ensure weld-prep aligns to WPS requirements	Yes		2885.2	Yes	Yes			Yes	Yes	Yes	Yes	Yes		No
1b	Yes	Yes	Yes	Field based to ensure weld-prep aligns to WPS requirements	Yes		4645.2	Yes	Yes			Yes	Yes	Yes	Yes	Yes		No
1c	Yes	Yes	Yes	Field based to ensure weld-prep aligns to WPS requirements	Yes		2885.2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
2a	Yes	Yes	Visual only	Workshop or Field based to ensure weld-prep aligns to WPS requirements		Yes	4645.2	As defined in WPS				Yes		Yes				Yes
2b	Yes	Yes	Visual only	Workshop or Field based to ensure weld-prep aligns to WPS requirements		Yes	4645.2	As defined in WPS				Yes						No
2c	Yes	Yes	Visual only	Workshop or Field based to ensure weld-prep aligns to WPS requirements		Yes	4646.2	As defined in WPS	Pending WPS basis			Yes		Yes				Yes
2d	Yes	Yes	Visual only	Workshop or Field based to ensure weld-prep aligns to WPS requirements		Yes	4645.2	As defined in WPS		Yes		Yes						Yes
2e	Yes	Yes	Visual only	Workshop or Field based to ensure weld-prep aligns to WPS requirements		Yes	4646.2	As defined in WPS	Pending WPS basis	Yes		Yes						Yes
3a	Yes	Yes	Visual only	Workshop or Field based to ensure weld-prep aligns to WPS requirements		Yes	4645.2					Yes		Yes				Yes
4a	Yes	Yes	Visual only	Workshop or Field based to ensure weld-prep aligns to WPS requirements		Yes	4645.2					Yes		Yes				Yes
5a	Yes	Yes	Yes	Field based to ensure weld-prep aligns to WPS requirements	Yes		4645.2	As defined in WPS	As-needs basis			Yes	Yes	Yes	Yes	Yes		No
5b	Yes	Yes	Yes	Field based to ensure weld-prep aligns to WPS requirements	Yes		4645.2	As defined in WPS	As-needs basis			Yes	Yes	Yes	Yes	Yes		No
6a	Yes	Yes	Yes	Field based to ensure weld-prep aligns to WPS requirements	Yes		4645.2	As defined in WPS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes

RESIDUAL CONSEQUENCE ANALYSIS / RESIDUAL RISK POST-CONTROLS / ALARP ASSESSMENT / PROPOSED FSA ACTIONS

ITEM	People	Supply	Env	Property	SEVERITY	LIKELIHOOD	RISK RANKING	ALARP: Yes/ No	ALARP: Basis / Comment	Action	Responsible	Due Date
1a	Burn-through could result in small hole (3-4 mm) and ignited jet fire, impacting welder / other nearby workers. Welder PPE assumed per industry JHA / SWMS etc including fire-retardant PPE and welding mask. If not initially ignited, dispersion would most likely mitigate delayed ignition.	In most networks a burn-through would be repaired with minimal delay and impact to off-take customers. Back-feed possible in some networks. Short duration impact only.	-	Ignited jet fire may impact adjacent structures and 3rd party property.	Severe	Remote	Low	Yes				
1b	Burn-through could result in small hole (3-4 mm) and ignited jet fire, impacting welder / other nearby workers. Welder PPE assumed per industry JHA / SWMS etc including fire-retardant PPE and welding mask. If not initially ignited, dispersion would most likely mitigate delayed ignition.	In most networks a burn-through would be repaired with minimal delay and impact to off-take customers. Back-feed possible in some networks. Short duration impact only.	-	Ignited jet fire may impact adjacent structures and 3rd party property.	Severe	Hypothetical	Negligible	Yes				
1c							#N/A					
							#N/A					
2a							#N/A					
2b	Burn-through could result in small hole (3-4 mm) and ignited jet fire, impacting welder / other nearby workers. Welder PPE assumed per industry JHA / SWMS etc including fire-retardant PPE and welding mask. If not initially ignited, dispersion would most likely mitigate delayed ignition.	In most networks a burn-through would be repaired with minimal delay and impact to off-take customers. Back-feed possible in some networks. Short duration impact only.	-	Ignited jet fire may impact adjacent structures and 3rd party property.	Severe	Remote	Low	Yes	More controls (eg wall thickness test, other NDT etc) should be considered where low confidence exists for line pipe condition, wall thickness etc			
2c							#N/A					
2d							#N/A					
2e							#N/A					
							#N/A					
3a												
							#N/A					
4a												
							#N/A					
5a	Burn-through could result in small hole (3-4 mm) and ignited jet fire, impacting welder / other nearby workers. Welder PPE assumed per industry JHA / SWMS etc including fire-retardant PPE and welding mask. If not initially ignited, dispersion would most likely mitigate delayed ignition.	In most networks a burn-through would be repaired with minimal delay and impact to off-take customers. Back-feed possible in some networks. Short duration impact only.	-	Ignited jet fire may impact adjacent structures and 3rd party property.	Severe	Remote	Low	Yes	If concern remain for burn-through and/or HACC, consider thermal modelling and/or apply AS2885.2			
5b	Burn-through could result in small hole (3-4 mm) and ignited jet fire, impacting welder / other nearby workers. HACC could result in cracked circumferential weld and small leak via sleeve annulus. Welder PPE assumed per industry JHA / SWMS etc including fire-retardant PPE and welding mask. If not initially ignited, dispersion would most likely mitigate delayed ignition.	In most networks a burn-through would be repaired with minimal delay and impact to off-take customers. Back-feed possible in some networks. Short duration impact only.	-	Ignited jet fire may impact adjacent structures and 3rd party property. HACC LOC more likely when re-buried and therefore a Class 1 leak.	Severe	Hypothetical	Negligible	Yes	If concern remains for burn-through and/or HACC, consider thermal modelling and/or apply AS2885.3			
							#N/A					
6a							#N/A					
							#N/A					

This has been prepared by Energy Networks Australia for the benefit of its members. A full list of member businesses is available at www.energynetworks.com.au/ena-members

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