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Butt Fusion Jointing of PE Pipes and Fittings – Recommend Parameters and Practices

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BUTT FUSION JOINTING OF PE PIPES AND FITTINGS – RECOMMENDED PARAMETERS AND PRACTICES

This industry guideline discusses recommended parameters and practices for butt fusion jointing of polyethylene pipe and fittings. The guideline is separated into two sections:

Section 1: Recommended butt fusion jointing parameters

Section 2: Recommended best practices for butt fusion jointing.

PIPA Industry Guideline POP014 Assessment of Polyethylene Welds should be read in conjunction with this guideline. It provides detailed information relevant to achieving and assessing sound welds.

Note: Butt welding and Butt fusion are equivalent terms referring to the same process.

SECTION 1 – RECOMMENDED BUTT FUSION JOINTING PARAMETERS

1. INTRODUCTION

PIPA recommends the butt fusion jointing procedures and parameters as specified in ISO 21307, *Plastics pipes and fittings – Butt Fusion Jointing Procedures for Polyethylene (PE) Pipes and Fittings Used in Construction of Gas and Water Distributions Systems.*

ISO 21307 specifies three proven butt fusion jointing procedures for pipes and fittings, taking into consideration:

- the materials and components used
- the fusion jointing procedure and equipment
- the quality assessment of the completed joint

Also included are weld procedures for activities such as surface preparation, clamping, alignment and cooling procedures.

Where ISO 21307 references other International Standards, the equivalent Australian Standard is deemed to apply. Where there is no equivalent Australian Standard then the International Standard applies. Refer to Table 1 for International Standards references and Australian Standard Equivalent.

Table 1

ISO 21307 International Standards references and the Australian Standard equivalent

INTERNATIONAL STANDARD	SUBJECT MATTER	AUSTRALIAN STANDARD
ISO 8085-2	Fittings	AS/NZS 4129 Section 6
ISO 4437	Gas Pipe	AS/NZS 4130
ISO 4427	Water Pipe	AS/NZS 4130
ISO 12176-1	Equipment	no AS/NZS equivalent standard
ISO/TS 10839	Installation	AS/NZS 2033, AS/NZS 4645
ISO 13953	Tensile Test	no AS/NZS equivalent standard
ISO 1167-1	Hydrostatic Pressure Test	AS/NZS 4130 Clause 10.1
ISO 1167-3	Hydrostatic Pressure Test	AS/NZS 4130 Clause 10.1
ISO 1167-4	Hydrostatic Pressure Test	AS/NZS 4130 Clause 10.1
ASTM F2634	High speed Tensile Test	no AS/NZS equivalent standard

2. BACKGROUND INFORMATION

Butt fusion jointing (also referred to as butt welding), involves the heating of two pipe ends to fusion temperature and then subsequently joining the two ends by the application of force. However, a successful butt weld requires the correct combination and sequence of the welding parameters in terms of time, temperature, and pressure.

Various proven butt fusion methods have been in use in different countries for many years. ISO 21307 brings together three distinct fusion methods described below for pipe and fittings. There is a significant difference between each of these procedures, but they each have a successful track record.

Note: It is essential that the parameters specified for a given method are followed. Do not "mix and match" parameters from each method. The use of each of these procedures varies globally depending on location.

Butt fusion methods

Single pressure – low fusion jointing pressure (SLP)

→ This method has been favoured by most European countries, the UK and in Australia. The pipe ends in this procedure are brought together and held at a pressure of 0.15 MPa for the fusion and cooling cycle.

Dual pressure – low fusion jointing pressure (DLP)

→ This method is used primarily by the water industry in the UK for pipe with a wall thickness greater than 22mm. The DLP fusion procedure is performed at the same pressure as SLP, but the pressure is reduced to 0.025 MPa during cooling

Single pressure – high fusion jointing pressure (SHP)

- This method has been used extensively in Northern America and more recently in Australia. The SHP procedure is similar to the SLP procedure but a much higher fusion pressure of 0.517 MPa is used for welding and during cooling. The fusion pressure is approximately three times the low-pressure method and, as a consequence, more of the molten material is extruded from the weld zone, thereby enabling a reduced cooling time.

Evaluation of methods

The performance of all three procedures was the subject of an extensive evaluation project in Europe carried out from 2008 to 2011. A paper presented at the 2012 Plastics Pipes XVI Conference in Barcelona[1] concluded:

"The tests demonstrate that good performance welds can be obtained by the three procedures for thickness up to 70 mm, but the Single High Pressure weld test samples are less ductile in appearance".

This concluding comment has significance in the context of visual assessment of weld test specimens. Refer to POP014 for further explanation.

SECTION 2 – RECOMMENDED BEST PRACTICES FOR BUTT FUSION JOINTING

In addition to the butt fusion parameters covered in Section 1 there are many other aspects of the butt fusion jointing process that should be considered. Section 2 provides guidance by identifying key aspects that should be considered when butt fusing PE pipe and fittings. These aspects could be included in specifications or form additional considerations to be addressed during the weld procedure.

1. PIPE SPECIFICATION

The pipe should be clearly specified. A thorough assessment of butt-welding parameters can then be made. The specification should include as a minimum:

- pipe standard if applicable,
- diameter,
- PN and/or SDR and/or wall thickness,
- standard pipe lengths,
- Series Number (if not specified, series 1 is assumed)

The applicable Australian Standards for polyethylene pipe in Australia are:

AS/NZS 4130:2003 *Polyethylene (PE) pipes for pressure applications*

AS/NZS 4401:2006 *PE pipe for soil and waste discharge*

AS/NZS 5065:2005 *PE and PP pipes for drainage and sewerage.*

Note: Pipes and fittings with the same diameter and SDR manufactured to the same Australian Standard are compatible in terms butt fusion.

As a default only pipes (and fittings) of the same diameter and wall thickness should be butt welded together.

Under circumstances where wall thickness variation occurs consideration should be given to using either Electrofusion fittings, mechanical fittings or consult the pipe manufacturer regarding chamfering options or transition fittings.

2. FITTINGS SPECIFICATION

Butt welded fittings should be clearly specified.

In general, butt fusion fittings are supplied in a limited range of SDR's. If the same SDR as the pipe is not available, then a smaller SDR (i.e., thicker wall) may be used providing it is approved within the hydraulic design. If fittings with a smaller SDR are used, then the inside needs to be chamfered to match the inside diameter of the pipe.

3. BUTT FUSION EQUIPMENT

ISO 21307 references ISO 12176-1 *Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems — Part 1: Butt fusion*. There is no Australian Standard equivalent to this ISO Standard. This represents the best available reference for butt fusion equipment.

The operator should confirm that the butt fusion equipment has sufficient structural strength and hydraulic capacity to achieve the specified parameters in a safe manner and is in good working order. Heater plate surface temperature and hydraulic pressure gauges should be checked with an external device that is regularly calibrated.

4. OPERATOR COMPETENCE

The value of having competent welders cannot be overstated. The biggest single contribution to a successful butt weld is the competency of the welder and their dedication to correct surface preparation and weld procedures.

It is important the competency level of the welder be considered in relation to the criticality of the pipeline. Specifying the minimum competency level required also ensures that quotes or tenders can be assessed on an equal basis.

A welding crew will normally contain people with a range of skills and experience from unskilled workers through to trained welders with extensive experience. The specification should define the composition of the crew in terms of expected skills and experience. Typically for a major project the welding supervisor on site should be a trained and experienced welder – i.e., a person trained by a Registered Training Organisation (RTO) and be able to provide objective evidence of at least 3 years relevant experience. This experience should include welding pipe of similar or larger sizes to those in the current project. The remainder of the crew would typically be trained welders (where training was provided by an RTO within the last 3 years) assisted by unskilled workers.

Note: All welding supervisors and operators should be qualified and regularly recertified by a suitable RTO to PMBWELD301E (Butt weld polyethylene plastic pipelines). Recertification should typically be done every 2-3 years.

5. QUALITY ASSURANCE PLAN

A Quality Assurance Plan represents best practice and demonstrates that the contractor has the resources, capacity, and sufficient controls to satisfy the requirements of the project.

A typical Quality Assurance Plan should contain the following:

- document control and distribution,
- list Quality Management Systems (i.e. ISO9001 etc),
- list of personnel showing responsibilities, training, experience,
- welding procedures,
- sample weld records (i.e., blank proforma sheet),
- inspection and Test Plan (tailored to suit the specification,
- hold points,
- any other items required by the specification.

6. TRANSPORT, HANDLING AND STORAGE

The responsibility for handling pipe on site should be clearly defined, considering:

- responsibility for stringing the pipeline,
- drop off points defined,
- storage and security,
- site accessibility,
- unloading responsibility.

Transporting, handling and storage of polyethylene pipes should be undertaken in accordance with AS/NZS 2033 Installation of Polyethylene Pipe Systems.

7. PRE-WELDING INSPECTION

Incorrect or damaged pipe should not be welded. Damaged pipe includes pipe that has excessive scoring, large variations in wall thickness, unusual surface appearance or visible contamination. The welding contractor should always inspect the pipe, using the same criteria as the pre-installation inspection specified in AS/NZS 2033.

8. OTHER FIELD WELDING FACTORS FOR CONSIDERATION

DRAG PRESSURE

Drag should be minimised by the use of rollers or other suitable devices.

CARRIAGE SPEED

When bringing the faces of the pipe together to be welded the carriage speed should be slow and the weld pressure increased progressively.

PIPE TEMPERATURE

Uneven pipe temperature should be avoided. For example, with pipe exposed to the sun the top can be significantly hotter than the bottom of the pipe. Use suitable structures to protect the weld site.

AIR FLOW THROUGH THE PIPE

Uncontrolled flow of air through the pipe can result in uneven temperatures. Block pipe ends to avoid uncontrolled air flow through the pipe.

EXTREME AMBIENT TEMPERATURES

If the site conditions vary significantly from the prequalification weld conditions, then considerations should be given to stopping welding or requalifying to the new conditions.

USE OF ALCOHOL WIPES IN THE BUTT FUSION JOINTING PROCESS

Different environments where butt fusion jointing process is undertaken will require different preparation prior to welding:

→ A Low risk of contamination environment

This may be within a building, a full welding enclosure or the cabin of a large welding machine. In these environments there may be no need to do any surface preparation beyond suitable planing of the pipe ends in the welding machine. Under these circumstances where the surface has not been contaminated post the planning operation no further action may be required in terms of preparation prior to welding.

→ A higher risk of contamination environment

This may be where welding is taking place in the field with limited or no shelter. In these instances, there may be a need to clean the planed pipe ends immediately prior to welding. This can remove fine surface contamination from airborne dust or ribbons of swarf from the planning process that have become lodged on the surfaces to be welded. Under these circumstances where the surface has been contaminated in such a way the use of alcohol wipes is the recommended option of removing these contaminants.

Note: When using alcohol wipes the same requirements apply as for electrofusion - Wipe the prepared pipe surface only with a recommended alcohol wipe to remove any dust residue and other contaminants. For larger diameter pipes use a multiple number of alcohol wipes.

Personal cleaning wipes may contain lanolin and detergent and are totally unsuitable for use in the preparation of surfaces to be welded – only use alcohol wipes recommended for preparation of PE surfaces prior to welding.

9. PREQUALIFICATION AND PILOT WELDS

Before production butt fusion jointing commences, pre-qualification of the welding procedure should be carried out. This is important to establish the optimum weld parameters for the project pipe under the expected site conditions and includes:

- Qualification welds should be tested in accordance with ISO 13953:2001 *Polyethylene (PE) pipes and fittings – Determination of the tensile strength and failure mode of test pieces from a butt-fused joint.*
- A pilot weld should be undertaken for each welding machine, pipe diameter and wall thickness. A record of the parameter values for each weld should be made.
- Each pilot weld should be performed on the actual pipe used in the project to confirm the test specification requirements. Pilot welds should be tested in accordance with ISO 13953. Options to assist in the interpretation and assessment of butt fusion tensile tests can be found in POP014.

Only when these welds demonstrate they pass the acceptance criteria should the project proceed.

10. OPTIMISING FUSION PARAMETERS

Successful butt fusion jointing requires these parameters be optimised, within the permitted range, on a project specific basis. This is particularly the case for critical pipelines and/or larger diameter and thicker walled pipe.

Optimising the fusion parameters takes into consideration site specific conditions such as temperature and shelter options, the actual equipment and the actual pipe being used on the project.

The actual weld parameters used on a specific project should be established during the weld prequalification or pilot weld stage where the optimum parameters are determined and tested within the range nominated in ISO 21307.

Aspects that should be considered when optimising fusion parameters include:

- Heater plate temperature
- Fusion temperature
- Change over times from heating to applying fusion pressure
- The rate of fusion pressure application
- Heat soak times
- Site specific conditions

11. SITE RECORDS

Maintaining records of the fusion parameters allows traceability for trouble shooting should a fault be found during weld testing, pipeline commissioning or operation. The specification should make it clear that records are to be maintained with copies available at any time during construction and a compiled dossier upon completion of the project.

Each weld should be numbered and records for each weld number retained. As a minimum the typical information to be recorded and retained includes:

- weld number
- operator identification
- date and time,
- location of the weld (e.g., GPS recording of location)
- welding equipment type and model,
- pipe DN and SDR,
- heater plate condition,
- actual values used for essential parameters as outlined for the method in ISO 21307 (i.e., heater plate temperatures, heat soak and cooling times, drag pressure, fusion pressure, calculated and total pressures),
- confirmation that the weld appears good (no signs of misalignment, porosity, or contamination; beads even and well-formed etc).

12. WELD BEAD EXAMINATION

Beading is the "overflow" of polyethylene that forms on the inside and outside of the pipe at the fusion joint. Debeading is the term used to describe the removal of the bead. Debeading should not gouge or otherwise damage the pipe.

BEAD SHAPE AND APPEARANCE

Visual examination of the weld bead is one of the most effective Non-Destructive Test (NDT) techniques. POP014 provides guidance on the visual assessment of the weld bead.

BEAD TESTING

The external bead itself can be removed (using a suitable bead removal tool) and tested by twisting or bending the removed bead to provide a non-destructive assessment of weld integrity. Guidance on bead testing can be found in POP014.

INTERNAL DEBEADING

Debeading the inside of a butt fusion welded pipeline is a significant additional cost, generally provides no hydraulic benefit, and should only be considered if absolutely necessary. Internal bead removal may be specified in situations where low flow fluids carry contaminants that may catch on the bead.

13. FIELD WELD TESTING

In addition to pre-qualification and pilot weld testing there should also be a requirement to test butt fusion joints welded from the field. POP014 provides guidance in relation to weld testing.

Field test welds should be removed from the pipeline and tested in accordance with the same requirements as used for pilot and prequalification welds.

The test frequency should be specified and will vary depending on multiple factors such as the criticality of the project, pipe size and SDR, production rate, competence and experience of the welder and previous track record of the contractor.

Where welds fail additional weld samples should be tested. All failed welds should be investigated to identify the cause of failure and recommended corrective action.

Where welders consistently pass field weld testing the field weld test frequency should be reduced.

Testing should be clearly specified including:

- the test method,
- who is responsible for the cost of testing,
- at which laboratory the tests are to be performed,
- frequency of testing (e.g., prequalification, random, at defined frequencies such as once per day per welder or once every 50 welds); reducing test frequency in response to consistent pass results.
- who selects the weld for testing,
- procedures if a test fails.

14. COMMISSIONING

For information regarding commissioning refer to AS/NZS 2033 *Installation of polyethylene pipe systems*

15. TECHNICAL REFERENCES

[1]Stephen Beech - SHB Consulting, UK, Christophe Salles – PE 100+ Association, FR Ulrich Schulte – PE 100+ Association, Harmonisation of Polyethylene Pipe Butt Fusion Procedures And Test Methods – Final Conclusions, DE Plastic Pipes XVI 2012 Barcelona Spain.

M. Heathcote, M. Hynes, L. Croker and M. Pearson, Case Study – Fusion parameters for large diameter PE Pipes, Ozpipe 2024 Sustainable Infrastructure – The future is now Conference, 2024, Sydney Australia

16. STANDARDS REFERENCES

- AS/NZS 4401:2006 *PE pipe for soil and waste discharge*
- AS/NZS 5065:2005 *PE and PP pipes for drainage and sewerage.*
- AS/NZS 4129:2020 *Fittings for polyethylene (PE) pipes for pressure applications*
- AS/NZS 4130:2003 *Polyethylene (PE) pipes for pressure applications*
- AS/NZS 2033 *Installation of Polyethylene Pipe Systems*
- AS/NZS 4645 *Gas Distribution Networks*
- ASTM F2634 *Polyethylene Butt Fusion Joint Test Testing Equipment*
- ISO 21307 *Plastics pipes and fittings – Butt Fusion Jointing Procedures for Polyethylene (PE) Pipes and Fittings Used in Construction of Gas and Water Distributions Systems.*
- ISO 8085-2 *Polyethylene fittings for use with polyethylene pipes for the supply of gaseous fuels – Metric series – Specifications – Part 2: Spigot fittings for butt fusion, for socket fusion using heated tools and for use with electrofusion fittings*
- ISO 4437 *Plastic pipes systems for the supply of gaseous fuels - Polyethylene (PE)*
- ISO 4427 *Plastic piping systems for water supply and for drainage and sewerage under pressure – Polyethylene (PE)*
- ISO/TS 10839 *Polyethylene pipes and fittings for supply of gaseous fuels – Code of practice for design, handling and installation*
- ISO 13953:2001 *Polyethylene (PE) pipes and fittings – Determination of the tensile strength and failure mode of test pieces from a butt-fused joint*
- ISO 1167-1 *Thermoplastic pipes, fittings and assemblies for the conveyance of fluids – Determination of the resistance of internal pressure – Part 1: General method*
- ISO 1667-3 *Thermoplastic pipes, fittings and assemblies for the conveyance of fluids – Determination of the resistance of internal pressure – Part 3: Preparation of components*
- ISO 1677-4 *Thermoplastic pipes, fittings and assemblies for the conveyance of fluids – Determination of the resistance of internal pressure – Part 4: Preparation of assemblies*
- ISO 12176-1 *Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems — Part 1: Butt fusion*
- ISO9001 *Quality Management Systems*

Note: With the publication of POP003 Issue 8 - PIPA has withdrawn Technical Paper TP003 Specifying Butt Welding of Polyethylene Pipe Systems 1.0.

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