Recommendations for Electrofusion Welding Specifications

It is intended for this document to be read in conjunction with PIPA's Technical Guideline **POP001 Electrofusion Jointing of PE Pipes and Fittings for Pressure Applications**. The purpose of this document is to provide commentary and information in addition to that contained in POP001 to assist in the preparation of specifications involving electrofusion welding of polyethylene pipelines. The document includes recommendations for:

- Required training/certification levels for installers and demonstrated experience
- Minimum requirements for installation tooling, measuring, and welding equipment
- Managing environmental factors on the work site
- Record keeping and joint identification information
- Quality control measures for monitoring and assessing installation quality

This document can assist asset owners in correctly specifying the installation requirements for electrofusion welding of PE pipelines.

1. TRAINING AND INSTALLER EXPERIENCE

Operator-trained, experienced, and qualified to **PMBWELD302E — Join polyethylene plastic pipelines using electrofusion welding** with a current statement of attainment. Trained welders also need to demonstrate relevant ongoing experience and attendance at refresher courses. Typically, the period between refresher training is of the order of 2 years. The timing of refresher training is set by the Registered Training Organisation (RTO) or training body. Attendance at refresher training is often a requirement of the client – for example the Australian water industry and the coal seam gas industry have required this for several years. Plastics Industry Pipe Association supports the need for refresher training to ensure:

- Key skills are reinforced and well understood
- Operators are aware of developments in surface preparation techniques
- Operators are aware of developments in electrofusion fittings and associated equipment

All operators planning to conduct electrofusion procedures on a project should have an up-to-date training statement from an accredited RTO. Industry experience has shown that projects utilising untrained operators working under the part time supervision of trained personnel have a significantly higher risk of welding problems compared to those projects where all operators and supervisors have

been formally trained. Operators should have demonstrated competency and experience with the sizes and types of fittings being installed on the project. Demonstrated competence could include:

- Documented experience, constructing PE joints of the same fitting type and diameter e.g., weld records and or joint information records from a previous project which show that the welders proposed for the project have successfully completed work in the diameters specified,
- Records of successful pre-qualification weld evaluation testing on fitting types to be used on the project, e.g., third party destructive test results to ISO 13954, ISO 13955, ISO 13956 or ISO 21751 as appropriate showing pass results,
- References from other clients.

SUGGESTED MINIMUM INSTALLATION TOOLS AND MEASURING EQUIPMENT

It is important that installers are equipped with the correct tools and measuring equipment to ensure all joints are prepared in accordance with both the manufacturers and industry guidelines, using polyethylene pipe that complies with Australian Standard AS/NZS 4130. This is to ensure factors including surface preparation, cleaning, permissible joint geometry, control of welding environment and welding parameters are correctly managed. To achieve this, the installers will need to have access to a range of tools, environmental controls and measuring devices for each type of fitting being used at the job site. If the installer plans to use multiple installation crews, then it is important that each crew has all the equipment required for successful welding. The installer should be able to demonstrate that welding will be conducted in accordance with POP001. POP001 provides a full listing of suggested measuring and installation aids in Section 1.3 Required Equipment. It is important that all items listed in POP001 are available to each installation crew. The following table explains the importance and reason for each item listed.

Table 1

CATEGORY	ITEMS	IMPORTANCE
Measuring Equipment	• Steel rule • Vernier calliper or Micrometer gauge • Pipe ovality gauge • Pi tape • Builders square • Permanent marker	Recommendations in POP001 for assembled joint geometry requires the operator to have the equipment and skill level necessary to measure the average diameter and ovality of the pipe. This includes both before and after preparation to ensure it complies with the dimensional tolerances listed in PIPA POP001 Table 3 and sections 2.1.6.1 "Pipe end Reversion" and 2.1.6.2 "Ovality". It should be noted that pipe complying with AS/NZS 4130 may require rounding, in addition to surface peeling, to meet the requirements for successful electrofusion welding specified within POP001.

CATEGORY	ITEMS	IMPORTANCE
Measuring Equipment continued…	• Steel rule • Vernier calliper or Micrometer gauge • Pipe ovality gauge • Pi tape • Builders square • Permanent marker	In addition, the recommended peel depth for pipe surface preparation in Table 2 also provides minimum and maximum permissible peel depths to be used when removing the oxidised layer from the pipe surface. To follow these guidelines, it is necessary to have a calliper to check peel depth regularly. Note the peel depth achieved by mechanical rotary peelers will vary with blade sharpness and other factors such as clamping force etc hence it is important to regularly check and record the peel depth being achieved.
Environmental Monitoring and Controls	• Surface and ambient temperature measuring devices. • Shade cloth or shelter • Dewatering equipment • Wet weather protection e.g., welding tent	Electrofusion quality can be adversely impacted if the welding is conducted in conditions that may result in contamination of the welding surface such as moisture, mud, dust and or other potential contaminants from the installation site. The installer should have the appropriate controls to manage these factors on each welding site. Measuring devices are also required to determine that the welding is taking place in the specified ambient temperature range for the assembled joint. For example - within the ISO 12176-2 allowable range of -10°C to 45°C. Some electrofusion machines monitor ambient temperatures and will not operate outside this temperature range. **Note:** pipe and fittings left in direct sunlight even within this allowable ambient temperature range can quickly reach high temperatures. Therefore, fittings and the pipe surfaces to be welded should be shaded from direct sun light prior to attempting EF welding.

CATEGORY	ITEMS	IMPORTANCE
Peeling Equipment	• Rotary mechanical peeler **Note:** Must be capable of removing a minimum depth of 0.2mm evenly around the complete pipe circumference and insertion depth of the fitting.	For successful welding it is important that oxidised material that forms on the pipe surface is completely removed by the installer prior to welding. The peeling tool must be able to evenly remove the oxidised layer around the complete circumference and over the total insertion depth of the EF fitting. The recommended tolerance on peel depth that is required to be evenly removed around the full circumference is not possible with hand scrapers or other improvised tools. Therefore, each installation crew should have access to dedicated rotational peeling tools for electrofusion welding. **Note:** Some rotary peeling tools can only be used on pipe ends, therefore if the installers are required to install EF saddles, they will need a mechanical peeling tool that can be used in the middle of the pipe i.e. works with only access to the pipe diameter for location and clamping.
Pipe Surface and Cleaning	• Electrofusion pipe surface cleaning alcohol wipes	It is critical that the prepared surface must be clean and free of contaminants prior to assembly and welding. Common sources of contamination include moisture, dust and dirt, hand and barrier creams, sunscreen, detergents, and surfactant used in direction drilling, oils and fuels from site machinery, etc. Even when care is taken with the preparation of the peeled surface it is possible for that surface to be contaminated with these types of substances. To prevent this, the installer should clean the surface just prior to assembly of the fitting for welding with a fitting manufacturer approved pipe surface wipe.

CATEGORY	ITEMS	IMPORTANCE
Pipe Surface and Cleaning continued…	• Electrofusion pipe surface cleaning alcohol wipes	The wipe's solvent evaporation rate varies with the ambient temperature, and the solvent must be allowed to fully evaporate prior to joint assembly. **Note**: The use of clean rags and cleaning solution is not recommended due to the risk of introducing additional sources of contamination e.g., incorrect rag material, contamination of cleaning fluid or incorrect fluid and accidental reuse of rags or use of dirty rags. Disposable latex or nitrile powder free gloves are recommended when handling the wipes for preparation of the surface.
Pipe dimensional correction and alignment clamps	• Pipe cutting tools • Rounding Clamps • Alignment Clamps	AS/NZS 4130 PE Pipe may require dimensional correction for suitability with EF jointing, particularly due to excessive ovality and circumferential reversion at the end on larger DN pipe. Circumferential reversion of pipe ends shall comply with AS/NZS 4130, requiring diameter compliance within 5% DN length from the pipe end. If after dimensional checking of the prepared pipe surface reversion and/or ovality is larger than the recommended range nominated in POP001 the installer will require tools for cutting the reverted section from the end of the pipe and rounding clamps to correct the ovality in the welding zone. Pipe cutting tools should be able to achieve a square pipe end. This is important as pipe not cut square may result in insufficient pipe insertion to achieve a satisfactory weld. The assembled joint will also require clamps to prevent movement during welding and the correct alignment of pipes and fittings

CATEGORY	ITEMS	IMPORTANCE
Pipe dimensional correction and alignment clamps continued…	• Pipe cutting tools • Rounding Clamps • Alignment Clamps	for the duration of the weld and first cooling period. This is to ensure the joint remains free of applied stresses during the welding process and subsequent cooling period.
Electrofusion Control Unit and Site Power Supply	• Electrofusion Control Unit • Power Supply	The control unit and power supply should comply with the parameters provided in POP001 and be compatible with the fittings being used in the project. **Control units** should comply with ISO 12176-2 and provide a DC output or AC + DC between 8-volts and 48-volts. Barcode units should be compatible with ISO 13950. **Control boxes** used should be checked to ensure they are within their calibration period. The installer should check with the fitting provider to ensure their proposed welding and site power solutions are suitable for the types of fittings being used. **Generators** used for power supply should be calibrated and serviced to ensure they provide the voltage and current input required for the electrofusion control unit. Incompatible generators may damage the control unit. **Note:** for larger diameter EF projects specialised control units and site power requirements may be required. Once again, the installer should liaise with the manufacturer to ensure they are using the appropriate equipment.

2. JOINT INFORMATION AND RECORD KEEPING

A critical part of successful electrofusion jointing is ensuring that the joint has been prepared correctly. The constructor should be able to provide documentation linked to each weld to demonstrate that the joint was prepared by suitably qualified welders using the correct installation equipment, joint geometry, and environmental controls to ensure the weld was constructed according to POP001.

It is suggested that a system is used to link each weld with the record keeping data such as a joint identification code stamped on the fitting or as part of the geographic information system for the project. The records should document:

- The identity of the welder(s) and accreditation information to PMBWELD302E
- Identify the fitting manufacturer, type, and identification code.
- Data to show prepared pipe ends (or pipe surface for saddles) are within the dimensional range specified in AS/NZS 4130 and POP001.
- Type of mechanical rotary peeler used.
- The operator has correctly removed the required depth of oxidised material from the surface of the pipe surface using a mechanical peeling tool, and accurately measured the peel strip thickness using Vernier calipers or Micrometer gauge.
- The type of manufacturer approved alcohol welding wipe used.
- The joint has been assembled correctly including correct insertion depth, pipe rounding (if necessary), pipe alignment and clamping to prevent movement during the welding process.
- Suitable environmental controls have been used to prevent damage to the joint from factors such as dust, water, and excessive heat or cold from environmental factors.
- The type of rounding and alignment clamps used.
- That the control box used was correctly calibrated and compliant to ISO 12176-2.
- That the weld was allowed to cool for the correct amount of time in the alignment clamp prior to removal of the clamps, including the additional manufacturer allocated joint cooling time, prior to undertaking pressure testing.

An example of a weld record that provides this information is shown in Appendix A.

2.1 TECHNOLOGIES FOR CAPTURING WELD INSTALLATION INFORMATION

Historically, destructive testing has been used to provide information on the long-term performance of welds. Destructive testing usually selects random welds from site in the hope all other welds have been installed with the same methodology, or alternatively, 'pre-construction' welds prepared in a workshop environment – results from these tests are often criticised for not representing actual installation conditions in-field.

In the past five years, suppliers associated with electrofusion and butt welding have developed and marketed technology to capture welding process information by non-destructive methods.

Electrofusion welding machines can function with wireless connectivity, collecting fusion data captured during the fusion process. Electronic data is stored and typically downloaded via a mobile phone app, comprising a wide range of data including:

- Photos of the weld being carried out including key steps and tooling used to monitor the installation process.
- The identification of personnel responsible for the installation.
- Recording of environmental and geolocation information. GPS coordinates can be automatically captured for each fusion weld record.
- Power consumption profile during the welding process.
- Pipe and fitting material and batch manufacturing traceability information.
- Machine internal memory can record thousands of jointing records, retrieved using a USB memory stick.
- QR code wireless scanners, based on a mobile phone with software application, can be installed for reading the barcode, providing evidence of the barcode type (operator, fusion data, traceability etc.). Welding machines can send all data captured during the welding process via Wi-Fi or telecommunication network, to a remote located supervisor to qualify the correct welding procedures.
- Track and Trace web platform services allowing asset owners to manage installed joints on jobsites, using mobile phone app's accessing online web portal services.

Previously this information has been collected by various means, cameras, USB flash drives and written notes. The new apps automate the collection of information and typically send it to the cloud for immediate storage or future retrieval by interested parties e.g., asset owners, consultants, contractors.

As information obtained from the apps is obtained in a non-destructive method, the apps avoid the time, effort and cost associated with destructive testing, and can be used to provide data on all welds completed during a project – not just a snapshot.

Years of accumulated industry knowledge is used to predict the likely long-term performance of a joint because steps completed (or missed) during the welding process have a strong correlation to long-term joint performance.

3. QUALITY CONTROL AND ASSURANCE

It is recommended that the constructor and asset owner utilise a system for monitoring and checking installation quality. The system should include:

- System of traceability to enable information on each weld is linked to the installer and the weld information record for that weld e.g., weld identification code and welder ID stamped or marked permanently on each fitting.
- Audit to ensure the installer is following PIPA POP001 and is complying with the requirements of the electrofusion weld specifications as suggested in this document.

- System to record and store weld information linked to the weld identification system to enable retrieval of the weld data.

Schedule of random visual inspections of weld quality as per the visual inspection guidelines shown in DVS2202 Table 3 or those in POP014. Where welds or processes are identified as non-compliant the identified joint or a random selection of joints prepared by the installer should be cut out for destructive testing using either ISO 13954, ISO 13955, ISO 13956 or ISO 21751 as appropriate.

3.1 DESTRUCTIVE TESTING

It is recommended that a program of destructive testing is established for the duration of each project. Typically, these programs will involve several phases with reduced frequency as welder competence is established. The phases usually consist of pre welder qualification, initial construction checks and then ongoing monitoring.

3.1.1 PRE-QUALIFICATION OF WELDERS

Welders are required to prepare test samples on site using the equipment they have provided for the project. Each welder prepares a weld for each size required in the project. The welds are then tested using accredited third-party destructive testing laboratories to either ISO 13954, ISO 13955, ISO 13956 or ISO 21751 showing pass results.

3.3 INITIAL CONSTRUCTION TESTING

During initial construction samples are selected from each installer and joint size prepared in actual construction conditions and tested as above.

3.1.2 ONGOING CONSTRUCTION TESTING

A random destructive testing regime is established with the constructor, typically 1 from every 100 production welds is used. In the event of a random joint failing a test, samples of other welds made by the same installer are tested. These samples are assessed to determine if the failure is isolated or a systematic failure to apply the procedures outlined in POP001.

At all times, the constructor and asset owner should be carrying out their own quality checks and any welds that appear to be installed incorrectly (using POP014 as a guide) should be cut out for destructive testing.

If it is agreed the failure is due to welding quality issues the welder should be managed to improve weld quality. Management actions could range from increased supervision, retraining and in the case of repeated issues, removal from the project.

One option is to cut out and test an earlier joint made by the welder. If that fails, all joints made in the period between the two failures are considered suspect and are removed. The process is repeated until all suspect welds have been removed and replaced.

REFERENCED DOCUMENTS

POP001	Electrofusion Jointing of PE Pipes and Fittings for Pressure Applications
POP014	Evaluation of PE welds
DVS	Technical Codes on Plastics Joining Technologies English Edition Volume 3 DVS 2202-1(2006-07) Imperfection in Thermoplastic Welded Joints, Features, description, and evaluation.
AS/NZS 4129	Fittings for polyethylene (PE) pipes for pressure applications
AS/NZS 4130	Polyethylene (PE) pipes for pressure applications
AS/NZS 2033	Installation of Polyethylene Pipe Systems
ISO 13954	Plastics pipes and fittings — Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal outside diameter greater than or equal to 90 mm
ISO 13955	Plastics pipes and fittings — Crushing decohesion test for polyethylene (PE) electrofusion assemblies
ISO 13956	Plastics pipes and fittings — Decohesion test of polyethylene (PE) saddle fusion joints -- Evaluation of ductility of fusion joint interface by tear test
ISO 21751	Plastics pipes and fittings — Decohesion test of electrofusion assemblies -- Strip-bend test
ISO 12176-2	Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems — Part 2: Electrofusion

APPENDIX A

SAMPLE WELD RECORD TEMPLATE

In addition to the data suggested by Appendix A in POP001 for "Servicing and Calibration Record Sheet", the following information should be recorded for each weld:

Project details

- Customer
- Project Name
- Date

Operator Details

- Name
- Company Name
- Phone
- Welder Qualifications / ID Number

Conditions

- Ambient Temperature
- Weather

Location of the weld

Pipe Information (upstream and downstream if used with a coupling)

- Grade of Pipe (PE100, PE80…)
- Brand
- DN
- SDR
- Production number
- Dimensions within tolerance
  - Mean Outside Diameter
  - Ovality (if out of tolerance defined in POP001 –use of rounding clamps)
  - Pipe end reversion checked, and pipe cut back if out of specification
- Re-rounding operation, if required, ovality after rounding
- Surface Temperature
- No evidence of flat spots

Fitting Details

- Clean and within original bag
- Type (Coupling, Tee, Saddle)
- Brand of Part Number
- Barcode number
- Batch Number
- Compatible pipe SDR range – confirm fits pipe SDR

Preparation

- Shelter / habitat preventing direct sun light and protection from contaminates
- Satisfactory clamping of pipes / fittings including alignment
- Pipe ends cut square

- Pipe ends washed clean and free from deformation and damage
- Brand, type, and batch number of wipe used for pipe cleaning subsequent to pipe peeling / deburring
- Pipe peeling depth and pipe diameter after peeling recorded
- Satisfactory deburring

Welding Information

- Weld Number
- Fitting welding time from fitting or barcode
- Fitting cooling time from fitting or barcode
- Time welding commences and finishes
- Time cooling commences and finishes

Post-weld

- Indicator pins risen
- No presence of melt exudation from the fitting socket
- Check that the pipe has not moved by inspecting the insertion depth marks
- Any errors on the control box
- Dated signature of operator

PIPA wishes to acknowledge and thank all our Technical Committee members and Industry Consultants for their contribution, expertise, and assistance in the development of this technical document.