

Quality Assurance with Electrofusion Jointing

Electrofusion jointing is a reliable method of joining two plastic pipes together, often in difficult conditions such as open excavation works. Joints that are well made will have the same properties as the pipes that they joint: long lifetimes, corrosion resistance and flexibility to respond to ground movement.

To ensure joints are well made, it is useful to understand what aspects of construction are likely to reduce quality. Equally, with knowledge of these, practices and techniques can be employed to examine or test joints that are made that assist with on-site quality assurance.

The purpose of this short guide is to draw attention to those non-destructive examination (NDE) and non-destructive testing (NDT) techniques that could be used to provide confidence in the quality of electrofusion joints.

Likely modes of failure

A good starting point is to understand what constitutes failure and with this knowledge consider the most appropriate NDE and NDT solutions to employ. Failure mode and effects analysis (FMEA) is a good starting point and for most pipeline owners the failure mode of interest would likely be described as “Loss of pressure containment” or “Leakage”.

There are three likely modes of failure that cause this event:

- 1) Rupture of the fitting body
- 2) Failure of the fitting to pipe interface weld
- 3) Pull-out of the pipe from the fitting

The preparation of this guide allows for a commentary to be made on the likelihood of such events occurring and the steps that could be taken to minimise occurrence. The aim always is to offer cost effective and practical solutions, indeed some of the most effective solutions are knowledge combined with visual assessment and record keeping.

Using the guide

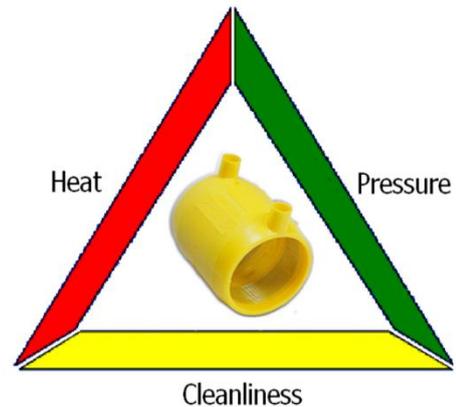
We have outlined a hierarchy of NDE/NDT techniques that could be specified as part of a quality assurance system for field made electrofusion jointing. The hierarchy principles start from least skill/cost to apply and progress through to services available from only a limited group of specialist suppliers suited to extreme risk situations.

The tables describe a system of classification that might be employed by installers. It presumes that the least effort would be employed in a ‘Level 1’ assessment. Equally it assumes that if you were to specify a ‘Level 4’ assessment that this by implication includes Levels 1, 2 and 3 by association.

Good workmanship

Attention is drawn to the key aspects of construction and in particular those where the skill of the installer is key to a successful outcome. This is especially important for those things that currently available NDE and NDT techniques cannot examine in practice.

A well-made joint generally has the attributes of cleanliness, heat and pressure during welding. This is in keeping with principles of welding involving any material and technique. This is illustrated in the image to the right. Reducing one aspect will result in a reduction in joint strength/quality.



The way in which these elements apply in electrofusion is as follows:

- **Cleanliness** comes from management of the work site. The pipe end to be jointed must be scraped to remove its oxidised outer layer along with any physical contamination that is present on the outside surface of the pipe. Care is then taken to prevent dust being attracted, splashing on the pipe end, sweating on, or physically touching the prepared pipe, the types of things that could interfere with jointing.
- **Heat** is applied by electrical current flowing through the wires in the fitting which in turn heat up the surrounding material. It is a feature of electrofusion that it automates the step of heating the material but this relies on the correct output voltage being maintained by the electrofusion control unit (i.e. in calibration) and the correct voltage and welding time being selected. Things that go wrong are pipes being misaligned in the fitting which move during the heating process and displace the wires so that they do not work in the intended manner which is preventable.
- **Pressure** is a design feature that is generated by the fitting once the melt from the fitting contacts the pipe surface. The outer edges of the weld area furthest from the wires tend to freeze off creating containment of the melt which as it continues to heat increases the pressure on the materials being joined. Care is taken to prevent the gap between pipe and fitting being excessive (due to pipe end reversion, pipe ovality, overscraping of the pipe end, pipe not fully inserted, pipe misaligned in the joint) which can act reduce welding pressure.

The techniques described can be used by installers to provide evidence that they have used reasonable standards of care and attention to detail in making joints, or in the case of visual cues as a guide for on-site auditing. In the NDE and NDT techniques that are outlined in the tables below, many of these aspects can be addressed through the use of suitably trained and competent individuals skilled in electrofusion jointing.

If the basic procedures are followed and evidenced it is rare to need to employ specialist imaging techniques which in themselves do not provide a complete assurance of joint integrity, rather it is the balance of evidence built through the assembly process that will do this.

Level	NDE/NDT Action	Informs
1	<p>Visual examination of pipe end scraping</p> <p>Methodology</p> <ol style="list-style-type: none"> 1 Mark the pipe end all over its surface with a permanent marker pen, making a hatched pattern. 2 Make sure the marking is over a length at least equal to the pipe socket plus 20mm or more on top. 3 After scraping make a visual assessment to confirm the pipe has been completely scraped. <p>Evidence</p> <ol style="list-style-type: none"> 1 A date / time stamped photograph is taken showing the hatched pipe end with the marking present. 2 A date/time stamped photograph is taken showing the pipe after it has been fully scraped. 	<p>Removal of material likely to contaminate the weld zone</p> <p>NDE of this type is good at...</p> <ol style="list-style-type: none"> 1 Providing confirmation that oxidised material on the pipe end has been removed, AND 2 Providing confirmation that large scale contamination is not present on the pipe end after scraping is complete <i>which removes material likely to inhibit welding of the fitting to pipe/helps assure the weld interface.</i> <p>NDE of this type is not good at...</p> <ol style="list-style-type: none"> 1 Showing if the scraped area has been touched (finger grease, sweat, etc) during preparation, AND 2 Showing if the installer wiped the pipe end after scraping, OR 3 Showing if very fine dust has been attracted to the pipe surface.
2	<p>Visual examination of pipe & fitting assembly</p> <p>Methodology</p> <ol style="list-style-type: none"> 1 The pipe end should be squarely cut. 2 The pipe end should be round. 3 The pipe should be inserted until it reaches the end of the socket in the fitting. 4 The pipe should be roughly centred in the fitting and not misaligned. <p>Evidence</p> <ol style="list-style-type: none"> 1 Installer may use a cutting jig or guide to trim the pipe end square. 2 Installer uses a pipe rounding tool prior to scraping the pipe. 3 A datum mark is placed on the pipe prior to insertion that can be used to confirm the pipe is fully inserted. 4 A date/time stamped photograph is taken showing the pipe inserted and the datum mark. 5 A date/time stamped photograph is taken showing the completed fitting is free of gross misalignment. 	<p>Gap between pipe and fitting to be joined is controlled in the range expected by manufacturer</p> <p>NDE of this type is good at...</p> <ol style="list-style-type: none"> 1 Providing confirmation that the pipe is fully inserted into the fitting to cover the welding zone. 2 Providing evidence that the pipe was not grossly mishapen or misaligned in the joint <i>which is useful to confirm that a controlled gap exists between the pipe and fitting in the weld area, likely to minimise voids.</i> <p>NDE of this type is not good at...</p> <ol style="list-style-type: none"> 1 Showing if contamination was drawn into the fitting during assembly. 2 Showing if the pipe was overscraped resulting in a big gap between pipe and fitting to be filled during welding.

NDE is verified by photographic evidence

NDE is verified by photographic evidence

Level	NDE/NDT Action	Informs
-------	----------------	---------

3	<p>Visual examination of pipe & fitting assembly</p> <p>Methodology</p> <ol style="list-style-type: none"> 1 The pop-up indicator is checked before welding and after cooling to confirm it has risen. 2 The ends of the fitting are checked to confirm no melt has exuded out of the fitting along the pipe. 3 The body of the fitting is checked to confirm no distortion due to heat has occurred. <p>Evidence</p> <ol style="list-style-type: none"> 1 A date/time stamped photograph can be taken of the completed assembly. 	<p>No gross defects due to over or underheating of the pipe to fitting have occurred</p> <p>NDE of this type is good at...</p> <ol style="list-style-type: none"> 1 Providing confirmation that the fitting was not overheated during the welding process. 2 Providing confirmation that the pipe did not move in the fitting during the welding process <i>which is useful to confirm that melt pressure was achieved (heat plus pressure needed to make a good weld).</i> <p>NDE of this type is not good at...</p> <ol style="list-style-type: none"> 1 Showing if melt has been extruded into the bore of the fitting due to displacement.
----------	--	--

NDE is verified by photographic evidence

4	<p>Physical measurement of pipe & fitting assembly</p> <p>Methodology</p> <ol style="list-style-type: none"> 1 When scraping the pipe, a mechanical scraper is used in preference (e.g. rotary pipe end scraping tool). 2 The pipe diameter is measured before scraping with a PI tape (area to be scraped but not welded). 3 The pipe diameter is measured after scraping with a PI tape (repeat at same position). 4 The difference in diameter before and after scraping should be no more than 1.6mm. <p>Evidence</p> <ol style="list-style-type: none"> 1 The installer may provide written records of the measurements. 2 The written records can be linked to the pipe batch number and manufacturers records. 	<p>Gap between pipe and fitting to be joined is controlled in the range expected by manufacturer</p> <p>NDE of this type is good at...</p> <ol style="list-style-type: none"> 1 Providing confirmation that the pipe has not been overscraped leading to a big gap between pipe and fitting. 2 Providing confirmation that flat spots have not been introduced to the pipe surface leading to localised gaps <i>which is useful to confirm that a controlled gap exists between the pipe and fitting in the weld area, likely to minimise voids.</i>
----------	--	--

NDE is verified by photographic evidence

NDE is verified by manual measurement record

Level	NDE/NDT Action	Informs
-------	----------------	---------

5	<p>Electrofusion control box with basic data recording is used</p> <p>Methodology</p> <ol style="list-style-type: none"> The date and time of the weld is recorded. The fusion time is recorded (whether manually or automatically entered). The actual fusion time achieved is recorded. Error codes describe which box stops if the full fusion time is not achieved. <p>Evidence</p> <ol style="list-style-type: none"> An electronic record can be printed from the electrofusion control box. 	<p>The expected welding parameters were used to make the weld</p> <p>NDE of this type is good at...</p> <ol style="list-style-type: none"> Linking to date/time stamped photographs of the assembly process. Providing confirmation that the correct fusion time was entered and achieved <i>which is useful to confirm that the correct fusion parameters were used.</i> <p>NDE of this type is not good at...</p> <ol style="list-style-type: none"> Confirming the expected heat energy for good welding was achieved (i.e. wire touching/shorting effects). Confirming temperature compensation was used where needed.
---	--	--

NDE is verified by photographic evidence

NDE is verified by manual measurement record

NDE is verified by use of automatic measurements

6	<p>Electrofusion control box with improved data recording is used</p> <p>Methodology</p> <ol style="list-style-type: none"> The ambient/pipe temperature is measured and automatically compensates fusion time. The fitting resistance is measured and recorded. The voltage and current are datalogged through the full weld cycle. Total energy consumed in welding is available as a measurement output. <p>Evidence</p> <ol style="list-style-type: none"> An electronic record can be printed from the electrofusion control box. 	<p>Welding took place in a manner that can be compared to manufacturers reference data</p> <p>NDE of this type is good at...</p> <ol style="list-style-type: none"> Providing confirmation that the expected heat energy for good welding was achieved Providing confirmation of ambient temperature and adjusting the weld process , when needed, to compensate <i>which is useful to confirm that the fitting is welded in the same way as reference tests by the manufacturer.</i> <p>NDE of this type is not good at...</p> <ol style="list-style-type: none"> Confirming the above unless the records are interrogated and linked to the installation site.
---	--	---

NDE is verified by photographic evidence

NDE is verified by manual measurement record

NDE is verified by use of automatic measurements

7	<p>A strength and leak tightness test is conducted</p> <p>Methodology</p> <ol style="list-style-type: none"> Hydrostatic pressure testing is conducted at 1.5x maximum long term pressure rating of the pipe. Pneumatic leakage testing is conducted at 1.5x maximum long term pressure rating of the pipe. <p>Evidence</p> <ol style="list-style-type: none"> Pressure test certificate. 	<p>To verify strength of the assembly and leak tightness</p> <p>NDE of this type is good at...</p> <ol style="list-style-type: none"> Providing confirmation that the body of the fitting will not suffer ductile rupture due to contained pressure. Providing confirmation that the weld interface will not separate in a ductile manner due to pressure. Providing confirmation that for the smallest conveyed molecule size that the system is leak tight. Providing confirmation that any minor damage to pipe/fitting is within acceptable limits (safety factor). <p>NDE of this type is not good at...</p> <ol style="list-style-type: none"> Identifying long term stress crack related failure modes. Identifying long term thermo-oxidative failure modes. 	NDE is verified by photographic evidence	NDE is verified by manual measurement record	NDE is verified by use of automatic measurements	Industry norm NDT measurements are taken	
8	<p>An ultrasonic imaging system is used</p> <p>Methodology</p> <ol style="list-style-type: none"> A probe is used, which is rotated around the circumference of the welded joint and across its width to create an image of the pipe, fittings and weld areas. <p>Evidence</p> <ol style="list-style-type: none"> A digital record is captured of the joint assembly, usually in the form of a three-dimensional dataset or image file. 	<p>To examine for evidence of flaws and/or weld imperfections</p> <p>NDE of this type is good at...</p> <ol style="list-style-type: none"> Detecting voids around or between the wires; forms of contamination; pipe under penetration; misalignment and wire movement. <p>NDE of this type is not good at...</p> <ol style="list-style-type: none"> Detecting flaws of dimensions less than or equal to the wire diameter that are directly beneath, or obscured by, the wire. Being used by an unskilled person due to the need to interpret the data output. 	NDE is verified by photographic evidence	NDE is verified by manual measurement record	NDE is verified by use of automatic measurements	Industry norm NDT measurements are taken	Advanced NDT with specialist interpretation

Level	NDE/NDT Action	Informs
-------	----------------	---------

9	<p>A high frequency imaging system is employed</p> <p>Methodology</p> <ol style="list-style-type: none"> 1 Ultrasonic thickness gauge is used around the circumference of the fitting. <p>Evidence</p> <ol style="list-style-type: none"> 1 An electronic record of measurements taken. 	<p>To examine for evidence of voids, wire location, physical contamination</p> <p>NDE of this type is good at...</p> <ol style="list-style-type: none"> 1 Providing confirmation that voids are not present between wires in the fitting/interface weld. 2 Providing confirmation that large particle contamination is not present in the weld areas between wires <i>which is useful to confirm the quality of the weld interface.</i> <p>NDE of this type is not good at...</p> <ol style="list-style-type: none"> 1 Reporting on voids or contamination beneath the wires. 2 Identifying the presence of cold lap welds. 3 Being used by a unskilled person, due to need for interpretation of data output.
---	--	--

NDE is verified by photographic evidence	NDE is verified by manual measurement record	NDE is verified by use of automatic measurements	Industry norm NDT measurements are taken	Basic NDT measurements are taken	Advanced NDT with specialist interpretation
--	--	--	--	----------------------------------	---