
WATER INDUSTRY SPECIFICATION

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(Page 1 of 26)

UK Water Industry

SPECIFICATION FOR THE FUSION JOINTING OF POLYETHYLENE PRESSURE PIPELINE SYSTEMS USING PE80 AND PE100 MATERIALS

FOREWORD

This specification has been prepared under the direction of the UKWIR Pipeline Innovation Group and the Water Industry Thermoplastic Jointing Group with membership drawn from the UK Water and Gas Industries. The specification covers welding of PE pipes using:

- conventional single and dual pressure butt fusion;
- butt fusion by 'Fastwelding' techniques for PE80 pipes; and
- electrofusion coupler and saddle jointing

This revision has been issued to replace WIS 4-32-08: Issue 2 because:

- with the exception of colour differences, the materials used by the gas and water industries have similar welding characteristics and there is a desire to have harmonised jointing conditions;
- when WIS 4-32-08: Issue 2 was prepared, butt fusion jointing using manual machines was the dominant welding method. However, most contractors now use automatic butt fusion machines, and in the UK gas industry this is mandatory;
- shorter welding cycle procedures may be achieved via 'UKWIR Fastweld' where an automatic machine is controlled to operate with reduced weld interface heat losses and this allows for a significant reduction in cooling time;

- with the forthcoming introduction of new European (CEN) standards for PE pipe systems for water and sewerage applications (prEN 12201 and prEN13244), the existing WISs for PE pipes and electrofusion fittings will be withdrawn.

WIS 4-32-03, 4-32-13 and 4-32-14 contained the test procedures for electrofusion welded joint assessments. These procedures have now been incorporated into this document. It should be noted that the tolerance to contamination test set out in Appendix A of this document is not included in prEN 12201-3 or 13244-3. Once prEN 12201-3 or 13244-3 is ratified the tolerance to contamination test may only be specified by clients purchasing in accordance with the Construction Products Directive by reference to this document (WIS 4-32-08).

Note: Whilst this document is aimed at UK water industry requirements, there are common practices in fusion jointing procedures across both the gas and water utilities. In particular electrofusion coupler and saddle jointing procedures are identical and conventional single pressure butt fusion is used by the gas industry across their full range of PE pipes.

Technical enquiries should be directed to: WRc plc, Frankland Road, Blagrove, Swindon, Wilts, SN5 8YF

Further copies from:
WRc, Frankland Road, Blagrove, Swindon, Wilts, SN5 8YF
Tel: +44 (0) 1793 865138/069/012 Fax: +44 1793 865001

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1. SCOPE

This document specifies the equipment, jointing procedures, maintenance, servicing and calibration, records, training and testing for fusion welding of all PE pipes and fittings. This specification requires that the installer shall operate a quality assurance system, preferably to BS EN ISO 9000/9001, which covers procedures and equipment provision and maintenance relating to the fusion jointing of PE pipe.

Users are reminded that it is essential that fusion jointing is carried out by skilled operators and all installers should be trained via an appropriate National Vocational Qualification (NVQ) or similar industry scheme.

2. DEFINITIONS

2.1 General

This method of jointing requires an electrically heated plate to raise the temperature of the pipe ends to the fusion temperature and is suitable for jointing pipes and fittings in the size range greater than 63 mm. In general:

- only pipes and fittings of the same SDR should be jointed together,
- PE80 (MDPE) pipes should not be welded to PE100 (HDPE) pipes. Note that PE80 (HDPE) is outside the scope of this specification, unless special test joints are made and tested using the assessment procedures outlined in this specification to ensure confidence in joint integrity.

NOTE: In principle, plates can also be heated by electromagnetic induction. This technique is not covered by this document, but the key stages of the jointing operation would remain the same.

2.2 Machine types

This specification is based on the overall requirements of both the gas and water industries and covers three types of welding machine:

- manual machines - where the trimmer and heater plate are inserted and removed manually and the interface pressures are controlled by a hand pump;
- semi-automatic machines - where the trimmer and heater plate are inserted/removed manually but interface pressures are controlled by an electro/hydraulic power pack. (A data logger should be used to record welding parameters);
- fully automatic machines - where the heater plate is removed automatically and all the process parameters are controlled by a microprocessor. The fusion pressures are automatically calculated and recorded by the machine.

2.3 Machine requirements - all butt fusion jointing

2.3.1 Chassis and Clamps

- a) The machine shall have a frame containing clamps which are sufficiently robust to re-round and accurately align the pipes to be jointed.

- b) The machine shall have a minimum of two rams mounted on the pipe centre-line axis. The rams shall move freely and control the movement of any sliding clamps. All slides shall be kept free from rust and lubricated at all times.

2.3.2 Hydraulic/pneumatic unit

- a) The unit shall be capable of actuating the clamp unit to provide adequate force and speed of operation. A monitoring device shall be provided to monitor ram pressure.
- b) For manual machines a data plate shall be permanently attached to the unit setting out jointing and cooling pressures and times for relevant sizes of pipe. For dual pressure jointing, the jointing pressure shall be calculated based on a weld interface stress of 0.15 Mpa and the cooling pressure based on a weld interface stress of 0.025 Mpa. UKWIR Fastweld jointing is not permitted using manual machines.
- c) The data plate shall be blue and printed in a contrasting colour.
- d) For automatic machines, jointing data may be provided by means other than a data plate.

2.3.3 Trimming tool

- a) The trimming tool shall be capable of being mounted securely within the frame of the jointing machine, to prevent twist during machining, so that this equipment can produce accurately matched planed faces.
- b) All trimming tools shall be fitted with suitable safety devices to prevent their operation outside the fusion machine.
- c) Trimming blades shall be sharp and have defect free cutting edges to provide continuous swarf of uniform thickness.

2.3.4 Heater plate

- a) The plate shall be electrically heated and be provided with a suitable temperature controller to give a uniform operating surface temperature of 230 +10, -5°C (225 to 240°C).

- b) The plate surfaces shall have adequate release properties. The surface shall clearly show the presence of any contaminants. **ADDITIONAL SPRAY-ON RELEASE AGENTS SHALL NOT BE USED**

- c) The heater plate shall be fitted with a temperature probe or indicator accurate to within +/- 1°C in the range 225 to 240°C.
- d) Surface temperature shall be measured during routine calibrations and in cases of dispute. To ensure that the temperature of the heater plate has stabilised, the machine shall be in operation with the plate in its guard or muff for at least twenty minutes prior to measurement. The probe shall be held in position for at least 60 seconds before the reading is taken. Site readings shall be taken inside a shelter.

NOTE 1: The temperature of each side of the plate should be measured, in still air, at a minimum of four equally spaced points denoted North, South, East, West (with North at the top of the plate) for pipes up to 250 mm diameter, and eight equally spaced points for all larger systems.

NOTE 2: The probe could scratch or otherwise mark the surface of the heater plate if used carelessly. Readings may therefore be taken just outside the position where the pipe contacts the heater plate.

2.3.5 Control system

The control system shall be designed to carry out the operations detailed in figures 1a, 1b and 1c, automatically at the temperatures, times and pressures indicated in the respective tables.

2.3.6 Generators

The nominal output voltage shall be 110V with an actual output voltage within the range 103V - 120V at any KVA loading between zero load and full load. The generator shall be selected to suit the butt fusion machine power requirements.

NOTE: Contractors should always seek the advice of the welding machine supplier for information on power requirements.

2.4 Machine requirements – butt fusion

All equipment for butt fusion jointing shall comply with the requirements of WIS 4-32-16. This specifies the requirements for design of the machine chassis, trimmer, heater plate, temperature control and interface force transmission.

2.5 Machine requirements - 'Fastweld process'

2.5.1 High productivity butt fusion jointing (UKWIR Fastweld) was initially developed for PE80 (MDPE) pipes with wall thicknesses up to 36mm, i.e. sizes 90 to 400 mm ONLY, SDR11 and thinner.

2.5.2 When jointing pipe using UKWIR Fastweld conditions, the control system shall be capable of recording, storing and downloading all target parameters and those actually achieved by the machine in the jointing process. The parameters shall include: Bead Pressure, Joining Pressure, Dynamic Drag, Heater Temperature, Bead Up Pressure, Heat Soak Time Dwell Time, Fusion Pressure, Cooling Time in the machine. (See Table 3 for details).

2.5.3 The servicing, conversion, up-grade and installation of any of the required components (including software) shall only be carried out by the original machine manufacturer or their approved agent.

2.6 Ancillary Equipment

In addition to the butt fusion welding machine and generator, the contractor shall also supply site crews with:

- shelters to protect pipe/fittings and equipment against dust, rain, snow and draughts;
- pipe support rollers (essential to minimize drag forces);
- external bead remover capable of removing the cold bead cleanly, in a continuous strip, without damage to either joint or bead or adjacent areas of the pipe. The bead removal tool shall not induce any slits, gouges or other defects into the pipe wall;
- calibrated digital thermometer with both calibrated surface and insert probes;
- timer (for manual machines);
- pipe end plugs;

- bead gauge;
- indelible marker pen for marking beads and joint numbers;
- clean ground sheet or base board.

3. BUTT FUSION JOINTING METHODS

3.1 Definitions – butt fusion welding

3.1.1 **Interface fusion stress:** the actual stress exerted on the heater plate by the pipe ends during both bead-up and during jointing and cooling.

3.1.2 **Fusion pressure:** the gauge pressure to provide, on a given machine and for a given pipe cross sectional area, a pressure equivalent to the interface fusion stress. [Note: This pressure is a function of the ram dimensions and the efficiency of the machine and this data should be given on the data plate of all, except fully automatic, machines.]

3.1.3 **Drag pressure:** the gauge pressure required to overcome, on a given machine and for a given pipe cross sectional area, the sliding frictional drag of the machine and pipe when closing. [NOTE: Gauge pressure is a function of ram dimensions and the efficiency of each machine and should be provided by the manufacturer.]

3.1.4 **Initial bead-up pressure:** the gauge pressure required to provide, on a given machine and for a given pipe cross sectional area, an interface stress of 0.15 MPa and thereby form the initial bead on the ends of the pipes.

3.1.5 **Soak pressure:** the gauge pressure required, on a given machine and for a given pipe cross sectional area, to positively maintain the pipe in contact with the heater plate.

3.1.6 **Jointing pressure:** the sum of the fusion pressure and the drag pressure.

3.1.7 **Cooling pressure:** the gauge pressure required to provide, on a given machine and for a given pipe cross sectional area, the appropriate interface stress to be maintained during the cooling phase.

3.1.8 Heater Plate Temperature: The temperature at any location on the surface of the heater plate shall be 230°C (+10°C, -5°C).

3.1.9 Plate removal time: the maximum time permitted for the separation of the pipe ends from the heater, removal of the heating plate and closure of the carriage to bring the two pipe ends together.

3.2 Siting the equipment

3.2.1 To aid alignment of pipes into the machine and for ease of movement, pipes to be jointed shall always be supported on rollers placed at suitable intervals to minimize the effect of pipe sagging between them.

3.2.2 The butt jointing machine shall be placed on a clean, level and firm surface.

NOTE: If necessary the jointing machine should be placed on a suitable baseboard or ground sheet.

3.2.3 Pipe strings shall be laid out on a level surface where possible. If the pipe string is on a slope, particular care shall be taken when measuring and controlling machine ram pressures to ensure that consistent results are obtained.

3.3 Preparation

3.3.1 The trimming tool surfaces shall be visually inspected every day for grease and dirt and cleaned where necessary.

3.3.2 Particular attention shall be paid to the condition of the blades. Blunt or damaged blades shall be replaced.

NOTE: Care should be taken when handling sharp blades.

3.3.3 The heater plate shall be thoroughly washed with copious quantities of clean water prior to any welding. The heater plate shall be cold and disconnected from the power supply when washed [Note: A hot plate will evaporate the water from the surface, cause smearing and leave hardness salts behind].

3.3.4 Only clean, disposable, lint-free materials shall be used to clean the plate. Grease and oily films are not fully removed by using water, therefore wiping with a clean, lint-free cloth or cleaning material dampened by isopropanol may be necessary.

NOTE: When using solvents for cleaning, the plate should be cold to prevent rapid evaporation and avoid unnecessary fumes.

3.3.5 Although washing will remove large patches of dirt, very fine particles of dust may still accumulate within the hollows of the textured surface of a heater plate. To remove such dust, a dummy joint shall be made at the start of each jointing session, whenever the plate has been allowed to cool below 180°C, or at a size change.

3.3.6 A second dummy joint shall be made for sizes greater than 180 mm. The procedure to be adopted is:

- A dummy joint may be made using pipe off cuts of the same size, SDR and material as the pipe being installed. Alternatively, lengths of pipe which are to be installed may be used for this procedure, providing the pipe ends are allowed to cool for at least 10 minutes before re-trimming to make the production joint.
- Follow the normal trimming, bead-up and full soak time routine for jointing (see 3.5).
- For automatic machines the procedure can be discontinued after the full heat soak cycle providing the machine automatically stores the parameters for verification. Otherwise, a full joint shall be made and cut out as proof that a dummy joint has been done.

3.3.7 Prior to clamping in the butt fusion machine, the ends of the pipes (in excess of the clamping area) shall be wiped with clean, damp lint free material or prescribed 'wet wipe' on both inner and outer surfaces to remove mud or dust.

3.3.8 The pipe shall be wiped dry prior to proceeding.

3.3.9 To prevent contamination, the pipe ends shall not be handled thereafter.

3.4 Pre-jointing checks

3.4.1 Ensure that the equipment is correctly sited (see 3.2 of this specification).

3.4.2 Check that there is sufficient fuel for the generator to complete the joint. Start the generator before connection to the machine and check that it is functioning correctly.

3.4.3 Check trimming tool, hydraulic pump and heater plate are clean and in working order (see 3.3 of this specification).

3.4.4 Check both pipes or pipe and fitting to be jointed are of the same size, SDR and material. Only compatible materials shall be joined together.

NOTE: If in doubt the advice of the pipe or fitting manufacturer should be sought.

3.4.5 The drag pressure (in bar) shall be assessed accurately prior to making each fusion joint and added to the obtained basic ram pressure values (in bar).

NOTE 1: The drag pressure should normally be less than the fusion pressure.

NOTE 2: Drag pressure is automatically measured when fully automated butt fusion jointing machines are used.

3.5 Jointing Procedure

3.5.1 Trimming

- a) Position pipes in the clamps with ends adjacent to the trimming tool and with pipe markings aligned. This will assist in obtaining the best match in diameter. Pipes shall be jointed so that the pipe markings are uppermost when the pipe is in the trench.
- b) Tighten pipe clamps to grip and re-round the pipes.
- c) Cover the free pipe ends to prevent cooling of the plate by internal draughts.
- d) Switch on the trimming tool and move the pipe ends against the trimmer with a steady pressure until continuous shavings are produced from each of the pipe ends.

- e) Release the pressure from the pipe ends slowly in order to avoid steps on the trimmed faces and move away from the trimmer tool.
- f) Once the trimming tool has come to a halt remove it from the chassis and then remove the loose shavings from the machine and inside the pipe or fitting. **DO NOT TOUCH THE MACHINED FACES OF THE PIPE OR FITTING** as this will contaminate the joint interface.
- g) Check the pipe or fitting faces are completely trimmed and re-trim if necessary.
- h) Bring the pipe or fitting ends together and check that there is no visible gap between the faces. Also check that mismatch of the outside pipe diameter is within the following limits:
 - No discernible mismatch up to and including 180 mm.
 - Less than 10% of wall thickness above 180 mm.
- i) If the mismatch is greater than that stated above then the pipe shall be realigned and re-trimmed.

3.5.2 Bead up

- a) Press the pipe against the heater plate using the appropriate initial bead up interface pressures for the chosen method of jointing (see 3.7 this specification.)

NOTE: The initial bead should be uniform around the circumference and be of a width similar to those given in the appropriate table.

3.5.3 Heat Soak

- a) After the initial bead up, the pressure in the system shall be released so that the pressure gauge registers between zero and the drag pressure to control bead growth during heat soak time. Check that the clamps do not move. The pipe ends shall be maintained in contact with the heater plate.

3.5.4 Plate removal

- a) During removal of the heater plate, no molten polymer shall stick to the heater plate. If it does then the joint shall be aborted, the plate cleaned and the surface quality of the plate examined.
- b) The heater plate shall be removed and the molten ends brought together within the specified time for the chosen method of jointing (see 3.7 of this

specification). If this criterion is not met then the joint shall be aborted.

- c) For single and dual pressure welding conditions the maximum plate removal time shall be less than 10 seconds.
- d) For UKWIR Fastweld joints the maximum plate removal time, shall be less than 3.5 seconds.

3.5.5 Fusion jointing

- a) Immediately after plate removal the hot pipe ends shall be brought together in a smooth controlled manner and the pressure raised to the interface fusion pressure for the chosen method of jointing (see 3.7 of this specification).

NOTE 1: The fused material should "roll" back in a uniform manner and there should be no signs of bubbles or contamination present.

NOTE 2: Provided that each half of the final bead is of a similar shape and size, it has been agreed that the overall width should not be a critical factor for the assessment of a butt fusion joint – hence the values quoted in the tables are typical only. However, significant deviations need to be investigated, looking at both pipe material and equipment to identify possible reasons.

NOTE 3: The uniformity of the fusion joint bead around the full circumference of the pipe and between the two halves of the bead at any single point around the circumferences, is however important, as this indicates whether the butt fusion equipment is set up and operating properly.

3.5.6 Cooling

- a) The joint shall be allowed to cool whilst maintaining the interface jointing pressure for at least the times for the chosen method of jointing for the appropriate size (see 3.7 of this specification).
- b) Pipes, which have not been supplied coiled, may be released from the clamps for the final stage of cooling.

- c) During the cooling time out of the clamps the pipe joint shall be lifted no more than absolutely necessary to progress to the next joint. Pipe strings shall not be pulled via a newly made joint until the full cooling time has elapsed.
- d) Any cover or plug used to block the ends of the pipe may be removed to promote a draught through the pipe to assist cooling.
- e) Installation of the pipe shall not take place until the surface temperature of the bead is below 40°C as measured by a digital surface probe thermometer.

3.5.7 Bead Appearance

- a) All machines shall ensure that there are no differences in final joint appearance due to the alteration between Fastweld and conventional welding techniques – for identical pipe types.

NOTE 1: The external weld beads should have no wrinkles or discontinuities and be of symmetrical appearance. The width should be similar to those indicated in the respective table.

NOTE 2: Provided that each half of the final bead is of a similar shape and size, the overall width should not be a critical factor for the assessment of a butt fusion joint – hence the bead sizes quoted in the appropriate table 1, 2 or 3 are typical only.

3.5.8 Debeading

- a) After the cooling time has elapsed the external beads (and internal beads if required) shall be removed using a suitable debeading tool approved by the client. The bead removal tool shall not induce any slits gouges or defects in the pipe wall or bead.
- b) On removal, the bead shall be examined for signs of defects or splitting along the length of the bead joint. Further testing shall be carried out by twisting the bead in several places along its length, again looking for splitting.

NOTE: For water/sewage transmission, the internal bead will not significantly affect the flow properties. Thus, there is no need to remove the bead to improve hydraulic characteristics). However, sticks and fibrous material can be trapped by internal beads in pumped sewerage mains.

- c) If such a defect or split is seen then the joint shall be cut from the pipeline and the joint remade. If a similar defect recurs, all further production jointing shall cease until the equipment has been thoroughly examined, problems rectified and new trial joints made and tested
- d) The beads and joint shall be numbered/coded using an indelible marker pen.

3.6 Welding at low temperatures

3.6.1 Where welding is conducted at ambient temperatures below 0°C, a space heater shall be provided for the welding shelter to raise the local temperature above 0°C for single pressure welding and 5°C for all other methods.

3.6.2 Test joints shall be made to establish whether satisfactory joint integrity is maintained. All tensile test samples shall fail in a ductile manner. If it is suspected that the low temperature has caused weld embrittlement, then the average heat plate temperature should be increased to the upper limit specified (240°C). Further checks shall then be made to ensure that satisfactory joint performance is achieved.

3.6.3 Welding machines with control systems that do not intrinsically compensate for ambient temperature changes shall demonstrate effective compensation operation through a defined appropriate test program as agreed by the client utility or his appointed representative.

3.7 Parameters specific to jointing method

3.7.1 Single pressure welding

- a) Single pressure welding is suitable for jointing pipes with wall thickness up to 22 mm. NOTE: This equates to 90 to 400 mm, SDR 17 for standard pipes but will be extended for thin wall PE lining pipes.
- b) For Single Pressure welding, the sum of the fusion pressure and drag pressure equals the bead-up pressure, the jointing pressure, and the cooling pressure (see figure 1a).

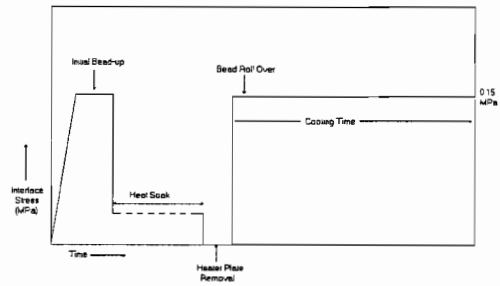


Figure 1(a) Single pressure butt fusion jointing cycle (not to scale)

Heater plate temp	230°C (+10°C, -5°C)
Initial bead-up stress	0.15 MPa (+/- 0.02 MPa)
Heat soak time	See Table 1
Indicated gauge pressure during heat soak	0 to drag
Heater plate removal time	10 secs maximum
Bead roll over stress	0.15 MPa +/- 0.02 Mpa
Interface fusion stress	0.15 MPa +/- 0.02 Mpa
Cooling time (in clamps)	See Table 1
Note: Jointing parameters for pipes of SDRs not given in the table should be sought from the pipe manufacturer.	

3.7.2 Dual pressure welding

- a) Dual pressure welding shall be used for all thicker walled (>22mm) PE pipes to enhance ductility.

NOTE 1: It is recognised that there are some materials for which conventional 'single pressure' conditions are satisfactory for all sizes of pipe. However, with certain PE 100 materials the polymers may also be more crystalline. The polymer can have a coarse crystal structure, and the region between the molten and solid PE material can become shear-distorted when force is applied during cooling. This region can then reduce overall ductility in the weld area.

NOTE 2: The objective of dual pressure welding is to allow the molten polymer to cool with minimal shear stress, thus allowing the crystal structure to develop without distortion.

- b) For Dual Pressure welding, the sum of the fusion pressure and drag pressure equals the bead-up

pressure, and the jointing pressure. The cooling pressure equals 1/6 of the fusion pressure (see figure 1b).

- c) The 'Dual Pressure' cycle is the same as for normal welding until the plate is removed, at which point:
- Apply the "conventional" interface pressure of 0.15Mpa for 10 secs **after** bringing the pipe ends together to allow the melt on each surface to mix and a bead to form – to clear any contaminants from the weld interface.
 - Reduce the pressure to 1/6th of the joining pressure (excluding drag) during cooling.

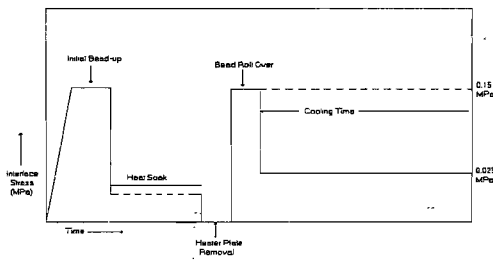


Figure 1(b) Dual pressure butt fusion jointing cycle (not to scale)

Heater plate temp	230°C (+10°C, -5°C)
Initial bead-up stress	0.15 MPa (+/- 0.02 MPa)
Heat soak time	See Table 2
Indicated gauge pressure during heat soak	0 to drag
Heater plate removal time	10 secs maximum
Bead roll over stress	0.15 MPa +/- 0.02 Mpa
Bead roll over time	10 secs +/- 1 sec
Interface fusion stress	See Table 2
Cooling time (in clamps)	See Table 2
Note: Jointing parameters for pipes of SDRs not given in the table should be sought from the pipe manufacturer.	

3.7.3 UKWIR Fastweld

- a) UKWIR Fastweld jointing conditions are suitable only for use with **fully automatic** butt fusion machines **ONLY**.

NOTE: The time savings achieved are as a direct result of the decrease in heater plate removal time, from a maximum of 10 seconds for manual and semi automatic machines to a maximum of 3.5 seconds for a fully automatic machine. This decrease in plate removal time effectively reduces the amount of heat energy lost from the pipe ends, therefore both the soak times and cool times can be reduced and still produce a high integrity joint. The Fastweld parameters also incorporate the principles of dual pressure welding for wall thicknesses greater than 22 mm.

- b) If drag conditions prevail which inhibit a 3.5 second plate removal time, the control system shall advise the operator that Fastwelding will not operate and that action must be taken to reduce the drag pressure or revert to conventional welding conditions.

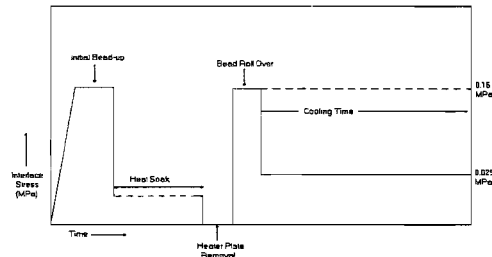


Figure 1(c) UKWIR Fastweld butt fusion jointing cycle (not to scale)

Heater plate temp	230°C (+10°C, -5°C)
Initial bead-up stress	0.20 MPa (+/- 0.02 MPa)
Heat soak time	See Table 3
Indicated gauge pressure during heat soak	0 to drag
Heater plate removal time	3.5 secs maximum
Bead roll over stress	0.15 MPa +/- 0.02 Mpa
Bead roll over time	10 secs +/- 1 sec
Interface fusion stress	See Table 3
Cooling time (in clamps)	See Table 3
Note: Jointing parameters for pipes of SDRs not given in the table should be sought from the equipment manufacturer.	

4. ELECTROFUSION JOINTING

4.1 General

4.1.1 This method of jointing uses electrofusion fittings containing electrical wires which, when connected to the appropriate power source, fuse the fitting onto the pipe without the need for additional heating equipment.

4.1.2 Electrofusion fittings are currently available for sizes up to and including 630 mm with larger sizes under development.

4.1.3 The effectiveness of this technique depends on attention to effective preparation of the jointing surfaces, in particular the removal of the oxidised surface of the pipe over the jointing area and ensuring the jointing surfaces are clean. Although any contamination may be removed prior to jointing, the Water Industry also requires that the pressure resistance of all electrofusion joints be assessed using a short term burst procedure on fittings welded to talc contaminated pipe in order to ensure that only fittings tolerant of site conditions are used. This requirement is met by specifying that fittings meeting the test requirements of WIS 4-32-14 be used.

NOTE: WIS 4-32-14 will be withdrawn on the publication of prEN 12201-3 but the relevant test has been included here as Appendix A and may be used by organisations purchasing in accordance with the

Construction Products Directive after WIS 4-32-14 is withdrawn.

4.1.4 With electrofusion saddle jointing, an electrical resistance element is incorporated in the base of the saddle (tapping tees or branch) which when connected to an appropriate power source, melts and fuses the materials of the pipe and fitting together.

The success of this technique, as with socket jointing, depends on effective preparation of the jointing surfaces, in particular the removal of the oxidized surface of the pipe over an area equivalent to the saddle base.

Three methods of holding the tapping tee / branch saddle during the fusion cycle are used:

- i. top loading
- ii. under clamping
- iii. wrap-around systems

Because of the variations of equipment used for under clamping and wrap around, common procedures for holding the saddle during the fusion cycle cannot be specified, although the general parameters are similar to those for top loading. Where such fittings are used, the manufacturer's procedure for holding the fitting during the fusion cycle shall be followed.

4.2 Machine requirements – control box

4.2.1 The control box input supply shall be from a nominal 110V (55V – 0 – 55V) generator of up to 4.8kVA capacity. The nominal output of the generator shall be 110V +25%, -10% between no load and full load.

4.2.2 No extension leads shall be used on the control box outlet connectors.

4.2.3 Control boxes shall have data retrieval to ensure full traceability of jointing/site practices.

NOTE: Control boxes are not 'intrinsically safe' and shall not be taken into any trench.

4.3 Ancillary Equipment

4.3.1 Besides the control box and generator, the contractor shall also supply site crews with ancillary equipment to be used as follows.

TABLE 1 Single Pressure Butt Fusion Joining Conditions for PE 80 and PE 100

Outside Diameter	SDR	Wall Thickness (minimum)	Bead-Up Interface Stress	Initial Bead Size (Approx)	Soak Time	Minimum Soak Interface Stress	Maximum Plate Removal Time	Fusion and Cooling Interface Stress	Cooling Time in Clamps	Cooling time out of Clamps	Cooling Time for Coiled Pipes in Clamps	Typical Final Overall bead Width	
												min	max
(mm)		(mm)	(MPa)	(mm)	(Seconds)	(MPa)	(seconds)	(MPa)	(minutes)	(minutes)	(minutes)	mm	mm
90	17	5.1	0.15	2	110	0	10	0.15	10	5	15	8	15
90	11	8.2	0.15	2	140	0	10	0.15	10	5	15	9	16
110	17	6.3	0.15	2	125	0	10	0.15	10	5	15	9	16
110	11	10.0	0.15	2	160	0	10	0.15	10	5	15	10	17
125	17	7.1	0.15	2	130	0	10	0.15	10	5	15	9	16
125	11	11.4	0.15	2	175	0	10	0.15	10	5	15	10	17
160	17	9.1	0.15	2	150	0	10	0.15	10	5	15	9	16
160	11	14.6	0.15	2	205	0	10	0.15	10	5	15	11	18
180	17	10.2	0.15	2	160	0	10	0.15	10	5	15	10	17
180	11	16.4	0.15	2	225	0	10	0.15	10	5	15	11	18
225	17	12.8	0.15	2	190	0	10	0.15	10	5	-	10	17
225	11	20.5	0.15	2	265	0	10	0.15	10	5	-	12	19
250	26	9.6	0.15	2	155	0	10	0.15	10	5	-	9	16
250	17	14.2	0.15	2	200	0	10	0.15	10	5	-	10	17
280	26	10.7	0.15	2	170	0	10	0.15	10	5	-	13	22
280	17	15.9	0.15	3	220	0	10	0.15	10	5	-	14	23
315	26	12.1	0.15	3	180	0	10	0.15	10	5	-	13	22
315	17	17.9	0.15	3	240	0	10	0.15	10	5	-	14	23

Outside Diameter	SDR	Wall Thickness (minimum)	Bead-Up Interface Stress	Initial Bead Size (Approx)	Soak Time	Minimum Soak Interface Stress	Maximum Plate Removal Time	Fusion and Cooling Interface Stress (First 10 Secs)	Cooling Interface Stress (After 10 secs)	Cooling Time in Clamps	Cooling time out of Clamps	Typical Final Overall bead Width	
												min	max
(mm)		(mm)	(MPa)	(mm)	(Seconds)	(MPa)	(seconds)	(MPa)	(MPa)	(minutes)	(minutes)	mm	mm
250	11	22.7	0.15	2	285	0	10	0.15	0.025	15	7.5	15	24
280	11	25.4	0.15	3	315	0	10	0.15	0.025	15	7.5	16	25
315	11	28.6	0.15	3	345	0	10	0.15	0.025	15	7.5	17	26
355	26	13.6	0.15	3	195	0	10	0.15	0.025	10	5.0	13	22
355	17	20.1	0.15	3	260	0	10	0.15	0.025	15	7.5	15	24
355	11	32.3	0.15	3	385	0	10	0.15	0.025	15	7.5	18	27
400	26	15.3	0.15	3	215	0	10	0.15	0.025	10	5.0	14	23
400	17	22.7	0.15	3	285	0	10	0.15	0.025	15	7.5	15	24
400	11	36.4	0.15	3	425	0	10	0.15	0.025	20	10.0	18	27
450	26	17.2	0.15	3	235	0	10	0.15	0.025	10	5.0	14	23
450	17	25.6	0.15	3	315	0	10	0.15	0.025	15	7.5	16	25
450	11	41.0	0.15	3	470	0	10	0.15	0.025	20	10.0	19	28
500	26	19.1	0.15	3	250	0	10	0.15	0.025	10	5.0	15	24
500	17	28.3	0.15	3	345	0	10	0.15	0.025	15	7.5	17	26
500	11	45.5	0.15	3	515	0	10	0.15	0.025	20	10.0	20	29
560	26	21.4	0.15	3	275	0	10	0.15	0.025	15	7.5	15	24
560	17	31.7	0.15	3	380	0	10	0.15	0.025	15	7.5	17	26
560	11	50.8	0.15	3	570	0	10	0.15	0.025	20	10.0	22	31
630	26	24.1	0.15	3	300	0	10	0.15	0.025	15	7.5	16	25
630	17	35.7	0.15	3	420	0	10	0.15	0.025	15	7.5	18	27
630	11	57.2	0.15	3	635	0	10	0.15	0.025	25	12.5	23	32
710	26	27.2	0.15	3	335	0	10	0.15	0.025	15	7.5	16	25
710	17	40.2	0.15	3	465	0	10	0.15	0.025	20	10.0	19	28
800	26	30.6	0.15	3	370	0	10	0.15	0.025	15	7.5	17	26
800	17	45.3	0.15	3	515	0	10	0.15	0.025	20	10.0	20	29
900	26	34.6	0.15	3	405	0	10	0.15	0.025	20	10.0	18	27
900	17	50.9	0.15	3	570	0	10	0.15	0.025	20	10.0	22	31
1000	26	38.4	0.15	3	445	0	10	0.15	0.025	20	10.0	19	28
1000	17	56.6	0.15	3	630	0	10	0.15	0.025	25	12.5	23	32

TABLE 2: Dual Pressure Butt Fusion Joining Conditions for PE80 and PE100

Outside Diameter	SDR	Wall Thickness (minimum)	Bead-Up Interface Stress	Initial Bead Size (approx)	Soak Time	Minimum Soak Interface Stress	Maximum Plate Removal Time	Fusion and Cooling Interface Stress (first 10 secs)	Fusion and Cooling Interface Stress (after 10 secs)	Cooling Time in Clamps	Cooling Time, Out. of Clamps	Cooling Time for Coiled Pipes in Clamps	Typical Final Overall bead width	
													(Min)	(Max)
(mm)		(mm)	(MPa)	(mm)	(secs)	(MPa)	(secs)	(MPa)	(MPa)	(secs)	(minutes)	(minutes)	(mm)	(mm)
90	17	5.1	0.2	2	15	0	3.5	0.15	0.15	260	5	15	8	15
90	11	8.2	0.2	2	20	0	3.5	0.15	0.15	260	5	15	9	16
110	17	6.3	0.2	2	15	0	3.5	0.15	0.15	260	5	15	9	16
110	11	10.0	0.2	2	20	0	3.5	0.15	0.15	270	5	15	10	17
125	17	7.1	0.2	2	20	0	3.5	0.15	0.15	260	5	15	9	16
125	11	11.4	0.2	2	25	0	3.5	0.15	0.15	270	5	15	10	17
160	17	9.1	0.2	2	20	0	3.5	0.15	0.15	270	5	15	9	16
160	11	14.6	0.2	2	30	0	3.5	0.15	0.15	280	5	15	11	18
180	17	10.2	0.2	2	20	0	3.5	0.15	0.15	270	5	15	10	17
180	11	16.4	0.2	2	30	0	3.5	0.15	0.15	280	5	15	11	18
225	17	12.8	0.2	2	25	0	3.5	0.15	0.15	270	5	-	10	17
225	11	20.5	0.2	2	35	0	3.5	0.15	0.15	290	5	-	12	19
250	26	9.6	0.2	2	20	0	3.5	0.15	0.15	270	5	-	9	16
250	17	14.2	0.2	2	30	0	3.5	0.15	0.15	270	5	-	10	17
250	11	22.7	0.2	2	40	0	3.5	0.15	0.025	290	7.5	-	15	24
280	26	10.7	0.2	3	25	0	3.5	0.15	0.15	270	5	-	13	22
280	17	15.9	0.2	3	40	0	3.5	0.15	0.15	270	5	-	14	23
280	11	25.4	0.2	3	50	0	3.5	0.15	0.025	290	7.5	-	16	25
315	26	12.1	0.2	3	25	0	3.5	0.15	0.15	270	5	-	13	22
315	17	17.9	0.2	3	40	0	3.5	0.15	0.15	280	5	-	14	23
315	11	28.6	0.2	3	50	0	3.5	0.15	0.025	300	7.5	-	17	26
355	26	13.6	0.2	3	30	0	3.5	0.15	0.025	270	5	-	13	22
355	17	20.1	0.2	3	40	0	3.5	0.15	0.025	280	7.5	-	15	24
355	11	32.3	0.2	3	60	0	3.5	0.15	0.025	300	7.5	-	18	27
400	26	15.3	0.2	3	30	0	3.5	0.15	0.025	280	5	-	14	23
400	17	22.7	0.2	3	50	0	3.5	0.15	0.025	280	7.5	-	15	24
400	11	36.4	0.2	3	70	0	3.5	0.15	0.025	310	10	-	18	27

TABLE 3 - UKWR Fastweld Butt Fusion Joining Conditions

4.3.2 A specialist pipe surface preparation tool to scrape the pipe surface. The pipe scraper shall be capable of removing the oxidised surface of the pipe over more than the insertion length before welding is attempted. The tool shall remove a layer 0.2 to 0.4 mm thick from the outer surface of the pipe preferably as a continuous strip of swarf over that length and round the pipe.

4.3.3 Pipe clamps or other approved method for restraining, aligning and re-rounding the pipe during the weld cycle shall be used.

NOTE: Some coiled pipes (notably 160 mm and 180 mm SDR 11 and SDR 17) may be too oval to fit on couplers, or the bend of the pipe may make alignment of the ends impossible. A number of approaches have been proposed, including:

- Use of a mechanical pipe straightener or rerounding tool.
- Butt fuse a straight length of pipe onto the end of the coil before jointing.
- Use of special hydraulic clamps.

4.3.4 A shelter shall be used to provide protection for pipe, fittings and equipment against adverse weather conditions and contamination.

4.3.5 The contractor shall ensure the pipe ends are cut square and parallel.

4.3.6 An Indelible marker pen shall be supplied for marking insertion depth/fusion area.

4.3.7 A clean baseboard or groundsheet shall be supplied.

4.4 Electrofusion jointing method for sockets

4.4.1 Pre-jointing checks

- a) Ensure there is sufficient space to permit access to the jointing area. In a trench, a minimum clearance of 150 mm is required all round. Larger clearances may be needed for larger nominal sizes.
- b) Ensure all required ancillary equipment is available (see 4.3).
- c) Check there is sufficient fuel for the generator to complete the joint. Start the generator before connection to the machine and check that it is functioning correctly.

- d) Check the connectors at the end of the control box leads are clean and undamaged.
- e) Check that the pipe and fittings are the same size, SDR rating and pressure rating.

4.4.2 Preparation – pipe surface

- a) The pipe ends to be jointed shall be cut square to the axis and burrs removed.
- b) The pipe ends shall be wiped (in excess of the clamping area) using clean, disposable, lint-free material or prescribed wet wipes as specified in 4.4.3 to remove traces of dirt or mud.

NOTE: The pipe surface should be prepared immediately before jointing. It is bad practice to prepare pipe ends well in advance of jointing as a matter of 'convenience'.

- c) Using the pipe end preparation tool, remove a thin layer of 0.2 mm to 0.4 mm uniformly from the entire surface of the pipe, preferably as a continuous strip of swarf over the area identified, i.e. in excess of penetration depth. Once prepared, the pipe surfaces shall never be touched.
- d) The area over which the oxidised surface is to be removed shall be marked in excess of the penetration depth on each pipe to be jointed by placing the socket of the bagged fitting alongside the pipe end. A line shall be traced round the circumference at the appropriate distance from the pipe end using a suitable marker.
- e) Pipe ovality, particularly on coiled pipes, can have a detrimental effect on the integrity of electrofusion joints on both socket and saddle type fittings. It is recommended that the pipe profile within the area to be jointed is re-rounded prior to fusion to within the limits of ovality prescribed by WIS 4-32-17 by means of tools designed specifically for this purpose.

4.4.3 Preparation – removal of contamination

- a) Pipes shall be debagged and freshly scraped immediately prior to assembly and jointing in preference to cleaning.
- b) Where dust contamination or mud (dry or wet) has settled on the pipe surface to be joined after it has been scraped, or is observed on the fitting bore prior to assembly, an approved 'wet wipe' shall be used to remove contamination.

- c) The 'wet wipe' shall be a pre-impregnated lint free cloth which has been soaked in a 90% isopropanol: 10% water mixture. No other detergents or cleaning agents shall be added.
- d) Separate 'wet wipes' shall be used for the pipe and the fitting if both are contaminated.
- e) 'Wet wipes' shall be used prior to joint assembly and allowed to dry prior to immediate joint assembly and fusing.
- f) No attempt shall be made to clean fittings or prepared pipe surfaces that have become heavily contaminated with mud or water. When contamination cannot be removed the fitting or prepared pipe surface shall be discarded.

4.4.4 Joint assembly and clamping

- a) Prepare one pipe end (see 4.4.2 of this specification) and immediately after scraping, open one end of the fitting bag and insert the pipe into the fitting so that it is in contact with the centre stop. Prepare the second pipe end, remove the fitting bag and repeat.
- b) Once the pipes are inserted correctly into the fitting, mark the insertion depth on the pipe and place into the restraining clamps.
- c) Clamps **SHALL** always be used to secure the pipe ends so that during the fusion cycle they cannot move outside the constraints of the fitting.
- d) The pipe ends and the fittings shall be visually checked to ensure that they are correctly aligned.
- e) Once prepared or debugged, the surfaces to be fused shall not be touched. Should this event occur, the surfaces shall be decontaminated using 'wet wipes' as set out in 4.4.3 above.

4.4.5 Fusion cycle

- a) Check that the reset stop button (*if fitted on the control box*), is in the correct mode and that the electrofusion control box input leads are connected to the generator.

- b) Connect the control box output leads to the fitting terminals and check that they have been fully inserted.
- c) Enter the fusion jointing time into the control box timer (this can be by either automatic recognition or manual entry depending on the control box or fitting).
- d) Check that the jointing time displayed on the control box matches that indicated on the fitting.
- e) Press the start button on the control box and check that the heating cycle is proceeding as indicated by the display countdown.

NOTE: It is strongly recommended that gloves and goggles be worn during the jointing process.

4.4.6 Visual joint checks

- a) Once the fusion cycle has been completed, check that the full fusion time has elapsed and that the control box displays no error warnings.
- b) Check the insertion marks on the pipe to ensure excessive pipe movement has not occurred.
- c) Ensure that the joint is retained in the clamps for the correct cooling time (stated on the fitting).
- d) Check that the melt indicators on the fitting have risen. If there is no apparent movement of one or both the melt indicators, the joint shall be cut out and a new joint made.
- e) Check for signs of melt movement outside the confines of the fitting, if melt has exuded beyond the ends of the fitting, the joint shall be cut out and new joint made.
- f) Under no circumstances shall an attempt be made to carry out a second fusion cycle on any fitting.

4.5 Electrofusion jointing method for saddles

4.5.1 Pre-jointing checks

The pre-jointing checks shall be in accordance with 4.4.1 of this specification.

4.5.2 Preparation – pipe surface

- a) The pipe surface over the general area on which the saddle is to be assembled shall be cleaned using clean disposable, lint-free material or a 'wet wipe'.
- b) The packaged fitting shall be placed over the required position on the main. The pipe surface to be welded shall be marked all round allowing a 10mm clearance from the saddle base area.
- c) The surface of the pipe over the full marked area shall be scraped using a suitable tool to a depth of 0.2 to 0.4 mm. All swarf shall be removed but once prepared, the pipe surfaces shall never be touched.
- d) If surfaces are contaminated by dust or mud following scraping, then 'wet wipes' shall be used to clean surfaces (see 4.4.3 of this specification).

4.5.3 Saddle jointing procedure

- a) The fitting shall be removed from its bag and carefully placed onto the prepared pipe surface. Neither the pipe nor fitting jointing faces shall be touched whilst assembling.
- b) The correct pre-set load shall be applied to the saddle fitting using the appropriate clamping method (seek manufacturers advice if unsure).
- c) Connect the fitting to the control box and fuse as 4.4.5.
- d) Once the fusion time has elapsed the clamp shall be retained on the fitting for the appropriate cooling time stated on the fitting.
- e) The main shall not be tapped with the integral cutter for at least 10 minutes after completion of the cooling cycle and on successful completion of a visual inspection.
- f) A 2 minute hydraulic pressure test at 1.5 times the nominal pressure rating of the pipe or fitting whichever is the lower shall be applied to the fused fitting prior to tapping.
- g) All joints shall be visually checked to ensure that there is no leakage whilst the pressure test is applied.

NOTE: It is strongly recommended that gloves and goggles be worn during the jointing process.

4.5.4 Visual saddle checks

- a) The visual checks shall be in accordance with 4.4.6 of this specification.
- b) If the saddle fails to complete the correct fusion cycle or fails a visual inspection, the tee shall be cut from its base as shown in Figure 2 and a new saddle joint made.

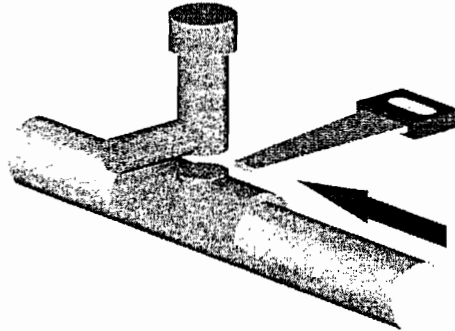


Figure 2 Removal of saddle joint

5. QUALITY ASSURANCE

5.1 Requirements

To claim compliance with this specification installers shall operate a management control system for site fusion jointing practice preferably to BS EN ISO 9000 criteria.

5.2 On-Site Quality Controls

5.2.1 The installer shall ensure that fusion jointing procedures as well as servicing and maintenance of fusion jointing equipment are carried out in accordance with the requirements of this specification.

5.2.2 On each site where pipes and fittings are to be jointed in accordance with the requirements of this specification, a person (or persons) shall be nominated to supervise work affecting quality.

5.2.3 The installer shall establish, and maintain procedures to show evidence of analysing work practices, quality records, service reports and customer complaints.

5.3 Materials controls

5.3.1 The client/installer (depending upon the specifying entity) shall ensure that all pipes and fittings conform to specified requirements given in CEN standards prEN12201 and prEN13244 or WIS 4-32-17 and WIS 4-32-14 as appropriate. Once these WIS standards are withdrawn, it is strongly recommended that the short term burst test set out in Appendix A is specified wherever EC procurement legislation permits.

5.3.2 The installer shall ensure that all fusion jointing equipment conform to the specified requirements given in WIS 4-32-16 or superseding standards.

5.3.3 The installer shall establish and maintain appropriate procedures for handling and storage of pipe, fittings and fusion jointing equipment.

5.3.4 The installer shall ensure that pipe, fittings and fusion jointing equipment are not used until they have been inspected and confirmed as conforming to the requirements of this specification.

5.4 Inspection and Testing

5.4.1 At the commencement of each contract, the frequency and type of inspection by the installer shall be agreed with the client and documented. This shall include evaluation of site joints, both electrofusion and butt fusion (if appropriate), using criteria stated in Clause 6.

5.4.2 The installer shall establish and maintain written records of appropriate fusion jointing procedures, servicing and calibration details in accordance with this specification.

5.4.3 The installer shall establish and maintain procedures for collection, indexing, filing and storage of quality records for a minimum period of 7 years after completion of the contract within which the work was undertaken or as otherwise specified by the client.

5.5 Maintenance, servicing and calibration of equipment

5.5.1 All equipment shall be well maintained and kept in a clean condition both in stores and at all times on site.

5.5.2 The equipment shall be serviced and calibrated at least once every 6 months or in accordance with the manufacturers recommendations and by authorized agents.

5.5.3 Calibration shall be carried out in accordance with BS5781: Part 1. Written records of appropriate servicing and calibration details shall be kept.

5.5.4 For butt fusion: particular attention shall be given to the heater plate, the hydraulic unit, the frame/clamp unit, trimming tool and the generator.

5.5.4 For electrofusion jointing, the control box and generator shall be checked every six months.

5.5.5 Mechanical scrapers shall be checked regularly for their scraping efficiency.

5.5.6 Top loading tools shall also be calibrated to ensure correct forces are applied.

5.6 Records

5.6.1 For manual machines with no dataloggers, written records of appropriate weld procedure details shall be kept as required by the client.

5.6.2 Where the datalogger or the control box stores records, these shall be made available in either printed or electronic file format by agreement with the client.

6. TESTING OF WELDS – ASSESSMENT OF TOUGHNESS

6.1 General

It is a requirement of both gas and water industries that no welded joint shall ever fail in a brittle manner. The welding procedures and quality requirements described above should ensure that this requirement is met for joints made on both construction sites and in suppliers' factories.

To ensure that joints have essentially the same properties as those of the parent materials, it is recommended that as part of inspection and testing (see 5.4), samples of welds made "on site" by both butt fusion and electrofusion techniques are tested to destruction to ensure that high toughness characteristics are obtained.

WIS 4-32-17 and WIS 4-32-14 contain some test methods to assess the integrity of butt fusion and electrofusion joints, but the test methods contained herein (Appendices B and C) take precedence in any dispute.

6.2 Assessment of toughness – butt fusion welds

6.2.1 Test joints shall be made prior to commencement on site using the certified welder and approved welding equipment to be used on the contract. The joints shall be tested in accordance with Appendix B.

6.2.2 For pipes above 355 mm diameter, the mechanical properties of sample welds shall be frequently tested during the course of the contract.

6.2.3 The failure modes of all the test samples shall be ductile, as shown in Figure 3. Unacceptable 'mixed' mode and brittle failures are shown in Figure 4.

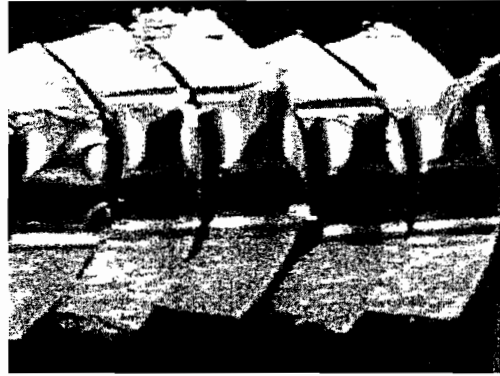


Figure 3 Acceptable ductile failure mode of tensile test samples

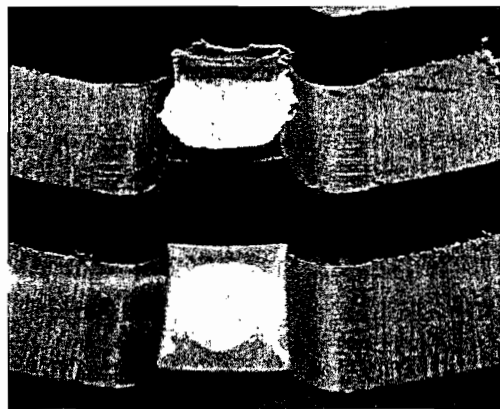


Figure 4 Unacceptable 'mixed' and brittle failure modes of tensile test samples

6.3 Assessment of toughness – electrofusion welds

6.3.1 Test joints shall be made prior to commencement on site using the certified welder and approved welding equipment to be used on the contract. The joints shall be tested in accordance with Appendix C.

6.3.2 For pipes above 250 mm diameter, the mechanical properties of sample joints shall be frequently tested during the course of any contract.

6.3.3 All failure modes of the test samples using either the peel test or cleavage test shall be ductile – as shown in Figure 5.

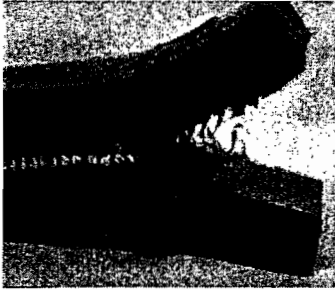


Figure 5 Acceptable ductile failure mode of coupler joint in DCB test

Using the cleavage test it is possible to measure a short-term fracture toughness (K_{Ic}). The interpretation of the values determined is given below assuming that at least 75% of the tear along the fusion length is ductile.

- If the value of $K_{Ic} > 1.7 \text{ MN/m}^{3/2}$, this indicates that the joint is totally satisfactory.
- If the value is $1.2 < K_{Ic} < 1.7 \text{ MN/m}^{3/2}$, this indicates that there is likely to be some significant fault that has reduced performance. The reduction may not cause service failures (non critical condition). The failure mode is likely to show brittle crack growth.
- If $K_{Ic} < 1.2 \text{ MN/m}^{3/2}$, this indicates that the performance has been reduced to a level where joint integrity in service is severely compromised. It is referred to commonly as a 'critical' condition. The failure mode will inevitably be via total brittle cracking (e.g. Figure 6) and a full investigation of control of welding parameters should be instigated.

NOTE: These values are valid only for site made joints and are not valid for type testing or for factory made joints. In these cases a value of $1.7 \text{ MN/m}^{3/2}$ and full ductility are required.

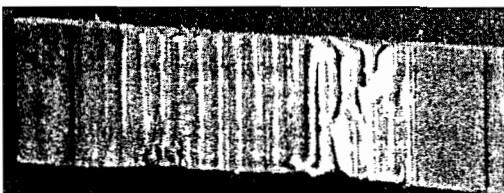


Figure 6 Unacceptable 'mixed'/brittle failure mode of coupler joint in DCB test

7. REFERENCES

This specification makes reference to the latest edition (except where otherwise stated) of the following publications, including all addenda and revisions which should also be consulted.

British Standards

BS EN ISO 9002: Quality systems: Specification for production and installation

BS 5781: Measurement and calibration systems (Part 1): Specification for system requirements.

Water Industry Specifications

WIS 4-32-14: Specification for PE80 and PE100 Electrofusion Fittings for sizes to 630 mm.

WIS 4-32-17: Specification for Polyethylene Pressure Pipes for Pressurised Water Supply and Sewerage Duties.

WIS 4-32-16: Specification for Butt Fusion Jointing Machines.

Draft CEN Standards

prEN 12201: Plastics piping systems for water supply - Polyethylene (PE)

prEN13244: Plastics piping systems for buried and above ground pressure systems for water for general purposes, drainage and sewerage - Polyethylene (PE)

Other

Draft IGN 4-32-18: The Choice of Pressure Ratings of Polyethylene Pipes for Water Supply and Sewerage Duties.

APPENDIX A

METHOD OF ASSESSING THE TOLERANCE OF ELECTROFUSION WELDS TO CONTAMINATION: SHORT TERM BURST TEST

A.1 Principle

This test assesses the resistance of an assembled electrofusion coupler to contamination on the pipe surface. A fitting is assembled and fused at minimum power onto pipe which has previously been scraped, cleaned and then contaminated with a fine china talc.

The performance of the assembled joint is assessed by the application of internal pressure at constant rate until burst.

- a) The fused pipe/fitting assembly is closed with full end load bearing fittings and is then subjected to a constant rate of pressure increase until failure occurs.
- b) For coupler testing, it is advised to assemble the end caps as close to the fitting as possible, leaving the minimum length of exposed pipe. There is then a very low likelihood that the pipe will fail before either the welded joint leaks or the coupler carcass itself fails.
- c) The performance of the assembled joint is assessed by the application of internal pressure at a constant rate until failure of pipe, coupler or the weld interface occurs.
- d) Experience has shown that the pressures to cause carcass failure are much higher than those required for 'satisfactory' joint performance.
- e) For sizes ≤ 180 mm it is required that the short term burst pressure is in excess of 40 bar – to ensure that long term operation at 16 bar will be secure.

A.2 Apparatus

A.2.1 Temperature-controlled water bath or room capable of maintaining a temperature of $(23 \pm 1)^\circ\text{C}$.

A.2.2 Pressurisation equipment capable of applying and displaying pressure at a constant rate of 5 bar/min to a minimum 25% beyond the peak test pressure required.

A.2.3 End caps, to fit on each end of the test pipe assembly, capable of maintaining a pressure of at least 25% greater than the peak test pressure required. The end caps shall be provided with connections for the entry of water and the release of air.

The test piece shall be monitored using a gauge connected to the end closure of the sample using 3/8" nominal pressure hose (or metric equivalent).

A.2.4 A 31 g/m² textile mesh screen with 34 μm thread and 53 μm aperture at a tension of 140 kN/m². The screen shall include a stencil of length equal to the nominal circumference of the test pipe, and a width greater than the fusion zone of the coupler under test, surrounded by a border of minimum width 100 mm.

A.2.5 A flexible squeegee of Shore hardness 70-75 set at an angle $(75 \pm 1)^\circ$ to the screen. This is used to force the talc through the screen.

A.2.6 The blade shall be changed when damage is visible without magnification or at least once a year if sooner.

A.2.7 A rig that allows the pipe to rotate and the screen to move over the pipe at a distance of (7 ± 0.5) mm, and which allows the screen to move over the pipe at a contact load of (1000 ± 100) N/m of squeegee length.

A.2.8 Fine china talc with a particle size of 0.63 μm to 6.3 μm .

A.3 Test Piece Assemblies

The test piece assembly shall comprise a coupler fused to prepared polyethylene pipe. The length of free pipe between the coupler and the end cap shall be less than the nominal diameter of the pipe.

NOTE: Limiting the free length of pipe to less than one diameter constrains the effect of hoop strain on the pipe, enabling the test pipe itself to withstand much higher pressures than would normally be expected of an unconstrained polyethylene pipe.

A.4 Preparation of The Contaminated Surface

A.4.1 After cleaning, six dummy pipe samples shall be prepared prior to applying contamination to the test piece. Dummy samples shall be prepared in accordance with A.4.2 – A.4.10.

A.4.2 Ensure that the test pipes are free from burrs and that the pipe ends are perpendicular to the pipe axis.

A.4.3 Scrape the pipes, in accordance with the requirements of this specification using a mechanical scraper and ensure that the scraped area is free from ridges.

A.4.4 Clean the scraped pipe surfaces with a 'wet wipe' and allow to dry.

A.4.5 Place the screen and the test-pipe onto the rig and lock the pipe into position.

A.4.6 Deposit a ridge of talc along the border of the screen.

NOTE: Talc shall be deposited on a masked area of the screen to prevent loss through the mesh.

A.4.7 Lower the flexible squeegee and lock into position adjacent to the ridge of talc on the side away from the stencil.

A.4.8 Holding the flexible squeegee in position, move the screen horizontally such that the talc is deposited evenly across the surface of the rotating pipe (see Figure A.1).

A.4.9 Remove the pipe from the rig. The prepared surface of the pipe shall not be handled or otherwise disturbed.

NOTE 1: Do not touch the screen with the pipe.

NOTE 2: The mesh should be cleaned after use with a vacuum cleaner and subsequently by wiping with ethanol on a lint-free cloth. The mesh should be visually inspected for signs of damage and replaced where necessary.

A.4.10 Place the contaminated surface into the coupler immediately and fuse the coupler onto the pipe surface.

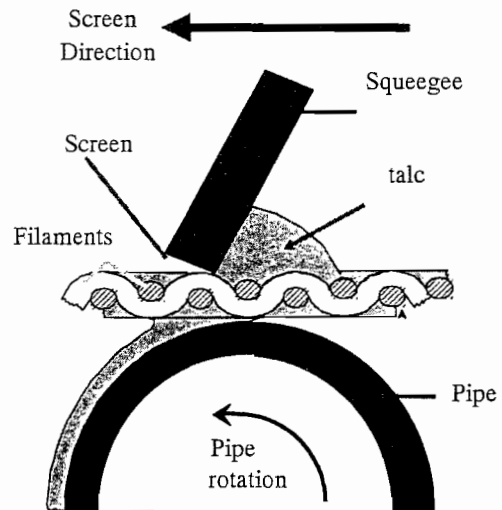


Figure A.1 Principle of screen apparatus for applying talc to pipe surface

A.5 Burst Pressure Test

A.5.1 Assemble the coupler on the test pipes and fuse at the minimum power.

A.5.2 Fit the end caps to each end of the assembly.

A.5.3 Fill the assembly with water and remove all air.

A.5.4 Condition the assembly at $(23 \pm 2)^\circ\text{C}$ for at least 2 hours and maintain the temperature

A.5.5 Pressurise the assembly at a constant rate of 5 bar/min to at least $2.5 \times \text{PN}$.

A.5.5 Record the failure pressure or maximum pressure reached. Record the type of failure.

A.6 Test Report

The test report shall include the following information:

- the identification of the test piece(s);
- a reference to this method of test;
- the failure pressure or maximum pressure reached;
- the type of failure;

- e) date of test.

A.7 Testing of Tapping Tees

A.7.1 General

- a) Additional clauses are provided for the testing of tapping tees.
- b) After fusion of the tee onto 'contaminated' pipe a short length of pipe should be fused to the service pipe outlet to allow the joint to be back-pressurised via the service connection.
- c) The hole should NOT be tapped through the pipe wall to allow the welded joint to be assessed.
- d) Again using a short term ramp-to failure method, the failure/leak potential can be assessed. It is generally required that a pressure of at least 18 bar be attained. This is 1.5* the PN rating of service pipes and will be a pressure level imposed by many water companies to tapping tee assemblies as a commissioning test.

A.7.2 Apparatus

The apparatus shall be as specified in A.2.

A.7.3 Test piece assembly

The test piece assembly shall be as specified in A.3. The three test samples required may be fused to different sections of one 'contaminated' pipe length.

A.7.4 Preparation of the contaminated surface

Preparation shall be as specified in A.4.

A.7.5 Burst pressure test

- a) Assemble the tee on the test pipe and fuse at the minimum power and with the minimum clamping force recommended by the fitting manufacturer.
- b) Fit an end cap either directly to the service pipe outlet or to a very short length of PE pipe welded to the service outlet.
- c) Condition the assembly at $(23 \pm 2)^\circ\text{C}$ for at least 2 hours and maintain the temperature.
- d) Pressurise the assembly at a constant rate of 5 bar/min until either the welded joint leaks or the welded interface/fitting itself ruptures.

- e) Record the failure pressure or maximum pressure reached. Record the type of failure.

A.8 Analysis of Test Data

NOTE: This clause is additional to the test method given in WIS 4-32-14. This analysis forms an integral part of the test method.

A.8.1 The average value of the three burst pressures shall be calculated (p_{av})

A.8.2 The long term PN rating that is acceptable to the UK water industry is calculated as:

$$PN = 0.4 * p_{av}$$

based on a factor of 0.5 - for long term creep regression combined with a safety factor of 1.25.

A.8.3 If the PN so derived is >16 bar, the fitting shall be rated as PN 16.

A.8.4 If the calculated value is less than 16 bar, the following PN cells are used:

- PN12 for PN between 12 and 16 bar
- PN10 for PN between 10 and 12 bar
- PN 8 for PN between 8 and 10 bar

NOTE: For sizes up to 180 mm, the water industry generally requires PN 16 fittings. For larger diameters other ratings are acceptable.

A.8.5 For tapping tees, if $p_{av} > 18$ bar, then the tapping system is considered to be totally secure for in-service proof testing at this pressure (which is 1.5* pipe PN).

APPENDIX B

**METHOD OF ASSESSING BUTT FUSION JOINT
DUCTILITY: TENSILE TEST**

B.1 Apparatus

All tests shall be conducted on a tensile testing machine confirming to grade A of BS 5214: Part 1 1975 or grade 1.0 of BS 1610: Part 1: 1985.

B.2 Test Pieces

B.2.1 Cut longitudinal rectangular samples across the weld from the full wall thickness of pipes butt fusion welded together using the technique recommended in section 3 of this specification.

B.2.2 Prepare test pieces of the form shown in Figure B1.

B.2.3 This may conveniently be performed by first drilling or milling holes at 45 mm centres along the weld then cutting towards the holes from the edges.

B.2.4 The radiused portions of the test pieces shall be smooth but the finish of the remaining edges is not critical.

B.3 Method

B.3.1 Condition the test pieces at $(23 \pm 2)^\circ\text{C}$ for at least 4 hrs and test them in tension at a grip separation rate of $5 \text{ mm min}^{-1} \pm 10\%$.

B.3.2 Allow the test to continue until the test piece breaks and observe the failure mode e.g. ductile tearing, 'mixed' ductile/brittle or 'flat' brittle failure.

B.3.3 Figures 3 and 4 (see 6.2) show examples of the failure modes of welds.

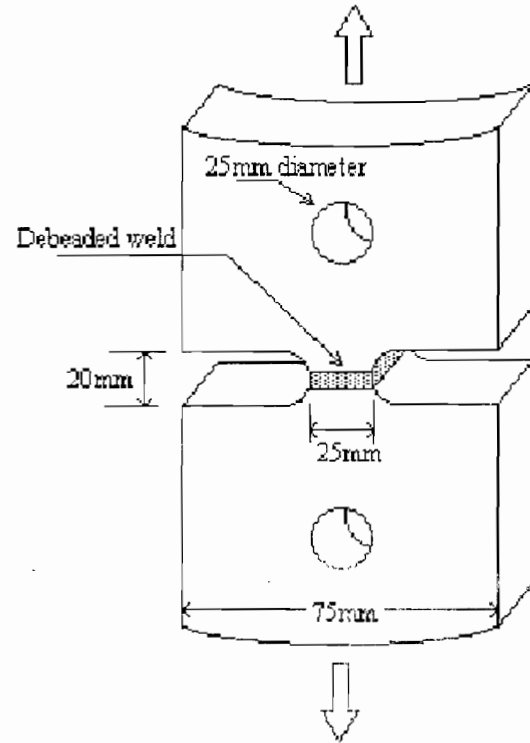


Figure B.1 Weld tensile test geometry

B.4 Report

The report shall include the following information:

- (a) The identification of the pipes;
- (b) Full description of the welding conditions including type of machine used;
- (c) The failure modes of all samples;
- (d) The date of test.

APPENDIX C

METHOD OF ASSESSING ELECTROFUSION JOINT TOUGHNESS: DOUBLE CANTILEVER CLEAVAGE TEST

C.1 Principle

A fused socket joint is sectioned at four equidistant positions around the circumference of the fitting and subjected to a longitudinal peel test, such that the resultant peel should be along the length of the fusion interface. Separation of the joint components is taken to completion and the parted surfaces are inspected for evidence of ductile and/or brittle failure of the joint interface.

C.2 Apparatus

All tests shall be conducted on a tensile testing machine confirming to grade A of BS 5214: Part 1 1975 or grade 1.0 of BS 1610: Part 1: 1985.

The tensile testing machine shall incorporate a means of providing a permanent record of the force/displacement history during tests.

C.3 Jointing Conditions

C.3.1 Joints shall be made in accordance with this specification.

C.3.2 Joints shall be made using the manufacturer's recommended heating times and minimum power input to the coupler.

C.3.3 Three joint assemblies shall be made using pipes and couplers preconditioned for at least 2 hours at (23 ± 2) °C.

C.3.4 All joints shall be made using clamping systems recommended by the coupler manufacturer.

C.3.5 The ends of the pipes to be jointed shall be prepared immediately prior to jointing using a pipe surface preparation tool which removes a layer of at least 0.2 mm from the pipe outside surface. The complete surface area of the end of the pipe to be inserted into the coupler shall be so prepared.

C.4 Preparation of Samples

C.4.1 Following jointing and cooling to (23 ± 2) °C, the coupler shall be cut into rectangular sections.

C.4.2 At least 6 samples shall be cut using a sharp band saw or equivalent from each end of the joint spaced at equidistant intervals around the joint circumference.

C.4.3 To form a flat surface to act as a register for further machining, the sample shall be held flat on a liner or skimmed with a saw/planer to remove the curved edges on the pipe surface.

C.4.4 A band saw shall then be used to produce rectangular samples with flat parallel surfaces which are symmetrical about the axis formed by the weld interface.

C.4.5 For couplers of nominal size up to and including 180, the sample width shall be 20 mm. For couplers of larger diameter, the width shall be increased to 30 mm.

C.4.6 One hole of at least 5mm diameter shall be drilled through the pipe and one hole of equal size through the fitting at the ends containing the 'cold zones' (see Figure C.1).

C.4.7 The holes shall be aligned in the vertical plane and shall be located as close to the joint interface as possible.

NOTE: Standard dimensions are not specified as individual manufacturer's dimensions vary.

C.5 Side Grooving

C.5.1 If the joint cannot be broken using a flat-faced sample, a side groove shall be machined in the sample.

C.5.2 Using a shaping machine (or similar apparatus), machine a 5 mm wide groove along the joint line (see Figure C.1).

C.5.3 Grooves shall be machined into both faces of the sample, penetrating to a quarter of the sample width.

C.5.4 The joint interface shall be along the centre of the groove.

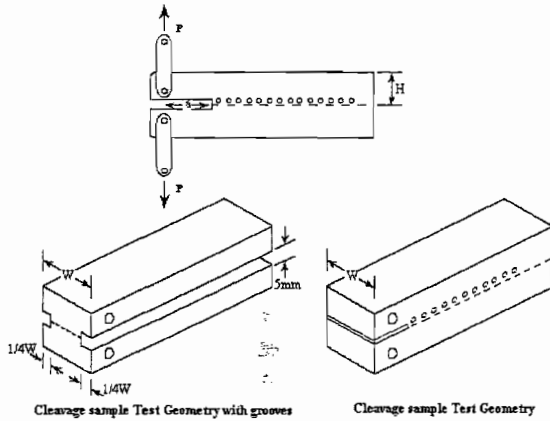


Figure C.1 DCB testing configuration

C.6 Testing Of Joints

- C.6.1 The test temperature shall be (23±2)°C.
- C.6.2 Push fit metal pins shall be placed in the holes drilled in the sample and drilled side plates attached which allow free movement during alignment.
- C.6.3 The tensile force shall be applied using a crosshead separation rate of 25±2.5 mm/min.
- C.6.4 The test shall be continued until there is complete separation of the sample.
- C.6.5 A force/displacement trace shall be obtained for each test.
- C.6.6 The peak force (P) obtained during the test shall be recorded.
- C.6.7 After failure has occurred, the size of the initial "crack" formed by the unfused section and cold crack zone shall be measured using a microscope and recorded.
- C.6.8 The initial "crack" size (a) shall be taken as the distance from the centre-line of the loading pinhole to start of the joint. This is defined by the presence of the first signs of stress whitening due either to the onset of slow crack growth or ductile yielding.
- C.6.9 The mode of failure shall be recorded by noting the location and length of either brittle crack growth (with no signs of macro ductility) or ductile yielding –

as defined by intense whitening and/or extensive cold drawing of the polymer.

C.7 Calculation of Joint Toughness

For each joint tested a value of the fracture toughness, K_c , shall be calculated using the equation:

$$K_c = \frac{Pa}{1 \times 10^6 \cdot WH^{3/2}} \left(3.46 + 2.38 \frac{H}{a} \right) \text{ MNm}^{-3/2}$$

where

- P = force measured at the onset of failure (N)
- a = crack length (m)
- W = sample width (m)
- H = half thickness of the specimen (m)

NOTE: Where side grooves are used, W is the net width (i.e. width of specimen – width of side grooves).

C.8 Test Report

The report shall include the following information:

- (a) identification of the assembly (size, SDR and batch no.);
- (b) details of the jointing conditions and equipment used;
- (c) the force P and dimensions W, H and a;
- (d) the calculated value of K_c ;
- (e) visual assessment of the failure mode (ductile or brittle);
- (f) the date of the test.

APPENDIX D

METHOD OF ASSESSING ELECTROFUSION JOINT DUCTILITY: PEEL TEST

D.1 Test Specimen Preparation

D.1.1 The test specimen shall consist of the socketed fitting fused at minimum power input.

D.1.2 Pipes and fittings shall be conditioned at $(23\pm 2)^{\circ}\text{C}$ for at least 2 hours before fusion. Pipe lengths shall protrude at least 125 mm either side of the coupling. The test temperature is $(23\pm 2)^{\circ}\text{C}$.

D.1.3 Four samples of width $18 + 0, -3$ mm for sizes up to 90 mm, or $25 + 5, -0$ mm for larger sizes shall be machined from four equidistant positions around the specimen. The samples shall include the maximum and minimum gap.

D.1.4 These samples shall be cut in half at the centre of the fitting to produce 8 test pieces.

D.1.5 The test pieces shall be fitted to the testing machine as shown in Figure D1.

D.1.6 A tensile axial load shall be applied at an extension speed of 25 ± 3 mm/min. The test shall continue until complete separation of the piece occurs.

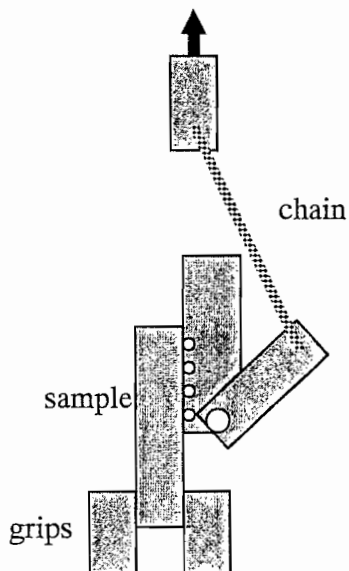


Figure D.1 Peel testing configuration

D.2 Failure Mode Criterion

D.2.1 The resultant peel should be along the fusion length and be ductile in appearance.

D.2.2 A brittle, or flat, failure path indicates a test failure.

D.2.3 The specimen passes the test providing the 'tear' along the fusion length is ductile for at least 75% of its length.

D.3 TEST REPORT

The report shall include the following information:

- (a) identification of the assembly (size, SDR and batch no.);
- (b) details of the jointing conditions and equipment used;
- (c) visual assessment of the failure mode (ductile or brittle)
- (d) length of ductile tear divided by length of total tear expressed as a percentage.