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Water Industry Specification

SPECIFICATION FOR POLYETHYLENE ELECTROFUSION COUPLERS AND FITTINGS FOR COLD POTABLE WATER SUPPLY FOR NOMINAL SIZES UP TO AND INCLUDING 180

FOREWORD

This specification has been prepared by the Water Research Centre (WRc) under the direction of the WAA Sewers and Water Mains Committee in consultation with the Water Industry and the British Plastics Federation to define the properties required for polyethylene electrofusion joints and fittings in the nominal size range 20 to 180.

Attention is drawn to the WRc/WAA Manual for MDPE pipe systems for water supply which has been prepared to offer guidance to the UK Water Industry on the practical design, installation and operation of PE water pipeline systems.

The dimensions and pressure ratings of the pipes with which these fittings are to be used are based on BS 5556 and are given in WIS No. 4-32-02*, BS 6572* and BS 6730 as well as WIS Nos. 4-32-03 and 4-32-09§. Such fittings may also be used with spigot fittings conforming to WIS No. 4-32-04.

Fittings manufactured to this specification are suitable for use with spigot fittings or plain ended pipe. These fittings will join pipes and fittings currently available and complying with the specifications referred to above even if they have different basic properties, e.g. melt flow rate, density, creep resistance, etc., provided the manufacturer's jointing instructions are respected.

Two design principles are covered by this specification. In the first, pipes or spigot fittings are inserted into the electrofusion socket and when the fusion temperature is reached the mating surfaces are fused together. In the second design, the socket of the electrofusion fitting is made oversize. When the appropriate temperature is reached the socket shrinks onto the pipe and when the fusion temperature is attained the mating surfaces are fused together. Both design principles are acceptable providing they satisfy all the requirements of this specification.

*BS 6572 is equivalent to WIS No. 4-32-02 but is now regarded as the lead specification.
§In course of preparation.

Attention is drawn to WIS No. 4-32-08, the specification for site fusion jointing of MDPE pipe and fittings. Good joints are a function of good pipe preparation and it is important that both pipe and fittings are clean and dry and that the surface of the pipe end has been removed over the full fusion area.

Purchasers are reminded that this specification requires that the manufacturer shall operate a quality system relating to the manufacture of fittings to this specification in compliance with BS 5750: Part 2 (EN 29002) which ensures that products claimed to comply with this specification consistently meet the required level of quality. Enquiries regarding the availability of third party certification should be addressed to an appropriate third party certification scheme or to WRc.

Compliance with this specification does not itself confer immunity from legal obligations.

This specification does not purport to include all the necessary provisions of a contract. Users of this specification are responsible for its correct application. Reference to a British Standard, Water Industry Specification or any other specification applies equally to any equivalent specification.

This specification includes the use of substances and/or procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

It has been assumed in the drafting of this specification that the execution of its provision is entrusted to appropriately qualified and experienced people.

Information contained in this specification is given in good faith but neither the Foundation for Water Research nor the Water Research Centre can accept any responsibility for actions taken as a result.

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WRc

CONTENTS

1. SCOPE

This document specifies the requirements for both blue pigmented and black pigmented polyethylene (PE) electrofusion couplers and fittings for the conveyance of cold potable water at temperatures up to 20°C at a nominal pressure rating of:

for sizes up to and including 63 – 12 bar
for sizes greater than 63 – 10 bar

Blue fittings shall be restricted to use underground or where protected from sunlight.

This specification applies to electrofusion fittings for use with PE pipe complying with BS 6572* or WIS No. 4-32-02 for nominal sizes up to and including 63 and WIS Nos. 4-32-03 and 4-32-09§ for nominal sizes 90 to 180 as well as for use with spigot fittings complying with WIS No. 4-32-04 for nominal sizes up to and including 180. Tapping tees and branch saddles are not covered by this specification.

Fittings complying with this specification shall be suitable for use with control boxes complying with WIS No. 4-32-07§.

Fittings may also comply with this specification if means are provided by the fittings manufacturer to enable their fittings to be connected to control boxes complying with WIS No. 4-32-07§, i.e with a fitting terminal and shroud in accordance with Figure 1 of this specification (WIS No. 4-32-06).

NOTE 1 The use of other control boxes is not precluded provided that they comply with National safety regulations.

NOTE 2 The titles of the publications referred to in this document are listed under clause 11 – REFERENCES

2. QUALITY ASSURANCE

Manufacturers shall operate a quality system relating to this specification in compliance with BS 5750: Part 2 (EN 29002).

3. MATERIALS REQUIREMENTS

3.1 Base polymer

The base polymer shall be a single grade of polyethylene with a derived density in the range 931 to 944 kg/m^3 at 23°C, when determined in accordance with BS 3412. This includes copolymers of ethylene and higher olefins, in which the higher olefin constituent does not exceed 10% by mass.

*BS 6572 is equivalent to WIS No. 4-32-02 but is now regarded as the lead specification.
§In course of preparation.

3.2 Compound composition

The base polymer shall be compounded with additives (antioxidants, pigment, carbon black, UV stabilisers, etc.) that are necessary for the manufacture, storage and use of fittings to this specification.

The base polymers and the compounds made therefrom shall conform to clauses 4, 5, 9 and 10 of BS 3412:1976 in respect of density, melt flow rate, colour variation and impurities. The compounds shall be free from excess moisture.

The blue compound shall be class N and the black compound class W as defined in BS 3412: 1976.

Where carbon black is used, the supplier of the compound shall certify that the carbon black has an iodine adsorption number of ≥110 when tested according to BS 5293:Part 10, and a maximum toluene extract of 0.10% by mass when tested according to ISO 6209. Further it shall have a maximum extinction coefficient of 0.1 when tested according to Appendix C of BS 6730:1986 and a maximum moisture content of 2.0% according to BS 5293:Part 5.

3.3 Antioxidants

Only antioxidants listed in Table 2 of BS 3412:1976 as amended, but excluding 6,6′ ditertbutyl – 4,4′ thiodi-m-cresol, shall be used provided they comply with 8.1 and 8.2 of BS 3412:1976 and the final fitting produced satisfies the requirements of this specification (WIS No. 4-32-06).

3.4 Rework material

No rework material shall be used in the manufacture of fittings to this specification.

3.5 Colour

Fittings shall be either blue or black. The colour of blue fittings shall lie within the range 18E51 and 18E53 of BS 4901: 1976.

NOTE Blue is the preferred colour for underground potable water use.

3.6 Metallic components

All exposed metallic components used in the fitting's electrical terminal connection shall be corrosion resistant or suitably protected against corrosion prior to jointing.

4. DESIGN REQUIREMENTS

4.1 Fitting

4.1.1 The fitting shall comply with the requirements specified in clause 6.

4.1.2 Compatibility of pipe complying with BS 6572, BS 6730, WIS Nos. 4-32-02, 4-32-03 and 4-32-09* and fittings complying with WIS No. 4-32-04 with fittings manufactured to this specification shall be demonstrated by testing assemblies of 125 nominal size to the requirements specified in 6.2.

4.1.3 Fusion indicators shall be provided on all fittings.

4.1.4 With the exception of fusion indicators and providing pipe ends are cut square and entered to correct penetration depth, melt from the fusion operation shall not exude outside the confines of the fitting or into the pipe/fitting bore.

4.1.5 Each fitting shall be capable of one reheat. This shall be demonstrated by the method described in 6.7.

4.1.6 A means of controlling the depth of pipe penetration within the socket shall be provided.

4.1.7 The design of the fitting shall be such that after conditioning both pipe and fitting over the temperature range -5°C to +23°C, joints shall be capable of being fused to meet the relevant requirements of this specification.

4.2 Electrical

4.2.1 *General*

Fittings produced to this standard shall be capable of being fusion jointed to pipes and/or fittings, using the control box specified in WIS No. 4-32-07.

4.2.2 *Fittings*

4.2.2.1 For each size and type of fitting the manufacturer shall declare the nominal resistance of the heating element and specify the production tolerances.

4.2.2.2 The maximum power requirement for any size of fitting shall be 2kW at 40V rms and the fitting voltage supply shall be 39V to 40V rms as measured at the terminal pins. The fitting fusion time shall be selected from Table 1.

*In course of preparation.

Table 1 – Fusion times

Fusion time (seconds)				
18	40	75	140	280
20	42	80	150	300
22	44	85	160	320
24	46	90	180	340
26	48	100	200	360
28	50	110	220	400
30	55	120	240	440
32	60	130	260	480
34	65			500
36	70			
38				

4.2.2.3 When selecting the fusion time, consideration of joint cooling time before handling is necessary. The maximum cooling time for each size and type of fitting when determined by the method described in Appendix A shall not exceed 20 minutes.

4.2.2.4 The preferred design of fitting terminal and shroud is illustrated in Figure 1. Other designs of fitting terminals are permitted as long as means are provided by the fittings' manufacturers to enable their fittings to be connected to control boxes complying with WIS No. 4-32-07.*

4.2.2.5 When a force of 50N is applied perpendicularly to each connector pin at the point of greatest moment during fusion, the electrical connection shall not be broken.

4.2.2.6 The heating elements shall be suitably designed to prevent accidental short circuiting or local overheating/underheating during the fusion operation when a square ended pipe has been entered to the correct penetration depth. Protective coatings applied to the heating element shall not detrimentally affect the PE fitting or connecting pipe material.

4.2.2.7 The heating element wire shall be embedded in the bore of the fitting to prevent dislodgement during field assembly of the fitting.

Where coated wires are used for heating elements in fittings, the coating material shall be suitably attached to the fitting to prevent dislodgement during field assembly of the fitting.

4.2.2.8 In the case of fittings with the heating wires wound in parallel, if a wire becomes open circuit during the fusion process, the indicators (see 4.1.3) shall not operate.

*In course of preparation.

Diameter A	Diameter B min	Diameter C min	D min	E	Radius F min
4.73/4.68	10	13	15.0	12.0-17.0	20

Note: All dimensions in mm.

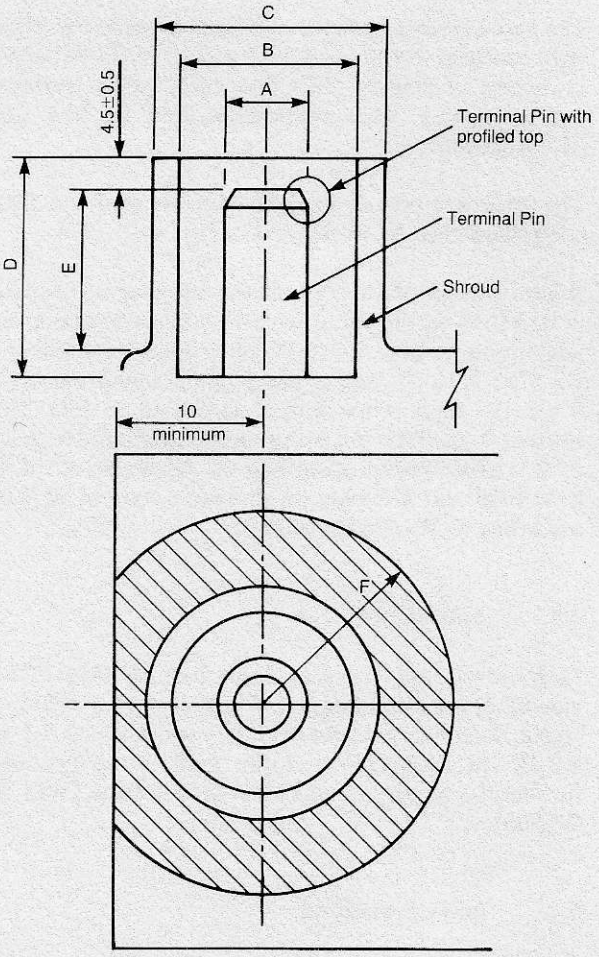

Figure 1 – Critical dimensions of manual fittings terminal and shroud—preferred design

5. DIMENSIONS AND TOLERANCES

5.1 The dimensions of fittings for compliance with this specification shall be determined after a period of not less than 14 days to allow for normalisation. The fitting shall be measured at an ambient temperature of 23 (+2−1)°C after a conditioning period of 5 hours.

5.2 The dimensions of fittings to Type 1 design shall be as specified in Table 2. See also Figures 2 and 3.

5.3 The dimensions of fittings to Type 2 design (shrink-fit) shall be as specified in Table 3. See also Figure 4.

5.4 Not withstanding the requirements of 5.2 and 5.3, the manufacturer shall demonstrate compliance with this specification by evaluating fittings to the requirements of clause 6 over the full tolerance range within which fittings are manufactured. If the tolerance range is less than that specified for "average inside dia-

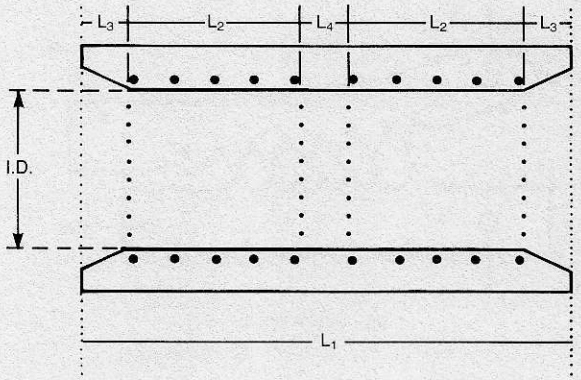

Figure 2 – Type 1 design – Coupler

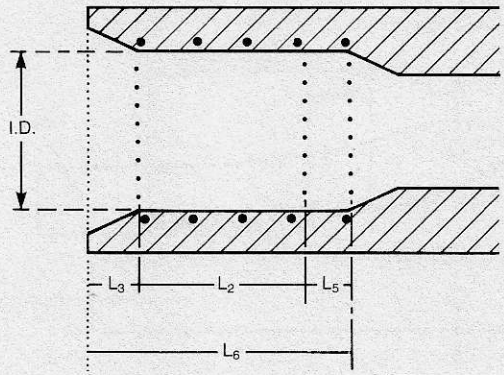

Figure 3 – Type 1 design – Socket

meter" in Table 2 or 3 as applicable, the manufacturer shall, on request by the purchaser or his agent, disclose the limits within which he is manufacturing.

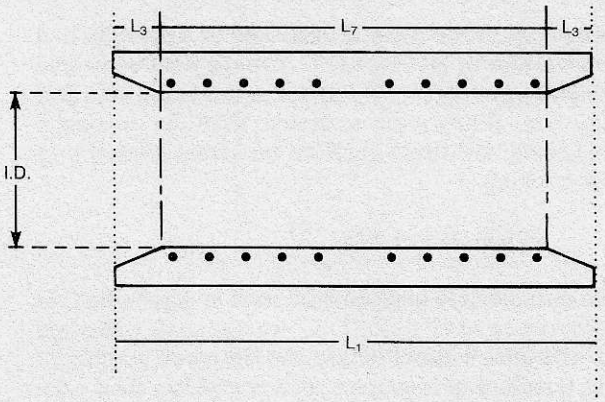

Figure 4 – Type 2 design – Shrink-fit coupler

Table 2 – Type 1 design – Coupler and socket — Dimensions (mm)

Nom. pipe size	Measure over fusion length				L_1	L_2	L_3	L_4	L_5	L_6	Thickness at mid point of socket length
	Limits for average inside diameter		Limits for individual inside diameter								
	min	max	min	max	max	min	min	min	min	min	min
20	20.3	20.6	20.25	20.65	70	12	6	10	5	35	2.3
25	25.3	25.6	25.25	25.65	78	14	6	10	5	35	2.3
32	32.3	32.9	32.25	32.95	82	17	6	10	5	35	3.0
50	50.4	51.1	50.3	51.2	100	20	8	10	5	43	4.6
63	63.5	64.1	63.4	64.2	118	21	10	15	7.5	49	5.8
90	90.7	91.5	90.55	91.65	155	26	12	15	7.5	66.5	8.2
125	125.9	126.7	125.75	126.85	171	32	15	25	12.5	82	11.4
180	181.4	182.1	181.25	182.25	210	43	15	25	12.5	105	16.4

Table 3 – Type 2 design – Shrink-fit coupler – Dimensions (mm)

Nom. pipe size	Measure over fusion length L_7				L_1	L_3	L_7	Thickness at mid point of socket length
	Limits for average inside diameter		Limits for individual inside diameter					
	min	max	min	max	max	min	min	min
20	20.1	21.0	19.9	21.2	70	6	24	2.3
25	25.2	26.1	25.0	26.4	78	6	26	2.3
32	32.3	33.2	32.0	33.6	82	6	30	3.0
50	50.3	51.6	49.8	52.1	100	8	36	4.6
63	63.3	64.9	62.7	65.6	118	10	42	5.8
90	90.5	92.4	89.6	93.3	155	12	65	8.2
125	125.5	128.1	124.5	129.1	171	15	77	11.4
180	181.1	184.2	180.1	185.2	210	15	83	16.4

6. TYPE TESTS

6.1 Long-term hydrostatic strength at 20°C

When tested by the method described in Appendix B at a temperature of 20 (+2−1)°C, fittings shall withstand an internal pressure of 19.0 bar for a minimum of 10,000 hours. The fitting/joint assembly shall be sectioned after testing and there shall be no visual evidence of stress cracking.

6.2 1,000-hour hydrostatic strength at 80°C

When tested by the method described in Appendix B at a temperature of 80 (+2−1)°C, fittings shall withstand an internal pressure of 8 bar for a minimum of 1,000 hours. The fitting/joint assembly shall be sectioned after testing and there shall be no visual evidence of stress cracking.

6.3 Fatigue test at 80°C

When tested by the method described in Appendix C at a temperature of 80 (+2−1)°C, fittings shall withstand 4.0×10^4 cycles without failure and the mean number of cycles to failure of 5 samples shall not be less than 4.8×10^4 cycles.

6.4 Joint adhesion test

When joints are tested in accordance with the method described in Appendix D, the fracture surface through the joint interface shall be compared with the illustrations given in Figure 5 and the type of failure recorded. The weld toughness shall also be determined in accordance with the procedure described in Appendix D and the result recorded.

Rupture in the brittle mode (see Fig. 5) shall not exceed ⅓ of L_2 for Type 1 fittings (see Figs. 2 and 3) or ⅓ of ½ x L_7 for Type 2 fittings (see Fig. 4.)

NOTE Whilst it has not yet been possible to set specific limits, this test will alert manufacturers and assessors to future requirements and provide a data base for correlation with developing procedures.

6.5 Effect on water quality

6.5.1 Non-metallic materials (in manufactured form) shall be tested to and meet the requirements of BS 6920: Part 1.

NOTE Products for installation and use in the United Kingdom which are verified and listed under the UK Water Fittings Byelaws Scheme are deemed to satisfy the requirements of this clause. (WRc Byelaws Advisory Service, 660 Ajax Avenue, Slough, SL1 4BG.)

6.5.2 Pending the determination of suitable means of characterising the toxicity of leachates for materials in contact with potable water, materials (in manufactured form) shall be approved by the Department of Environment Committee on Chemicals and Materials of Construction for use in Public Water Supply and Swimming Pools as being free from adverse health effects.

NOTE A list of approved chemicals and materials is available from the Technical Secretary of the above committee at DoE, Water Division, Romney House, 43 Marsham Street, London SW1P 3PY.

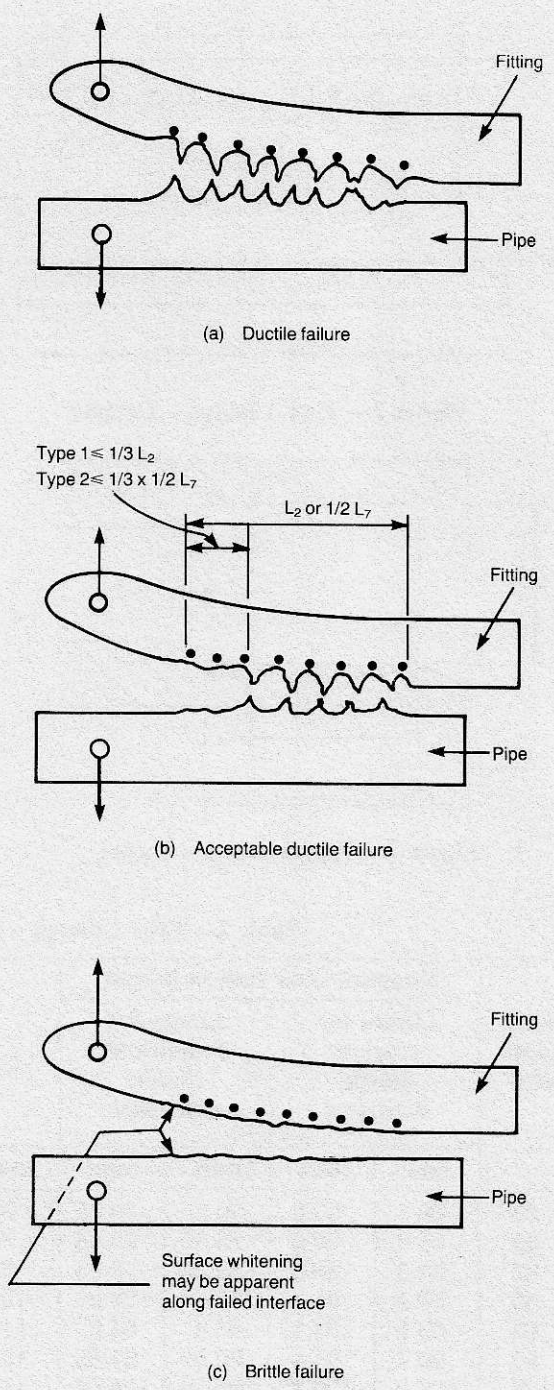

Figure 5 – Examples of brittle and ductile failures of weld assemblies

6.6 Melt exudation test

Compliance with the requirements of 4.1.4 shall be checked by sectioning assemblies of pipes and fittings and examining the inside surface of the joint. There shall be no signs of exudation into the bore of the fitting or into the pipe/fitting bore.

6.7 Reheat test

When tested in accordance with Appendix E, an assembly shall be capable of withstanding one reheat.

7. QUALITY CONTROL TEST REQUIREMENTS

7.1 170-hour hydrostatic strength at 80°C

When tested by the method described in Appendix B at a temperature of 80 (+2−1)°C, fittings shall withstand a pressure of 9.2 bar for 170 hours.

7.2 1-hour hydrostatic strength at 20°C

When tested by the method described in Appendix B at a temperature of 20 (+2−1)°C, fittings shall withstand the hold pressure of 26 bar for 1 hour.
The pressure shall then be raised until failure of the test assembly. Fitting or joint failure shall not occur before pipe failure.

NOTE If during the 1 hour hold test the pipe fails, then the test shall be repeated.

7.3 Blue fittings – pigment dispersion

When tested across the fitting's wall, by the method described in BS 2782: Method 1106A, the pigment dispersion shall be at least as uniform in appearance as that shown in photomicrograph 1 or 2 of Figure 1 of that standard, i.e. appearances similar to those shown in photomicrographs 3 to 6 of that figure are unacceptable.

7.4 Black fittings – pigment dispersion

When tested across the fitting's wall by the method described in BS 2782: Method 823B, the pigment dispersion shall be at least as uniform in appearance as that shown in photomicrograph 4 or less of Figure 1 of that standard.

7.5 Stress relief test

Fittings shall be tested according to BS 2782: Method 1103A at 110 (+2−1)°C for the times shown in Table 4. The fitting shall be sectioned after removal from the oven and on inspection shall show no cracking, opening of weld lines, cavities or blisters.

For convenience, large diameter fittings may be sectioned circumferentially prior to insertion into the oven.

Table 4 – Stress relief test times

Wall thickness (mm)	Test time (minutes)
Up to 8.6	120
8.6 to 28.2	240
Greater than 28.2	480

7.6 Crush strength test

When tested by the method described in Appendix F, no cracking shall occur at the fusion interface. End effects over the first two turns of wire shall be ignored.

7.7 Oxidation induction time

The material in fitting form shall have an oxidation induction time (OIT) of at least 20 minutes when tested according to Appendix G.

7.8 Freedom from defects

The internal and external surfaces of the fitting shall be free from defects such as cracks, holes, blisters, distortion, inclusions, dents or sink marks.

7.9 Electrical continuity

Electrical continuity checks shall be carried out by the manufacturer.

8. CONTROL OF TEST CONDITIONS

8.1 Test conditions

Unless otherwise specified, test measurements shall be conducted at 23 (+2−1)°C.

8.2 Specimen conditioning during type testing or in case of disagreement

Specimens shall be conditioned prior to test by being kept at 23 (+2−1)°C in air for not less than 12 hours for fittings of wall thickness up to and including 12.7mm or not less than 24 hours for fittings of wall thickness greater than 12.7mm, unless otherwise stated.

For hydrostatic tests involving liquid immersion, the specimens shall be conditioned in the liquid at the test temperature for 24 hours.

9. MARKING

The marking of fittings to this specification shall remain legible under normal handling, storage and installation procedures. No method of marking shall prejudice the performance of the fitting when tested to the requirements of this specification. The marking shall give the following information:

(a) the manufacturer's identification.

(b) the number of this specification, i.e. WIS 4-32-06. (The use of this mark is a claim by the manufacturer that the product has been manufactured in accordance with the requirements of this specification and the claim is his sole responsibility.)

(c) batch identification code.

(d) the nominal size and pressure rating in bar, or SDR* of the pipe with which the fitting is intended to be used.

NOTE Whilst the pressure rating in bar is the preferred permanent mark, the SDR rating may be used as long as the pressure rating is appended to the fitting and clearly marked on the packaging, (see clause 1).

(e) the fusion and cool down times.

NOTE This information may be printed on a label.

(f) the type of fitting in accordance with Tables 2 or 3, i.e. Type 1 or Type 2.

10. PROTECTION OF FITTINGS

Fittings shall be suitably packed to be afforded protection during normal handling, storage and installation procedures.

11. REFERENCES

BS 1610 Materials testing machines and force verification equipment.
Part 1 Specification for the grading of the forces applied by materials testing machines.

BS 2782 Methods of testing plastics.
Part 0: Introduction.
Method 452B: Determination of carbon black content of polyolefin compound.
Method 823B: Methods for the assessment of carbon black dispersion in polyethylene using a microscope.
Method 1103A: Stress relief test for injection moulded fittings: oven method.
Method 1106A: Assessment of pigment dispersion in polyolefin pipes and fittings: microbome method.

BS 3412 Specification. Polyethylene materials for moulding and extrusion.

BS 4728 Methods for determination of the resistance to constant internal pressure of thermoplastics pipes.

BS 4901 Specification for plastics colours for building purposes.

BS 5214 Specification for testing machines for rubbers and plastics.
Part 1 Constant rate of traverse machines.

BS 5293 Methods for sampling and testing carbon black for use in the rubber industry.
Part 5 Method for determination of loss of mass on heating.
Part 10 Method for determination of iodine adsorption number.

BS 5556 Specification for general requirements for dimensions and pressure ratings for pipe of thermoplastics materials.

BS 5750 Quality systems.
Part 2. Specification for production and installation.

BS 6572 Specification for blue polyethylene pipes up to nominal size 63 for below ground use for potable water.

BS 6730 Specification for black polyethylene pipes up to nominal size 63 for above ground use for cold potable water.

BS 6920 Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of water.
Part 1 Specification.
Part 2 Methods of test.

International Standard

ISO 6209 Rubber compounding ingredients – Carbon black – Determination of solvent extractable material.

European Standard

EN 29002 Quality Systems – model for quality assurance in production and installation.

WAA Sewers and Water Mains Committee Water Industry Specifications:

No. 4-32-02 Specification for polyethylene pressure pipe for cold potable water (underground use)(for pipes up to nominal size 63).

No. 4-32-03 Specification for blue polyethylene (PE) pressure pipe for cold potable water (for nominal sizes 90 to 1000 for underground or protected use.)

No. 4-32-04 Specification for polyethylene socket and spigot fittings, saddles and drawn bends for fusion jointing for use with cold potable water PE pressure pipes.

No. 4-32-07 Specification for electrofusion control boxes.*

No. 4-32-08 Specification for site fusion jointing of MDPE pipes and fittings.

No. 4-32-09* Specification for black polyethylene (PE) pressure pipes for sewage and above ground potable water (nominal sizes 90 – 1000).

WRc. Manual for MDPE pipe systems for water supply.

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* Standard dimension ratio (SDR) = $\frac{\text{minimum mean pipe outside diameter}}{\text{minimum wall thickness}}$

*In course of preparation.

APPENDIX A – METHOD FOR THE DETERMINATION OF FITTING COOLING TIME

A.1 APPARATUS

The apparatus shall consist of:

(a) a 4-wire resistance bridge with the following specification as a minimum:

Range	Resolution	Accuracy
0 – 1Ω	100μΩ	±0.25% of reading
0 – 10Ω	1mΩ	
0 – 100Ω	10mΩ	

(b) a true RMS voltmeter with an accuracy of at least ±0.1% and a resolution of 10mV in the 0 – 100V range.

(c) thermocouples suitable for operation up to 400 ± 1°C connected to a temperature recording device.

(d) an electrofusion control box meeting the performance requirements of WIS No. 4-32-07*.

A.2 SPECIMEN

A2.1 Pipes and fittings shall be conditioned at a temperature of 23°C for at least 1 hour.

A2.2 For socket fittings, two thermocouples shall be positioned diametrically opposite each other with the thermocouple tip on the outside surface of the pipe. The thermocouples will, consequently, be positioned in the centre of the resulting fusion joint. One thermocouple shall be on the top of the pipe during the fusion operation.

A.3 PROCEDURE

A3.1 Measure the resistance of the fitting under test.

A3.2 Adjust the voltage of the control box to simulate maximum power input into the fitting. This can be calculated from:

$$\text{Applied voltage} = 40 \left(\frac{\text{Actual fitting resistance}}{\text{Minimum fitting resistance specified by manufacturer}} \right)^{1/2}$$

A3.3 The fitting shall be energised for the required fusion time. The temperatures shall be recorded.

A3.4 On switching off the power the time for the thermocouples to reach 110°C shall be recorded.

A3.5 The fitting cooling time shall be the mean time from the power off for the thermocouples at the centre of the fusion joint to reach 110°C.

APPENDIX B – HYDROSTATIC STRENGTH TEST

B.1 PREPARATION OF TEST SAMPLES

More than one fitting may be tested at a time. Pipe produced to BS 6572, BS 6730 and WIS Nos. 4-32-02, 4-32-03 or 4-32-09* shall be used to connect the fittings to each other (using the manufacturer's published technique) and also to end caps. The type of end cap shown in Figure 1 of BS 4728:1971 or free end load bearing or mechanical fittings shall be used. There shall be a free length between any two fittings or a fitting and an end cap of not less than 250mm or three times the nominal size, whichever is the greater. For type testing test pieces shall be conditioned for 1 hour prior to assembly at the temperatures given in Table 5.

Table 5 – Conditioning temperatures before fusion jointing

Sample	Temperature before fusion (°C)	
	Pipe	Fitting
1	−5	−5
2	−5	+23
3	+23	+23

For quality control testing samples shall be conditioned for 1 hour at ambient temperature prior to assembly.

B.2 TEST TEMPERATURE

The test temperature of the water bath shall be maintained within (+2−1)°C of the specified temperature for the duration of the test.

B.3 TEST METHOD

Tests shall be performed according to the method described in BS 4728 unless otherwise stated.

Failure of the pipe within a distance of less than 0.1 L (where L is the free length of pipe between fittings or fittings and end caps) from the mouth of the fitting shall be disregarded and the test repeated.

*In course of preparation.

APPENDIX C – FATIGUE TEST AT 80°C

C.1 TEST EQUIPMENT

The equipment shall consist of a thermostatically controlled water bath maintained at 80 (+2−1)°C, together with equipment that permits the application of a fatigue load using pneumatics or other suitable means, to produce a trapezoidal pressure change profile (see Figure 6).

Typical equipment is illustrated in Figure 7 and consists principally of compressed air supplied from line A, filtered (B) and then regulated (C) to the desired pressure. The filtered and regulated compressed air is then passed through a 5-way solenoid (D) which is controlled by a dual timer (E). The valve D cycles the compressed air between two lines (F and G) which supply the two samples (SF and SG). By using a symmetrical loading profile, the greatest use is made of the one supply of compressed air (line A) with the two samples out of phase, as shown schematically in Figure 8. Between the 5-way valve (D) and the two samples (SF and SG) there are two 3-way solenoid valves (H and I) on the two lines (F and G)) which are normally open. When one or both of the samples are detected as having failed, a current is supplied to either or both solenoid valves (H and I) to isolate the sample(s) from the compressed air.

Equipment in which a pressure point is connected to a single sample is also permitted.

C.2 TEST PIECES

For each test, 5 test pieces shall be evaluated.

Test pieces shall consist of fittings into which pipes have been jointed together with suitable end caps. The free length (L) of pipe between fitting and end cap shall be calculated from:

L = 3 x outside diameter (with a minimum of 250mm.)

Test pieces shall be assembled so that there is a gap between pipe ends of not less than 5mm for nominal sizes 20 to 50 inclusive, 7.5mm for sizes 63 and 90 and 12.5mm for sizes 125 and 180.

For socket fittings, the gap shall be not less than L_5 as given in Table 2 and illustrated in Figure 3.

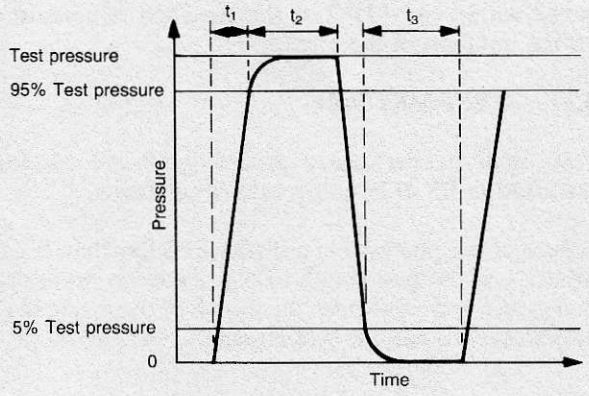

Figure 6 – Schematic representation of pressure loading profile

C.3 CONDITIONING

The assembly shall be conditioned at 80 (+2−1)°C.

C.4 TEST METHOD

The sample shall be connected to the pressurising unit to produce the following pressure régime:

t_1 = 2 ±1.0 second
t_2 = 10 ±1.0 second
t_3 = 5 ±1.0 second

Where t_1 = time to raise the pressure from 0 bar to 95% of the test pressure (8 bar).

t_2 = time from when 95% of the test pressure has been reached to removal of the test pressure.

t_3 = time from when the pressure has decayed to 5% of the test pressure to the time when pressure is raised again.

NOTE 1 See Figure 6.

NOTE 2 The test pressure shall be reached and maintained during time t_2 at 8 ±0.2 bar.

NOTE 3 The test pressure shall reduce to 0 bar gauge pressure during time t_3.

Failure of the pipe within a distance of less than 0.1 L from the mouth of the fitting shall be disregarded.

APPENDIX D – JOINT ADHESION TEST FOR ELECTROFUSION ASSEMBLIES GREATER THAN NOMINAL SIZE 90

D1 WELDING CONDITIONS (see also WIS No. 4-32-08)

D1.1 For each test, 3 couplers from a single production run shall be evaluated. Each size shall be evaluated from at least 5 different production runs.

D1.2 Welds shall be made using the manufacturer's recommended heating times and minimum power input to the coupler.

D1.3 Three joint assemblies shall be made using pipes and couplers preconditioned for at least 2 hours at 23(±2)°C or −5(±2)°C as appropriate and assembled in accordance with the requirements of clause B.1 Table 5.

D1.4 All welds shall be made using clamping systems recommended by the coupler manufacturer.

D1.5 The ends of the pipes to be welded shall be prepared immediately prior to welding using a pipe surface preparation tool which removes a layer of at least 0.2mm 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.

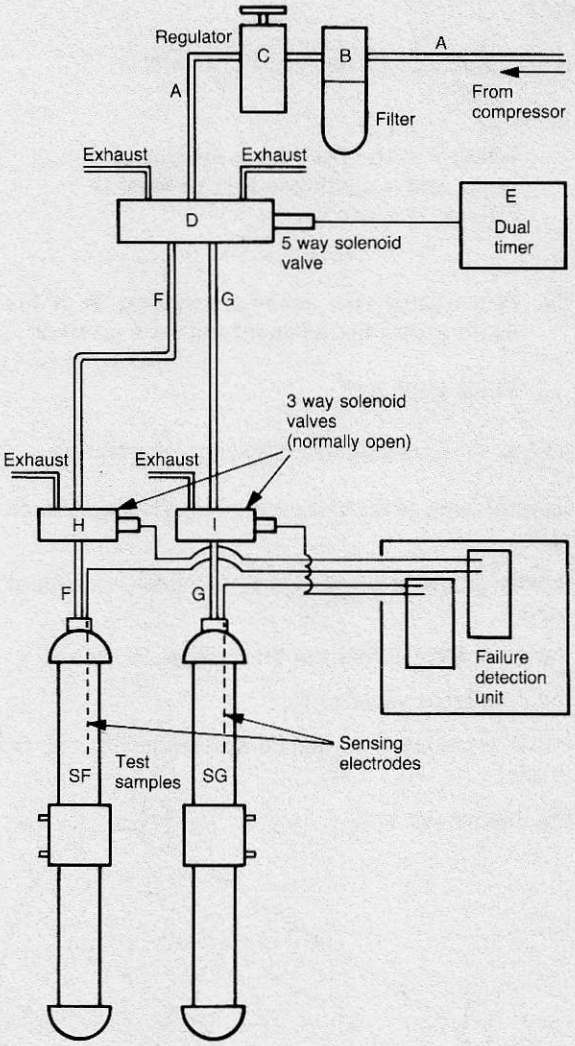

Figure 7 – Typical pneumatic equipment

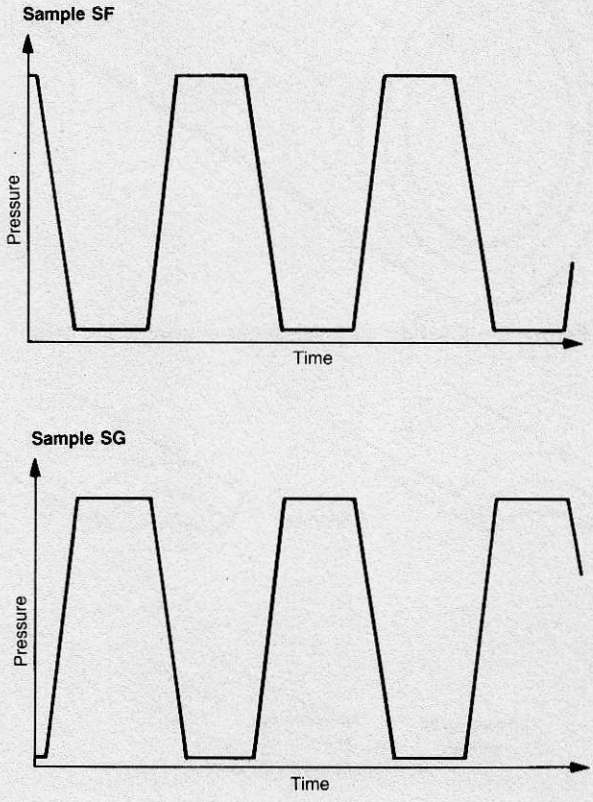

Figure 8 – Schematic representation of internal pressure changes using one test point connected to two samples

D.2 PREPARATION OF SAMPLES

D2.1 Preparation of standard test pieces

D2.1.1 Following welding and cooling to 23(±2)°C, the coupler shall be cut into rectangular sections – see Figure 9.

D2.1.2 At least 6 samples shall be cut (using a sharp bandsaw or equivalent) from each end of the welded joint spaced at equi-distant intervals around the weld circumference.

D2.1.3 To form a flat surface to act as a register for further machining, the sample shall be held flat on a linisher or skimmed with a saw/planer to remove the curved edges on the pipe surface – see Figure 10.

D2.1.4 A bandsaw (or similar) shall then be used to produce rectangular samples with flat parallel surfaces which are symmetrical about the axis formed by the weld interface.

D2.1.5 For couplers of nominal size 125 and 180, the sample width shall be 20mm.

NOTE For couplers of larger diameter, the width shall be increased to 30mm.

D2.1.6 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 11.

D2.1.7 The holes shall be aligned in the vertical plane and shall be located as close to the weld interface as possible.

NOTE Individual manufacturer's dimensions vary. Standard dimensions are therefore difficult to specify.

Correct positioning is a trial and error procedure. Drilling close to the interface minimises risk of pull-through of pins and proximity to the edge increases the initial "crack" length.

D2.2 Side grooving

D2.2.1 If the weld cannot be broken using a flat faced sample, it is necessary to side groove the sample.

D2.2.2 Using a shaping machine (or similar), machine a 3mm wide groove along the weld line – see Figure 12.

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

D2.2.3 The weld interface shall be along the centre of the groove.

D.3 TESTING OF WELDS

D3.1 The test temperature shall be 20(±2)°C.

D3.2 All tests shall be conducted on a tensile testing machine conforming to grade A of BS 5214: Part 1: 1975 or grade 1.0 of BS 1610: Part 1: 1985.

D3.3 The tensile testing machine shall incorporate a means of providing a permanent record of the force/displacement history during the test.

D3.4 Metal pins (push fit) shall be placed in the holes drilled in the sample and drilled side plates attached which allow free movement during alignment – see Figure 11.

D3.5 The tensile force shall be applied using a cross-head separation rate of 25mm/min.

D3.6 The test shall be continued until there is complete separation of the sample.

D3.7 A force/displacement trace shall be obtained for each test – see Figure 13.

D3.8 The peak force (P) obtained during the test shall be recorded.

D3.9 After failure has occurred, the size of the initial "crack" formed by the unwelded section and cold zone shall be measured using a microscope and recorded.

D3.10 The initial "crack" size (a) shall be taken as the distance from the centre-line of the loading pin hole to the start of the weld. This is defined by the presence of first signs of stress whitening due either to the onset of slow crack growth or ductile yielding.

NOTE Whatever the failure mode, a white zone can always be discerned at the origin of the initial "crack ".

D3.11 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.

Figure 5 illustrates the difference between ductile and brittle failure.

D.4 CALCULATION OF WELD TOUGHNESS

D4.1 For each weld tested, a value of the fracture toughness, K_c, shall be calculated using the formula:

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

where P is the peak force measured
W, H and a are dimensions defined in Figures 11 and 12.

NOTE When using side grooved samples, W is the width across the ligament between grooves.

D.5 TEST REPORT

The report shall include the following information:

(a) identification of the assembly (size, SDR and batch no)

(b) details of the welding conditions and equipment used

(c) the peak force P and the 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.

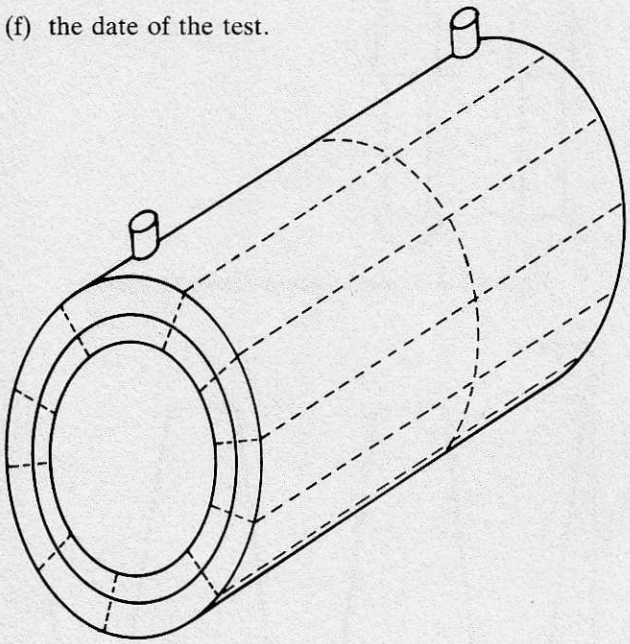

Figure 9 – Cutting samples from coupler/pipe joint

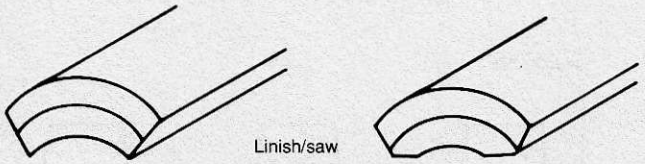

Figure 10 – Preparing samples

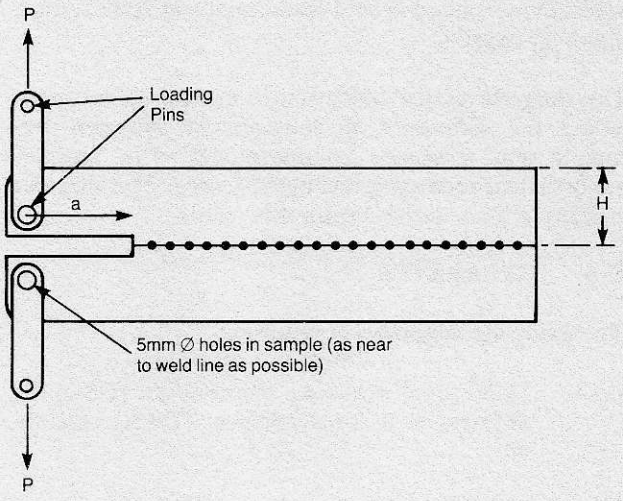

Figure 11 – Loading arrangement for joint adhesion samples

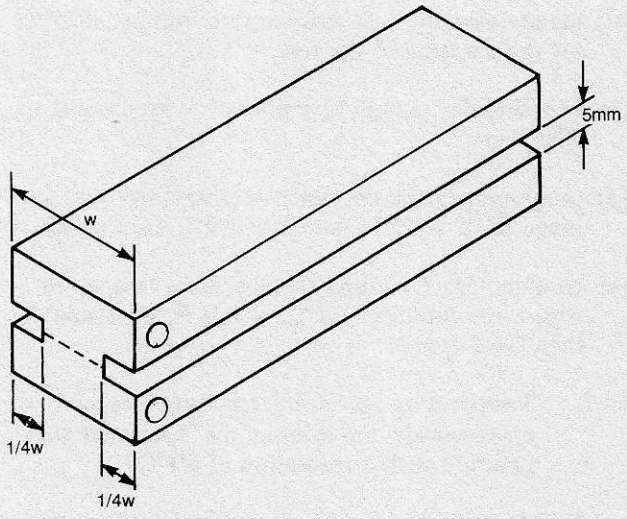

Figure 12 – Side grooving for tough welds or pipe/coupler where beam depth (H) is small

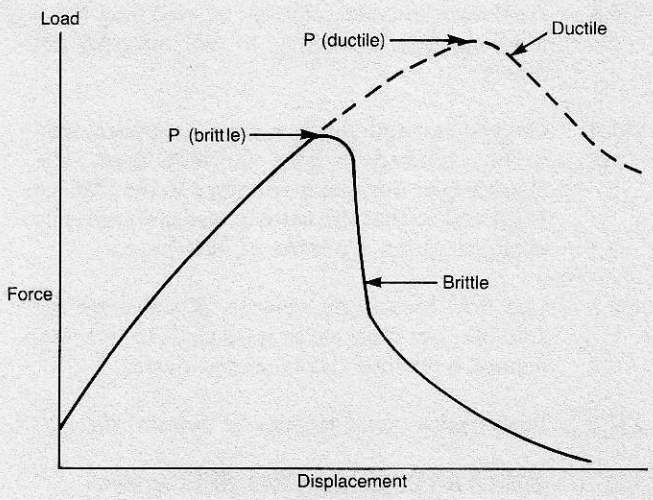

Figure 13 – Typical force/displacement traces from joint adhesion tests

APPENDIX E – REHEAT TEST

E.1 PREPARATION OF TEST SAMPLES

Test samples shall be prepared in accordance with clause B.1 of Appendix B.

E.2 TEST METHOD

Each sample shall be subjected to a complete heat cycle using minimum power calculated from:

$$39 \left(\frac{\text{Actual fitting resistance}}{\text{Maximum fitting resistance specified by manufacturer}} \right)^{1/2}$$

The sample is then allowed to cool to ambient temperature and then submitted to a further heat cycle, again at minimum power. The sample is again allowed to cool to ambient temperature.

E.3 ASSESSMENT OF RESULTS

The test samples shall be submitted to the test described in Appendix F and shall meet the requirements of 7.6.

APPENDIX F – CRUSH STRENGTH TEST

F.1 SPECIMENS

The test specimens shall be prepared in accordance with clause D.1 of Appendix D, unless otherwise specified in this specification.

F.2 PROCEDURE

F2.1 The pipe/fitting joint shall be halved along its length with approximately 150mm of pipe protruding either side of the fitting.

F2.2 One half of the assembly shall be held in a vice or similar across the cut diameter as shown in Figure 14. Both halves of the assembly shall be tested.

F2.3 The pipe shall be squeezed in the vice until the inner pipe surfaces meet.
The assembly shall be held in this position for 10 minutes.

No cracking shall occur at the fusion interface. End effects over the first two turns of wire shall be ignored.

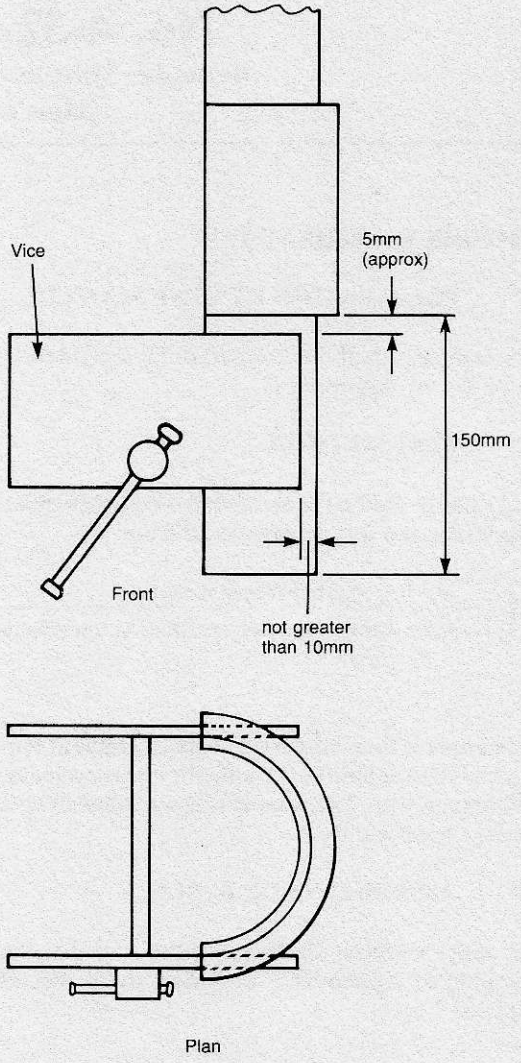

Figure 14 – Crush test arrangements

APPENDIX G – METHOD FOR THE DETERMINATION OF OXIDATION INDUCTION TIME

G.1 INTRODUCTION

This method measures the oxidation induction time of polyethylene in oxygen at elevated temperatures.

G.2 SCOPE

The method provides a means of measuring the oxidative thermal stability of polyethylene pipe and fittings material in oxygen at typical processing and welding temperatures. It may be used for measuring the stability of either raw materials or finished products, and may be taken as an indication of polymer or anti-oxidant performance.

The test temperature is 200°C which is suitable for adequately stabilised pipe and fittings materials.

The thermal stability measured by this method is dependent on specimen mass.

G.3 PRINCIPLE

In principle the test measures the time during which the anti oxidant present in the sample inhibits oxidation whilst the specimen is held isothermally at 200°C under a flow of oxygen.

The progress of the oxidation is monitored by measuring the difference in temperature between the sample and reference compartments of a thermal analyser and recording this against time. The thermal stability is then derived from this record.

G.4 APPARATUS

The following apparatus is required:

G4.1 Differential scanning calorimeter (DSC) or differential thermal analyser (DTA) capable of:

(a) recording the difference in temperature or energy flow between sample and reference compartments against time.

(b) maintaining the test temperature within ±0.25°C for the duration of the test.

(c) exposing the sample to a flow of oxygen equal to 50mL.min^{-1}.

(d) programming the specimen temperature over the range 150°C to 250°C at a rate of 1°C.min^{-1} or less.

(e) continuously recording the specimen temperature with a resolution of 0.1°C. If this is not available then G4.2 applies.

G4.2 Temperature measuring apparatus, capable of continuously monitoring the specimen temperature with a resolution of 0.1°C.

A high impedance digital voltmeter with a resolution of 15V has been found suitable when connected to the specimen thermocouple and the associated cold junction, or cold junction compensator, of the thermal analyser.

G4.3 Analytical balance, capable of weighing the 5 ±0.5mg test specimen to an accuracy of 0.1mg.

G4.4 Oxygen and high purity nitrogen supplies, able to be switched to give alternate flow. The change-over must be made close to the DSC or DTA cell so that the atmosphere is completely changed within 1 minute of switch-over.

G4.5 Gas flow measuring devices. Rotameters are suitable, but their calibration shall be checked against a positive displacement device.

G4.6 High purity metal standards: indium, tin.

G.5 PREPARATION OF TEST SPECIMENS

A cylindrical disc specimen of a specified weight, with a diameter just less than the inner diameter of the sample pans of the thermal analyser is required:

G5.1 Test specimens from fittings:

(a) Take two through-wall cores from the top segment of the fitting as manufactured by using a core drill of suitable size (or equivalent method), ensuring that the sample is not overheated during this operation.

NOTE 1 The sides of the core should be lightly scraped to remove any contamination, etc.

NOTE 2 Any swarf which collects near the inner surface should be carefully lifted away.

(b) Using a scalpel, cut discs from the core sample of an approximate thickness to give a specimen weight of 5 ±0.5mg. Select two inner and one outer surfaces as the minimum sample points which are to be tested individually.

(c) The specimens shall be prepared for testing during the same day and should not be unduly handled or left in direct sunlight.

G.6 PROCEDURE

G6.1 **Temperature calibration**

Establish an oxygen flow of 50mL.min^{-1} over the specimen and reference compartments of the apparatus at a temperature of 10°C below the expected melting point of indium or tin.

Heat 2mg specimens of indium or tin in a sealed aluminium pan, using an empty aluminium pan as reference, at a rate not exceeding 1°C. min^{-1} until the melting endotherm is recorded. If the apparatus does not automatically do so, the indicated temperature shall be marked on the chart at intervals in the region of the endotherm so that the melting point can be determined to a precision of ±0.1°C. Determine the melting points of both indium and tin.

The melting point of the metal is taken as the temperature given by the intercept of the extended baseline and the extended tangent to the first slope of the endotherm (see Figure 15).

Adjust the apparatus so that the indicated melting points of indium and tin lie within 156.6 ±0.5°C and 231.9 ±0.5°C respectively.

NOTE 1 Unless tin of high purity is used, its melting point can vary considerably.

NOTE 2 In cases where the thermogram exhibits a knee in the trace the relevant maximum slope is that of the first part.

G6.2 **Time calibration**

Check that the pen moves along the abscissa at the selected rate using a stopwatch.

G6.3 **Oxidation induction time measurements**

Establish a nitrogen flow of 50mL.min^{-1} through the DSC or DTA cell. Check that when a switchover to oxygen is made, the gas flow will continue at that rate and then revert to a nitrogen flow of 50mL.min^{-1}.

Introduce a 5 ±0.5mg cylindrical PE sample in an open aluminium pan and an empty aluminium reference pan into the cell. Specimens which contain the inner or outer surfaces of a fitting shall be placed in the sample pan with that surface uppermost. Set the instrument to run isothermally at 200 ±0.1°C raising the temperature at a rate of 20°C.min^{-1}, and allow the temperature to stabilise. Make any minor corrections to the heater voltage to bring the specimen temperature to 200 ±0.1°C. Start to record the thermogram which is a plot of the temperature differential against time.

When steady conditions exist under nitrogen after 5 minutes, switch over to oxygen and mark this point on the thermogram. The cell shall be purged within 1 minute of atmosphere changeover. Continue to run the thermogram until the oxidation exotherm has occurred, and has reached its maximum.

G.7 INTERPRETATION OF RESULTS

The oxidation induction time of the specimen is the time taken in minutes from the introduction of oxygen to the intercept of the extended baseline and the extended tangent drawn to the exotherm at the point of maximum slope (see Figure 16).

At least three oxidation induction time measurements shall be made for each determination, two from the inner surface and one from the outer surface.

G.8 TEST REPORT

The report shall include the following information:

(a) Full identification of the product from which samples were taken.

(b) Test specimen weights.

(c) Individual oxidation induction times.

(d) Position of specimen in pipe wall.

(e) Test temperature.

(f) The date of the test.

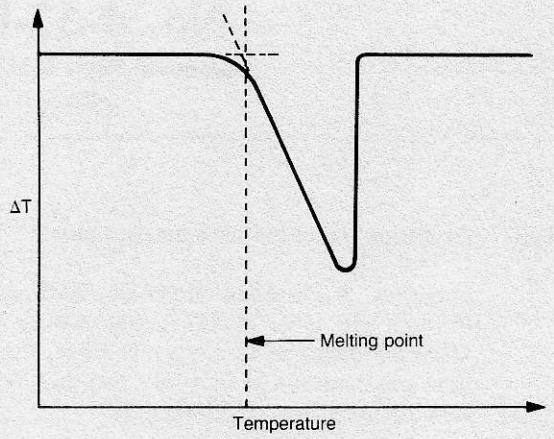

Figure 15 – Metal melting point

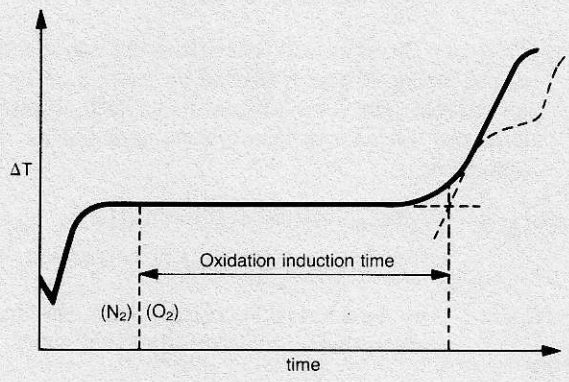

Figure 16 – Example of thermogram