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Water Industry Specification

SPECIFICATION FOR NON-CIRCULAR POLYETHYLENE SEWER LININGS

FOREWORD

This specification is one of a number of specifications which have been prepared by the Water Research Centre (WRc) in consultation with the Water Industry in order to assist engineers responsible for renovation of sewers. It covers rotationally moulded non-circular polyethylene pipes suitable for Type II lining designs as defined in the Sewerage Rehabilitation Manual (published by WRc). It is intended that the pipes should be joined by butt fusion welding, sliplined into the sewer and the remaining annulus subsequently grouted with a low density grout.

Polyethylenes are manufactured by different processes and contain a range and varying quantities of co-monomers, which can result in substantially different basic properties, e.g. melt flow rate, density, creep resistance, etc. Consequently, it is possible that different materials found to be suitable for the manufacture of linings to this specification may not be compatible for fusion jointing.

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.

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 NACCB or equivalent accredited third party certification scheme or to WRc.

This specification calls for 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 provisions is entrusted to appropriately qualified and experienced people, for whose guidance it has been prepared.

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.

Throughout this specification SI units are used, thus stress and modulus values are quoted in MPa (megapascals)*.

* 1MPa = 1MN/m^2 = 1N/mm^2

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WRc

1. SCOPE

This specification defines the requirements for quality assurance, materials, dimensions, jointing, testing, marking and workmanship of rotationally moulded non-circular polyethylene (PE) linings intended for the renovation of gravity sewers by sliplining where the lining is designed to act as a flexible pipeline, i.e. one in which the passive reaction of side support is required to assist resistance to deformation by vertical forces (Type II design).

This specification is not intended to cover polyethylene pipes or linings for use in pressure or pumping mains.

2. DEFINITIONS

For the purpose of this specification the following definitions apply:

Effective length of unit The distance between planes normal to the unit axis and passing through the real end points of the lining unit (see Figure 1).

Lining section A discrete length of circumferentially continuous sewer lining which may be either a single pipe lining unit or a combined pair of segmental lining units.

Out-of-squareness of unit end The maximum distance between the real end surface and a plane normal to the unit axis and passing through the real end point (see Figure 1).

Out-of-straightness The maximum radial distance between the lining inner surface and any line parallel to the unit axis touching the lining inner surface (see Figure 1).

Pipe lining Non-circular sewer lining that has no longitudinal joints.

Real corner points The two points at each end of a lining segment at which the real end surface meets the lines along which the inner surface of the lining is intended to be jointed longitudinally to the adjacent lining segment (see Figure 1).

Real end point The extreme point on the real end surface (see Figure 1).

Real end surface A surface joining the points against which the inner surface of the lining is intended to be jointed to the next lining section (see Figure 1).

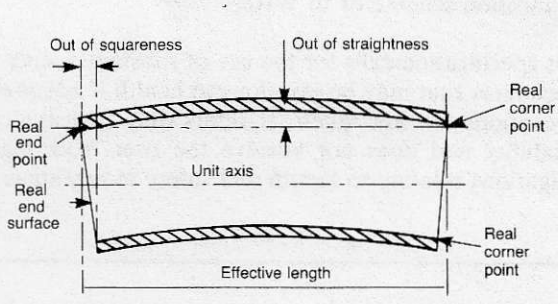
Springings The highest point at each side of an installed lining where the tangent to the internal surface is vertical.

Total major axis length The distance between the crown and invert of a lining section.

Type II design (Sewerage Rehabilitation Manual) This procedure is applicable to the design of pipe linings forming no reliable bond to the grout or old sewer. The design assumption is that the lining eventually bears the full load from the ground and traffic. The lining system is designed to act as a flexible pipe with the old sewer, annulus grout and soil providing the necessary support to maintain stability. The design concepts are applicable to both circular and non-circular linings.

Unit axis For a pipe lining section, the unit axis is a line passing through the centroids of the two real end surfaces. For a segment the unit axis is a line passing through the midpoints of lines joining the real corner points at each end of the segment (see Figure 1).

Figure 1 – Section through nominally straight lining unit



3. QUALITY ASSURANCE

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

4. MATERIALS

4.1 Base polymer

The base polymer shall be polyethylene with a derived density greater than 930 kg/m^3 when determined by the method specified in Appendix A.

4.2 Compound composition

The base polymer shall be blended with additives (antioxidants, pigment, ultra-violet stabilisers, etc.) that are necessary for the manufacture, storage and use of pipes to this specification.

The base polymer 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.

4.3 Antioxidants

Antioxidants listed in Table 2 of BS 3412: 1976 may be used at the recommended concentrations without prior agreement between manufacturer and purchaser.

The use of non-listed antioxidants is only permissible with the prior agreement of the purchaser.

4.4 Rework material

No rework material shall be included in the mouldings.

4.5 Thermal stability

The material in moulded lining form shall have a thermal stability (and individual oxidation induction time) of at least 15 minutes when tested in accordance with Appendix B.

5. APPEARANCE AND INTERNAL CONDITION

5.1 Appearance

The external and particularly the internal surface of the pipe shall be smooth and free from defects which might impair properties.

5.2 Internal condition

There shall be no evidence of poorly melted polymer.

6. DIMENSIONS

6.1 Section length

Lining sections shall be manufactured to within a tolerance of ±10mm of the nominal overall or effective lengths specified by or agreed with the purchaser. The sum of the lining section lengths shall not be less than the total length of lining required.

Where end caps form part of the moulding this clause shall apply after end cap removal. The method used to remove end caps shall be such that the required degree of accuracy can be achieved.

6.2 Cross-section

The tolerance on external height and width of the lining unit cross-section shall be $\pm(4 + 0.002D)$mm, where D(mm) is the nominal major axis of non-circular linings specified by or agreed with the purchaser.

6.3 Wall thickness

The wall thickness of the lining, shall be at least the minimum specified by or agreed with the purchaser.

6.4 Out-of-squareness

The out-of-squareness at each end shall be compatible with the jointing system employed and shall not be more than 2mm +0.005 ø or 10mm, whichever is the lesser, where ø is the average of the maximum and minimum internal diameters measured in mm.

Where end caps form part of the moulding this clause shall apply after end cap removal. The method used to remove end caps shall be such that the required degree of accuracy can be achieved.

6.5 Out-of-straightness

The out-of-straightness of a unit shall be no more than 10mm.

7. JOINTING

The linings shall be capable of being joined by fusion welding techniques. The lining manufacturer shall, upon request, provide the purchaser with written welding instructions appropriate for the size of linings supplied and the welding machine intended for use. Guidance as to the information necessary for the production of good quality welds is given in Appendix C.

8. PERFORMANCE REQUIREMENTS

The pipes shall meet the minimum requirements given in Table 1 when tested as prescribed in 9.2.

Table 1 – Lining performance requirements

Property	Minimum mean requirement
Short term flexural creep modulus (24 hour) E_S	350 MPa
Long term flexural creep modulus (50 year) E_L	130 MPa

On request, the manufacturer shall supply to the purchaser, the short and long term moduli of the lining material.

9. TYPE TESTS

9.1 General

The requirements in this section shall be met before compliance with this specification can be claimed. If there is a change in process technique or the introduction of a new or modified material then it will be necessary to ensure that the conditions of the specification are still satisfied after the introduction of such changes.

The Quality Assurance Schedule of the quality system may also require type tests to be repeated at specified intervals.

Unless otherwise specified, the test samples shall be taken from a production run from which the product has complied with all other requirements of this specification.

Details and results for type tests relevant to each material composition and manufacturing process shall be made available to the purchaser or his representative on request.

Specimens shall be conditioned prior to testing by being kept at 23 ±2°C in air for not less than 12 hours for linings of wall thickness up to and including 12.7mm and not less than 24 hours for linings of wall thickness over 12.7mm.

9.2 Creep modulus

The interpolated 24-hour and the extrapolated 50-year creep moduli shall be not less than the values given in Table 1, when tested according to Appendix E.

NOTE Complying certificated results from the pipe manufacturer's polymer supplier will be acceptable.

9.3 Density

The density of samples taken from inner surface, mid-wall and outer surface regions of the test pieces used in 9.2 shall be determined in accordance with Appendix A.

9.4 Tensile strength and elongation at break

When tested in accordance with Appendix F the tensile yield stress and elongation at break of each test piece shall not be less than 15.0 MPa and 450% respectively.

9.5 Resistance to stress cracking

The stress crack resistance, F_{50}, shall be equal to or greater than 500h when tested by the method given in ASTM D1693.

9.6 Tensile weld test

When tested in accordance with Appendix G the failure mode shall be ductile tearing. No "flat" fracture consistant with a brittle-like manner of failure shall be evident. At least two welds shall be made and tested from at least each pipe size.

9.7 Heat reversion test

The polyethylene sewer lining shall be tested in accordance with BS 2782: Method 1102B. After the test samples have been maintained at a temperature of 110°C for 15 minutes, the value of T (referred to in that method) shall not be greater than 3%.

10. QUALITY CONTROL TESTS

10.1 General

The test requirements given in this section are necessary in order to demonstrate a continuing satisfactory level of product quality in day-to-day production. The manufacturer shall not knowingly supply any defective unit in any batch.

The required sampling frequency for quality control tests is given in Appendix D.

10.2 Dimensions

The internal height and width shall be determined midway along each lining unit to an accuracy of ±1mm. The tolerance on internal height and width shall be ±(4 + 0.002D)mm where D is the nominal relevant dimension in mm.

The wall thickness shall be measured to an accuracy of 0.1mm. The minimum and maximum wall thickness shall be within the values specified or otherwise agreed between manufacturer and purchaser.

10.3 Thermal stability

The oxidation induction time shall be at least 15 minutes when determined according to the method given in Appendix B.

10.4 Elongation at break

When tested in accordance with Appendix F the value of elongation at break for each test piece shall not be less than 450%.

11. WORKMANSHIP, INSPECTION AND CERTIFICATION

11.1 Workmanship

All raw materials shall be tested to ensure consistency and compliance with this specification.

The manufacturer shall adequately supervise all stages of production and keep records of the raw material batches used and products made each work shift or day.

Manufacture shall be under environmental conditions compatible with producing satisfactory linings and raw materials shall be stored and used in compliance with the recommendations of their manufacturers.

The manufacturer shall provide the purchaser with written recommendations for the transport, handling and storage of all lining units.

11.2 Inspection

In addition to the manufacturer's own inspection and supervision, the purchaser or his appointed inspecting authority shall have access at all reasonable times to those parts of the manufacturer's works engaged on production and testing of linings for the purchaser and all relevant test records.

11.3 Certification

The manufacturer shall, on request, furnish the purchaser or purchaser's representative with copies of a signed certificate for each size of lining stating that the manufacture and testing of lining units supplied comply with the requirements of this specification. If required by the purchaser, the quality control test results or a suitable summary shall be provided with the certificate. A typical certificate is shown in Appendix H.

12. MARKING

All linings shall be permanently marked along opposite sides. No method of marking shall prejudice the performance of the lining in service. The markings shall give the following information:

(a) the manufacturer's name, initials or identification mark.

(b) the number of this specification, i.e. WIS 4-32-10. (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 solely his responsibility.)

(c) the nominal size, outside diameter.

(d) identification of the shift, production line and date of manufacture. Coding of this information is permitted provided that the meaning of the code is available on request.

(e) the words "PE SEWER LINING".

(f) the orientation of the lining with respect to the mould. This is to enable the lining to be correctly positioned for welding.

The marking shall remain legible under normal handling, storage and installation procedures.

13. PROTECTION OF LINING UNITS

Whilst under the manufacturer's control the pipes shall be stored in such a way so as to minimise dimensional changes, and external damage.

Unless otherwise agreed with the purchaser the ends of the pipes shall be covered and protected. This cover may take the form of an end plate integrally fabricated with the lining unit.

14. REFERENCES

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

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.
Method 320A Tensile strength, elongation and elastic modulus.
Method 620D Determination of density of solid plastic, excluding cellular plastics (density gradient column method).
Method 930A Preparation of test specimens by machining.
Method 1102B Longitudinal reversion of pipes: oven method.

BS 3412 Specification. Polyethylene materials for moulding and extrusion.

BS 4618 Recommendations for the presentation of plastics design data.
Sub-Section 1.1.2. Creep in flexure at low strains.

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

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

BS 6000 Guide to the use of BS 6001, sampling procedures and tables for inspection by attributes.

BS 6001 Sampling procedures for inspection by attributes.
Part 1 Specification for sampling plans indexed by acceptable quality level (AQL) for lot-by-lot inspection.

ASTM D1693 Environment stress-cracking of ethylene plastics.

EN 29002 (European Standard). Quality systems-model for quality assurance in production and installation.

WRc Sewerage Rehabilitation Manual.

APPENDIX A – METHOD FOR THE DETERMINATION OF DENSITY USING THE DENSITY GRADIENT METHOD

A.1 APPARATUS

A density gradient column is required containing a sufficient number of calibrated floats to cover the density range of the product. (Refer to BS 2782: Method 620D for preparation of density gradient columns and floats.)

A.2 TEST SPECIMENS

A sample of material comprising the whole thickness of the pipe wall and approximately 10mm square in cross-section shall be taken from the pipe. The test specimens shall be prepared from this sample by cutting sections from the inner and outer pipe walls and from a mid-wall position. The two sections from the pipe surfaces shall be less than 0.3mm in thickness and those within the pipe wall no thicker than 1mm. The specimens shall then be individually shaped such that their original position within the pipe can be identified.

A.3 PROCEDURE

After the density column has been stabilised at 23± 0.5°C for at least 6 hours a graph shall be prepared from the calibrated floats relating density to position within the column.

Each specimen in turn shall be pre-wetted and then placed with tweezers into the density column, care being taken to ensure that no air bubbles are attached to the surface of the specimens. After a period of one hour the position of each specimen within the column is noted and its density determined from the calibration graph.

A.4 REPORT

The report shall include the following:

(a) Full identification of the sample.
(b) Position of test specimens in relation to the internal and external surfaces of the lining unit.
(c) The measured density.
(d) The date of the test.

APPENDIX B – METHOD FOR THE DETERMINATION OF OXIDATION INDUCTION TIME

B.1 INTRODUCTION

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

B.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 antioxidant 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.

B.3 PRINCIPLE

This test measures the time during which the antioxidant 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.

B.4 APPARATUS

The following apparatus is required:

B4.1 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 50 $mL.min^{-1}$.

(d) Programming the specimen temperature over the range 150 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 cannot be achieved B4.2 applies.

B4.2 Temperature measuring apparatus, capable of continuously monitoring the specimen temperature with a resolution of 0.1°C.

NOTE A high impedance digital voltmeter with a resolution of 1μV has been found suitable when connected to the specimen thermocouple, and the associated cold junction, or cold junction compensator of the thermal analyser.

B4.3 Analytical balance, capable of weighing the 15 ±0.5mg test specimen to an accuracy of 0.1mg.

B4.4 Oxygen and high purity nitrogen supplies, through equipment which permits switching 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 one minute of switch-over.

B4.5 Gas flow measuring devices. Rotameters are suitable, but their calibration shall be checked against a positive displacement device.

B4.6 High purity metal standards: Indium, Tin.

B.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.

B5.1 Test specimens from pipe or fittings:

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

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

NOTE 2 Any swarf which collects near the surface corresponding to the lining unit inner surface shall be carefully lifted away.

(b) Using a scalpel, cut from the core samples discs of an approximate thickness to give specimen weights of 15 ±0.5mg. Select the two inner and one outer surface positions as the minimum sample points which are to be tested individually.

(c) The specimens shall be prepared for testing within a single working day and shall not be unduly handled or left in direct sunlight.

B.6 PROCEDURE

B6.1 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 2).

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.

B6.2 Time calibration

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

B6.3 Oxidation induction time measurement

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

Introduce a 15 ±0.5mg cylindrical PE specimen in an open aluminium pan and an empty aluminium reference pan into the cell. Specimens which contain the inner or outer surfaces of a pipe shall be placed in the sample pan with that surface uppermost. Set the instrument to run isothermally at 200 ±0.1°C. To commence the test raise the temperature at a rate of 20°C. min^{-1} to the test temperature and allow 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 should be purged within one minute of atmosphere change-over. Continue to run the thermogram until the oxidation exotherm has occurred, and has reached its maximum.

B.7 INTERPRETATION OF RESULTS

The oxidation induction time of each 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 3).

B.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.

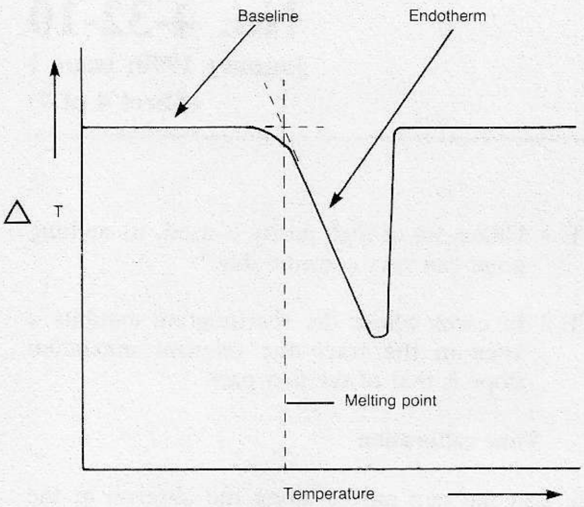


Figure 2 – Metal melting point

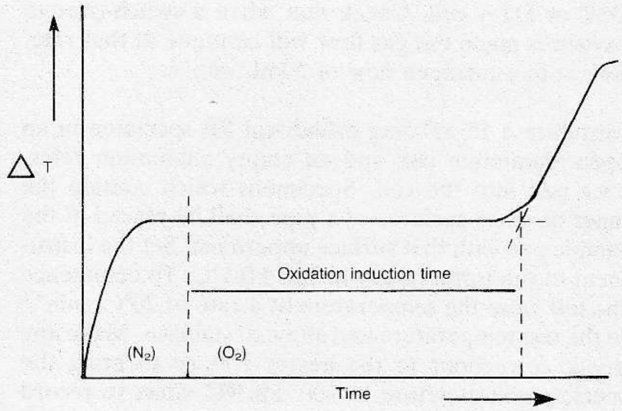


Figure 3 – Example of thermogram

APPENDIX C – FUSION WELDING CONDITIONS

This appendix does not form a mandatory part of the specification and is included for the guidance of both purchasers and manufacturers.

The purchaser is recommended to request from the manufacturer, welding instructions including details of the following as a function of temperature where appropriate:

(a) Heater plate temperature and acceptable limits.

(b) Pressure cycle for initial beading and/or bead size.

(c) The soak time and pressure at soak.

(d) Maximum heater plate removal/pipe contact time.

(e) The welding pressure and limits (appropriate to particular welding machines). Where machine gauge pressures for a particular welding machine are not available from the pipe manufacturer then the force per unit area of pipe wall necesssary for the appropriate operation should be provided.

(f) The weld cooling time and pressure conditions during cooling.

(g) The finished bead size limits.

(h) Any debeading limitation.

APPENDIX D – SAMPLING FREQUENCY FOR QUALITY CONTROL TESTS

D.1 Acceptable Quality Level (AQL)

Quality control tests shall be carried out to achieve an AQL of 10% defectives at an inspection level of S-3 as described in BS 6001: Part 1 using the double sampling plan.

This inspection level covers production batches up to and including 150 units of one size and classification, and specifies sampling requirements and acceptance/ rejection levels as summarised in Table 2.

D.2 Defectives

A test unit failing a quality control test is defined as having a defect. A test unit having one or more defects is defined as a defective. All defective test units shall be rejected and the acceptability of the batch from which they were drawn shall be determined as follows:

(a) If the number of defectives in a sample is less than or equal to the acceptance number corresponding to that sample then the batch is accepted.

(b) If the number of defectives in a sample is greater than or equal to the rejection number corresponding to that sample then the batch is rejected.

(c) If the number of defectives in a first sample from a batch is between the acceptance and rejection numbers corresponding to that sample, then a second sample is tested except in the case of reduced inspection.

Table 2 – Summary of sampling plans for inspection level S-3 giving acceptance/rejection numbers

Batch size	Sample	Normal inspection				Tightened inspection				Reduced inspection			
		Sample size	Cumulative sample size	Ac	Re	Sample size	Cumulative sample size	Ac	Re	Sample size	Cumulative sample size	Ac	Re
Up to 150 units	First	3	3	0	2	5	5	0	2	2	2	0	2
	Second	3	6	1	2	5	10	1	2				

NOTE Ac is the acceptance number and Re is the rejection number.

(d) If the number of defectives in a sample at reduced inspection is between the acceptance and rejection numbers corresponding to that sample, then the batch is accepted, but the sampling level for further batches shall be at normal level.

D.3 Switching rules for sample frequency variation

The switching rules between the different inspection levels are described in BS 6001:Part 1 and BS 6000 and may be summarised as follows:

(a) Normal inspection shall be used at the start of inspection for any one size and classification of production unit.

(b) Tightened inspection shall be used if 2 out of 5 or less successive batches are rejected on normal inspection.

(c) Tightened inspection shall be continued until 5 successive batches have been accepted on tightened inspection, when normal inspection shall be restored.

(d) Reduced inspection may be used at the discretion of the manufacturer provided that:

(i) The preceding 10 batches have been on normal inspection and none has been rejected (see Table VIII of BS 6001: Part 1: 1972 for exceptions).

(ii) The total number of defectives in all the sample tests from the preceding 10 batches (or such other number of batches as was used for condition (i) above) is equal to or less than the applicable number given in Table VIII of BS 6001: Part 1: 1972.

(iii) The production is at a steady rate.

(iv) Reduced inspection is considered acceptable by the independent inspector where a third party certification scheme is in operation, or reduced inspection is agreed to by the purchaser in writing.

(e) Any batch resubmitted for inspection shall be inspected at tightened inspection level and the result shall not be taken into consideration for the switching rules.

The manufacturer shall not knowingly supply any defective unit in any batch.

APPENDIX E – METHOD FOR THE DETERMINATION OF FLEXURAL CREEP

E.1 SCOPE

This test is used to determine the 50-year flexural creep modulus of sewer lining material subjected to a constant flexural stress. The method is based on BS 4618: Subsection 1.1.2: 1976.

E.2 APPARATUS

The apparatus is shown schematically in Figure 4. It shall consist of the following equipment such that the specimen is maintained at 23 ±2°C for the duration of the test.

E2.1 A pair of supports that:

(a) are parallel,
(b) can be adjusted to give a variable span,
(c) do not deflect under experimental forces,
(d) do not impose significant longitudinal restraint on the specimen,
(e) provide line contacts with the specimen without significant indentation, and
(f) preferably have a radius r of less than 1.0% of the span length L,

E2.2 A means of applying to the specimen a force that:

(a) is constant,
(b) is applied by a mass through a central loading member which shall preferably have a radius r of less than 1.0% of the span length L,
(c) is midway between the supports (within a tolerance of ±1% of the span), and
(d) is uniform along a continuous line perpendicularly across the width of the specimen.

E2.3 A means of measuring the deflection of the specimen that:

(a) is as close as practicable to the line of application of the force,
(b) itself applies only an insignificant force to the specimen, and
(c) is accurate to within ±0.3%.

E.3 TEST PIECES

E3.1 Preparation

At least three test pieces shall be machined representative of each range manufactured to produce rectangular cross sections (without rounded corners) with the following dimensional requirements:

(a) Span length (L) of 10d or greater.
(b) Total length of not greater than 1.2L.
(c) Width b greater than thickness (d) but less than 3d.
(d) Width and thickness constant to within a tolerance of ±1%.

NOTE BS 2782: Method 930A should be consulted for guidance on machining.

E3.2 Conditioning

The specimens shall be stored in air at 23 ±2°C for at least 24 hours prior to testing.

E.4 PROCEDURE

(a) Prepare each test piece.

(b) Mark on the test piece with a felt tipped marker the approximate positions where each end support will bear, then mark 10 intermediate positions on the test piece so that the span length is divided into 11 equal sections.

(c) Determine the width and thickness at each of the 10 lines to within an accuracy of ±0.2% and calculate the arithmetic mean of each set of measurements.

(d) Condition each test piece (see E3.2).

(e) Set the span length L to approximately the required value.

(f) Measure the span length L mm (±0.5%).

(g) Calculate the mass M to be applied to the test pieces to give the required flexural stress from:

$$M = \frac{bd^2S}{14.71L} \text{ kg} \qquad (1)$$

Where b = the average width of the test piece (between the supports) (mm)

d = the average thickness of the test piece between the supports (mm)

S = the required flexural stress = 3 MPa.

L = the distance between the supports or span length (mm).

The applied mass shall be accurate to within ±0.1% of the calculated mass.

(h) Place the test piece in the apparatus with its longitudinal axis at right angles to the supports.

(i) Set and zero the deflection measuring device.

(j) Immediately after carrying out step (i), smoothly apply the mass M and commence timing the test.

(k) If continuous monitoring of deflection (δ) is not employed a series of readings shall be taken between approximately 1 minute and at least 10,000 hours. There shall be at least 18 data points between 10 hours and 10,000 hours for each test piece. The following nominal times are recommended: 1, 2, 3, 4, 12, 18, 24, 36 and 48 minutes. 1, 2, 4, 6, 8, 10, 20, 40, 80, 100, 200, 400, 600, 1,000, 2,000, 4,000, 8,000, 10,000 hours.

(l) Calculate the flexural creep modulus for each value of $\delta_{(t)}$ at time t from

$$E_t = \frac{2.45\ ML^3}{b\ d^3\ \delta_{(t)}} \text{ MPa} \qquad (2)$$

(m) Plot $\log_{10} E_{(t)}$ against $\log_{10}$ time. If for any reason the readings do not approximate to a smooth trace the test shall be abandoned, the occurrence recorded and the test repeated.

(n) The graph produced for each test specimen may consist of a line which goes through a transition to an approximately straight line of greater slope. This being so, observe the position of the transition. After the transition regress the calculated values of $\log_{10}$ creep modulus on $\log_{10}$ time using the method of least squares and determine the extrapolated 50 year value of creep modulus E_L.

From the graphs determine the value of creep modulus E_s at 24 hours.

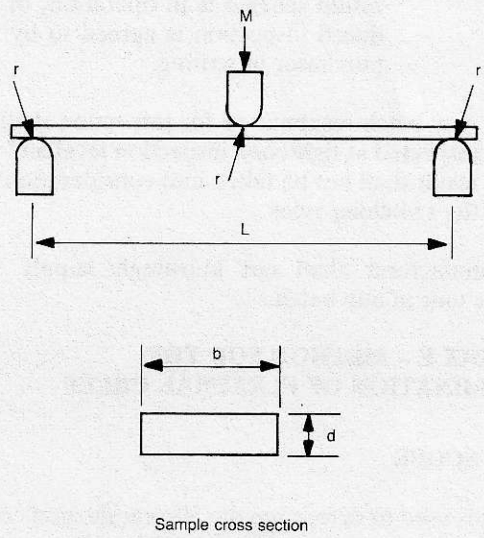
(o) If the graph does not approximate to a straight line but continues to curve downwards the procedure in (n) is invalid.

E.5 REPORT

For each specimen the test report shall include:

(a) Complete description and identification of the lining.
(b) Dimensions of the specimen.
(c) Method of specimen preparation.
(d) Graph of $\log_{10}$ flexural creep modulus versus $\log_{10}$ time.
(e) Mass applied to the specimen.
(f) The calculated value of flexural creep modulus E_s at 24 hours.
(g) The extrapoluted value of flexural creep modulus E_L at 50 years.
(h) The period of the test.
(i) Any other relevant information.

Figure 4 – Schematic layout for three-point flexural creep tests



APPENDIX F – METHOD FOR THE DETERMINATION OF TENSILE YIELD STRESS AND ELONGATION AT BREAK

F.1 APPARATUS

A tensile testing machine accurate to grade A of BS 5214: Part 1: 1975 or grade 1.0 of BS 1610: Part 1: 1985 shall be used.

F.2 TEST PIECES

Longitudinal samples shall be taken from the full wall thickness at positions equally spaced around the circumference of the pipe. The minimum number required is four.

For wall thicknesses greater than 12.7mm and, where possible, for thicknesses below this, the test pieces shall be machined to the profile shown in Figure 5 (see NOTE 5).

Reference lines (gauge marks) shall be perpendicular to the longitudinal axis of the test piece and symmetrically placed along the parallel section. They shall not be scratched, punched or impressed on the test piece.

Heat shall not be applied to the pipe to enable flattening or aid cutting.

F.3 PROCEDURE

Measure the mean width and thickness of the test pieces in the gauge length to an accuracy of 0.01mm. Condition the test pieces prior to testing (see 9.1). The test pieces shall be tested individually at a grip separation rate of $10mm.min^{-1}$ ±10%.

At ultimate break the measured distance between the gauge marks shall be expressed as a percentage of the original gauge length.

The yield stress for each test piece shall be calculated from the force at yield and the original gauge area dimensions.

NOTE 1 The standard of sample production is very important.

NOTE 2 BS 2782: Method 930A should be consulted for guidance on machining.

NOTE 3 Wherever possible a continuous record of force vs displacement shall be retained.

NOTE 4 The measurement of yield stress is not obligatory for quality control tests in this specification.

NOTE 5 For wall thicknesses of 12.7mm or less test pieces may be machined to the form shown in BS 2782: Method 320A (with or without radius F). These shall be tested at 100mm. min^{-1} ±10%.

NOTE 6 Alternative test methods for determining yield stress and elongation at break may be used provided that equivalence to specified methods can be demonstrated.

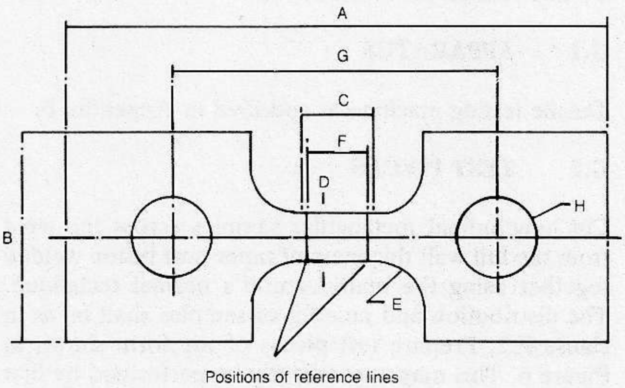
F.4 REPORT

The report shall include the following information:

(a) The full identification of the pipe from which samples were taken.
(b) Type of test specimen.
(c) Rate of grip separation.
(d) Test temperature.
(e) Individual results of elongation at break and tensile yield stress if required.
(f) Make and model of test instrument used.
(g) The date of the test.

A – overall length, minimum 250
B – width at ends (recommended) 100 ±3
C – length of narrow parallel portion 25 ±1
D – width of narrow parallel portion 25 ±1
E – minimum radius 25
F – distance between reference lines 20 ±1
G – initial distance between grips or centres of loading pins (recommended) 165 ±5
H – holes for loading pins if required, recommended diameter 25 to 35 (All dimensions in mm).

Figure 5 – Tensile test piece



A – overall length, minimum	250
B – width at ends (recommended)	100 ± 3
C – length of narrow parallel portion	25 ± 1
D – width of narrow parallel portion	25 ± 1
E – minimum radius	25
F – distance between reference lines	20 ± 1
G – initial distance between grips or centres of loading pins (recommended)	165 ± 5
H – holes for loading pins if required, recommended diameter	25 to 35

(All dimensions in mm)

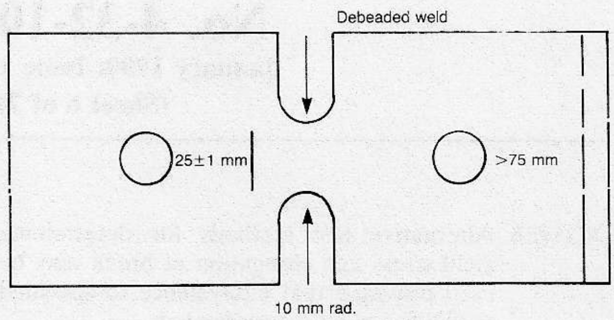
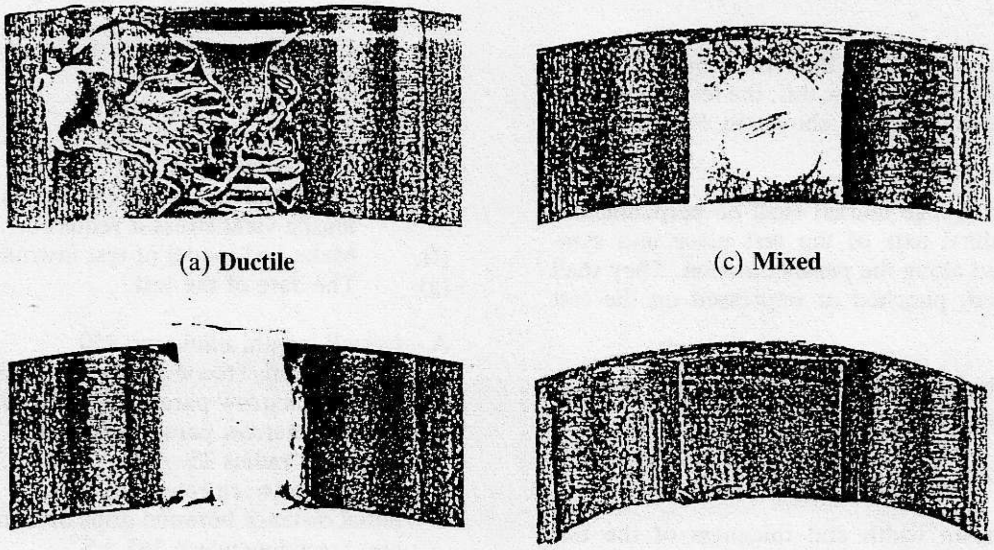


Figure 6 – Tensile specimen geometry for welds



(a) **Ductile**

(b) **Mixed**

(c) **Mixed**

(d) **Brittle**

Figure 7 – Examples of tensile failure modes

APPENDIX G – METHOD OF ASSESSING INITIAL BUTT WELDING CAPABILITY

G.1 APPARATUS

Tensile testing machine as specified in Appendix F.

G.2 TEST PIECES

Cut longitudinal rectangular samples across the weld from the full wall thickness of pipes butt fusion welded together using the manufacturer's normal technique. The distribution and number of samples shall be as in clause F.2. Prepare test pieces of the form shown in Figure 6. This may conveniently be performed by first drilling or milling holes at 45mm centres along the weld then cutting towards the holes from the edges. The radiused portions of the test pieces shall be smooth but the finish of the remaining edges is not critical.

NOTE 1 A "spade" type wood drill has been found to give satisfactory results.

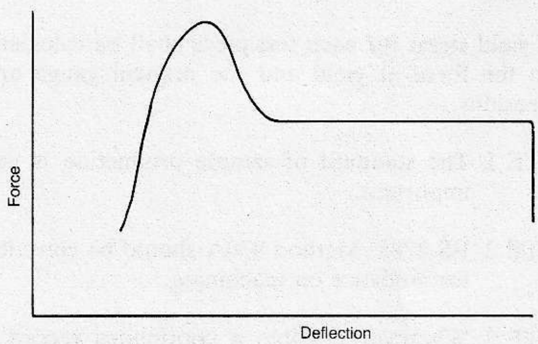
NOTE 2 To minimise the possibility of contamination it is recommended that the **cold** heater plates are thoroughly cleaned using water (or if necessary a suitable solvent) and a clean lint-free cloth or tissue before welding. For optimum results an initial weld shall be made and discarded.

G.3 METHOD

Condition the test pieces (see 9.1) and then test them in tension at a grip separation rate of 5mm. $\min^{-1} \pm 10\%$. Allow the tests to continue until the test piece breaks and observe the failure modes, e.g. ductile tearing, flat brittle failure.

Figure 7 shows examples of the tensile failure modes of welds.

Figure 8 – Example of force/deflection trace for ductile failure



NOTE Where a force/deflection trace is available it would be expected to appear as in Figure 8 prior to acceptable failure.

G.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.
(d) The date of the test.

CERTIFICATE

We, ...,

hereby certify that the polyethylene linings manufactured on ....

and supplied to .... on ....

have been manufactured and tested in accordance with the requirements of WIS No. 4-32-10: Issue 1 published by FWR/WRc

and have a minimum wall thickness of ....mm.

The lining units are/are not* marked with the number 4-32-10.

Our company has/does not have* third party certification in respect of this specification.

* Delete whichever is not applicable.

Signed: ....

on behalf of: ....

on: ....