PRODUCT ASSESSMENT SPECIFICATION

PAS 27:1999

Incorporating Corrigendum No. 1

Unplasticized poly(vinyl chloride) alloy (PVC-A) pipes and bends for water under pressure

ICS 23.040.20; 23.040.45; 91.140.60

BSi

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Amendments issued since publication

Amd. No.	Date	Text affected
10516 Corrigendum	May 1999	Correction to equation (1), p4

Summary of pages

The following table identifies the current issue of each page. Issue 1 indicates that a page has been introduced for the first time by amendment. Subsequent issue numbers indicate an updated page.

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Front cover	2	1	original
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Foreword

This Product Assessment Specification, PAS 27, has been published to provide an interim specification for a new generation of unplasticized poly(vinyl chloride)-based plastics alloy (PVC-A) pipes exhibiting a combination of high strength and ductility. Pipes conforming to this specification will provide systems with a high level of integrity and predictable performance.

The specification recognizes advances in both materials and processing. Improved understanding of material technology has allowed materials to be developed with a high level of ductility and high resistance to both impact and slow crack propagation.

A comprehensive series of quality control and type tests are included to ensure the pipes exhibit the intended performance characteristics under a wide variety of conditions.

The material exhibits very predictable long-term performance characteristics which allow a relatively high design stress of 17.5 MPa to be adopted. The pipes therefore have a combination of high strength, high ductility and reduced wall thickness.

Regulation 25 of the Water Supply (Water Quality) Regulations 1989 specified the circumstances in which water undertakers may use products in contact with public water supplies in England and Wales. All pipes used to convey public water supplies have to be approved under the provisions of regulation 25(1)(a) in order to ensure that use will not cause adverse effect on water quality or risk to the health of consumers. Similar provisions apply in Scotland and Northern Ireland.

This Product Assessment Specification is not to be regarded as a British Standard. It will be withdrawn upon the publication of its content in, or as, a British Standard.

Acknowledgement is given to the following organizations who were consulted in the development of this specification:

British Plastics Federation;
Water UK.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 23 and a back cover.

Introduction

During the finalization of this Product Assessment Specification, from which further editions or a British Standard may be derived in due course, the following decisions, observations or proposals were made upon which comment is invited from users to assist amendment or updating of the contents as appropriate.

a) The minimum wall thickness for pipes was set at 3.0 mm (see Table 1), compared with as little as 2.2 mm in the base documents considered and a suggestion that 3.2 mm should be specified to tolerate severe surface damage or abuse (at levels which would not be acceptable under relevant installation codes).

b) The range of nominal pipe sizes covered should be extended to include 710 and 800, with the corresponding values introduced into Tables 1, 2 and 4 accordingly.

c) For elastomeric seals, in addition to conformity to BS EN 681-1, attention is drawn to traditional UK requirements for resistance to microbiological degradation which could be invoked by contractual reference to BS 7874:1998 if and when this was considered essential.
Opinions differed on whether it was appropriate to embody these requirements in this Product Assessment Specification so as to apply to seals for all the applications for which such pipes may be used.

d) For analysis of data for long-term properties, reference is made to ISO/TR 9080:1992 instead of WIS 4-31-06:1990, which has been superseded by a later edition which in turn refers to ISO/TR 9080. ISO/TR 9080:1992 is itself under revision and expected to result in a full International Standard, i.e. ISO 9080, during 1999.

e) For consistency with existing British Standards and Water Industry Specifications, the method for determination of C-ring toughness given in annex B, and referred to in annex C, allows use of restraining rods as an option. Two considerations arise:

   1) wherever alternative test conditions may be used, one should be identified as the reference method in case of dispute (not necessarily the same one for all circumstances, e.g. one could be the reference method for some sizes and the other the reference method for the remaining sizes.)

   2) for the purposes of this Product Assessment Specification, the test is not to be used to determine a performance value but only the nature of the initial fracture mode, i.e. ductile or brittle.

1 Scope

This Product Assessment Specification specifies the requirements for unplasticized poly(vinyl chloride)-based plastics alloy (PVC-A) pipes, and PVC-A post-formed bends with integral joints, intended for the conveyance of drinking water under pressure. The pipes are intended for use below ground, and also above ground provided they are not exposed to direct sunlight.

The pipes are suitable for service temperatures between 0 °C and 40 °C.

NOTE 1 At temperatures above 20 °C, pressure derating is necessary and should be in accordance with guidelines provided by the manufacturer.

NOTE 2 If it is intended to use pipes conforming to this specification for the conveyance of fluids other than water, the manufacturer should be consulted.

NOTE 3 For any application involving surge and fatigue, reference should be made to the relevant UK Water Industry Information and Guidance Note [1]. For drinking water, the recommended temperature for rerating is 10 °C, whereas for other fluids higher temperatures may be appropriate.

NOTE 4 PVC-A pressure pipes conforming to this specification, and associated fittings, should be installed and used in accordance with the manufacturer's recommendations.

To assist arrangements for quality control or assessment of conformity, annex A gives a classification for assigning each requirement and associated test to quality control or type test purposes respectively.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Product Assessment Specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Product Assessment Specification are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

BS 903-A26, *Physical testing of rubbers — Method A26: Method for determination of hardness (hardnesses between 10 IRHD and 110 IRHD).*

BS 2782-11:Method 1101A, *Measurement of dimensions of pipes.*

BS 7874:1998, *Microbiological deterioration of elastomeric seals for joints in pipework and pipelines.*

BS EN 681-1:1996, *Elastomeric seals — Materials requirements for pipe joint seals used in water and drainage applications — Part 1: Vulcanized rubber.*

ISO 1167:1996, *Thermoplastics pipes for the conveyance of fluids — Resistance to internal pressure — Test method.*

ISO 2505-1:1994, *Thermoplastic pipes — Longitudinal reversion — Part 1: Determination methods.*

ISO 2507-2, *Thermoplastics pipes and fittings — Vicat softening temperature — Part 2: Test conditions for unplasticized poly(vinyl chloride) (PVC-U) or chlorinated poly(vinyl chloride) (PVC-C) pipes and fittings and for high-impact resistance poly(vinyl chloride) (PVC-HI) pipes.*

ISO 3127, *Thermoplastics pipes — Determination of resistance to external blows — Round-the-clock method.*

ISO 5893:1993, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Description.*

ISO 6259-1, *Thermoplastics pipes — Determination of tensile properties — Part 1: General test method.*

ISO 6259-2:1997, *Thermoplastics pipes — Determination of tensile properties — Part 2: Pipes made of unplasticized poly(vinyl chloride) (PVC-U), chlorinated poly(vinyl chloride) (PVC-C) and high-impact poly(vinyl chloride) (PVC-HI).*

ISO/TR 9080:1992, *Thermoplastics pipes for the transport of fluids — Methods of extrapolation of hydrostatic stress rupture data to determine the long-term hydrostatic strength of thermoplastics pipe materials.*

3 Terms and definitions

For the purposes of this Product Assessment Specification the following terms and definitions apply.

3.1
pipe batch

clearly identifiable number of pipes, all of the same nominal size and nominal wall thickness, extruded from the same compound on the same machine

NOTE The batch from which any pipe is made is identified by the pipe manufacturer, who also defines the size of a batch.

3.2
ductile mode

type of failure of the material where plastic deformation occurs, indicated, in the case of a fracture surface, by stress whitening visible to correct vision without magnification

3.3
elevated temperature
any temperature above 20 °C

3.4
hoop stress
stress in a pipe under pressure, acting tangentially to the perimeter of a transverse section

3.5
hydrostatic design stress (HDS) (σ_{HD})
hoop stress due to internal hydrostatic pressure that can be continuously applied at a specified temperature, derived by the application of a design factor to the extrapolated lower 97.5 % confidence limit of the mean long-term hydrostatic stress (σ_{LCL})

3.6
lower confidence limit long-term hydrostatic strength (σ_{LCL})
quantity, with the dimensions of stress in megapascals (MPa), which can be considered as a property of the material and represents the 97.5 % lower confidence limit of the mean long-term strength at 20 °C for 50 years with internal water pressure

3.7
type test
test intended to prove the suitability and performance of a new composition, a new processing technique or a new design or size of pipe

NOTE Type tests are carried out when a change is made to a formulation or method of manufacture.

3.8
working pressure
maximum pressure that can be sustained by the class of pipe for its estimated useful life under the expected working conditions

4 Symbols

$d_{e,min.}$	the minimum outside diameter of the pipe, in millimetres
DN	the nominal size
e	the pipe wall thickness, in millimetres
$e_{min.}$	minimum permissible wall thickness, in millimetres
PN	nominal working pressure designated in bar[1)]
p	the maximum allowable working pressure, in bar
σ_{HD}	hydrostatic design stress, in megapascals

NOTE Symbols used only in an annex are defined therein.

5 Material

PVC-A pipes shall consist of a poly(vinyl chloride)-based plastics alloy to which is added only those additives necessary to manufacture pipes, integral joints and post-formed bends which conform to this PAS.

No reworked material, even of the same composition, shall be added to PVC-A pipes.

NOTE The recommended colour for pipes and post-formed bends is blue within the range 18E51 to 18E53 of BS 4901:1976 but other colours may be used in accordance with the requirements of the purchaser, see note 2 to clause 1.

[1)] 1 bar = $10^5 N/m^2$ = 0.1 MPa.

6 Dimensions

6.1 General

Dimensions shall be measured in accordance with BS 2782-11:Method 1101A.

6.2 Pipes

6.2.1 *Wall thickness*

The wall thickness of pipes shall be calculated using the following equation

$$e_{min.} = \frac{p d_{e,min.}}{20\sigma_{HD} + p} \quad (1)$$

where

$e_{min.}$	is the minimum wall thickness in millimetres (mm) (see Table 1);
p	is the internal pressure, in bar;
$d_{e,min.}$	is the minimum outside diameter of the pipe, in millimetres (mm) (see Table 1);
σ_{HD}	is the hydrostatic design stress, in megapascals (MPa).

6.2.2 *Cross-sectional dimensions*

The mean outside diameter, wall thickness and out-of-roundness of the pipe shall conform to Table 1.

6.2.3 *Effective length*

The effective length of the pipe shall be not less than that specified when measured at (23 ± 2) °C or as agreed between the manufacturer and the purchaser.

NOTE The coefficient of thermal expansion of PVC-A may be taken as $7 \times 10^{-5}\ K^{-1}$.

6.2.4 *Pipe spigot ends*

Pipe spigot ends shall be normal to the main axis of the pipe.

6.2.5 *Chamfers*

Chamfered pipe ends shall conform to Figure 1.

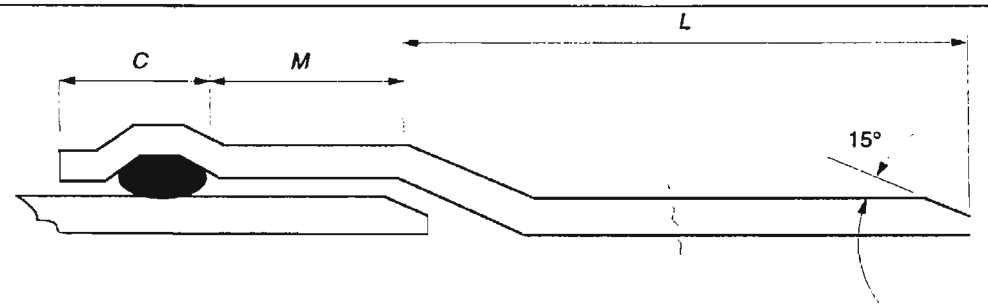
6.3 Integral joints

6.3.1 *Cross-sectional dimensions*

The inside diameter and the out-of-roundness shall conform to Table 2. The wall thickness at any point of an integral socket, on the pressure side of the seal, shall be not less than the minimum wall thickness $e_{min.}$ specified for the pipe (see Table 1).

6.3.2 *Depth of engagement*

Spigotted pipe for elastomeric seal jointing shall be marked with an insertion (witness) mark such that, when the spigot is inserted into a matching pipe socket with the mark at the mouth of the socket, the joint shall be able to accommodate the expansion and contraction expected in service and shall conform to Table 2.



L = Effective pipe length
M = Minimum available engagement depth
C = Length of socket entrance and sealing area

Figure 1 — Chamfers

6.4 Post-formed bends

6.4.1 *Wall thickness*

Bends post-formed from pipes shall have a wall thickness not less than that specified for the pipe of the same diameter and pressure rating. The maximum wall thickness specified for the pipe may be exceeded.

NOTE It may be necessary to make post-formed bends from pipe having a thicker wall to allow for the thinning that can occur during the bending operation.

6.4.2 *Bend radius*

The radius of any post-formed bend, measured to the centre line, shall be not less than three times the outside diameter.

6.4.3 *Spigot lengths*

The spigot ends of post-formed bends shall be straight and of sufficient length to satisfy the depth of engagement requirements specified for integral joints (see **6.3.2**).

6.4.4 *Bend angle*

The angle of bends shall be within ±5° of the nominal value.

7 Appearance

When viewed without magnification, the internal and external surfaces of the pipe shall be free from defects and the internal surface shall appear to be clean.

NOTE The ends of the pipes may be plugged or covered to maintain their condition and exclude contamination.

8 Elastomeric jointing rings

Elastomeric jointing rings shall conform to the requirements for type WA of BS EN 681-1:1996.

NOTE For applications where resistance to microbiological deterioration is considered to be important, attention is drawn to the requirements described in the foreword of BS 7874:1998 and the possibility of applying by agreement between manufacturer and purchaser such requirements for data obtained by testing in accordance with BS 7874:1998.

Table 1 — Outside diameter, out-of-roundness and wall thickness of pipes

Dimensions in millimetres

Nominal size of pipe	Mean outside diameter[a]		Out-of roundness[b]	Wall thickness[c]							
				PN8		PN10		PN12.5		PN16	
DN	$d_{e,min.}$	$d_{e,max.}$	max.	$e_{min.}$	$e_{max.}$	$e_{min.}$	$e_{max.}$	$e_{min.}$	$e_{max.}$	$e_{min.}$	$e_{max.}$
63	63.0	63.3	1.0	—	—	—	—	—	—	3.0	3.4
90	90.0	90.3	1.1	—	—	—	—	3.1	3.6	4.0	4.4
110	110.0	110.4	1.4	—	—	3.1	3.6	3.8	4.3	4.9	5.5
160	160.0	160.5	2.0	3.6	4.1	4.5	5.1	5.6	6.2	7.0	7.8
200	200.0	200.6	2.4	4.5	5.1	5.6	6.3	6.9	7.7	8.8	9.8
250	250.0	250.8	3.0	5.6	6.3	7.0	7.8	8.7	9.7	11.0	12.2
315	315.0	316.0	3.8	7.1	8.0	8.8	9.8	10.9	12.1	13.8	15.3
355	355.0	356.0	4.3	8.0	8.9	9.9	11.0	12.3	13.7	15.6	17.3
400	400.0	401.0	4.8	9.0	10.0	11.2	12.5	13.8	15.3	17.5	19.4
450	450.0	451.0	5.4	10.1	11.3	12.5	13.9	15.6	17.3	19.7	21.8
500	500.0	501.0	6.0	11.2	12.5	13.9	15.4	17.3	19.2	21.9	24.2
630	630.0	631.0	7.6	14.1	15.7	17.5	19.4	21.8	24.1	27.6	30.5

[a] Tolerances conform to grade C of BS ISO 11922-1:1998 with a maximum of 1 mm.

[b] Maximum out-of-roundness calculated as $d_{e,min.} \times 0.012$.

[c] Minimum wall thicknesses are based on a design stress of 17.5 MPa with a minimum of 3 mm. The calculated values are rounded in accordance with BS ISO 4065.

Table 2 — Dimensions of integral sockets with elastomeric sealing rings

Dimensions in millimetres

Nominal size of socket	Inside diameter of socket min.	Out-of-roundness max.	Depth of engagement min.	Length of socket entrance and sealing area *C* min.
63	63.4	0.4	65.0	32.0
90	90.4	0.6	71.0	36.0
110	110.5	0.7	75.0	40.0
160	160.6	1.0	86.0	48.0
200	200.7	1.2	94.0	54.0
250	250.9	1.5	106.0	62.0
315	316.1	1.9	118.0	72.0
355	356.2	2.2	124.0	79.0
400	401.3	2.4	130.0	86.0
450	451.5	2.7	138.0	94.0
500	501.6	3.0	145.0	102.0
630	632.0	3.8	165.0	123.0

9 Performance requirements

NOTE *Effect on water quality*. At the tme of publication, products for use in contact with public water supply have to be approved by the Secretary of State for the Environment under the provisions of regulation 25(1)(a) of the Water Supply (Water Quality) Regulations 1989[1], unless any of the subsections 25(1)(b), (c) or (d) apply.

9.1 Pipes

9.1.1 *Longitudinal reversion*

When tested in accordance with ISO 2505-2, in either an air oven or an oil bath, at a temperature of (150 ± 2) °C, the longitudinal reversion of the pipe shall not exceed 5.0 %, nor shall the pipe show any signs of cracks, cavities or blisters resulting from the immersion. In case of dispute the oil bath method shall be the reference method.

9.1.2 *Freedom from defects*

When tested as follows, the test piece shall show no delamination, cracks, cavities, inclusions, porosity or blisters when viewed without magnification.

Heat a test piece in accordance with ISO 2505-1:1994, except that reference marks need not be scribed onto the test piece, in either an oven or bath at (150 ± 2) °C, for the applicable time period specified in Table 3.

Table 3 — Test piece immersion periods

Overall pipe wall thickness	Minimum immersion period	
	in oil bath	in air oven
mm	min	min
≤8.6	15	60
>8.6 and ≤14.1	30	120
>14.1	60	240

Immediately after removal of the test piece from the oven or bath, use a razor sharp blade to make four cuts each of minimum length 150 mm along the length of the test piece and through the full wall thickness, at points equidistant around its circumference. Allow the cut test piece to cool. Inspect all surfaces of the test piece and record any signs of any of the relevant defects.

9.1.3 ***Resistance to internal pressure at 20 °C***

When tested in accordance with ISO 1167:1996 at a temperature of (20^{+2}_{-1}) °C and using type B end caps, except that the free length of the test piece shall be not less than three times the outside diameter for pipes up to and including nominal size 315 and not less than 1 m for larger diameters, the test piece shall withstand a hoop stress of 36 MPa for not less than 1 h.

9.1.4 ***C-ring toughness***

When tested at a temperature of (23 ± 2) °C in accordance with annex B, the fracture surface shall exhibit only ductile mode (**3.2**) failure and not brittle fracture.

9.1.5 ***Vicat softening temperature***

When tested in accordance with ISO 2507-2, the Vicat softening temperature of the pipe material shall be not less than 80 °C.

9.1.6 ***Resistance to impact at 0 °C***

When tested in accordance with ISO 3127 at (0 ± 1) °C, with a striker diameter of (25 ± 1) mm, a drop height of (2.0 ± 0.01) m and a striker mass as specified in Table 4, the TIR shall be not greater than 5 %.

NOTE Attention is drawn to specification in **9.1.6** of use of a striker diameter of (25 ± 1) mm for all the test conditions covered by Table 4, i.e. users of this Product Assessment Specification should not use a nominal striker diameter of 90 mm as specified in ISO 3127:1994 for striker masses exceeding 0.8 kg.

Table 4 — Striker mass

Nominal pipe size DN	Striker mass kg
63	1.75
90	2.25
110	2.75
160	3.75
200	4.00
250	5.75
315	7.50
400	7.50
450	7.50
500	7.50
630	7.50

9.1.7 ***Resistance to long-term hydrostatic pressure.***

When tested at (20^{+2}_{-1}) °C and using type B end caps in accordance with ISO 1167:1996, except that the free length of the sample shall be not less than three times the outside diameter for nominal pipe sizes up to and including 315 and not less than 1 m for larger sizes, the lower 97.5 % confidence limit (σ_{LCL}) of the mean extrapolated stress at 50 years shall be not less than 24.5 MPa when the test data is analysed in accordance with method II of ISO/TR 9080:1992.

All test pieces shall exhibit ductile behaviour before rupture.

9.1.8 ***Long-term toughness***

When tested in accordance with annex C, the lower 97.5 % confidence limit of the mean extrapolated net section stress at 50 years shall be not less than 24.5 MPa.

All failures shall be ductile with crack surfaces showing no signs of brittle fracture.

9.1.9 ***Resistance to diurnal pressure fluctuations***

When tested in accordance with annex D, the lower 97.5 % confidence limit of the mean extrapolated net section stress at 50 years shall be not less than 24.5 MPa. All failures shall show evidence of ductility before rupture. In case of dispute the reference method shall be method A.

9.1.10 ***Resistance of notched pipe to sustained hydrostatic pressure***

When tested in accordance with annex E, the extrapolated time to failure, based on the stress applied to the ligament, shall be not less than the 97.5 % confidence limit value at 50 years for pipes tested under static conditions in accordance with **9.1.7**.

All failures shall show evidence of ductility before rupture.

9.1.11 ***Resistance to weathering***

Following an outdoor exposure of 3.5 GJ/m^2, where the exposure shall be at 45°, facing south in the northern hemisphere or north in the southern hemisphere as applicable, the pipe shall conform to the following requirements:

a) when tested in accordance with **9.1.3**, the pipe shall withstand a hoop stress of 36 MPa at (20^{+2}_{-1}) °C for not less than 1 h;

b) the requirements of **9.1.6**.

9.1.12 ***Resistance to three-point bend when notched***

When tested in accordance with annex F at 23 °C, the test data shall form straight lines having slopes such that the stress at crack initiation is greater than or equal to the yield stress and the stress at peak used is greater than or equal to 1.5 times the yield stress, where the yield stress is that determined uniaxially at the same strain rates as the bending test.

9.1.13 ***Tensile strength at yield***

When tested in accordance with the method described in ISO 6259-1 and the conditions given in ISO 6259-2:1997 for PVC-HI, the tensile strength at yield shall be not less than 40 MPa.

9.2 Elastomeric ring seal joints

9.2.1 ***Resistance to short-term hydrostatic pressure***

When tested at (20^{+2}_{-1}) °C in accordance with ISO 1167, a test piece incorporating an elastomeric seal joint shall withstand an internal hydraulic pressure equivalent to a hoop stress in the pipe wall of 36 MPa for not less than 1 h.

9.2.2 ***Resistance to long-term hydrostatic pressure***

When tested at (20^{+2}_{-1}) °C in accordance with ISO 1167, the joint shall withstand, without observable leakage, a hydrostatic pressure equivalent to a hoop stress of 26 MPa for a period of not less than 10 000 h.

9.2.3 ***Resistance to negative pressure***

When tested in accordance with annex G, the deformed joint shall withstand an internal vacuum or external hydrostatic pressure of (0.25 ± 0.03) bar at ambient temperature for a period of 1 h without leakage.

10 Marking

All pipes shall be indelibly and legibly marked without indentation along two strips on opposite sides of the pipe in a contrasting colour to the pipe at intervals not greater than 1 m longitudinally with the following information:

a) manufacturer's name or trademark;

b) nominal size;

c) nominal pressure rating (e.g. 10 bar);

d) date of manufacture and shift or time;

e) extruder reference (where applicable);

f) "PAS 27" and date of issue;

g) for post-formed bends, the appropriate nominal pressure;

h) if applicable, third-party certification mark.[2)]

[2)] *Product certification.* Users of this Product Assessment Specification are advised to consider the desirability of third-party certification of product conformity to this Product Assessment Specification. Appropriate conformity attestation arrangements are described in BS EN 45011.

Annex A (informative)
Test classification

For the purpose of demonstrating conformity to this specification some of the requirements have been classified as appropriate for quality control tests as listed in Table A.1, intended to be performed at intervals during production. The remainder of the requirements are listed as appropriate for conformity to be established primarily by type tests (**3.7**).

Table A.1 — Test classification

Clause	Requirement and associated test	Test classification
6	Dimensions	
	Outside diameter	Quality control test
	Out-of-roundness	Quality control test
	Wall thickness	Quality control test
	Pipe length	Quality control test
	Socket dimensions	Quality control test
7	Appearance	Quality control test
9	Performance requirements	
NOTE	Effect on water quality	
9.1	Pipes	
9.1.1	Longitudinal reversion	Quality control test
9.1.2	Freedom from defects	Quality control test
9.1.3	Resistance to internal pressure at 20 °C	Quality control test
9.1.4	C-ring toughness	Quality control test
9.1.5	Vicat softening temperature	Type test
9.1.6	Resistance to impact at 0 °C	Quality control test
9.1.7	Long-term hydrostatic pressure test	Type test
9.1.8	Long-term toughness	Type test[a]
9.1.9	Resistance to diurnal pressure fluctuations	Type test
9.1.10	Resistance of notched pipe to sustained hydrostatic pressure	Type test
9.1.11	Resistance to weathering	Type test
9.1.12	Notched three-point bend test	Type test
9.1.13	Tensile strength at yield	Type test
9.2	Elastomeric ring seal joints	
9.2.1	Short-term hydrostatic pressure test	Quality control test
9.2.2	Long-term hydrostatic pressure test	Type test
9.2.3	Resistance to negative pressure	Type test
10	Marking	Quality control test

[a] A shortened procedure, using six points as required by **D.3.2.2**, may be appropriate for a quality control test, e.g. on particular batches of pipes by agreement between manufacturer and purchaser.

Annex B (normative)
Determination of C-ring toughness

B.1 Principle

C-ring test pieces are subjected to an applied load so that failure occurs within a few minutes. The fracture surface is examined for evidence of brittle behaviour.

B.2 Reagents

B.2.1 *Dichloromethane,* industrial grade. Clean.

NOTE If necessary, the dichloromethane may be cleaned by filtering.

WARNING Direct contact with dichloromethane should be avoided as it can be absorbed through the skin. Eye protection should be worn when handling the solvent. Attention is drawn to the relevant COSHH Regulations [2].

WARNING It is essential that this solvent is stored in a well ventilated room or area.

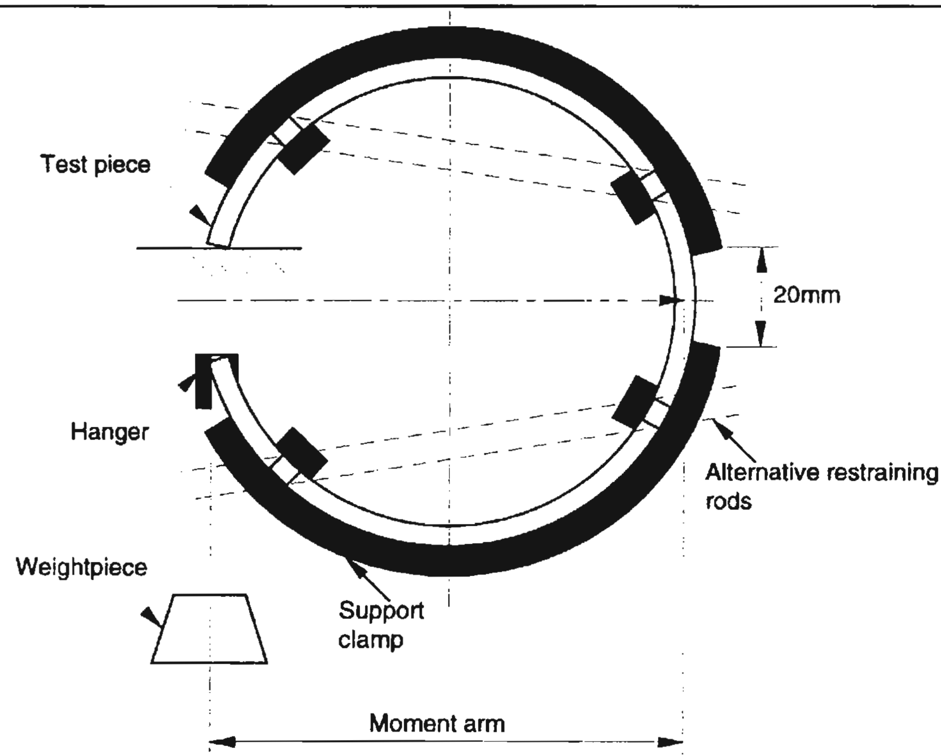


Figure B.1 — Typical arrangement of the test piece and equipment for determination of C-ring toughness

B.3 Apparatus

B.3.1 *Cutting equipment*, by which an external chamfer can be cut on a test piece so that the chamfer extends through at least 90 % of the wall thickness and the chamfer is at least 10 mm wide.

B.3.2 *Container*, covered, of glass or stainless steel, for storage of the dichloromethane.

B.3.3 *Thermal control equipment*, capable of maintaining the temperature of the dichloromethane at (23 ± 2) °C.

B.3.4 *Broach*, with an angle of 45° ± 2°, capable of cutting a notch with a tip radius of not greater than 30 µm and such that the thickness of the remaining ligament does not vary by more than 0.1 mm.

B.3.5 *Frame*, capable of supporting the upper portion of a test piece and weights of approximately 0.5 kg mass and 1 kg mass to apply to the lower section.

B.3.6 *Timing device*, having an accuracy within ±5 s over 2 min.

B.3.7 *Rigid support clamps*, to match the curvature of the test piece, minimize the distortion of the test piece and ensure that the intended bending moment is transmitted to the notch.

B.4 Test pieces

B.4.1 A sample of pipe at least 200 mm in length shall be selected and a reference line drawn along its complete length.

B.4.2 From one end of the sample five rings of width (30 ± 3) mm shall be cut so that the cut surfaces are perpendicular to the longitudinal axis of the pipe.

NOTE The first ring is used to establish the initial weight (mass) for testing the other four rings.

B.4.3 The remaining piece of the pipe shall be cut to provide a test piece with a chamfer at least 10 mm wide and through at least 90 % of the thickness of the pipe wall.

B.5 Conditioning

Condition the test pieces at (23 ± 2) °C for a period not less than the applicable period given in Table B.1.

Table B.1 — Conditioning periods for test pieces

Pipe wall thickness e mm	Minimum conditioning time in water min
$e \leq 8.6$	15
$8.6 < e \leq 14.1$	30
$14.1 < e$	60

B.6 Procedure

B.6.1 Place the chamfered test piece in the dichloromethane at (20 ± 2) °C so that at least the chamfer is fully immersed for (15 ± 1) min.

B.6.2 Remove the test piece from the dichloromethane and allow the solvent to evaporate.

B.6.3 Inspect the chamfered surface, and determine and record the degree of attack as conforming to one of the following descriptions:

a) no attack;

b) uniform attack over the whole chamfer;

c) non-uniform attack.

B.6.4 In the case of non-uniform attack, select the area of most severe attack and note the position in relation to the reference line.

B.6.5 Select the first of the five rings (see **B.4.2**). Using the broach, cut a notch in the inside wall at the position of minimum wall thickness. The notch shall traverse the full width of the test piece to a depth of 25 % of the wall thickness ± 0.1 mm.

B.6.6 Cut a (20 ± 2) mm section from the notched ring diametrically opposite the notch, to obtain an initial notched test piece.

B.6.7 Apply the support clamps (**B.3.7**) to the notched test piece and mount the assembly on a test frame (**B.3.5**). Load the assembly with a mass of between 1 kg and 2 kg. Carefully add additional masses in increments of about 1 kg at a rate to cause failure by breaking approximately 2 min after application of the first load. Note the total mass W_1 added at failure.

B.6.8 Select the first of the remaining four rings and cut a notch in the inside wall, as described in **B.6.5** but at the position coinciding with the area of greatest attack by dichloromethane on the chamfered sample: if there was either no attack or uniform attack by dichloromethane (see **B.6.3**), cut the notch at the point of maximum wall thickness.

B.6.9 Notch the three remaining rings at positions 90°, 180° and 270° offset respectively relative to the position of the notch in the second ring as in **B.6.5**. Cut a (20 ± 2) mm section out of each ring diametrically opposite the notch.

B.6.10 Attach the support clamps and apply a test mass of $(W_1 - 3)$ kg to the first of the four notched test pieces. At 5 min intervals add an additional 0.5 kg until failure occurs. Similarly test the remaining three notched test pieces.

B.6.11 Examine each of the fracture surfaces and record the type of failure observed as ductile (**3.2**) or brittle, as applicable.

B.7 Test report

The test report shall include the following information:

a) the name of the manufacturer together with the place of manufacture of the pipe tested;

b) a reference to the method of test, i.e. PAS 27:1999, annex B;

c) the size and pressure rating of the pipe;

d) the type of failure, i.e. ductile or brittle;

e) the date of test.

Annex C (normative) Determination of long-term toughness

C.1 Principle

Notched C-ring test pieces are subjected to loads such that rupture of the ligament occurs at various time intervals. The log of the net section stress is regressed against the log of the time to fail. The mean stress and lower 97.5 % confidence limit at 50 years are calculated.

C.2 Reagents

C.2.1 *Dichloromethane,* conforming to annex B.

WARNING Direct contact with dichloromethane should be avoided as it can be absorbed through the skin. Eye protection should be worn when handling the solvent.

WARNING It is essential that this solvent is stored in a well ventilated room or area.

C.3 Apparatus

C.3.1 *Equipment conforming to annex B,* except that the C-rings can be subjected to fixed, rather than increasing, loads.

C.4 Test pieces

C.4.1 A sample of pipe comprising a full section at least 750 mm in length shall be selected and a reference line drawn along its complete length.

C.4.2 The pipe section shall be cut from one end into at least 18 ring specimens each of width (30 ± 3) mm so that the cut surfaces are perpendicular to the longitudinal axis of the pipe.

C.4.3 The remaining piece of the pipe shall be cut with a chamfer at least 10 mm wide and through at least 90 % of the thickness of the pipe wall.

C.5 Conditioning

Condition as described in annex B the specimens obtained in accordance with **C.4.2** and the chamfered test piece obtained in accordance with **C.4.3**.

C.6 Procedure

C.6.1 *Immersion in dichloromethane*

C.6.1.1 Place the chamfered test piece in the dichloromethane at (20 ± 2) °C so that at least the chamfer is fully immersed for (15 ± 1) min.

C.6.1.2 Remove the chamfered test piece from the dichloromethane and allow the solvent to evaporate.

C.6.1.3 Inspect the chamfered surface, and determine and record the degree of attack as conforming to one of the following descriptions:

a) no attack;

b) uniform attack over the whole chamfer;

c) non-uniform attack.

C.6.1.4 In the case of non-uniform attack, select the area of most severe attack and note the position in relation to the reference line (**C.4.1**).

C.6.2 *Determination of yield stress*

C.6.2.1 For a pipe showing uniform attack or no attack by dichloromethane when tested in accordance with **C.6.1**, for each of the ring specimens measure and record the wall thickness to the nearest 0.1 mm at the reference line. For a pipe showing variable attack, measure the wall thickness on each ring test piece at the position corresponding to the greatest attack.

C.6.2.2 Measure and record the mean outside diameter, D_m, of each ring specimen to the nearest 0.1 mm.

C.6.2.3 Measure and record the width, w, of each ring at the same position as that at which its thickness was determined in accordance with **C.6.2.1**.

C.6.2.4 Using the broach, cut a notch in the inside wall of each ring specimen at the position where the thickness was measured. The notch shall traverse the full width of the specimen to a depth of 25 % of the wall thickness ± 0.1 mm.

C.6.2.5 Cut a (20 ± 2) mm section from each ring specimen diametrically opposite the notch to produce one test piece, comprising a notched C-ring.

C.6.2.6 Weigh each test piece and a corresponding lower clamp (see **B.3.7** and **Figure B.1**) to the nearest 2 g.

C.6.2.7 For each test piece, fix the corresponding clamps so that the ends of its clamps are within (10 ± 2) mm of the position of the notch and of the cut ends of the C-section.

C.6.2.8 Apply sustained loads to the test pieces so that a distribution of failure times is achieved in accordance with ISO/TR 9080.

C.6.2.9 Inspect all of the failure surfaces for, and note any evidence of, brittle fracture.

C.6.3 *Calculations*

C.6.3.1 Calculate the net section stress σ_n for each test piece using the following equation

$$\sigma_n = \frac{4g(m_1 + 0.5m_2)(D_m - e + a)}{we^2\left(1 - \frac{a}{e}\right)^2} \qquad (C.1)$$

where

- m_1 is the mass in kilograms (kg) applied to generate the sustained load;
- m_2 is the mass of the lower support ring plus half the mass of the test piece in kilograms (kg);
- g is the gravitational constant, to be taken as 9.807 m/s^2;
- D_m is the mean outside diameter of the ring specimen from which the test piece was obtained in millimetres (mm);
- e is the relevant wall thickness of the test piece (see **6.2.1**) in millimetres (mm).
- a is the depth of the notch in millimetres (mm);
- w is the width of the test piece in millimetres (mm).

C.6.3.2 Using the data obtained for σ_n and method II of ISO/TR 9080:1992, fit a straight line to the data regressing log time on log stress with log stress as the independent variable and calculate and record the lower 97.5 % confidence limit at 50 years of the mean long-term net section stress at 50 years.

C.7 Test report

The test report shall include the following information.

a) the name of the manufacturer together with the place and time of manufacture of the pipe tested;

b) a reference to this method of test, i.e. PAS 27:1999, annex C;

c) the nominal size and nominal pressure rating of the pipe;

d) the lower 97.5 % confidence limit for the net section stress at 50 years;

e) the type of failure, i.e. ductile (**3.2**) or brittle;

f) the dates between which the tests were conducted.

Annex D (normative)
Determination of the resistance to diurnal pressure fluctuations

D.1 Principle

D.1.1 *Method A*

Pipe sections are subjected to a fluctuating internal pressure regime until failure occurs. The total time at maximum pressure is required to be greater than the lower 97.5 % confidence limit of the failure time for pipe tested at constant pressure in accordance with **9.1.7**.

D.1.2 *Method B*

Notched C-rings are subjected to a high and low net section stress until failure occurs. The total time at maximum load is required to be greater than the lower 97.5 % confidence limit of the failure time for pipe tested at constant load in accordance with **9.1.8**.

D.2 Apparatus

D.2.1 *Temperature-controlled environment,* capable of maintaining the test pieces at (20 ± 2) °C for the duration of testing in accordance with **D.3.1.2** to **D.3.1.4** inclusive or with **D.3.2.3** and **D.3.2.4**, as applicable.

D.2.2 Method A. *Pressure equipment,* capable of testing pipe samples in accordance with ISO 1167.

D.2.3 Method B. *Equipment for preparing and loading C-rings*, conforming to annex C.

D.3 Procedure

D.3.1 *Method A*

D.3.1.1 Prepare at least six test pieces for pressure testing in accordance with the procedure described in ISO 1167.

D.3.1.2 From the static pressure test data generated in accordance with **9.1.7** select stresses σ_p to be applied such that at least two failure times will occur in each of the following intervals: 1 h to 10 h; 10 h to 100 h and 100 h to 1 000 h.

D.3.1.3 Apply an internal pressure to the pipe specimen such that the hoop stress generated is equal to $0.67\sigma_p$ for (12 ± 0.5) h. Increase the pressure to σ_p for an additional (12 ± 0.5) h and then reduce back to $0.67\sigma_p$.

D.3.1.4 Continue to cycle the pressure as specified in **D.3.1.3** until failure occurs. Record the time to failure as the cumulative time at the higher stress only. Note the failure mode, i.e. brittle or ductile (**3.2**).

D.3.2 *Method B*

D.3.2.1 Prepare at least eight C-rings as described in annex C.

D.3.2.2 From the static C-ring test data generated in accordance with annex C, select net section stresses σ_n to be applied such that at least two failure times will occur in each of the following intervals: 1 h to 10 h, 10 h to 100 h and 100 h to 1 000 h.

D.3.2.3 Apply a load to the C-ring such that the stress is equal to $0.67\sigma_n$ for (12 ± 0.5) h. Increase the stress to σ_n for an additional 12 h and reduce back to $0.67\sigma_n$.

D.3.2.4 Continue to cycle the load until failure occurs. Record the time to failure as the cumulative time at the higher stress only. Note the failure mode, i.e. brittle or ductile (**3.2**).

D.4 Test report

The test report shall include the following information:

a) the name of the manufacturer together with the place and time of manufacture of the pipe tested;

b) the nominal size and nominal pressure rating of the pipe;

c) the test method used, i.e. PAS 27:1999, annex D, method A or method B;

d) the time to failure (only the time at the higher stress level is considered, see **D.3.1.4** or **D.3.2.4**.);

e) the lower 97.5 % confidence limit of the mean extrapolated net section stress at 50 years at the same stress levels in the static pressure or static C-ring tests as appropriate;

f) the type of failure, i.e. ductile or brittle;

g) the dates between which the tests were conducted.

Annex E (normative) Determination of the resistance of notched pipe to internal pressure

E.1 Principle

Pipe samples, having two longitudinal notches cut into the outside wall, are subjected to internal hydraulic pressure until rupture occurs. The test duration is at least as long as for an unnotched pipe of the same wall thickness as the ligament (at the notch).

E.2 Apparatus

E.2.1 *Milling machine,* with a mandrel that supports the pipe sample rigidly and in a straight line. The mandrel shall support the bore of the pipe immediately under the full length of the section to be notched. The "V" cutter shall have an included angle of 60°, be 12.5 mm wide and have a cutting rate of (0.010 ± 0.002) mm per revolution per tooth. The radius of the tip of the cutter shall be not greater than 30 µm. The milling cutter shall be used for no other material and shall be replaced after 100 m of cutting.

NOTE A suitable configuration is a cutter with 20 teeth rotating at 700 r/min and traversing at a speed of 150 mm/min.

E.2.2 *Pressure equipment,* capable of enabling notched pipe samples conforming to **E.3** to be tested in accordance with ISO 1167.

E.2.3 *Temperature-controlled environment,* capable of maintaining the test pieces at (20 ± 2) °C while under pressure in accordance with **E.4.2**.

E.3 Test pieces

E.3.1 Prepare at least six test pieces as follows, each having a length of at least three times the nominal outside diameter for nominal pipe sizes up to 315 and not less than 1 m for larger pipes.

E.3.2 Locate the section of minimum wall thickness. At this position cut a first notch in the outside wall of the pipe by climb milling in a single pass so that the notch is at least 100 mm long and cut to a depth of at least 10 % of the wall thickness of the pipe measured at the position of the notch.

E.3.3 Measure the wall thickness of the pipe at a point diametrically opposite the first notch. Cut a second notch in the outside surface of the pipe at this position so that both notches are located centrally along the pipe.

E.4 Procedure

E.4.1 Select the test pressures so that failure times are equally distributed in the ranges of 1 h to 10 h, 10 h to 100 h and 100 h to 1 000 h.

E.4.2 Pressurize each test piece and maintain under pressure until rupture occurs.

E.4.3 Note the failure mode (ductile (**3.2**) or brittle) at the ligament of each test piece.

E.4.4 Calculate the circumferential stress on each ligament and compare the time to failure with that of unnotched pipe when tested in accordance with **9.1.7**.

E.5 Test report

The test report shall include the following information:

a) the name of the manufacturer together with the place and time of manufacture of the pipe tested;

b) a reference to this method of test, i.e. PAS 27:1999, annex E;

c) the nominal size and nominal pressure rating of the pipe;

d) the failure mode, i.e. ductile or brittle;

e) the circumferential stress on the failed ligament of each test piece and the time to failure together with the lower 97.5 % confidence limit for the mean extrapolated net section strength at 50 years;

f) the dates between which the tests were conducted.

Annex F (normative) Determination of net section stresses by three-point bending

F.1 Principle

Flattened sections of pipe are notched across one face and subjected to three-point bending in such a way that the notch is in tension. The load at crack initiation and the maximum load are recorded. The gross section stresses are calculated at initiation and at maximum load. The net section stresses at initiation and maximum load are determined graphically and compared with the uniaxial yield stress at the same failure times.

F.2 Apparatus

F.2.1 *Press*, capable of producing flattened samples from sections of pipe heated to 120 °C.

F.2.2 *Broach*, having an angle of 45° ± 2°, able to cut a notch with a top radius of not greater than 30 µm, such that the thickness of the remaining ligament does not vary by more than 0.1 mm.

F.2.3 *Three point bending test jig to accommodate the test pieces*, such that the span-to-thickness ratio is at least 16.

F.2.4 *Compression or universal testing machine*, conforming to the requirements of grade A of ISO 5893:1993.

F.2.5 *Temperature-controlled environment*, capable of maintaining the test pieces at the test temperature (see **9.1.12**) ± 2 °C for the duration of testing in accordance with **F.4.1** and **F.4.4**.

F.3 Test pieces

F.3.1 Select a sample of the thickest-wall pipes manufactured.

F.3.2 Slit each sample longitudinally and heat to (120 ± 2) °C, followed by flattening and cooling in a press.

F.3.3 From each of the flattened samples machine 15 rectangular test pieces each 30 mm wide and long enough for the span-to-thickness ratio for the test pieces to be greater than 16.

F.3.4 Condition the flattened samples at (23 ± 2) °C for at least 1 h in water or 24 h in air.

F.3.5 Machine a notch of constant depth across the centre of each test piece so that the notch depths for the 15 test pieces range from $0.05e_B$ to $0.08e_B$ in increments of $0.05e_B$, where e_B is the thickness of the test piece overall, i.e. notch depth plus ligament thickness.

F.3.6 Measure each notch depth to the nearest 0.01 mm.

F.4 Procedure

F.4.1 If necessary, recondition the test pieces to the test temperature (see **9.1.12**) ± 2 °C.

Place each test piece into the three-point test jig in turn and, using the compression or universal tester (**F.2.4**), apply a load at a constant rate of deflection of 10 mm/min from a recorded starting time until failure occurs, while monitoring the response of the test piece as follows.

During the application of the load, observe the crack tip. Note the time to achieve crack initiation and the force F_i occurring at this time. Also note the time from commencement of the test until the peak force F_p is recorded. When testing test pieces with very shallow notches, if the ratio of the deflection to the span of the supports becomes greater than 0.05, disregard the test result (because the bending theory has become invalid).

F.4.2 Examine each test piece and record the mode of failure as either ductile (**3.2**) or brittle.

F.4.3 For each test piece, calculate the gross section stresses at initiation σ_i and at peak load σ_p using the following equation.

$$\sigma_1 \text{ (or } \sigma_p) = \frac{3FS}{2w(e_B)^2} \qquad \text{(F.1)}$$

where

F	is the force recorded at crack initiation or peak respectively, i.e. F_i or F_p, in newtons (N);
S	is the span across the three point bend jig, in metres (m);
w	is the width of the test piece, in metres (m);
e_B	is the thickness of the test piece, in metres (m).

F.4.4 If necessary, recondition three test pieces to the test temperature (see **9.1.12**) ± 2 °C.

Determine the value of $\overline{\Delta a}$, the mean crack extension at peak load, by unloading, from peak load, three test pieces with notch depth-to-thickness ratios of 0.1, 0.25 and 0.6. After unloading, section the test pieces and measure the crack extension Δa on each. Calculate and record the mean value $\overline{\Delta a}$ of the three crack extensions.

F.4.5 Plot the gross section stresses, σ_1 and σ_p, against $\left(1 - \frac{a + \overline{\Delta a}}{e_B}\right)^2$

where

a	is the depth of the notch, in millimetres (mm);
e_B	is the thickness of the test piece, in millimetres (mm).

F.4.6 Using the method of least squares[3)], determine the two lines of best fit for each pipe sample. Determine the net section stresses at crack initiation and peak load by calculating the slope of each line.

F.4.7 From the pressure regression data produced in accordance with **9.1.7** determine the yield stresses σ_y of the pipe material at the time intervals measured in accordance with **F.4.1**.

F.5 Test report

The test report shall include the following information:

a) the name of the manufacturer together with the place and time of manufacture of the pipe tested;

b) a reference to this method of test, i.e. PAS 27:1999, annex F;

c) the size and pressure rating of the pipe;

d) the failure mode, i.e. ductile or brittle;

e) the net section stresses at crack initiation σ_i and at peak load σ_p (see **F.4.6**);

---

3) Details of the method of least squares can be found in many fundamental text books on statistics, e.g. *Applied Regression Analysis* [3].

f) the yield stresses σ_y of the material at loading times commensurate with the time for crack initiation and to reach peak load (see **F.4.7**);

g) the date of test.

NOTE. The report does not require the graphs to be included as it is the calculated slopes of the lines that form part of the pass/fail criteria, not the graphs.

Annex G (normative)
Test method for resistance to negative pressure

G.1 Apparatus

The apparatus shall be generally in accordance with that shown in Figure G.1 and shall be capable of permitting the application of a constant load to distort the diameter of the pipe and of the application of a negative pneumatic pressure inside the test specimen. A means shall be provided of flooding with water the annular space between the pipe and the socket mouth.

The distorting load shall be applied to a rocker on the top of a beam which is free to move in the vertical plane through the axis of the pipe. The effective beam length shall be equal to the nominal diameter of the pipe under test. The pipe assembly under test shall be placed so that the face of the socket housing the joint under test is 10 mm from the end of the load-bearing beam.

G.2 Procedure

Carefully dry the interior of the test specimen before assembly.

Apply the distorting load to the pipe so as to cause a 10 % reduction of the original outside diameter measured at the end of the beam remote from the face of the socket under test.

Reduce the air pressure in the assembly to (0.25 ± 0.03) bar below ambient pressure and adjust the distorting load to maintain the 10 % reduction in the original diameter.

Maintain these conditions for 1 h $^{+5}_{0}$ min during which time the annular space between the pipe and socket mouth shall be kept filled with water.

At the end of this period remove the assembly from the apparatus, dry the exterior and then examine the interior of the pipe for evidence of and record any water infiltration.

G.3 Test report

The test report shall include the following information:

a) the name of the manufacturer together with the place and time of manufacture of the pipes tested;

b) a reference to this method of test, i.e. PAS 27:1999, annex G;

c) the result of the test, i.e. whether or not any water infiltration was detected;

d) the date of test.

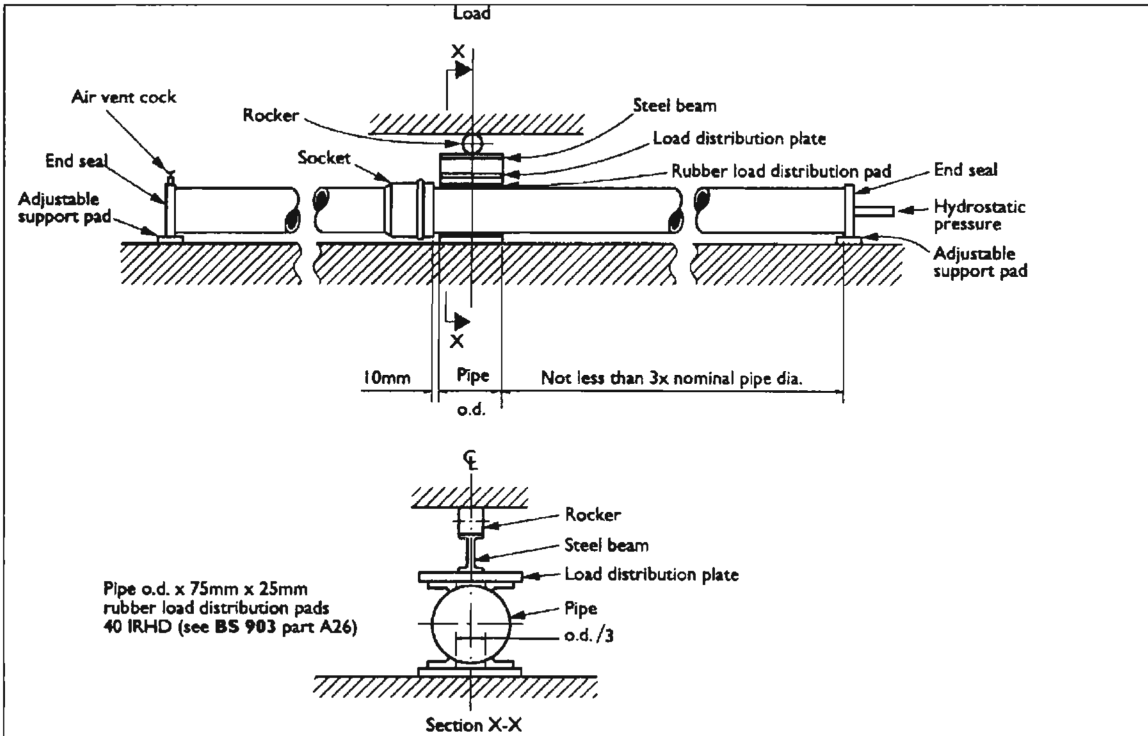


Figure G.1 — Typical arrangement of the pipe assembly and equipment for testing for resistance to negative pressure

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