No. 4-31-06
January 1990: Issue 1
WSA/FWR Sewers and Water Mains Committee: Materials and Standards **(Sheet 1 of 7)**
ISSN 0267-0305

Water Industry Specification

Water Industry Specifications and IGNs are also issued by:
UK Water Fittings Byelaws Scheme ISSN 0267-0313
Process Systems Committee ISSN 0956-5132

SPECIFICATION FOR BLUE UNPLASTICISED PVC PRESSURE PIPES, INTEGRAL JOINTS AND POST-FORMED BENDS FOR COLD POTABLE WATER (UNDERGROUND USE)

FOREWORD

This specification has been prepared by the Water Research Centre (WRc) under the direction of the Sewers and Water Mains Committee in consultation with the Water Industry and the British Plastics Federation and introduces metrication for harmonisation with the single European Market.

Where possible the requirements of ISO/DIS 4422, the draft International Standard for pipes and fittings in PVC-U for water supply, has been followed. However, this specification includes the fracture toughness test, first introduced in February 1986 and now incorporated in BS 3505. In line with current practice, the colour of the pipe shall be blue, for identification purposes, but fittings may be blue or grey.

The size range for pipes has been rationalised to 11 sizes from nominal size 63 to 630 in each of two pressure classes: 8 and 12.5 bar. Manufacturers have also generated data to support a change to a single stress rating of 12.5 MPa in line with ISO/DIS 4422 throughout the proposed range of diameters and pressure classes and the stress rating has been accordingly raised to this value.

The method of determining the stress rating in this document is that specified in Appendix A of BS 3505: 1986. Attention is, however, drawn to ISO/DTR 9080.2, in course of preparation, which, if approved, will replace this procedure.

Attention is also drawn to the uPVC Pipe Manual, which gives guidance on the use and installation of PVC-U pressure pipelines, and WIS No. 4-31-07 which is the specification for PVC-U injection-moulded pressure fittings and assemblies of pipes and fittings for cold potable water (underground use).

Purchasers are reminded that this specification requires that the manufacturers shall operate a quality system relating to the manufacture of pipe, integral joints and post-formed bends 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 NACCB or equivalent accredited third party certification should be addressed to an appropriate third party certification body or to WRc.

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

This specification does not purport to include all the necessary provisions of a contract. Users of this specification are responsible for its correct application.

Reference to a British Standard, Water Industry Specification or any other specification applies equally to any equivalent specification.

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

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

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

CONTENTS

FWR
FOUNDATION
for water research

Further copies from FWR, PO Box 16, Henley Road, Medmenham, Marlow, Bucks., SL7 2HD. Tel: (0491) 571531 Fax: (0491) 579094 Telex: 848632

Technical enquiries to WRc, PO Box 85, Frankland Road, Blagrove, Swindon, Wilts., SN5 8YR. Tel: (0793) 511711 Fax: (0793) 511712 Telex: 449541

WRc

1. SCOPE

This specification specifies the properties required of pipes, integral joints incorporating elastomeric sealing rings and bends post-formed from pipe made from unplasticised polyvinyl chloride (PVC-U) for use for the conveyance of cold potable water below ground. The requirements include quality assurance, material, geometric characteristics, quality control and type tests including effect on water quality, and marking.

NOTE The titles of the publications referred to in this document are listed under clause 9 - REFERENCES.

2. FIELD OF APPLICATION

This specification applies to pipes, integral joints and post-formed bends made of PVC-U, in nominal sizes 63 to 630 for maximum working pressures of 8 and 12.5 bar. These products shall be pigmented blue to identify their use for potable water pipelines below ground.

NOTE The working pressures (PN) given above are the calculated maximum working pressures for the conveyance of cold water at a temperature of 20°C. For use at higher temperatures or under conditions of pulsating pressures, reference should be made to the uPVC Manual: Pressure Applications.

3. QUALITY ASSURANCE

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

4. MATERIAL

4.1 Composition

The material from which pipes and integral joints are made shall consist of polyvinyl chloride, together with only those additives that are needed for the manufacture and performance of pipe, integral joints and post-formed bends to this specification.

4.2 Pigmentation

The colour of pipes and integral joints shall be blue within the range 20 E53 to 20 E56 of BS 4901.

4.3 Rework Material

If rework material is used, it shall be clean and in accordance with 4.1 and 4.2 derived from pipe produced in accordance with this specification. It shall be reground under the supervision of and used by the same manufacturer in the production of pipe sizes up to and including nominal size 160. No rework material shall be included in pipe of nominal sizes greater than 160.

4.4 Elastomeric Sealing Rings

Elastomeric sealing rings shall conform to Type W of BS 2494: 1986.

5. GEOMETRIC CHARACTERISTICS

5.1 Dimensions of pipes, integral joints and post-formed bends

5.1.1 Outside diameters and wall thicknesses

The outside diameters and wall thicknesses of pipes shall comply with Table 1. The wall thicknesses of integral sockets shall not be less than the minimum values for wall thicknesses specified in Table 1. The outside diameters of pipes have been selected from ISO 161/1 and their wall thicknesses from ISO 4065. Tolerances on outside diameters and wall thickness have been determined in accordance with ISO 3606*.

* Under revision

Table 1 - Outside diameters and wall thicknesses of pipes - mm

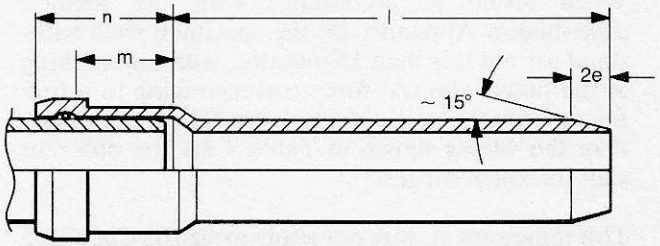
Nominal size	Outside diameters (d_e)		Wall thicknesses (e)			
			PN-8 bar (S* = 16)		PN-12.5 bar (S* = 10)	
	min	max	min	max	min	max
63	63.0	63.3	-	-	3.0	3.6
90	90.0	90.3	2.8	3.3	4.3	5.0
110	110.0	110.4	3.4	4.0	5.3	6.1
160	160.0	160.5	4.9	5.6	7.7	8.7
200	200.0	200.6	6.2	7.1	9.6	10.8
250	250.0	250.8	7.7	8.7	11.9	13.3
315	315.0	316.0	9.7	10.9	15.0	16.7
400	400.0	401.0	12.3	13.8	19.1	21.3
450	450.0	451.0	13.8	15.4	21.5	23.9
500	500.0	501.0	15.3	17.1	23.9	26.5
630	630.0	631.0	19.3	21.5	30.0	33.2

$*S = \frac{\sigma}{0.1 \times P}$ in accordance with ISO 4065

where σ = is the induced stress in MPa
P = pressure in bar

Table 2 - Minimum available engagement depth and minimum socket depth

Nominal size	Minimum available engagement depth (mm)	Miminum socket depth (mm)
63	65	130
90	71	147
110	75	160
160	86	187
200	94	212
250	106	239
315	118	256
400	130	285
450	138	302
500	145	318
630	165	364



Where e = minimum thickness of pipe (mm) (see Table 1)
l = effective pipe length (m)
m = minimum available engagement depth (mm)
n = minimum socket depth (mm)

Figure 1 – Effective length and depth of engagement

5.1.2 The measurement of dimensions shall be in accordance with ISO 3126.

5.1.3 Length and tolerance on length of pipe

5.1.3.1 The preferred effective length, l, (see Figure 1) of pipes is 6m. if the length of a pipe is specified, such length shall not be less than that specified.

5.1.3.2 Where pipes have plain ends they shall be cut clean and square. Where a chamfer is required it shall be in accordance with Figure 1.

5.1.3.3 The minimum available engagement depth, m, (see Figure 1) for integral joints incorporating elastomeric sealing rings shall be not less than those given in Table 2 in accordance with ISO 2045. The socket depth, n, (see Figure 1) shall be not less than those given in Table 2.

The inside diameter of the socket, the form of the groove for the elastomeric sealing ring and the form of the elastomeric sealing ring shall be such that the requirements of 6.2 and 7.2 are met.

5.1.4 Post-formed bends

5.1.4.1 Post-formed bends shall be made from pipe conforming to this specification, i.e. WIS No. 4-31-06, although the maximum thickness may be exceeded.

5.1.4.2 The minimum and maximum thickness of the bend shall conform to the values specified in Table 1. The centre line radius shall not be less than 3 x outside diameter of the pipe. The leg length shall not be less than the minimum depth of insertion given in Table 2.

5.1.4.3 The tolerance on the nominal bend angle (in the same plane) shall not be greater than ±5°.

6. TYPE TEST REQUIREMENTS

6.1 Pipes

6.1.1 Long term hydrostatic pressure test at 20°C

When tested in accordance with Appendix A, using the end caps illustrated in ISO 1167:1973 Figure 1(b) or Figure 1(c), the value of the mean stress data at 50 years shall not be less than 26.0 MPa and that of the 97.5% lower confidence of the stress at 100 000 hours shall not be less than 23.0 MPa.

6.1.2 1 000 Hour pressure test at 60°C

When tested in accordance with Appendix B, at a temperature of 60(+2-1)°C, pipe samples shall withstand an internal pressure equivalent to a hoop stress of 12.5 MPa for 1 000 hours.

6.2 Integral Joints

6.2.1 10 000 hour pressure test at 20°C

When tested in accordance with Appendix B, at a temperature of 20(+2-1)°C, the assembly shall withstand an internal pressure equivalent to a hoop stress of 30.0 MPa, determined on the pipe which fits into the integral joint, for 10 000 hours.

6.2.2 Negative pressure requirements for elastomeric sealing ring type joints

When tested by the method described in Appendix C, the joint whilst deformed shall withstand a pressure of 25 ±3kN/m^2 (0.25 ±0.03 bar) below atmospheric pressure for 1 hour without leakage.

6.3 Effect on water quality

6.3.1 Pipes, joints and sealing rings

When used under the conditions for which they are designated, non-metallic products in contact with or likely to come into contact with potable water shall comply with the requirements of BS 6920 : Part 1 : 1988.

NOTE 1 Non-metallic products for installation and use in the United Kingdom which are verified and listed under the UK Water Fittings Byelaws Scheme are deemed to satisfy the requirements of this clause. Details of the Scheme are obtainable from the Water Research Centre Byelaws Advisory Service, 660 Ajax Avenue, Slough SL1 4BG.

Non-metallic products approved by the Department of Environment Committee on Chemicals and Materials of Construction for use in Public Water Supply and Swimming Pools are considered free from adverse health effects for the purposes of compliance with this clause.

NOTE 2 A list of approved chemicals and materials and details of the approvals scheme is available from the Secretary of the Committee at the Department of the Environment, Water Division, Romney House, 43 Marsham Street, London SW1P 3PY.

7. QUALITY CONTROL REQUIREMENTS

7.1 Pipes

7.1.1 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.

7.1.2 1 hour pressure test at 20°C

When tested in accordance with Appendix B, at a temperature of 20(+2−1)°C, the specimen shall withstand a pressure equivalent to a hoop stress of 42.0 MPa for 1 hour.

7.1.3 External impact resistance at 20°C

When tested in accordance with Section 1 of ISO 3127: 1977 at a temperature of 20(+2−1)°C, the TIR of the batch of pipe tested shall not exceed 10% when tested under the conditions specified in Section 2: Table 3 of ISO 3127.

7.1.4 Longitudinal reversion

When tested in accordance with ISO 2505, the pipe shall not change in length by more than 5%.

7.1.5 Fracture toughness test (Resistance to slow crack growth)

When tested in accordance with the method described in Appendix D, the specimen shall withstand for not less than 15 minutes, without breaking at the notch, the test force corresponding to a true fracture toughness K_{IC} (see clause D3.5), of not less than the values shown in Table 7 for the different wall thickness ranges.

This requirement does not apply to size 63 Class 12.5 nor sizes 90 and 110 Class 8.

7.2 Integral Joints

7.2.1 1 hour pressure test at 20°C

When tested in accordance with Appendix B at a temperature of 20(+2−1)°C, the assembly shall withstand an internal pressure equivalent to a hoop stress of 42.0 MPa, determined on the pipe which fits into the integral joint, for 1 hour.

7.2.2 Forming faults

No voids or cracks shall be found by sectioning the integral socket both longitudinally and across its major axes, i.e. at the point where the degree of expansion from the original pipe diameter is greatest.

Alternatively testing by X-ray or ultrasonic methods may be used by agreement between the purchaser and the manufacturer.

8. MARKING

8.1 Pipes

All pipes shall be indelibly and legibly marked in white* at intervals not greater than 1 metre along two strips on opposite sides of the pipe. It shall show the following information:

(a) reference to this Water Industry Specification, i.e. WIS No. 4-31-06; (The use of this mark is a claim by the manufacturer that the product has been manufactured in accordance with the requirements of this specification and the claim is his sole responsibility).
(b) manufacturer's name or trade mark;
(c) nominal outside diameter;
(d) pipe material - PVC-U;
(e) nominal pressure (8 or 12.5 bar);
(f) identification of the shift, production line and date of manufacture.
Coding of this information is permitted providing that the meaning of the code is available to purchasers or their representatives on request. This information need only be marked on one side;
(g) a third party certification scheme mark (if permissible).

* This is for clarity only and is at variance with BS 5556.

9. REFERENCES

International Standards:

ISO 161/1	Thermoplastics pipes for the transport of fluids - nominal outside diameters and nominal pressures Part I: Metric series.
ISO 1167	Plastics pipes for the transport of fluids - determination of the resistance to internal pressure.
ISO 2045	Single sockets for unplasticised polyvinyl chloride (PVC) pressure pipes with elastomeric sealing rings type joints. Minimum depth of engagement.
ISO 2505	Unplasticised polyvinyl chloride (PVC) pipes - Longitudinal reversion - Test method and specification.
ISO 3126	Plastics pipes - Measurement of dimensions.
ISO 3127	Unplasticised polyvinyl chloride (PVC) pipes for the transport of fluids. Determination and specification of resistance to external blows.
ISO 3606	Unplasticised polyvinyl chloride (PVC) pipes. Tolerances on outside diameters and wall thickness.
ISO 4065	Thermoplastics pipes - Universal wall thickness table.
ISO/DIS 4422	Pipes and fittings in unplasticised polyvinyl chloride (PVC-U) for water supply - Specification.
ISO/DTR 9080.2	Thermoplastics pipes. Extrapolation method.

British Standards:

BS 903	Methods of testing vulcanised rubber Part A26 Determination of hardness
BS 1994	Specification for dichloromethane (methylene chloride)
BS 2494	Specification for elastomeric joint rings for pipework and pipelines.
BS 3505	Specification for unplasticised polyvinyl chloride (PVC-U) pressure pipes for cold potable water.
BS 4901	Specification for plastic colours for building purposes.
BS 5556	Specification for general requirements for dimensions and pressure ratings for pipe of thermoplastics materials (metric series)
BS 5750	Quality systems Part 2 (EN 29002) Specification for manufacture and installation.

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

Water Industry Specification:

No 4-31-07 Specification for unplasticised PVC pressure fittings and assemblies for cold potable water (underground use).

WAA/WRc uPVC Manual: Pressure Applications.

European Standard

EN 29002 Quality Systems - Model for quality assurance in production and installation

APPENDIX A

METHOD FOR THE DETERMINATION OF THE LONG TERM HYDROSTATIC PRESSURE RESISTANCE OF PIPE AT 20°C

A.1 Test pieces

Test pieces shall be as described in Appendix B.

A.2 Procedure

Using equipment and procedures in accordance with ISO 1167 obtain at least 18 test results for the calculation of the log time versus log stress regression line. The recommended failure point distribution is given in Table 3. A failure point (or unfailed sample on test) at >10 000 hours is mandatory.

A straight line shall be fitted to the data using the method of least squares regressing log time on log stress as the independent variable.

A.3 Method of calculation

A.3.1 Linear regression with one independent variable

The following symbols are used:

n = number of observations

f_i = log of stress in MPa of observation i; i=1,.....,n;

h_i = log of time in hours of observation i; i=1,.....,n;

$\bar{f}$ = arithmetic mean of all f_i values = $\frac{1}{n}\Sigma^n_{i=1}f_i$ (1)

$\bar{h}$ = arithmetic mean of all h_i values = $\frac{1}{n}\Sigma^n_{i=1}h_i$ (2)

The regression equation of log time (h) on log stress (f) is:

$h = a + bf$ ...(3)

A.3.2 Calculate the following three quantities

$S_{ff} = \Sigma^n_{i=1}f^2_i - n(\bar{f})^2$ ...(4)

$S_{hh} = \Sigma^n_{i=1}h_i^2 - n(\bar{h})^2$ ...(5)

$S_{fh} = \Sigma^n_{i=1}f_ih_i - n\bar{f}\bar{h}$ ...(6)

A.3.3 Calculate b and a from:

$b = \frac{S_{fh}}{S_{ff}}$ ...(7)

$a = \bar{h} - b\bar{f}$ ...(8)

The slope of the regression line b shall be negative otherwise the data are unsuitable.

Table 3 - Failure point distribution

Failure time range (hours)	Suggested minimum points per range	Recommended data point distribution
> 10 ≤ 50	2	4
> 50 ≤ 2 500	3	5
> 2 500 ≤ 6 500	3	4
> 6 500 ≤10 000	2	4
>10 000	1	1
TOTAL	11 + 7 others	18

A.3.4 Calculate the mean stress for a time of 50 years for a mean stress value of 26 MPa from Equation 3

A.3.5 Calculate the lower 97.5% confidence limit as follows:

(a) Determine the residual variance about the regression line, s_r^2, from the following:

$$s_r^2 = \frac{1}{n-2}\left[S_{hh} - \frac{S_{fh}^2}{S_{ff}} \right] \quad ...(9)$$

(b) Calculate the lower 97.5% confidence limit for one future observation at a given stress of: 23.0 MPa from Equation 10.

$$h_o = a + bf_o - t_\nu s_r\left[1 + \frac{1}{n} + \frac{(f_o - f)^2}{S_{ff}} \right]^{1/2} \quad ...(10)$$

Table 4 - Value of Student's "t" distribution – upper 2½% points

ν	t_ν	ν	t_ν	ν	t_ν
1	12.7062	46	2.0129	91	1.9864
2	4.3027	47	2.0117	92	1.9861
3	3.1824	48	2.0106	93	1.9858
4	2.7764	49	2.0096	94	1.9855
5	2.5706	50	2.0086	95	1.9853
6	2.4469	51	2.0076	96	1.9850
7	2.3646	52	2.0066	97	1.9847
8	2.3060	53	2.0057	98	1.9845
9	2.2622	54	2.0049	99	1.9842
10	2.2281	55	2.0040	100	1.9840
11	2.2010	56	2.0032	102	1.9835
12	2.1788	57	2.0025	104	1.9830
13	2.1604	58	2.0017	106	1.9826
14	2.1448	59	2.0010	108	1.9822
15	2.1315	60	2.0003	110	1.9818
16	2.1199	61	1.9996	112	1.9814
17	2.1098	62	1.9990	114	1.9810
18	2.1009	63	1.9983	116	1.9806
19	2.0930	64	1.9977	118	1.9803
20	2.0860	65	1.9971	120	1.9799
21	2.0796	66	1.9966	122	1.9796
22	2.0739	67	1.9960	124	1.9793
23	2.0687	68	1.9955	126	1.9790
24	2.0639	69	1.9949	128	1.9787
25	2.0595	70	1.9944	130	1.9784
26	2.0555	71	1.9939	132	1.9781
27	2.0518	72	1.9935	134	1.9778
28	2.0484	73	1.9930	136	1.9776
29	2.0452	74	1.9925	138	1.9773
30	2.0423	75	1.9921	140	1.9771
31	2.0395	76	1.9917	142	1.9768
32	2.0369	77	1.9913	144	1.9766
33	2.0345	78	1.9908	146	1.9763
34	2.0322	79	1.9905	148	1.9761
35	2.0301	80	1.9901	150	1.9759
36	2.0281	81	1.9897	200	1.9719
37	2.0262	82	1.9893	300	1.9679
38	2.0244	83	1.9890	400	1.9659
39	2.0227	84	1.9886	500	1.9647
40	2.0211	85	1.9883	600	1.9639
41	2.0195	86	1.9879	700	1.9634
42	2.0181	87	1.9876	800	1.9629
43	2.0167	88	1.9873	900	1.9626
44	2.0154	89	1.9870	1000	1.9623
45	2.0141	90	1.9867	INF	1.9600

Where:

t_ν is Student's t for $\nu = n - 2$ degrees of freedom, as given in Table 4 which gives the upper 2½% points.

h_o is the estimated log (time).

f_o is log (stress) in this case log 23.0.

A.4 Report

The report shall include the following:

(a) The identification of the test pieces,
(b) The mean stress for a time of 50 years for the relevant design stress category,
(c) The lower 97.5% confidence limit at the stress for the relevant design stress category,
(d) The period of the test.

APPENDIX B

METHOD FOR PRESSURE TESTING OF PIPES AND INTEGRAL JOINTS

B.1 Test pieces

Up to nominal size 315 the test piece shall be a pipe of minimum free length between end fittings of 250mm or 3 × nominal size, whichever is the greater. For nominal sizes above 315 the minimum free length shall be 1000mm. The test piece shall be closed with pressure tight caps or plugs as illustrated in Figures 1(b) or 1(c) of ISO 1167: 1973. The type of end caps used shall be reported.

To allow the hydrostatic tests to be carried out upon joints incorporating elastomeric sealing components, it may be necessary to replace the sealing component by a harder or differently shaped seal or to prevent it from blowing out by using a retaining device. If a retaining device is used, it shall not reinforce or restrict the expansion of the body of the joint.

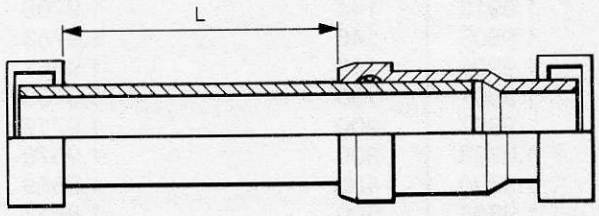


Figure 2 – Illustration of the free pipe length on pipe and assembly

B.2 Test procedure

The test procedure shall be as specified in ISO 1167 at the specified temperature and pressure. The time to failure shall be recorded. If the specimen under test has not failed within the specified time, the test may be discontinued and the test recorded as a "Pass".

B.3 Report

The report shall include the following:

(a) full identification of the test specimen;
(b) the type of end fittings used;
(c) the test temperature with degree of accuracy;
(d) the circumferential stress and test pressure with degree of accuracy;
(e) the number of specimens tested;
(f) the test results, and the time to failure (if failure occurs before the specified period of time has elapsed) or the time after which the test was discontinued.

APPENDIX C

NEGATIVE PRESSURE TEST

C.1 Apparatus

The apparatus shall be generally in accordance with that shown in Figure 3 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 10mm from the end of the loadbearing beam.

C.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 pipe to 25 $\pm 3 kN/m^2$ below ambient pressure and adjust the distorting load to maintain the 10% reduction in the original diameter. Maintain these conditions for 1 hour, 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 water leakage.

APPENDIX D

METHOD FOR THE DETERMINATION OF FRACTURE TOUGHNESS

D.1 Principle

On the basis of the prior response of a test piece of pipe to immersion in dichloromethane, a selected portion of a ring section of a pipe test piece is notched on its internal face and subjected in the form of a "C" profile cantilever to a sustained flexural stress for a specified period.

D.2 Response to immersion in dichloromethane

D2.1 Apparatus

D2.1.1 Equipment capable of cutting an external chamfer on the test specimen such that the chamfer penetrates at least 90% of the wall thickness of the test specimen with a minimum length of 10mm when it is cut at an angle inclined to the longitudinal pipe axis.

D2.1.2 A covered tank resistant to dichloromethane e.g. glass, stainless steel.

D2.1.3 Equipment to maintain the temperature of the dichloromethane at 20 ±2°C.

D2.1.4 Clean BS 1994 dichloromethane

It is permissible to "clean" the dichloromethane by filtering. This shall be performed at least once per 15 days. If during that period the dichloromethane becomes heavily contaminated additional filtering shall be required. The dichloromethane shall be completely replaced at least every 3 months.

WARNING: Dichloromethane is harmful to the skin and eyes and the vapour should not be inhaled.

D2.2 Test specimen

D2.2.1 The test specimen shall be a pipe of length not less than 200mm.

D2.2.2 A reference line shall be drawn along the complete length of the test specimen and marked with arrows to indicate the extrusion direction in such a manner that the pipe is not scored. An arrow in the same direction shall be marked on the C-ring test sample (D2.2.3).

D2.2.3 A ring of width 30 ±3mm shall be cut from the test specimen in such a manner that the cut surfaces are perpendicular to the longitudinal axis of the pipe. This ring is retained for fracture toughness testing by the method described in D.3.

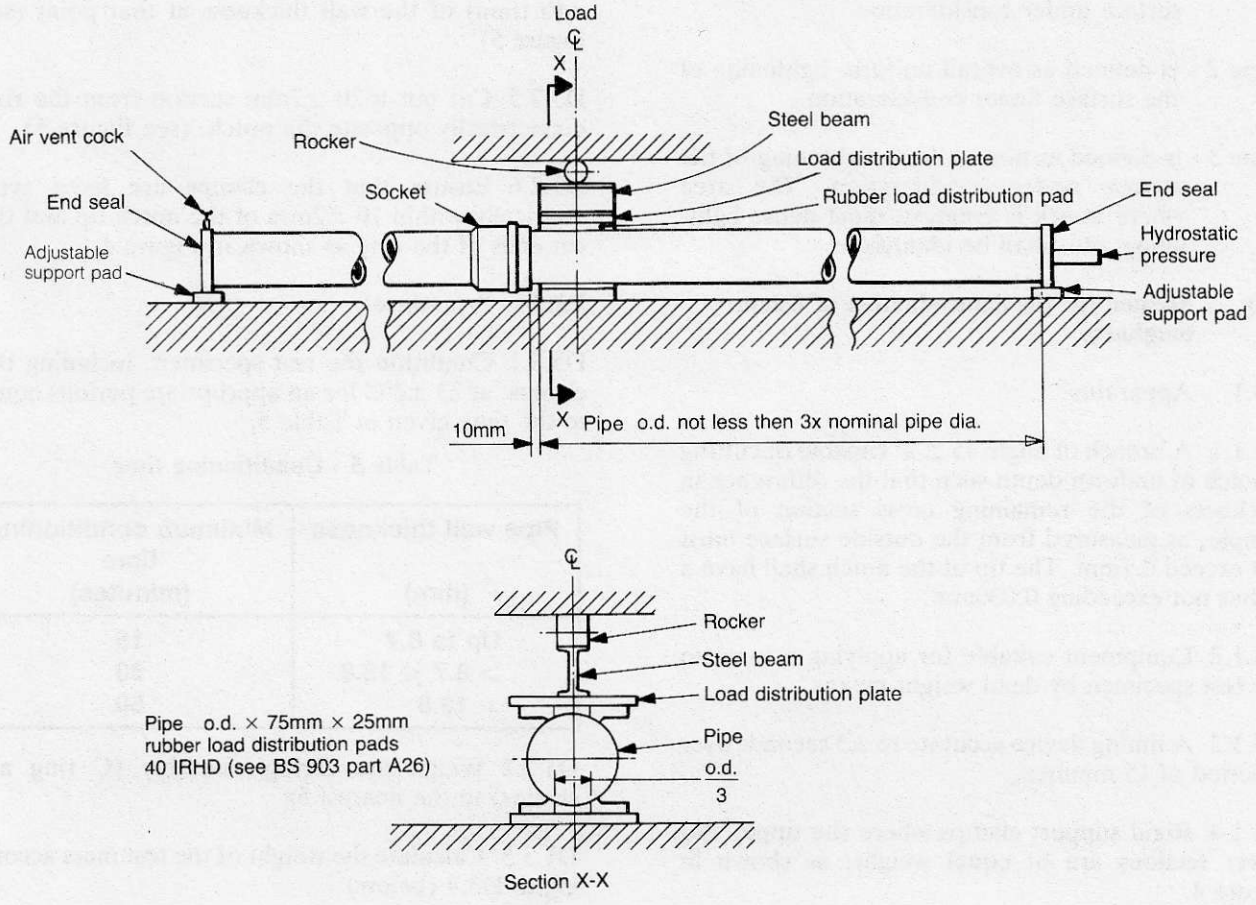


Figure 3 – Apparatus for negative pressure test

D2.2.4 A chamfer shall be cut on the remaining ring, which is the test specimen for the dichloromethane test, using the apparatus described in D2.1.1.

NOTE Where the tank is not big enough to take a large diameter pipe it is permissible to cut the test specimen longitudinally into sections provided that the resultant sections can be related to the reference line.

D2.3 Procedure

D2.3.1 Place the chamfered end(s) of the test specimen in dichloromethane, such that the chamfer is completely submerged, at the test temperature, for a minimum period of 15 minutes.

D2.3.2 Remove the test specimen to a well ventilated area e.g.. a fume cupboard, until the dichloromethane has evaporated from its surface.

D2.3.3 Inspect the chamfered surface and record the "type of attack" in relation to the reference line, after carrying out an assessment as described in D2.4.

D2.4 Assessment of results

For the purposes of the dichloromethane test the "attack" is defined by the lightening of the chamfered surfaces. There are three types of "attack" as follows:

Type 1 - is defined as no apparent lightening of the surface under consideration.

Type 2 - is defined as overall uniform lightening of the surface under consideration.

Type 3 - is defined as non-uniform lightening of the surface under consideration. The area where attack is greatest, most dense lightening, etc. shall be identified.

D.3 Method for the determination of fracture toughness

D3.1 Apparatus

D3.1.1 A broach of angle 45 ± 2° capable of cutting a notch of uniform depth such that the difference in thickness of the remaining cross section of the sample, as measured from the outside surface must not exceed 0.1mm. The tip of the notch shall have a radius not exceeding 0.030mm.

D3.1.2 Equipment suitable for applying a force to the test specimen by dead weight means.

D3.1.3 A timing device accurate to ±5 seconds over a period of 15 minutes.

D3.1.4 Rigid support clamps where the upper and lower sections are of equal weight, as shown in Figure 4.

D3.1.5 A balance capable of weighing to an accuracy of ±5g.

NOTE Clamps are used to ensure that a controlled bending moment is transmitted to the notched section and this has been accounted for in the method of calculation.

D3.2 Test Specimen

D3.2.1 The test specimen shall be the 30mm pipe ring prepared as described in the dichloromethane test.

D3.2.2 Measure the external diameter of the test specimen to the nearest 0.05mm.

D3.2.3 For test specimens having Type 1 and Type 2 attack of the chamfered surface as assessed in the dichloromethane test (D.2) measure the wall thickness to the nearest 0.05mm and the width of the test specimen to the nearest 0.1mm at the reference line.

For test specimens having Type 3 attack of the chamfered surface measure the wall thickness to the nearest 0.05mm and the width of the test specimen to the nearest 0.1mm at the area corresponding to that of greatest attack using the reference line as data.

D3.2.4 Cut the notch, in the bore of the test specimen, at the point at which the wall thickness was measured. The notch should be cut across the complete width of the test specimen to a depth of 25% ±(0.1mm) of the wall thickness at that point (see Figure 5).

D3.2.5 Cut out a 20 ±2mm section from the ring diametrically opposite the notch. (see Figure 5).

D3.2.6 Ensure that the clamps are fixed symmetrically within 10 ±2mm of the notch tip and the cut ends of the ring as shown in Figure 4.

D3.3 Procedure

D3.3.1 Condition the test specimen, including the clamps, at 23 ±2°C for an appropriate periods equal to the time given in Table 5.

Table 5 - Conditioning time

Pipe wall thickness (mm)	Minimum conditioning time (minutes)
Up to 8.7	15
> 8.7 ≤ 13.8	30
> 13.8	60

D3.3.2 Weigh the C-ring assembly (C ring and clamps) to the nearest 5g.

D3.3.3 Calculate the weight of the test mass according to D3.4 (below).

D3.3.4 Support the test specimen on the cut out section opposite the notch and apply the test mass to the test specimen. The force shall be maintained for a period of 15 minutes or until the specimen fails across the notch, whichever is the shorter. Throughout the test the temperature shall be maintained at 23 ±2°C. A typical test arrangement is shown in Figure 4.

D3.3.5 At the conclusion of the test, record a pass/fail result as appropriate.

D3.4 Calculation of test mass

(1) Read off the value of the pipe wall thickness factor (F_e) from Table 6.
(2) Calculate the ring geometry factor F_r using $F_r = W/Dm$. See also Annex 1.

(3) Calculate F_c by dividing the ring assembly weight by 4.

i.e. $F_c = \frac{\text{ring assembly weight}}{4}$

(4) Calculate the test mass as follows:

$$\text{Test mass} = F_r \times F_e - F_c$$

A detailed explanation of the calculation of the factors F_e and F_r is given in Annex 1. Annex 1 may also be used to calculate other values of K_{IC}.

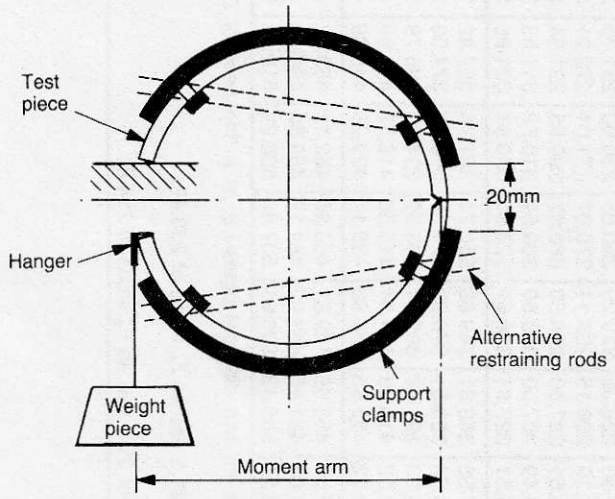


Figure 4 – Typical arrangement of the test pieces and equipment for testing for fracture toughness

ANNEX 1

1.1 For notch-sensitive materials, including unplasticized polyvinyl chloride, failure may be predicted in the presence of a sharp notch using a linear fracture mechanics model. Where the dimensions of the test piece are large by comparison with those of the notch, failure occurs at a fracture toughness given by the equation:

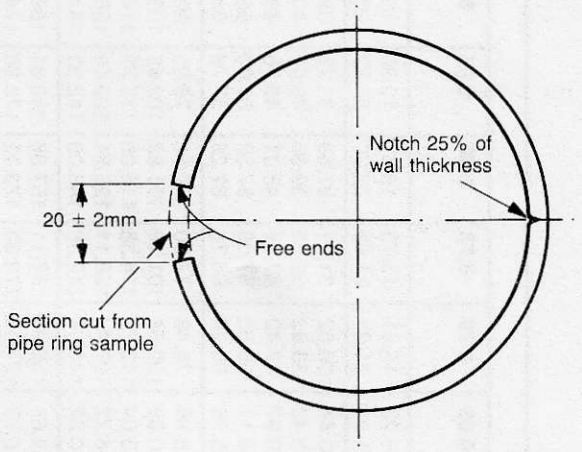


Figure 5 – Fracture toughness test piece

$$K_C = \frac{3YM}{Be_n^{3/2}} \times 10^{-6} \quad (1)$$

where K_C is the fracture toughness (in $MN.m^{-3/2}$)

Y is the geometry correction factor

NOTE $Y = 1.08\sqrt{\pi}$ for (notch depth/e_n) = 0.25

M is the bending moment applied to the test piece (in N.m)

B width (in m) of the test ring at the point where the notch was cut

e_n is the wall thickness (in m) at the notch including the depth of the notch.

For product dimensions in accordance with this standard, a model which compensates for the dimensions of the test piece should be used in conjunction with equation (1) as follows:

$$K_{IC} = \left[-2x^2 \left(\cos \frac{K_C}{x} \right) \right]^{1/2} \quad (2)$$

where K_{IC} is the true fracture toughness (in $MN.m^{-3/2}$);

x is $32.56\sqrt{e_n}$ for notch depth/e_n = 0.25, assuming an ultimate tensile strength of 50 MPa.

1.2 The following equation has been used in calculating Table 6:

$$\text{Test mass} = F_r \times F_e - F_c \quad (3)$$

$$\text{Where } F_r = \frac{W}{Dm} \quad (4)$$

Table 6 - Pipe wall thickness factor F_e

Integer pipe wall thickness (mm)	Decimal pipe wall thickness (mm)																			
	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
4	11.80	12.05	12.31	12.57	12.82	13.09	13.35	13.61	13.88	14.15	14.41	14.69	14.96	15.23	15.51	15.79	16.07	16.35	16.63	16.92
5	17.20	17.49	17.78	18.07	18.36	18.66	18.96	19.25	19.55	19.85	20.16	20.46	20.77	21.07	21.38	21.69	22.00	22.32	22.63	22.95
6	23.26	23.58	23.90	24.23	27.07	27.44	27.81	28.18	28.55	28.93	29.30	29.68	30.06	30.44	30.82	31.21	31.59	31.98	32.37	32.76
7	33.16	33.55	33.95	34.34	34.74	35.14	35.54	35.95	36.35	36.76	37.17	37.58	37.99	38.40	38.82	39.23	39.65	40.07	40.49	40.91
8	41.34	41.76	42.19	42.62	43.05	43.48	43.91	44.34	44.78	45.21	45.65	46.09	46.53	46.97	47.42	47.86	48.31	48.76	49.41	49.66
9	50.11	50.56	51.02	51.47	51.93	52.39	52.85	53.31	53.78	54.24	54.71	55.17	55.64	56.11	56.58	57.06	57.53	58.00	58.48	58.96
10	59.44	59.92	60.40	60.88	61.37	61.85	62.34	62.83	63.32	63.81	64.30	64.79	65.28	65.78	66.28	66.78	67.28	67.78	68.28	68.78
11	69.29	69.79	70.30	70.81	71.32	71.83	72.34	72.85	73.36	73.88	74.40	74.91	75.43	75.95	76.48	77.00	77.52	78.05	90.40	91.02
12	91.65	92.27	92.90	93.53	94.16	94.79	95.42	96.06	96.69	97.33	97.97	98.61	99.25	100.89	100.54	101.18	101.83	102.48	103.13	103.78
13	104.43	105.08	105.74	106.40	107.05	107.71	108.37	109.04	109.70	110.37	111.03	111.70	112.37	113.04	113.71	114.38	115.05	115.73	116.41	117.09
14	117.46	118.45	119.13	119.81	120.50	121.18	121.87	122.56	123.25	123.94	124.63	125.33	126.02	126.72	127.42	128.11	128.81	129.52	130.22	130.92
15	131.63	132.34	133.04	133.75	134.46	135.18	135.89	136.60	137.32	138.04	138.76	139.47	140.19	140.92	141.64	142.36	143.09	143.82	144.54	145.27
16	146.00	146.74	147.47	148.20	148.94	149.67	150.41	151.15	151.89	152.63	153.38	154.12	154.86	155.61	156.36	157.11	157.86	158.61	159.36	160.11
17	160.87	161.63	162.38	163.14	163.90	164.66	165.42	166.19	166.95	167.72	168.48	169.25	170.02	170.79	171.56	172.33	173.11	173.88	174.66	175.43
18	176.21	176.99	177.77	178.55	179.34	180.12	180.91	181.69	182.48	183.27	184.06	184.85	185.64	186.43	187.23	188.02	188.82	189.62	190.42	191.22
19	192.02	192.82	193.62	194.43	195.23	196.04	196.85	197.66	198.47	199.28	200.09	200.90	201.72	202.53	203.35	204.17	204.98	205.80	206.63	207.45
20	208.27	209.09	209.92	210.75	211.57	212.40	213.23	214.06	214.89	215.73	216.56	217.40	218.23	219.07	219.91	220.75	221.59	222.43	223.27	224.12
21	224.96	225.81	226.65	227.50	228.35	229.20	230.05	230.90	231.75	232.61	§	255.75	256.70	257.65	258.60	259.55	260.50	261.45	262.40	263.36
22	264.31	265.27	266.23	267.19	268.15	269.11	270.07	271.04	272.01	272.97	273.94	274.90	275.87	276.84	277.82	278.79	279.76	280.71	281.70	282.69
23	283.67	284.65	285.63	286.61	287.60	288.58	289.57	290.55	291.54	292.53	293.52	294.51	295.50	296.50	297.49	298.49	299.48	300.48	301.48	302.48
24	303.48	304.48	305.49	306.49	307.50	308.50	309.51	310.52	311.53	312.54	313.55	314.57	315.58	316.60	317.61	318.63	319.65	320.67	321.69	322.71
25	323.73	324.76	325.78	326.81	327.84	328.87	329.90	330.93	331.96	332.99	334.02	335.06	336.09	337.13	338.17	339.21	340.25	341.29	342.33	343.38
26	344.42	345.47	346.51	347.56	348.61	349.66	350.71	351.76	352.82	353.87	354.93	355.98	357.04	358.10	359.16	360.22	361.28	362.34	363.40	364.47
27	365.53	366.60	367.67	368.74	369.81	370.89	371.95	373.02	374.09	375.17	376.25	377.32	378.40	379.48	380.56	381.64	382.72	383.81	384.89	385.98
28	387.06	388.15	389.24	390.33	391.42	392.51	393.60	394.69	395.79	396.88	397.98	399.08	400.18	401.27	402.37	403.48	404.58	405.68	406.79	407.89
29	409.00	410.11	411.21	412.32	413.43	414.54	415.66	416.77	417.89	419.00	420.12	421.23	422.35	423.47	424.59	425.71	426.84	427.96	429.08	430.21
30	431.33	432.46	433.59	434.72	435.85	436.98	438.11	439.25	440.38	441.51	442.65	443.79	444.93	446.06	447.20	448.35	449.49	450.63	451.77	452.92
31	454.07	455.21	456.36	457.51	458.66	459.81	460.96	462.11	463.27	464.42	465.58	466.73	467.89	469.05	470.21	471.37	472.53	473.69	474.85	476.02
32	477.18	478.35	479.52	480.68	481.85	483.02	484.19	485.36	486.54	487.71	488.88	490.06	491.24	492.41	493.59	494.77	495.95	497.13	498.31	499.50
33	500.68	501.87	503.05	504.24	505.43	506.61	507.80	508.99	510.18	511.38	512.57	513.76	514.96	516.15	517.35	518.55	519.75	520.95	522.15	523.35

§ There is an overlap in permitted tolerance for two different pipes i.e. at a thickness of 21.5 relating to size 630 class 8 and size 450 class 12.5 (see Table 7).

For size 630 class 8 with a wall thickness of 21.5 use an F_e value of 233.47.

For size 450 class 12.5 with a wall thickness of 21.5 use an F_e value of 254.81.

Table 7 - Fracture toughness values required for specific wall thickness ranges

Wall thickness	K_{IC} ($MNm^{-3/2}$)
4.0 - 6.15	3.25
6.2 - 11.85	3.75
11.9 - 21.5*	4.50
21.5*- 33.95	5.00
* See Table 6.	

$$F_e = \frac{t^2}{29.43\pi}\,\sigma_{pc}\cos^{-1}\left[\exp\left\{-\left(\frac{\pi^2}{0.008}\,\frac{k_{IC}^2}{y^2\sigma_{pc}^2 a}\right)\right\}\right] \quad (5)$$

NOTE The result yielded from

$$\left[\exp\left\{-\left(\frac{\pi^2}{0.008}\,\frac{k_{IC}^2}{y^2\sigma_{pc}^2 a}\right)\right\}\right]$$ is in radians.

$$F_c = \frac{\text{Weight of C-ring assembly}}{4} \quad (6)$$

and W = width of C-ring (mm)
t = pipe wall thickness (mm)
$\sigma_{pc} = 1.891\ \sigma_y\ (1 - a/t)^2$ (MNm^{-2})
σ_y = tensile yield stress (MNm^{-2})
a = crack length: (notch depth) (mm)
k_{IC} = assumed value of fracture toughness at 15 minutes ($MNm^{-3/2}$)
D_m = pipe OD - (t - a) (mm)
y = 1.914 - geometric factor

NOTE To obtain the test mass for different values of K_{IC} insert the appropriate value of K_{IC} in Equation 5 above.

The value of the pipe wall thickness factor, F_e, for different pipe wall thickness is given in Table 6.