UK Water Industry Engineering and Operations Committee:
Materials and Standards

No. 4-31-06
March 1994: Issue 2
(Page 1 of 16)
ISSN 1353-2510

Water Industry Specification

The Materials and Standards Group also issues Information and Guidance Notes (IGNs) ISSN 1353-2529

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 WRc under the direction of the Water Industry Engineering and Operations Committee in consultation with the UK Water Industry and pipe manufacturers.

When Issue 1 of this specification was published, the requirements of ISO/DIS 4422, the draft International Standard for pipes and fittings in PVC-U for water supply, were followed where possible except where specific UK requirements were involved. ISO/DIS 4422 has been under further revision and reformatting and is subject to international comment and voting. Also, the similar draft CEN System Standard 19 has been under development. Part 2 of each of these draft standards is particularly relevant to pipes and, when published, the CEN standard will predominate in Europe. The CEN and ISO drafts are subject to further comment, voting and completion of supporting standards. Whilst certain aspects have been taken into this revision of WIS 4-31-06, full alignment has not been attempted. WIS 4-31-06 retains the fracture toughness test, first introduced in February 1986 and subsequently incorporated in BS 3505. In line with current UK practice, the colour of the pipe shall be blue for identification purposes, but fittings used with this pipe may be blue or grey.

The size range for pipes chosen by the UK Water Industry remains rationalised at 11 sizes from nominal size 63 to 630 in each of two pressure classes, 8 and 12.5 bar. In order to accommodate various countries' requirements a compromise on service (design) coefficients may mean that a modification to the wall thickness of several of the smaller sizes will have to be adopted in due course. The modifications extant at the time of writing are shown in brackets in Table 1. The nominal pressures will be unaffected.

Wall thickness concessions agreed with UK manufacturers for desirable pipe thickening during socket formation have been included in this issue. Other points arising during third party certification have been clarified.

Symbols relating to dimensions have been changed to support International/European conventions where appropriate.

Manufacturers have generated data to support a change to a single stress rating of 12.5 MPa in line with the original ISO/DIS 4422 intentions throughout the proposed range of diameters and pressure classes and this stress used has been used in WIS 4-31-06.

The method of determining the stress rating in this specification has been changed to align with current draft CEN/ISO classifications of plastic pressure pipes. It is based on the determination of the minimum required strength (MRS) for the pipe material and division by an overall service (design) coefficient (C) as required by prEN 32162. In this case the MRS is 25 MPa and C is 2.0. Despite the change in determination of design stress the result is the same. Although this issue of WIS 4-31-06 takes immediate effect, data produced by manufacturers either already certified to Issue 1, or in the process of certification, will not be invalidated. Revised data should be produced as part of an audit process.

Attention is also drawn to the Manual for PVC Pipe Systems for Water Supply which gives guidance on the use and installation of PVC-U pressure pipelines, and WIS 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,

FWR FOUNDATION for water research

Further copies from WRc, PO Box 16, Henley Road, Medmenham, Marlow, Bucks, SL7 2HD. Tel: (0491) 571531 Fax: (0491) 411059

WRc

Technical enquiries to WRc, Frankland Road, Blagrove, Swindon, Wilts. SN5 8YF. Tel: (0793) 511711 Fax: (0793) 511712

integral joints and post-formed bends to this specification in compliance with BS EN ISO 9002 (BS 5750 Part 2) which should ensure 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 has been made to some draft European Standards (e.g. prEN 32162) which are expected to be published shortly. When they are published as European Standards (ENs) they will retain the same number. European national standards bodies will be obliged to withdraw any conflicting standards and publish the ENs unaltered within their own system and chosen language. The example will thus become BS EN 32162, NF EN 32162 (French) etc.

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 the Water Services Association, Foundation for Water Research and WRc plc accept no responsibility for actions taken as a result.

CONTENTS

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 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. The requirements include quality assurance, material, geometric characteristics, quality control and type tests including effect on water quality, and marking.

NOTE 1: 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 FWR/WRc Manual for PVC Pipe Systems for Water Supply.

NOTE 2: The titles of the publications referred to in this document are listed under clause 9 - REFERENCES.

2. DEFINITIONS

For the purposes of this specification the following definitions apply.

Mean outside diameter (d_e): The value of the measurement of the outer circumference of the pipe in any cross section divided by π (=3.142), rounded up to the nearest 0.1mm.

Out of roundess (ovality): The difference between the measured maximum outside diameter and the measured minimum outside diameter in the same cross section of the pipe.

Mean inside diameter of socket (d_i): The mean inside diameter of a socket is the arithmetical mean of the measured diameters perpendicular to each other at the midpoint of the socket length.

ISSN 1353-2570

Table 1 - Outside diameters, out of roundness and wall thicknesses of pipes - mm

Nominal outside diameter (d_n)	Mean outside diameter (d_e)		Out of roundess (max)	Wall thickness (e)			
				PN 8 (bar)		PN 12.5 (bar)	
	min	max		min	max	min	max
63	63.0	63.3	0.8	-	-	3.0[3](3.8)[4]	3.6[3](4.4)[4]
90	90.0	90.3	1.1	2.8[1] (3.5)[2]	3.3[1](4.1)[2]	4.3[3](5.4)[4]	5.0[3](6.2)[4]
110	110.0	110.4	1.4	3.4	4.0	5.3	6.1
160	160.0	160.5	2.0	4.9	5.6	7.7	8.7
200	200.0	200.6	2.4	6.2	7.1	9.6	10.8
250	250.0	250.8	3.0	7.7	8.7	11.9	13.3
315	315.0	316.0	3.8	9.7	10.9	15.0	16.7
400	400.0	401.0	4.8	12.3	13.8	19.1	21.3
450	450.0	451.0	5.4	13.8	15.4	21.5	23.9
500	500.0	501.0	6.0	15.3	17.1	23.9	26.5
630	630.0	631.0	7.6	19.3	21.5	30.0	33.2

NOTES:
(1) S16, SDR 33 (current) (2) S 12.5, SDR 26 (3) S10, SDR 21 (current) (4) S8, SDR 17
$S = \frac{\sigma}{0.1 \times PN}$ in accordance with ISO 4065 where σ = is the induced stress in MPa
PN = pressure in bar
SDR = 2S+1

Nominal (outside or inside) diameter (d_n): The specified diameter, in millimetres, assigned to a nominal pipe size. The nominal inside diameter of a socket equates to the nominal outside diameter of the connecting pipes.

Lower confidence limit (LCL): A quantity, with the unit of stress in megapascals, which can be considered as a property of the material under consideration, representing the 97.5% lower confidence limit of the predicted long-term hydrostatic strength at 20°C for 50 years in water.

Minimum required strength (MRS): Rounded down value of LCL (as defined in prEN 32162).

3. QUALITY ASSURANCE

Manufacturers shall operate a quality system relating to this specification in compliance with BS EN ISO 9002 (BS 5750: Part 2).

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 Reprocessable material

If reprocessable material is used in addition to virgin material, it shall be clean and in accordance with 4.1 and 4.2. It shall be derived from the manufacturers own unused pipe produced in accordance with this (or equivalent) specification and generated under his supervision. No reprocessable material shall be included in pipe having wall thicknesses greater than 11.85 mm.

4.4 MRS-value

The pipe material shall have a minimum required strength (MRS) at least equal to 25.0 MPa.

The pipe material shall be evaluated according to ISO TR 9080 following pressure tests performed in

accordance with prEN 921 (or ISO/DIS/1167.3) to find the LCL. This LCL shall be classified according to prEN 32162 to give the MRS-value.

4.5 Elastomeric sealing rings

Elastomeric sealing rings shall conform to Type W of BS 2494: 1990.

NOTE: It is likely that BS 2494 will be withdrawn when EN 681-1 is published. Users should then be careful to specify the optional biodeterioration test.

5. GEOMETRIC CHARACTERISTICS

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

5.1.1 Outside diameters, out of roundness and wall thicknesses

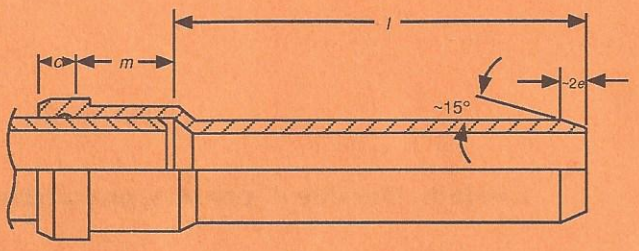
5.1.1.1 Pipes

The outside diameters and out of roundness of pipes shall comply with Table 1. Where pipe is thickened by a controlled process, expressly for the purpose of producing complying sockets, a portion of the pipe spigot (following on from the socket and remaining after cutting), and/or the portion preceding the socket shoulder, may exceed the normal maximum wall thickness. The wall thicknesses and lengths of pipe over which this concession may operate shall not exceed the values given in Table 2.

Table 2 - Wall thickness concessions following socket formation

Nominal outside diameter	Wall thickness (mm)		Concession length (mm)
	PN 8 (bar) process maximum	PN 12.5 (bar) process maximum	
90	5.0	6.6	55
110	6.1	8.1	59
160	8.7	11.3	68
200	10.8	13.8	75
250	13.3	16.8	84
315	16.7	21.3	95

NOTE: The outside diameters of pipes were 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/DIS 11922-1.



Where e = minimum thickness of pipe (mm) (see Table 1)
l = effective pipe length (m)
m = minimum available engagement depth (mm)
c = length of socket entrance and sealing area (mm)

Figure 1 - Effective length and depth of engagement

5.1.1.2 Integral sockets

The wall thicknesses of integral sockets shall be not less than the minimum wall thickness of the corresponding pipes specified in Table 1. The inside diameter and minimum engagement depth, m, (see Figure 1) for integral joints incorporating elastomeric sealing rings shall be not less than those given in Table 3. The internal diameter ovality of integral joints incorporating elastomeric sealing rings shall not exceed the values given in Table 3.

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 6.3, and 7.2 are met.

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 be not 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.

5.1.4 Post-formed bends

5.1.4.1 Post-formed bends shall be made from pipe conforming to this specification, i.e. WIS 4-31-06, although the maximum thickness may be exceeded.

ISSN 1353-2510

Table 3 - Dimensions of integral sockets with elastomeric sealing rings

Dimensions in mm

Nominal inside diameter of socket d_n	Minimum socket inside diameter d_i min(1)	Out-of-roundness (max)	Depth of engagement		Minimum length of socket entrance and sealing area c(3)
			Minimum (CEN value)(2) m	UK traditional value m_t	
63	63.4	0.4	58	65	32
90	90.4	0.6	61	71	36
110	110.5	0.7	64	75	40
160	160.6	1.0	71	86	48
200	200.7	1.2	75	94	54
250	250.9	1.5	81	106	62
315	316.1	1.9	88	118	72
400	401.3	2.4	92	130	86
450	451.5	2.7	95	138	94
510	501.6	3.0	97	145	102
630	632.0	3.8	105	165	123

(1) d_i min. (measured in the middle of the cylindrical length of engagement) is calculated using the applicable equation as follows:
d_i min. = d_n + 0.4 mm, when $d_n < 110$
d_i min. = 1.003 d_n + 0.1 mm when $d_n \geq 110$

(2) m is calculated from the applicable equation as follows:
m min. = 50 + 0.22 d_n - 2e (S10), when $d_n < 280$
m min. = 70 + 0.15 d_n - 2e (S10), when $d_n > 280$
All figures shall be rounded up to the next 1.0 mm
(complies with draft CEN requirements)

(3) c is calculated using the following equation:
$c = 22 + 0.16\, d_n$
It is given for guidance only in calculating minimum spigot lengths. Manufacturers shall state the c-values in their literature.

5.1.4.2 The minimum thickness of the bend shall conform to the values specified in Table 1. The centre line radius shall be not less than 3 x outside diameter of the pipe. The leg length (straight spigot section) shall be not less than the sum of the values of m_t and c given for the applicable diameter in Table 3.

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 General requirements

Type tests shall be performed on pipes which comply with all other requirements of this specification. If there is a change in process or technique, or a new or modified material is introduced, then it will be

necessary to ensure that the conditions of this specification are still satisfied. (For third party certificated products, the significance of changes and any additional tests required shall be agreed with the certification body.)

To ensure that, initially, a representative cross-section of the manufacturer's product range is evaluated, a minimum of the smallest pipe and the largest size manufactured from within each size range (see Table 4) shall be evaluated and shall meet the requirements of 6.2 and 6.3. Sampling to meet the requirements of 6.4 shall be in accordance with clause 2.1 of BS 6920: 1990.

Following satisfactory completion of initial type tests, for ongoing confirmation purposes, at least one test piece shall be tested on rotation from each of the size and nominal pressure combinations within the limits of the manufacturer's product range, and shall meet the 2500 h requirements of 6.2.1 and also the requirements of 6.2.2. All size/pressure combinations for 6.2.2 shall be completed in a 2 year period.

When a manufacturer extends his product range, the pipe with the thickest nominal wall shall be selected for testing and shall meet the requirements of 6.2, 6.3 and 6.5.

Table 4 - Size ranges for tests

Range No.	Nominal pipe size
1	63 - 315
2	400 - 630

6.2 Pipes

6.2.1 Long term hydrostatic pressure test at 20°C

When tested in accordance with the method described in Appendix A, the failure times of the 3 test pieces for each of the sizes tested (see 6.1) shall equal or be greater than the failure times relevant to the stresses at 2500, 5000, and 10000 hours determined from the data generated by the application of 4.4.

Manufacturers can claim provisional acceptance with the requirements of this clause by successfully completing the 2500 hour and 5000 hour pressure tests providing that test pieces expected to achieve 10000 hours are also in progress.

6.2.2 1,000 hour pressure test at 60°C

When tested in accordance with Appendix A, at a temperature of $60(^{+2}_{-1})$°C, five pipe samples shall withstand an internal pressure equivalent to a hoop stress of 12.5 MPa for 1000 hours.

6.3 Integral joints

6.3.1 10,000 hour pressure test at 20°C

When tested in accordance with Appendix A, 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 10000 hours.

6.3.2 Negative pressure requirements for elastomeric sealing ring type joints

When tested by the method described in Appendix B, the joint, whilst deformed, shall withstand a pressure of 25 ±3kN/m² (0.25 ±0.03 bar) below atmospheric pressure for 1 hour without leakage.

NOTE: When CEN/ISO PVC-U pipe standards are published it is the intention to adopt the combination positive/negative pressure and bending test therein.

6.4 Effect on water quality of pipes joints and sealing rings

When used under the conditions for which they are designed, all materials in contact with, or likely to come into contact with, water for public supply shall be introduced in accordance with the requirements of Regulation 25 of the Water Supply (Water Quality) Regulations 1989 [Water Supply (Water Quality) (Scotland) Regulations 1990 in Scotland].

For products not approved under the former voluntary system, and not eligible for use under regulation 25(1)(b) or 25(1)(c), Secretary of State Approval shall be obtained via submission of the product to the "Department of the Environment Committee on Chemicals and Materials of Construction for Use in Public Water Supply and Swimming Pools" for consideration. Products shall comply with the requirements of BS 6920: Part 1: 1990; evidence of compliance shall be submitted to the above committee by the manufacturer.

NOTE 1: A list of approved substances and products is published annually and is available from the Technical Secretary of Committee at the

Drinking Water Inspectorate, Room B 153, 43 Marsham Street, London SW1 3PY.

NOTE 2: Regulation 25 applies only to products used by water companies in the treatment and distribution of public water supplies; it does not apply to use of fixtures and fittings on consumers' own premises. All such fixtures and fittings should satisfy the requirements of BS 6920. Approval under the Water Byelaws Scheme and listing in the Water Fittings and Materials Directory is desirable.

6.5 Vinyl chloride monomer (VCM) content

When determined by means of gas-phase chromatography using the "headspace" method according to ISO 6401 samples of PVC-U pipe wall shall not contain more than 1 ppm VCM. This test shall be performed at least annually on samples of pipe taken from each extruder used.

7. QUALITY CONTROL REQUIREMENTS

7.1 Pipes

7.1.1 Appearance

When viewed without magnification the internal and external surfaces of pipes shall be smooth, clean and free from scoring, cavities, and other surface defects which may affect pipe performance. The material shall not contain visible impurities. The colour shall be as expected from the applied material grade.

NOTE: It is advisable for the ends of the pipes to be delivered plugged or covered to maintain their condition and exclude contamination. This should be agreed between the purchaser and manufacturer.

7.1.2 1 hour pressure test at 20°C

When tested in accordance with Appendix A, 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.

NOTE: When CEN/ISO PVC-U pipe standards are published it is the intention to adopt the impact test method specified therein.

7.1.4 Longitudinal reversion

When tested in accordance with prEN 743, 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 C, 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} of not less than the values shown in Table 5 for the different wall thickness ranges.

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

Table 5 - Fracture toughness values required for specific wall thickness ranges

Wall thickness (mm)	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	

* Under revision

7.2 Integral joints

7.2.1 1 hour pressure test at 20°C

When tested in accordance with Appendix A 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 joints, 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, by agreement, testing by discriminatory X-ray or ultrasonic methods may be used.

NOTE. For third party certificated products agreement should be with the certification body, otherwise, with the purchaser.

8. MARKING

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 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

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

European Standards:

pr EN 681-1	Elastomeric seals - materials requirements for pipe joint seals used in water and drainage applications. Part 1: vulcanised rubber.
pr EN 743	Plastic piping and ducting systems - thermoplastic pipes - determination of longitudinal reversion.
prEN 921	Plastics piping systems - thermoplastics pipes - Determination of resistances to internal pressure at constant temperatures.
prEN 32162	Thermoplastics materials for pipes and fittings for pressure applications - classification and designation - overall service (design) coefficient.
System standard 19	Plastic piping systems for water supply - unplasticised poly (vinyl chloride) (PVC-U).

International Standards:

ISO 161/1	Thermoplastics pipes for the transport of fluids - nominal outside diameters and nominal pressures. Part I: Metric series.
ISO/DIS 1167.3	Thermoplastic pipes for the transport of fluids - Resistance to internal pressure - test method.
ISO 2045	Single sockets for unplasticised polyvinyl chloride (PVC) pressure pipes with elastomeric sealing ring type joints. Minimum depth of engagement
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 4065	Thermoplastics pipes - Universal wall thickness table.
ISO/DIS 4422	System standard for water supply - Unplasticised polyvinyl chloride (PVC-U).
ISO 6401	Plastics - Homopolymer and copolymer resins of vinyl chloride - Determination of residual vinyl chloride monomer - Gas chromatograph method.
ISO/TR 9080	Plastics pipes for the transport of fluid - Standard extrapolation method for the long-term resistance to constant internal pressure.
ISO/DIS 11922-1	Thermoplastics pipes for the transport of fluids - Dimensions and tolerances.

British Standards:

BS 903	Methods of testing vulcanised rubber. Part A26 Determination of hardness.
BS 1994	Specification for dichloro-ethane (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
BS EN ISO 9002	Specification for production, installation and servicing (to be published to replace BS 5750: Part 2).

Water Industry Specification:

4-31-07	Specification for unplasticised PVC pressure fittings and assemblies for cold potable water (underground use).
FWR/WRc	Manual for PVC pipe systems for water supply.
HMSO	The Water Supply (Water Quality) Regulations, SI 1989 No. 1147, 1989.

APPENDIX A - METHOD FOR PRESSURE TESTING PIPES AND INTEGRAL JOINTS

A.1 Test pieces

Up to nominal size 315 the test piece shall be a pipe having a free length between end fittings of minimum of 250mm or 3 x nominal size, whichever is the greater. For nominal sizes above 315 the free length shall be a minimum of 1000mm. The test piece shall be closed with pressure tight caps or plugs as illustrated in Figure 1(b) of ISO/DIS 1167.3. The type of end caps used shall be reported.

For hydrostatic tests required to be carried out upon joints incorporating elastomeric sealing components (see Figure 2 which indicates the free length L in that case), 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.

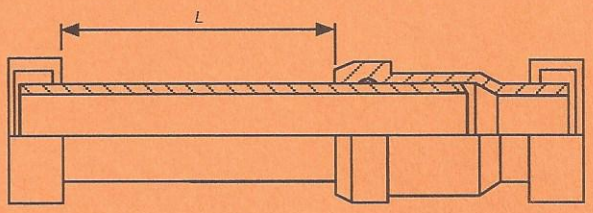


Figure 2 - Illustration of the free pipe length on pipe and assembly

A.2 Test procedure

The test procedure shall be as specified in prEN 921 or ISO/DIS 1167.3 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".

A.3 Report

The report shall include the following:

(a) full identification of the test pieces;

(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;

(g) date of test.

APPENDIX B - NEGATIVE PRESSURE TEST

B.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 force 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 force 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.

B.2 Procedure

Carefully dry the interior of the test piece before assembly. Apply the distorting force 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$3kN/m^2 below ambient pressure and adjust the distorting arc 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.

B.3 Report

The report shall include the following:

(a) full identification of the test pieces;

(b) pipe deflection;

(c) reduced air pressure;

(d) any evidence of water ingress;

(e) date of test.

APPENDIX C - METHOD FOR THE DETERMINATION OF FRACTURE TOUGHNESS

C.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.

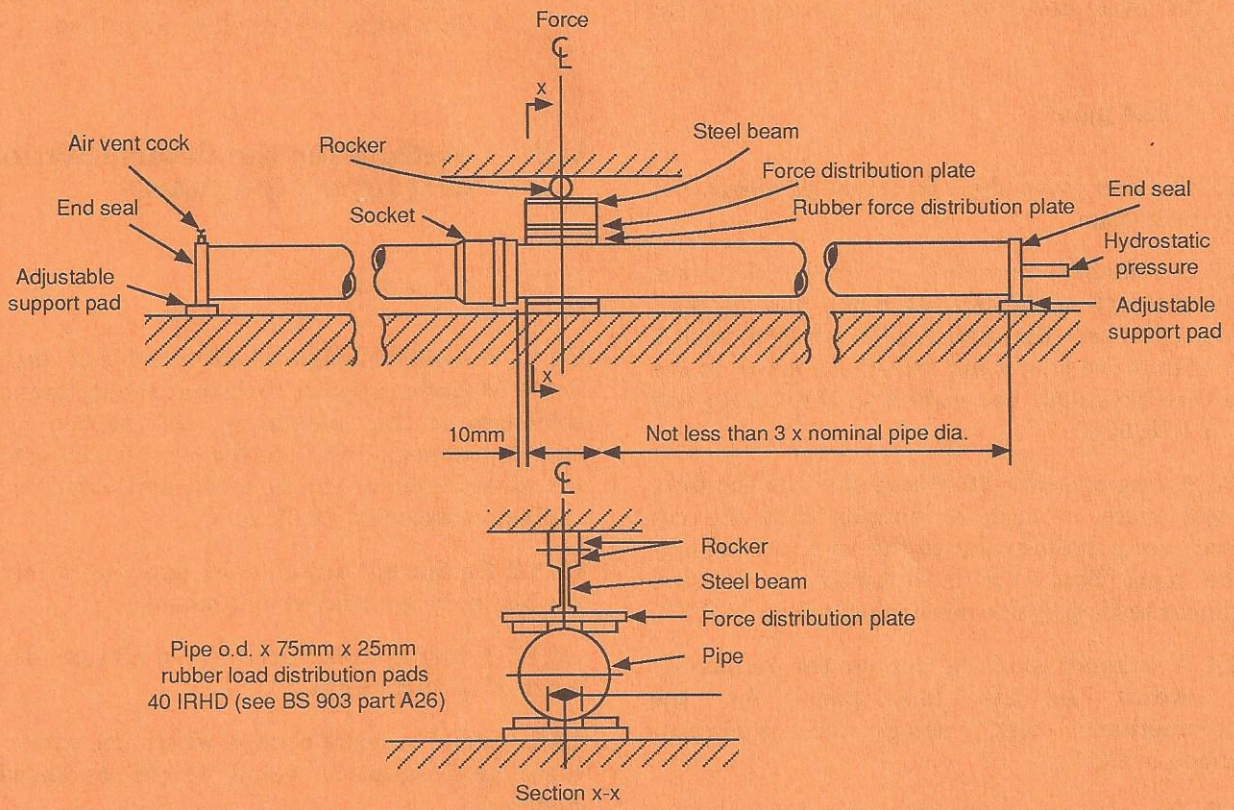


Figure 3 - Apparatus for negative pressure test

C.2 Response to immersion in dichloromethane

C.2.1 Apparatus

C2.1.1 Equipment capable of cutting an external chamfer on the test piece such that the chamfer penetrates at least 90% of the wall thickness of the test piece with a minimum length of 10mm when it is cut at an angle inclined to the longitudinal pipe axis.

C2.1.2 A covered tank resistant to dichloromethane e.g. glass, stainless steel.

C2.1.3 Equipment to maintain the temperature of the dichloromethane at 20 ±2°C.

C2.1.4 Dichloromethane, clean and complying with BS 1994. It shall be in use, for the purposes of this test, for not more than three months without complete replacement.

NOTE. To maintain the cleanliness of the dichloromethane during its 3 months' period of use, it is desirable to filter it at least once every 15 days. If, during that period, the dichloromethane becomes heavily contaminated, additional filtering may be required.

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

C.2.2 Test piece

C2.2.1 The test piece shall be a pipe of length not less than 200mm.

C2.2.2 A reference line shall be drawn along the complete length of the test piece 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 (C2.2.3).

C2.2.3 A ring of width 30 ±3mm shall be cut from the test piece 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 C.3.

C2.2.4 A chamfer shall be cut on the remaining ring, which is the test piece for the dichloromethane test, using the apparatus described in C2.1.1.

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

C.2.3 Procedure

C2.3.1 Place the chamfered end(s) of the test piece(s) in dichloromethane, such that the chamfer is completely submerged, at the test temperature, for a minimum period of 15 minutes.

C2.3.2 Remove the test piece to a well-ventilated area e.g. a fume cupboard, until the dichloromethane has evaporated from its surface.

C2.3.3 Inspect the chamfered surface and record the "type of attack" in relation to the reference line, after carrying out an assessment as described in C2.4.

C.2.4 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 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.

C.3 Method for the determination of fracture toughness

C.3.1 Apparatus

C3.1.1 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 does not exceed 0.1mm. The tip of the notch shall have a radius not exceeding 0.030mm.

C3.1.2 Equipment suitable for applying a force to the test piece by dead weight means.

C3.1.3 A timing device accurate to ±5 seconds over a period of 15 minutes.

C3.1.4 Rigid support clamps where the upper and lower sections are of equal weight, as shown in Figure 4.

C3.1.5 A balance capable of weighing to an accuracy of ±5g.

ISSN 1353-2510

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.

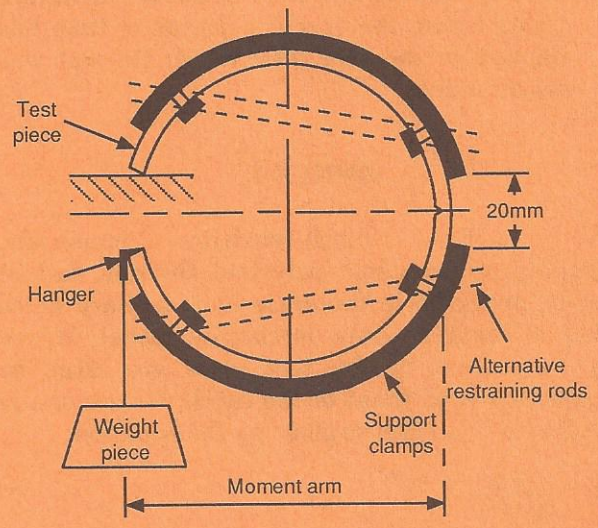


Figure 4 - Typical arrangement of the test pieces and equipment for testing for fracture toughness

C.3.2 Test piece

C3.2.1 The test piece shall be the 30mm pipe ring prepared as described in the dichloromethane test (see C2.2.3).

C3.2.2 Measure the external diameter of the test piece to the nearest 0.05mm.

C3.2.3 For test specimens having Type 1 or Type 2 attack of the chamfered surface as assessed in the dichloromethane test (C.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.

C3.2.4 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).

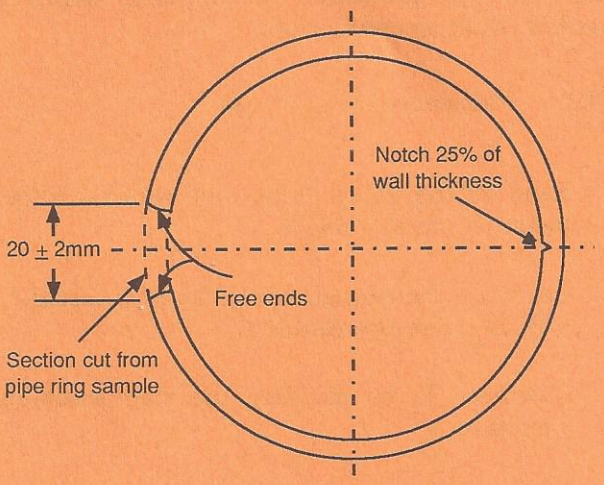


Figure 5 - Fracture toughness test piece

C3.2.5 Cut out a 20 ±2mm section from the ring diametrically opposite the notch (see Figure 5).

C3.2.6 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.

C.3.3 Procedure

C3.3.1 Condition the test specimen, including the clamps, at 23 ±2°C for an appropriate periods equal to the time given in Table C.1.

Table C.1 - Conditioning time

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

C3.3.2 Weigh the C-ring assembly (C ring and clamps) to the nearest 5g.

C3.3.3 Calculate the weight of the test mass according to C.3.4 (below).

C3.3.4 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.

C3.3.5 At the conclusion of the test, record a pass/fail result as appropriate.

C.3.4 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 $F_r = W/D_m$. 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:

   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}.

C.4 Report

The report shall include the following:

(a) full identification of the test pieces.

(b) temperature of dichloromethane and degree of accuracy.

(c) type of dichloromethane attack.

(d) external diameter of test piece.

(e) wall thickness and width of test pieces.

(f) weight of C ring assembly.

(g) target K_{IC} value.

(h) test mass.

(i) test temperature and degree of accuracy.

(j) test results pass or fail.

(k) date of test.

(l) the test results, and time to failure (if failure occurs before the specified period of time has elapsed) or the time after which the test was discontinued.

ANNEX 1

1.1 For notch-sensitive materials, including unplasticised 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:

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

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:

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

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 calculation has been used in calculating Table 6:

Test mass = $F_r \times F_e - F_c$ (3)

ISSN 1353-2510

Where $F_r = \frac{W}{D_m}$ (4)

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

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.

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

and

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

NOTE 1: 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 thicknesses is given in Table 6.

NOTE 2: The units $MNm^{-3/2}$ for fracture toughness have been retained for familiarity. The correct SI unit is now $MPam^{1/2}$. There is no difference in numerical values.

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	25.38	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	69.78	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	95.06	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	107.71	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	121.18	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	135.18	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	173.94	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	272.97	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	292.53	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	405.67	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	439.25	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 5)
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.