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# ORIENTED POLYVINYL CHLORIDE (PVC-O) PRESSURE PIPES FOR UNDERGROUND USE

## FOREWORD

This specification has been prepared by pipe manufacturers under the direction of Water UK Standards Group to define the properties for oriented PVC pressure pipes intended for below ground potable water, grey water, irrigation and sewer pumping mains.

Where applicable, test methods in this specification are based on published or draft International Standards (ISO) (which may differ when published). Where appropriate ISO Standards are not available, British Standards or Water Industry Specifications and test methods are used.

The manufacturing technology used in the production of PVC-O pressure pipes orientates the molecules primarily in the circumferential direction. This orientation enhances the physical properties of the finished PVC-O pipe compared with PVC-U pipes of similar outside diameter and pressure ratings.

The 50 year, 20℃, 97.5% lower confidence limit (LCL) strength of PVC-O pipes shall be as declared by the manufacturer, who shall make data available upon request to customers or their representatives. The LCL strength value is derived from testing pipe not subjected to any axial stresses arising from the applied internal pressure. The LCL strength value depends on the manufacturing process and pipe diameter.

The maximum recommended operating pressure depends on the LCL value, on the factor of safety employed and on the wall thickness of the pipe.

PVC-O pipes are normally supplied in 6m effective lengths complete with integral rubber ring push-fit mechanical joints. Conventional fittings with mechanical joints in PVC-U, PVC-O or coated metals may be used in conjunction with PVC-O pipes.

PVC-O pipes cannot be solvent cement jointed together, nor can they be solvent jointed to other PVC pipes or fittings.

The metric nominal size range included in this specification has been selected to align with BS EN 1452 for blue, metric PVC-U pressure pipes.

All standard flexible pipeline design criteria apply to PVC-O pressure pipes. Where fatigue and surcharge loading is present, IGN 4-37-02 should be consulted. For all other loading conditions, the manufacturer's advice should also be sought.

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 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 provisions is entrusted to appropriately qualified and experienced people.

Information contained in this specification is given in good faith. Neither UK Water Industry Research Ltd, Water UK nor WRc plc can accept any responsibility for actions taken as a result.

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# 1. SCOPE

This document specifies the properties and testing required for PVC-O pipes and integral joints (incorporating elastomeric sealing rings) for buried cold potable water systems, grey water systems, irrigation pipes and sewer pumping mains. This specification relates to blue, grey and black PVC-O pressure pipe in the nominal size range 90 to 630, and for 10, 12.5, 16 and 20 bar pressure classes.

Grey or black PVC-O pipes are for use in sewer pumping main applications and for irrigation pipes. Blue pipes shall be used for buried potable water pipelines only.

# 2. DEFINITIONS

**Molecular oriented pipe (PVC-O) -** A finished pipe, complying with the requirements of this specification, containing preferred molecular orientation.

# 3. MATERIAL

### 3.1 Base material

The material from which PVC-O pipes are made shall consist substantially of polyvinyl chloride resin to which may be added only those additives that are needed to facilitate the manufacture of sound, durable pipes of the correct colour.

### 3.2 Pigmentation

The colour of blue pipes shall be uniform throughout the wall of the pipes within the range 20E53 to 20E56 of BS 5252: 1976.

The colour of grey pipes shall be uniform throughout the wall of the pipe, darker than 00A09 of BS 4800: 1989.

Black pipes shall be uniform in colour throughout the wall of the pipe, and darker than 00A11 of BS4800: 1989.

### 3.3 Reprocessable material

If reprocessable material is used, it shall be clean and only derived from the manufacturers own unused pipe or extrusions. The material shall meet the requirements of 3.1 and 3.2 and the pipe produced from reprocessable material shall meet the requirements of 8.1, 8.2, 8.3 and 8.4.

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# 4. ELASTOMERIC SEALING RINGS

Elastomeric seals shall be in accordance with BS EN 681-1 : 1996 Type WA and the microbiological requirements detailed in the forward to BS 7874 : 1997.

# 5. PIPE STRENGTH, FACTOR OF SAFETY AND NOMINAL PRESSURES

### 5.1 Pipe Strength

The strength of PVC-O pipes, extrapolated to 50 years at 20°C at the 97.5% lower confidence limit (LCL) shall be determined using the procedures defined in Appendix A and declared by the manufacturer. The LCL strength value may vary with pipe diameter and the manufacturing process utilised to induce the molecular orientation. The LCL strength value is for pipe not subjected to any axial stresses arising from the applied internal pressure.

### 5.2 Factor of Safety

The factor of safety, or overall service design coefficient (C), shall be a minimum of 1.6 for PVC-O pipes.

### 5.3 Design Stress

The design stress, $\sigma_{DS}$ , which is used to calculate the required pipe wall thickness for a given pressure rating, shall be calculated from the following equation:

$$\sigma_{DS} = \frac{LCL}{C}$$

where LCL and C are given in 5.1 and 5.2 respectively.

### 5.4 Pressure Classes

PVC-O pipes can have pressure ratings (PN) at 20℃ for 50 years for water, of 10, 12.5, 16 or 20 bar. The required wall thickness for these pressure classes shall be calculated from the design stress, via the manufacturer specified 20℃, 97.5% LCL strength and the required factor of safety.

# 6. GEOMETRIC CHARACTERISTICS

### 6.1 Outside diameter

The outside diameters of PVC-O pipes shall conform to the dimensions and tolerances of Table 1.

**Table 1 - Minimum and maximum mean outside diameters of PVC-O pipes**

| Nominal Diameter | Mean Outside Diameter (mm) | |
|---|---|---|
| | Minimum | Maximum |
| 90 | 90.0 | 90.3 |
| 110 | 110.0 | 110.4 |
| 125 | 125.0 | 125.4 |
| 140 | 140.0 | 140.4 |
| 160 | 160.0 | 160.5 |
| 200 | 200.0 | 200.6 |
| 225 | 225.0 | 225.7 |
| 250 | 250.0 | 250.8 |
| 315 | 315.0 | 316.0 |
| 400 | 400.0 | 401.0 |
| *450* | *450.0* | *451.0* |
| *500* | *500.0* | *501.0* |
| *560* | *560.0* | *561.0* |
| *630* | *630.0* | *631.0* |

Note to Table 1: At the time of writing Issue 2, sizes at and above 450 mm are not available. These larger sizes are included to cover likely developments.

### 6.2. Wall thickness

#### 6.2.1 Minimum Value

The minimum thickness shall be as given in 6.2.2 – 6.2.4 as appropriate and not less than 3.0 mm, regardless of LCL strength value or pipe diameter.

#### 6.2.2 Calculation of minimum pipe wall thickness ($e_{min}$).

The value for $e_{min}$, in mm, for PVC-O pipe shall be calculated using the following equation

$$e_{min} = \frac{PN \times DN}{[(2 \times LCL)/C + PN]}$$

where:

PN is the desired maximum pressure rating of the pipe in MPa

DN is the nominal pipe diameter in mm

LCL is the manufacturer's specified 20°C, 50 year, 97.5% lower confidence limit strength of the pipe in MPa

The factor of safety shall have a minimum value of 1.6, and C is a dimensionless number.

For wall thicknesses calculated using this equation, $e_{min}$ shall be rounded up to the nearest 0.1 mm. For convenience, the wall thicknesses of pipes with a 20°C 50 year, 97.5% LCL strength of 40 and 43 MPa are given below in sections 6.2.3 and 6.2.4 respectively.

**6.2.3 Pipes with a strength of 40MPa**
The minimum wall thicknesses of PVC-O pipes, having a minimum LCL strength of 40MPa (at 20℃ and 50 years), are specified in Table 2.

**6.2.4 Pipes with a strength of 43MPa**
The minimum wall thicknesses of PVC-O pipes, having a minimum LCL strength of 43MPa (at 20℃ and 50 years), are specified in Table 3.

**Table 2 - Minimum wall thicknesses for PVC-O pipes having a 20℃, 50 year LCL strength of 40MPa**

| Nominal Pipe Size | Minimum Wall Thickness (mm) | | |
|---|---|---|---|
| | **12.5** | **16.0** | **20.0** |
| 90 | 3.0 | 3.0 | 3.5 |
| 110 | 3.0 | 3.3 | 4.2 |
| 140 | 3.5 | 4.3 | 5.4 |
| 160 | 3.9 | 4.8 | 6.2 |
| 200 | 4.9 | 6.1 | 7.7 |
| 250 | 6.1 | 7.6 | 9.6 |
| 315 | 7.7 | 9.5 | 12.1 |
| 400 | 9.8 | 12.1 | 15.4 |
| *450* | *11.0* | *13.6* | *17.3* |
| *500* | *12.2* | *15.2* | *19.2* |
| *560* | *13.7* | *17.0* | *21.5* |
| *630* | *15.4* | *19.1* | *24.2* |

Note to Table 2: See note to Table 1

**Table 3 - Minimum wall thicknesses for PVC-O pipes having a 20℃, 50 year LCL strength of 43 MPa**

| Nominal Pipe Size | Minimum Wall Thickness (mm) | | |
|---|---|---|---|
| | **12.5** | **16.0** | **20.0** |
| 90 | 3.0 | 3.0 | 3.3 |
| 110 | 3.0 | 3.2 | 4.0 |
| 140 | 3.2 | 4.1 | 5.1 |
| 160 | 3.7 | 4.7 | 5.8 |
| 200 | 4.6 | 5.8 | 7.2 |
| 250 | 5.7 | 7.3 | 9.0 |
| 315 | 7.2 | 9.2 | 11.3 |
| 400 | 9.1 | 11.6 | 14.4 |
| *450* | *10.3* | *13.0* | *16.2* |
| *500* | *11.4* | *14.5* | *18.0* |
| *560* | *12.8* | *16.2* | *20.1* |
| *630* | *14.4* | *18.2* | *22.6* |

Note to Table 3: See note to Table 1

**6.3 Effective Lengths**
The standard effective length *L* (see Figure 1) of PVC-O pipes is 6m. If an alternative length of pipe is required, such length shall not be less than that specified at (23 ± 2)℃.

PVC-O pipes are provided with the spigot end chamfered. The dimensions of the chamfer are in accordance with Figure 1.

**6.4 Integral Joints**
The minimum depth of engagement (see Figure 1) for integrally formed sockets with elastomeric sealing rings shall be as given in Table 4.

**Table 4 - Minimum depth of engagement (metric sizes)**

| Nominal pipe size (mm) | Minimum depth 'm' (mm) |
|---|---|
| 90 | 65 |
| 110 | 70 |
| 140 | 70 |
| 160 | 75 |
| 200 | 80 |
| 250 | 85 |
| 315 | 95 |
| 400 | 100 |
| Note to Table 4: Sizes at and above 450 mm to be advised by the manufacturer. | |

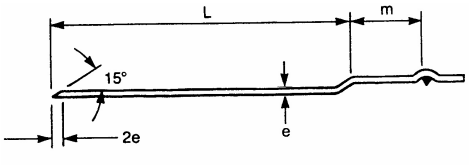


**Figure 1 - Effective length and depth of engagement (m)**

# 7. TYPE TEST REQUIREMENTS

### 7.1 Effect of materials on water quality

For use in public water supply in the UK the requirements given in both 7.1.1 and 7.1.2 shall be complied with.

#### 7.1.1 Basic requirements

When used under the conditions for which they are designed, 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: 2000.

**Note** Non-metallic products for installation and use in the United Kingdom which are verified and listed under the UK Water Regulations Advisory Scheme (WRAS) are deemed to satisfy the requirements of this clause. Details of the scheme are obtainable from the Water Regulations Advisory Service.

#### 7.1.2 DETR requirement

Non-metallic products approved by the Department of Environment, Transport and the Regions (DETR) shall meet the requirements of Regulation 25 (1) (a) of the Water Supply (Water Quality) Regulations 1989.

**Note** A list of approved chemicals and materials and details of the approvals scheme are available form the secretary of the above Committee at the Department of the Environment, Transport and the Regions, Ashdown House, 123 Victoria Street, London SW1E 6DE.

### 7.2 Feedstock Test

The feedstock for PVC-O pipes shall be extruded into pipe form and subjected to an internal pressure test at 60 (+ 2, -1) ℃ and a pipe hoop stress of 12.5 MPa for 1000h without pipe failure. The test method shall be as in ISO 1167.

### 7.3 Short term ring stiffness

The short term ring stiffness of pipes shall be not less than 4 kN/m2 when tested in accordance with BS EN ISO 9969 : 1995.

### 7.4 Long term hydrostatic pressure tests on pipes

Each manufacturer shall undertake 20℃ long term hydrostatic pressure tests in accordance with Appendix A of this specification on pipes for which an LCL strength is required. It is permissible to use pipes of different dimensions in order to meet the failure point distribution defined in Appendix A, provided that all these pipes will have the same LCL strength. A calculation of the 20℃, 50 year, 97.5% LCL shall be made in order to identify the manufacturers stated LCL.

### 7.5 20℃ Pressure test on notched pipe

Three dimensions of pipe (the smallest, largest and one in-between) shall be subjected to a 20℃ pressure test on pipe prepared in accordance with Appendix B of this specification. When tested in accordance with Appendix B, the pipe shall be subjected to a net section stress (pressure calculated on the minimum ligament remaining below the notch) calculated from the regression analysis for failure at 1000h using the 97.5% LCL curve. The pipe shall not fail within 1000h. If the pipe fails prematurely, retest five samples under the same conditions; all five shall pass.

### 7.6 Long term leak tightness tests on sockets

When an axially aligned assembly with one or more elastomeric sealing ring type socket joints is tested in accordance with ISO 13846, under each of the following conditions:
(a) 20℃ testing at 1.65 PN for 1000h
(b) 40℃ testing at 1.30 PN for 1000h or 60℃ testing at 1.0PN for 1000h
it shall not fail nor leak at any point of the jointing areas.

### 7.7 Tests for axially misaligned, sealing ring type socket joints

#### 7.7.1 Assembly force for dimensions to 250 mm

For each pressure class, and for three dimensions between 90 and 250 mm, a joint shall be assembled with the pipe axes of the spigot pipe and the socket pipe misaligned by a minimum of $3^{o}$ or greater. The force required to assemble the joint shall be measured and recorded in accordance with Appendix C of this specification.

#### 7.7.2 Positive Pressure Test for dimensions to 250 mm

For all joints assembled at $3^o$ misalignment in 7.7.1, the assembly shall be filled with water. The socket assembly shall be subjected to the following conditions in accordance with Appendix C of this specification:

(a) a pressure of 1.5 x PN for 15 minutes, followed by
(b) a pressure of 1.5 x PN for 30 minutes at a $(5 \pm 0.5)°$ axial misalignment without the joint leaking at any point.

#### 7.7.3 Joint Tests on Dimensions greater than 250 mm

For all dimensions above DN 250, a pressure test shall be conducted as in 7.7.1 except that the axial misalignment shall be single valued at a minimum of 3°. The joints shall not leak.

### 7.8 Negative Pressure Test

When tested in accordance with BS EN ISO 13844, all dimensions of joint shall not leak.

### 7.9 Impact resistance of pipes

When tested in accordance with Section 1 of ISO 3127:1997 at a temperature of $(0 \pm 1)$℃, and at the conditions given in Table 5, the TIR of the batch of pipe tested shall not exceed 5%.

**Table 5 - Impact test conditions**

| Nominal size | Mass of falling weight (kg) | Fall height (mm) |
|---|---|---|
| 90 to 315 | $2 \pm 0.010$ | $2000 \pm 10$ mm |
| 400 to 630 | $4 \pm 0.010$ | $2000 \pm 10$ mm |

# 8. QUALITY CONTROL REQUIREMENTS

### 8.1 Dimensions

PVC-O pipe shall meet the requirements of 6.1, 6.2 and 6.3. Integral sockets shall meet the requirements of 6.4.

### 8.2 Short term hydrostatic pressure test at 60℃

When tested in accordance with Appendix D at a temperature of 60 (+2-1)℃, the time to failure shall be not less than 100 hours for a pipe hoop stress equal to 0.7 times the manufacturer's specified 50 year, 20℃ 97.5% LCL strength. Samples shall include an integral socket provided that the full length requirement of the pipe is maintained. Should this not be possible, a separate sample incorporating a socket shall be tested.

### 8.3 Resistance to impact at 0℃

When tested at a temperature of $(0 \pm 1)$℃, each batch of the pipe tested shall sustain 5 impacts from a mass of 5kg falling from $(2000 \pm 10)$mm. The mass shall be fitted with a tup as defined in ISO 3127:1980. Any failure shall require a retest and pass as specified in 7.9 of this specification.

### 8.4 Forming faults

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

# 9. MARKING

All PVC-O pipes shall be legibly marked in black for blue pipes, and white or yellow for grey and black pipes, at intervals not greater than 1 metre along the pipe. The marking shall run in two strips $(180 \pm 10)^o$ apart. The lettering shall be durable and the characters a minimum of 10 mm tall. The marking shall show the following information:

a) manufacturer's identification;

b) the number of this specification i.e. WIS No 4-31-08. (The use of this mark is a claim by the manufacturer that the product has been manufactured in accordance with the requirements of this specification and the claim is his sole responsibility.);

c) the letters PVC-O;

d) the LCL strength value of the pipe and the factor of safety;

e) the pressure classification in bar;

f) the nominal size of the pipe as nominal diameter and wall thickness;

g) batch identification (may be coded provided the information of this code is made available to customers and their representatives);

h) third party certification mark (if permissible).

## 10. PROTECTION OF PIPES

Whilst under manufacturer's control the pipes shall be stacked/stored in such a way as to minimise dimensional changes, scratches etc. Pipes shall be either packaged in bags or have end caps fitted to stop the ingress of foreign matter.

## 11. EXTENSION TO NOMINAL SIZE RANGE OR CHANGE IN FORMULATION OR PROCESS

The following procedure will apply when a manufacturer wishes to extend his manufactured range of sizes beyond that already fully tested, or to change a material formulation, or introduce a new pressure class, provided that neither the long term strength nor the manufacturing route are changed.

The following requirements shall be met before compliance with this standard can be met.

a) All the quality control and type test requirements (clauses 7 and 8) of this specification shall be repeated and met with the exception of 7.4.

b) 2500 hours testing, to the requirements of clause 7.4 shall be successfully met

c) Sufficient test pieces shall be under test, at appropriate stress levels, to enable 10,000h testing to be carried out.

## 12. REFERENCES

This specification makes reference to the latest editions of the following publications (except where otherwise stated) including all addenda and revisions which should be consulted.

**BRITISH STANDARDS**

| | |
|---|---|
| BS EN 681-1 | Elastomeric Seals. Material equipment for pipe and joint seals used in water and drainage applications<br>Part 1 : Vulcanised Rubber |
| BS EN 1452 | Plastic Piping Systems for Water Supply: Unplasticized poly (vinyl chloride) (Pvc-U). |
| BS 4800 | Schedule of paint colours for building purposes. |
| BS 5252 | Framework for colour co-ordination for building purposes. |
| BS 6920 : Part 1 | Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water.<br>Part 1 : Specification. |
| BS 7874 | Method of test for microbiological deterioration of elastomeric seals for joints in pipework and pipelines. |
| BS EN ISO 9969 | Thermoplastic pipes – Determination of ring stiffness. |
| BS EN ISO 13844 | Plastic piping systems – Elastomeric sealing ring type joints of unplasticized (vinyl chloride) (Pvc-u) for use with Pvc-U Pipes – Test method for leak tightness under negative pressure. |
| BS EN ISO 13846 | Plastic Piping Systems – End load bearing and non end load bearing assemblies and joints for thermoplastic pressure piping systems – Test method for long term leak tightness under internal water pressure. |

**OTHER**

| | |
|---|---|
| ISO 1167 | Thermoplastic pipes for the conveyance of fluids – Resistance to internal pressure – Test method. |
| ISO 3127 | Thermoplastic pipes – Determination of resistance to external blows – Round the clock method. |
| IGN 4-37-02 | Design against surge and fatigue conditions for thermoplastic pipes. |

# APPENDIX A – METHOD FOR THE DETERMINATION OF THE LONG TERM HYDROSTATIC PRESSURE RESISTANCE OF PIPE AT 20° C

### A.1 Test Pieces

Up to a nominal size 315 the test piece shall be a pipe of minimum free length between end fittings of 250 mm or 3 x nominal size, whichever is the greater. For nominal sizes above 315 mm the free length shall be 1000 mm. The test piece shall be closed with pressure tight caps or plugs that include end restraint, as illustrated in Figure 1 (b) or 1(c) of ISO 1167 : 1996

### 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**.**

**Table A.2 Value of Student's "t" distribution – upper 2½% points**

| ν | $t_\nu$ | ν | $t_\nu$ | ν | $t_\nu$ |
|---|---|---|---|---|---|
| 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 | 1.9863 |
| 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 |

### 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

$$= \frac{1}{n}\sum_{i=1}^{n} f_i \quad (8)$$

$\bar{h}$ = arithmetic mean of all $h_i$ values = $\frac{1}{n}\sum_{i=1}^{n} h_i$ (9)

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

$$h = a + bf \quad (10)$$

A.3.2 Calculate the following three quantities:

$$S_{ff} = \sum_{i=1}^{n} f_i^2 - n(\bar{f})^2 \quad (11)$$

$$S_{hh} = \sum_{i=1}^{n} h_i^2 - n(\bar{h})^2 \quad (12)$$

$$S_{fh} = \sum_{i=1}^{n} f_i h_i - n\,\overline{fh} \quad (13)$$

A.3.3 Calculate b and a from:

$$b = \frac{S_{fn}}{S_{ff}} \quad (14)$$

$$a = \bar{h} - b\,\bar{f} \quad (15)$$

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

**Table A.1 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.3.3 Calculate the mean stress for a time of 50 years from equation (10).

A.3.4 Calculate the lower 97.5% confidence limit as follows:

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

$$S_r^2 = \frac{1}{n-2}\left[S_{hh} - \frac{S_{fh}^2}{S_{ff}}\right] \quad (16)$$

(b) Calculate the lower 97.5% confidence limit of stress for a 20°C 50 year lifetime:

$$h_o = a + bf_o - t_v S_r \left[1 + \frac{1}{n} + \frac{(f_o - \bar{f})}{S_{ff}}\right]^{1/2} \quad (17)$$

where

$t_v$ is Student's t for ν = n – 2 degrees of freedom, as given in Table A.2 which gives the upper 2½% points

$h_o$ is the estimated log time

$f_o$ is log stress (in this case log 41)

**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 stress for a 50 year, 20°C lifetime;

(d) the period of the test.

# APPENDIX B - METHOD FOR PREPARING AND PRESSURE TESTING NOTCHED PIPES

### B.1 Apparatus

A milling machine, the cutter having an included angle of (60 ±1)°, be (12.5 ±0.50)mm wide and have a cutting rate of (0.010 ±0.002)mm per revolution per tooth (note, this typically equates to a 20 tooth cutter rotating at 700 rev/min, and traversing at 150 mm/min). The radius of the tip of the cutter shall not be greater than 30 μm. The milling cutter shall be used for no other material, and shall be replaced after 100 m of cutting.

### B.2 Test Pieces

Test pieces shall have a length between end closures of at least three times the nominal outside diameter for pipe sizes up to 315 mm, and not less than 1 m for larger diameter pipes.

### B.3 Notching of Pipe Samples

**B.3.1** Locate the section of the pipe with the minimum wall thickness and mark that point and record the wall thickness.

**B.3.2** Measure and record the wall thickness of the pipe diametrically opposite (180 ± 5)° around the circumference) the point of minimum wall thickness.

**B.3.3** Rigidly support the pipe internally with a mandrel immediately under the full length of the section to be notched.

**B.3.4** Locate the section of pipe with the minimum wall thickness. At this position cut the first notch in the outside wall of the pipe by climb milling in a single pass. The notch shall be at least 100 mm long and cut, over 100 mm, to a depth of at least 10% of the pipe wall thickness measured at the position of the notch.

**B.3.5** At a point diametrically opposite (180° around the circumference) to the first notch, cut the second notch in the outside surface of the pipe, as per B.3.4. Both notches shall be located centrally along the pipe.

### B.4 Pressure Testing

**B.4.1** The notched pipes shall be tested at (20 ±2)℃ in accordance with ISO 1167:1996 using constrained end test ends (type b).

**B.4.2** The stress required shall be identified from the appropriate regression curve and shall correspond to the 97.5% LCL stress required to cause failure in 1000h.

**B.4.3** The test pressure shall be calculated using the stress identified in B.4.2, using the minimum ligament remaining below the notch, and using the pipe outside diameter.

**B.4.4** Pressurize the test piece and maintain under pressure until rupture occurs or 1000h, whichever occurs first. Note the failure time or test time (as appropriate) and record the failure location and mode if the pipe fails before 1000h.

### B.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 (which may be coded) of the pipe tested;

b) a reference to this method of test, that is Appendix B of WIS 4-31-08 : 2001;

c) the dates between which the test(s) were conducted;

d) the declared 97.5% LCL strength value, at 50 years and 20℃, of the pipe class under test, together with the nominal size and nominal pressure rating of the pipe;

e) the stress required for 1000h failure time using the 97.5% LCL curve at 20℃;

f) the actual time to pipe failure or length of test, as appropriate;

g) the location of failure, and the failure mode (ductile, brittle etc) as appropriate.

# APPENDIX C - METHOD FOR MEASURING THE RESISTANCE TO ANGULAR INSERTION OF PIPE INTO SOCKET AND SPIGOT JOINTS, AND THE PRESSURE TIGHTNESS OF THE ANGULARLY MIS-ALIGNED JOINTS

### C.1 Test Pieces

Test pieces shall consist of matching spigot pipe ends and socket joints for pipe diameters up to 250 mm. The length of the test pieces is such as to conduct the test described below.

### C.2 Test Rig

**C.2.1** Figure C1 shows the test rig. The rig shall consist of two stout cylindrical metal tubes (2U and 2L) welded to rigid metal base plates (1U and 1L). Both sets of base plates and/or metal tubes shall be drilled and fitted with valves to enable the pipe joint under test to be filled with water whilst venting.

**C.2.2** 'O' ring seals are to be retained in internal circumferential grooves within the metal tubes to form watertight seals between the metal tubes and the joint under test. Note, the internal diameter of the metal tubes shall be matched to the external diameter of the pipe joint under test.

**C.2.3** The lower base plate (1L) shall be held by four screws (illustrated) to the flat plate (5) to enable angular rotation to be produced to the specified minimum values. The flat plate shall be capable of horizontal movement to allow alignment of the two halves of the joint (3U and 3L). To vary the angular misalignment of the two parts of the PVC-O pipe joint under test, a hardened steel rod (4) is incorporated between the lower metal plate 1L and the flat plate (5).

**C.2.4** The complete test rig shown in Figure C1 shall be capable of being attached to a hydraulically or screw driven compression testing machine capable of maintaining a constant displacement rate and also a fixed displacement. The machine shall incorporate a mechanical or electronic system capable of recording load and displacement.

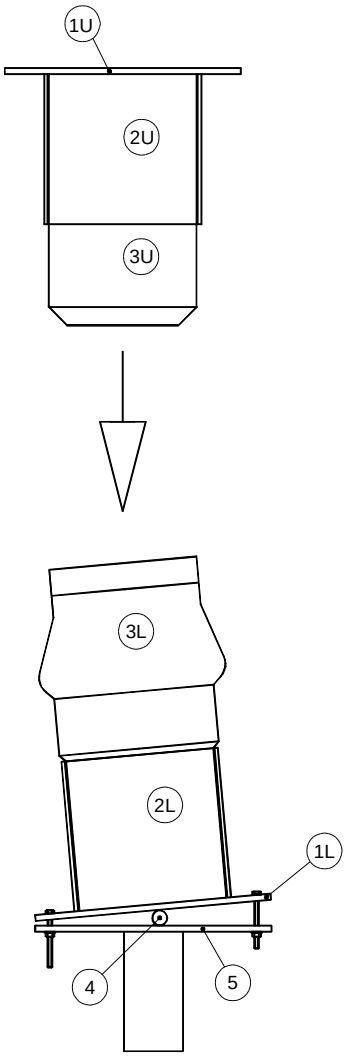


**Figure C1 Test Rig**

### C.3 Test Method

**C.3.1** The test shall be conducted at a temperature of (23 ±2)°C.

**C.3.2** A pipe containing a socket and spigot at opposite ends shall be carefully cut in two. The section containing the socket 3L shall be cut to a length so that when fully inserted into the lower tube 2L, the transition from socket to pipe is at the mouth of the metal tube 2L.

**C.3.3** Depending on the available clearance on the testing machine, the spigot section of the pipe (3U) shall be cut such that when fully inserted into the top metal tube 2U, the chamfered spigot end (3U) is a minimum distance from the socket 3L. Ideally, the free length of this pipe (3U) should be at least three times its nominal outside diameter.

**C.3.4** The socket part of the joint (3L) shall be rotated, using the screws, the metal rod (4), the flat plate (5) and the lower base plate (1L) to the specified minimum insertion angle of 3°. The insertion angle is measured as the angular difference between the pipe and socket axes. The flat plate (5) shall be adjusted by horizontal movement to align the mouth of the socket (3L) with the spigot (3U) while maintaining the minimum angular misalignment of 3°.

**C.3.5** After marking the correct insertion depth, the pipe ends shall be brought together at a constant speed of (20 ± 2)mm/min until full insertion is achieved. This position shall then be maintained during the remainder of the test.

**C.3.6** During the insertion phase, a continuous record of the load as a function of the displacement shall be recorded.

### C4 Positive Pressure Test

**C.4.1** After insertion, the completed pipe and socket assembly (3U and 3L) still held at an angle of 3° minimum, shall be filled full with water. Use the vent valve in the upper base plate (1U) or upper tube (2U) to expel all the air.

**C.4.2** The assembly shall then be pressurised to 1.5 x PN, and this pressure shall be held for 15 minutes. No leakage is allowed.

**C.4.3** If no leakage is observed from the joint, the assembly shall be de-pressurised and the angular deflection of the joint (3U and 3L) increased to 5° using the angled base plate system and the retaining screws.

**C.4.4** The joint assembly (3U and 3L) shall then be re-pressurised to 1.5 x PN for a further period of 30 minutes, whilst observing the joint for any signs of leakage. No leakage is allowable.

Note: During pressurisation all necessary precautions must be taken to protect personnel conducting the test. The worst case of failure by brittle fracture of the pipe barrel shall be assumed, and protective screens and other measures employed to protect personnel.

### C.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 (which may be coded) of the joint tested;

b) a reference to this method of test, that is Appendix C of WIS 4-31-08;2001;

c) the dates between which the tests were conducted;

d) the declared 97.5% LCL strength value, at 50 years and 20℃, of the pipe class under test, the nominal size and nominal pressure rating of the pipe, and finally the manufacturer and product reference of the seal used within the joint;

e) the plot of force versus displacement measured during insertion of the spigot into the socket, and any evidence of seal displacement;

f) the results of the various pressure tests;

g) if failure of the joint or pipe occurred the mode of failure.

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# APPENDIX D - METHOD FOR UNDERTAKING 60℃ PRESSURE TESTING OF PIPES AND INTEGRAL JOINTS

**D.1 Test Pieces**

Test pieces shall consist of correctly aligned spigot and socket joints, with the pipe spigot fully inserted into the socket. On one side of the joint there shall be a length of pipe equal in length to at least three times the nominal diameter of the pipe, for pipe diameters up to 315 mm. For larger diameters the pipe length must be at least one metre. On the other side of the joint the pipe length (for all diameters) shall be at least half of one pipe diameter.

**D.2 Test Pieces**

**D.2.1** The assembled joint shall be pressure tested at a temperature of 60 (+2, -1)℃. Samples shall be filled with water at 60℃, and condition as per ISO 1167:1996.

**D.2.2** The assembly shall be subjected to a pressure using end caps that fully constrain axial movement (type (b) in ISO 1167:1996)

**D.2.3** The pressure applied within the test assembly shall create a pipe hoop stress, $\sigma_H$ equal to 0.7 times the manufacturer's specified 50 year, 20°C, 97.5% LCL pipe strength. The full pressure shall be maintained (within the limits of ISO 1167) for 100h without the pipe or joint leaking or failing.

**D.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 (which may be coded) of the joint tested;

b) a reference to this method of test, that is Appendix D of WIS 4-31-08 : 2001;

c) the dates between which the test(s) were conducted;

d) the declared 97.5% LCL strength value, at 50 years and 20℃, of the pipe class under test, together with the nominal pressure rating of the pipe;

e) the actual stress, and pressure, used in the test;

f) the time of duration of the test or, if appropriate, the time to failure;

g) if the pipe or joint failed, the location and mode of failure.