
THE DETERMINATION OF END-LOADS FOR THE PERFORMANCE TESTING OF PIPELINE FITTINGS

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APPENDIX A - CALCULATED TEST FORCES FOR TYPE 1 AND TYPE 2 MECHANICAL FITTINGS FOR USE WITH PE 80 PIPE MANUFACTURED TO WIS 4-32-03	8	This document is intended to provide a basis for the formulation of test criteria to assess the resistance of mechanical fittings to end-loads, for below ground use in water supply, distribution and service pipe applications in the Water Industry. It does not include methods of test but details methods to determine the end-loads imposed on fittings due to those operating conditions which can be predicted. The pipe materials to which the calculations can be applied are PE 80 and PE 100 (of nominal size 20 to 1000), PVC-U (of nominal size 90 to 630) and ductile iron (of nominal size 100 to 1600).
APPENDIX B - CALCULATED TEST FORCES FOR TYPE 1 AND TYPE 2 MECHANICAL FITTINGS FOR USE WITH PE 100 PIPES MANUFACTURED TO WIS 4-32-13	9	Examples of the application of the theory to PE 80 (to BS 6572/WIS 4-32-03), PE 100 (to WIS 4-32-13), PVC-U (to WIS 4-31-06) and ductile iron (to BS EN 545) pipes and fittings have been included to illustrate the use of the equations.
APPENDIX C - CALCULATED TEST FORCES FOR MECHANICAL FITTINGS FOR USE WITH PVC-U PIPE (TYPE 2 FITTINGS ONLY)	10	Appendices A, B, C and D contain examples of suitable forces for pull-out tests on PE 80, PE 100, PVC-U and ductile iron pipe/fitting assemblies respectively, to act as a guide for the development of test methods.
APPENDIX D CALCULATED TEST FORCES FOR MECHANICAL FITTINGS FOR USE WITH DUCTILE IRON PIPE (TYPE 2 FITTINGS ONLY)	11	It is intended that this document be used by those involved in the future preparation of specifications to ensure that a consistent approach is adopted in the testing of mechanical fittings for Water Industry applications.
		This document is not intended to be used as a Specification. Information contained within it is given in good faith but neither UK Water Industry Research Ltd., Water UK nor WRc plc can accept any responsibility for actions taken as a result.

2. DEFINITIONS

It is recommended that mechanical fittings should be classified into 3 distinct end-load performance levels. For the purpose of this document these are defined as follows:

Type 1 fitting: The end-load resistance of the joint shall be greater than the longitudinal strength of the pipe.

NOTE 1: Type 1 fittings are applicable to polyethylene pipe only. Such fittings would be used on PE pipelines, for example, in areas of mining subsidence and for pull-through applications. Pipelines installed using this type of fitting would not normally require anchoring.

NOTE 2: All fittings for use with polyethylene pipe with outside diameters up to and including 63mm are required to be Type 1.

Type 2 fitting: The end-load resistance of the joint shall be greater than the maximum axial forces (described in Section 3 of this document) assumed to be acting on the joint.

NOTE: Pipelines installed using Type 2 fittings would not normally require anchoring.

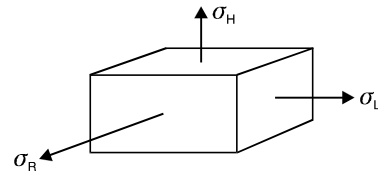
Type 3 fitting: The end-load resistance of the joint is less than that required by the Type 2 definition.

NOTE: Pipelines installed using Type 3 fittings will normally require anchoring as for an unrestrained pipeline and the advice of the manufacturer should be sought.

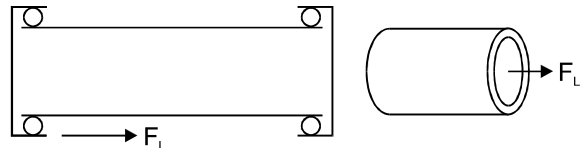
3. THEORETICAL CALCULATIONS (TYPE 2 FITTINGS)

3.1 Principal stresses

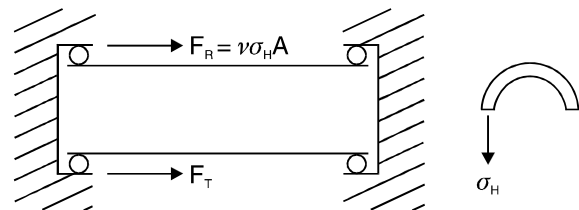
When under pressure, three principal stresses may exist in the pipe wall; the longitudinal stress (σ_L) the circumferential (or hoop) stress (σ_H) and the radial stress (σ_R) (see Figure 1a).



(a) The principal stresses in three dimensions



(b) The force on an unrestrained joint between a pipe and fitting



(c) The forces on a restrained fitting

Figure 1 - The principal forces exerted on a joint due to pressure

It has been assumed that the stresses exerted on the wall of a pressurised pipe covered by this document can be most closely modelled by comparison with a thin-walled cylinder and therefore that the hoop and longitudinal stresses are constant over the wall thickness and that the radial stress is small and can be neglected. However, the use of the mean pipe diameter ($D-t$) in the formulae instead of the internal diameter (d) practically eliminates any error which may arise from this assumption.

Stresses due to expansion or contraction of the pipe due to a change in temperature between installation and testing may be significant and have been included in the calculations.

Other stresses which may be induced in the pipeline in service but which cannot readily be predicted, e.g. bending, external loading and shear, have not been included in these calculations.

The following calculations involve the quantitative assessment of the forces which tend to separate the fitting from the pipe when a section of pipeline is pressurised.

For the purposes of the calculations, it has been assumed that fittings include a sealing element which forms a frictionless seal on the external surface of the pipe and which is fixed to the bore surface of the fitting in question. Of the sealing arrangements available, this case gives a suitably conservative view of the forces tending to cause separation of a fitting from the pipe.

3.2 Longitudinal forces at the joint due to pressure

3.2.1 Unrestrained joint

Where the joint between the fitting and the pipe is unrestrained and using the assumptions given above, it can be shown that the force tending to separate a fitting from a pipe when subjected to internal pressure (p) has a maximum value of F_L (see Figure 1b):

$$F_L = p\pi D^2/4 \quad (1)$$

where D is the external diameter of the pipe.

NOTE: This case might apply to above ground systems and to systems with a free end (e.g. end cap) undergoing a site pressure test.

Figures for end-load testing are not given in the Appendices for this case, but can be calculated from equation (1).

3.2.2 Restrained joint

When a section of pipe is pressurised, it tends to increase in diameter and reduce in length. The relationship between expansion in the hoop direction and contraction in the longitudinal direction is given by Poisson's ratio ν .

Considering an arrangement of a section of pipe between two fixed (encastré) fittings, the longitudinal force at each joint could achieve a maximum of F_R on pressurisation due to Poisson's ratio effects.

Using the assumption that a pipe can be represented by a thin-walled cylinder under pressure, the hoop stress acting on the longitudinal cross-section area of the pipe is given by:

$$\alpha_H = p (D-t)/2t$$

Since the pipe ends are restrained, the Poisson's ratio effect will induce a longitudinal force at each joint tending to separate the pipe from the fitting given as F_R (see Figure 1c):

$$F_R = \nu \alpha_H A = \nu p (D-t) \cdot A/2t \quad (2)$$

where ν is Poisson's ratio
 A is annular cross-sectional area of pipe
 $D-t$ is the mean pipe diameter.

3.3 Longitudinal forces at the joint due to temperature effects

If the pipe ends are restrained, an additional force F_T may be induced due to temperature changes between installation and testing tending to separate the pipe from the fitting:

$$F_T = \sigma_T A = \Delta T \cdot K \cdot E \cdot A \quad (3)$$

where ΔT = change in temperature ($^{\circ}\text{C}$)
 K = coefficient of expansion ($^{\circ}\text{C}^{-1}$)
 E = Young's modulus (MPa)

3.4 Maximum longitudinal force on a joint

Based on the above three cases, the **maximum** longitudinal force F_{\max} which a fitting may be required to withstand is given by:

(a) *Unrestrained end caps*

$$F_{\max} = p\pi D^2/4 \quad (4)$$

or

(b) *Restrained end caps*

$$F_{\max} = F_R + F_T = \nu p \frac{(D-t)A}{2t} + \Delta T K E A \quad (5)$$

For the purposes of type testing, the greatest value of F_{\max} will be used to calculate the test forces.

4. EXAMPLES OF THE USE OF THE EQUATIONS FOR DEFINING TEST FORCES FOR PIPE/FITTING ASSEMBLIES

The assessment of the end-load resistance of mechanical fittings can be accomplished by means of a pull-out test. The following procedures demonstrate the application of the theory given in clause 3 to the calculation of pull-out forces for such performance tests.

NOTE: This pull-out without pressure application represents the worst case. It is used because (a) end-load resistant fittings would be expected to hold even when the system is depressurised and (b) it is more practical to test in dry conditions.

4.1 PE 80 pipe/fitting assemblies

4.1.1 Assumptions

In order to calculate the maximum end-loads exerted on a fitting due to the stresses in a pressurised SDR 11 125mm PE 80 pipe, the following assumptions are made:

Maximum working pressure (P_w)	= 10 bar
Maximum site test pressure (P_s)	= $1.5 \times P_w = 15$ bar
Maximum temperature variation (ΔT)	= 40°C
Poisson's ratio (ν)	= 0.42
Young's modulus (E at 20°C)	= 593 MPa
Coefficient of expansion (K)	= $1.45 \times 10^{-4} \text{ } ^\circ \text{C}^{-1}$
External diameter (D)	= 125mm
Wall thickness (t)	= 11.4mm
Internal diameter (d)	= 102.2mm
Yield stress (σ_y) (measured at a strain rate of $125\% \text{ min}^{-1}$ and 23°C)	= 15 MPa

NOTE 1: The maximum temperature variation has been estimated from the maximum recorded UK summer temperatures and the minimum recorded UK ground temperatures (at pipe cover depth).

NOTE 2: The Young's modulus is defined as that appropriate to the mean of the temperatures used in these calculations (i.e. 20°C).

NOTE 3: The strength properties of polyethylene are strain-rate dependent. Where strain-rate dependent properties have been used in the calculations, the test forces must be applied at the equivalent strain-rate. Testing at other strain-rates is permissible provided the test forces have been recalculated using yield stress values appropriate to the chosen strain-

rate. Figure 2 can be used to define yield stress values for other extension rates between 1 and $1000 \text{ mm} \cdot \text{min}^{-1}$.

4.1.2 Calculations

4.1.2.1 Type 1 fittings

To comply with the definition given in clause 2, Type 1 fittings for PE 80 pipes shall be capable of withstanding a force equivalent to that required to cause yield of a PE 80 pipe (i.e. fully end-load resistant).

For a pull-out test to assess the end-load resistance of Type 1 fittings, the applied pull-out force, F_y , is therefore required to be equivalent to that which causes yield in a PE 80 pipe, i.e.

$$F_y = \sigma_y A$$

where σ_y = yield stress

A = pipe wall cross-sectional area

The test forces for nominal pipe sizes from 20 to 1000 have been calculated using the appropriate polyethylene pipe dimensions and assuming a yield stress of 15 MPa (see 4.1.1). These are presented in Table A.1 of Appendix A.

4.1.2.2 Type 2 fittings

To comply with the definition given in clause 2, Type 2 fittings shall be capable of withstanding the maximum axial forces assumed to be acting on the joint under normal operating conditions. Thus, for the assessment of the end-load resistance, a Type 2 fitting shall be considered to be subjected to a force equivalent to that induced in a pipeline installed under conditions of maximum temperature change and operated at its site test pressure. The following details the calculations conducted to determine the appropriate test forces.

$$(1) \quad F_L = \frac{\rho \pi D^2}{4} \quad \text{from Equation (1)}$$

$$= \frac{1.5 \times \pi \times 125^2}{4}$$

$$= 18.41 \text{ kN}$$

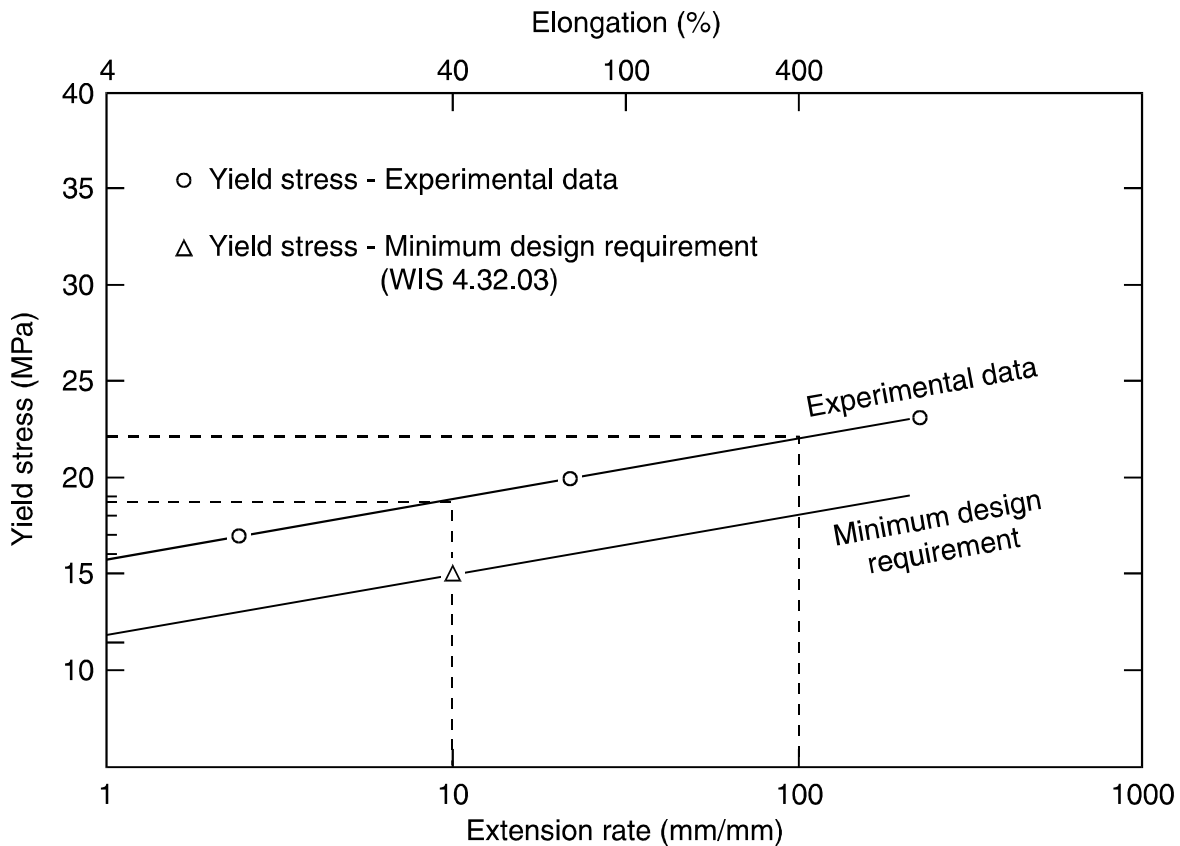


Figure 2 - The relationship between yield stress and extension rate for an MDPE pipe

(2) $F_R = v_p (D-t) A/2t$ from Equation (2)

$$= 0.42 \times 1.5 \times \frac{(125 - 114) \times \pi}{8 \times 114} \times (125^2 - 102.2^2)$$

$$= 12.77 \text{ kN}$$

and

(3) $F_T = \Delta T \cdot K \cdot E \cdot A$ from Equation (3)

$$= 40 \times 1.45 \times 10^{-4} \times 593 \times \frac{(125^2 - 102.2^2) \times \pi}{4}$$

$$= 13.99 \text{ kN}$$

(4) Unrestrained end-caps

$$F_{\max} = F_L = 18.41 \text{ kN}$$

Restrained end-caps

$$F_{\max} = F_R + F_T = 26.76 \text{ kN}$$

Since $F_R + F_T > F_L$, then F_{\max} is assumed to be 26.76 kN.

F_{\max} represents the maximum longitudinal force on a fitting joined to a predicted 10 bar rated, 125mm PE 80 pipe restrained at both ends and pressurised to a test pressure of 15 bar.

A Type 2 fitting is required to maintain resistance to end-loads at least equivalent to F_{max} . For a pull-out test to assess the end-load resistance, the applied pull-out test force F should be that which can be induced by F_{max} plus a safety factor (25% has been agreed for current purposes).

NOTE: A margin of safety has already been included in the calculations through the use of site test pressures and the maximum value of ΔT . Only a small safety factor has therefore been added to allow resistance to be maintained during integrity testing of the pipeline.

Using appropriate values of F_{max} , test forces (F) can be calculated for each remaining combination of pipe sizes and classes. All test force values are presented in Table A.2 of Appendix A.

4.1.2.3 Type 3 fittings

There are no requirements for pull-out resistance of Type 3 fittings.

4.1.3 Assemblies incorporating polyethylene and other service pipe materials

Where pipe/fitting assemblies incorporate both polyethylene and other service pipe materials, for the purposes of end-load resistance assessment, the assembly is required to meet the performance criteria defined by the polyethylene pipe material.

4.2 PE 100 pipe/fitting assemblies

4.2.1 Assumptions

In order to calculate the maximum end-loads exerted on a fitting due to the stresses in a pressurised SDR11 125mm PE 100 pipe (to WIS 4-32-13), the following assumptions are made:

Maximum working pressure (P_w)	= 16 bar
Maximum site testing pressure (P_s)	= $1.5 \times P_w$ = 24 bar
Maximum temperature variation (ΔT)	= 40° C
Poissons ratio (ν)	= 0.38
Young's modulus (E at 20° C)	= 712 MPa
Coefficient of expansion (K)	= $1.30 \times 10^{-4} \text{C}^{-1}$
External diameter (D)	= 125mm
Wall thickness (t)	= 11.4mm
Internal diameter (d)	= 102.2mm
Yield stress (σ_y) (measured at a strain rate of 125% min^{-1} and 23° C)	= 19 MPa (from WIS 4-32-13)

NOTES 1, 2 and 3 from 4.1.1 apply.

4.2.2 Calculations

To comply with the definition given in clause 2, the applied pull-out force, F_y (as given in 4.1.2.1) is required to be equivalent to that which causes yield in a PE 100 pipe.

The test forces for pipe sizes from 90 to 1000 have been calculated using the appropriate PE 100 dimensions and assuming a yield stress of 19MPa (see 4.2.1). These are presented in Table B1 of Appendix B.

4.2.2.2 Type 2 fittings

To comply with the definition given in clause 2, Type 2 fittings shall be capable of withstanding the maximum axial forces assumed to be acting on the joint under normal operating conditions. Thus, for assessment of the end-load resistance, a Type 2 fitting shall be considered to be subject to a force equivalent to that induced in a pipeline installed under conditions of maximum temperature change and operated at its site test pressure. The following details the calculations conducted to determine the appropriate test forces.

$$\begin{aligned} (1) \quad F_L &= \frac{p\pi D^2}{4} && \text{from Equation (1)} \\ &= \frac{2.4 \times \pi \times 125^2}{4} \\ &= 29.452 \text{ kN} \end{aligned}$$

$$\begin{aligned} (2) \quad F_R &= \nu p (D-t)A/2t && \text{from Equation (2)} \\ &= 0.38 \times 2.4 \times \frac{(125 - 11.4) \times \pi}{8 \times 11.4} \\ &\quad \times (125^2 - 102.2^2) \\ F_R &= 18.487 \text{ kN} \end{aligned}$$

$$\begin{aligned} (3) \quad F_T &= \Delta T.K.E.A \\ &= 40 \times 1.3 \times 10^{-4} \times 712 \times \frac{(125^2 - 102.2^2) \times \pi}{4} \\ &= 15.063 \text{ kN} \end{aligned}$$

$$(4) \quad \text{Unrestrained end-caps}$$

$$F_{max} = F_L = 29452 \text{ N}$$

Restrained end-caps

$$F_{\max} = F_R + F_T = 18487 + 15063$$

$$= 33550\text{N}$$

Since $F_R + F_T > F_L$ then F_{\max} is assumed to be 33.6kN.

F_{\max} represents the maximum longitudinal force on a fitting joined to a predicted 16 bar rated, 125mm PE 100 pipe restrained at both ends and pressurised to a test pressure of 24 bar.

A Type 2 fitting is required to maintain resistance to end-loads at least equivalent to F_{\max} . For a pull-out test to assess the end-load resistance, the applied pull-out test force F should be that which can be induced by F_{\max} plus a safety factor (25% has been agreed for current purposes).

NOTE: A margin of safety has already been included in the calculations through the use of site test pressures and the maximum value of ΔT . Only a small safety factor has therefore been added to allow resistance to be maintained during integrity testing of the pipeline.

Using appropriate values of F_{\max} , test forces (F) can be calculated for each remaining combination of pipe sizes and classes. All test force values are presented in Table B2 of Appendix B.

4.3 PVC-U pipe/fitting assemblies

4.3.1 Assumptions

In order to calculate the maximum end-loads exerted on a fitting due to the stresses in a pressurised 12.5 bar rated, 110mm PVC-U pipe, the following assumptions are made:

Maximum working pressure (P_w)	= 12.5 bar
Maximum test pressure (P_s)	= 1.5 x P_w = 18.75 bar
Maximum temperature variation (ΔT)	= 40° C
Poissons ratio (ν)	= 0.38
Young's modulus (E)	= 3.4 GPa
Coefficient of expansion (K)	= $6 \times 10^{-5} \text{C}^{-1}$
External diameter (D)	= 110.0 to 110.4mm
Wall thickness (t)	= 5.3mm
Internal diameter (d)	= 99.4 to 99.8mm

4.3.2 Calculations

Type 1 fittings are not currently made for use with PVC-U pipes. For Type 2 fittings the calculations detailed in 4.1.2.2 for polyethylene pipe can be similarly conducted for PVC-U using the assumptions given in 4.3.1.

$$(1) F_L = \frac{1.875}{4} \times (110.2)^2 \times \pi = 17.88\text{kN}$$

$$(2) F_R = 1.875 \times \frac{(110.2 - 5.3) \times 0.38}{8 \times 5.3} \times (110.2^2 - 99.6^2) \times \pi = 12.32\text{kN}$$

$$(3) F_T = 40 \times 6 \times 10^{-5} \times 3400 \times (110.2^2 - 99.6^2) \times \pi = 14.25\text{kN}$$

(4) Unrestrained end-caps

$$F_{\max} = F_L = 17.88\text{kN}$$

Restrained end-caps

$$F_{\max} = F_R + F_T = 26.57\text{kN}$$

Since $F_R + F_T > F_L$, then F_{\max} is assumed to be 26.57kN.

F_{\max} represents the predicted maximum longitudinal force on a fitting joined to a 12.5 bar rated, 110mm PVC-U pipe restrained at both ends and pressurised to a test pressure of 18.75 bar. To this maximum force, a safety factor of 25% is added to calculate the pull-out test force, F , for a Type 2 fitting for this size and class of PVC-U pipe.

Using appropriate values of F_{\max} , test forces (F) can be calculated for each remaining combination of pipe sizes and classes. All test force values are presented in Table B.1 of Appendix B.

4.4 Ductile iron pipe/fitting assemblies

4.4.1 Assumptions

In order to calculate the maximum end-loads exerted on a fitting due to the stresses in a pressurised 100mm, Class K9 ductile iron pipe, the following assumptions are made:

Maximum working pressure (P_w)	= 16 bar
Maximum test pressure (P_s)	= 1.5 x P_w = 24 bar
Maximum temperature variation (ΔT)	= 40° C

Poissons ratio (ν)	= 0.26 - 0.29
Young's modulus (E)	= 169 GPa
Coefficient of expansion (K)	= 10.5 - 11.8 $\times 10^{-6} \text{C}^{-1}$
External diameter (D)	= 118mm
Wall thickness (t)	= 6.1mm
Internal diameter (d)	= 105.8mm

4.4.2 Calculations

Type 1 fittings requirements are not applicable to ductile iron pipes.

For the assessment of the end-load resistance of Type 2 fittings for DN 100, Class K9 ductile iron pipe, F_{\max} can be calculated as follows:

$$(1) F_L = 2.4 \times \frac{(118)^2 \times \pi}{4} = 26.25 \text{ kN}$$

$$(2) F_R = 2.4 \times \frac{(118 - 6.1) \times 0.27}{8 \times 6.1} \times (118^2 - 105.8^2) \times \pi = 12.75 \text{ kN}$$

(3) Due to the relative rate of heat transfer in a ductile iron pipe for a given wall thickness (coefficient of heat transfer k is 48, 0.5 and 0.15W/m/K for cast iron, HDPE and PVC respectively), it has been assumed that any contraction due to temperature variation will occur during installation, such that the temperature change after assembly will be negligible. In particular for a temperature change ΔT of less than 22°C after installation, $F_R + F_T < F_L$.

F_{\max} is assumed to be 26.25kN.

F_{\max} represents the maximum predicted longitudinal force on a fitting joined to a DN 100, Class K9 ductile iron pipe pressurised to a test pressure of 24 bar. To this maximum force, a safety factor of 25% is added to calculate the pull-out test force, F , for a Type 2 fitting for this size and class of ductile iron pipe.

Using appropriate values of F_{\max} , test forces (F) can be calculated for each remaining pipe size. All test force values are presented in Table D.1 of Appendix D.

5. REFERENCES

This IGN refers to:

BS EN 545	Ductile iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods.
BS 6572	Specification for blue polyethylene pipes up to nominal size 63 for below ground use for potable water.
WIS 4-31-06	Water Industry Specification for blue unplasticised PVC (PVC-U) pressure pipes and fittings for buried cold potable water - Metric series.
WIS 4-32-03	Water Industry Specification for blue polyethylene (PE) pressure pipe for cold potable water (nominal size 90 to 1000) for underground or protected use.
WIS 4-32-13	Specification for blue higher performance polyethylene, HPPE/PE 100, pressure pipes, nominal size 90 to 1000, for underground or protected use for the conveyance of water intended for human consumption.

APPENDIX A - CALCULATED TEST FORCES FOR TYPE 1 AND TYPE 2 MECHANICAL FITTINGS FOR USE WITH PE80 PIPE MANUFACTURED TO WIS 4-32-03

A.1 Type 1 Fittings

Table A.1 presents the pull-out test forces for PE80 pipe/Type 1 fitting assemblies of nominal sizes over the range 20 to 1000. The properties listed in 4.1.1 are assumed to apply with the relevant pipe dimensions.

NOTE: For PE80 pipes whose parameters vary from these assumed values, the criteria in Table A.1 will need to be re-calculated using the appropriate figures.

Table A.1 - Pull-out test forces for Type 1 fittings for use with PE80 pipe

Nom Size	Test force F_y (kN)				
	SDR	SDR	SDR	SDR	SDR

	11	17	17.6	26	33
20	2				
25	3				
32	4				
50	10				
63	15				
90	32	21	20		
110	47	32	31		
125	61	41	39		
160	100	67	65	45	
180	126	85	82	56	
225	198	132	128	88	
250	243	163	158	109	
280	305	205	198	136	
315	386	259	251	173	
355	491	329	317	219	177
400	624	417	404	277	225
450	790	528	512	351	284
500	975	652	629	433	349
560	1219	818	789	543	440
630	1544	1035	1000	688	555
710		1315	1269	875	707
800		1670	1611	1109	895
900		2113	2037	1411	1135
1000		2609	2516	1740	1398

Strain rate = 125% min⁻¹ at 23° C

A.2 Type 2 Fittings

Table A.2 presents the pull-out test forces for PE80 pipe/Type 2 fittings assemblies of nominal sizes over the range 20 to 1000. The properties listed in 4.1.1 are assumed to apply with the relevant pipe dimensions and site test pressures.

NOTE: For PE80 pipe whose parameters vary from these assumed values, the criteria in Table A.2 will need to be re-calculated with the appropriate figures.

Table A.2 - Pull-out test forces for Type 2 fittings for us with PE80 pipe

Nom Size	Test force F (kN)				
	SDR 11	SDR 17	SDR 17.6	SDR 26	SDR 33
90	40	27	26		

90	14	12	12		
110	21	18	18		
125	27	23	23		
160	44	38	37	34	
180	55	48	47	43	
225	87	75	74	66	
250	107	92	91	82	
280	134	116	114	103	
315	170	146	145	130	
355	216	186	184	166	158
400	274	236	233	210	200
450	347	299	296	266	253
500	428	369	364	328	313
560	536	463	457	412	392
630	679	585	579	521	496
710		744	735	662	631
800		944	933	840	800
900		1195	1181	1065	1013
1000		1475	1458	1314	1251

Strain rate = 125% min⁻¹ at 23° C

APPENDIX B - CALCULATED TEST FORCES FOR TYPE 1 AND TYPE 2 MECHANICAL FITTINGS FOR USE WITH PE100 PIPES MANUFACTURED TO WIS 4-32-13

B.1 Type 1 Fittings

Table B.1 presents the pull-out test forces for PE100 pipe/Type 1 fitting assemblies of nominal sizes over the range 90 to 1000. The properties listed in 4.2.1 are assumed to apply with the relevant pipe dimensions.

NOTE: For PE100 pipes whose parameters vary from these assumed values, the criteria in Table B.2 will need to be re-calculated using the appropriate figures.

Table B.1 - Pull-out test forces for Type 1 fittings for use with PE100 pipe

Nom Size	Test force F (kN)				
	SDR 11	SDR 17	SDR 17.6	SDR 26	SDR 33
90	40	27	26		

110	60	40	39		
125	77	52	50		
160	127	85	82	57	
180	160	107	103	71	
225	250	167	162	111	
250	308	207	200	138	
280	386	259	251	172	
315	489	328	317	219	
355	622	416	402	277	224
400	790	529	511	351	285
450	1001	669	649	444	359
500	1234	826	797	548	443
560	1544	1036	1000	688	557
630	1956	1312	1266	872	704
710		1666	1607	1109	896
800		2115	2041	1405	1134
900		2677	2580	1787	1437
1000		3305	3187	2204	1771
Strain rate = 125% min ⁻¹ at 23° C					

B.2 Type 2 Fittings

Table B.2 presents the pull-out test forces for PE100 pipe/Type 2 fittings assemblies of nominal sizes over the range 90 to 1000. The properties listed in 4.2.1 are assumed to apply with the relevant pipe dimensions and site test pressures.

NOTE: For PE100 pipe whose parameters vary from these assumed values, the criteria in Table B.2 will need to be re-calculated with the appropriate figures.

Table B.2 - Pull-out test forces for Type 2 fittings for use with PE100 pipe

Nom Size	Test force F (kN)				
	SDR 11	SDR 17	SDR 17.6	SDR 26	SDR 33
90	17	15	15		
110	26	23	23		
125	34	30	30		

160	55	49	49	45	
180	70	62	61	57	
225	109	97	96	89	
250	134	120	119	110	
280	168	150	149	137	
315	213	190	188	174	
355	270	241	239	221	213
400	343	306	303	280	271
450	435	387	384	355	343
500	536	478	474	438	423
560	672	600	594	550	531
630	851	759	753	696	671
710		964	956	884	853
800		1224	1213	1122	1082
900		1549	1535	1421	1370
1000		1913	1896	1754	1691
Strain rate = 125% min ⁻¹ at 23° C					

APPENDIX C - CALCULATED TEST FORCES FOR MECHANICAL FITTINGS FOR USE WITH PVC-U PIPE (TYPE 2 FITTINGS ONLY)

Table C.1 presents the pull-out test forces for PVC-U pipe/Type 2 fitting assemblies of nominal sizes over the range 90 to 630. The properties listed in 4.2.1 are assumed to apply with the relevant pipe dimensions and site test pressures.

Table C.1 - Pull-out test forces for Type 2 fittings for use with PVC-U pipe

Nominal size	Test force F (kN)	
	12.5 bar rated pipe	8 bar rated pipe
90	22	15
110	33	22
160	70	46
200	109	72
250	170	112
315	270	178
400	436	287
450	552	363
500	681	448
630	1080	711

NOTE: For PVC-U pipes whose parameters vary from these assumed values, the criteria in Table C.1 will need to be re-calculated using the appropriate figures.

APPENDIX D - CALCULATED TEST FORCES FOR MECHANICAL FITTINGS FOR USE WITH DUCTILE

IRON PIPE (TYPE 2 FITTINGS ONLY)

Table D.1 presents the pull-out test forces for ductile iron pipe/Type 2 fitting assemblies of nominal sizes over the range 100 to 1600. The properties listed in 4.4.1 are assumed to apply with the relevant pipe dimensions and site test pressures.

NOTE: For ductile iron pipes whose parameters vary from these assumed values, the criteria in Table D.1 will need to be re-calculated using the appropriate figures.

Table D.1 - Pull-out test forces for Type 2 fittings for use with ductile iron pipe

Nominal size	Test force F (kN)
100	33
150	68
200	116
250	177
300	250
350	337
400	434
450	543
500	667
600	950
700	1283
800	1670
900	2104
1000	2588
1100	3127
1200	3711
1400	5036
1600	6555