WATER INDUSTRY SPECIFICATION

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UK Water Industry

Specification for hydrostatic pressure testing of polyethylene and polyethylene barrier water supply pipelines and sewer rising mains

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1. INTRODUCTION

BS EN 805 requires that every pipeline shall undergo a water pressure test prior to going into service to demonstrate the leaktightness of the installed system. This can be achieved by pressurising the constructed pipeline under controlled conditions to correctly specified test parameters and pass/fail criteria.

It is essential that every water supply pipeline is tested, but hydrostatic pressure testing is a hazardous activity. It is the responsibility of all parties involved to ensure that this is carried out in a safe manner through assessment and management of risks, the application of safe systems of work and compliance with national legislation.

BS EN 805: 2000 permits the designer to specify a test procedure for pipes with viscoelastic behaviour.

This document specifies the UK test procedure for hydrostatic testing of below ground pressure pipelines constructed from polyethylene or polyethylene barrier pipes.

This document does not explicitly state a requirement to comply with legislation. It follows the general principle that activities are to be designed to comply with all relevant statutes. Section 4 provides guidance on preparations for testing, choice of test section, and apparatus for testing to assist those planning and carrying out a hydrostatic pressure test. As such, Section 4 is written using the verbal form “should”.

This document replaces IGN 4-01-03: 2015 which has been archived (withdrawn).

Note: For pipes of non-viscoelastic materials such as iron, steel, concrete and glass-reinforced polyester (GRP), the water loss method for hydrostatic testing given in Section 11 of BS EN 805: 2000 applies. The water loss method is also advised by manufacturers of PVC-O pipes.

This document has been prepared on behalf of the Water UK Standards Board. Information contained in this specification is given in good faith. Water UK cannot accept any responsibility for actions taken by others as a result.

2. SCOPE

This document specifies the procedure for hydrostatic pressure testing of below ground water supply pipelines and sewer rising mains made of polyethylene pipes to BS EN 12201-2 or polyethylene barrier pipes (Type A) to BS 8588.

It also specifies simplified procedures for the pressure testing of replacement sections of, and service connections to, below ground water supply pipelines and sewer rising mains made of polyethylene pipes to BS EN 12201-2 or polyethylene barrier pipes (Type A) to BS 8588.

Note 1: Pressure testing of pipelines designed to operate in service at temperatures above 20°C are not covered by this document.

Note 2: Pressure testing of plumbing systems inside premises are not covered by this document.

Note 3: All references in this document to polyethylene pipe refer equally to Type A polyethylene barrier pipes.

3. PRINCIPLES OF THE TEST FOR POLYETHYLENE PIPELINES

3.1 Viscoelastic behaviour of polyethylene pipes

When subjected to internal hydrostatic pressures, pipes made of a viscoelastic material such as polyethylene creep under constant stress conditions (when internal pressure is applied and maintained) or suffer stress relaxation (when initial pressure is applied but not maintained).

When an initial pressure is applied but not maintained, the pressure in a polyethylene pipe under test will naturally decay as the pipe expands, so a simple pressure loss method is not appropriate (Marshall et al, 1995).

The pressure decay in a leaktight polyethylene piping system follows a linear relationship when plotted on a logarithmic scale, so any deviation from this line can be used as an indication that the pipeline is not leaktight.

Analysis of the measured values of pressure over the test period is used to reveal whether there is likely to be a leak in the pipeline.

3.2 Terminology

The terminology used in this document is consistent with BS EN 805: 2000 and product standards for plastic piping systems.

Allowable Operating Pressure (PFA): maximum hydrostatic pressure that a component is capable of withstanding continuously in service.

Design Pressure (DP): maximum operating pressure of the system or of the pressure zone fixed by the designer considering future developments but excluding surge.

Maximum Design Pressure (MDP): maximum operating pressure of the system or of the pressure zone fixed by the designer considering future developments.

Nominal Pressure (PN): numerical designation used for reference purposes related to the mechanical characteristics of the component of a piping system.

Note: For polyethylene pipes, PN corresponds to the Allowable Operating Pressure which can be sustained with water at 20° C with a design basis of 50 years and based on the minimum design coefficient. For most UK applications, PFA in bar corresponds to PN. Further information on this topic is given in IGN 4-32-18: 2003.

Replacement: construction of a new pipeline, on or off the line of an existing pipeline, where the function of the new pipeline system incorporates that of the old (source: BS EN ISO 11295: 2022).

Static Head (P_0): height, relative to an arbitrary reference level, of a column of water that can be supported by the static pressure at a given point.

System Test Pressure (STP): the hydrostatic pressure applied to a newly laid pipeline in order to ensure its integrity and tightness.

3.3 Overview of test methods

3.3.1 New pipelines

The System Test Pressure (STP) is calculated from the Design Pressure (DP) of the pipeline according to the system requirements determined by the designer.

The section of main under test is filled from the lowest point in a controlled manner and allowed to thermally stabilise.

The pressure is raised to STP, the pump is shut off and the section of main under test is isolated. The time to raise the pressure to STP determines the length of the test. The pressure is measured and recorded over the test period.

The results are plotted on a logarithmic scale and the slope (n) of the plot between two time points is calculated using a simple equation. Slopes are compared as a ratio. The test is considered 'a pass' if the ratio is within a defined range.

For the testing of new pipelines, see Sections 4, 5 and 8 of this document.

3.3.2 Replacement pipelines

The test described in 3.3.1 is only appropriate where the section of pipeline under test can be completely isolated.

Where new pipes are installed on the line of an existing pipeline, a 10-minute test can alternatively be used. This short duration, high pressure test provides assurance when used in conjunction with visual inspection whilst recognising the need for a quick return to service.

The pressure is raised to STP and maintained by pumping over a period of 10 minutes. The pressure and flow are measured and recorded over the test period.

The reduction in flow as the test progresses is compared to reference data. The test is considered 'a pass' if the reduction in flow is within a defined tolerance.

After connection to the existing pipeline, the joints between the replacement section and the live main are visually inspected for signs of leaks.

For the testing of replacement pipelines, see Sections 4, 6 and 8 of this document.

Note 1: This test is intended for use on a replacement section of pipeline no more than 200m in length, typically coiled pipe up to and including DN180 installed using a trenchless technique. For longer lengths and larger diameters, the test described in 3.3.1 should be used.

Note 2: The replacement section is not connected to the live main until this test has been successfully completed. This is to avoid the risk of failure of components which are rated below that of the replacement polyethylene pipe either through design or wear and tear.

3.3.3 Service connections

Service connections to pressurised water mains or sewers are a potential source of leakage and should be visually inspected and tested.

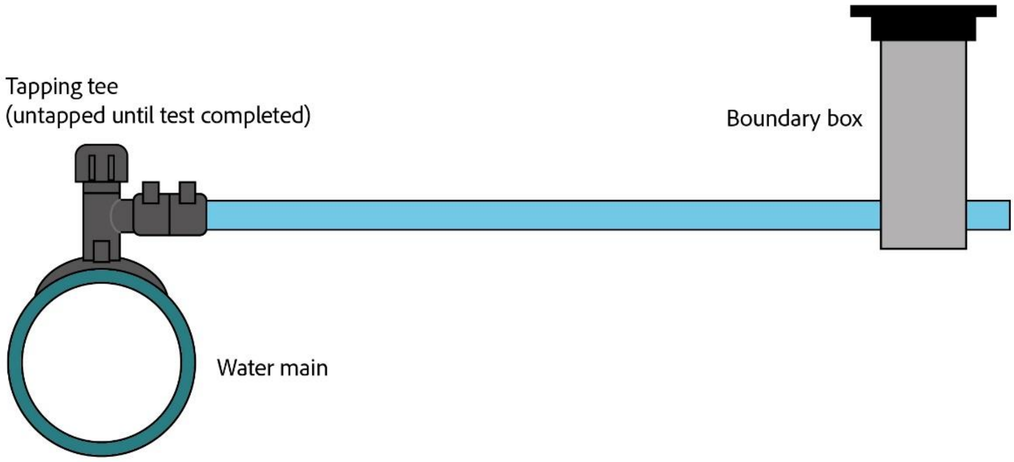


Fig. 1 Service connection

This short test has been designed to be quick and easy to conduct when used in conjunction with visual inspection. There is no data logging to support the reported result.

For the testing of service connections, see Sections 4, 7 and 8 of this document.

Note 1: This test is intended for use on service pipes up to DN 32 for new service connections to new pipelines or replacement pipelines.

Note 2: Service connections should be tested individually and not as part of the new pipeline. The services are made, but not tapped, until this test has been successfully completed.

3.3.4 Visual inspection for leakage

For polyethylene or polyethylene barrier pipes, leaks generally only occur at joints or welds. The integrity of most joints in the pipeline are assessed during the pressure test.

Where the pressure test indicates the presence of leakage, the pipeline should be depressurised to allow visual inspection. If there are no visible signs of water loss, a leak-noise correlator or other suitable leak detection method should be used.

Joints and welds which are not assessed during the pressure test, typically at each end of the test section, should be visually inspected for signs of leakage including damp patches on the surrounding ground.

4. GENERAL

4.1 Safety

In all hydraulic testing, there are dangers involved when high pressures are being employed. All applicable national health and safety regulations should be taken into account. Appropriate safe systems of work and risk assessment should be implemented and thorough risk assessment undertaken before pressure testing is commenced.

HSE guidance on safety requirements for pressure testing exists at www.hse.gov.uk/pressure-systems/index.htm. HSE documents GS4 "Safety requirements for pressure testing" and INDG261 "Pressure systems: A brief guide to safety" provide a useful entry point into the subject.

Testing should only be undertaken by organisations and individuals able to demonstrate their competence in this activity.

Only competent and trained persons who are aware of the risks should be allowed near any exposed part of the pipeline when it is under pressure.

Guidance is also available in BS EN 805: 2000 Section 11.

Specific hazards include, but are not limited to:

- High pressures can be dangerous if there is an unexpected pipeline failure.
- Forces on end fittings or thrust blocks during testing are high and insecurely anchored ends can lead to the end caps disengaging from the pipeline. Suitable temporary works should be installed.
- Residual air in the pipeline is compressed during testing and can lead to a massive and sudden release of stored energy if a failure occurs.
- Fluids other than potable water can introduce air or other gases into the pipeline.

Care should be taken to manage these hazards:

- The whole section should be backfilled before testing (see 4.2.1).
- End-load resistant fittings, temporary strutting, thrust blocks, backfilling or other means of securing the ends should be used to guard against separation of the pipe and fittings during the test.
- Test sections should be filled slowly from the lowest point to avoid any entrapped air being pressurised and storing energy (see 4.2.5).
- Air in the pipeline should be minimised through swabbing and the correct operation of valves (see 4.2.6).
- The impact of fluid on air content in the pipeline and on the environment when discharging after completion of the test should be considered.

4.2 Preparations

4.2.1 Backfilling and anchoring

Prior to the pressure test, it is essential that:

- Any thrust blocks or other anchorages are sufficient to withstand the thrust forces generated at the test pressure - in particular at changes in direction.
- Concrete thrust blocks have been cured to develop adequate strength.
- End caps and any temporary blanking fittings are fully end load bearing or adequately anchored to prevent separation from the pipe when pressure is applied.
- The section of pipeline to be tested has been backfilled and compacted. This prevents any axial movement and minimises temperature variance due to weather changes.

Joints and welds which are not assessed during the pressure test should be left exposed for visual inspection (see 3.3.4).

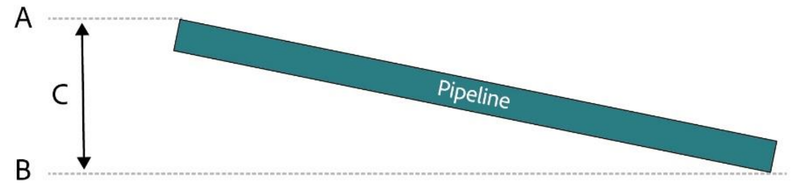
Temporary supports or anchorage at the ends of the test section should not be removed until the test is completed and the pipeline depressurised.

4.2.2 Choice of test section

The test sections should be selected so that after raising the pressure:

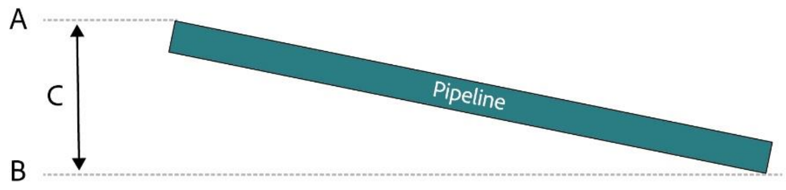
- the System Test Pressure (STP) can be achieved at the lowest point of each test section; <u>and</u>
- the pressure at the highest point of each test section is not less than the Design Pressure (DP), unless otherwise specified by the pipeline designer.

Figures 2(a) and 2(b) illustrate pressures at elevations along a test section



A = highest point of pipeline being tested with air vent open
B = lowest point of test section with pump and pressure gauge. Pressure on gauge = static head due to weight of water (bar)
C = elevation (m)

Fig. 2 (a) Pressures in test section - Pipeline filled, no pressure applied



A = highest point of pipeline being tested. Pressure ≥ DP (bar)
B = lowest point of test section with pump and pressure gauge. Pressure on gauge = STP = 1.5 x DP (bar)
C = elevation (m)

Fig. 2(b) Pressures in test section – Pipeline filled and pressure applied by pumping

There is no theoretical limit to the maximum length of section that can be tested, but consideration should be given at the planning stage to:

- The availability of water for testing (see 4.2.5) and the point of discharge after the test (see Clause 8).
- The number of joints and fittings in the proposed test section and the ability to efficiently identify the source of any leak detected.
- The ability to minimise air content in the test section.
- The overall time available in which to carry out the test as the time needed for the test is linked to the time (t_P) to pump the section up to STP (see 5.1).
- The pipe materials in the proposed test section.

It is best practice to test different materials separately and especially viscoelastic / non viscoelastic materials. Test sections should be selected accordingly.

Where short lengths of pipe of other materials and metallic fittings (e.g. a puddle flange) are present in a polyethylene pipeline, the detection of any leaks could be masked by the viscoelastic behaviour of polyethylene pipe. These lengths and any joints connecting them to the polyethylene pipeline should be left exposed and be visually inspected.

Note 1: Isolation of the test section can be provided by blanking plates but not by components such as valves and hydrants.

Note 2: For guidance on the test section for the 10-minute replacement pipeline test, see Note 1 to 3.3.2.

4.2.3 Choice of System Test Pressure (STP)

4.2.3.1 Values determined by the pipeline designer

When planning the pipeline project, the designer determines the design pressure (DP) and the maximum design pressure (MDP) for the system considering the intended use and future use of the pipeline.

For polyethylene pipes, MDP and DP can be assumed to be identical (see explanation in Note).

Each component to be used in construction of the pipeline should be specified so that the maximum hydrostatic pressure that the component is capable of withstanding continuously in service (PFA) is greater than the design pressure (DP) for the system i.e. PFA > DP.

Note: Where there is a short-term increase in pressure from a surge event, the associated energy is absorbed by the viscoelastic behaviour of the polyethylene material.

IGN 4-37-02 : 1999 shows that the maximum pressure that a PE pipe is capable of withstanding during a surge event is two times its maximum rated pressure (PN) which it is capable of withstanding in long-term service.

When calculating MDP for polyethylene pipes and polyethylene barrier pipes, conforming to BS EN 12201-2 and BS 8588 respectively, no additional factors need be included to account for the effect of surge on the pipe. MDP and DP can be assumed to be identical.

Further information on choice of pressures ratings is given in IGN 4-32-18: 2003.

4.2.3.2 Calculation of System Test Pressure

The test is carried out at the System Test Pressure (STP).

To ensure the leak tightness of the pipeline is confirmed, the magnitude of STP needs to be greater than that of the Design Pressure of the system (DP).

(a) For a new pipeline

When testing a new polyethylene or polyethylene barrier pipeline (see 3.3.1), STP is calculated as follows:

- STP = 1.5 x MDP or MDP + 5 bar (whichever is the lower of the two values).
- For polyethylene pipes, MDP = DP (see 4.2.3.1).

When planning a new polyethylene pipeline and at the design stage, the calculated value of STP should be checked as follows to confirm that the viscoelastic test procedure in this document is suitable (see explanation in Note 1):

- If the calculated value of STP is ≥ 0.7 x PN, then this test procedure would deliver valid results and the test can proceed.
- If the calculated value of STP < 0.7 x PN, the results would be invalid. Suitable adjustments to the pipeline design or test procedure (see Note 2) should be made prior to testing.

Example calculations and selection of STP are given in Table 1.

Note 1: Checking the calculated value of STP against PN is only used to confirm that the viscoelastic test procedure is suitable. It does not mean that STP is set to 0.7 x PN. STP is always calculated using the equation in 4.2.3.2 (a).

The viscoelastic behaviour of PE pipes occurs when the stress in the pipe wall exceeds a value determined by the strength of the PE material and the stiffness of the pipe.

The correct application of the pressure test is achieved when STP is greater than 0.7 x PN.

This ensures that the viscoelastic response is achieved and the test delivers valid results.

Note 2: If STP < 0.7 x PN, suitable adjustments should be made at the design stage to either the choice of pipe (review the pipe specification against the operating requirements) or the choice of STP.

Where it is not possible to reduce the pressure rating of the pipe, for example the pipe is selected to meet structural design requirements, the value of STP needs to be increased to at least 0.7 x PN. In this case, there is a risk that STP might exceed 1.5 x PFA of other pipeline components, so great care needs to be taken to protect these by choice of test section to prevent damage during the pressure test.

(b) For a replacement pipeline

When testing a replacement pipeline (see 3.3.2) of polyethylene or polyethylene barrier pipe, SDR 11 or SDR17, up to DN 180: STP is 15 bar.

(c) For a service connection

When testing a service connection (see 3.3.3) of polyethylene or polyethylene barrier pipe, SDR 11, up to DN 32: STP is 18 bar.

Table 1: Examples showing selection of STP for testing a new pipeline

Design Pressure DP determined by the pipeline designer (bar)	**Pipe classification (shows typical selection for DP in Column 1)**	**Calculation of System Test Pressure (bar)**		**Pressure to activate viscoelastic response (bar)**	**Test Pressure selected (bar)**
		1.5 x DP	DP + 5	0.7 x PN	
1	PN 6	1.5	6	**4.2**	4.2
2	PN 6	3	7	**4.2**	4.2
3	PN 6	**4.5**	8	4.2	4.5
4	PN 6	**6**	9	4.2	6
5	PN 6	**7.5**	10	4.2	7.5
6	PN 6	**9**	11	4.2	9
7	PN 8	**10.5**	12	5.6	10.5
8	PN 8	**12**	13	5.6	12
9	PN 10	**13.5**	14	7	13.5
10	PN 10	**15**	15	7	15
11	PN 12.5	16.5	**16**	8.75	16
12	PN 12.5	18	**17**	8.75	17
13	PN 16	19.5	**18**	11.2	18
14	PN 16	21	**19**	11.2	19
15	PN 16	22.5	**20**	11.2	20
16	PN 16	24	**21**	11.2	21

Notes to Table:

- For pipelines with design pressures greater than 16 bar, the polyethylene pipe manufacturer can advise on suitable pipe classification.
- The STP selected in these examples are highlighted and also shown in Column 6.

4.2.4 Elevations along the test section

When testing a pipeline with high points along its section, the test equipment (gauge and logger) should ideally be located at the lowest point of the test section. Air vents should be located at all high points of the test section.

The pressure at the lowest point is achieved by a combination of the Static Head (the pressure due to the weight of water in the pipeline above the lowest point) and raising the pressure using a pump.

After filling the pipeline and before commencement of the test, pressure at the lowest point should be equal to Static Head (P_0) in bar.

After raising the pressure at the start of the test, the pressure at the lowest point should be equal to STP in bar (see 4.2.3.2).

If the test equipment (gauge and logger) is located higher than the lowest point on the pipeline, a correction needs to be made to ensure that the pressure at the lowest point meets but does not exceed these values.

The gauge pressure should be:

- After filling the pipeline and before commencement of the test

$$gauge\ pressure = P_0 - \left(\frac{vertical\ distance\ between\ gauge\ and\ lowest\ point}{10}\right) \quad \text{(Equation 1)}$$

where P_0 (Static Head) is in bar and distance is in metres.

- After raising the pressure at the start of the test

$$gauge\ pressure = STP - \left(\frac{vertical\ distance\ between\ gauge\ and\ lowest\ point}{10}\right) \text{(Equation 2)}$$

where STP is in bar and distance is in metres.

To ensure that the pressure at the lowest point does not exceed STP, the pressures at the highest points are necessarily less than STP.

To ensure the leaktightness of the pipeline is confirmed, the test section should be selected so that, after raising the pressure at the start of the test, the pressure at the highest point in the test section is not less than the Design Pressure (DP), (see 4.2.2). If this is not possible, the test section should be further divided.

4.2.5 Filling the test section

Sufficient water should be available to fill and complete the test without interruption. The volume of water to fill the test section should be established (see Note 1).

The main should be filled slowly and completely from the lower end, with all air valves open and an open valve at the highest point.

Care needs to be taken that, when filling the test section from the water supply system, the pressure at the lowest point of the test section does not exceed the Static Head (see Note 2).

If immediately after filling, leaks are apparent, the faults should be rectified. This might require emptying and refilling the pipeline.

After filling the test section and removing air (see 4.2.7), the valve at the highest point should remain open to ensure that the pressure is zero (i.e. no static head) at that point. The filled test section should be left in this unpressurised state for a minimum period of 2-3 hours to allow the temperature of the water and in the pipe wall to equalise (see Note 3).

Note 1: Guidance on the volume of water needed to fill and raise the pressure in the test section to the System Test Pressure is given in Appendix A.

Note 2: If the pressure is accidentally raised above Static Head at the lowest point during filling, it is important that water is bled from the highest point of the test section to reduce the pressure for a period of no less than 4 x t (where t is the total time for which the pressure exceeded the static head at the lowest point) prior to commencing the test. Holding the test section at the System Test Pressure prior to commencing the test (known as pre-conditioning) or starting the test at a raised pressure invalidates the test (see 5.1).

Note 3: Large diameter, thick-walled pipes might require a longer period to reach thermal stability. Advice may be sought from the polyethylene pipe manufacturer.

4.2.6 Removal of air

Due to the risks involved in testing where air is present in the test section (see 4.1), ideally all air should be removed from the test section during, and after, filling with water and before the start of the test procedure. The method of work should adequately describe methods for the removal of air.

To assist in this:

- Air valves should be functioning correctly.
- Air valves should not be closed during filling.
- Non-self-sealing air vents should be used to vent the pipeline and then closed before the start of the test.
- A foam swab should be used ahead of the water column to assist the removal of air.
- Swabbing should be carried out as one continuous operation and at sufficient velocity to prevent the swab stalling and getting trapped in the pipeline.
- Swabbing should be carried out from the lower end (i.e. uphill) so that the swab can be removed prior to testing.

Practically, some trapped or entrained air might persist and the procedure described in 5.1 provides a method of assessing residual air content prior to applying any pressure to the pipeline. The responsible parties should determine whether it is safe to conduct the pressure test with the volume of air assessed to be present.

The length and diameter of a pipeline under test influences stored energy that results from compression of any air remaining within the pipeline during testing. The location, and maximum spacing between, any air valves present in the test section should be considered when assessing whether to proceed with the test.

Additionally, air in the pipeline can impact on interpretation of the results (see 5.1). The presence of air in a test section markedly increases the pressure rise time (t_P) and consequently the period over which pressure decay readings need to be taken. It will also distort the interpretation of pressure decay results. To deliver a valid test result whilst minimising the overall duration of the test, the maximum air content in a pipeline prior to conducting a pressure test should be limited to 4% of the internal volume of the test section.

Where air content in a pipeline prior to conducting a pressure test exceeds 4%, the test should not proceed as the result would not be valid.

4.2.7 Testing pipelines where the pipe surface is exposed

Wherever possible, the pipeline should be backfilled prior to testing (see 4.2.1). Where this is not possible, pressure testing should not be undertaken if there is a risk that the temperature on the outer surface of the pipe during the test might exceed 20°C (see explanation in Note).

Note: The allowable operating pressure for the pipe (PFA) would temporarily be reduced due to the increased temperature. There is a risk that pressuring the system to STP determined in accordance with 4.2.3.2 could lead to rupture of the PE pipe.

4.3 Test apparatus

Figure 3 shows the test equipment typically used for the pressure test.

Prior to the pressure test, it is essential that equipment is checked to be in good working order, calibrated and fitted correctly to the test section.

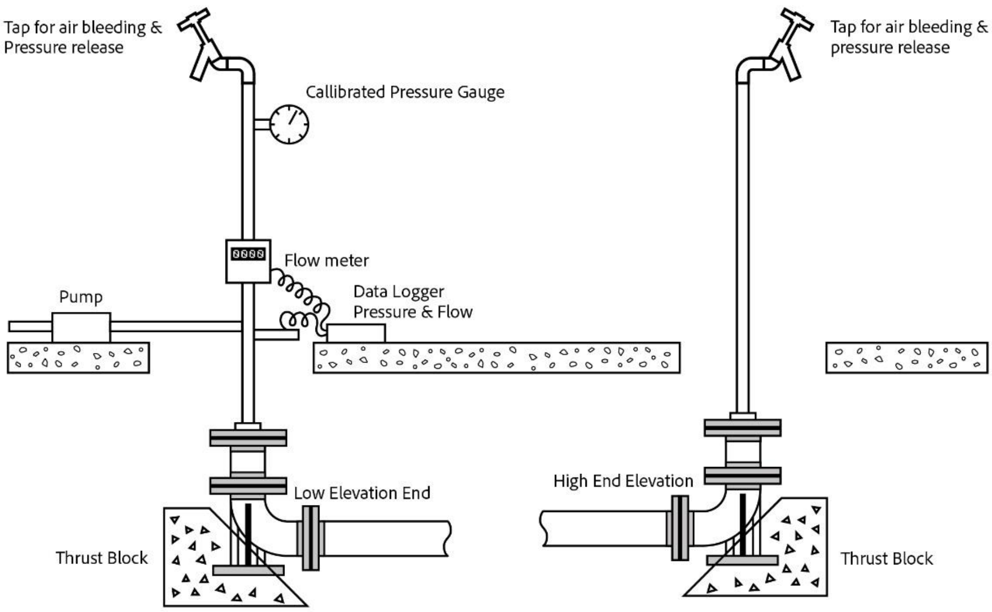


Fig. 3 Schematic of test apparatus layout

Air valves: Valves to facilitate the removal of air during filling.

Data logger system: a calibrated pressure transducer and logger (typically linked to a meter to record flow) with pressure recording interval of 0.01 bar or better and time recording interval of 10 seconds or better. Accuracy ± 0.2% Full scale 0-50°C.

Flow meter:

- For new pipelines (see 3.3.1), a calibrated flow meter with a resolution of 1 litre or better to measure and record the volume of water added as the pressure is raised to STP.
- For the 10-minute replacement pipeline test (see 3.3.2), a calibrated flow meter with a resolution of 0.1 litre or better to measure and record the volume of water added as the pressure is raised to STP.

GPS: To allow test location to be identified and recorded. Where required, this is typically fitted to the data logger.

Pipeline fittings: Fittings to facilitate the filling and pumping of the water, swabbing to purge air and water removal, typically tapped blank end plates, hydrants or ferrules.

Pressure gauge: A calibrated digital pressure gauge with a 0.01 bar resolution or better. Accuracy ± 0.2% Full scale 0-50°C.

Pump:

- For new pipelines (see 3.3.1), a pump with the capacity to raise the pressure smoothly to System Test Pressure within 30 minutes.
- For the 10-minute replacement pipeline test (see 3.3.2), a pump with the capacity to raise and hold the pressure at STP over the test period and measure the volume of water added using a flow meter.
- For the service connection test (see 3.3.3), a pump capable of delivering positive pressure.

5. TEST PROCEDURE FOR NEW PIPELINES

Note: Information on preparations for testing, choice of test section and apparatus for testing is given in Section 4.

5.1 Raising test pressure and checking air content

The pressure in the test section shall not be increased above the Static Head (P_0) at any time prior to commencement of the test (see Note 1).

At the start of the test, the pressure shall be raised to STP by pumping in a controlled manner.

The time to raise the pressure to STP shall be no longer than 30 minutes (see Note 2).

The pressure change (rise) and the volume of water added shall be continuously logged.

Prior to commencement of the test and using Appendix A, the volume of water required to raise STP shall be calculated for percentage volumes of air from 0% to 4%. This is used to determine the volume of air present in the test section. The volume of water added to raise the pressure to STP shall be compared to the volume of water calculated to raise STP. If the actual volume of water added to raise the pressure to STP is more than predicted, it is likely that air is present.

The percentage of air in the system determines the next stage in the testing, as follows:

- For air content 0% - 4% and following a decision by the responsible parties (see 4.2.6), the test may proceed in accordance with 5.2 – 5.5.
- For air content > 4%, the test shall not proceed as the test would not be valid.

Note 1: Any pressure above Static Head before the start of the test would mean that the time to raise the pressure to STP (t_P) would be lower than the true value to raise pressure from zero to STP. Subsequent pressure readings would not be taken at the correct time intervals and the test outcome would not be valid. Calculation of air content would also be affected.

Note 2: A shorter 'ramp-up' time (t_P) is preferred as this minimises the length of the overall test.

5.2 Data collection

After the System Test Pressure (STP) has been reached, the test section shall be isolated from the pump and the pump shut off.

The pressure change (decay) shall be continuously logged over a minimum pressure decay time, t_3, where t_3 is determined by the time to raise the pressure (t_P) and is a minimum of 20 x t_P (see Note).

Where 20 x t_P is less than 1 hour, the length of the test is extended to 1 hour by taking a further pressure decay time, t_4, see Appendix B.

The data shall be analysed whilst the test is in progress, i.e. as the pressure decays, to check for the presence of leaks.

Note: Minimum test duration is given here. Additional data points could provide increased confidence in test results.

5.3 Data use

Figure 4 shows a typical pressure v time graph.

The Static Head on the pipeline (P_0) is a fixed value and does not decay over time (see 4.2.4). All pressures shall be displayed and analysed discounting the static head as shown in Equation 3.

$$Pressure\ P = Gauge\ Pressure - P_0 \qquad \text{(Equation 3)}$$

After STP has been reached and the test section isolated (time t_0), the pressure may fluctuate. Data collected in the period t_0 to t_1 (equal to t_p, see Figure 1) shall not be included in the analysis.

5.4 Analysis of results

5.4.1 Step 1 – Pressure data

The pressures (P_1 at t_p, P_2 at $8t_p$, P_3 at $20t_p$) shall be read from the graph at times (t_1, t_2, t_3). These pressures are used to calculate the rate of decay (see 5.4.3).

5.4.2 Step 2 - Correcting for creep during pressurisation time

During the time spent in raising the test section to STP (t_P), the polyethylene pipe creeps under the internal pressure. To account for this behaviour, a factor shall be added to each of the times (t_1, t_2, t_3) for calculating the rate of decay (see 5.4.3).

A factor of 0.4 x t_P is added, such that the correct decay times (t_{c1}, t_{c2}, t_{c3}) are:

- $t_{c1} = (0.4 \times t_P) + (t_P)$
- $t_{c2} = (0.4 \times t_P) + (8t_P)$
- $t_{c3} = (0.4 \times t_P) + (20t_P)$

5.4.3 Step 3 - Calculating rates of decay

A graph of the pressures (P_1, P_2, P_3) against the corrected decay times (t_{c1}, t_{c2}, t_{c3}) shall be plotted on logarithmic axes.

Figure 5 shows a typical graph of pressure v corrected decay times on logarithmic axes.

The rate of decay shall be calculated using the pressure change between the times t_{c1} and t_{c2} (slope n1) and the pressure change between the times t_{c2} and t_{c3} (slope n2) as shown in Equations 4 and 5.

$$n1 = [\log(P_1) - \log(P_2)] / [\log(t_{c2}) - \log(t_{c1})] \qquad \text{(Equation 4)}$$

$$n2 = [\log(P_2) - \log(P_3)] / [\log(t_{c3}) - \log(t_{c2})] \qquad \text{(Equation 5)}$$

Note 1: Where a fourth reading is taken, see 5.2 and Appendix B.

Note 2: The value of n is dependent on numerous factors and cannot be used to determine leaktightness. For PE pipes, the value of n is typically in the range -0.07 and -0.1. A value of less than -0.06 might indicate pre-pressurisation of the pipeline. No great significance should be placed on the absolute value provided that it is within this range. For PE barrier pipes which exhibit less creep, the absolute values may be lower.

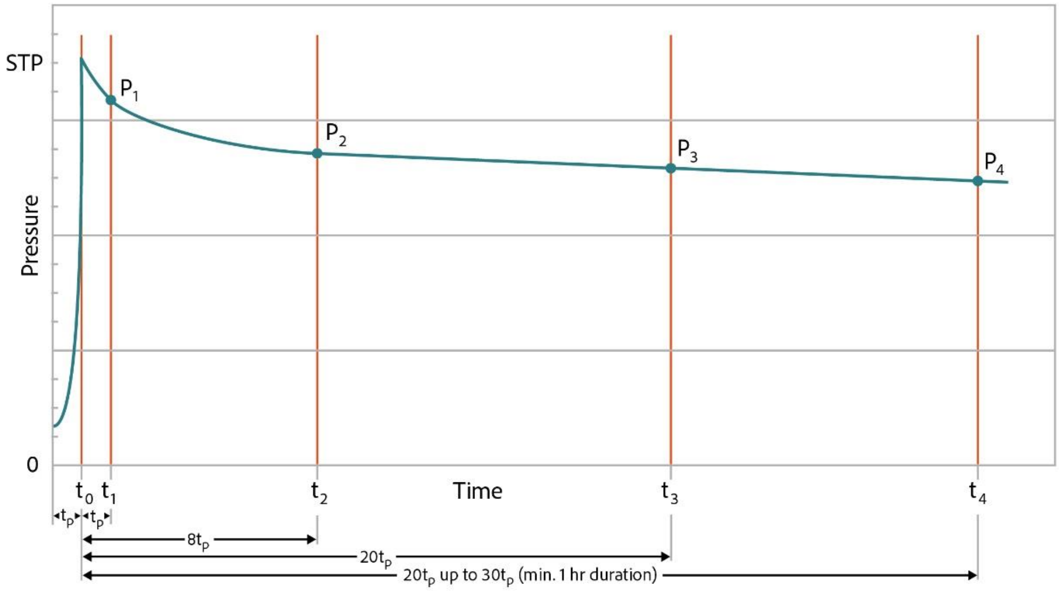


Fig. 4 Typical pressure v time graph (showing test extended to fourth reading)

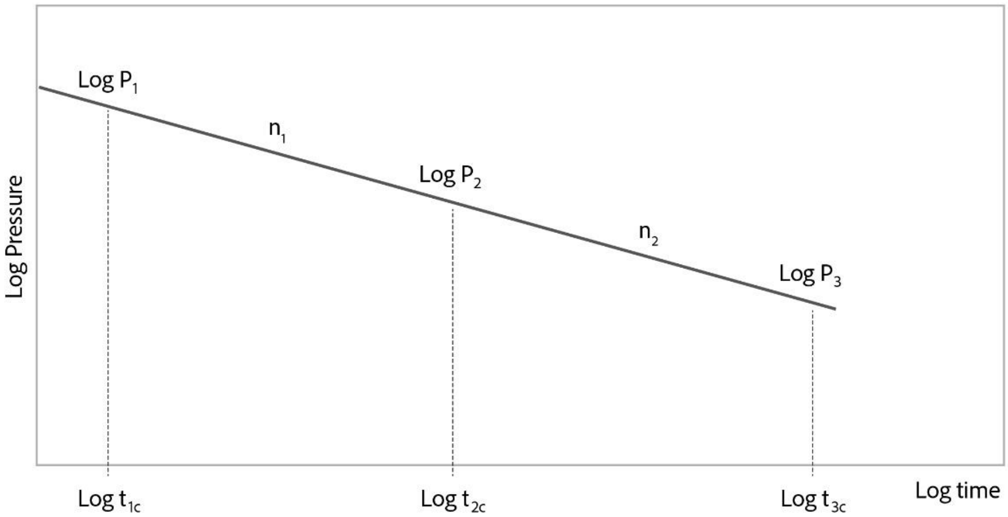


Fig. 5 Typical graph of pressure v corrected decay times on logarithmic axes

5.4.4 Step 4 – Checking results against pass / fail criteria

n2/n1 is used to indicate whether there is leakage in the system as illustrated in Figure 6.

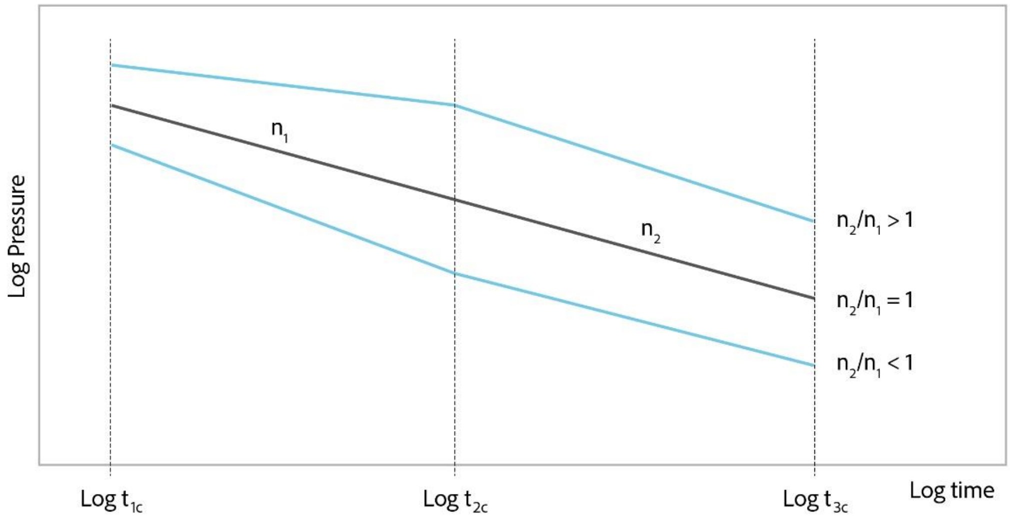


Fig. 6 Slopes n1 and n2

<u>If n2/n1 lies between 0.75 and 1.25</u> (see Note 1), then the test is a pass.

If n2/n1 is near the upper limit (i.e. between 1.1 and 1.25), it is recommended that data is re-analysed to confirm that the result is within the pass envelope as follows:

- Plot all logged pressure data between t_1 and t_3 using a spreadsheet program.
- Determine power law trendlines for the two time periods t_{c1} to t_{c2} and t_{c2} to t_{c3}; and
- Check n2/n1 against the pass criteria above.

<u>If n2/n1 lies outside of the range 0.75 to 1.25,</u> the pressure decay is unacceptable and could indicate the presence of leaks or air. The test shall be stopped and the following action taken:

- the test section shall be depressurised slowly (i.e. until the pressure at lowest point of the test section is returned to Static Head, see 4.2.5);
  - the pipeline shall be inspected for signs of leaks and air content checked and action taken to rectify the problem; and
  - the test shall be repeated after a period of no less than 4 x t (where t is the total time to raise the pressure to STP and to carry out the first test), (see Note 2).

Note 1: The pressure decays with a constant power law slope. The slope is proportional to the leakage rate. In a leaktight system, n2 /n1 is 1.0. Computer analysis has shown that, assuming air content of up to and including 4%, a 25% change in slope corresponds to the maximum allowable pressure loss specified in BS EN 805: 2000. The minimum value for n2/n1 is therefore 0.75 (75%) and the maximum value 1.25 (125%).

Note 2: This period between tests allows the pipe to recover its original dimension. If this is not done, the effect is the same as starting the test at a raised pressure and the test is invalid.

Note 3: Where a fourth reading is taken, see 5.2 and Appendix B.

5.5 Recording of test results

A report shall be prepared for the test, containing as a minimum:

- The name, company and contact details of the person carrying out the test.
- The date, start and finish time, location including GPS co-ordinates.
- Plan of the site including elevations, and other significant features.
- Plan of the test section showing length, elevations, static head, location of air valves, test equipment and filling points.
- Details of the pipe under test – pipe materials, dimensions, pressure rating, fittings.
- The System Test Pressure (STP).
- Test equipment records including maximum range, precision and calibration history of flow meter and pressure gauges.
- All logged measurements of the pressure and flow and the volume of water added during the pressure rise phase.
- All logged measurements of the pressure during the pressure decay phase.
- Details of any analysis carried out in accordance with the method described in this document.
- Outcome of test (pass / fail).
- Causes of failure, if appropriate, and any remedial action taken.

6. TEST PROCEDURE FOR REPLACEMENT PIPELINES

Note: Information on preparations for testing, choice of test section and apparatus for testing is given in Section 4.

6.1 Raising test pressure

The pressure shall be raised to System Test Pressure (STP) by pumping in a controlled manner.

The flow rate to hold the pressure at STP shall be checked to ensure that rate measurements can be taken consistently over the test period. This determines the next stage in the testing as follows:

- If after reaching STP, the flow rate drops to 0.06 litres / second or less (i.e. 0.6 litres in 10 seconds or less), the test may proceed.
- If after reaching STP, the flow rate does not drop to 0.06 litres / second or less, there is almost certainly a leak in the system which shall be identified and rectified and the test repeated.

6.2 Data collection

The pressure shall be maintained by pumping for 1 minute to stabilise the system prior to commencing the 10-minute test.

After stabilisation for 1 minute, the pressure shall be maintained by pumping for a test period of 10 minutes.

The pressure and the flow rate shall be continuously logged over the test period in 10-second increments.

The test is considered to be ‘a fail’ if during the test:

- the maintained pressure changes by more than 0.1 bar on 2 consecutive data points (10-second increments); or
- the test period of 10 minutes is not achieved and/or data are not recorded for the full period.

In the case of a ‘fail’, the problems shall be identified and rectified before repeating the test.

6.3 Analysis of results

6.3.1 Volume of water

The data from the 10-minute test shall be analysed in three stages of equal times (i.e. 3 mins 20 secs per stage).

The total volume of water input in each stage shall be calculated using flow rate and time to give V_1, V_2 and V_3 for Stages 1, 2 and 3 respectively.

The test is considered to be ‘a fail’ and problems shall be identified and rectified and the test repeated, if any of the following occur:

a) Either $V_2 > V_1$ or $V_3 > V_2$.

b) $V_1 < 0.2$ litres and V_2 is zero.

c) $V_2 < 0.2$ litres and V_3 is zero.

Note: The volumes in (b) and (c) above assume that each stage is 3 minutes 20 seconds. Where this is not the case, the total volume of water input in the stage (V) should be corrected such that the corrected volume V_c = (V x 3.33)/(time taken for stage in minutes). The test is ‘a fail’ if $V_{2c} < 0.2$ litres and V_3 is zero or $V_{1c} < 0.2$ litres and V_2 is zero.

6.3.2 Checking results against pass / fail criteria

The percentage reduction in total volume of water input between Stage 2 and Stage 3 is used to indicate whether there is leakage in the system.

The percentage reduction in total volume between Stage 2 and Stage 3 is calculated using Equation 6.

$$Percentage\ reduction = \frac{(V_2 - V_3)}{V_2}.100 \qquad \text{(Equation 6)}$$

For test sections up to and including 150 m in length, the minimum percentage volume reduction shall be 20%.

For test sections greater than 150m in length, the minimum percentage volume reduction shall be 18%.

If the percentage reduction is greater than or equal to these values and there is no visible leakage at the joints, then the test is a pass.

For values outside of this range, the reason should be established, and action taken to rectify the problem.

6.4 Recording of test results

A report shall be prepared for the test in accordance with 5.5.

7. TEST PROCEDURE FOR SERVICE CONNECTIONS

Note: Information on preparations for testing, choice of test section and apparatus for testing is given in Section 4. The service should not be tapped until this test has successfully been completed.

7.1 Raising test pressure

The test section shall be filled with water.

The pressure shall be raised to System Test Pressure (STP) by pumping in a controlled manner.

The pressure shall be maintained by pumping for a test period of 2 minutes. The test section shall be inspected visually throughout the test period.

The test is considered a 'fail' if, during the test, there are visible signs of water loss. The problems shall be identified and rectified before repeating the test.

If there are no visible signs of water loss, the test is a 'pass'.

7.4 Recording of test results

A report shall be prepared for the test , containing as a minimum:

- The name, company and contact details of the person carrying out the test.
- The date, start and finish time, location including GPS co-ordinates.
- Details of the pipe under test – pipe materials, dimensions, pressure rating, fittings.
- The System Test Pressure (STP).
- Outcome of test (pass / fail).
- Causes of failure, if appropriate, and any remedial action taken.

8. PRESSURE RELEASE AND DISCHARGE OF WATER

When the pressure test has been satisfactorily completed, the test section shall be depressurised slowly and the water discharged safely from the pipeline.

Note: Guidance on the disposal of water can be found in the 'Protocol for the disposal of contaminated water and associated wastes at incidents' jointly issued by Water UK, Environment Agency, NIEA, Natural Resources Wales, DWI, Fera, Defra's CBRN Recovery Team, NFCC National Resilience and available via https://www.water.org.uk/ .

9. REFERENCES

BS 8588 Polyethylene pressure pipe with an aluminium barrier layer and associated fittings for potable water supply in contaminated land. Size 20 mm to 630 mm. BSI.

BS EN 12201-2 Plastics piping systems for water supply, and for drains and sewers under pressure. Polyethylene (PE) – Pipes. BSI.

HSE Guidance Note GS4 Safety requirements for pressure testing.

HSE Leaflet INDG261 Pressure systems: A brief guide to safety.

Protocol for the disposal of contaminated water and associated wastes at incidents: jointly issued by Water UK, Environment Agency, NIEA, Natural Resources Wales, DWI, Fera, Defra's CBRN Recovery Team, NFCC National Resilience.

Dated references:

The development of a mains pressure test for PE and PVC pressure pipes. GP Marshall, MW Birch, K Morley. 1995. (https://plasticpipesconference.com/)

BS EN 805: 2000 Water supply - Requirements for systems and components outside buildings. BSI, 2000.

BS EN ISO 11295: 2022 Plastics piping systems used for the rehabilitation of pipelines. Classification and overview of strategic, tactical and operational activities.

IGN 4-01-03: Issue 2: 2015 Pressure testing of pressure pipes and fittings for use by public water suppliers. Water UK.

IGN 4-37-02: 1999 Design against surge and fatigue conditions for thermoplastic pipes. Water UK.

IGN 4-32-18: 2003 The choice of pressure ratings for polyethylene pipe systems for water supply and sewerage duties. Water UK.

APPENDIX A. ESTIMATE WATER INPUT VOLUME

A.1 Introduction

For new pipelines, the pressure should be raised smoothly to System Test Pressure (STP) within 30 minutes. The estimated water input volume can be calculated (see A.2) to assist in the choice of pump and projected test duration.

A.2 Volume of water to fill the test section (unpressurised)

Where there is no air present, the volume of water to fill the unpressurised test section is equal to the internal volume of the pipe.

Therefore, volume of water to fill the test section (m^3) is given by Equation A.1.

$$V_0 = \left(\pi . \frac{d^2}{4} . L\right) \quad \text{(Equation A.1)}$$

Where:

d = internal diameter of pipe (m)

L = length of test section (m)

(1 m^3 = 1000 litres)

Table A.1 gives example values for internal volume of a 100m length of polyethylene or polyethylene barrier pipe.

Using Table A.1, where there is no air present in the pipeline prior to pressurisation, the values in Table A.1 can be taken to be the volume of water to fill a 100m unpressurised test section. For example, the volume of water to fill an unpressurised test section of 100m of 63mm diameter, PE100, SDR 11 is 207 litres.

Volumes for other lengths of test section can be calculated on a pro-rata basis.

Note: Where air is present in the unpressurised test section, the combined volumes of water and air equates to the internal volume of the test section.

Table A.1: Volume of water to fill a 100m length of test section (no air present, unpressurised)

Nominal diameter DN / OD	Internal volume of 100m test section (litres) [a] = Volume of water to fill test section (no air present, unpressurised), V_0		
	PE 100 SDR 11[b]	PE 100 SDR 17	PE 100 SDR 21
63	207	241	255
75	296	342	361
90	425	493	520
110	636	736	776
125	820	954	1003
140	1031	1196	1259
160	1344	1561	1642
180	1702	1976	2082
200	2102	2438	2567
225	2659	3085	3249
250	3288	3815	4019
280	4126	4784	5035
315	5220	6052	6379
355	6633	7685	8103
400	8419	9765	10281
450	10648	12354	13010
500	13151	15247	16060
560	16504	19136	20157
630	20879	24210	25518
710	26512	30758	32391
800	33675	39058	41146
900	42614	49440	52066
1000	52604	61015	64269
1200	-	87881	92561

Notes to Table:
a) 10°C has been selected as the reference temperature as this is a typical value for buried water supply pipelines. See IGN 4-32-18: 2003. An increase in the temperature of the pipe material by 1°C would cause the material modulus to reduce slightly and, if the pipeline is free to change in length, would cause the pipe to expand. Volumes should be decreased by approximately 1.35% per degree for temperatures below 10°C and increased by approximately 1.35% per degree for higher temperatures.
b) For PE80 / SDR 11 pipe, the volume of water to fill a test section (100m long at 10°C) is 131 litres for DN50 and 208 litres for DN63.
c) Volumes have been calculated using values from BS EN 12201-2 & BS 8588 for minimum OD and minimum wall thickness.

A.3 Volume of water to raise pressure to STP

Once the test section has been filled (see A.2), the additional volume of water required to raise the pressure from the unpressurised state (i.e. gauge pressure equal to Static Head at the lowest point of the test section, see 4.2.4) to STP can be calculated from first principles using thin-walled cylinder theory but is complex and time-consuming.

Tables A.2 – A.4 therefore provide look-up tables of values established for IGN 4-01-03: Issue 2: 2015 and updated for this document.

Using Tables A.2 – A.4 where there is no air present in the pipeline prior to pressurisation, *Column 2* gives the additional volume of water in litres to raise the pressure in a 100m length of polyethylene or polyethylene barrier pipe from the unpressurised state to 10 bar.

Example, where there is no air present (0%) in the test section after filling, the volume of water to raise the pressure from the unpressurised state to 10 bar for a test section of 100m, 63mm diameter, PE100, SDR 11 is 2 litres.

For other test section lengths and System Test Pressures, Equation A.2 can be used to calculate the additional volume of water to raise the pressure to STP from the values provided in Tables A.2 – A.4

$$V_p = V_{p10} . \left(\frac{STP}{10}\right) . \left(\frac{L}{100}\right) \qquad \text{(Equation A.2)}$$

Where:

V_{P10} = volume of water to raise the pressure in a test section of 100m from zero to 10 bar, given in Table A.2 (litres)

STP = System Test Pressure (bar)

L = length of test section (m)

($1m^3$ = 1000 litres)

A.4 Using volume of water added to estimate percentage of air in system

If air is present, a larger volume of water is required to raise the pressure from the unpressurised state (i.e. gauge pressure equal to Static Head at the lowest point of the test section, see 4.2.4) to STP as the air is compressed.

Tables A.2 – A.4 provides look-up tables of values for volume of water for air content (i.e. percentage air prior to pressurisation) of 1% - 4%.

Using Tables A.2 – A.4 where there is air present in the water prior to pressurisation, *Columns 3 - 6* give the additional volume of water in litres to raise the pressure in a 100m length of polyethylene or polyethylene barrier pipe from the unpressurised state to 10 bar.

Example, where 1% of the internal volume of the test section after filling was air, the additional volume of water to raise the pressure from the unpressurised state to 10 bar for a test section of 100m, 63mm diameter, PE100, SDR 11 is 4 litres (Column 3 of Table A.2). Where 2% of the internal volume of the test section after filling was air, the additional volume of water for the same test section is 6 litres (Column 4 of Table A.2).

For other test section lengths and System Test Pressures, Equation A.2 can be used to calculate the additional volume of water to raise the pressure to STP from the values provided in Tables A.2 – A.4.

The measured volume of water added can be used to estimate the volume of air in the test section. Prior to commencing the test, the volume of water corresponding to air content up to 4% should be calculated and recorded. A flow meter and logger should be used to monitor the volume of water being added during the pressurisation phase.

Where the monitoring shows that the volume of water added is reaching the value corresponding to air content up to 4% and STP has not been attained, the test should immediately be stopped as any results would be invalid and the system safely depressurised (see 4.2.6).

Table A.2: Additional volume of water to raise the pressure in 100m long test section to 10 bar in presence of air – PE 100 SDR 11

Nominal diameter DN / OD	Volume of water to raise pressure in 100m long test section from 0 bar to 10 bar (litres) [a]				
	Percentage of the internal volume of the test section filled with air after filling (prior to applying pressure)				
	0%	1%	2%	3%	4%
63	2	4	6	8	10
75	3	6	9	11	14
90	5	8	12	16	20
110	7	13	19	24	30
125	9	16	24	31	39
140	11	21	30	39	49
160	15	27	39	51	63
180	19	34	49	65	80
200	23	42	61	80	99
225	29	53	77	101	126
250	36	66	96	126	155
280	45	83	120	158	195
315	57	105	152	199	247
355	73	133	193	253	314
400	92	169	245	322	398
450	116	213	310	406	503
500	144	263	383	502	622
560	181	331	481	630	780
630	229	418	608	797	987
710	290	531	771	1012	1253
800	369	675	980	1286	1592
900	467	853	1240	1627	2014
1000	576	1053	1531	2009	2486
1200	-	-	-	-	-

Notes to Table:

a) 10°C has been selected as the reference temperature as this is a typical value for buried water supply pipelines. See IGN 4-32-18: 2003.

Table A.3: Additional volume of water to raise the pressure in 100m long test section to 10 bar in presence of air – PE 100 SDR 17

Nominal diameter DN / OD	Volume of water to raise pressure in 100m long test section from 0 bar to 10 bar (litres) [a]				
	Percentage of the internal volume of the test section filled with air after filling (prior to applying pressure)				
	0%	1%	2%	3%	4%
63	4	6	9	11	13
75	6	9	12	15	19
90	9	13	18	22	27
110	13	20	26	33	40
125	17	26	35	43	52
140	22	32	43	54	65
160	28	42	56	71	85
180	36	53	71	89	107
200	44	66	88	110	132
225	55	83	111	139	167
250	69	104	138	173	208
280	86	130	173	217	260
315	109	164	219	274	329
355	138	208	278	348	417
400	176	265	354	442	531
450	223	335	447	559	672
500	275	413	552	690	828
560	345	519	693	867	1040
630	436	656	876	1096	1316
710	555	834	1114	1393	1672
800	706	1060	1415	1770	2124
900	894	1343	1791	2240	2689
1000	1101	1655	2209	2763	3317
1200	1588	2386	3184	3982	4779

Notes to Table:

a) 10°C has been selected as the reference temperature as this is a typical value for buried water supply pipelines. See IGN 4-32-18: 2003.

Table A.4: Additional volume of water to raise the pressure in 100m long test section to 10 bar in presence of air – PE 100 SDR 21

Nominal diameter DN / OD	**Volume of water to raise pressure in 100m long test section from 0 bar to 10 bar (litres)** [a]				
	Percentage of the internal volume of the test section filled with air after filling (prior to applying pressure)				
	0%	1%	2%	3%	4%
63	6	8	11	13	15
75	8	12	15	18	21
90	12	17	21	26	31
110	18	25	32	39	46
125	23	32	41	50	59
140	29	40	52	63	75
160	37	52	67	82	97
180	48	67	86	105	123
200	59	82	105	129	152
225	74	104	133	163	192
250	93	129	166	202	239
280	116	161	207	253	298
315	147	205	263	321	379
355	187	261	334	408	481
400	236	330	423	517	610
450	299	417	535	653	772
500	369	515	661	806	952
560	464	647	830	1013	1196
630	589	820	1052	1284	1516
710	745	1039	1333	1627	1922
800	949	1323	1696	2070	2444
900	1200	1673	2145	2618	3091
1000	1480	2064	2647	3231	3814
1200	2133	2974	3814	4655	5495

Notes to Table:

a) 10°C has been selected as the reference temperature as this is a typical value for buried water supply pipelines. See IGN 4-32-18: 2003.

APPENDIX B. EXTENDING THE LENGTH OF A TEST

B.1 Data collection

With reference to 5.2, if 20 x t_p is less than 1 hour, the length of the test can be extended to 1 hour by taking a further pressure decay time, t_4.

B.2 Analysis

By taking a fourth pressure reading (P_4), a further n value (n3) can be calculated using Equation B.1.

$$n3 = [\log(P_3) - \log(P_4)] / [\log(t_{c4}) - \log(t_{c3})] \quad \text{(Equation B.1)}$$

B.3 Pass / fail criteria

If n3/n1 and n2/n1 lie between 0.75 and 1.25, then the test is a pass.

Note: If the slope of the pressure decay curve, n, is less than 0.04, there is probably air in the system.