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WATER INDUSTRY
INFORMATION & GUIDANCE NOTE

UK Water Industry

PRESSURE TESTING OF PRESSURE PIPES AND FITTINGS FOR USE BY PUBLIC WATER SUPPLIERS

1 Introduction

One of the primary reasons for justifying the refurbishment of water distribution and transmission mains is to replace and renovate pipes that have been shown to have unsatisfactory leakage levels. It therefore follows that the new systems should be demonstrated to be as secure and leak-free as possible.

In 2000, BS EN 805 was published and for the first time, there are now specified European criteria for assessing acceptability for different pipe materials.

BS EN 805 also gives advice on different test methods that may be used to assess pipelines for leakage. These methods are not mandatory; it is left to the Engineer/Client to choose the appropriate procedure.

A major review of the merits of all the methods proposed by BS EN 805 has been made and a summary of the findings is given in Appendix 3.

As a consequence of this review, it has been decided to adopt one procedure to test all new PE & PVC pipelines laid in U.K. water systems and another method for Ductile Iron, Steel & GRP pipelines.

The PE & PVC procedure is simple. It involves raising pressure in a controlled manner to the standard test pressure (STP) and allowing the pressure to decay after isolating the main.

The assessment of allowable leakage follows the principle of specifying an acceptable limit of the pressure loss/hr/km. The values of allowable pressure loss rate for different materials are given in Table 2. The basis for the choice of these rates is described in Appendix 3.

For PE and PVC mains, viscoelastic stress relaxation effects affect the simple linear decay in pressure since PE pipes will lose pressure without any leakage being present as the molecular structure relaxes. These effects dominate the pressure decay until some 24-36 hours after reaching test pressure. Therefore, to give an earlier warning that mains are leaking at an unacceptable level, the analysis for PE and PVC materials should be modified. The analysis given here for all plastic pipes is now aligned with that successfully used for many years in the 1980s and 90s by the U.K. Water Industry

The DI, Steel & GRP procedure is essentially the same as that detailed in BS EN 805 and the methods traditionally conducted on these materials.

The test method specified here is only appropriate where a test section of the pipeline and associated fittings can be completely isolated. Where new pipelines are already installed as part of a working water system – as for example is the case for most rehabilitation projects, other tests are required.

This IGN applies only to pipes and fittings which form part of the distribution system that is owned by the water supplier. Pipes and fittings which are part of privately-owned distribution or plumbing systems in premises, and which are supplied with water from the public supply system, come under the scope of the Water Supply (Water Fittings) Regulations 1999 (England and Wales), the Scottish Water Supply Byelaws (2004) or the Northern Ireland Water Fittings Regulations (2009), which have different performance requirements.

This IGN provides details beyond that normally required to successfully complete pressure testing in the field, but a less detailed "Contractors Guide" is provided for that purpose as Appendix A5. This section may also be used as a summary of the whole document to gain first understanding of the whole process before reading further..

This document has been prepared Exova Ltd. in conjunction with the Water UK Standards Board in consultation with the Water Industry and manufacturers.

Information contained in this Information and Guidance Note is given in good faith. Neither Exova Ltd., nor Water UK can accept any responsibility for actions taken by others as a result.

2.0 Allowable Rates of Leakage

BS EN 805 specifies that the 'allowable leakage' should be calculated by using the common criterion that a pipe under pressure should not suffer a pressure loss of greater than 0.2 bar/hr because of water leakage. For the 'Pressure Drop' test, the standard requires that this pressure decay be translated into an acceptable water volume loss by calculating the change in volume caused by the pressure drop - using the pipe stiffness to calculate the diameter change.

BS EN 805 gives a formula to translate this pressure loss into a water volume loss. The standard gives a criterion for acceptance which is described in terms of an allowable pressure loss per hour. The BS EN 805 formula for allowable leakage (Δv) is:

$$\Delta v = (1.2 * \Delta p) * Vp * ((1/Ew) + (SDR/Ep)) \ldots\ldots\ldots (1)$$

Δv = Loss in water due to decrease in pressure Δp and Vp = Pipe Volume

Ew = Bulk Modulus of Water and Ep = Pipe Material Modulus

SDR = standard diameter ratio = D/e = pipe diameter divided by wall thickness

Δp = 'Allowable' pressure loss of 0.2 bar/hr,
1.2 = a factor to account for air etc

For materials which do not have stiffness properties that vary with time and temperature (DI, Steel) it is simple to calculate the allowable leakage using known material properties. For plastics materials, which are inherently more flexible and have modulus (stiffness) properties that change very significantly with temperature and time under load there are major problems.

The lack of commonly agreed values of material modulus values for plastics, makes it impossible to define universally agreeable water loss rates. As discussed in Appendix 3, there is also a strong implication, whether intended or not, that the lower modulus materials (e.g. plastics) have a higher "allowable water loss". Obviously, this cannot be tolerated.

The U.K. water industry wishes to standardize on a common rate of water volume loss as the assessment criterion. Therefore, the water volume changes caused by the 0.2 bar/hr decay rate stated in BS EN 805 have been adopted as standard – using DI pipe as the yardstick. These volume changes are sensitive to pipe diameter and using equation 1, this gives (Δv) allowable water loss (litre/hr/km):

$$\Delta v = 0.000018 * D^2 \ldots\ldots\ldots..(2)$$

Where D is the nominal diameter in mm

Values in litres/km/hr for individual nominal pipe diameters are given in Table 1 below.

Nominal Pipe Diameter (mm)	Leakage Rate (litres/km/h)
100	0.18
150	0.41
200	0.72
250	1.13
300	1.62
350	2.21
400	2.88
450	3.65
500	4.50
600	6.48
700	8.82
800	11.52
900	14.58
1000	18.00

Table 1: Standard Allowable Leak Rates (litres/km/hr) for All Pipes, Based upon BS EN 805 and Equation 2.

2.1 Allowable Pressure Drop Rates for Single Materials

The corresponding 'allowable pressure decay rates' which would cause the allowable volume changes for pipes made from PE, GRP and PVC materials are given in Table 2 (on page 3). Values of modulii used are those measured at 10°C (ref. 1).

Because small pressure changes applied to the less stiff pipes cause considerable volume changes, the

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allowable pressure drop rates are always lower for the lower stiffness systems.

For plastics, creep stress relaxation alone will cause higher pressure drop rates than those given in table 2 for up to 10 hours with PVC and for at least 36 hours with PE pipes. This obscures leakage assessment in simple pressure drop tests and so the analysis for plastics needs to differ from non-elastic materials such as DI – see Section 7.

Material	Allowable Pressure Loss (bar/hr)
Ductile Iron	0.240
PE 100 SDR 11	0.036
PE 100 SDR 17	0.019
PE 80 SDR 11	0.029
PE 80 SDR 17	0.015
PVC SDR 17	0.029
PVC SDR 26	0.027
GRP	0.027

Table 2: Allowable Pressure Decay Rates (APDR) for Different Pipe Materials arising from the "allowable" leakage given in Table 1

2.2 Allowable Pressure Drop Rates for Pipelines with Multiple Materials

Sometimes, pipes of different types may be accommodated within a system under test. If there are pipelines with sections of different materials (A&B), a law of mixtures may be used to obtain the allowable pressure loss rate (in bar/hr) for the whole system: The formula for allowable pressure drop (Δp) is:

$$\Delta p = L_{fA} * (APDR)_A + L_{fB} *(APDR)_B \ldots\ldots(3)$$

Where L_{fA} and L_{fB} are the respective length fractions of materials A and B.

It would be most unusual to find more than two materials or a large multiplicity of SDR ratings in a test length, but if this is the case, the Law of Mixtures principle expounded in equation 3 may be extended as necessary.

For small lengths of relatively stiff elastic (metal) pipe mixed with pipe made from viscoelastic (plastic pipe) material, it is necessary to check the metal pipe locally for leaks that are likely to be masked by the viscoelastic nature of the neighbouring pipe.

3.0 Choice of System Test Pressure (STP)

Historically, different Water Companies have used an ad hoc range of test pressures. These have usually resulted as the whim of individuals. Some engineers have used the mains working pressure as the basis for the test pressure; some have used the pipe rating.

It is now strongly recommended that all companies universally follow the guidelines specified in BS EN 805 and establish common levels for the standard test pressure (STP). This has the benefit of greatly simplifying data analysis and increasing the ability to detect leakage which is sensitive to pressure.

The BS EN 805 method for choosing the test pressure is that STP should be the lowest of:

- o 1.5* PN
- o PN + 5 bar

- The PN rating of the lowest rated component in the system should be used.
- The value of STP should apply at the lowest elevation of the pipeline and should therefore include the initial maximum static head applied (Po).
- The test pressure at the highest elevation should be at least the maximum operating pressure. If this is not possible due to the elevations involved then the line should be split prior to testing.

Note: Some companies may prefer to use an STP value of 1.5 Design Continuous Maximum Operating Pressure*

3.1 Safety Issues

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. Specific hazards/precautions to note are identified below.

- High pressures could involve danger if either there is an unexpected pipeline failure or an end cap blows off.
- Only approved staff who are aware of the risks should be allowed near to any exposed part of the pipeline when it is under pressure.
- The test area should be cordoned off and a warning notice erected when the test is in progress.
- On a long length of main under test, staff involved in the test should be in radio/mobile phone contact at all times.

4.0 Choice of Test Section/Length of Pipeline

There is no technical reason to limit the length of main or diameter being tested. Historically for example, successful pressure decay tests have been made on 5km of 1400mm PE pipes.

The choice of the test section and its length is governed generally by:

- fitting density – most leaks will occur at fittings and joints
- availability of potable water to pre-charge the main and also a source for discharge of water after the test.
- elevations on the main – to meet the minimum applied head criterion
- the ability to identify the source of any leak detected. Testing long lengths can make such identification difficult and on many occasions numerous re-tests have had to be made on smaller sections of long mains - to pinpoint the source of leakage.
- The time available in which to obtain a valid test result

5.0 Mains Testing Set-Up

5.1 General

To carry out a quantifiable assessment of leakage from either the pipeline or the joints by a pressure decay test, it is essential that:

(a) The length of main to be tested should be isolated with end load bearing end fittings with sealed plates. End fittings should have pressure ratings at least 1.5* STP. For higher test pressures such fittings will of necessity be specialist re-useable items.

(b) Simple closed valves or 'squeeze-off' seals (for PE) should NOT be used to hold the water. It is highly likely that leakage may occur past the internal valve seals or through any gap at a squeeze-off'.

(c) Any service connections should not be tapped prior to pressure testing.

(d) Wherever possible, all joints made to the pipeline should be in open trenches – visible for direct visual inspection.

(e) The main pipeline should have been backfilled and compacted prior to the test. This prevents any axial movement which could distort data analysis.

(f) Air valves should be located at all high points to facilitate the removal of air during charging of the main. Air valves should not be isolated during the test. The air valve connection is a potential source of leakage.

5.2 End Loads

Where socket and spigot joints have been used (e.g. for PVC, DI and GRP mains) sufficient thrust blocks or other anchorages should be in position and any concrete used should have been adequately cured.

The ends of the pipeline should be securely anchored and any temporary strutting should be properly designed.

It is the responsibility of the site engineer to ensure that all end fittings can safely withstand the end forces generated by high test pressures.

These forces can be very high and examples of the end loads on PE SDR 11 and 17 pipes raised to a test pressure of 15 bar are given in Table 3 below. The forces given should be multiplied pro rata for other pressures.

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It is essential that the end fittings themselves are watertight.

End fittings or struts installed to resist pressure forces should not be removed until all applied pressure has been removed from the main.

Diameter (mm)	SDR	End Force (tonnes)	SDR	End Force (tonnes)
90	17	0.7	11	0.9
180	17	3.0	11	4.0
250	17	5.7	11	7.6
315	17	9.1	11	12.1
400	17	14.7	11	19.5
500	17	22.9	11	30.4
610	17	34.1	11	45.3
720	17	47.6	11	63.3
800	17	58.7	11	78.0
1000	17	91.7	11	121.9

Table 3: Examples of End Forces Generated by 15 bar Pressure on PE Pipes to illustrate the level of danger
(note that this varies with pressure and type of material)

5.3 Test Fixtures

- Fixed jumper hydrants or ferrules should be installed at the lowest point of the main to facilitate charging and pumping of the water and its subsequent removal after the test is completed.
- Consideration may be given to use of a duckfoot hydrant bend as a temporary measure – to allow easier removal of swabs used to scour air from the system.
- There should be a secure connection on the stop end at the highest point to allow air and water to be vented.
- Any air vent should be located as close to the top of the pipe as possible.

5.4 Instrumentation

- A calibrated pressure gauge or a calibrated transducer connected to a datalogger should be mounted on a standpipe at the lower elevation end.
- A calibrated flow meter should be attached to measure the volume of water added during the pressure rise phase – again this may be connected to a datalogger.
- The flow meter range should be chosen in the knowledge of the likely inputs needed to raise pressure to STP – using Tables A1.1-6 in Appendix 1 as guidance of the volumes of water needed.
- Pressure sensors should have non linearity better than +/- 0.2% with no temperature sensitivity between -5ºC and 50ºC. The gauge/transducer should have a resolution to 0.01 bar or better.

5.5 Ancillary Data

The following ancillary data should be recorded:

- The elevations of both ends of the test section should be recorded and the measured static head at the lowest elevation should be determined and recorded when the valve at the highest elevation is open.
- The start and end times and the date of the test should be recorded.
- All details of the pipe (material, length, diameter, PN /SDR) should be noted.
- The type and volume flow rate of the pump should be recorded.
- Details of the type and ratings of pressure and flow measuring devices should be recorded, including calibration certificate references.

5.6 Charging of Main

- Water for testing of potable water mains should be taken from the existing supply.
- An adjacent main may be used to charge the main but for PE & PVC pipelines every effort should be made to ensure the pressure in the pipeline does not exceed 2 bar above any static head generated by elevation changes. If the pressure is raised above this value then water should be bled from the

main to reduce the pressure prior to the test commencing.

- The main should be charged from the lower end with all air valves open and an open valve at highest elevation.

- After charging the main and bleeding air from the system, the valve at the highest elevation should remain open to ensure that there is no residual head at that point.

There should be no attempt to shorten the pumping phase for PE & PVC pipelines by increasing the initial pressure to local mains pressure using an adjacent main. The test result will be invalid. The following points should be noted by contractors tempted to save on pumping by pre-charging:

- It will be obvious from input volumes and elevations that pre-charging has occurred.

- The time for which the main has been pre-charged will distort the effective loading time. The time correction factor will be in error. The error in correcting time will result in a larger slope change of the pressure decay characteristics.

- There is a greater likelihood of the test failing the specified criteria.

5.7 Pump Capacity

- For PVC & PE materials the contractor should ensure that a pump of capacity to raise pressure smoothly to STP in a time period of approximately 10-20 minutes is available.

- For PVC & PE materials the total test time is related to rise time and it is important for PE pipes to have short rise times – since creep deformation accumulates during the pressure rise.

An estimate of the volumes required for different materials may be obtained from Tables A1.1 to A1.6 for DI, PVC and PE mains (Appendix 1).

5.8 Removal of Air

The presence of air in a main will have a number of effects viz:

1. air will markedly increase the pressure rise time for PE & PVC pipelines – see graph Figure A2.1 in Appendix 2.

2. air will distort the interpretation of pressure decay results for PE & PVC pipelines.

3. the main acts as an accumulator – the air expands as the pipe expands (or water is lost).

4. air will thus reduce the rate of pressure loss.

Analysis (ref. 1) has shown that air has a significant effect on the interpretation of data when the air volume is > 4%.

It has therefore been agreed that there should be an upper limit of 4% air in any main for a valid test in a short time.

A method for determining the air content from the pressure rise data is given in Appendix 2.

Attempts should be made to purge air from the main during/after charging with water and before the start of the Pressure Test.

- It is necessary to ensure that all air valves are functioning properly

- For larger diameter mains (generally >250mm) where there is considerable undulation – it is recommended to use a foam swab ahead of the water column.

All non self-sealing air vents should be closed prior to testing.

6.0 Mains Testing Procedure

6.1 Preliminary Conditioning of Main

BS EN 805 recommends that there should always be a preliminary test phase where the pressure is taken to the operating pressure (without exceeding STP) to:

a. “stabilize the part of the pipeline to be tested by allowing most of the time dependent movements”.

b. “achieve an appropriate saturation with water when using water absorbing materials’ (e.g cement linings on iron pipes).

For iron pipes with epoxy linings and PVC or GRP pipes with socket and spigot joints, the settlement test should be completed in 15 minutes.

Where DI pipes have cement linings, the main should be allowed to ‘settle’ overnight.

N.B. It is not advised to have any preliminary test for PE pipes (as recommended by BS EN 805). The standard states that such a test would allow time dependent increases in volume to occur. This is not the case and pre-pressurising PE pipes totally confuses subsequent data analysis.

6.2 Raising Pressure

The pressure should be raised to the test level (STP) by pumping in a controlled manner.

The pressure changes and the added volume of water should be continuously logged.

If there is less than 1% air in the main, the pressure should rise at a uniform rate.

If there is significant air present, the pressure will rise slowly at first and will gradually increase until a constant rate is achieved.

Typical characteristics are shown in Appendix 2, figure A2.1.

6.3 Assessing Air Content

An approximate estimate of the air volume can be made by comparing the actual water input volume with that predicted for mains with different levels of contained air – see Appendix 1 for tables.

As a more precise alternative, the actual air volume may be calculated using the pressure rise characteristics – as outlined in detail in Appendix 2.

If the air volume estimate is >4% the test should be abandoned. Such large air volumes would confuse data analysis. The pressure should be reduced to zero and efforts made to bleed air from the system. The test should be restarted.

For all PE & PVC pipelines the new test should not start until a period of 4 times the period the pipe was under pressure, including the initial rise time.

6.4 Pressure Decay Phase

For PE & PVC pipelines it is recommended that after reaching test pressure (STP), pressure readings should be taken until the decay time (commencing from when full pressurisation is achieved) is:

- at least 5 hours for all types of PVC pipes - to allow non linear creep relaxation effects to be minimised
- at least 1 hour or 20* pressurisation time - whichever is the greater – for PE pipes - to be certain that there has been a significant pressure drop due to leakage.

As the pressure decays an analysis should be carried out to check whether there is reason to believe that the main is leaking. This should be done whilst the test is in progress.

It is strongly recommended that the test system applied to the main is not de-commissioned or the main put into service until the pipeline meets the appropriate test criteria and is deemed to be free from leakage.

7.0 Data Analysis

7.1 Air content

To assess that the air content is less than the acceptable criteria, use the tables for estimated water input volumes to raise the pressure to STP and/or logged pressure rise data - see 6.2 and Appendix 2.

7.2 Analysis for Ductile Iron, Steel and GRP pipes

If the pressure drops less than the allowed pressure decay rate given in Table 2 the pipeline is secure. If the pressure decay rate is close to the allowed rate the test may be repeated immediately.

When an unacceptable pressure decay rate has been identified, the test should be stopped. The main should be gradually depressurised until only static head remains.

A search should be instituted to identify any leaks. Guidance is given in section 7.7

7.3 Analysis for PVC and PE pipelines

The rate of linear decay of pressure with time caused by creep stress relaxation, will give rates of pressure drop that greatly exceed the BS EN 805 allowed rate for times up to 12 hours for PVC pipes and 36 hours for PE pipes.

To check whether there is evidence that the rate of decay is predicted to be unacceptably high, it is necessary to analyse the logarithmic decay of pressure with time and compare this with known material creep relaxation behaviour.

7.3.1 Correcting for Creep during Rise Time

It should be noted that for both PVC and PE pipes, a correction to the decay time is needed to account for the time spent in raising the pressure. This is achieved by adding 0.4* rise time (t_L) to the decay time. The time is the 'corrected decay time'.

Corrected Decay Time (t_L) = 0.4 * Rise Time + Time since pump shut off...(5)

7.3.2 Analysis of Pressure Above Static Head

Where there is a significant static head on the main, this can affect the analysis. This head is always present and cannot decay. Therefore, all pressure data should be analysed using the pressure applied by pumping above the initial static head.

Applied Pressure (P_A) = Current Pressure (P) – Start Pressure (Po)…….(6)

Data may be analysed by a graphical method and also by calculation.

7.3.3 Data to be Used for Analysis - Filtering Short Term Decay Pressures

(i) Because there are frequently odd pressure variations in the time immediately after closing the main via the isolating valve, no data for either PVC or PE should be analysed until a time period equal to the rise time has passed.

(ii) With PVC, the initial decay data will not settle to a constant logarithmic decay rate for at least 1 hr. No data at times < 1 hour should be used for PVC pipes.

7.3.4 Trendline Analysis

(i) A graph of the applied pressure (P_A) value vs 'corrected decay time' time should be plotted on logarithmic axes.

(ii) For PE pipes, it is expected that for 'corrected times' greater than the rise time, the applied pressure decay results should lie on a straight line with a slope between -0.07 and -0.09.

If pressure decay results are plotted using a spreadsheet program, power law trendlines can be applied to all the data in two separate time intervals[1].

For PE pipes: the intervals are: (t_1 to t_2) between t_L and 8 t_L and (t_2 to t_3) between 8t_L and 20 t_L.

Where t_L = time taken to achieve test pressure (also known as "rise time")

For PVC pipes: the intervals are: (t_1 to t_2) between 1hr and 3hr and (t_2 to t_3) between 3hr and 8hr.

The resulting equations will be of the form:

P_A =(Corrected Decay Time)$^{-n}$ ……...…….(7)

The slopes between the two time intervals should be determined as the power law exponent (n). The absolute value of n is dependent on numerous factors and cannot be used to determine leak-tightness – this can only be done through change of slope (see section 7.4). However, the values are given below as a guide.

PE pipes: The expected slope (n) for most PE materials is between 0.07 and 0.09[2].

N.B. values of n may occasionally range between 0.06 and 0.1 – depending to some degree on compaction and also the air content. (A slope below 0.06 may be indicative of excessive pre-charging).

PVC pipes: The expected slope (n) for most PVC materials is between 0.03 and 0.07.

N.B. When pipelines utilise different materials, equation 3 (section 2.2) may be modified to calculate expected power law pressure decay exponents for lines with multiple materials (A&B) by replacing APDR with values of 'n'. The formula for allowable value of n is:

$n = L_{fA}*(n)_A + L_{fB}*(n)_B$…………….(8)

Where L_{fA} and L_{fB} are the respective length fractions of materials A and B.

7.4 Calculation Analysis for PE and PVC Pipes

After adding 0.4* t_L to the decay times, two rates of decay should be calculated using the pressure

[1] The interval times are approximate – take nearest readings to those recommended

[2] *NB* Special 'barrier layer' PE pipes with Polypropylene or Aluminium layers, will have lower slopes. Reference should be made to the pipe suppliers for the expected creep relaxation exponents.

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change (P_A) data between the times t_1 and t_2 (slope n_1) and between t_2 and t_3 (slope n_2) as follows:

$$n_1 = \frac{[\log(P_A at\, t_1) - \log(P_A at\, t_2)]}{[\log(t_2) - \log(t_1)]} \qquad \text{.............(9)}$$

$$n_2 = \frac{[\log(P_A at\, t_3) - \log(P_A at\, t_2)]}{[\log(t_3) - \log(t_2)]} \qquad \text{............(10)}$$

For PE: $t_1 = t_L$, $t_2 = 8t_L$, $t_3 = 20t_L$.
For PVC: t_1 = 1hr, t_2 = 3hr, t_3 = 8h

7.5 Pass/Fail Criteria for PE and PVC Pipes

For either PE or PVC pipes, no great significance should be placed on the absolute value of n within the ranges quoted.

It is important to note that for a secure main, the pressure will decay with a constant power law slope and it is any *increase in slope* that is important in assessing whether a main is suffering leakage. Any slope change is directly proportional to the leakage rate and computer analysis has shown that assuming up to 4% air content, a 25% increase in slope corresponds to the allowable BS EN 805 leakage rate.

Small slope changes or occasional decreases in value at longer decay times are not an issue of concern. It is where there is a consistent increase in slope that leakage is indicated.

The assessment criteria are:

- For both PE and PVC pipes, the value for the longer time period should not increase above the short term value by more than 25%.
- For PE pipes - if the longer term slope exceeds 0.13, the rate of pressure decay is unacceptably high.
- For PVC pipes – if the longer term slope exceeds 0.08, the rate of pressure decay is unacceptable high.

7.5.1 Steadily Increasing Pressure Decay

An example of a set of pressure decay data is shown in Figure 2 – for a PE pipe with a leak generating a pressure loss (in excess of that expected for creep alone) - which is just at the BS EN 805 limit (see Table 2).

It is to be noted that the simple analysis in section 7.4 relies heavily on single point data and if there is an indication that the slope has increased by more than 10%, results should be plotted and a computer trend line determined (as in section 7.3.4) using all data in the specified time ranges.

If pipelines fail to meet the acceptance criteria, the test should be stopped and the excess water bled carefully from the system. A search for potential leaks should be initiated.

After leaks are found and repaired, the test should be repeated. – but only after a time greater than 4 times the
total original test time has elapsed – to allow for complete creep deformation recovery.

7.5.2 Checking Absolute Rate of Pressure Decay for PVC and PE Pipes

As a final confirmation that the rate of pressure decay is in excess of the allowed limits, it is possible to calculate the current pressure decay rate at the end of the test period. This is only valid if the test has been running for more than 36 hours since creep stress relaxation effects will confuse results at shorter times.

The decay rate should be calculated by use of the time interval over which the pressure decayed by more than 0.05 bar in the last phase of the test.

If the pressure decay rate is in excess of 2*APDR[3] (see Table 2), the pipeline has unacceptable leakage.

7.6 Estimating the Rate of Leakage

When a pipeline has been shown to have an unacceptable pressure decay rate, it is frequently of use to the installation contractor to know the extent of the actual leakage. Knowing the leak rate may indicate whether for example a single joint is leaking

[3] The factor 2 allows for the residual creep stress relaxation which will still occur at 36 hours

or whether there are multiple leak paths in various places.

To estimate the leak rate, it is necessary to know the current pressure decay rate in the test. This can be calculated by taking the pressure decay over the last time increment (if the logger is setup to log the time for a defined pressure drop, or if the logger is setup to log at specific time intervals the time taken for the pressure to decay by the last 0.05bar should be used) and dividing by the time interval - let this be P/ t.

The leakage rate in litres/hr/km can be estimated (see Appendix 4) as:

$$\text{Water loss} = (\text{Measured Pressure Decay Rate}/\text{APDR}) * 0.000018 * (\text{OD})^2 \text{.......}(11)$$

Where APDR is the ‘Allowed Pressure Decay Rate’ given in Table 2

Different coefficients for materials and SDRs in Table 2 reflect the differences in pipe stiffnesses. Values have been calculated via eqn A3.1 in Appendix 3.

7.7 Visual Inspection for Leakage

(a) With most pipes, there is seldom any leakage through the pipe wall. All pressure pipes in use in the UK will have been tested at the factory to much higher pressure levels than STP.

(b) With PE pipes, 25 years of testing has never detected a failure of a butt fusion weld with systems welded with modern equipment.

(c) Leaks will occur generally at mechanical joints or electrofusion welded pipes/fittings in PE systems.

It is recommended that the main be raised in pressure back to STP and that the contractor carry out a visual inspection of all joints that are visible.

If there are no signs of visible water loss a leak-noise correlator may be used and the ground inspected for damp patches.

If there is no success, the pipeline should be divided into shorter sections and further pressure tests conducted.

7.8 Post Test Procedure

When a main has been positively accepted as being free from leaks, the water should be released slowly from the pipeline with all valves opened.

The water should be discharged safely to a pre-planned site.

8. Test Report

For every test, a formal report should be made giving complete details of the tests that have been carried out.

The report should contain:-

- The name, company and contact details of the person carrying out the test.
- All details of the materials, dimensions, length and PN ratings of the pipeline – as required in section 5.5.
- The type of pressure and flowmeter should be described – together with details of their maximum range, precision and calibration history.
- The pump volume flow rate at rated speed should be given, or the logged data from the flow meter
- The report should give all the recorded measurements of the pressure and water flow during the pressure rise phase.
- The pressure decay data should be recorded in the report.
- Details of any analysis carried out in accordance with the methods described in Section 7 of this specification should be given.

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Appendix 1

Estimated Water Input Volumes for Different Pipes

To assist contractors in the choice of pumps to raise pressure in mains, the estimated input volumes have been calculated for different pipe materials. These are given in Tables A1.1 to A1.3.

Values of the calculated pipe volumes are also given in the tables.

The tables given here are for guidance only :

- Precise values will alter for different types/grades of PE (PE80/PE100) and PVC (PVC-U,PVC-A,PVC-O)

- Values for all plastics will be affected by temperature – plastics become stiffer as temperature is reduced – volumes should be decreased by approx 5% per degree for temperatures below 10°C and vice versa for higher temperatures.

- Values for all materials will be affected by the volume of air in the pipeline

The calculations assume **100m** length of main and give the estimated volume inputs for a **10 bar** pressure rise (from 1-11bar). Values for other lengths/pressures should be scaled pro rata.

- The test pressure STP should be quoted.

- The report should give details of the date and time of the test and its location.

Ductile Iron

The data for Table A1.1 assume K9 pipe is used

.

Appendix 2

Analysis to Determine Initial Volumes of Air in a Pipeline

A2.1 Modelling the Effects of Different Air Volumes

- Large volumes of air contained in a pipeline can be dangerous if a pipe failure occurs. There will be a massive sudden release of stored energy
- All testing standards acknowledge that contained air will totally confuse 'added volume' measurements in constant pressure tests and will have some effect on pressure decay characteristics.
- Having large initial air volumes will always increase pressure-rise times
    - High air content will slow down the rate of pressure decay
    - Air may mask signs of leaks since air expansion will delay the time before leakage affects the degree to which the pressure decays.
- Thus, having high air content always leads increased test times and the possibility of reduced test sensitivity.

A2.2 Effects of Different Air Volumes on Pressure Decay for PE Pipes

An analysis has been made of the effects of air on pressure decay data in PE pipe systems (ref. 1). The results (Figure A2.2) show how air produces a delay before leakage becomes apparent via a slope change in the logarithmic decay data.

The results of modelling different pressure drops below the expected creep power law stress relaxation profile are shown in Figure A2.3. The presence of air will tend to mask the pressure decay due to a leak. In pipelines with higher air contents, it will take longer to detect any given % drop in pressure caused by a leak. This is shown in Figure A2.3 where the time to detect two different pressure drops below expected rates is shown vs air content. The time is shown as a multiple of the loading time.

For a main with no air, the pressure will have dropped by 2% more than expected at 6* the rise time. With 4% air, the pressure will have dropped by 2% more than expected at 9* the rise time. When the pressure has decayed by 5% more than expected, the power law slope 'n' will have doubled. It is always advantageous to have less air in the system – leak detection sensitivity is increased at shorter times

A2.3 Estimating the Volume of Air in a Pipeline

Because air has an effect on the pressure decay, it is essential to have a quantitative measure of the air contained in a pipeline under test.

A 2.3.1 Approximate Estimation

The tables for water input volumes given in Appendix 1 may be used on site to give an initial estimation of the air volume in a pressurised main. By comparing the actual water input volume to raise the pressure by P_A with the estimated volumes given in the tables, it should be possible to swiftly compare the real input with that expected at different air contents.

If the air content so estimated is close to the acceptable limit of 4% of the total pipe volume, it would be wise to extend the test time to 20 times the loading time t_L. The pressure decay time needs to be extended to counteract the effect of air in slowing the pressure decay and accurately determine whether the pipe is leaking.

A 2.3.2 Calculating Air Volume from Pressurisation Characteristics

The shape of the Applied Pressure vs Input Volume characteristic is a good measure of whether significant air is present. When there is negligible air, the pressure will rise quickly as water is pumped into the main. Eventually, the pressure rise rate will slow down slightly – as the plastic pipe becomes less stiff due time dependent creep effects. This is shown as curve (1) in Figure A2.4.
If the pressure rises slowly in the initial phase and then more rapidly at higher pressures (curve (2) in Figure A2.4), this is a sign that there is significant air present.

Even when air is present (curve (2)), the slope of the pressure vs time curve during the rise phase becomes constant as time increases - when the air is compressed to small volumes and only small volumes of water are added to compress the air.
Thus, if the slope at high Applied Pressures is extrapolated back to the volume axis, the intercept is a good indication of the air volume. This is illustrated in Figure A2.4 where the extrapolation gives Va= 14,600 litres. (Note that the slope of this line is almost the same as curve (1)).

This method of estimation of air volume does not depend on the rate of pressure increase to any significant extent, nor is the method of estimation sensitive to the type of material, diameter, SDR or length of the pipeline.

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Correction for Tangent Pressure: If the extrapolation is made by taking the pressure rate at low applied pressures - when air occupies a significant volume and there is heavy curvature, the intercept is not an 'accurate' measure of the air volume (e.g. in Fig A2.4, the tangent at point X has an intercept of 11,000 litres). This may be the case where there is a high initial static pressure (Po) or a low STP value (< 16bar).

To correct for this effect, it has been possible to derive empirical values of a scaling factor (SF) which should be used to multiply the intercept. The factor is given by:

SF = 2 * (Tangent Pressure)$^{-0.2}$ ……………..…………A2.1

The tangent should be taken as close to STP as possible – where the tangent pressure then equals STP.

Correction for Initial Pressure Po: When tests are conducted with high initial Po values, the initial air is already compressed by this pressure. To allow for this and calculate a true initial air volume, a further correction is needed. The correction factor for Po effects (PSF) is given in Figure A2.5 and alternatively via equation A2.2.

PSF = 0.03*(Po)^2 + 0.08*(Po) + 1 …………………A2.2

The Air Volume is then given by:

Air Volume = (SF * PSF * Intercept) ÷ Original Pipe Volume........ A2.3

A 2.3.3 Worked Example by Calculation

As an example of the calculation of the air volume, the pressure rise data shown for a test on 1000m of 800mm SDR 11 PE100 pipe (Figure A2.4) can be taken. The initial pressure (Po) was 0.2 bar.

At point Y just before peak pressure, 22,000 litres had been added to raise the pressure to 14.46 bar

At point Z, (STP), 22,880 litres had been added to raise the pressure to 16.18 bar.

Therefore, for the last 1.72 bar increment between A and B the pressure rise rate was:

$$Rate = \frac{1.72}{22880 - 22000} = 0.00195\, bar/litre$$

The peak pressure STP was 16.18 bar and 22,180 litres was added (V_w) to attain STP :

$$\therefore$$

$$Intercept = \left(V_W - \frac{STP}{Rate} \right) = \left(22880 - \frac{16.18}{0.00195} \right) = 14580\; litres$$

This estimate should be 'corrected' for the pressure rise curvature via the SF factor

From equation A2.1, the scaling factor SF =2 * (16.18)$^{-0.2}$ = 1.15

From equation A2.2, the initial pressure scaling factor PSF is 1.017 for Po = 0.2 bar

Thus from equation A 2.3, the

Estimated air volume =1.15*1.017*14,580 = 17,052 litres

The original internal pipe volume for 1000m of 800mm SDR 11 pipe is 336,530 litres - from Table A1.3

$$Initial\ Air\, Content = \frac{17052}{336530} = 5.08\%$$

This would be considered unacceptable for a short term pressure decay analysis. The limit is 4%. Thus, the test result should be calculated at an extended time of 20*t_L.

Appendix 3

BS EN 805

A3.1 Rates of Leakage – General Issues

Historically, the acceptance testing of pipe systems in the U.K. has been governed by codes of practice and specifications which have followed procedures developed by clients and suppliers over a long time period.

For ductile iron (DI) and PVC pipes there was specified a minimum rate of volume loss of 0.02 litres per day per mm diameter per km per bar pressure applied. This was originally specified in BS COP 312 and BS 8010.

This criterion was a sensible model of a leakage rate in that it is implicit that the rate of leakage will be directly proportional to the pipe diameter and the applied pressure.

For PE systems where creep relaxation effects can make the discernment of leakage problematical, the procedure was to compare and contrast the actual decay in pressure with that which was to be expected because of stress relaxation due to creep.

In 2000, BS EN 805 was issued. This is a global standard entitled: *"Water supply - Requirements for systems and components outside buildings"*

The standard gives a criterion for acceptance which is described in terms of an allowable pressure loss per hour.

The BS formula is:

Allowable Leakage $\Delta v = (1.2 * \Delta p) * Vp * ((1/Ew) + (SDR/Ep))$……. (A3.1)

Where:

Δv = Loss in water due to decrease in pressure Δp

Vp = Pipe Volume

Ew = Bulk Modulus of Water

Ep = Pipe Modulus

1.2 = An *allowance* factor to account for air etc

Δp = 'allowable' pressure loss

It is noted that this formula has nothing whatsoever to do with leakage rates per se. The formula is a simple stress – strain relationship, where $\Delta v / Vp$ is the strain and the Δp * SDR component is the stress in the pipe wall.

The formula allows for calculation of the pipe contraction (or expansion) if water is lost (or added) because of a pressure change Δp.

'Allowable leakage' is that water loss which causes a drop in pressure of Δp

Because the formula works in terms of pipe volumes, any allowable water loss rate is automatically proportional to Diameter^2. This may/may not be the real case.

In practice, many leaks around flanges or socket and spigot joints are likely to vary as a linear function of diameter. They are controlled by changes in the pipe circumference rather than the pipe volume.

In other cases (such as with leaks at tapping tee connections), there may be no pipe diameter sensitivity since the hole for the tapping does not vary significantly.

A3.2 BS EN 805 – Deriving a Water Loss Criterion

In BS EN 805, the allowable pressure loss is 0.2 bar[4] in any test where the main is raised to the test pressure and then sealed. This drop in pressure is specified to be common to DI, steel, concrete and 'plastic' pipes.

There is a major problem in adopting this universal criterion for both metal and plastic pipes. Because plastics are much less stiff the volume change caused by a decrease in pressure of 0.2 bar will be some 10-20 times larger than for DI where the volume change is small.

For example, consider the volume of water loss that would cause a pressure drop of 0.2 bar in 1km of a 250mm pipeline:

- For a stiff pipe such as Ductile Iron, 1.13 litres would need to be lost.
- For a flexible pipe such as PE80, some 16 litres would be lost.

The specification of one simple pressure loss rate in BS EN 805 leads to the acceptance of totally different water volume losses for pipes of different wall thicknesses and made from different materials.

[4] to which a factor of 1.2 is applied to 'correct' for air effects

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WRc have offered advice based on the simplistic BS EN 805 principle and in their latest Pressure Testing IGN[5] they give tables for DI, PVC and Steel pipes which have allowable loss rates which vary massively between the different materials and SDRs.

Since water engineers are driven to maintain leakage at very low uniform rates – independent of the pipe material, it is recommended here that the water loss rates calculated from equation A3.1 for K9 ductile iron pipes be taken as the acceptable measure of water loss. These rates should then apply for all materials – based on nominal pipe diameters.

The allowable leakage rates for K9 Ductile Iron are shown in Figure A3.1. They are given in tabular form in Table 1 in the main text.

For an exact calculation:

Allowable water loss (litre/hr/km) = $0.000018*(OD)^2$ (A3.2)

A3.3 Acceptable Pressure Loss Rates

Because a value of pressure loss may be an easier parameter to measure in any test, it is necessary to calculate acceptable loss rates for different pipe materials and stiffnesses.

Having accepted that the BS EN 805 allowable pressure loss rate of 0.2 bar/hr should apply for DI pipes, the resulting acceptable pressure loss rates for pipes made in different stiffness categories for all other materials have then been calculated.

The criterion is that the acceptable water losses are those given in Figure A3.1. Equation A3.1 has then been used to calculate Δp – given Δv as an input for pipes of different SDRs and with different modulus values Ep .

The values of acceptable pressure decay rates (APDR) are given in Table 1 in the main text.

A3.4 Pressure Test Methods

BS EN 805 does not directly specify any given test method for pipes. In section 11 of the standard and in Appendices A26 and A27, the details for mains testing and data analysis are given. It is always left to the discretion of the 'designer' to choose the test method and for PE pipes, the method described is a recommendation rather than a requirement. The tests described are:

[5] "A Guide to Testing of Water Supply Pipelines and Sewer Rising Mains"

A3.4.1 Limited Pressure Decay - Pressure Loss Method (BS EN 805 11.3.3.4.3)

Following raising of pressure to STP, the main is closed and it is stated that any changes in pressure are monitored over 1 hour period (or longer if specified by the designer).

BS EN 805 states that the rate at which the pressure is lost should not exceed the specified limit of 0.2 bar per hour for DI, steel or 'plastic' pipes.

This test is appropriate for the assessment of DI and steel pipes but the simple analysis recommended is inappropriate for plastic pipes which suffer from creep stress relaxation. This has been considered in detail and the recommended analysis methods to allow for creep are given in section 7 of the main text.

It is likely that a result which can be accepted with confidence will only be obtained after at least 10 hours of pressure decay for PVC and some 36 hours for PE pipes. It is only at these times that the pressure drop from creep stress relaxation has decayed to the same level as the 'allowable leakage rate'.

A3.4.2 Limited Pressure Decay – Water Loss Method (BS EN 805 11.3.3.4.2 a)

In this procedure (long used for DI evaluation in the UK), the pressure is raised to STP and is then allowed to decay over a 1-2 hour period to a pressure P1. The pressure is then returned to STP. Immediately, water is drained from the system to return the pressure to P1. The volume drained in this final process is deemed to be the amount lost due to leakage in the decay phase. There are two fundamental problems with this test:

a. The new BS EN 805 allowable leakage rates are so small that if the pressure is not returned to STP and subsequently drained to P1 with great precision, then the result will be meaningless. Very small errors in pressure control (e.g. of the order +/- 0.05 bar) cause significant variations in the water volumes lost.

b. If even small volumes of air are present, the water volume measurements will be meaningless as a true measure of leakage if pressures are not controlled with great precision – an unlikely event on most construction sites.

Whilst this test may have been used satisfactorily in the past for DI pipes, the new allowable leakage ratesa) specified in BS EN 805 are 10-50 times lower[6] than hitherto.

The new demands for a more sensitive measure of leakage means that water loss assessment is likely to lead to confusing results and the test is not recommended.

A3.4.3 Constant Pressure Test – Water Added Method (BS EN 805 11.3.3.4.2 b)

In this procedure, it is required to hold the pressure at STP and then measure any water needed to be added to hold pressure. There are two fundamental problems with this method:

a. The control equipment to hold the pressure absolutely constant needs to be very sophisticated. Again, small pressure fluctuations can cause large errors in assigning water leakage rates.

b. The water losses allowed are so small that it is simply not feasible to measure the flow rates of any water added to maintain pressure.

Because the new BS EN 805 allowable water loss rates are so low, it is not recommended that this test be used.

A3.5 Use of BS EN Test Methods for Plastic Pipes

The wording in BS EN 805 is very confusing with respect to different materials under test. The standard doesn't mention PVC or GRP pipes specifically at all, but recommends that "plastics pipes" be treated the same as DI.

There is only mention of PE and PP pipes as being special cases of materials with viscoelastic properties and thereby in need of different assessment.

This is quite wrong. PVC will suffer from creep stress relaxation – although not to the same degree as with PE and PP.

The pressure in PVC pipes will naturally decay without leakage and the effects are significant for times up to 10 hours. Thus pressure decay test data (or water volume measurements) on PVC and GRP are difficult to analyse in first 10 hours since stress relaxation effects could be confused with leakage.

[6] depending on diameter. BS EN specifies leak rates as a function of diameter^2

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Appendix 4

Pressure Decay (Type 2) Test

A4.1 Advantages of Pressure Decay Test

1. The test method itself is extremely simple. The pipeline is raised to pressure with a pump and when the test pressure is achieved, the pump is switched off, a valve is closed and the pressure is monitored.

2. The equipment needed to raise the pressure is unsophisticated.

3. The pressure measurements may be made using either pressure gauges or transducers. There is no need for highly sophisticated or highly sensitive monitoring equipment.

4. Data may be recorded by simple loggers so that constant monitoring by staff is not necessary. (There is also a permanent record for QA purposes).

5. The test gives more accurate results the longer the pressure is allowed to decay. However, leaks of the order specified in Table 1 can first be detected in relatively short timescales.

6. The basic test method may be used for all pipe materials.

7. The test actually measures the rate of pressure decay which is the main criterion specified by BS EN 805.

8. The analysis of results for thermoplastics varies depending on the material, but in all cases there are relatively simple procedures that can be performed quickly to give answers that can be directly interpreted as water volume losses – using the principles specified by BS EN 805.

A4.2 Modified U.K. Pressure Decay (Type 2) Test for Metal Pipes

The analysis for metal pipes is simple.

- The results of pressure decay with time can be plotted to derive a rate of pressure loss

or

- The rate of pressure loss with time can be calculated after any initial pressure fluctuations have settled.

With metal pipes, there should be no loss in pressure if there has been a pre-test to allow for joint settlement (see section 6.1) and so any continuous decay is a sign of leakage. The measured rate of decay can be compared with the BS EN 805 level of 0.2 bar/hr. If it is above this level, the pipeline has an unacceptable leakage level.

A 4.3 Modified U.K. Pressure Decay (Type 2) Test for PVC and GRP Pipes

With PVC, pressure will decay naturally without leakage for at least 10 hours after achievement of STP. Thereafter the pressure drop caused by stress relaxation alone becomes of less and less significance.

Thus, where there are leaks in PVC pipelines, the sign of a leak can be discerned by plotting a linear graph of the Pressure vs Decay Time. Two typical tests on PVC-A pipes, one known to be leaking, the other secure are shown in Figure A4.1.

For the case with the leaking pipe, the pressure was approximately 10 times in excess of the allowable rate (Table 1) and was detectable after less than 2 hours on test. This was caused by a single leaking socket and spigot joint.

After 4 hours there was a constant rate of pressure drop with time when the creep stress relaxation rate became a small fraction of the rate of loss caused by the leakage.

For much smaller leaks, the pressure decay rate caused by the leak becomes dominant in comparison to the creep stress relaxation rate after 7-10 hours. Thus test on PVC materials need to be continued for 8 hours to be certain that the pipeline is secure.

A4.4 Modified U.K. Pressure Decay (Type 2) Test for PE Pipes

Historically, the U.K. Water Industry has used a pressure decay test to assess PE pipes for leakage. This is in accord with BS EN 805. The test procedure itself is in full accord with that outlined simply in clause 11.3.3.4.3 in the standard.

In the original test procedure, the absolute value of gauge pressure was required to be plotted as a function of time.

A 'correction' of 0.4*Rise time was required to be added to all the decay times – to account for creep deformation that had accumulated during the pressure rise phase.

A4.4.1 Use of Change in Pressure for Analysis

It is now known that the use of an absolute value of pressure led to confusion in the rates of creep stress relaxation when high initial static heads existed. The BS EN 805 analysis is actually calculated in terms of the change in pressure (e.g. equation A4.1) and so the new requirement also requires measurement of a pressure change above the initial static level. Examination of some hundreds of historic tests has shown that this greatly enhances the consistency of data expected for creep deformation in tests which showed no signs of leakage.

The basis of the decay data analysis is as follows:

- Pressure will fall continuously with time because of creep stress relaxation.
- The decay is linear on logarithmic axes – because creep stress relaxation follows a power law, i.e.

$P_A = P_1$* (Corrected Time)$^{-n}$………………(A4.1)

Where :

P_A is the pressure applied above static head Po

P_1 is the value of P_A when time = 1

n = creep stress relaxation exponent

- Leakage is a linear decay of pressure with time and thus, any leak will cause the pressure to deviate continuously from the log-log power law.
- A steady increase in the negative slope of the logarithmic plot of P_A vs corrected time is a sure sign of leakage.

In this example on a 7.7km length of 500mm pipe, the leak generated a pressure decay rate that was some 4* in excess of the allowable leakage rate given in Table 1. It was obvious from the slope changes that there were serious leakage problems after approximately 12 hours – this was at about twice the pressure rise time.

The change in slope of the log-log plot of pressure change with time is a very sensitive measure of leakage.

A4.4.1 Derivation of the Pressure Loss Rate due to Leakage

If equation A4.1 is differentiated, we have:

dP_A/dt = -n* P_1 * (Corrected Time) $^{-(1+n)}$ …………..(A4.2)

this rate can be predicted from known creep stress relaxation data

and if there is a leak which causes a pressure change $(dP_A/dt)_{leak}$, the total rate of negative pressure change will be:

Measured Rate of Pressure Drop = - (n* P_1 * Time $^{-(1+n)}$) + $(dP_A/dt)_{leak}$, ……(A4.3)

The leak rate is the only unknown and can thus be derived.

This relationship can be plotted on logarithmic axes (where the creep relaxation component will follow a linear power law) and the leak component will be a constant.

For a PE pipe leaking at the 'allowable' rate, this would be as shown in Figure A4.3.

The test data shown were calculated by simply taking the incremental changes in pressure P over logged time intervals t as the test continued.

(N.B. If transducers are set at too sensitive levels, the pressures will oscillate. Therefore, it is recommended that the minimum pressure change P should be at least 0.05-0.1 bar to prevent *flutter* of logged pressures being too significant).

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It can be seen that in this case after 30 hours on test[7], there is a significant deviation from the expected linear decay due to creep stress relaxation and the leak rate falls to a constant value after approx 72 hours. This is beyond the time when creep stress relaxation causes any major pressure change and can thus be considered to be the rate of pressure loss caused by a leak.

If this value is in excess of the values given in Table 2, then the pipeline has failed to pass the required criteria.

In the case for the 800mm pipe test shown in Figure A 4.3 (diamond points), the final pressure decay rate was 0.013 bar/hr. This is just below the allowable rate (Table 2) of 0.015 bar/hr for SDR 17 PE 80 pipe. It corresponds to a water loss of 10 litres/hour /km – via equation 4.3.

It is to be noted that sometimes, leaks are quite sensitive to the pressure level, in which case the final pressure decay rate may not settle at a constant value. The rate will still be well in excess of the ever decreasing creep rate but in this case it would be necessary to introduce a pressure factor to calculate a leakage rate.

This type of analysis requires that the PE pressure test be continued for at least 36 hours – to be certain that the pressure drop caused by the water leakage rate is in excess of the pressure drop due to creep. However, the early signs that there is a problem can be discerned when the test data deviate from the power law line. The analysis of the slope changes given in section 7 give a much more sensitive early warning that there are unusual pressure changes occurring and this analysis is preferred as the first stage in test data interpretation.

The pressure change with time analysis here is to be used when an absolute value of the pressure change due to leakage is required.

A4.4.2 Conversion of Pressure Decay Rate to Volume Loss

The derived pressure drop due to leakage can be converted to a water volume loss (litres/hr/km) by the following calculation involving scaling via equation A3.2:

Water loss = (Measured Pressure Decay Rate/ APDR) * 0.000018* $(OD)^2$…..(A4.4)

Values of the Allowable Pressure Decay Rates (APDR) are given in Table 2 in the main text.

If the absolute level of leakage is known, it can be of great assistance to the installation contractor in finding and repairing the source of the leak.

[7] The pipe was 800m diameter and 3.8km long – hence the long test time.

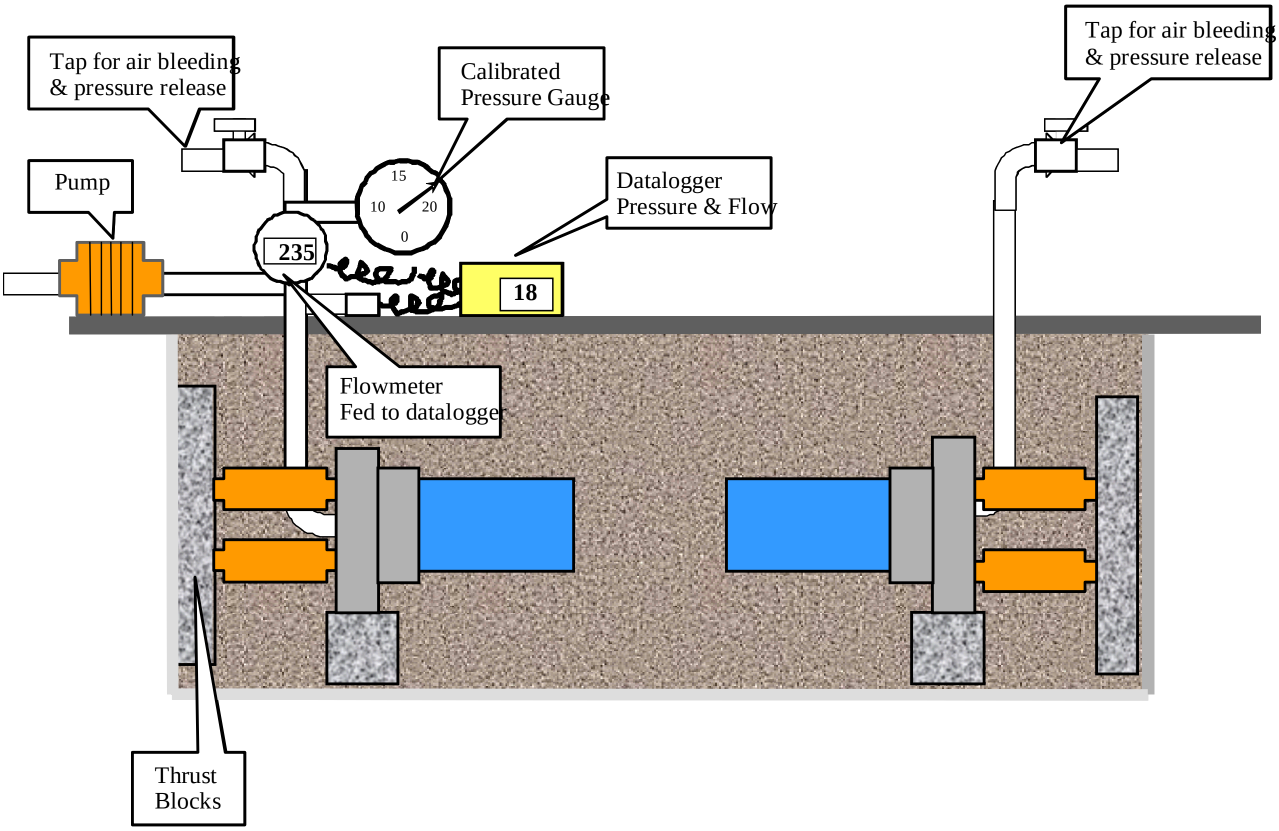

Figure 1: General Layout for Testing Equipment

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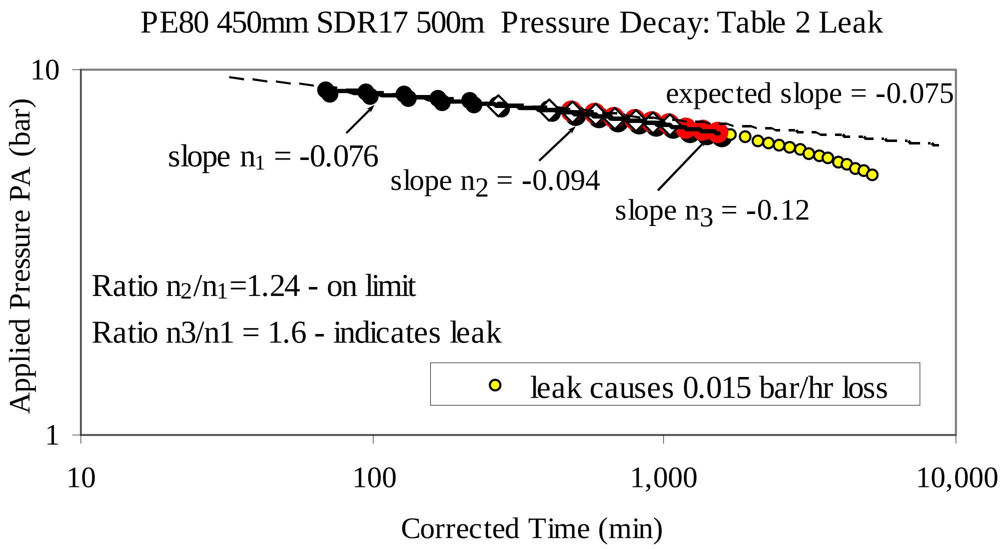

Figure 2: Example of Pressure Decay in PE Pipeline with Leaking Joint – Pressure Loss just within the "acceptable" criteria of Table 2.

		Input as function of % Air							Pipe Volume (l)
SDR	**Diameter**	**0**	**1**	**2**	**3**	**4**	**5**		
19	**100**	0	8	15	22	29	36		785
24	**125**	1	12	23	34	45	57		1227
28	**150**	1	17	33	49	65	81		1767
35	**200**	2	31	59	88	116	145		3142
40	**250**	3	48	93	137	182	227		4909
45	**300**	5	70	134	198	262	327		7069
49	**350**	7	95	182	270	357	445		9621
53	**400**	10	124	238	353	467	581		12566
55	**450**	13	157	302	446	591	736		15904
59	**500**	16	195	373	552	730	909		19635
64	**600**	24	281	538	795	1052	1309		28274
68	**700**	34	384	734	1083	1433	1783		38485
72	**800**	45	502	959	1416	1873	2330		50265
75	**900**	59	637	1215	1794	2372	2950		63617
77	**1000**	73	787	1501	2215	2929	3643		78540

Table A1.1 Estimated Water Volumes (litres) for 10 bar Pressure Increment for 100m of D.I. Pipe

PE 100 Pipes (SDR 11)

	Air %							Pipe Volume (l)
Diameter	0	1	2	3	4	5		
63	2	4	6	8	10	12		209
90	5	9	12	16	20	24		426
110	7	13	19	24	30	36		636
125	9	16	24	31	39	46		822
160	15	27	39	51	64	76		1346
180	19	34	50	65	81	96		1703
225	29	53	78	102	126	150		2662
250	36	66	96	126	155	185		3286
280	45	83	120	158	195	233		4122
315	57	105	152	199	247	294		5217
355	73	133	193	253	314	374		6626
400	92	169	245	322	398	475		8412
500	144	263	383	502	622	741		13144
560	181	330	480	630	780	930		16488
630	229	418	608	798	987	1177		20868
710	290	531	772	1013	1254	1495		26504
800	369	674	980	1286	1592	1898		33649
1000	576	1054	1532	2010	2488	2966		52576

Table A1.2 Estimated Water Volumes (litres) for 10 bar Pressure Increment for 100m of PE100 SDR 11 at 10^{o}C

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PE 100 Pipes (SDR 17)

	Air %							
Diameter	**0**	**1**	**2**	**3**	**4**	**5**		**Pipe Volume (l)**
63	4	7	9	11	13	15		243
90	9	13	18	22	27	31		495
110	13	20	27	33	40	47		740
125	17	26	35	43	52	61		955
160	28	42	57	71	85	99		1565
180	36	54	72	90	108	126		1981
225	56	84	112	140	168	196		3096
250	69	103	138	173	207	242		3822
280	86	130	173	217	260	304		4794
315	109	164	219	274	329	385		6067
355	138	208	278	348	418	488		7706
400	175	264	353	442	531	620		9784
500	274	413	552	691	830	969		15287
560	344	518	692	867	1041	1215		19176
630	435	656	876	1097	1318	1538		24269
710	553	833	1113	1393	1674	1954		30824
800	702	1057	1413	1769	2125	2480		39134
1000	1096	1652	2208	2764	3320	3876		61147

Table A1.3: Estimated Water Volumes (litres) for 10 bar Pressure Increment for 100m of PE100 SDR 17 at 10°C

PE 80 Pipes (SDR 11)

	Air %						
Diameter	**0**	**1**	**2**	**3**	**4**	**5**	**Pipe Volume (l)**
63	3	5	7	9	10	12	209
90	6	10	14	17	21	25	426
110	9	15	20	26	32	38	636
125	11	19	26	34	41	49	822
160	18	31	43	55	67	80	1346
180	23	39	54	70	85	101	1703
225	37	61	85	109	133	158	2662
250	45	75	105	135	165	194	3286
280	57	94	132	169	206	244	4122
315	72	119	166	214	261	309	5217
355	91	151	211	272	332	392	6626
400	115	192	268	345	421	498	8412
500	180	300	419	539	658	778	13144
560	226	376	526	676	826	976	16488
630	286	476	666	855	1045	1235	20868
710	364	605	846	1087	1327	1568	26504
800	462	768	1074	1379	1685	1991	33649
1000	722	1199	1677	2155	2633	3111	52576

Table A1.4 Estimated Water Volumes (litres) for 10 bar Pressure Increment for 100m of PE80 SDR 11 at 10^{o}C

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PE 80 Pipes (SDR 17)

	Air %					
Diameter	**0**	**1**	**2**	**3**	**4**	**5**
63	5	8	10	12	14	17
90	11	16	20	25	29	34
110	17	23	30	37	44	50
125	22	30	39	48	56	65
160	35	50	64	78	92	106
180	45	63	81	99	117	135
225	70	98	126	154	182	211
250	86	121	156	190	225	260
280	108	152	195	239	282	326
315	137	192	247	302	357	413
355	174	244	314	384	454	524
400	221	310	398	487	576	665
500	345	484	623	762	901	1040
560	432	607	781	955	1130	1304
630	547	768	988	1209	1430	1650
710	695	975	1255	1536	1816	2096
800	882	1238	1594	1950	2305	2661
1000	1379	1935	2490	3046	3602	4158

Pipe Volume (l)
243
495
740
955
1565
1981
3096
3822
4794
6067
7706
9784
15287
19176
24269
30824
39134
61147

Table A1.5 Estimated Water Volumes (litres) for 10 bar Pressure Increment for 100m of PE80 SDR 11 at 10^{o}C

PVC SDR 26 Pipes - (PVC-A PN12.5, PVC-U PN8)

	Input as function of % Air						
Diameter	**0**	**1**	**2**	**3**	**4**	**5**	**Pipe Volume (l)**
90	7	12	17	22	27	32	542
110	11	18	25	33	40	47	810
160	22	38	54	69	85	100	1713
200	35	59	84	108	132	157	2677
250	55	93	131	169	207	245	4183
315	87	147	208	268	329	389	6640
400	140	238	335	432	530	627	10707
450	178	301	424	547	671	794	13552
500	219	372	524	676	828	980	16730
630	348	590	831	1073	1314	1556	26561

Table A1.6 Estimated Water Volumes (litres) for 10 bar Pressure Increment for 100m of PVC at 10°C

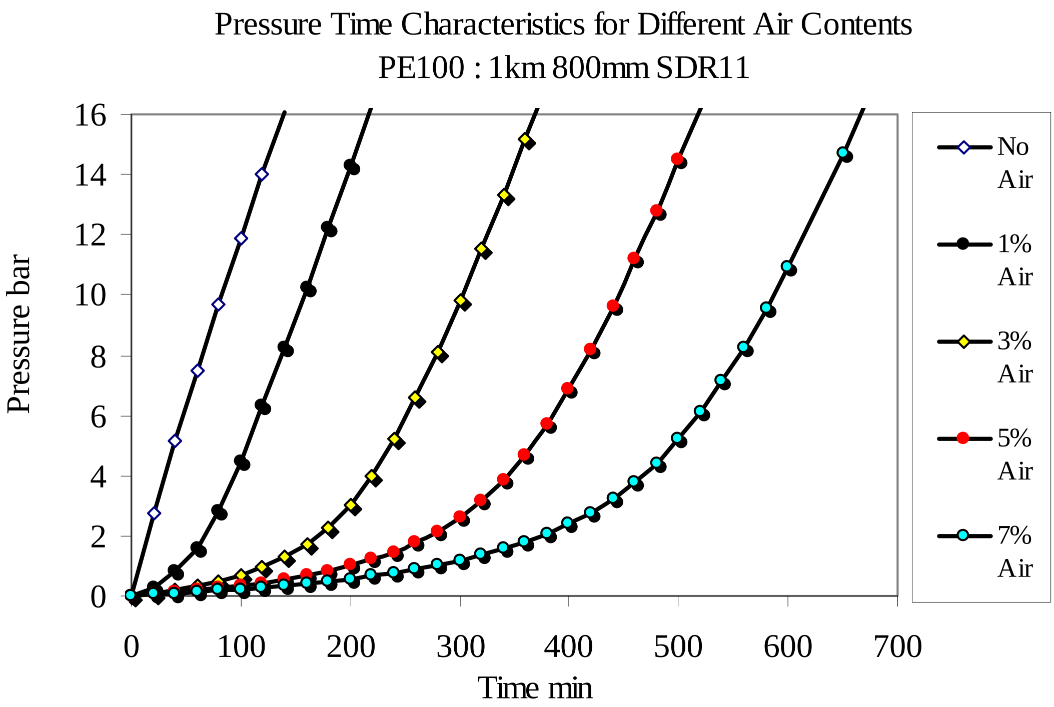

Figure A2.1: Pressure Rise Characteristics for 1 km of 800mm SDR 11 PE 100 Pipe

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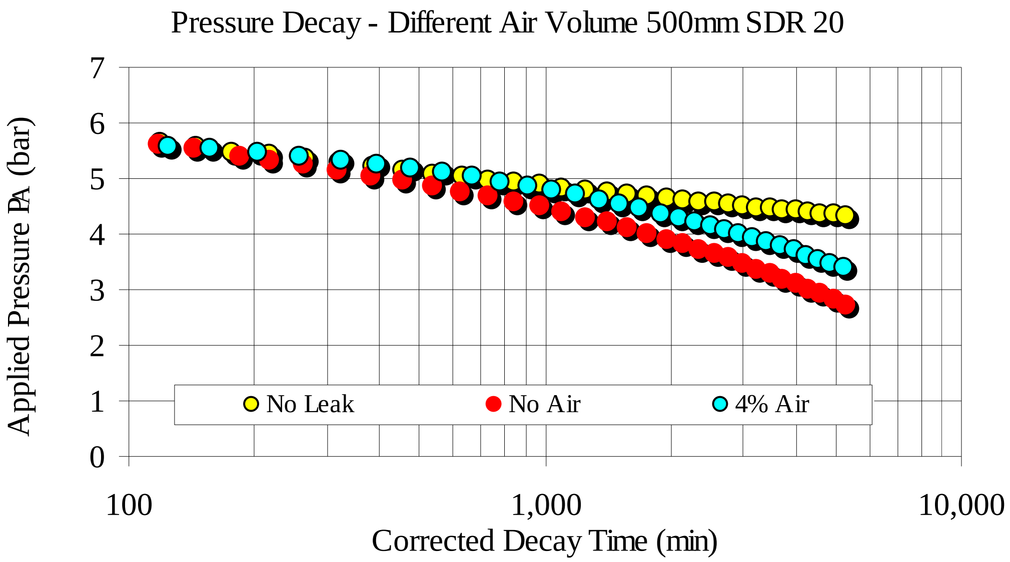

Figure A2.2 Effect of Air on Pressure Decay in a PE Main with No Leak and with Leakage at 4 times Allowable Rate

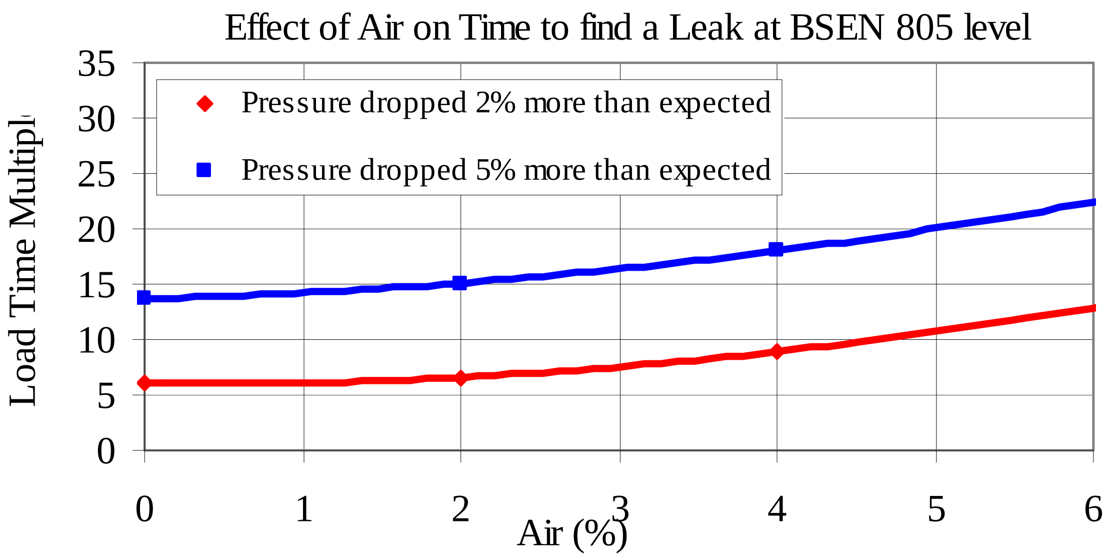

Figure A2.3: Effect of Air on Time (multiple of loading time) to detect a leak at BS EN 805 level

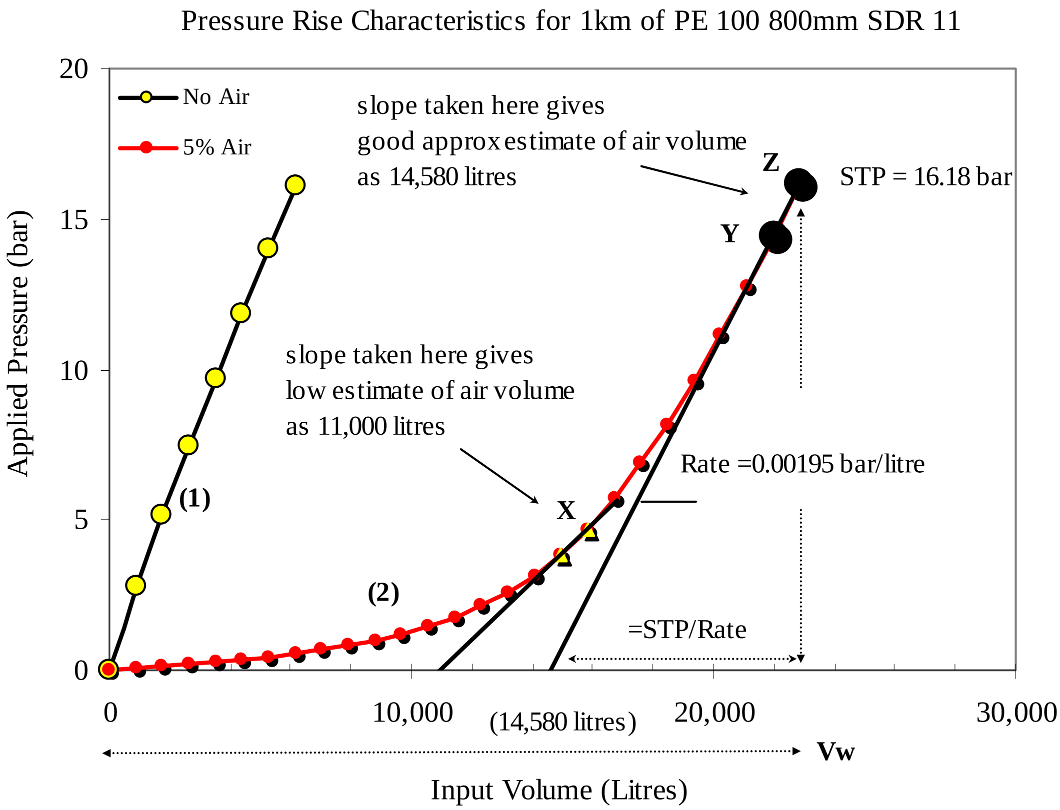

Figure A2.4: Pressure vs Vol for No Air & 5% Air - 1km : 800mm SDR 11 Pipe

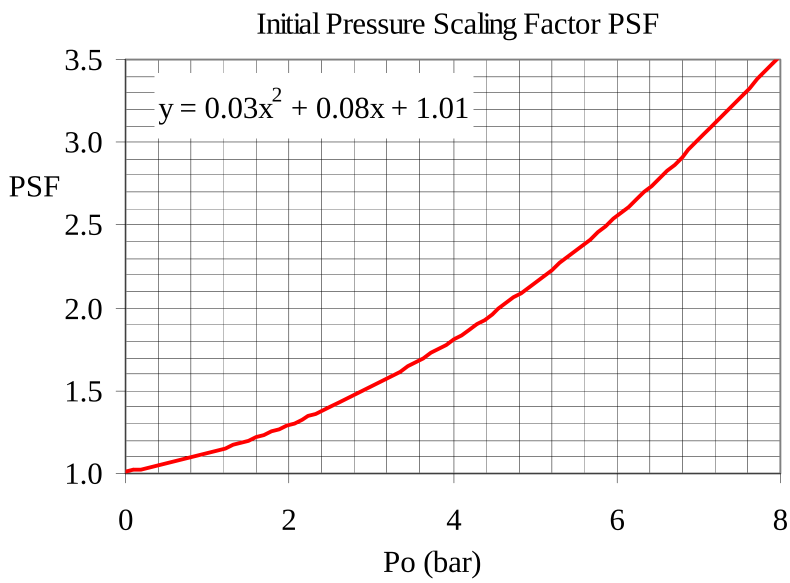

Figure A2.5: Initial Pressure Scaling Factors (PSF) to Estimate the Air Volume

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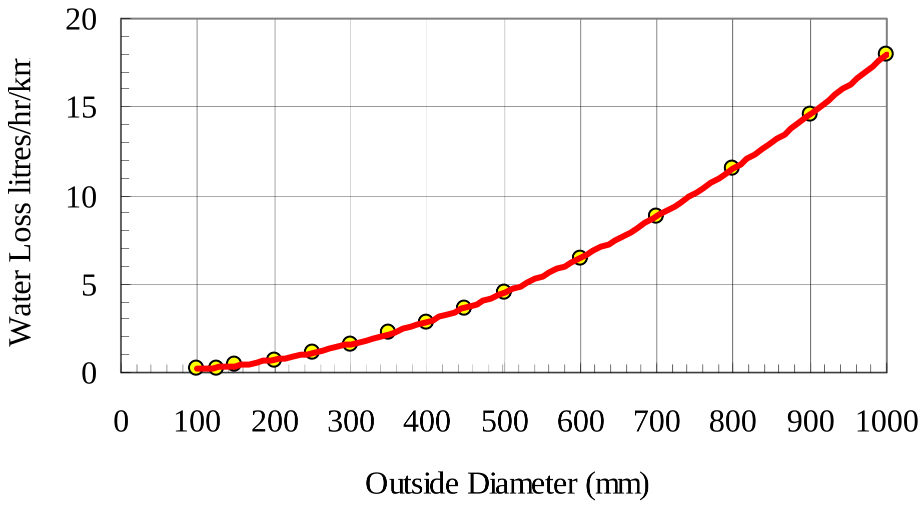

Figure A3.1: Allowable Leak Rates for DI with a Pressure Loss of 0.24 bar/hr.

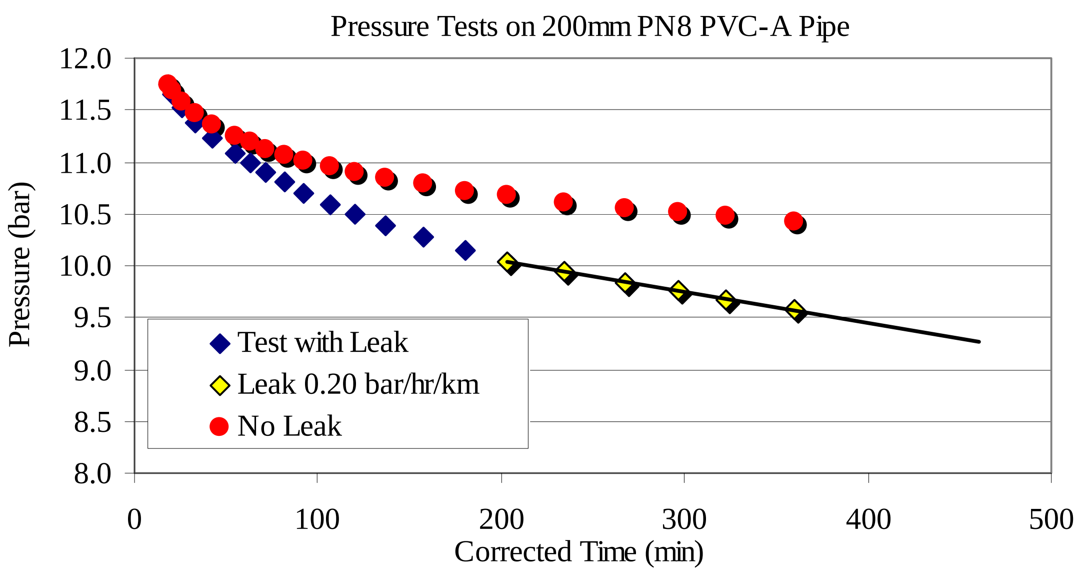

Figure A4.1 : Pressure Decay Curves for PVC-A Pipe: with and without leaks

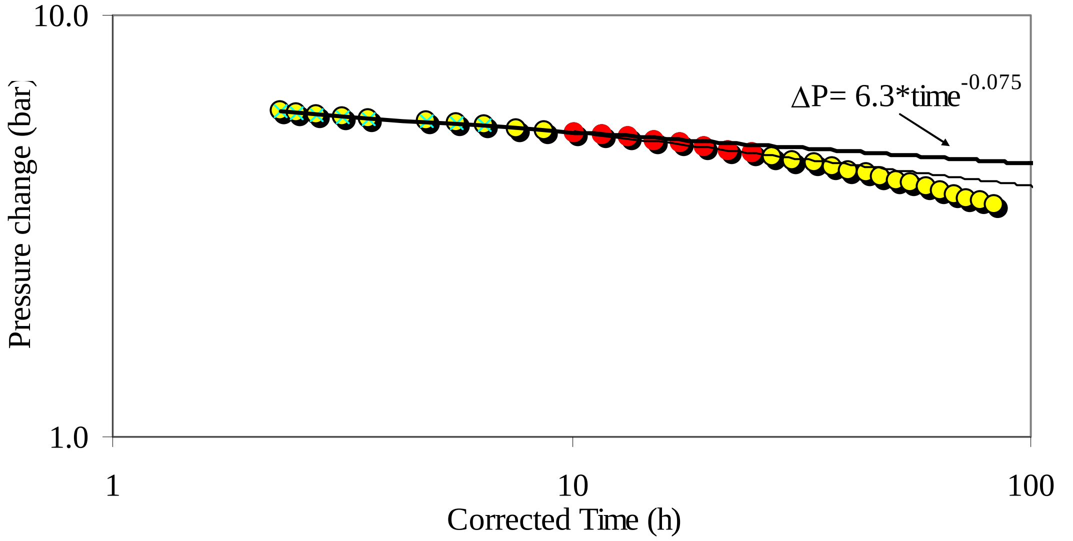

Figure A4.2 : Applied Pressure (P_A) vs Corrected Time (on logarithmic axes) for a PE Pressure Test

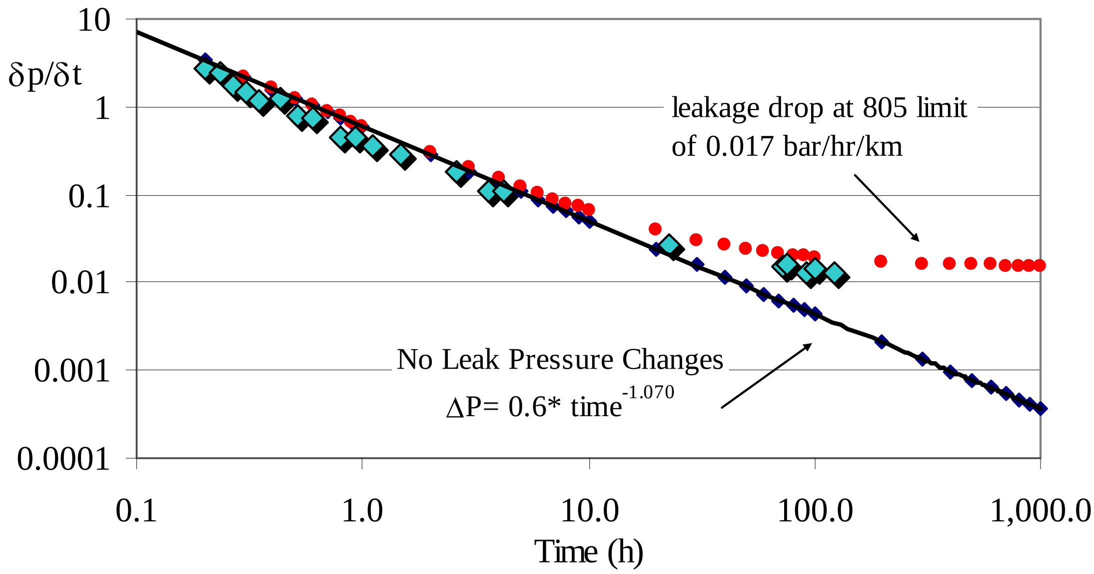

Figure A 4.3: Rate of Pressure Decay as a function of Time for a PE Pipe (log axes)

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WATER INDUSTRY
INFORMATION & GUIDANCE NOTE

UK Water Industry

PRESSURE TESTING OF PRESSURE PIPES AND FITTINGS FOR USE BY PUBLIC WATER SUPPLIERS APPENDIX A5: CONTRACTORS GUIDE

Contents

1. Introduction

One of the primary justifications for the refurbishment of water distribution, transmission mains and sewer rising mains is to replace and renovate pipes that have been shown to have unsatisfactory leakage levels. It therefore follows that the new systems should be demonstrated to be as secure and leak-free as possible.

In 2000, BS EN 805 was published and for the first time, there are now specified European criteria for assessing acceptability for different pipe materials.

BS EN 805 gives advice on different test methods that may be used to assess pipelines for leakage. These methods are not mandatory; it is left to the Engineer/Client to choose the appropriate procedure.

As a consequence of this review, it has been decided to adopt the Type II test for all new pipelines laid in U.K. water systems apart from Ductile Iron (DI) and Glass Reinforced Plastic (GRP). With the exception of DI & GRP the test method is common to all materials and combinations of materials, only the methods of data analysis are different – primarily to account for the effects of viscoelastic stress relaxation with PE materials.

DI and GRP pipelines will continue to be tested using the Water Loss Method (although this can also be determined from water added too, reference section 3)

Where new pipelines are already installed as part of a working water system – as is the case for most rehabilitation projects, other tests are required and are detailed in this document.

This document is for contractors physically undertaking the testing and provides details of the test methods to be used. Key points which affect the test are listed along with a test procedure and a brief discussion on the interpretation of the results.

Further information on the derivation of the tests and the interpretation can be found in the full Pressure Testing of Pressure Pipes and Fittings IGN.

2. New lay pipelines (PE & PVC) - Type II Test

There is no point considering a Type II pressure test without the required equipment as shown in the diagram below (Figure 1) and for which more details are provided below.

Test Fixtures – A typical setup requires tapped blank end plates, hydrants or ferrules at the lowest point on the main to facilitate the filling of the pipeline. Duckfoot hydrant bends may be used as a temporary measure to allow easier removal of swabs used to scour air from the system.

Pump - Where available a pump of capacity to raise pressure smoothly to System Test Pressure (STP) in a time period of approximately 10-20 minutes should be used where practical. For smaller volume tests the pressure rise time should be at least 2-5 minutes, this may be more suited to a hand pump.

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An estimate of the water volumes required to pressurise mains of different materials can be found in Appendix A

Flow meter – A calibrated flow meter, ideally with a resolution of 1 litre, to measure the volume of water taken to pressurise the main and capable of being logged.

Pressure Gauge – A calibrated conventional circular pressure gauge, minimum 200mm diameter, or a digital pressure gauge with a 0.01bar resolution should be available to view the pressure in the pipeline.

Data Logger – This should comprise of a pressure transducer with an accuracy 0.2% of full scale. The transducer should be connected to a logger which can record data at fixed time intervals (20s intervals are normally suitable unless the test is unusually long or short) or at fixed pressure decay increments (a minimum of 0.1bar). The data logger should be mounted at the lowest elevation of the pipeline, any deviation from this should be noted

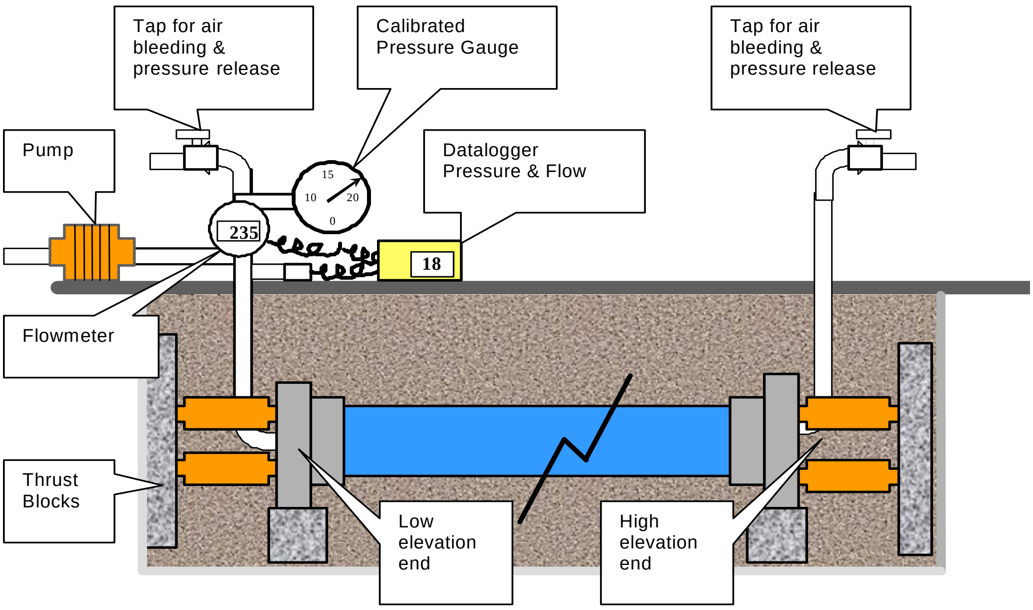

Figure 1: General Layout for Testing Equipment

Ancillary Information

The following ancillary information should also be recorded:

- The elevations of both ends of the test section (data maybe available from the design drawings or onsite measurement) and the measured static head at the lowest elevation must be determined when the valve at the highest elevation is open. The difference in head between the position of the lowest elevation and that of the transducer used in the test is an important consideration.
- The start and end times and the date of the test
- All details of the pipe (material, length, diameter, PN/SDR)
- Target Standard Test Pressure (STP)
- Type and volume flow rate of the pump
- Details of the type and ratings of pressure and flow measuring devices should be given and any calibration certificates made available

Choice of System Test Pressure (STP)

The standard test pressure (STP) should be the lowest of:

- o 1.5*PN
  or
- o PN+5 bar

- The PN rating of the lowest rated component in the system should be used.
- The value of STP should apply at the lowest elevation of the pipeline and must therefore

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include the initial maximum static head applied (Po).

- The test pressure at the highest elevation should be at least the maximum operating pressure. If this is not possible due to the elevations involved then the line should be split prior to testing.

Note 1: Some companies may prefer to use an STP value of 1.5 Design Continuous Maximum Operating Pressure*

Note 2 To be a valid test the STP should be achieved. Raising the pressure significantly (more than 2 bar) above the STP will not affect the test analysis but may damage a polymeric pipe if the pressure is maintained for more than 2 hours (however the creep should reduce the pressure in the pipeline significantly within 2 hours).

Choice of Test Section/Length of Pipeline

There are no theoretical limits to the maximum length of main which can be tested but there are a number of practical issues which limit the length, these are:

- Number of joints & fittings on the main
- Availability of potable water to pre-charge the main
- Source for discharge of water after the test.
- Elevations on the main
- Ability to identify the source of any leak detected
- The time available in which to obtain a valid test result

Mains Testing Set-Up

To carry out a quantifiable assessment of leakage from either the pipeline or the joints by a pressure decay test, it is essential that:

- The main to be tested should be isolated with end load bearing end fittings with sealed plates. End fittings should have pressure ratings of at least 1.5* STP.
- Closed valves or 'squeeze-off' seals (for PE) should NOT be used to hold the water.
- Service pipe connections using tapping tees may have been bolted/welded to the main, but the tapping hole should not have been made.
- Wherever possible, all joints made to the pipeline should be in open trenches – visible for direct visual inspection.
- The main pipeline should have been backfilled and compacted prior to the test. This prevents any axial movement or thermal effects on a sunny day.
- Air valves should be located at all high points to facilitate the removal of air during charging of the main. Air valves should not be closed during the test but non self-sealing air vents should be closed.

Charging of Main

Water for testing of potable water mains should be taken from the existing supply

An adjacent main may be used to charge the main but every effort should be made to ensure the pressure in the pipeline does not exceed 2 bar above any static head generated by elevation changes. If the pressure is raised above this value then water should be bled from the main to reduce the pressure prior to the test commencing.

The main should be charged from the lower end with all air valves open and an open valve at the highest elevation. After charging the main and bleeding air from the system the valve at the highest elevation should remain open to ensure there is no residual head at that point.

Any attempt to shorten the pumping phase by increasing the initial pressure to local mains pressure using an adjacent main is forbidden and may result in the test being classed as invalid. The following points should be noted by contractors tempted to save on pumping by pre-charging:

- It will be obvious from input volumes and elevations that pre-charging has occurred
- There is a greater likelihood of the test failing the specified criteria

Removal of Air

The presence of air in a main will have a number of effects:

- Air will markedly increase the pressure rise time.

- Air will distort the interpretation of pressure decay results.

There is an **upper limit of 4% air** in any main for a valid test.

An approximate estimate of the air volume can be made by comparing the actual water input volume (obtained from the flow meter) with those given in Appendix A.

Attempts should be made to purge air from the main during/after charging with water and before the start of the Pressure Test.

For any pipeline where there is undulation it is recommended to use a soft foam swab ahead of the water column.

Test Procedure

Once the air has been removed from the main the data logger should be connected and all information logged.

Preliminary Conditioning of Main

For PVC pipes with socket and spigot joints, the pressure should be raised to the STP and allowed to settle for 15 minutes.

There should be no conditioning of PE mains, any such conditioning will result in the test being classed as invalid and a retest will be required.

Raising Pressure

The pressure should be raised to the test level (STP) by pumping in a controlled manner.

An approximate estimate of the air volume can be made by comparing the actual water input volume (obtained from the flow meter) with those given in Appendix A.

If the inputted volume indicates an air volume greater than 4% the test should be abandoned and actions taken (as detailed previously) to remove the air from the system prior to retest.

For all plastic pipes the new test should not start until a period of 4 times the period the pipe was previously under test pressure for, including the initial rise time.

Pressure Decay Phase

After the test pressure (STP) has been reached the system should be isolated and the pressure decay logged for the times given in Table 1.

Material	Test decay time (hours)
PVC	≥8
PE	≥1 hour or at least 20*pressurisation time – whichever is greater

Table 1 – Minimum test decay times for different materials

- As the pressure decays an analysis may be carried out to check whether there is reason to believe that the main is leaking. This may be done whilst the test is in progress.
-

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- It is recommended that the test apparatus attached to the main is not de-commissioned or the main put into service until there is strong reason to believe that the pipeline meets the appropriate test criteria and is deemed to be free from leakage.

Data Analysis

PVC and PE pipes

- PE and PVC materials creep under stress and therefore the analysis of the test data is a little more complicated than for the other materials. The calculations below can be used to obtain two 'n' values

$$n_1 = \frac{[\log(P_A @ t_1) - \log(P_A @ t_2)]}{[\log(t_2) - \log(t_1)]}$$

$$n_2 = \frac{[\log(P_A @ t_3) - \log(P_A @ t_2)]}{[\log(t_3) - \log(t_2)]}$$

- P_A: Applied Pressure = Current Pressure – Initial Static Pressure
- t_r: Pressure rise time
- t=0 when STP has been reached

- For PE: $t_1 = t_r + 0.4t_r$ $t_2 = 8t_r + 0.4t_r$, $t_3 = 20t_r + 0.4t_r$.
- For PVC's: t_1 = 1hr, t_2 = 3hr, t_3 = 5h

- If $\frac{n_2}{n_1} \leq 1.25$ then the test is a pass

- *Note: If $\frac{n_2}{n_1}$ is slightly greater than 1.25 the data may be analysed graphically and the "n" values obtained by a trend line analysis to reduce single point errors, the graphical "n" values should then be used to establish if the test passes. More details can be found in the full Pressure Testing of Pressure Pipes and Fittings IGN or a specialist maybe contacted to offer advice.*

If pipelines fail to meet the acceptance criteria, the test should be stopped and the excess water bled carefully from the system. A search for potential leaks should be initiated. After leaks are found and repaired, the test should be repeated. – but only after a time greater than 4 times the total original test time has elapsed – to allow for complete creep deformation recovery.

Post Test Procedure

- When a main has been positively accepted as being free from leaks, the water should be released slowly from the pipeline with all valves opened.
- The water should be discharged safely to a pre-planned site

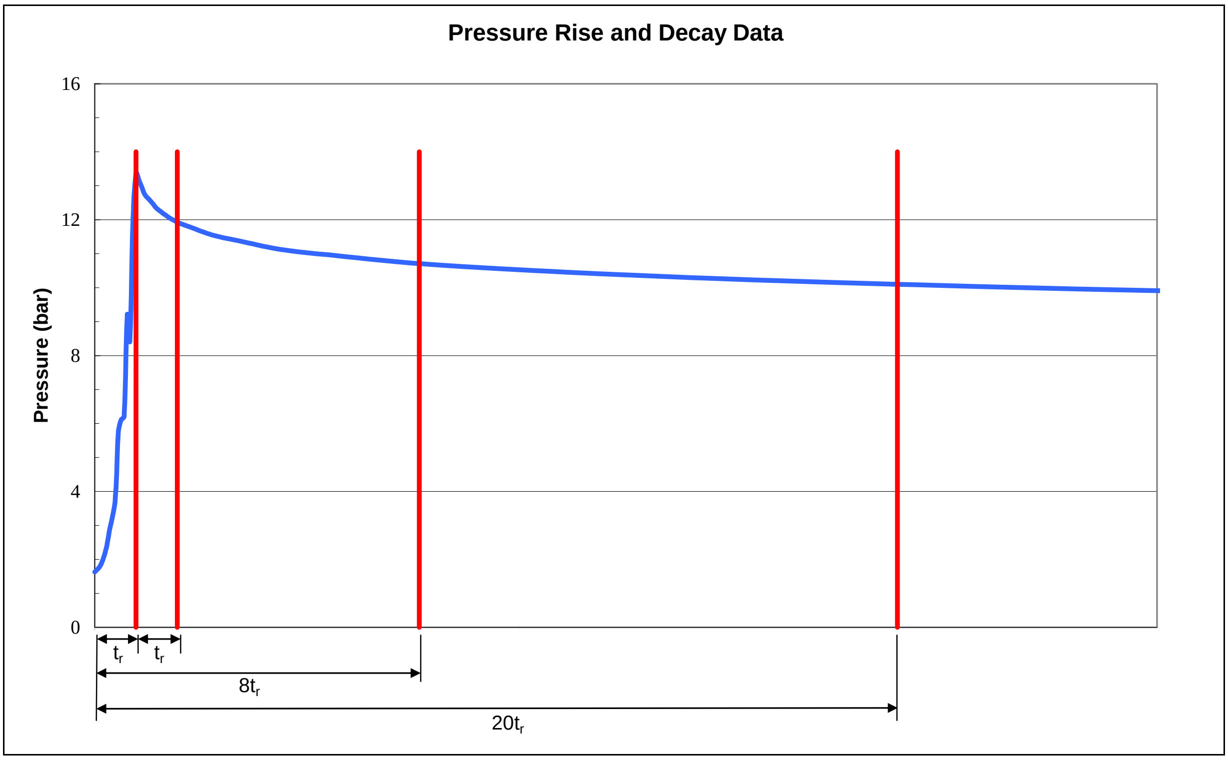

Figure 2 – Response of Pressure v Time for a PE pipe showing the times at which pressure values are analysed to determine the “n” values

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3. New lay pipelines (DI, Steel & GRP) – Water Loss/Added Method

Equipment

As with the Type II pressure test there are certain items of equipment which are necessary for the Water Loss Test and without which the test should not be conducted.

Test Fixtures – A typical setup requires tapped blank end plates, hydrants or ferrules at the lowest point on the main to facilitate the filling of the pipeline. Duckfoot hydrant bends may be used as a temporary measure to allow easier removal of swabs used to scour air from the system.

Pump – A pump capable of raising and controlling the test pressure (STP) and in the case of measurement of the water volume added: a pump capable of maintaining test pressure and measuring the volume of water pumped in to achieve this.

An estimate of the water volumes required to pressurise mains of different materials can be found in Appendix A.

Pressure Gauge – A calibrated conventional circular pressure gauge, minimum 200mm diameter, or a digital pressure gauge with a 0.01bar resolution should be available to view the pressure in the pipeline.

Volume Container – A calibrated container, suitable for the expected volume loss (e.g. a 200ml measuring cylinder would be suitable for small volumes). This will allow the draw off to be accurately measured.

Ancillary Information

The following ancillary information should also be recorded:

- The elevations of both ends of the test section and the measured static head at the lowest elevation should be determined when the valve at the highest elevation is open. The difference in head between the position of the lowest elevation and that of the transducer used in the test is an important consideration.
- The start and end times and the date of the test
- All details of the pipe (material, length, diameter, PN/SDR)
- Target Standard Test Pressure (STP)
- Details of the type and ratings of pressure measuring devices should be given and any calibration certificates made available.

Choice of System Test Pressure (STP)

The standard test pressure (STP) should be the lowest of:

- o 1.5*PN
  or
- o PN+5 bar

- The PN rating of the lowest rated component in the system should be used.
- The value of STP should apply at the lowest elevation of the pipeline and should therefore include the initial maximum static head applied (Po).
- The test pressure at the highest elevation should be at least the maximum operating pressure. If this is not possible due to the elevations involved then the line should be split prior to testing.

Note: Some companies may prefer to use an STP value of 1.5 Design Continuous Maximum Operating Pressure*

Choice of Test Section/Length of Pipeline

There are no theoretical limits to the maximum length of main which can be tested but there are a number of practical issues which limit the length, these are:

- Number of joints & fittings on the main
- Availability of potable water to pre-charge the main
- Source for discharge of water after the test.
- Elevations on the main
- Ability to identify the source of any leak detected
- The time available in which to obtain a valid test result

Mains Testing Set-Up

To carry out a quantifiable assessment of leakage from either the pipeline or the joints by a pressure decay test, it is essential that:

- The main to be tested should be isolated with end load bearing end fittings with sealed plates. End fittings should have pressure ratings at least 1.5* STP.
- Any service connections should not be tapped
- Wherever possible, all joints made to the pipeline should be in open trenches – visible for direct visual inspection.
- The main pipeline should have been backfilled and compacted prior to the test. This prevents any axial movement or thermal effects on a sunny day.
- Air valves should be located at all high points to facilitate the removal of air during charging of the main. Air valves should not be closed during the test but non self-sealing air vents should be closed.
- It is essential that all thrust blocks or other anchorages are sufficient to withstand the forces generated by the pressure test and any concrete used has been adequately cured.

Charging of Main

Water for testing of potable water mains should be taken from the existing supply

The main should be charged from the lower end with all air valves open and an open valve at the highest elevation. After charging the main and bleeding air from the system the valve at the highest elevation should remain open to ensure there is no residual head at that point.

There is an **upper limit of 4% air** in any main for a valid test.

An approximate estimate of the air volume can be made by comparing the actual water input volume (obtained from the flow meter) with those given in Appendix A.

Attempts should be made to purge air from the main during/after charging with water and before the start of the Pressure Test.

For larger diameter mains where there is undulation – it is recommended to use a foam swab ahead of the water column.

Test Procedure

Raising Pressure

The pressure should be raised to the test level (STP) by pumping in a controlled manner.

An approximate estimate of the air volume can be made by comparing the actual water input volume (obtained from the flow meter) with those given in Appendix A.

If the inputted volume indicates an air volume greater than 4% the test should be abandoned and actions taken (as detailed above) to remove the air from the system prior to retest.

Preliminary Conditioning of Main

For iron or steel pipes with epoxy linings or GRP pipes with socket and spigot joints, the pressure should be raised to the STP and allowed to settle for 15 minutes. Where DI or steel pipes have cement linings, the main should be allowed to settle overnight.

Test Phase

After the Preliminary Conditioning the pressure should be raised to the STP. Once the STP has been achieved, use either of the following two procedures

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for measuring the amount of water required to maintain pressure.

Volume of Water Added

Maintain STP for a period of one hour by additional pumping as necessary, accurately measure the flow of water and record with a resolution of 5ml or better.

Volume of Water Lost

Maintain STP for a period of one hour by additional pumping as necessary. Isolate the main by disconnecting the pump and closing all valves. Allow pressure to decay for a period of one hour. The pressure should then be raised and returned in a controlled manner to STP. Water is then drained back to the decay level pressure and captured in to a calibrated volume container.

Data Analysis

If the drawn off or added volume is less than the allowable volume (Table 2) then the test is a pass, if it is above the test is a fail.

Nominal Pipe Diameter (mm)	Leakage Rate (litres/km/h)
100	0.18
150	0.41
200	0.72
250	1.13
300	1.62
350	2.21
400	2.88
450	3.65
500	4.50
600	6.48
700	8.82
800	11.52
900	14.58
1000	18.00

Table 2 – Allowable leak rates (litres/km/hour) as a function of diameter

If pipelines fail to meet the acceptance criteria, the test should be stopped and the excess water bled carefully from the system. A search for potential leaks should be initiated. After leaks are found and repaired, the test should be repeated.

Note: These are small volumes and as such the pressure gauge used to monitor the STP and the decayed pressure need to have a resolution of 0.01 bar or less. Small errors in the pressure may lead to relatively large differences in the drawn off volume and therefore lead to secure pipelines failing the test.

Post Test Procedure

When a main has been positively accepted as being free from leaks, the water should be released slowly from the pipeline with all valves opened.

The water should be discharged safely to a pre-planned site.

4. Mains Renewal Test (10 minute test)

The rehabilitation of mains is often conducted under severe time constraints to ensure disruption to customers supplies are kept to a minimum. At a minimum of 1 hour long the Type II test is often unsuitable for a situation such as this.

The Mains Renewal Test does not provide the same level of robustness (especially with regards to data interpretation and therefore identification of a small leak) as the Type II or Water Loss test but can provide an element of confidence in the system being installed especially if there are few joints (e.g. the testing of two 100m coils with an EF coupler joining them). It can identify leaks at joints or if a straight coil is being tested it can identify damage such as that caused during slip lining.

Equipment

The Mains Renewal Test is a constant pressure test rather than a constant volume test as the Type II is. The main differences between the equipment required for a mains renewal test and a Type II Test are:

Test Fixtures – The test can be conducted against valves and squeeze offs. There is no necessity to remove the air from the system as this will not affect the result. It is advisable to remove the majority of the air from a health & safety perspective.

Pump – A pump capable of raising and controlling the test pressure for a period of at least 10 minutes is required.

Flow meter – A calibrated flow meter, with a resolution of at least 0.1 litre, to measure the volume of water taken to pressurise and then maintain the pressure of the main and capable of being logged.

Pressure Gauge – The pressure in the pipeline should be monitored by a calibrated conventional circular pressure gauge, minimum 200mm diameter, or a digital pressure gauge with a 0.01bar resolution.

Data Logger – This should comprise of a pressure transducer with an accuracy 0.2% of full scale. The transducer should be connected to a logger which can record data at fixed time intervals (20s intervals are normally suitable unless the test is unusually long or short) or at fixed pressure decay increments (a minimum of 0.1bar). The data logger should be mounted at the lowest elevation of the pipeline; any deviation from this should be noted.

Ancillary Information

The following ancillary information should also be recorded:

- The start and end times and the date of the test
- All details of the pipe (material, length, diameter, PN/SDR)
- Type and volume flow rate of the pump
- Details of the type and ratings of pressure and flow measuring devices should be given and any calibration certificates made available.

Choice of System Test Pressure (STP)

The standard test pressure (STP) should be the lowest of:

- o 1.5*PN
  or
- o PN+5 bar

- The PN rating of the lowest rated component in the system should be used.
- The value of STP should apply at the lowest elevation of the pipeline and should therefore include the initial maximum static head applied (Po).
- The test pressure at the highest elevation should be at least the maximum operating pressure. If this is not possible due to the elevations involved then the line should be split prior to testing.

The tolerance for the pressure is ±10% of the STP. A breach of this tolerance will lead to the test being classed as invalid and a retest being required.

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Choice of Test Section/Length of Pipeline

This test is only suitable for short test lengths with a small number of joints. The maximum recommended length is 200m comprised of two jointed 100m coils.

Any lengths in excess of this should be tested using a Type II test.

Charging of Main

Water for testing of potable water mains should be taken from the existing supply

An adjacent main may be used to charge the main and, unlike the Type II test, to raise the pressure up to mains pressure.

Test Procedure

Once the main has been charged (prior to pressurisation) the data logger should be connected and all information logged.

The pressure should be raised to the test level (STP) by pumping in a controlled manner. Once the STP has been realised the pump should be left on to maintain the STP for a minimum of 10 minutes. A visual inspection of all possible sources of leakage (e.g. a squeeze off or valve) should be made by walking down the length of the pipeline under test, and if these are present a note should be made on the results sheet.

Data Analysis

The data is analysed by inspecting the graphs of pressure v time and flow v time. A successful test will have a high flow as the main is being pressurised, this will reduce significantly when the STP is achieved. To keep the pressure constant more water will need to added as PE creeps. The amount of water needed should reduce with time and, depending on the diameter and length of main being tested, should be small in magnitude. A slightly increased level of flow can be attributed to a slight leak on a squeeze off or valve but this should have been identified by the contractor when they conducted a visual inspection of the test length. Although not ideal the use of squeeze offs and testing against valves is needed to ensure this test is quick to conduct.

A successful test is one where the pressure does not fluctuate significantly and there are low, reducing flow rates. If the volume inputted over 3 equal periods in the duration of the test is analysed there should be steady volume or reduction in the volume inputted to maintain the pressure. Allowable volumes can not be given as there is no control of air volume and pre-pressurisation is allowed.

An unsuccessful test is one where the pressure fluctuates significantly and a significant amount of water, which does not reduce, is required to maintain pressure.

Once a contractor has become familiar with the test it should be possible for him to identify if the test will be a pass or fail by monitoring the flow meter – both the magnitude (depending on the diameter and length) and how the flow rate varies with time.

If the test indicates there is a leak this should be identified and the test repeated until a satisfactory result is obtained

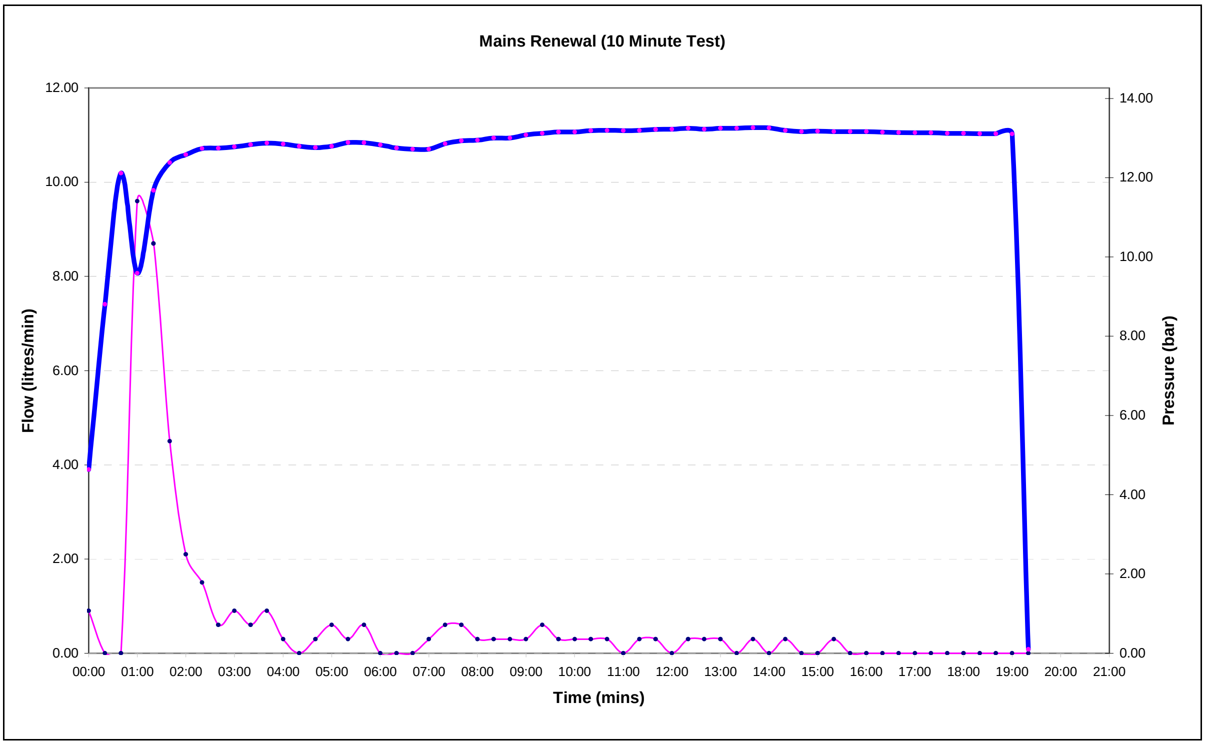

Figure 3 – Typical Mains Renewal test graph showing the pressure increasing with high flows, the flow reducing as the test pressure is reached and then decreasing as the rate of creep slows

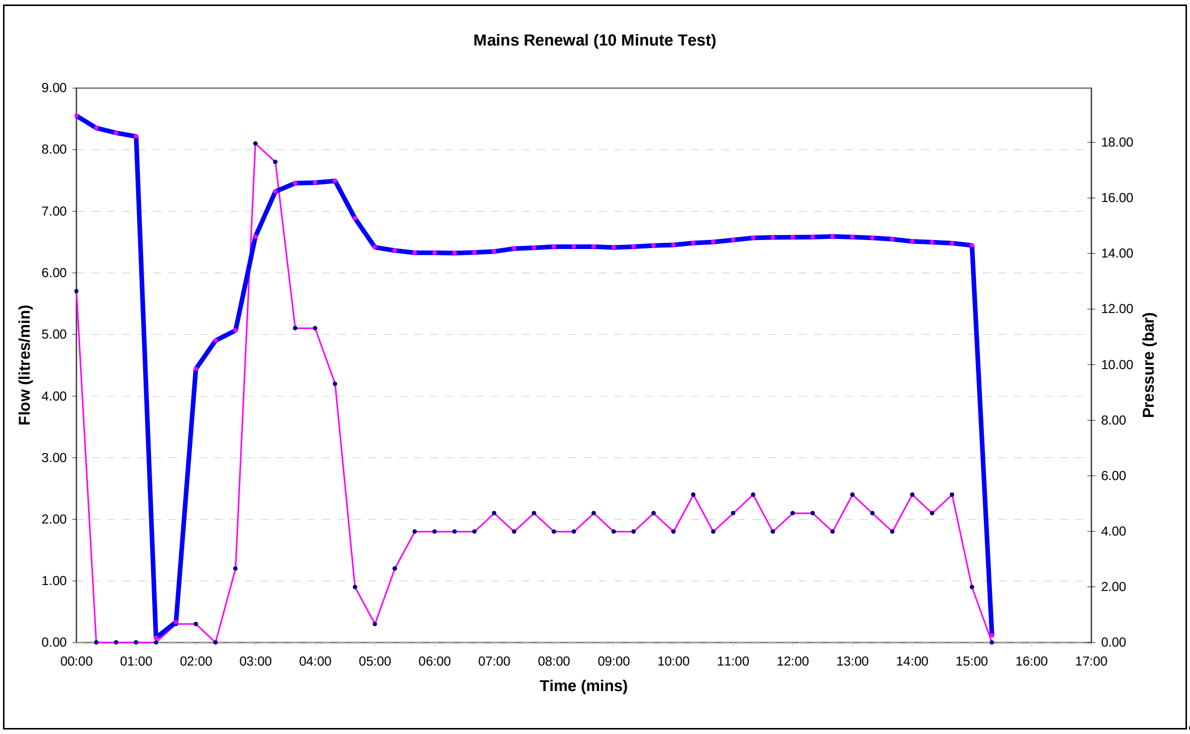

Figure 4 – Mains Renewal test graph indicating a leak. Pressure fluctuates from the test pressure and flow rate is high and does not reduce over the duration of the test

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5. Service Test

To ensure a leak free system all joints and connections should be tested. The service connections are often overlooked and are a potential source of leakage.

As there can be a large number of services on a main this test has been designed to be quick and easy to conduct. It is essentially a visual test and there is no data logging to support the reported result.

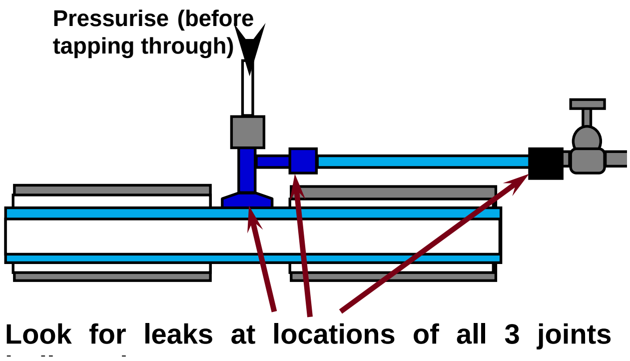

Figure 5 – Three joints which can be tested by the service test

Equipment

Pump – A hand pump capable of raising and maintaining the pressure in the test length at 18bar.

Ancillary Information

The following ancillary information should also be recorded:

- The start time and date of the test
- All details of the location of the service pipe
- Details of the contractor who conducted the test.

Test Preparation

Choice of System Test Pressure (STP)

- The test pressure is 18bar

This may seem high but the service will not suffer any damage from this pressure if it is only applied for a short period of time

The service should not have been tapped prior to this test being conducted.

Test Procedure

Fill the section to be tested. Raise the pressure to 18bar and maintain the pressure for 2 minutes. Inspect the service visually during the test. Release the pressure.

If a leak has been identified then the service should be replaced, if no leak has been identified then the test is a pass.

Appendix A

Water Volumes to pressurise pipelines – pressures and lengths can be scaled pro rata (e.g. for 15bar increase multiply value by 1.5 for 50m divide value by 2)

K9 Ductile Iron

		Input as function of % Air				
Diameter (mm)	**SDR**	**0%**	**1%**	**2%**	**3%**	**4%**
100	**19**	0	6	12	18	23
125	**24**	1	10	19	29	38
150	**28**	1	15	29	43	56
200	**35**	2	27	53	78	103
250	**40**	3	44	84	124	164
300	**45**	5	64	122	181	240
350	**49**	7	88	168	248	329
400	**53**	10	115	221	327	433
450	**55**	13	147	281	416	550
500	**59**	16	183	349	516	682
600	**64**	24	266	507	748	989
700	**68**	35	364	694	1023	1353
800	**72**	47	478	910	1342	1774
900	**75**	60	608	1156	1704	2252
1000	**77**	76	754	1431	2109	2787

Estimated Water Volumes (litres) for 10 bar pressure Increment per 100m length

PVC SDR26 – (PVC-A PN12.5, PVC-U PN8)

	Input as function of % Air				
Diameter (mm)	**0%**	**1%**	**2%**	**3%**	**4%**
90	7	12	17	22	27
110	11	18	25	33	40
160	22	38	54	69	85
200	35	59	84	108	132
250	55	93	131	169	207
315	87	147	207	268	328
400	140	237	334	432	529
450	177	300	423	546	670
500	218	370	522	675	827
630	347	588	829	1071	1312

Estimated Water Volumes (litres) for 10 bar pressure Increment per 100m length at 10ºC

PE100 Pipes SDR 17

	Input as function of % Air				
Diameter (mm)	**0%**	**1%**	**2%**	**3%**	**4%**
63	4	7	9	11	13
90	9	13	18	22	27
110	13	20	27	33	40
125	17	26	35	43	52
160	28	42	57	71	85
180	36	54	72	90	108
225	56	84	112	140	168
250	69	103	138	173	207
280	86	130	173	217	260
315	109	164	219	274	329
355	138	208	278	348	418
400	175	264	353	442	531
500	274	413	552	691	830
560	344	518	692	867	1041
630	435	656	876	1097	1318
710	553	833	1113	1393	1674
800	702	1057	1413	1769	2125
1000	1096	1652	2208	2764	3320

(i)

Estimated Water Volumes (litres) for 10 bar pressure Increment per 100m length at 10ºC

PE100 Pipes SDR 11

	Input as function of % Air				
Diameter (mm)	**0%**	**1%**	**2%**	**3%**	**4%**
63	2	4	6	8	10
90	5	9	12	16	20
110	7	13	19	24	30
125	9	16	24	31	39
160	15	27	39	51	64
180	19	34	50	65	81
225	29	53	78	102	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
500	144	263	383	502	622
560	180	330	480	630	780
630	228	418	608	798	987
710	290	531	772	1013	1254
800	368	674	980	1286	1592
1000	576	1054	1532	2010	2488

Estimated Water Volumes (litres) for 10 bar pressure Increment per 100m length at 10ºC

PE 80 Pipes SDR 11

	Input as function of % Air				
Diameter (mm)	**0%**	**1%**	**2%**	**3%**	**4%**
63	3	5	7	9	10
90	6	10	14	17	21
110	9	15	20	26	32
125	11	19	26	34	41
160	18	31	43	55	67
180	23	39	54	70	85
225	36	61	85	109	133
250	45	75	105	135	165
280	57	94	131	169	206
315	72	119	166	214	261
355	91	151	211	272	332
400	115	192	268	345	421
500	180	300	419	539	658
560	226	376	526	676	826
630	286	476	666	855	1045
710	363	604	845	1086	1327
800	461	767	1073	1379	1685
1000	721	1199	1677	2155	2633

Estimated Water Volumes (litres) for 10 bar pressure Increment per 100m length at 10ºC

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PE 80 Pipes SDR 17

	Input as function of % Air				
Diameter (mm)	**0%**	**1%**	**2%**	**3%**	**4%**
63	5	8	10	12	14
90	11	16	20	25	29
110	17	23	30	37	44
125	22	30	39	48	56
160	35	50	64	78	92
180	45	63	81	99	117
225	70	98	126	154	182
250	86	121	156	190	225
280	108	152	195	239	282
315	137	192	247	302	357
355	174	244	314	384	454
400	221	310	398	487	576
500	345	484	623	762	901
560	432	607	781	955	1130
630	547	768	988	1209	1430
710	695	975	1255	1536	1816
800	882	1238	1594	1950	2305
1000	1379	1935	2490	3046	3602

Estimated Water Volumes (litres) for 10 bar pressure Increment per 100m length at 10ºC