

11 Testing

11.1 General

Following completion of construction and backfill, it is essential that pipelines are subject to comprehensive inspection and assessment to confirm their integrity. Demonstration of integrity is mandatory, and in general it is confirmed by pressure testing.

It is recommended that pipelines are pressure tested after completion of the construction work and backfill, to establish the existence of a margin of safety against failure at operational pressure conditions, and to prove their strength and leak-tightness prior to commissioning.

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Where information regarding safety margin can be robustly obtained through technical approaches such as inspection and structural reliability analysis (SRA), the operator may select to use such an approach as an alternative to pressure testing to demonstrate the safety margin of the pipeline. When applied, it is essential such approaches are carried out and documented by competent experts.

NOTE 2, Prefabricated assemblies and tie-in sections may be pre-tested or subject to an alternative assessment before installation, provided no subsequent construction activity will impair the component integrity. Testing or alternative assessment may be carried out in suitable sections as work progresses (see 11.3.1).

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Topography or other considerations may require testing in a number of sections, and consideration should be given to a final tightness test.

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The tests should be carried out with the trench adequately backfilled to avoid the influence of temperature changes.

The number of test sections should be minimized. Selection of test sections should take into account:

- a) safety of personnel and the public, and the protection of the environment and other facilities;
- b) construction sequence;
- c) terrain, pipeline section profile and access;
- d) availability and disposal of test water.

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Are there any instances where this would not be advantageous?

Equipment which should not be subjected to the test pressures should be isolated from the pipeline during testing. This should be achieved by introducing battery limit isolations to clearly limit portions of the system under test.

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Valves should not be used as end closures during pressure-testing, unless rated for the differential pressure across the valve during testing. Valves should be pretested to a

minimum of the proposed test pressure and have a current test certificate stating that they have sufficient strength to withstand the proposed test pressure.

Temporary testing manifolds, temporary pig traps and other testing components connected to the test section should be designed and fabricated to withstand the internal design pressure of the pipeline.

Pre-tested assemblies should be tested to at least the test pressure that is required for parts of the pipeline system (refer to 11.9).

All testing should be carried out under the supervision of a competent and experienced test engineer.

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11.2 Safety

11.2.1 General

Work on, or near, a pipeline under test should not be permitted for the period from the start of the increase in pressure to the reduction in pressure at the end of the test, except where necessary for conducting the test. Where appropriate, precautions such as reducing test pressure to allow test personnel to work on the pressurised pipeline should be applied.

The safety of the public, construction personnel, adjacent facilities and the protection of the environment should be ensured throughout testing operations. If air or gas is used as a test medium, depressurising should be carried out by reducing pressure in a controlled manner.

Where public safety could be compromised by the release of energy during pneumatic testing, a limit of 30% SMYS is recommended to ensure that any failure should be limited to a stable leak rather than a propagating rupture or crack. In addition, all manufactured components should be subject to a prior hydrostatic test. All welds should be subjected to 100 % examination and adequate fracture toughness properties should be demonstrated.

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Consideration should be given to environmental noise limitations and safety of personnel regarding gas dispersion to a safe area.

11.2.1 Precautions to be taken during a test

Reference should be made to the Health and Safety Executive Guidance note, General series 4 Safety in pressure testing [12]. When formulating safety procedures it should be recognized that pneumatic testing will store far greater energy in the pipeline than the equivalent hydrostatic testing.

All crossings and areas of public access should be patrolled during the period of the test to prevent access.

Warning notices should be erected indicating that testing is in progress.

Boundaries should be clearly marked around the test equipment at each end of the section to deter persons not involved with the testing from approaching closer than the recommended safety distances. The typical safety distance for hydrostatic testing is 15 m. For high-level or pneumatic testing, greater distances should be enforced.

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11.2.3 Cold weather

In cold weather, after the completion of hydrostatic testing, all lines, valves and fittings should be drained completely to prevent frost damage.

11.2.4 Use of temporary pig traps

Care should be taken in the operation of temporary pig launchers and receivers during the test and these should not be opened unless the pressure in launcher or receiver is zero.

It is essential that any temporary pig traps attached to a pipeline under test are isolated from the pipeline unless they are designed and fabricated to the same standard as the pipeline.

11.3 Pressure testing

11.3.1 General

Pressure testing should be carried out hydraulically where feasible, but may be carried out pneumatically in some circumstances. The principles of the test and the results obtained are the same for both methods, but the stored energy in the pressurised system, and therefore the severity of any failure which could result is much greater in the case of pneumatic testing. The method of testing should be selected and justified based on a rigorous assessment of safety issues associated with the stored energy and the practical issues associated with the test arrangements.

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Text from 11.1 and 11.3 has been incorporated here.

NOTE 1 Re-routing of short pipeline sections or short tie-in sections for pipelines in operation are examples of situations for which pressure tests with water may not be expedient.

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NOTE 2 Pipelines designed to carry category C substances that operate at a design factor of 0.3 or less, may also be tested pneumatically using dry, oil free air or nitrogen (see 11.4.2).

NOTE 3: Terrain issues may necessitate the use of a pneumatic test.

Reliable communications should be provided between all points manned during testing.

NOTE 3 See also 11.4.

11.3.2 Test medium

Where possible, pressure tests should be conducted with water from a public utility supply.

Where this is not practicable, water may be taken from other sources. In this case, samples should be analysed and suitable precautions taken to remove or inhibit any harmful substances. Special care is needed in dealing with water sources containing potentially harmful chemicals or bacteria; it is advisable to take specialist advice and the local water authority should be notified.

Water for testing and any subsequent flushing should be clean and free from any suspended or dissolved substance that:

- a) could be harmful to the pipe material or internal coating (where applied);
- b) could form deposits within the pipeline.

NOTE Water extraction and disposal licences will be required from the appropriate Environmental Agencies.

If the test medium is subject to thermal expansion during the test, provisions should be made for relieving excess pressure.

If the ground temperature in the immediate vicinity of the pipes is less than 2°C, antifreeze should be added.

Air or a non-toxic gas should be used for a pneumatic test.

11.3.3 Level of Test

The level of test and the associated test pressure should be selected in order to demonstrate a safety margin which is adequate for the proposed operation of the pipeline. The levels of test recommended in this document are:

11.3.3.1 High Level Test

A high level pressure test involves testing to a pressure which generates a hoop stress 85%-105% SMYS of the pipeline material. This test level removes defects which are considerably smaller than would fail at the operating pressure. It provides a rigorous demonstration of a quantified safety margin which accommodates an allowance for defect growth during service, and is therefore recommended in cases where operational requirements may involve significant cyclic pressures, or where increases in the MOP to design factors exceeding 0.72 may be considered.

For details of the requirements for high level testing, reference to IGE TD/1 Edition 4 Section 8 and Appendix 5 is recommended.

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Note 1 Where limit state design has been used, reference to BS EN 1594 should be made for guidance on maximum hydrostatic test pressures.

11.3.3.2 Standard Test

A standard pressure test involves testing to a pressure of not less than 150% of the MOP. This test level demonstrates that the quality of the pipeline materials and construction is adequate for future operation of the pipeline. It is recommended in cases where significant cyclic pressures and/or increases in the pipeline MOP are not anticipated in the future operation of the pipeline.

11.3.3.3 Leak Test

A leak test involves testing to a pressure of not less than 110% of the MOP. This test level demonstrates pressure containment at the MOP for future operation. It is recommended in cases where the pipeline safety margin has been demonstrated by alternative methods not requiring high-level or standard testing (ie SRA and inspection).

Note 1 It is essential that the test pressure is not less than the sum of the maximum operating pressure plus any allowance for surge pressure and other variations likely to be experienced by the pipeline system during normal operation

11.3.4 Type of Test

11.3.4.1 Hydraulic Test

The pressure at the point of application should be such that the test pressure is generated at the lowest point in the section under test. The additional static head at any point in the section should not cause a hoop stress in excess of the specified minimum yield stress of the material at that point.

11.3.4.2 Pneumatic Test

Pneumatic tests should be carried out in accordance with ambient temperature recommendations given in PD 5500:2000.

11.3.5 Pressure Variations

Pressure variations during strength testing are acceptable if they can be demonstrated to be caused by factors other than a leak, e.g. by variations in ambient temperature or pressure.

In cases where a pipeline section is found to be leaking under test, an investigation should be carried out to establish the cause. If appropriate, the leak should then be repaired and the pipeline section re-tested.

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11.3.6 Inhibitors and additives

If test water analysis indicates that inhibitors and additives, such as corrosion inhibitors, oxygen scavengers, biocide and dyes, are necessary, then consideration should be given to their interaction and the effect on the environment during test water disposal. Consideration should also be given to the effect of any such additives on the materials throughout the pipeline system.

11.3.7 Filling rate

Filling should be performed at a controlled rate.

During filling, one or more pigs or spheres may be used to provide a positive air/water interface and to minimize air entrainment. All spaces in which air could be trapped, such as valve bodies, bypass pipework, etc. should be vented during filling and sealed prior to commencement of the hydrostatic test.

Where the fill rate is slow and there are steep downhill sections it may be necessary to maintain an air pressure to inhibit pigs running ahead of the line-fill. A safe limit of any such air backpressure should be established and carefully maintained.

The use of devices to track the pig, and control the pig speed is recommended.

11.3.8 Air content

Where the air content could affect the accuracy of the hydrostatic test, the air content should be determined and accounted for during the evaluation of the test results.

The measurement of air content should be carried out by constructing a plot of pressure against volume (see Figure 4) during the initial stage of pressurization until a definite linear relationship is apparent. By extrapolating this linear curve back to the volume axis, the air volume may be assessed, and compared with the total volume of the test section.

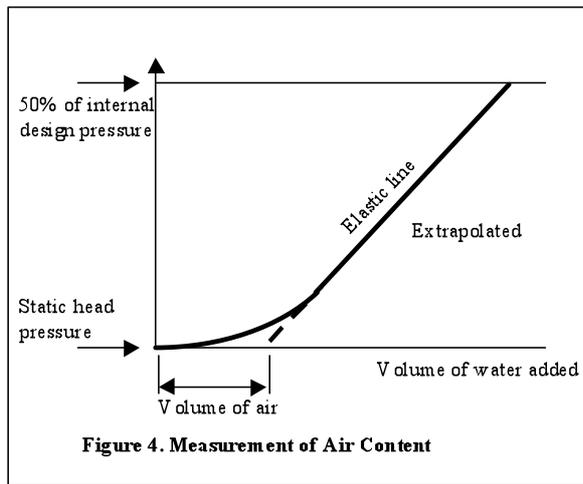


Figure 1— Measurement of air content

A comparison should also be made between the linear slope of the pressure/volume relationship for 100 % water content. If these two slopes differ by more than 10 %, the test section should be refilled. The theoretical slope may be calculated from the following formula:

$$\frac{\Delta V}{\Delta P} = V \left(0.044 \frac{D}{t} + 4.50 \right) 10^{-5}$$

where

ΔV is the incremental volume of water added (in m³);

V is the volume of test section (in m³);

ΔP is the incremental pressure change (in bar);

D is the nominal pipe diameter (in m);

t is the nominal wall thickness (in mm).

11.3.9 Temperature stabilization

After filling and prior to beginning the hydrostatic test, time should be allowed for the temperature of the water in the pipeline to stabilize with the ground temperature at pipeline depth.

11.3.10 Temperature effects and correlations

Correlations that show the effect of temperature changes on the test pressures, should be developed to assess the possible differences between the initial and final test pressures and temperatures.

11.3.11 Written procedures

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Written procedures for pressure tests should be prepared prior to the beginning of testing and should include the requirements of **11.3** and the following:

- a) the profile, including the pipe grade and wall thickness, and length of each test section with the test pressure specified for each end of pipe section being tested;
- b) the section minimum pressure and maximum pressure related to the profile;
- c) safety provisions;
- d) the requirements for continuous monitoring (see **11.6** and **11.7**);
- e) source and composition of test water and its disposal;
- f) the equipment requirements;
- g) all pressures and durations;
- h) evaluation of the test results;
- i) acceptance criteria;
- j) leak-finding procedure.

NOTE It may be necessary to give notice to a statutory authority of the intention to carry out the pressure test.

11.4 Test procedures

11.4.1 Hydrostatic testing

The pressure in the test section should be raised at a controlled rate to the test pressure calculated in accordance with **11.3.3**. The volume of water added, the corresponding pressure rise and the time should be logged during this operation, and the air content calculated. A period should be allowed for stabilization. During this period residual air will continue to go into solution and time-dependent straining of the pipe can take place. Test pressure should then be held for a period of 24 h. Pressure and temperatures should be recorded every 30 minutes, and the volume of any water added to maintain test pressure noted.

NOTE 1 For volumes of less than 20 m³ or for uncovered sections which can be fully inspected visually, this duration may be reduced.

Pressure, temperature and volume should be logged throughout the test, see **11.4.3**.

NOTE 2 *Cyclic testing*. As an alternative, a cyclic testing procedure may be followed, which accentuates time-related straining. Pressure is initially raised to test pressure for a period of 2 h, then reduced to half the value and then

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raised again to test pressure for a further 2 h. Pressure is again reduced to half the test pressure, then raised again and the test pressure held for 24 h.

11.4.2 Pneumatic testing

Pneumatic testing may be carried out if hydrostatic testing is not possible, and all applicable safety precautions should be taken.

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A pneumatic pre-test should be carried out on the pipeline section at a pressure of 1.5 bar before commencing the full pneumatic test. At this stage the pipeline section should be carefully inspected for signs of leakage.

The full pneumatic test should be carried out by raising the pressure in the test section at a controlled rate in increments of 7.0 bar to the test pressure specified in **11.3.4** for a strength test and held for a period of 45 min. The pressure should be lowered at a controlled rate in similar decrements to 110 % of the maximum operating pressure of the pipeline and held for a period of 24 h as a leak test.

A pressure-relieving device should be fitted to compressors used in pneumatic testing to prevent over-pressurizing the pipeline.

Pressure, temperature and volume should be logged throughout the test, see **11.4.3**.

11.4.3 Test data recording

A record of pressure, volume change, underground and ambient temperature should be compiled over the full duration of a pipeline pressure test. The record of pressure and temperature should be monitored and recorded every 45 min throughout the test. For hydrostatic testing, underground temperature measuring equipment should be installed at least 2 days before the pressure test is planned, to establish an underground temperature trend over several days including the 24 h hold period.

NOTE Temperature trends can be measured to a sensitivity of better than 0.1°C if plotted graphically over several days. A graphical plot of pressure, underground temperature and ambient temperature against time prepared during the test period will assist in the interpretation of test results.

11.4.4 Leak-finding

Leak detection and location procedures should be developed as part of the hydrostatic or pneumatic test procedure.

11.5 Acceptance criteria

11.5.1 General

The pressure test should meet the requirements of **11.3**.

The pressure test should be considered as satisfactory if no observable pressure variation occurs which cannot be accounted for by temperature change taking into account the accuracy and sensitivity of the measuring equipment.

11.5.2 Method of assessment for hydrostatic test

The relationship between pressure and temperature should be calculated in accordance with the following formula:

$$\Delta P = \frac{264.7 T_f}{D/t + 100}$$

where

ΔP is the pressure change (in bar/°C);
 T_f is the temperature factor change (from Figure 5);
 D is the nominal pipe diameter (in m);
 t is the nominal wall thickness (in m).

The temperature factor change T_f should be read from Figure 5 at the mean test temperature. ΔP should be multiplied by the temperature change during the test to find the pressure correction.

Account should be taken of both ambient and underground temperatures according to the respective lengths of pipeline involved, when calculating the pressure/temperature relationship.

NOTE 1 It has been observed that a significant time lag may occur between a change in ground temperature and a corresponding change in pressure in the test section.

NOTE 2 Chill or heat factors on exposed pipe may have an effect on pressure readings.

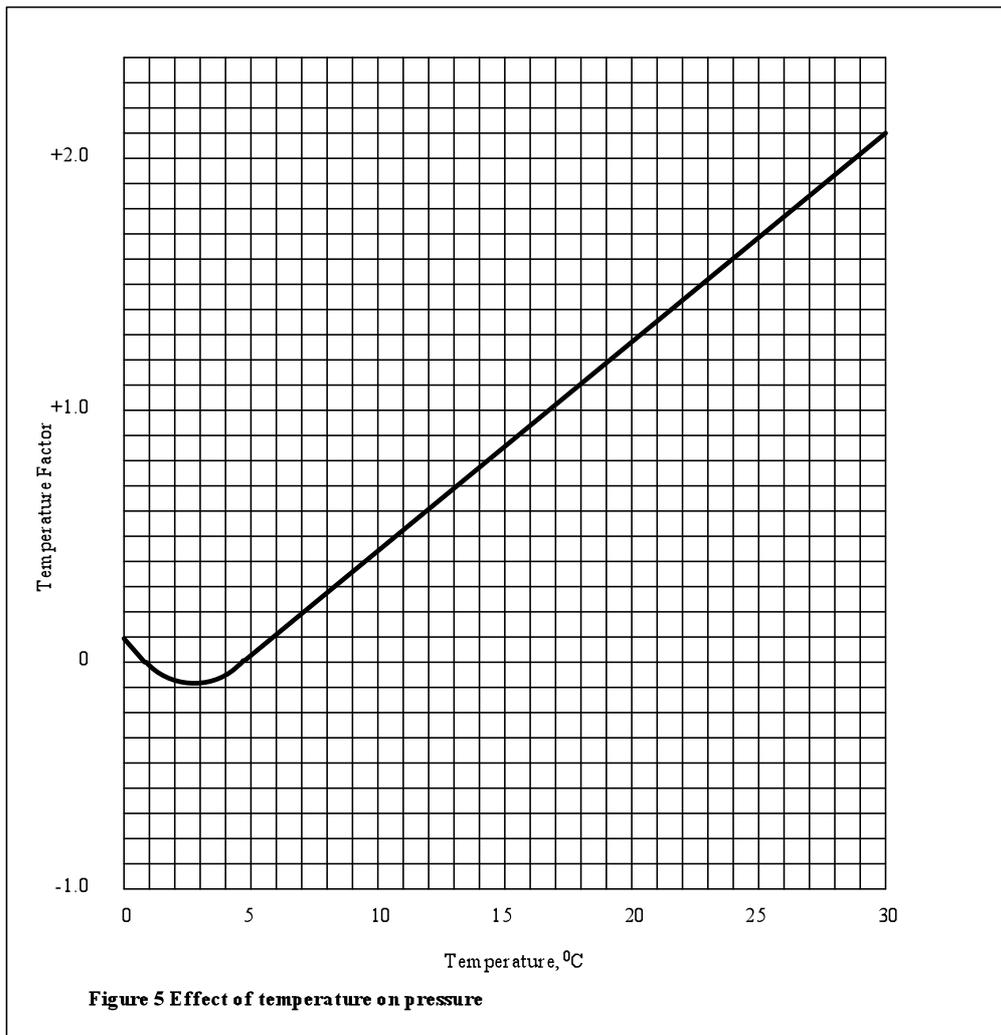


Figure 2— Effects of temperature on pressure

11.5.3 Method of assessment of pneumatic test

The relationship between pressure and temperature should be calculated in accordance with the Gas Laws. Owing to the difficulty in assessing the actual gas temperature within the test section, inconclusive results of such calculations may occur. In this event consideration should be given to extending the pneumatic test hold period to obtain more conclusive results.

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11.6 Repairs to test failures

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Any pipeline which fails a pressure test should be repaired and re-tested. The failed portion should be replaced and the welds subjected to both radiographic and ultrasonic inspection in accordance with ISO 13847.

For pipelines subjected to high level testing, repairs should be carried out using pre-tested pipe. The pipeline or section should then be re-tested for an aggregate period of not less than 24 h.

11.7 Tie-ins following testing

Consecutive test sections should be constructed to overlap so that the tie-in can be made with a single weld. If the tie-in cannot be made without using a length of pipe, this length of pipe should be pre-tested in accordance with 11.9 before installation. All tie-in welds not subject to subsequent pressure testing, should be subject to radiographic inspection supplemented by ultrasonic testing or other accepted examination method if radiography or ultrasonic testing are not possible.

Non-welded tie-in connections not pressure-tested after construction should be leak-tested at commencement of operation at the maximum available pressure but not exceeding the design pressure.

11.8 Pre-testing

Pipe and fittings should be pre-tested in following circumstances:

- a) when they cannot be tested after installation in subassemblies to be incorporated into an existing installation;
- b) when they are to be installed in close proximity to operating plant which cannot be protected against test failure;
- c) when it is considered that the consequences of a test failure justify pre-testing.

Road and rail crossings classified as major crossings, river crossings, canal crossings and bridge crossings (see 10.4) should be fabricated from pre-tested pipe or should be pre-tested after fabrication but before installation and final test. Pre-testing of pipe or fabrications should be carried out in accordance with 11.10 except that:

- a) the pre-test pressure should be at least 1.05 times the test pressure appropriate to the section into which the crossing is to be installed taking into account the elevation of the crossing within the test section; and
- b) the duration of the final hold period should be not less than 3 h.

The test should be considered acceptable if no leaks are detected on visual examination.

11.9 Testing of fabricated components

Fabricated components (such as pig traps, slug catchers, insulation joints or manifolds) should be pressure tested to limits equal to those required for the

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completed pipeline. If the components are also to be tested out as part of the completed system the tests should be designed in accordance with test procedures and pressure in 11.3, 11.4 and 11.5.

11.10 Testing equipment

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11.10.1 General

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Hydrostatic testing equipment should be selected to be appropriate to the test pressure and should include the following:

- a) deadweight tester or previously calibrated pressure data logger;
- b) pressure gauges;
- c) volume-measuring equipment;
- d) temperature-measuring equipment;
- e) pressure- and temperature-recording equipment.

Instruments and test equipment used for measurement of pressure, volume and temperature should be certified for accuracy, repeatability and sensitivity. Gauges and recorders should be checked immediately prior to each test. Dead weight testers and other equipment should have been certified within the 12 months preceding the test. All test equipment should be located in a safe position outside the boundary area.

Current certificates of calibration which identify the instrument with the calibration certification should be provided.

11.10.2 Measurement of pressure

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Hydrostatic test pressure should be measured by a dead weight tester having an accuracy better than ± 0.1 bar and a sensitivity of 0.05 bar. Pressure gauges should be selected with ranges which show between 50 % and 90 % of full scale deflection at test pressure.

11.10.3 Measurement of volume

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The volume of liquid added or subtracted during a hydrostatic test should be measured by equipment having an accuracy better than ± 1.0 % and a sensitivity of 0.1 % of the calculated volume of a liquid to be added after line filling has been completed to produce, in the test section, the required test pressure (see 11.4). Where pump strokes are used to determine the added volume an automatic stroke counter should be used.

11.10.4 Measurement of temperature

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Temperature-measuring equipment should have an accuracy of ± 1.0 °C and a sensitivity of 0.1 °C.

11.10.5 Other measuring equipment

Pressure and ambient temperature recording equipment should be used to provide a graphical record of test pressure and above ground ambient shade temperature for the duration of the test.

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11.10.6 Test end design

Test ends should be designed and fabricated to the same or higher standard as the pipeline and pre-tested to a minimum of 10 % above the specified test pressure of the pipeline.

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11.11 Test documentation and records

All certificates and records produced in connection with pressure testing a pipeline should be retained by the registered operator for the lifetime of the pipeline system and should include the following:

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- a) test procedure;
- b) pressure and volume change at half-hour intervals over the test period;
- c) seawater, underground and air temperature, where appropriate and weather conditions at hourly intervals;
- d) pressure-recording charts;
- e) test instrument calibration data;
- f) name of the pipeline system operator;
- g) name of the person responsible for making the test;
- h) name of the test company, if used;
- i) date and time of the test;
- j) minimum and maximum test pressures at the test site;
- k) test medium;
- l) test duration;
- m) test acceptance signature;
- n) description of the facility tested and the test apparatus;
- o) an explanation and disposition of any pressure discontinuities, including test failures, that appear on the pressure-recording charts;
- p) where elevation differences in the section under test exceed 30 m, a profile of the pipeline showing test sections.

11.12 Disposal of test fluids

Test fluids should be disposed of in such a manner as to minimize damage to the public and the environment.

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Arrangements should be made for the disposal of test water from the pipeline section after completion of pressure testing, bearing in mind that it may be heavily discoloured with rust particles. Consents should be obtained from landowners and occupiers, and from river, drainage and water authorities.

11.13 Protection of pipeline following test

Test fluids should not be left in the pipeline following testing, unless provisions identified in accordance with **9.2** have been incorporated.

If water is used as a test medium in cold regions, provisions should be made to prevent freezing of the test water.

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