BRITISH STANDARD

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Specification for

Thermally insulated underground piping systems —

Part 4: Specific testing and inspection requirements for cased systems without air gap

UDC [66.026 + 697.34:697.334]:621.644.2:662.998

Cooperating organizations

The Refrigeration, Heating and Air Conditioning Standards Committee, under whose direction this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Association of Consulting Engineers
Association of Manufacturers of Domestic Electrical Appliances
Boiler and Radiator Manufacturers' Association Ltd
British Combustion Equipment Manufacturers' Association
British Gas Corporation*
British Mechanical Engineering Confederation
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EUROSOL-UK Association of Manufacturers of Mineral Fibre Insulation
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Process Plant Association
Spray Contracts Technical Committee
Thermal Insulation Contractors' Association

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Contents

Foreword

This Part of BS 4508 has been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Committee, and deals with requirements for the independent certification of components and assemblies of components of cased, thermally insulated underground piping systems without air gap.

Other Parts of the standard are as follows:

— *Part 1: Steel cased systems with air gap;*

— *Part 2: Asbestos-cement cased systems with air gap;*

— *Part 3: General requirements for cased systems without air gap.*

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 10, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 4508 specifies specific requirements for the testing, inspection and certification of pipe-in-pipe systems with an insulated service or product pipe enclosed in a pressure-tight casing; general requirements are specified in Part 3.

Data on soil conductivity are given in Appendix A.

2 References

The titles of the publications referred to in this standard are listed on the inside back cover.

3 Definitions

For the purposes of this Part of BS 4508 the definitions given in Part 3 apply.

4 General

Testing and inspection procedures are necessary to prove compliance with the performance specification, and include type testing and inspection in the laboratory and in the ground, together with production testing and inspection. Routine service inspections and tests are required to ensure continued compliance with the performance specification, and guidance on such tests is given in Appendix G of BS 4508-3:1977.

5 Type tests and inspections

5.1 Purpose and scope of the tests. Type test and inspection requirements that are common to all piping systems are specified in this Part of the standard.

Type tests and inspections shall be carried out in the order given.

5.2 Type tests and inspections in the laboratory. The tests and inspections specified in **5.2.1** to **5.2.6** shall be carried out on samples of the proposed service or product pipe.

5.2.1 Compatibility of pipes. The vendor shall be responsible for ensuring, throughout the temperature range of the service pipe fluid, that the requirements specified in **5.2.1.1** and **5.2.1.2** are complied with.

5.2.1.1 *Pipes protected against external corrosion.* Where service or product pipes are protected by surface coatings against external corrosion, such coatings shall be chemically compatible with the insulating material.

In such cases, a sample of pipe-in-pipe shall be prepared and after a 30-day period at the maximum temperature for which the system will be offered, the sample shall be examined for evidence of chemical reaction between the service pipe coating and the insulating material. Deterioration due to chemical reaction as judged by visual inspection shall constitute a failure of the system.

NOTE During this test a certain amount of discoloration of the insulating material may be in evidence, even if the service pipe coating has not reacted chemically with it; such discoloration is entirely an effect of temperature and the extent to which it shall be permitted to occur is stated in **5.2.3.2**.

5.2.1.2 *Pipes not protected against external corrosion.* Where service or product pipes are not protected by surface coatings against external corrosion, the insulation proposed for the system shall provide such protection.

In such cases, a sample of pipe-in-pipe shall be prepared and after a 30-day period at the maximum temperature for which the system will be offered, the sample shall be examined for evidence of corrosion on the service pipe. Any corrosion of this nature shall constitute a failure.

5.2.2 *Pressure test on service or product pipe.* The service or product pipe shall be subjected to a hydraulic pressure test of 1.5 times the maximum design pressure, at the system design temperature for which the system is offered, with a minimum gauge test pressure of 10 bar[1)]. This pressure shall be maintained for a period of not less than 30 min.

5.2.3 *Tests on insulating material.* The tests and inspections specified in **5.2.3.1** to **5.2.3.4** shall be carried out on samples of the proposed insulating material.

5.2.3.1 *Thermal conductivity or thermal conductance.* The thermal conductivity or thermal conductance of the proposed insulating material shall be tested in accordance with BS 874 and compared with the specification.

For a typical size of pipe-in-pipe offered, calculations shall be made, using the calculation method shown in **7.4** e) of BS 4508-3:1977, to ensure that any casing material temperature limitation is not exceeded, and in no instance shall the casing temperature exceed 30 °C. In no case shall the thermal conductivity or thermal conductance exceed that declared in the specification (see Appendix B of BS 4508-3:1977). The thermal conductivity or thermal conductance shall be obtained from the appropriate test method specified in BS 874.

[1)] 1 bar = 10^5 N/m^2 = 100 kPa.

5.2.3.2 *Heat test.* A sample length of pipe-in-pipe shall have heat applied to the service pipe to obtain a temperature 10 °C in excess of the maximum fluid temperature specified. Discoloration of the insulating material shall stabilize at a radial distance of not greater than 5 mm from the service pipe after a period of 1 month. The insulation during this test shall in no way indicate thermal or mechanical deterioration.

5.2.3.3 *Physical properties.* Samples of the proposed insulation shall be tested in accordance with BS 2972 or BS 4370, as appropriate, to confirm the physical properties as declared in Appendix B of BS 4508-3:1977.

5.2.3.4 *Test for the action of fungi and bacteria.* Samples of the proposed insulating material shall be tested in accordance with ISO/R 846 in order to determine the behaviour of the material under the action of fungi and bacteria. (Levels of acceptance to be specified.)

5.2.4 *Tests on pipe-in-pipe samples.* The tests and inspections specified in **5.2.4.1** to **5.2.4.3** shall be made on samples of the pipe-in-pipe including joints and fittings.

5.2.4.1 *Preparation.* Samples of the proposed casing and jointing materials shall be prepared and tested in accordance with **5.3.5**.

5.2.4.2 *Impact test.* Samples of the proposed casing material shall be tested for impact strength in accordance with method 306 of BS 2782:1970, as appropriate.

5.2.4.3 *Resistance to ultra-violet light.* The casing material, joints and fittings shall be protected against ultra-violet light degradation, this protection being sufficient for the period prior to backfilling.

5.2.5 *Tests on field closure joints.* The test specified in **5.2.5.1** to **5.2.5.3** shall be carried out on at least one field closure joint by means of a test tank. Two samples shall be provided, one for the joint test (see **5.2.5.2**) and another for the bulkhead test (see **5.2.5.3**). The pipe-in-pipe shall pass through the tank walls, without restraint on movement, by using a standard mechanical gland. A typical arrangement for the test tank is shown in Figure 1.

5.2.5.1 *Test facilities*

5.2.5.1.1 *Dimensions of test pipe.* The test pipe shall comprise a straight 2 m length of 50 mm service pipe with standard insulation and casing incorporating a field closure joint.

5.2.5.1.2 *Tank water temperature.* Provision shall be made for the tank water temperature to be varied between 10 °C approximately and 30 °C maximum, this variation being made in either direction at the rate of 20 °C/h, and also for it to be controllable at either of the two above mentioned limiting temperatures for a minimum period of 1 h.

5.2.5.1.3 *Tank water pressure.* The required tank pressure range shall be 0.1 bar (gauge) to 1.5 bar (gauge) and shall be capable of being varied from minimum to maximum in 10 min or less and be controllable at both of the above mentioned pressures.

5.2.5.1.4 *Service pipe temperature.* The temperature of the service pipe shall be capable of being varied between 10 °C [2)] and the maximum fluid temperature of the system (which shall be that specified in **B.2.9** of BS 4508-3:1977), plus an excess of 10 °C on the latter for the test purposes. It shall be controlled at either of these limits for a minimum period of 1 h. The pipe may be heated and cooled by a wet method of passing water through it or by a dry method of inducing an electric current into the pipe and cooling with air.

5.2.5.1.5 *Service pipe longitudinal movements.* Provision shall be made on the testing rig to move the service pipe in such a way that an oscillatory movement of 5 mm relative to the casing is achieved. This is done to simulate expansion and contraction on a larger system.

5.2.5.1.6 *Indication of water ingress.* Equipment giving an indication of the ingress of water into the joint shall be employed. When using the dry method, early ingress of water can be noted by the decrease in the electrical resistance between the service pipe and the water in the test tank, or by the increased length of time taken to reach the service pipe maximum temperature for the same current setting. The temperature should be measured with a thermocouple near the closure joint. Earlier indications may not be possible in the wet method.

5.2.5.1.7 *Moisture content.* Equipment for checking insulation moisture content shall be provided, for example, by weighing.

5.2.5.1.8 *Vehicle loading simulation.* Where the system is liable to be affected by vehicle loads and vibrations these effects should be simulated[3)].

[2)] The 10 °C minimum figure is selected as being mains water temperature.
[3)] At present there is no established test requirement for vehicle loading, and a suitable test should be agreed between the purchaser and the vendor.

5.2.5.2 *Test procedure (joints)*

5.2.5.2.1 *Water temperature* (see Figure 2). The test shall commence with the tank water at 10 °C approximately and cycling shall continue in the following manner:

a) 1 h at 10 °C approximately;

b) 1 h heating period to 30 °C maximum;

c) 1 h at 30 °C maximum;

d) 1 h cool down to 10 °C approximately.

5.2.5.2.2 *Tank water pressure* (see Figure 2). The test shall commence with the tank water pressure at 0.1 bar (gauge) and cycling shall continue in the following manner:

a) immediate applicational pressure to 1.5 (gauge) (10 min maximum);

b) 1 h at 1.5 bar (gauge);

c) immediate drop in pressure to 0.1 bar (gauge);

d) 2 h at 0.1 bar (gauge).

5.2.5.2.3 *Service pipe temperature* (see Figure 2). The test shall commence with the service pipe at 10 °C and cycling shall be synchronized with the tank water temperature to vary in the following manner:

a) 1 h at 10 °C;

b) 1 h heating period to the maximum fluid temperature specified plus 10 °C;

c) 1 h at the maximum fluid temperature specified plus 10 °C;

d) 1 h cool down to 10 °C.

5.2.5.2.4 *Service pipe longitudinal movement* (see Figure 2). The test shall commence with the service pipe in the normal or neutral position and cycling shall be synchronized with the changing service pipe temperature as follows:

a) hold with zero movement for 1.5 h approximately;

b) 10 mm/h longitudinal movement in one direction for 0.5 h (5 mm displacement);

c) hold at a displacement of 5 mm for 1 h;

d) return to normal or neutral position in 0.5 h.

5.2.5.2.5 *Total test time.* The successful completion of 108 cycles each of 4 h (based on tank temperature) will show that the joint is satisfactory.

5.2.5.2.6 *Failure indication*

5.2.5.2.6.1 The joint shall be deemed to have failed if any water is evident when it is dismantled for inspection, in which case the moisture content test required in **5.2.5.2.6.2** is unnecessary.

5.2.5.2.6.2 A test for moisture content of the thermal insulation of the joint shall be made to ascertain if any water has penetrated and has been absorbed by the insulation. Failure shall be deemed to have occurred when the moisture content measured for the test sample from the joint is greater than its initial mass.

5.2.5.3 *Test procedure (bulkheads).* The purpose of this test is to ensure that the bulkheads do not fail before any failure of the casing joint.

The second joint shall be subjected to the bulkhead reliability test specified in **5.2.5.3.1**. When the bulkhead test is carried out in conjunction with the test on field closure joints, the bulkhead test shall be conducted first. The bulkhead test shall be carried out using the same rig as that used in the test on field closure joints.

5.2.5.3.1 *Requirements.* A joint shall be prepared with a 6 mm hole drilled in the service pipe between the bulkheads and, if site foamed, plugged with a temporary filling such as soft wax. The following test parameters shall apply:

a) tank temperature: constant at 30 °C;

b) tank pressure: constant at 1.5 bar (gauge);

c) service pipe temperature: constant at the maximum fluid temperature specified plus 10 °C;

d) service pipe pressure: 5 bar (gauge).

The test shall commence using coloured water in the service pipe. The pressure in the pipe shall be maintained at 1.5 bar until the maximum temperature of 130 °C is reached. If a closed system is used, the pressure can increase with the rising temperature. When maximum temperature has stabilized, the pressure shall be increased at the rate of 1 bar/min to 5 bar or the pressure at which the sleeve fails. The pressure in the tank and pipe shall then be reduced to 0.2 bar and held for at least 8 h. The joint shall then be dissected for examination.

5.2.5.3.2 *Indication of failure.* A failure shall be indicated by discoloration of the insulation on the opposite side of the bulkhead from the joint.

5.2.6 *Tests on pipe-in-pipe assembly.* The tests specified in **5.2.6.1** to **5.2.6.4** shall be carried out on samples of the pipe-in-pipe assembly.

5.2.6.1 *Inspection.* The pipe-in-pipe assembly shall be inspected for adequate provision and location of devices used to locate the service or product pipe correctly within the casing. In addition, the material that such devices are made from shall be checked for thermal transmittance (to be specified by the vendor). Measurements shall be made on the annular space and the dimensions shall not vary by more than ± 10 % along the whole length. Lengths of complete pipe-in-pipe shall not vary from true straightness.

5.2.6.2 *Flexural strength.* A sample of the pipe-in-pipe assembly including a field closure joint shall be tested for flexural strength using the methods specified in Appendix H of BS 4660:1973, suitably adapted to the pipe-in-pipe assembly, the apparatus being also suited to the requirements of **5.2.2**. There shall be no failure of the assembly during the test.

5.2.6.3 *Loading.* A sample of the pipe-in-pipe assembly shall be tested for the loading effect of a 1 m soil coverage in accordance with the method specified in Appendix K of BS 4660:1973 but without the requirement for water being in the service pipe.

5.2.6.4 *Pressure-tightness.* The following test shall be carried out to determine the pressure-tightness of the system at operating temperatures.

A sample system shall be tested at a depth of 2 m, measured from the top of the outer casing, in a tank of cold water containing a fluorescent dye and wetting agent. The system shall comprise a straight run of pipe, bulkheads, two straight joints, two tees horizontally opposite, two elbows, two anchors, one system termination, as shown in Figure 3.

The service pipe shall have fluid circulated at 10 °C above the operating temperature for which the system is designed.

Tests shall be made as follows.

a) The first series of tests shall be of 32 days continuous operation, with the fluid being circulated at the design operating temperatures.

b) The second series of tests shall be of 32 days intermittent on-off operation, the cycle comprising 4 days on temperature and 4 days off.

The system shall then be removed from the tank test rig and cut open, including all joints. Any penetration of the coloured water shall constitute a failure.

Any single such failure shall be regarded as a failure of the whole system.

5.3 Type tests on a system in the ground. Once a system has been accepted as having satisfied the laboratory type test requirements, the type test specified in **5.3.1** to **5.3.10** on an operational piping system shall be put into effect.

5.3.1 *Test period.* The test in the ground shall be carried out for a period of 2 years.

5.3.2 *Test ground.* Wet soil conditions, as defined in Appendix A, will normally occur naturally because of weather conditions during the two-year test period. Made-up ground, ground with a drainage system or a soil filled tanked enclosure shall not be used. The ground conditions under which the tests have been carried out shall be clearly stated in a test report.

5.3.3 *Water table.* The water table levels adjacent to the system shall be periodically recorded at a minimum of four positions in the test ground [see also **5.3.7** i)].

5.3.4 *Soil cover.* The depth of soil cover shall be 750 mm for the purpose of the test.

5.3.5 *Test installation.* The design, dimensions, materials and installation of the system shall be truly representative of the intended standard production. The installation, including trenching, compacting and back filling, should be in accordance with CP 3009.

The test system[4)] shall comprise standard production items as follows:

a) a straight length of the system (to be the manufacturer's recommended maximum straight length) which shall be installed between an anchor and the first 90° change in the direction of the system;

b) three elbows or bends;

c) one tee connection, terminating 2 m away at an anchor and a pressure-type termination underground;

d) two factory made, non-standard tee connections;

e) one puddle-flanged underground building entry point or points, as specified by the manufacturer;

f) two anchors;

g) two pressure-tight end seals with facilities for thermal expansion of the service pipe;

h) one pressure-tight access chamber with typical valves;

i) one item of each special feature that is part of the system being tested;

j) a return main of the same system including an expansion device.

[4)] For flexible systems see Appendix F of BS 4508-3:1977.

5.3.6 *Operational temperatures.* The following operational temperatures shall be achieved.

a) *Hot service or product fluid.* The temperature of the hot circulating fluid shall be 10 °C above the declared maximum recommended by the manufacturer.

b) *Cold service or product fluid.* The temperature of the chilled circulating water shall be tested not higher than 3 °C.

The temperature and circulation of the fluid shall be constant for 2 days.

The heat source and circulation shall then be turned off for the following 5 days. This 7-day programme of 2 days on and 5 days off shall be continued for a 2-year period.

5.3.7 *Instrumentation.* The instruments shall first be checked for accuracy. The following items a) to f) shall be recorded continuously and items g), h) and i) shall be recorded periodically:

a) the heat input (Q) required to maintain the underground portion of the system at the stipulated temperature;

b) the temperature of the fluid (± 0.5 °C) at system flow and return connection points;

c) the pressure of the fluid (± 0.1 bar) at system flow and return connection points;

d) the flow rate of the fluid;

e) the temperature (± 0.5 °C) on top of the casing at the joints;

f) the temperatures (± 0.5 °C) of the outside air (dry-bulb, see BS 692) and of the soil at 1 m depth and 3 m from the system);

g) the fluid make-up quantity;

h) the expansion movements, between minimum and maximum operational temperatures and at selected 20 °C intervals between these temperatures during every fourth complete test cycle, of the system in the ground at each side of a bend at each change of route direction (± 1 mm);

i) the water table level adjacent to the system (see Appendix J500 of CP 2001:1957).

5.3.8 *Calculated rates of heat loss.* The thermal resistances of the service pipe, casing and soil/air boundary are small compared with that of the insulation and the soil cover, and therefore for calculational purposes may be ignored.

The rate of heat loss Q (in W/m) of a buried pipe is given by:

$$Q = \frac{\theta_w - \theta_a}{R_1 + R_s}$$

where R_1 is the thermal resistance of the insulation (in m K/W), given by:

$$R_1 = \frac{\ln (1 + 2t/d_1)}{2\pi k_1}$$

and R_s is the thermal resistance of the soil (in m K/W), given by:

$$R_s = \frac{\ln (4h/d_2)}{2\pi k_s}$$

Of the thermal resistances between the fluid in the pipe and the air above ground, all except that of the insulation and of the soil can be ignored. The meaning of the symbols is as follows.

Q is the rate of heat loss (in W/m)

θ_w is the fluid temperature (in °C)

θ_a is the air temperature (in °C)

d_1 is the outside diameter of service pipe (in m)

t is the insulation thickness (in m)

d_2 is the outside diameter of casing (in m)

h is the depth of burial of pipe centre line (in m) (assumed to be greater than $2d_2$)

k_1 is the thermal conductivity of the insulation [in W/(m K)]

k_s is the thermal conductivity of the soil [in W/(m K)] (see Appendix A)

ln is the natural log

The temperature θ at the casing is given by:

$$\frac{\theta_w - \theta}{\theta_w - \theta_a} = \frac{R_1}{R_1 + R_s}$$

5.3.9 *Identification of a failure during test.* A failure of the system during the 2-year test period is defined as any event, shown by test readings or other indications, that reveals that a leakage of the circulating fluid or of ground water into the system has occurred. The following are indicative of a failure during the period of the test:

a) if the measured heat loss is greater than the calculated heat loss when the measured heat input (Q), as shown by instrument readings, has been compared with calculated rates of heat loss (see **5.3.8**);

b) a rise in the temperature of the casing on top of the joints in excess of 3 °C above the upper limit of the casing temperature as specified by the manufacturer;

c) an increase of greater than 5 % in the addition of make-up water during the subsequent consecutive 30-day periods above that addition recorded during the first 30 days of the test;

d) hot spots found by touch or by infra-red thermometer.

5.3.10 *Identification of a failure after the test.* At the end of the test period the system shall be excavated and removed for external examination and, following dissection, for internal examination. An assessment shall be made by the independent inspecting authority in the presence of the vendor to establish whether any observed deterioration is compatible with the declared life of the system.

This assessment shall be made on the following basis.

External examination

a) Gaps between joint sleeve (or equivalent) and the casing. Possible causes: sleeve located incorrectly, movements due to cyclic expansion and contraction, faulty anchoring.

b) Holes in casing, joint sleeve or fittings. Possible causes: damage during installation, in normal service or by other trades/services.

c) Discoloration of casing or other parts. Possible causes: overheating during installation, in normal service or by other trades/services.

d) Splits in fittings or casings at factory made joints, e.g. right-angled mitres.

e) Damp insulation found by test with moisture meter through small drilled holes or saw cuts in the casing.

Internal examination (after dissection)

a) Voids in insulation due to a design fault or inadequate prefabrication or jointing on site.

b) Damp, wet or destroyed insulation due to water ingress from service pipe, external sources, faulty joint or fittings, effects of faults observed during external examinations, or moisture entrained prior to jointing.

c) Corrosion of service pipe due to water ingress from service pipe or through the casing/joint.

d) Insulation thickness less than that of design figure due to faulty prefabrication or normal service conditions, e.g. crushing at tees or changes of route direction.

e) Discoloration of insulation that is otherwise satisfactory due to excessive temperatures (transient or designed). Scorching of insulation for a radial distance from the service pipe in excess of 5 mm.

5.4 *Reporting.* The report shall include the results of the physical examination (see **5.3.10**) and may include photographs, sketches, etc., so that any defects or incipient faults that may have been found and that would be likely to cause failure may be analysed by the manufacturer and design improvements made to the system.

5.5 *Design changes.* The decision of the independent inspecting authority will be final in the consideration of what constitutes a design change but every effort should be made to encourage improved designs without necessitating extensive retesting.

6 Production inspections and tests

6.1 Witnessing of tests. The independent inspecting authority and the purchaser's representative shall be entitled a) to witness the manufacturer's production, test and inspection procedures and to select the components or the assembly of components to be tested and b) to be advised of the probable cause of any failure, e.g. faults in material, workmanship, production plant, or inspection procedures.

The tolerances on quality control shall be related to the component and to the system as installed. One test failure may indicate a material change or production fault. A pattern of failures may indicate an inherent system defect needing redesign.

6.2 *Selection of samples.* It is recommended that manufacturers should select random samples for inspection and tests as follows:

a) each size of service or product pipe;

b) at least one sample per production run;

c) at least one sample per shift if the production run continues for more than one shift.

6.3 *Concentricity testing.* Testing for concentricity of the service pipe within the casing and insulation, and also for the detection of voids, shall be carried out by the manufacturer.

7 Test failure interpretation

In the case of third party approval it shall be determined whether the failure was inherent in the system or in a particular component or due to local extraneous damage.

Any system failure shall require full retesting after redesign or modification.

A component failure shall necessitate a certain amount of retesting to be specified.

Discretion shall be exercised in cases of extraneous damage and the vendor shall take any necessary steps specified by the third party.

8 System approvals

In the case of third party approval following the successful completion of type and production tests and inspections, a provisional certificate of compliance shall be issued.

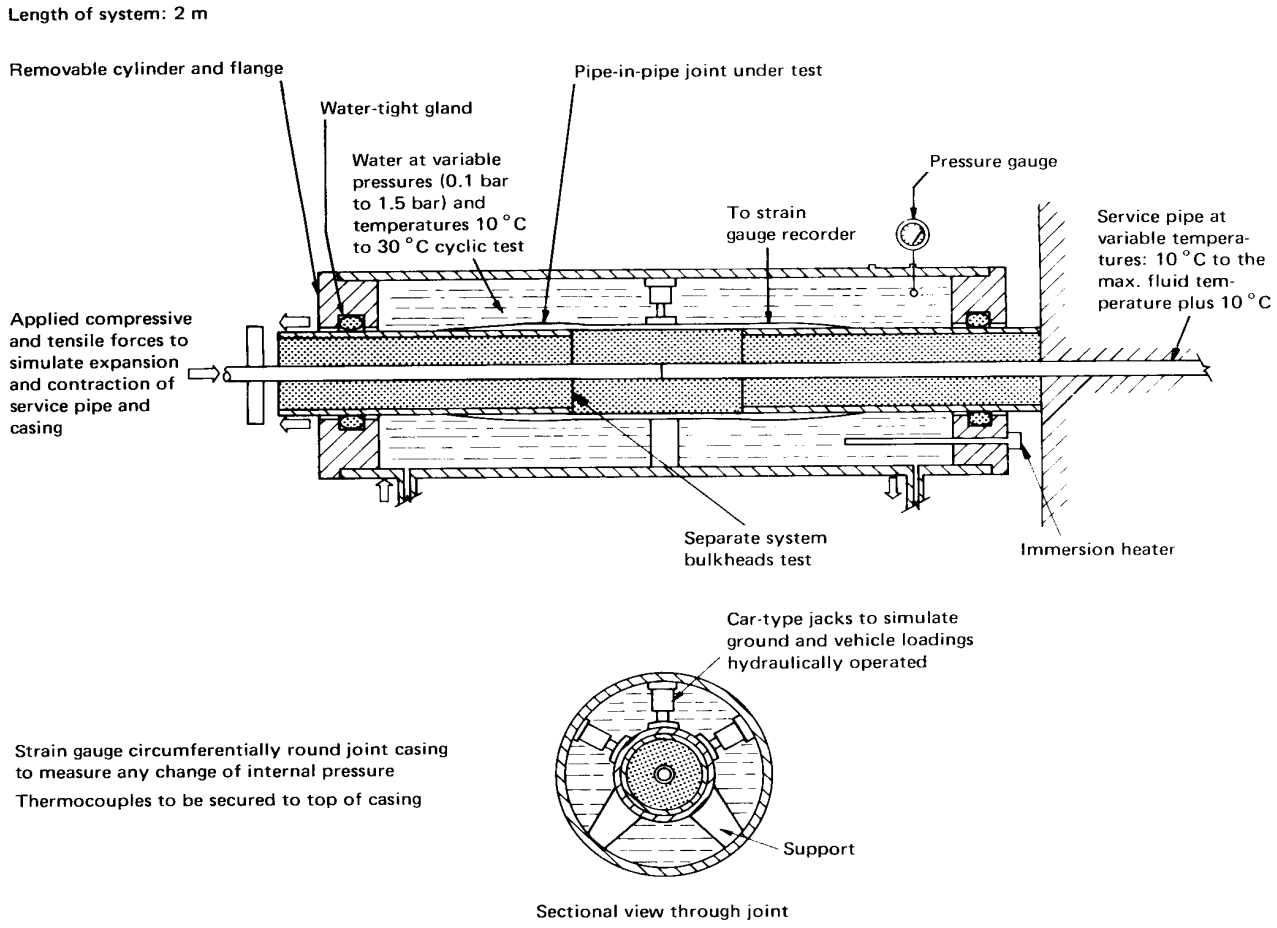
Following successful completion of field and commissioning tests and inspections on the first full scale installation incorporating a complete range of fittings, a full certificate of compliance shall be issued by the independent inspecting authority.

Appendix A Soil conductivity data

The conductivity of the soil makes only a small contribution to the overall heat loss of a pipe buried and insulated in a normal manner; the main factor determining the heat loss is the pipe insulation. An approximate value of the soil conductivity is all that is required and, on this basis, soil moisture is the main factor affecting its thermal conductivity.

Values should be chosen from the following:

Soil	Thermal conductivity
	W/(m K)
Wet	2.1
Dry	0.7



NOTE Joints on elbows and tees require similar equipment; separate tests are made for anchors, elbows and other fittings

Figure 1 — Joint testing apparatus to simulate actual operating conditions (see **5.2.5**)

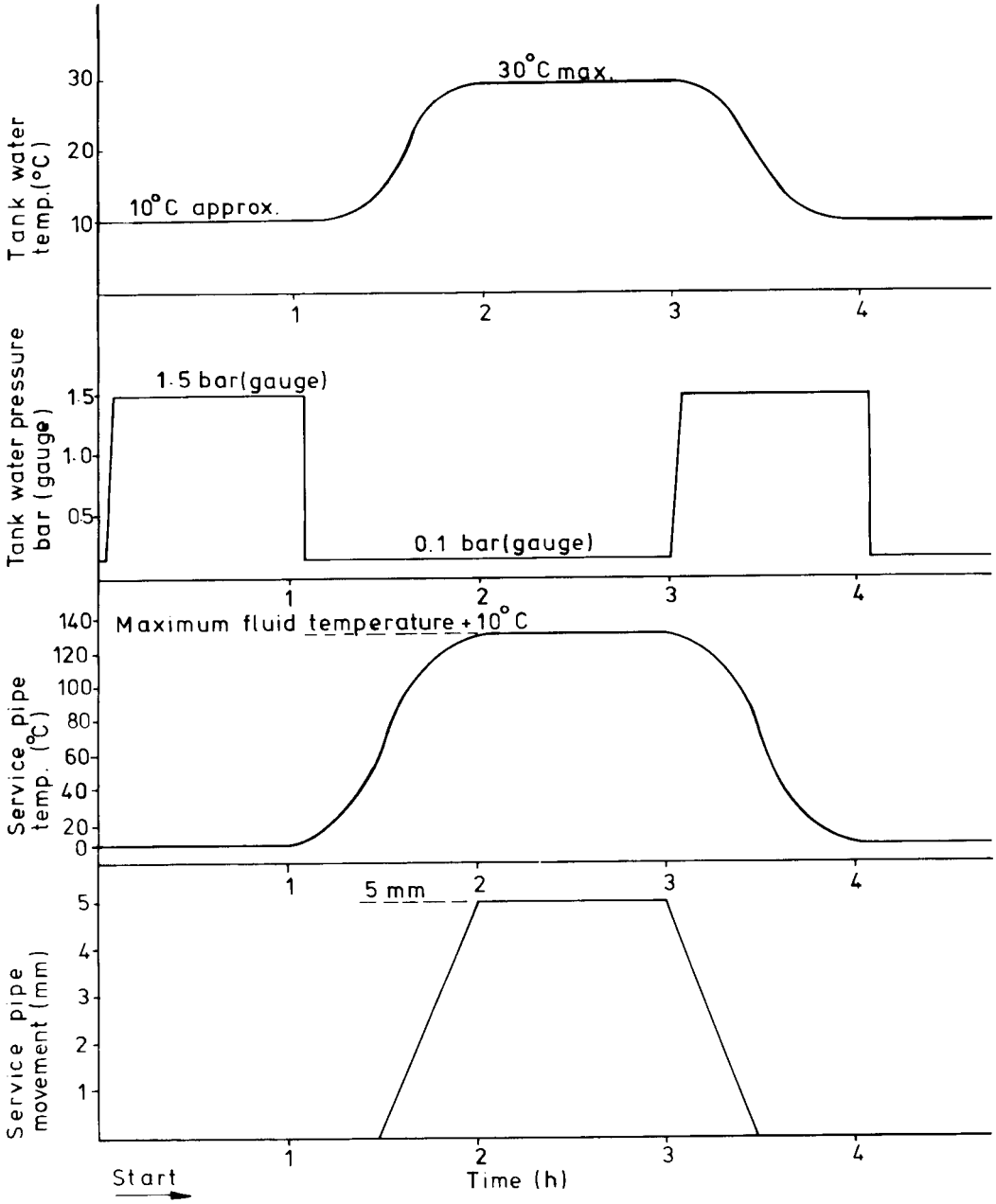


Figure 2 — Physical variations during a four-hour test cycle (see **5.2.5.2**)

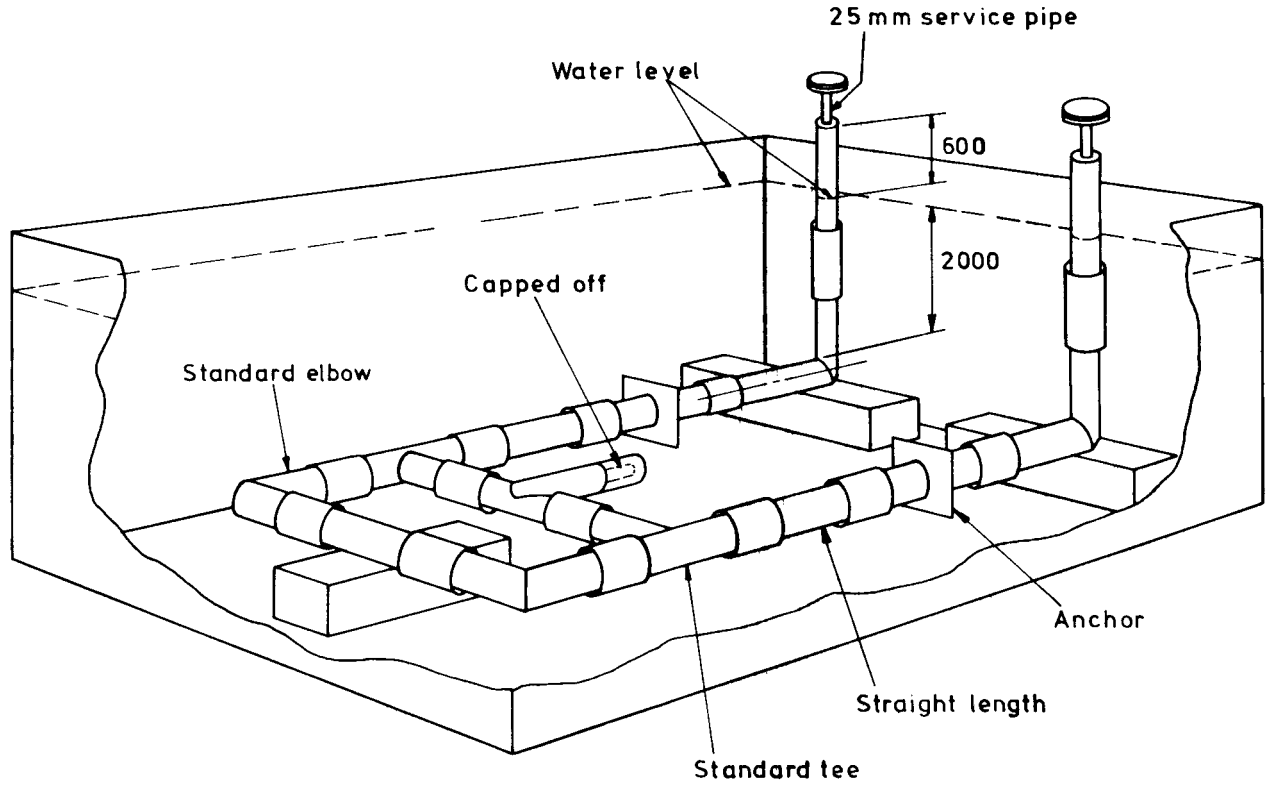


Figure 3 — Test rig for the determination of system pressure-tightness (see **5.2.6.4**)

Publications referred to

BS 692, *Meteorological thermometers.*

BS 874, *Methods for determining thermal properties, with definitions of thermal insulating terms.*

BS 2782, *Methods of testing plastics.*

BS 2972, *Methods of test for inorganic thermal insulating materials.*

BS 4370, *Methods of test for rigid cellular materials.*

BS 4508, *Specification for thermally insulated underground piping systems.*

BS 4508-3, *General requirements for cased systems without air gap.*

BS 4660, *Unplasticized PVC underground drain pipe and fittings.*

CP 2001, *Site investigations.*

CP 3009, *Thermally insulated underground piping systems.*

ISO/R 846, *Plastics — Recommended practice for the evaluation of the resistance of plastics to fungi by visual examination.*

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