HEALTH AND SAFETY EXECUTIVE

SPECIFICATION LASS 1

SEAMLESS LIGHTWEIGHT ALLOY STEEL

CONTAINERS FOR COMPRESSED GASES

REVISION 2

MAY 1991

SPECIFICATION FOR SEAMLESS LIGHTWEIGHT ALLOY STEEL CONTAINERS FOR COMPRESSED GASES

1. APPLICATION OF THIS SPECIFICATION

(a) The containers designed in accordance with this specification will have thinner walls and a consequential lower weight than steel container intended for the same gas service that are designed in accordance with other standards.

(b) It is for this reason that this specification places conditions upon:

(i) the use of the container (Clause 2);

(ii) the material of manufacture (Clauses 3 to 6);

(iii) the manufacturing process of the material and the container (Clause 3 and 7);

(iv) the examinations during manufacture (Clauses 9 and 10);

(v) the testing to be carried out on containers from the first and subsequent production batches including any re-heat treatment where necessary (Clauses 12 to 19);

(vi) the protection of the internal and external surfaces of the container against corrosion (Clause 20).

(c) Recommendations relating to the periodic inspection and testing of the containers are given in Appendix B. Appendix C gives advice to the manufacturer on information to be given to the user.

SCOPE

2. (a) This specification is intended for containers to be used for breathing apparatus for rescue purposes (except underwater).

(b) Containers shall not exceed a capacity of 12 litres of water.

QUALITY OF MATERIAL

3. The steel used in the manufacture of the containers shall have been made in an electric furnace and shall be inspected to the latest issue of the BS S100 series.

CHEMICAL COMPOSITION

4. The steel used in the manufacture of the containers shall on analysis give the following results:-

(1)	Carbon	not less than 0.25 per cent and not more than 0.35 per cent.
(2)	Silicon	not less than 0.10 per cent and not more than 0.35 per cent.
(3)	Manganese	not more than 0.70 per cent.
(4)	Phosphorus	not more than 0.020 per cent.
(5)	Sulphur	not more than 0.020 per cent.
(6)	Chromium	not less than 0.50 per cent and not more than 1.30 per cent.
(7)	Molybdenum	not less than 0.20 per cent and not more than 0.65 per cent.
(8)	Nickel	not less than 3.00 per cent and not more than 3.75 per cent.

STEELMAKER'S CERTIFICATE

5. The steelmaker shall supply the container manufacturer with a certificate giving the chemical analysis of the steel and confirming that the steel was made by an electric process and was tested in accordance with paragraph 2.

MARKING OF STEEL

6. The steel shall be marked and records shall be kept so as to enable the material from which the container is made to be identified.

MANUFACTURER OF CONTAINERS

7. The containers shall be of seamless construction and shall be made from:-

(a) billets, pierced hot or cold (back extruded) followed by hot and/or cold drawing, or

(b) plates, cupped hot or cold followed by hot and/or cold drawing.

THICKNESS OF CONTAINER WALLS

8. The thickness of the container wall shall not be less than the value of t given by the appropriate formula below for a cylindrical container.

$$t = \frac{0.3P_1D_i}{7fe - P_1} \quad (1)$$

$$t = \frac{0.3P1D_o}{7fe - 0.4P_1} \quad (2)$$

except that the thickness may in no case be less than the value:-

$$t = 2.48 \ (D_i / Rm)^{½} \quad (3)$$

The design thickness shall not exceed 4.5 mm.

Formula (3) will override formulae (1) and (2) for comparatively low values of P_1, in which case it is necessary to use a somewhat higher actual test pressure P_2 (see 8.2).

Nomenclature

t = Minimum permissible wall thickness (mm) excluding any additional thickness to resist influences other than those of internal pressure and external forces due to ordinary handling and stacking.

p = pressure developed by the contents of the container at the pressure reference temperature.

P_1 = minimum test pressure (bar) applicable to design governed by formulae (1) and (2) - see clause 8.1.

P_2 = corresponding test pressure (bar) permissible for design governed by formula (3) - see clause 8.2.

D_i = internal diameter of container (mm).

D_o = external diameter of container (mm).

f_e = maximum permissible equivalent stress at test pressure, 0.875 x minimum specified yield stress of material of construction

= 0.875 x 930 = 814 N/mm^2.

Rm = minimum specified tensile strength of the material of construction = 1100 N/mm^2.

8.1 **Test Pressure - formulae (1) and (2)**

The minimum allowable test pressure P_1 for design shall be calculated as shown in the following table from the internal pressure p (bar) developed by the contents at the pressure reference temperature shown for the category of gas concerned. For developed pressures and reference temperatures for other climatic regions see BS 5355.

Category	Developed Pressure reference temperature for UK only	Test Pressure P_1
Permanent Gases	60°C	1.389p

8.2 **Test Pressure - formula (3)**

Where, for comparatively low values of P_1, the thickness calculated by formula (1) or formula (2) is less than the minimum permissible thickness calculated by formula (3) the test pressure P_2 consistent with the latter thickness shall be derived from the formula (4) below:-

$$P_2 = \frac{7\,fe}{1 + 0.12\,(D_i / Rm)^{½}} \text{ bar} \qquad (4)$$

In these circumstances it is permissible to re-assess the pressure duty of the container, within the maximum limitation obtained by using p as calculated from P_2 in the previous table.

EXAMINATION OF CONTAINER BEFORE CLOSING IN

9. Each container shall be examined before the closing-in operations for maximum and minimum wall thickness and for external and internal surface defects; the defects shall be ground out or the container rejected. The wall thickness shall not be less than the minimum design thickness at any point.

EXAMINATION FOR NECK FOLDS

10. Each container shall be examined for neck folds by means of an introscope or other suitable instrument.

Folds that are clearly visible as depressions having rounded peaks and roots shall not be deemed to constitute defects, but those which have sharp profiles or whose shape cannot definitely be identified, particularly those which are only discernible as a crack or a line of oxide on the container surface or in the threaded portion, as shown in figure 1, shall be removed by a machining operation which produces a contour similar to that in figure 1.

After machining, the whole area shall be re-inspected and measured for thickness. If the defects have not been completely removed, or if the thickness at any part of the machined area is less than twice the designed wall thickness, the container shall be deemed not to comply with the requirements of this specification.

HEAT TREATMENT

11. Each container after manufacture shall be hardened by quenching in oil from a temperature of 830/850°C; the method of quenching shall be such as to ensure satisfactory uniformity of hardness. Each container after hardening shall then be tempered at a temperature not less than 450°C to give the hardness value specified in paragraph 12.

HARDNESS TEST

12. Each container after final heat treatment shall be subjected to a hardness test employing a spherical indentor in accordance with BS 240. Brinell Hardness Test, or BS 891: Part 1: 1962 - Rockwell Hardness Test. The diameter of the ball and the applied load shall be in accordance with the requirements of these standards and shall be such as not to damage the container. When the Rockwell hardness test is applied the hardness shall be stated in terms of equivalent Brinell hardness number (see BS 860: 1967). The Brinell hardness number shall be not less than 315 not more than 365. If the hardness is not within this range, the container may be re-heat treated in accordance with Clause 17, and if it then passes the test it may be released for service.

The surface of the container may be prepared by polishing lightly with abrasive paper where the impression, which shall be in the middle of the body, is to be placed, but the thickness of the wall must not be reduced thereby below the minimum value required by Clause 8.

TENSILE TESTS

13. Tensile tests shall be made on the material of one finished container in every batch constructed or when the number in any batch exceeds 100 on the material of at least one finished container in every 100. Containers shall not be regarded as in a single batch unless they are made consecutively of the same size, design and material specifications, heat treated in the same manner and at the same conditions of temperature and duration.

The tests shall be made on a strip, cut longitudinally from a finished container, and its form and dimensions shall be in accordance with BS EN 10 002: Part 1: 1990. In preparing a test piece, the face and back of the test piece shall not be machined but shall represent the surface of the container as manufactured. The ends only may be flattened for gripping in the testing machine. The results of the tensile test shall conform to the following conditions:-

(a) 0.2% Proof Stress not less than 930 N/mm^2

(b)	Tensile Strength	not less than 1100 N/mm^2 not more than 1200 N/mm^2
(c)	Elongation	
	On 5.65 (Area)^{½}	not less than 8%
	On 4 (Area)^{½}	not less than 10%

BEND TEST

14. Cold bend tests shall be made on four strips cut from the same container as used for the tensile test. The width of each strip shall be not less than 25 mm; the strips may be made by cutting a ring of the required width from the container and dividing it into four parts of equal length, provided that the length is sufficient to permit the amount of bending specified in this clause to be obtained. Alternatively two rings shall be cut from a container and each ring shall be cut into two strips of equal length. The original inside and outside surfaces of the container shall not be machined, but the edges of each strip may be rounded to a radius not exceeding one quarter of the thickness. Each strip shall remain visually uncracked when bent inwards round a forming tool of diameter not more than ten times the minimum design thickness of the container until the interior edges are at a distance apart not greater than the diameter of the forming tool.

VOLUMETRIC EXPANSION TEST

15. Each completed container shall be subjected to a volumetric expansion test by the "water jacket" method as described in the Appendix A. The pressure applied internally in this test shall be not less than that specified in clause 8.1 or 8.2.

No pressure greater than 80% of the test pressure shall have been applied to the container before this test. The container shall be deemed to have passed the test if the permanent volumetric expansion shown by the test expressed as a proportion of the total expansion under the test pressure does not exceed 5%.

If the permanent volumetric expansion exceeds 5% of the total expansion under the test pressure the container shall be rejected except that, if the container does not show visible deformation, it may be re-heat treated in accordance with Clause 18 and then re-tested.

BURST TEST

16. From every batch, or from every 100 cylinders when the batch exceeds 100 cylinders, one container, which shall have first been subjected to the volumetric expansion test, shall be subjected to a steadily increasing hydraulic pressure until it bursts. It shall burst with a shear fracture into not more than two pieces. The nominal hoop stress corresponding to the burst pressure shall be calculated from the formula:

$$f_b = \frac{P_b D_i}{}$$

20 t

Where f_b is the nominal hoop stress in N/mm^2 at which destruction occurs.

P_b is the burst pressure in bar.

D_i is the internal diameter of the container in mm.

t is the minimum manufacturing wall thickness on the drawing.

The value of f_b shall be not less than 0.95 of the minimum specified tensile strength of the material of the container.

PROTOTYPE PRESSURE CYCLING TEST

17. Three containers made to a new design shall be selected from the first production batch and shall be submitted to the following pressure cycling test. The test shall be carried out using a non-corrosive fluid with a range of pressure equivalent to either 0.9 times or 0.6 times the test pressure of the container. The value of the lower cyclic pressure shall not exceed 10% of upper cyclic pressure. The frequency of reversals shall not exceed 15 cycles/min. The temperature measured on the outside surface of the container shall not exceed 50^{o}C during the test.

A container shall be considered to be of a new design when:-

(a) it is manufactured in a different factory, or

(b) it is manufactured by a different process, or

(c) the base profile and the base thickness have changed relative to the container diameter and calculated wall thickness, or

(d) the diameter has changed by more than 5%, or

(e) the length of the container has increased by more than 50% (containers with an L/D ratio less than 3 shall not be used as reference containers for any new design with an L/D greater than 3), or

(f) the hydraulic test pressure has changed.

Containers shall be considered to have passed the test if they satisfactorily complete:-

either 7000 cycles at 0.9 times test pressure

or 50,000 cycles at 0.6 times test pressure

without any signs of leakage.

RE-HEAT TREATMENT

18. Containers which have failed to meet the tensile test, hardness test or the volumetric expansion test may be re-heat treated by either hardening and tempering or tempering only in accordance with Clause 11. After any such reheat treatment the container shall be thoroughly examined and subjected to the volumetric expansion test specified in Clause 15. No container shall be hardened more than 3 times or tempered more than four times. If after the permitted number of treatments a container does not satisfy the requirements of Clauses 12 or 13 or the hydraulic volumetric expansion test specified in Clause 15, it shall be rendered unserviceable for holding gas under pressure.

RESULTS OF TESTS

19. A record shall be kept by the container manufacturer of the results of all tests required to be made by this Specification, and copies of all such records shall be forwarded to the purchaser of the container.

CORROSION PROTECTION

20. Both internal and external surfaces of the containers shall be protected against corrosion.

(a) **The Internal Surface**

(i) Phosphating, followed by the application of a suitable sealant. If the container is to be used in oxygen service the sealant shall not be of organic composition.

(ii) Such other methods as may from time to time be approved.

(b) **The External Surface**

The external surface shall be protected from corrosion by one of the following methods:-

(i) Phosphating followed by painting, or other suitable sealant.

(ii) In accordance with BS DD 24: 1973 Group 300 with a metallic coating of zinc not less than 0.13 mm in thickness. The thickness of metal and paint coating shall be checked instrumentally for minimum thickness and the results recorded.

(iii) Such other methods as may from time to time be approved.

MARKING

21. Each container shall be permanently and legibly marked on a non corrodible metal collar, affixed by an approved method, with the following information:-

(a) The charging pressure at 15^{o}C in bar if the cylinder is to be used for permanent gases.

(b) The test pressure in bar and the test date. This may be month and year or year with a symbol indicating the quarter of the year.

(c) The number of this specification is LASS 1.

(d) The identification mark of the Verification Body.

(e) Manufacturer's trade mark and serial number.

(f) The mass of container only in kg.

APPENDIX A

VOLUMETRIC EXPANSION TESTING OF SEAMLESS CONTAINERS

A.1 General.

This appendix gives details of two methods for determining the volumetric expansion of seamless steel gas containers as required by clause 15 by the water jacket volumetric expansion test. The test may be carried out on equipment with a levelling burette or with a fixed burette.

A.2 Test equipment.

The requirements specified in A.2.1. to A.2.7 are general to both methods of test.

A.2.1 Hydraulic test pressure pipe lines shall be capable of withstanding pressures twice the maximum test pressure of any container that may be tested.

A.2.2 Glass burettes shall be of sufficient length to receive water equivalent to the full volumetric expansion of the container and capable of being read to an accuracy of 1 ml.

A.2.3 Pressure gauges shall be to the requirements of BS 1780: Part 2: 1971, industrial class 1. They shall be tested at regular intervals and in any case not less frequently than once a month.

A.2.4 A suitable device shall be employed to ensure that no container is subjected to a pressure in excess of its test pressure.

A.2.5 Pipework shall utilize long bends in preference to elbow fittings and pressure pipes shall be as short as possible. Flexible tubing shall be capable of withstanding twice the maximum test pressure of any container that may be tested and have sufficient wall thickness to prevent kinking.

A.2.6 All joints shall be leak-tight.

A.2.7 When using the equipment care shall be taken to avoid trapping air in the system.

A.3 Water jacket volumetric expansion test

This test necessitates enclosing the water-filled container in a jacket also filled with water. The total volumetric expansion of the container is measured by the amount of water displaced from the jacket when the container has been pressurized. The permanent volumetric expansion of the container is measured by the amount of water that continues to be displaced from the jacket when the pressure has been released.

The water jacket shall be fitted with a safety device capable of releasing the energy from any container that may burst at the test pressure.

An air bleed valve shall be fitted to the highest point of the jacket.

Two methods of performing this test are described in A.3.1 and A.3.2. Other methods are acceptable provided that they are capable of measuring the total and, if any, the permanent volumetric expansion of the container.

A.3.1 Levelling burette method

An example of the equipment required is shown in figure 2, but other types of installation may be acceptable. The following procedure shall be carried out:

(a) Fill the container with water and attach the water jacket cover to it.

(b) Seal the container in the jacket and attach the pressure line to the container.

(c) Fill the jacket with water, allowing air to bleed off through the air bleed valve. Close the air bleed valve when water issues freely from it.

(d) Adjust the zero level on the burette to the datum mark on the burette support stand. Adjust the height of the water to the burette zero level by manipulation of the jacket filling valve and the drain valve.

(e) Raise the pressure in the container to two-thirds of the test pressure. Close the hydraulic pressure supply valve and check that the burette reading remains constant.

NOTE: A rise in water level indicates a leaking joint between container and jacket. A fall in water level indicates a leaking joint between water jacket and atmosphere.

(f) Open the hydraulic pressure line valve and continue the pressurization of the container until the test pressure is reached. Close the hydraulic pressure line valve.

(g) Lower the burette until the water level is at the datum mark on the burette support stand. Take the reading of the water level in the burette. This reading is the total expansion and shall be recorded on the test certificate.

(h) Open the hydraulic pressure line drain valve to release pressure from the container. Raise the burette until the water level is again at the datum line on the burette support stand. Check that the pressure is at zero and that the water level is constant.

(i) Read the water level in the burette. This reading is the permanent expansion, if any, and shall be recorded on the test certificate.

(j) Check that the permanent expansion does not exceed 5% of the total expansion as determined by the following:

$$\frac{\text{permanent expansion} \times 100}{} = \ \%$$

total expansion

A.3.2 Fixed burette method

An example of the equipment required is shown in figure 3, but other types of installation may be acceptable. The following procedure shall be carried out:

(a) Fill the container with water and attach the water jacket cover to it.

(b) Seal the container in the jacket and attach the pressure line to the container.

(c) Fill the jacket with water, allowing air to bleed off through the air bleed valve. Close the air bleed valve when water issues freely from it.

(d) Adjust the water level to the zero mark on the burette.

(e) Raise the pressure in the container to two-thirds of the test pressure. Close the hydraulic pressure supply valve and check that the burette reading remains constant.

NOTE: A rise in water level indicates a leaking joint between container and jacket. A fall in water level indicates a leaking joint between water jacket and atmosphere.

(f) Open the hydraulic pressure line valve and continue the pressurization of the container until the test pressure is reached. Close the hydraulic pressure line valve.

(g) Read the level of the water in the burette. This reading is the total expansion and shall be recorded on the test certificate.

(h) Open the hydraulic pressure line drain valve to release pressure from the container. Check that the pressure is at zero and that the water level is constant.

(i) Read the level of the water in the burette. This reading is the permanent expansion, if any, and shall be recorded on the test certificate.

(j) Check that the permanent expansion does not exceed 5% of the total expansion as determined by the following:

$$\frac{\text{permanent expansion} \times 100}{\text{total expansion}} - \%$$

APPENDIX A

PERIODIC INSPECTION AND TESTING

This appendix does no form part of the design specification approved by the Health and Safety Executive for the purposes of Regulation 16 of the Pressure Systems and Transportable Gas Containers Regulations 1989.

The recommendation for periodic inspection and testing is as follows:

Where three years or more have elapsed since the cylinder was manufactured and tested in accordance with the provisions of this Specification, the cylinder in the three years immediately preceding the use, filling or conveyance should have satisfied an inspection and hydraulic test conducted by a competent person in accordance with the relevant provisions of Part 1 of British Standard BS 5430 in force at the date of the test, and any corrosion protection removed from the cylinder has been replaced in accordance with the relevant provisions of this specification.

The competent person should, when assessing the acceptable limits of mechanical or corrosion damage, take into account the special characteristics of containers manufactured to this specification.

APPENDIX B

INFORMATION TO BE GIVEN BY THE MANUFACTURER TO THE USER

This appendix does not form part of the design specification approved by the Health and Safety Executive for the purposes of Regulation 16 of the Pressure Systems and Transportable Gas Containers Regulations 1989.

Section 6(1) of the Health and Safety at Work Act 1984 requires (amongst other things) that a person who manufactures an article for use at work provides adequate information about the use for which the article is designed and about any conditions necessary to ensure that it will be safe when used.

Manufacturers are advised that the information they provide to comply with the Section 6 requirement should include a clear statement that the containers should during conveyance, whether full or empty and in use be carried or mounted by a method which will prevent external surface damage.

APPENDIX C

BRITISH STANDARDS PUBLICATIONS REFERRED TO

BS 240	Method for Brinell hardness test and for verification of Brinell hardness testing machines
BS 860	Tables for comparison of hardness scales
BS 891	Method for Rockwell hardness test Part 1 Testing of metals
BS 5355	Filling ratios and developed pressures for liquifiable and permanent gases
BS 5430 : Part 1	Periodic inspection, testing and maintenance of transportable gas containers (excluding dissolved acetylene containers) : Specification for seamless steel containers of water capacity 0.5 litres and above)
BS EN 10 002 : Part 1	Tensile testing of metallic materials method of test and ambient temperature
BS DD24	Recommendations for methods of protection against corrosion on light section steel used in building.
BS 4S100	Procedure for inspection and testing of wrought steels (other than sheet strip or tubes)

FIGURE 1. CYLINDER NECK FOLDS BEFORE AND AFTER MACHINING

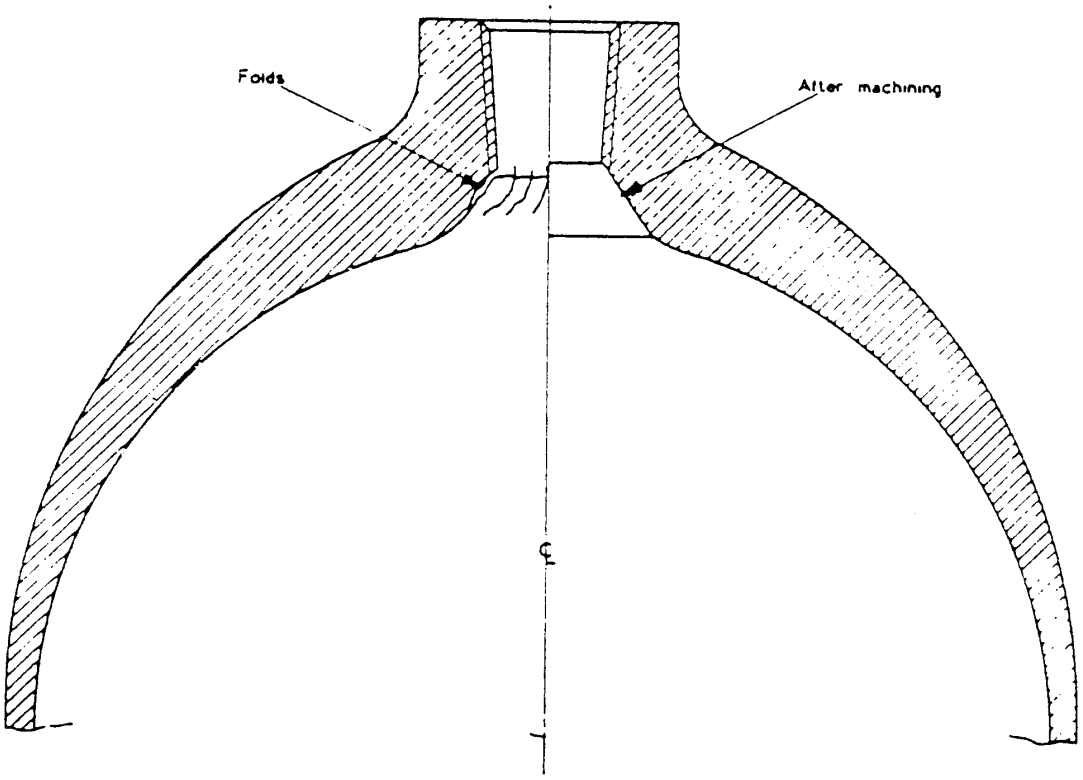

FIGURE 1(a)
BEFORE MACHINING

FIGURE 1(b)
AFTER MACHINING

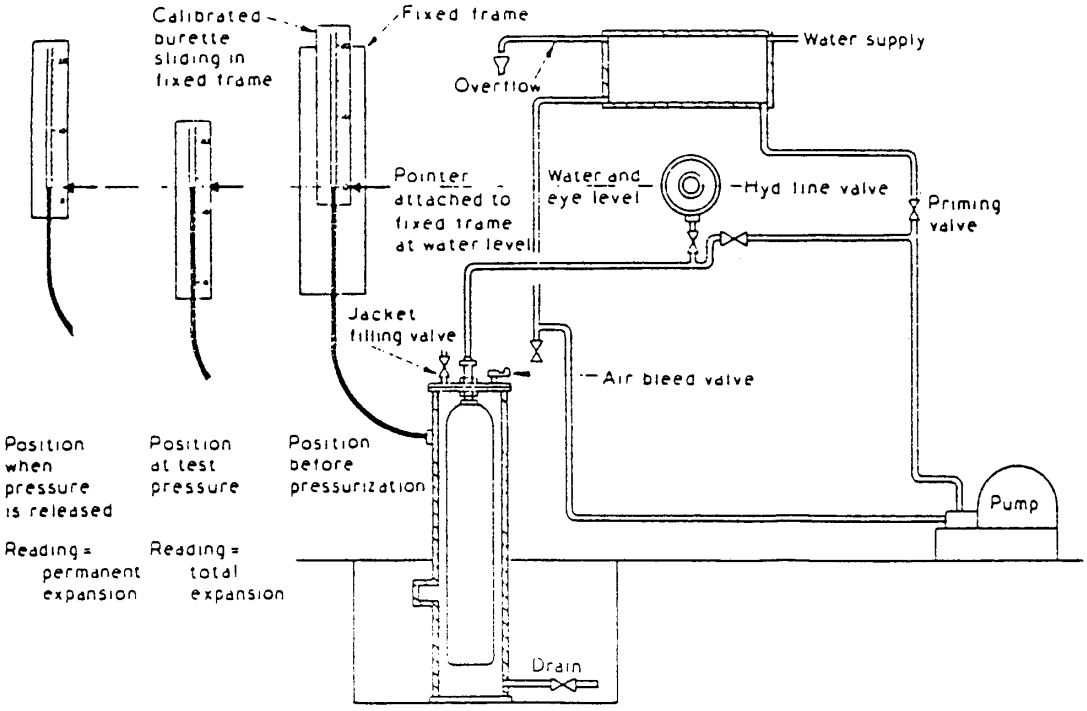

Figure 2 Water-jacket volumetric expansion test (levelling burette method)

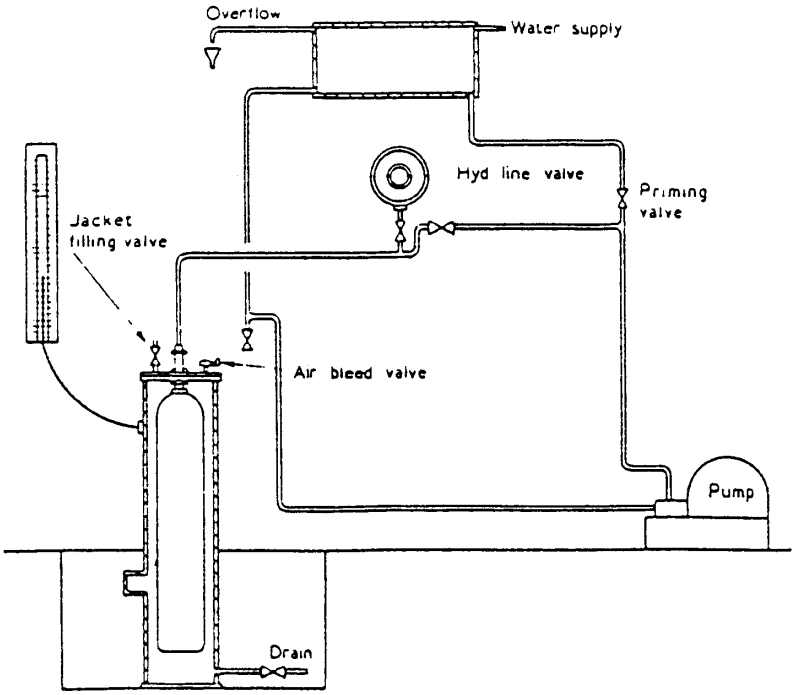

Figure 3. Water-jacket volumetric expansion test (fixed burette method)