HEALTH AND SAFETY EXECUTIVE

SPECIFICATION HOAL 4

SEAMLESS ALUMINIUM ALLOY CONTAINERS

FOR THE CONVEYANCE OF COMPRESSED AND LIQUEFIED GASES

REVISION 1

JUNE 1980

SECTION ONE - GENERAL

1. FOREWORD

This revision of specification HOAL 4 replaces the original version dated January 1970 and issued by the Home Office. It incorporates amendment No 1 dated 10 December 1976 and amendment No 2 dated 21 May 1979.

Any enquiries regarding this specification should be addressed to HM Inspector of Explosives, Health and Safety Executive, Thames House North, Millbank, London SW1 (01 211 6479).

2. SCOPE

This specification gives requirements for the material, design, construction and testing of aluminium alloy containers of water capacity 1 to 130 litres for the conveyance of certain gases under pressure; such containers are suitable also for storing gas under pressure.

It includes appendices giving examples of design calculations, a description of the method for pressure testing containers, and model forms of design and acceptance certificates.

3. REFERENCES

The titles of the British Standards referred to in this specification are listed in Appendix E.

4. MANUFACTURE AND TESTING OF CONTAINERS

Containers shall only be manufactured to this specification by manufacturers of aluminium alloy containers recognised by the Health and Safety Executive who will require proposals to be supported by the results of tests on representative containers under pulsating pressure.

The aluminium alloy from which containers are made shall have been manufactured by a maker on the Health and Safety Executive list of recognised makers of aluminium alloy for seamless containers.

The manufacture, inspection and testing of containers complying with the requirements of this specification shall be carried out to the satisfaction of an Independent Inspecting Authority on the Health and Safety Executive list of recognised inspecting authorities, hereinafter referred to as the Independent Inspecting Authority.

5. CLASSIFICATION OF GASES

Gases which may be conveyed in aluminium alloy containers are classified in Table 2.

For the purposes of the design and filling of the container, gases are classified as follows:

Permanent gases - those gases which have a critical temperature below -10°C.

Liquefiable gases - those gases which are liquefiable by pressure at -10°C but which boil below -17.5°C when at not more than 1013 mbar[1].

High pressure liquefiable gases are those having a critical temperature between -10°C and 70°C.

Low pressure liquefiable gases are those having a critical temperature above 70°C.

Those toxic substances which are liquids at 1013 mbar at 0°C, but which boil at or below 30°C at that pressure shall be treated as low pressure liquefiable gases.

6. INFORMATION TO BE SUPPLIED BY THE PURCHASER AND MANUFACTURER

6.1 **Information to be supplied by the purchaser**. The purchaser shall inform the manufacturer of the following as appropriate:

(a) name or classification of gas(es);

(b) service application;

(c) volumetric capacity (minimum for liquefiable gases);

(d) for permanent gases the filling pressure at 15°C;

(e) for liquefiable gases, the mass of gas or filling ratio at the prescribed reference temperature or the required developed pressure in service;

(f) preferred dimensions;

(g) shape of base;

(h) internal and/or external neck thread dimensions;

(i) fittings required;

(j) external/internal finish required;

(k) any special or adverse conditions under which the container will be required to operate and any corrosion allowance required;

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[1] 1 bar = 10^5 N/M^2 = 100 kPA.

(l) any requirements in excess of those specified in this standard;

(m) the name of the Independent Inspecting Authority.

6.2 **Information to be supplied by the manufacturer**. The manufacturer shall supply the purchaser and the Independent Inspecting Authority with the following information:

(a) fully dimensioned sectional drawing of the container including:

(i) name or classification of gas(es);

(ii) volumetric capacity (minimum for liquefiable gases);

(iii) filling pressure at 15°C for permanent gas(es) or mass of liquefiable gas(es);

(iv) specification of the aluminium alloy;

(v) test pressure;

(vi) minimum and maximum masses of container;

(vii) statement that the container will be constructed to the requirements of this specification;

(viii) design approval (see 17);

(ix) corrosion allowance if any;

(b) method of manufacture;

(c) fittings to be supplied;

(d) drawing showing layout of stamped markings (see clause 26);

(e) certificate of test for materials and container (see appendix C).

7. CERTIFICATE OF COMPLIANCE

The Independent Inspecting Authority shall certify that the manufacture, inspecting and testing of the container was carried out in accordance with the requirements of this specification.

Note: a suitable form of certificate is shown in Appendix C.

SECTION TWO - MATERIAL OF CONSTRUCTION

8. CHEMICAL COMPOSITION

8.1 The cast analysis shall comply with the limits given in Table 1.

8.2 A cast is defined as:

(a) the product of one furnace melt; or

(b) the product of one crucible melt; or

(c) the product of a number of crucible or furnace melts mixed prior to casting; or

(d) the amount of metal tapped from the furnace without any further addition of metal having been made (when a continuous melting process is employed); or

(e) as may be otherwise defined by the Independent Inspecting Authority.

8.3 Analysis of the product may vary from the cast analysis due to heterogeneity arising during the casting and solidification of the ingot. The rounding off rule given in BS 1957 applies to composition limits in Table 1.

Note: product analysis is any analysis of the aluminium alloy subsequent to cast analysis.

9. ALUMINIUM PRODUCERS CERTIFICATE

The container manufacturer shall have obtained from the aluminium alloy producer, a certificate that the material specified therein conforms to the limits given in Table 1.

10. IDENTIFICATION OF ALUMINIUM ALLOY

The aluminium alloy shall be marked and records shall be kept so as to enable the cast from which a container is made to be identified.

Table 1 - Cast Analysis of the Aluminium Alloy

Element	Limit %
Copper	Max 0.10
Magnesium	Min 0.5
	Max 1.2
Silicon	Min 0.7
	Max 1.3
Iron	Max 0.5
Manganese	Min 0.40
	Max 1.0
Zinc	Max 0.2
Chromium	Max 0.25
Titanium and/or other grain refining elements	Max 0.2
Aluminium	The remainder

11. HEAT TREATMENT AND MECHANICAL PROPERTIES

11.1 The finished containers shall be solution heat treated at 520°C to 540°C and quenched in water followed by precipitation treatment at 160°C to 190°C.

11.2 Mechanical properties required in the finished containers at room temperature are as follows:

Tensile strength	325 N/mm^2 min
0.2% proof stress	275 N/mm^2 min
Elongation % on 5.65 √SO	12% min
Bend test former radius	3t[2] max
Hardness	
Brinell	90 min
Rockwell B	48 min

[2] T is the minimum manufacturing thickness as specified on the drawing, including corrosion allowance if any.

12. SERVICE CONDITIONS FOR DESIGN

12.1 Where gases are to be conveyed in the United Kingdom in uninsulated containers, it shall be assumed that the most severe conditions of exposure to the climate will cause the contents to reach the developed pressure at the reference temperature specified in 12.2 the values of which vary with the type of gas it contains.

The maximum permissible pressure in service, to which the test pressure of the container is related (see 15.2) is the pressure developed by the contents at the pressure reference temperature, taking into account the filling ratio for high pressure liquefiable gases, and the intended filled pressure at 15°C for permanent gases. The necessary data on the relationship between filled pressure, or filling ratio, and developed pressure at the reference temperature are given in BS 5355.

The reference temperature for the filling ratios of low pressure liquefiable gases in uninsulated containers is given in 12.3. Examples of design calculations are given in Appendix B.

12.2 The reference temperatures for developed pressures for conveyance in the United Kingdom in uninsulated containers are as follows:

Low pressure liquefiable gas	55°C
High pressure liquefiable gas	52.5°C[3]
Permanent gas	60°C

12.3 The reference temperature for filling ratios for low pressure liquefiable gases shall be 45°C.

12.4 The water capacity of a container for a liquefiable gas shall not be less than the intended maximum mass of the contents divided by the filling ratio. The necessary data on the physical properties of the liquefiable gases are given in BS 5355.

12.5 The internal volume of a container for a permanent gas shall be such as to provide a nominal gas content at 15°C and 1013 m bar.

The charging pressure shall be controlled so as to ensure that the maximum developed pressure, at the reference temperature, does not exceed the requirements given in this specification.

[3] When safety devices are fitted to carbon dioxide containers the reference temperature may be reduced to 50°C.

Table 2 - Classification of gases suitable for conveyance in containers to this specification

Permanent gases (TC < - 10°C)	Liquefiable gases	
	High pressure (-10°C ⩽ Tc ⩽ 70°C)	**Low pressure (TC > 70°C)**
Air	Carbon dioxide	Ammonia* Bromochlorodifluoromethane (R.12B1)
Argon Carbon monoxide* Coal gas* Helium Hydrogen Krypton Methane (natural gas and town gas excluding coal gas) Neon Nitrogen Oxygen Xenon	Ethane Ethylene Nitrous Oxide Nitric Oxide Bromotrifluoromethane (R 13B1)	Butadiene+ Butane 2-Chloro-1, 1, 1-trifluoroethane (R.133a) Chlorodifluorometahne (R.22) Cyclopropane+ Dichlorofluoromethane (R.12) Dichlorofluoromethane (R.21) 1, 2-Dichlorofluoromethane (R.114) Hydrogen cyanide*+ Hydrogen selenide Hydrogen sulphide*+ Isobutane+ Propane+ Sulphur Dioxide*† Sulphur hexafluoride

* These gases are poisonous and are the ones referred to in this standard as toxic gases requiring special treatment. Other gases not so marked may have poisonous properties in less degree or be suffocating in heavy concentrations.

\+ For the purpose of transport these gases are considered to be flammable.

† These gases are considered corrosive for the purpose of periodic testing (BS 5430).

Note 1 - T^C is the Critical temperature.

Note 2 - Reference to refrigerants by number designation (eg R.12) is in accordance with international agreements (see BS 4580).

12.6 When gases are being conveyed in insulated containers the reference temperatures quoted in 12.2 and 12.3 do not apply. The temperature which can be reached by their contents, the corresponding developed pressure required for design and allowable mass of liquefiable gas are all conditional upon the intended degree of insulation proposed with or without the assistance of some form of refrigeration and upon the journey duration. In these cases the operational criteria for design shall be sought from HM Inspectors of Explosives.

13. GASES THAT SHALL NOT BE CONTAINED IN ALUMINIUM ALLOY CONTAINERS

The following gases shall not be contained in containers to this specification:

Acetylene
Boron trifluoride
Bromotrifluorethylene
Carbonyl chloride
Chlorine
Chlorine trifluoride
Cyanogen chloride
Fluorine
Hydrogen chloride
Hydrogen fluoride
Methyl bromide
Methyl chloride
Nistrosyl chloride

14. UNLISTED GASES

For conditions pertaining to the carriage in containers to this specification, of any gas not listed in Table 2 or Clause 13 reference shall be made to HM Inspector of Explosives.

15. DESIGN OF CONTAINER SHELL

15.1 Nomenclature

t	Is the minimum wall thickness (mm) to resist internal pressure and external forces due to normal handling.
P_1	Is the test pressure (bar) applicable to design governed by equation (1).
P_2	Is the test pressure (bar) applicable to design governed by equation (2).
p	Is the pressure (bar) developed by the contents of a container at the pressure reference temperature.
D_O	Is the external diameter of container (mm).
D_i	Is the internal diameter of container (mm).
f_e	Is the maximum permissible equivalent stress in N/mm^2 at test pressure;
	= 0.75 x minimum specified 0.2% proof stress 275 N/mm^2
	= 206 N/mm^2
T	= Minimum specified tensile strength (N/mm^2) = 325 N/mm^2.
Y	= Minimum specified 0.2% proof stress (N/mm^2) = 275 N/mm^2.

15.2 **Permissible pressure**. The maximum pressure attainable in service by a permanent gas in an uninsulated container or a liquefiable gas in an insulated container shall not exceed 0.63 of the test pressure times the ratio of the minimum specified tensile strength to the minimum specified 0.2% proof stress of the alloy namely:

$$P_1 = \frac{pY}{0.63T} = 1.34p$$

The maximum pressure attainable in service by a liquefiable gas in an uninsulated container shall not exceed 0.70 of the test pressure times the ratio of the minimum specified tensile strength to the minimum specified 0.2% proof stress of the alloy namely:

$$P_1 = \frac{pY}{0.7T} = 1.21p$$

Carbon dioxide containers shall be designed for a test pressure of not less than 200 bar.

15.3 **Thickness of cylindrical shell**

The thickness of the cylindrical shell of a container shall be not less than the value given by equation (1).

$$t = \frac{0.3\, P_1\, D_i}{7f_e - P_1} \text{ or } t = \frac{0.3\, P_1\, Do}{7f_e - 0.4\, P_1} \quad (1)$$

except that the thickness of the cylindrical shell shall not be less than the value given by equation (2)

$$t = 2.48\, x \sqrt{\frac{D_i}{T}} \quad (2)$$

Equation (2) will override equation (1) for comparatively low values of P_1 in which case the test pressure P_2 shall be derived from equation (3).

$$P_2 = \frac{7f_e}{1 + 0.12\sqrt{D_i T}} \quad (3)$$

In these circumstances it is permissible to reassess the pressure duty of the container, within the maximum limitation obtained, by the substitution of P_2 for P_1 in 15.2.

15.4 **Additional thickness**. Influences other than those of internal pressure and external forces due to ordinary handling may require the provision of additional wall thickness above the calculated value of t. Additional thickness may be necessary on containers for liquefied gases so that the containers can withstand stress due to horizontal acceleration and retardation in road transport. The variety of conditions occurring in practice make it impracticable to give a general specification of the necessary allowances; they should be carefully considered and agreed upon in each particular case by the manufacturer and the user of the containers. If a pronounced departure from normal practice is proposed or if other unusual features arise, HM Inspector of Explosives should be consulted.

16. FITTINGS

16.1 Valve fittings

16.1.1 The quality of valve fittings shall comply with BS 341: Parts 1 and 2 or BS 1319 as appropriate and shall be constructed of a material compatible with aluminium alloys and with the gas conveyed in the container unless the requirements of 16.1.2 or 16.1.3 are met.

16.1.2 Fittings to containers (eg valves) that are constructed of copper base alloys shall be coated externally and internally in accordance with Appendix D.

16.1.3 Fittings manufactured with other materials of construction that are not compatible with aluminium alloys, the product conveyed in the container or the environment in which the container is used may be protected with a suitable coating or plating provided approval is obtained from HM Inspector of Explosives.

16.1.4 The design of a spindle operated valve shall be such that when fitted to the container it shall not be possible to withdraw the spindle under normal operating conditions.

16.1.5 Screw threaded valve outlet connections shall be left hand on containers used for flammable gases and right hand on containers used for non-flammable gases. If banks of containers are permanently connected to a common manifold, this requirement shall apply to the manifold outlet only. Containers not exceeding 10 litres water capacity that are used for flammable gases and are fitted with self sealing valves that can only be connected to matching appliances are exempt from the requirement to have a left hand outlet connection.

Only lubricants compatible with the container and contents shall be used on valves or other fittings.

Valve protection

16.1.6 Containers intended for the transport of toxic and/or flammable gases shall have their valves protected against damage, either by the design of the container or by the provision of a stout metal cap or shroud, securely attached to the body of the container. The construction of the metal cap or shroud shall be such that it is nowhere in contact with any part of the valve or valve body.

The valve cap or shroud shall be provided with a side vent of such a size as to prevent any gas pressure accumulating inside the cap or shroud unless the cap, collar and its fixing are designed to withstand the pressure that could be developed in the container by the contents at the reference temperature. If the container is used for highly toxic gases[4], the protection shall be a non-vented gas tight valve cap designed to withstand the pressure which could be developed in the container by the contents at the reference temperature.

If the container is used for highly toxic gases suitable additional protection shall be provided such as a valve locking device and/or by the removal of the valve hand-wheel. A suitably designed gas-tight plug or cap shall be fitted to the valve outlet to minimise the risk of valve leakage in transit.

The additional protection can also be provided by means of a non-vented gas-tight valve cap designed to withstand the pressure that can be developed in the container by the contents at the reference temperature.

The protective device shall be of adequate construction to prevent causing damage to the valve that results in the escape of the product if a filled container is dropped from a height of 1.2 m so that the protective device strikes a hard, flat surface.

[4] For the purpose of 16.2.1 the following gases listed in Table 2 which are compatible with aluminium alloy gas containers are classified as highly toxic: carbon monoxide, hydrogen cyanide, hydrogen sulphide.

16.1.7 In the case of a container or group of containers securely attached to a cradle, the valves shall be protected as required by 16.2.1 or, alternatively the valves shall be protected by the design of the cradle or by the secure attachment to the cradle of a stout guard. If the containers are connected to a common manifold, the manifold as well as the valves shall be so protected. The guard may be hinged or removable and if so it shall be provided with a lock to enable it to be kept in the locked position during conveyance.

16.1.8 The requirements of 16.2.1 may be waived in the case of containers intended for the transport of non-toxic flammable gases and carbon monoxide and mixtures thereof, where direct consignments are made between filler and user.

16.1.9 **Dip pipes**. Where a dip pipe is fitted to a container its presence shall be indicated.

This requirement may be fulfilled by the placing of a disc, suitably marked, between the valve and the neck of the container or by a one inch wide white stripe painted along the longitudinal axis of the container. An indication shall be given whether the dip pipe is short or long and straight or curved.

16.2 Pressure relief devices

16.2.1 General requirements. No pressure relief device shall be fitted to a container intended for the conveyance of the toxic gases listed in Table 2. A pressure relief device may be fitted to a container intended for the conveyance of non-toxic gases.

The materials of construction for all pressure relief devices shall be compatible with the material of construction of the container, the gas to be conveyed and other service conditions.

All pressure relief devices shall be so designed and fitted as to ensure that the cooling effect of the contents of the container during discharge shall not prevent the effective operation of the devices.

Pressure relief devices shall be capable, under the most severe temperature conditions, including exposure to fire, of a discharge rate that prevents the pressure of the container contents from exceeding the test pressure of the container.

The outlets from all pressure relief devices shall be so sited that free discharge from the devices is not impaired.

The outlets from all pressure relief devices shall be so designed and constructed as to prevent the collection of moisture or other foreign matter that could adversely affect the performance of the devices.

16.2.2 Pressure relief valve. Where a pressure relief valve is fitted to a container it shall be of the spring loaded type. Where practicable, the pressure at which the relief valve is designed to start lifting shall be marked on the relief valve or the outlet valve body where the relief valve forms part of the outlet valve.

The full discharge rate from the pressure relief valve shall be attained at a pressure not greater than the test pressure of the container.

The pressure relief valve shall be so constructed as to prevent unauthorised interference with the relief pressure setting during service.

16.2.3 Bursting discus. A bursting disc may be fitted to any valve in any container intended for the conveyance of non-toxic and non-flammable gases. A bursting disc, if fitted, shall comply with BS 2915, and shall be so designed as to ensure that rupture occurs at a pressure not greater than the test pressure of the container.

The pressure at which the bursting disc is designed to rupture shall, where practicable, be stamped on the bursting disc holder.

If a container is liable to be subjected to vacuum conditions during service, the bursting disc shall be fitted with vacuum supports.

16.2.4 Fusible plugs. HM Inspector of Explosives shall be consulted where it is proposed to fit containers with one or more fusible plugs.

Where practicable, fusible plugs shall be externally marked to indicate the temperature at which they are designed to relieve pressure.

SECTION FOUR - MANUFACTURE AND WORKMANSHIP

17. APPROVAL OF DESIGN AND CONSTRUCTION DETAILS

Before manufacture is commenced 3 copies of detailed drawings showing each new design of container together with the method of manufacture shall be submitted to HM Inspector of Explosives for approval.

No alteration shall be made to the design after approval unless such alteration has received prior agreement of HM Inspector of Explosives.

18. PERMISSIBLE PROCESSES

The container shall be made:

(a) by cold or hot extrusion from cast or extruded billets;

(b) by cold or hot extrusion followed by cold drawing from cast or extruded billets;

(c) by cupping and cold drawing sheet or plate;

(d) by necking at both ends extruded or cold drawn tube.

They shall be made only by a process which has been shown to produce containers free from cracks or other flaws which could adversely affect the safety of the containers.

The ends shall be of an approved shape and shall be formed by forging, swaging, or spinning.

19. TOLERANCES

The difference between the maximum and minimum external diameter measured at any cross-section of the cylindrical portion of the container shall not exceed 1% of the nominal external diameter.

The wall thickness shall not at any point be less than the value of 't' calculated in accordance with 15.3.

The length shall be such that the nominal water capacity for permanent gases and the minimum water capacity for liquefiable gases shall be obtained as agreed between purchaser and manufacturer.

SECTION FIVE - INSPECTION AND TESTS

20. GENERAL

The inspection and testing of containers shall be carried out to the satisfaction of an Independent Inspecting Authority which shall certify that the containers comply with the requirements of this specification. The purchaser and Independent Inspecting Authority shall have access at all reasonable times, to those parts of the manufacturers works engaged upon that order. They shall be at liberty to carry out any inspection deemed necessary to ensure that the containers comply with this specification.

The manufacturer shall give reasonable notice to the Independent Inspecting Authority, as agreed between them of when the containers will reach a stage at which inspection is required. Adequate facilities for inspection and witnessing of tests shall be provided by the manufacturer.

21. HARDNESS TEST

21.1 Each aluminium alloy container after heat treatment shall be subjected to a hardness test.

The Brinell hardness test as given in BS 240: Part 1 may be used in which case the:

$$\frac{load\ (kgf)}{ball\,dia^2\ (mm^2)} = 10$$

The Rockwell hardness test in accordance with BS 891: Part 1, may be used. The value obtained shall be as given in 11.2.

22. MECHANICAL TESTS

22.1 **General**. Mechanical tests shall be carried out on the material of finished containers.

For the purpose of testing, the term batch is intended to indicate a group of containers of the same size, design and material specification heat treated at the same conditions of temperature and duration.

Tests required.

The following tests shall be made on one finished container in every batch, or where the number in a batch exceeds 100, from one container in every 101 or part thereof:

(a) tensile test (22.3);

(b) bend test (22.4).

22.2 Tensile test

22.2.1 The tensile test specimen shall be made from a strip cut longitudinally from a finished container and its form and dimensions shall be in accordance with BS 18: Part 1. Non Ferrous Metals, the cross-section shall either be formed by a portion of the wall of the container or (when the wall thickness permits) be circular with a diameter of not less than 7 mm for the central position.

22.2.2 In preparing the test piece with the cross section formed by a portion of the wall of the container, 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.

22.2.3 The tolerance on form (difference between maximum and minimum values of a given dimension in any one test piece) for the unmachined surfaces of a test piece shall be to the tolerance grade IT9 of BS 4500: Part 1. For test pieces of circular cross section the machining tolerance on nominal dimensions (the tolerance, compliance with which permits the nominal cross section to be used in computing the test results without calculation of the individual cross-sectional area for each test piece) shall comply with limit of tolerance IT12 to BS 4500: Part 1.

22.2.4 The cause length for test pieces and the test results shall conform to the requirements specified in BS 18: Part 1.

22.2.5 Tensile testing shall be carried out as specified in BS 18: Part 1.

The limit of error of measurement of $\pm$ 0.5% in each dimension prescribed in 3.2.1 of BS 18: Part 1 should be interpreted as applying to each measurement. Individual measurements of the thickness of a test piece whose 2 faces are formed by the surfaces of the container wall may differ somewhat from one another and the minimum thickness shall be taken for calculation.

When the parallel length of the specimen as specified in BS 18: Part 1 is in excess of the gauge length, a series of overlapping gauge lengths shall be marked, or alternatively gauge marks be applied every 5 mm, 10 mm or 20 mm along the parallel length so that the elongation on the prescribed gauge length can be determined by some suitable method of interpolation.

22.2.6 The tensile testing machine shall be maintained to Grade A of BS 1610.

22.2.7 The results obtained shall meet the requirements of 11.2.

22.3 Bend test

22.3.1 Cold bend tests shall be made on 4 strips cut from the same container as that used to provide the tensile test piece. A ring shall be cut from the container and divided into 4 strips of equal length. The width of the ring shall be 25 mm unless 25 mm is less than 4 times the minimum manufacturing thickness of the container as specified on the drawing (including corrosion allowance if any), in which case the width shall be not less than 4 times the minimum manufacturing thickness of the container or where machining of the test piece is permitted, not less than 4 times the thickness of the test piece. Alternatively 2 rings shall be cut from a container and each ring shall be cut into 2 strips of equal length. Except for large containers, the face of the back of the test piece shall not be machined except that the edges may be rounded off. Where bending the full thickness of the container is impracticable, the test piece may at the discretion of the Independent Inspecting Authority, be thinned uniformly by machining from one side; the unmachined surface shall be bent in tension.

The test piece shall remain uncracked when bent inwards round a former of radius not greater than 3 times the minimum manufacturing thickness of the container as specified in 11.2 until the gap between the ends is not greater than twice the radius of the former.

23. EXAMINATION OF THICKNESS, SURFACE IMPERFECTIONS AND NECK FOLDS

23.1 Before the closing in operation each container shall be examined for minimum thickness and for external and internal surface defects.

23.2 **Examination for neck folds**. Each container shall be examined for neck folds by means of an introscope or other suitable method.

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(a), shall be removed by a machining operation which produces a contour similar to that in figure 1(b).

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 the designed wall thickness, the container shall be deemed not to comply with the requirements of this specification.

HYDRAULIC TESTS

23.3 **General**

23.3.1 Each completed container shall be subjected to a volumetric expansion test as in Appendix A.

23.3.2 The test pressure shall be determined by the requirements of clause 15. No pressure greater than 80% of the test pressure shall have been applied to any container before the test.

23.4 **Volumetric expansion test**

23.4.1 The permanent volumetric expansion shown by the test expressed as a proportion of the total expansion under the test pressure shall not exceed 5%.

23.4.2 If the test is made by the ‘non-jacket’ method (see Appendix A) the container shall be examined for signs of leakage when subjected to the test pressure.

23.4.3 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 reheat treated in accordance with 24.4 and then re-tested.

23.5 **Drying out**. The interior of each container shall be thoroughly dried by a suitable method immediately after hydraulic testing. Containers shall not be heated above 150°C.

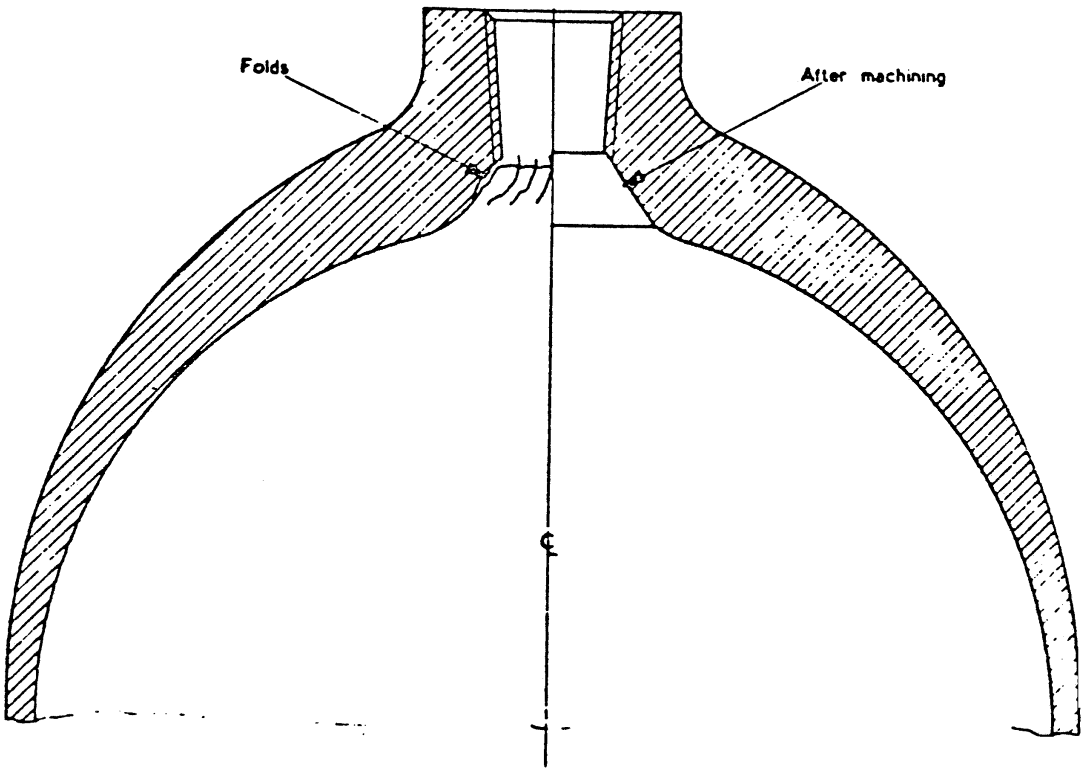

FIGURE 1(a)
BEFORE MACHINING

FIGURE 1(b)
AFTER MACHINING

FIGURE 1. CYLINDER NECK FOLDS BEFORE AND AFTER MACHINING

23.6 **Re-heat treatment**

23.6.1 Where it can be established from the heat treatment furnace records that the artificial ageing (precipitation) treatment has not been adequate, additional time at the ageing treatment temperature may be given.

23.6.2 Where it can be established that the solution heat treatment was at fault, the containers may be re-solution treated and artificially aged.

23.6.3 Containers shall be re-solution treated once only.

23.7 **Hydraulic testing of prototype containers**

23.7.1 Burst test. In addition to the foregoing tests, one container of the first batch to be made to a new design shall be hydraulically tested to destruction. The container shall remain in one piece after bursting. In the case of large containers or of small batches where this test may be impracticable, HM Inspector of Explosives shall be consulted.

The nominal hoop stress corresponding to the pressure at which destruction occurs shall be calculated from the formula:

$$fb \frac{P_b\ D_i}{20\ t_m}$$

where

f_b is the nominal hoop stress (N/mm^2) at which destruction occurs;

P_b is the internal pressure (bar) at which destruction occurs;

D_i is the internal diameter (mm) of the container;

t_m is the minimum manufacturing wall thickness (mm) of the container as specified on the drawing (including corrosion allowance, if any).

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

23.7.2 Pressure cycling test. In addition to the tests specified in clauses 21, 22, 24.2 and 24.5.1, 3 containers of the first batch to be made to a new design shall be submitted to the following pressure cycling test. The containers shall be guaranteed by the manufacturer to be representative of his design and manufacturing procedure.

23.7.2.1 The test shall be carried out using a non-corrosive fluid, with a range of pressure equivalent to either 0.9 times the test pressure or 0.6 times the test pressure of the container. The value of the lower cyclic pressure shall not exceed 10% of the upper cyclic pressure. The frequency of reversals shall not exceed 15 cycles/min. The temperature measured on the outside surface of the containers shall not exceed 50°C during the test.

23.7.2.2 The containers shall be considered to have passed the test if they satisfactorily complete:

either 10,000 cycles at 0.9 x test pressure; or

75,000 cycles at 0.6 x test pressure

without sign of leakage.

24. RESULTS OF TESTS

24.1 A record shall be kept of all tests made at the container maker's works.

24.2 If any of the test specimens fail the mechanical tests, then:

if the Inspecting Authority considers that the failure was due to an error in carrying out the test, he may authorise a re-test and the first test shall be ignored but, otherwise, at the manufacturers discretion, either:

(a) the mechanical test in which the failure occurred shall be repeated on the container or test ring originally tested and in addition the tests under 22.3 and 22.4 shall be carried out on another container or test ring from the same batch. If both containers or both test rings then comply with the test requirements of 22.3 and 22.4 the batch may be accepted; or

(b) the batch may be re-heat treated as specified in 24.4.1 or 24.4.2 and the mechanical tests called for under 22.3 and 22.4 shall be carried out. If the test rings then comply with the test requirements, the batch may be accepted.

24.3 If any of the mechanical tests required by 25.2(a) or (b) fail, the batch may be re-heat treated as specified in 24.4.1 or 24.4.2, as appropriate and re-tested as specified in 25.2 and if the containers then comply with the test requirements the batch shall be accepted.

24.4 Not more than 2 containers or 2 test rings from one batch shall be submitted for test and the limitations on re-heat treatments in 24.4.3 shall apply.

24.5 If after the permitted number of re-tests and re-heat treatments the mechanical test requirements have not been complied with the containers in the batch shall be rendered unserviceable for holding gas under pressure, by one of the following methods:

(a) the container shall be crushed by mechanical means;

(b) an irregular hole shall be burned in the top dome of the container, equivalent in area to approximately 10% of the area of the top dome; or, in the case of thin walled containers, the containers shall be pierced in at least 3 places.

Any alternative method approved by HM Inspector of Explosives may be used instead. Drilling a hole in a container shall not be considered as satisfying the requirements of this clause.

25. **MARKETING OF CONTAINERS**

25.1 Each container which satisfies the requirements of this specification shall be permanently and legibly marked with:

(a) the manufacturer's mark and serial number;

(b) the test pressure in bars and date of the hydraulic test (which date may be indicated by the month and year, or by the year with a symbol to denote the quarter of the year) and the identification mark of the person or firm who made the test;

(c) the identification mark(s) of the Independent Inspecting Authority;

(d) the specification to which the container was manufactured, ie HOAL 4;

(e) the charging pressure in bar at 15°C if the container is intended to be used for the conveyance of liquefiable gases;

(f) the minimum water capacity in litres of the container if it is intended to be used for the conveyance of liquefiable gases;

(g) the tare in kg, ie the mass of the container and valve (excluding the valve cover) if it is intended for the conveyance of liquefiable gases;

(h) the mass in kg of the container only, if it is intended for the conveyance of permanent gases.

25.2 The marks shall be on the neck end of the container with the exception of the manufacturer's mark which may be on the base.

25.3 The permanent marking shall not be made on the body of the container but shall be at areas in the formed neck and base ends where the thickness of metal is greater than the design minimum and where it is adequate for marking to be carried out.

25.4 To verify the thickness of the metal at the ends of the container and the areas suitable for marking, a prototype container shall be sectioned at the ends and the areas where marking is permitted shall be agreed between the manufacturer and the Independent Inspecting Authority.

25.5 A further prototype container shall be similarly sectioned and examined after marking. The marking shall cause no change in contour of the container. The characters in the marking shall normally be at least 6 mm in height. On small containers this height may be reduced but in no case shall the characters be less than 3 mm in height.

25.6 When the conditions set out in 26.2 to 26.5 cannot be satisfied HM Inspectors of Explosives shall be consulted.

APPENDIX A - HYDRAULIC VOLUMETRIC EXPANSION TESTING OF GAS CONTAINERS

A.1 General

This appendix described 2 methods, as follows, for determining the volumetric expansion of seamless aluminium alloy gas containers as required by clause 24:

(a) the water-jacket method (preferred method);

(b) the non-water jacket method.

The water-jacket volumetric expansion test may be carried out on equipment using a levelling burette or a fixed burette.

A.2 Test equipment

The following requirements are common to both methods of test:

(a) hydraulic test pressure pipelines shall be capable of withstanding a pressure twice the maximum test pressure of any container that may be tested;

(b) glass burettes shall be of sufficient length to contain the full volumetric expansion of the container and shall be capable of being read to an accuracy to 1% or 0.1 ml;

(c) pressure gauges shall be manufactured and maintained in accordance with BS 1780: Part 2 Industrial class 1. They shall be tested at regular intervals and in any case not less frequently than once per month;

(d) a suitable device shall be employed to ensure that no container is subjected to a pressure in excess of its test pressure;

(e) pipework should utilise long bends in preference to elbow fittings and pressure pipes should be as short as possible. Flexible tubing shall be capable of withstanding twice the maximum test pressure in the equipment and have sufficient wall thickness to prevent kinking;

(f) all joints should be leak-tight;

(g) when installing equipment, care shall be taken to avoid trapping of air in the system.

A.3 Water-jacket volumetric expansion test

The water-jacket volumetric expansion test necessitates enclosing the water-filled container in a jacket also filled with water. The total and, if any, the permanent volumetric expansion of the container are measured in relation to the amount of water displaced by the expansion of the container when under pressure and after the pressure is released.

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

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

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

A.3.1 Water-jacket volumetric expansion test (levelling burette method)

The equipment should be installed as shown in figure 2.

Procedure

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

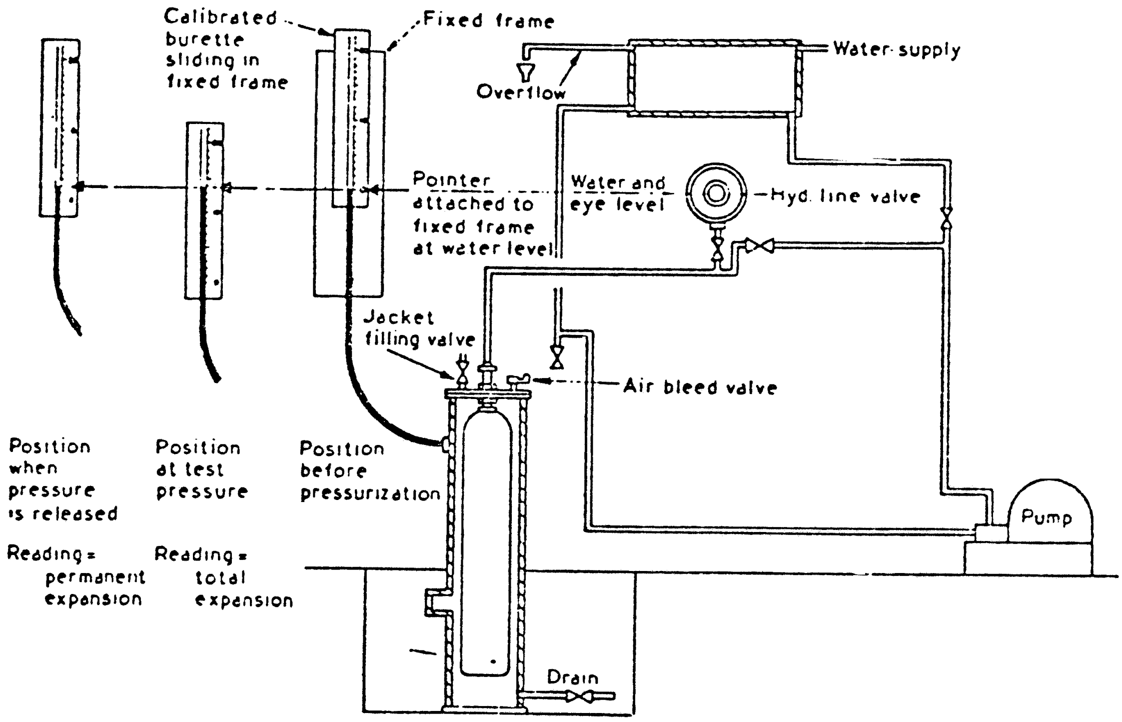

Figure 2. Water jacket volumetric expansion test (levelling burette)

(b) Seal the container in the jacket and fill the jacket with water, allowing the air to bleed off through the air bleed valve.

(c) Connect the container to the pressure line. Adjust the burette to zero level by manipulation of the jacket filling valve and drain valve. Raise the pressure to two-thirds of the test pressure, stop pumping, and close the hydraulic pressure supply valve.

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

(d) Restart the pump and open the hydraulic pressure line valve until the container test pressure is reached. Close the hydraulic pressure line valve and stop pumping.

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

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

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

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

$$\frac{permanent\ \exp ansion\ x\ 100}{total\ \exp ansion} \leq 5\%$$

A.3.2 Water-jacket volumetric expansion test (fixed burette method)

The equipment should be installed as shown in figure 3. The procedure for this method of test is similar to that specified in A.3.1, except that the burette is fixed.

Procedure

(a) Adjust the water level to a datum. Apply pressure until the test pressure is reached and record the burette reading. The reading above the datum is the total expansion, and shall be recorded on the test certificate.

(b) Release the pressure and record the burette reading. The reading above the datum, if any, is the permanent expansion, and shall be recorded on the test certificate.

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

$$\frac{permanent\ expansion\ x\ 100}{total\ expansion} \leq 5\%$$

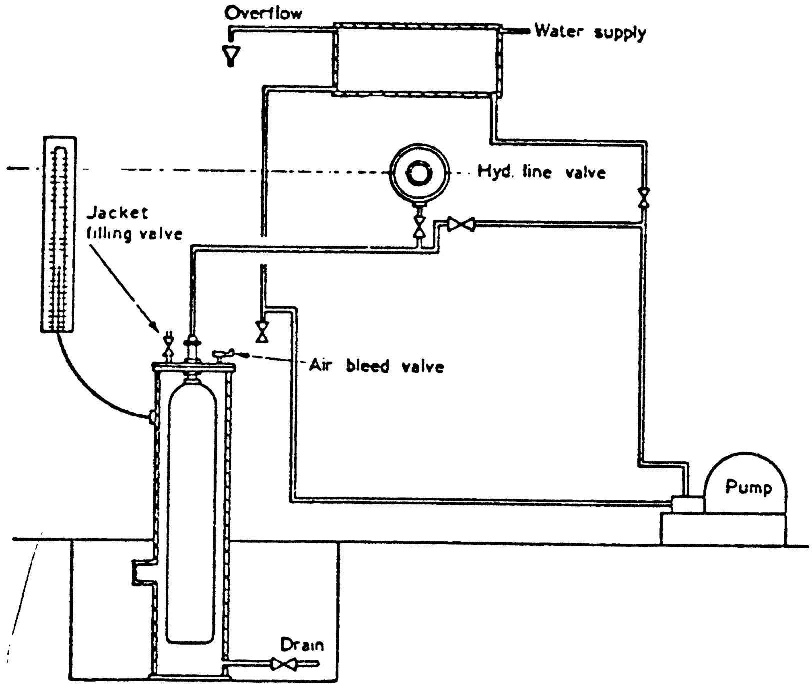

Figure 3. Water jacket volumetric expansion test (fixed burette)

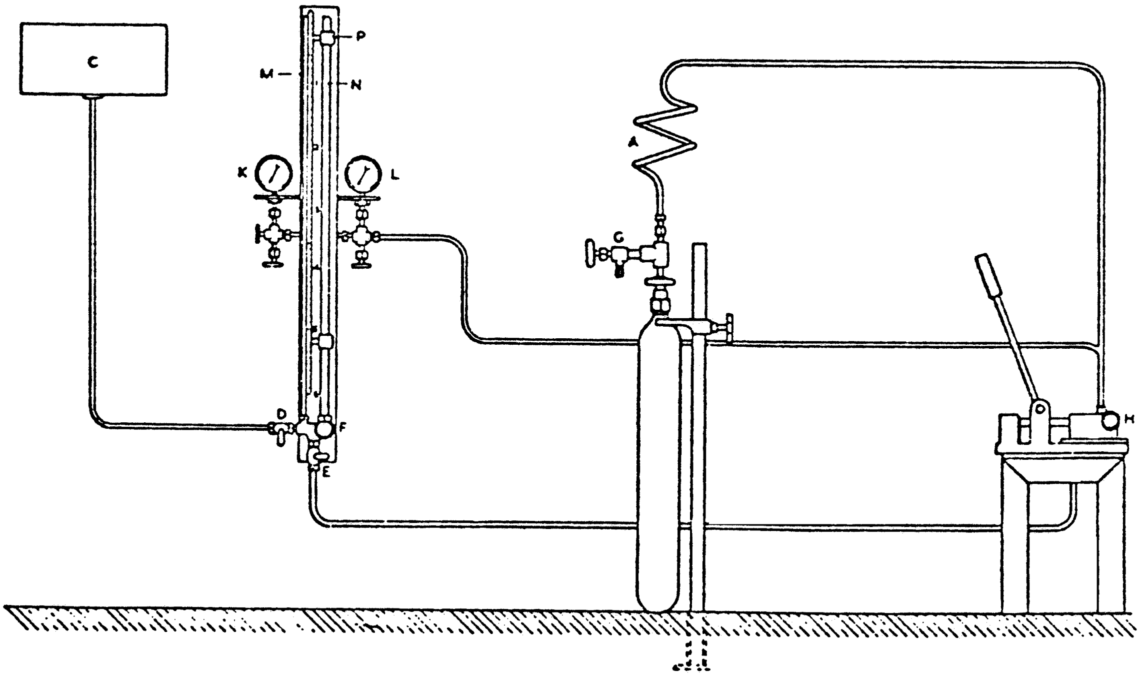

Figure 4. Non-water jacket' volumetric expansion test

A.4 Non-water jacket volumetric expansion test

The non-water-jacket volumetric expansion test consists of measuring the amount of water passed into the container under proof pressure and, on release of this pressure, measuring the water returned to the manometer. It is necessary to allow for the compressibility of water and for the volume of the container under test to obtain true volumetric expansion. No fall in pressure during this test is permitted.

The water used should be free of air. Any leakage from the system or the presence of free or dissolved air will result in false readings.

The equipment should be installed as shown in figure 4. The figure illustrated diagrammatically the different parts of the apparatus. The water supply pipe should be connected to an overhead tank as shown, or to some other supply giving a sufficient head of water.

A.4.1 Requirements for testing

The apparatus shall be so arranged that all air can be removed and accurate readings can be obtained both of the volume of water required to pressurise the filled container and of the volume expelled from the container when depressurised. In the case of larger containers, it may be necessary to augment the glass tube with metal tubes arranged in a manifold.

If a single acting hydraulic pump is used, care shall be taken to ensure that the piston is in the 'back' position when water levels are noted.

A.4.2 Test method

Proceed as follows:

(a) completely fill the container with water and determine the mass of water required;

(b) connect the container to the hydraulic test pump through coil A and check that all valves are closed;

(c) fill the pump and system with water from tank C by opening valves D, E and H;

(d) to ensure the expulsion of air from the system, close valve H and raise the system pressure to approximately one-third of the test pressure. Open bleed valve G to release trapped air by reducing the system pressure to zero, and reclose valve G. Repeat if necessary;

(e) continue to fill the system until the level in glass tube M is approximately 300 mm from the top of this tube. Close valve D and mark the water level by pointer P, leaving valves E and H open. Record the level;

(f) close valve H. Raise the pressure in the system until pressure gauge(s) records the required test pressure. Stop the pump. After approximately 30 s there should be no change in either the water level or the pressure. A change in level indicates leakage. A fall in pressure, if there is no leakage, indicates that the cylinder is still expanding under pressure.

(g) record the fall of the water level in the glass tube. Providing there has been no leakage, the water drained from the glass tube will have been pumped into the container to achieve test pressure. This difference in water level is the volumetric expansion;

(h) open valve H slowly to release the pressure in the container and allow the water so released to return to the glass tube. The water level should return to the original level marked by pointer P. If the water level returns to a point below pointer P, this difference in level will denote the amount of permanent volumetric expansion in the container, neglecting the effect of the compressibility of the water at test pressure. The true permanent volumetric expansion of the container is obtained by correcting for the compressibility of the water obtained from the calculation given in A.4.4;

(i) before disconnecting the container from the test rig, close valve E. This will leave the pump and system full of water for the next test. Action (d) shall, however, be repeated at each subsequent test;

(j) if permanent volumetric expansion has occurred, record the temperature of the water in the container.

A.4.3 Test results

A.4.3.1 The tests determine the volume of water required to pressurise the filled container to test pressure.

A.4.3.2 The total mass and temperature of the water in the container are known, enabling change in the volume of the water in the container due to its compressibility to be calculated. The volume of water expelled from the container when depressurised is known. Thus total volumetric expansion (TE) and permanent volumetric expansion (PE) can be determined.

A.4.3.3 The permanent volumetric expansion shall not exceed 5% of the total volumetric expansion.

A.4.4 Calculation of the compressibility of water

The formula used for the calculation of the compressibility of water is as follows:

$$C = mP\left(K - \frac{0.68P}{10^5}\right)$$

where:

C is the compressibility (in ml)

m is the mass of water (in kg)

P is the test pressure (in bar)

K is the factor for individual temperatures as given in Table 3.

Table 3 - K factors for the compressibility of water

°C	K	°C	K	°C	K
6	0.04915	13	0.04759	20	0.04654
7	0.04886	14	0.04742	21	0.04643
8	0.04860	15	0.04725	22	0.04633
9	0.04834	16	0.04710	23	0.04623
10	0.04812	17	0.04695	24	0.04613
11	0.04792	18	0.04680	25	0.04604
12	0.04775	19	0.04668	26	0.04594

A.4.5 Example calculation

In the following example calculation, allowance for pipe stretch has been neglected.

Example:

Test pressure	=	232 bar gauge
Mass of water in container at zero gauge pressure	=	113.8 kg
Temperature of water	=	15°C

Water forced into container to raise pressure to 232 bar	=	1745 ml (or 1.745 kg)
Total mass of water (m) in container at 232 bar = 113.8 + 1.745	=	115.545 kg
Water expelled from container to depressurise	=	1742 ml
Permanent expansion (PE) = 1745 - 1742	=	3 ml
From Table 3 K factor for 15°C	=	0.04725

C = mp $\left(K - \frac{0.68p}{10^5}\right)$

= 115.545 x 232 (0.04725 - $\frac{0.68 \times 232}{10^5}$) = 1,224.31

Total volumetric expansion (TE) = 1745 - 1224.3 = 520.7 ml

% PE = $\frac{3 \times 100}{520.7}$ = 0.58%

APPENDIX B - EXAMPLES OF DESIGN CALCULATIONS FOR CYLINDRICAL WALLS OF SEAMLESS CONTAINERS

B.1 Container for permanent gas

A container having an external diameter of 176 mm, made from aluminium alloy to the chemical composition given in Table 1, is to be filled with oxygen to a pressure (at the equilibrium temperature of 15°C) not exceeding 136.5 bar gauge.

Determination of developed pressure at reference temperature

From 12.2 the reference temperature for permanent gas is 60°C for the United Kingdom.

From BS 5355 the developed pressure p, at 60°C for oxygen filled to 136.5 bar is 166 bar.

Calculation of test pressure

From 15.2 $P_1 = 1.34 \times 166 =$ 222 bar.

Minimum thickness of cylindrical wall

Equation (1) of 15.3 gives $t = \frac{0.3 P_1 D_O}{7 f_e - 0.4 P_1}$

where:

$P_1 = 222$ bar

$D_O = 176$ mm

$F_e = 206$ N/mm^2 from 15.1

Thus $t = \frac{0.3 \times 222 \times 176}{(7 \times 206) - (0.4 \times 222)} = 8.66$ mm

However, the thickness of the cylindrical wall shall not be less than the value given by equation (2) of 15.3

$t = 2.48 \sqrt{\frac{Di}{T}} = 2.48 \frac{158.7}{325} = 1.73$ mm

As this thickness does not exceed the value obtained by calculation from equation (1) of 15.3, the required minimum thickness is 8.66 mm.

B.2 Container for high pressure liquefiable gas

A container having an external diameter of 152 mm is to be manufactured from aluminium alloy to the composition given in Table 1, have a water capacity of 8.0 litres and be suitable for use with carbon dioxide for dispensing soft drinks.

Determination of developed pressure at reference temperature

From 12.2 the reference temperature for carbon dioxide is 50°C when a safety device is fitted.

From BS 5355 the developed pressure, p, at 50°C for carbon dioxide used for purposes other than fire extinguishing (ie a filling ratio of 0.75) is 174.51 bar.

Calculation of test pressure

From 15.2 P_1 = 1.21 x 174.51 = 211 bar

Minimum thickness of cylindrical shell

Equation (1) of 15.3 gives $t = \frac{0.3 P_1 D_o}{7f_e - 0.4 P_1}$

where:

P_1 = 211 bar

D_O = 152 mm

f_e = 206 N/mm^2 from 15.1

Thus $t = \frac{0.3 \times 211 \times 152}{(7 \times 206) - (0.4 \times 211)}$ = 7.08 mm

However, the thickness of the cylindrical wall shall not be less than the value given by equation (2) of 15.3

$t = 2.48 \sqrt{\frac{Di}{T}}$ = 2.48 $\frac{137.8}{325}$ = 1.61 mm

As this thickness does not exceed the value obtained by calculation from equation (1) of 15.3, the required minimum wall thickness is 7.08 mm.

APPENDIX C - SPECIMEN CERTIFICATES FOR SEAMLESS ALUMINIUM ALLOY GAS CONTAINERS

C.1 Specimen acceptance certificate for seamless aluminium alloy gas containers

Certificate number ....

We certify that containers manufactured to Specification HOAL 4

Drawing number .... Against order number ....

For: Customer
Address

Conform to the following requirements

1. **Minimum wall thickness**. The minimum wall thickness has been measured by inspection personnel to a minimum of ...... mm for all containers.

2. **Minimum hardness value**. All containers have been checked to satisfy the minimum hardness value of ....

3. **Heat treatment**. Each container had been treated between 520°C and 540°C followed by water quenching, and artificially aged between 160°C and 190°C followed by air cooling to give the properties required in 11.2 of HOAL 4.

4. **Hydraulic pressure test**. Each container has been subjected to a hydraulic pressure test of ...... bar.

The total volumetric expansions at test pressure were within the range .... to .... ml. The permanent volumetric expansions as a percentage of the total volumetric expansion were within the range .... to .... %.

5. **Material**. All containers have been manufactured from material conforming in chemical analysis to Table 1 of HOAL 4. The cast numbers used were ....

6. **Tare and capacities are within the limits stated**:

Tare ....

Capacity ....

The test report numbers are ....

The containers covered by the above certification are serial numbers ....

Date:

Signature: Signature:

Chief Inspector Independent Inspecting Authority

C.2 LABORATORY TEST CERTIFICATION

Test Report No	Mechanical Test Results				Cast analysis (impurities not quoted are less than .0.1% each)						
	.2% Proof stress N/mm^2	Tensile strength N/mm2	Elonga-tion %	180% bend test Former radius 35 Pass/Fail	Cast No	% Cu	% Mg	% Si	% Fe	% Mn	% other elements

APPENDIX D - APPROVED METHOD OF COATING COPPER BASED ALLOYS FOR SERVICE WITH ALUMINIUM ALLOY CONTAINERS

D.1 Flash of electrotin internally and externally

D.2 Cadmium plating of 0.010/0.025 mm on the body stem thread

D.3 Cadmium plating to 0.008 mm on all other internal and external parts of the valve body

D.4 Passivate in accordance with the following procedure:

(a) Surface preparation

(1) Degreasing - freshly plated or heat treated components do not require degreasing. Otherwise degrease in trichloroethylene.

(2) Cleaning - freshly plated or heat treated components do not require cleaning. Otherwise immerse for 5 min - 15 min in a boiling solution containing 100 g - 200 g trisodium phosphate per litre of water.

(3) Washing - wash in cold running water to remove all electrolyte or cleaning solution. Allow to drain, immediately before passivation, immerse for not more than 10 s in a weak solution of nitric or sulphuric acid containing not more than 1 ml/litre concentration.

(b) Passivation

Immerse for 5 s - 10 s in either of the following solutions at room temperature:

sodium dichromate crystals	150 - 200 g/litre of water
sulphuric acid (sg 1.84)	6 - 10 ml/litre of water
or	
anhydrous sodium sulphate	25 - 30 g/litre of water
chromic acid	200 - 250 g/litre of water

(c) Final washing and drying

(1) Transfer immediately to a tank of cold running water for a few seconds.

(2) Transfer to a second tank of cold running water for approximately one minute.

(3) Warm water insertion up to 50°C for 30 s maximum is permissible to assist drying.

(4) Dry in circulating air at a maximum temperature of 50°C.

APPENDIX E - BRITISH STANDARD REFERRED TO IN SPECIFICATION HOAL 4

BS 18	Methods for tensile testing of metals Part 1: 1970 Non-ferrous metals
BS 240	Method for Brinell hardness test Part 1: 1962 Testing of metals
BS 341	Valve fittings for compressed gas cylinders Part 1: 1962 Valves with taper stems (excluding valves used for breathing and medical purposes) Part 2: 1963 Valves with taper stems for use with breathing apparatus (excluding medical gas cylinders to BS 1319)
BS 891	Method for Rockwell hardness test Part 1: 1962 Testing of metals
BS 1319: 1976	Medical gas cylinders, valves and yoke connections
BS 1610: 1964	Methods for load verification of testing machines
BS 2915: 1974	Bursting discus and bursting disc assemblies
BS 4500	ISO limits and fits Part 1: 1969 General tolerances and deviations
BS 4580: 1970	Number designations of organic refrigerants
BS 5355: 1976	Filling ratios and developed pressures for liquefiable and permanent gases
BS 5430	Periodic inspection, testing and maintenance of transportable gas containers Part 3: 1980 Seamless aluminium alloy containers