BS 6144:1990

Specification for

Expansion vessels using an internal diaphragm, for unvented hot water supply systems

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Refrigeration, Heating and Air Conditioning Standards Policy Committee (RHE/-) to Technical Committee RHE/7, upon which the following bodies were represented:

Associated Offices Technical Committee

Association of Consulting Engineers

Association of Manufacturers of Domestic Unvented Supply Systems Equipment (MODUSSE)

British Marine Equipment Council

Building Services Research and Information Association

Chartered Institution of Building Services Engineers

Heating and Ventilating Contractors' Association

Hevac Association

Institute of Domestic Heating and Environmental Engineers

Sealed System Equipment Association

Waterheater Manufacturers' Association

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Contents

Foreword

This revision of BS 6144, which has been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Policy Committee, supersedes BS 6144:1981, which is withdrawn. In this revision, maximum working pressure grades have been discontinued and provision for clench ring design and construction has been introduced.

In an unvented hot water supply system, allowance has to be made to accommodate the increased volume of contained water resulting from an increase of temperature. Change in volume is directly related to change in temperature and can be calculated for given conditions. Since gases are compressible, it is possible to use a vessel filled with air/gas, connected to the system, to accommodate the water volume increase by compressing the air/gas. The system pressure thus increases as the gas is compressed. To prevent mixing, a flexible diaphragm is fitted in the expansion vessel to act as a permanent barrier between the gas and the system water. It is common practice, initially, to pressurize the air/gas side of the expansion vessel with air or nitrogen.

NOTE An unvented hot water supply system is a system that does not have an open vent connection to a storage vessel. In this context the terms unvented and sealed are synonymous, but the latter is used more for heating systems.

BS 4814 is a companion standard for expansion vessels for water heating systems.

Product certification. Users of this British Standard are advised to consider the desirability of third party certification of product conformity with this British Standard based on testing and continuing surveillance, which may be coupled with assessment of a supplier's quality systems against the appropriate Part of BS 5750.

Enquiries as to the availability of third party certification schemes will be forwarded by BSI to the Association of Certification Bodies. If a third party certification scheme does not already exist, users should consider approaching an appropriate body from the list of Association members.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 8, 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 British Standard specifies the manufacture and testing of steel expansion vessels, having an internal diaphragm and which are intended for use in systems where the heated fluid is potable water.

This British Standard specifies expansion vessels suitable for any maximum working pressure of up to 10 bar.[1)]

NOTE 1 In this standard, all pressures are gauge pressures unless otherwise stated.
NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard, the following definitions apply.

2.1
diaphragm (or membrane)

the flexible means by which the chamber of an expansion vessel is partitioned to maintain separation between the expanding hot water and the gas or air which in consequence becomes compressed

2.2
maximum vessel temperature

the maximum temperature at which the vessel may be allowed to operate continuously

2.3
maximum vessel working pressure

the maximum pressure that the vessel may be allowed to contain in operation

2.4
charging pressure

the initial pressure to which the gas side of the vessel is charged

2.5
total vessel volume

the volume occupied by gas when the vessel is empty of water

3 Design and construction

3.1 General

Expansion vessel manufacturers shall clearly state upon the vessel any limitations in the maximum working pressure.

3.2 Effect of materials on water quality

When used under the conditions for which they are designed, all materials in contact with or likely to come into contact with potable water, including any linings that may be necessary to protect the vessel against corrosion shall:

a) not constitute a toxic hazard;

b) not support microbial growth;

c) not give rise to unpleasant taste or odour, cloudiness or discoloration of the water.

Concentrations of substances, chemicals and biological agents leached from materials in contact with potable water, and measurements of the relevant organoleptic/physical parameters shall not exceed the maximum values recommended by the World Health Organization in its publication "Guidelines for drinking water quality" Volume 1 "Recommendations" or as required by the EEC Council Directive of 15 July 1980 relating to the quality of water intended for human consumption, whichever in each case is the more stringent.

NOTE 1 Requirements for the testing of non-metallic materials in these respects are set out in the UK Water Fittings Byelaws Scheme Information and Guidance Note No. 5-01-02.
NOTE 2 Pending the determination of suitable means of characterizing the toxicity of leachates from materials in contact with potable water, listed materials and chemicals approved by the Department of the Environment Committee on Chemicals and Materials of Construction for use in Public Water Supply and Swimming Pools are considered free from toxic hazard for the purposes of compliance with this subclause.
NOTE 3 Products manufactured for installation and use in the United Kingdom which are verified and listed under the UK Water Fittings Byelaws Scheme, administered by the Water Research Centre, are deemed to satisfy the requirements detailed in this subclause.

3.3 Vessel

The vessel shall be constructed of steel plate, sheet or strip suitable for the process of manufacture, which has a minimum tensile strength of 275 N/mm^2, and which complies with BS 1501-1. Deep-drawn vessels shall be constructed from material complying with BS 1449-1 or BS 1449-2.

NOTE All materials should be capable of verification to the steel makers' test certificates.

The internal surface of the vessel shall be smooth and clean, and all internal edges shall be rounded off.

The external surface of a carbon steel vessel shall be stove enamelled.

Openings in the vessel in excess of 51 mm diameter shall be compensated in accordance with clause **33** of BS 5169:1975.

Vessels having welded seams shall be made in accordance with BS 5135.

[1)] 1 bar = $10^5 N/m^2$ = 10^5 Pa.

The vessel, including diaphragm, shall be capable of continual operation at a normal system temperature up to 65 °C but shall also be capable of operating at 100 °C for up to 1 h under fault conditions.

3.4 Wall thickness of spherical and cylindrical type vessels

3.4.1 *Minimum thickness*

The minimum thickness of steel sheet for construction of vessels having a maximum stored volume of 500 L and a maximum vessel working pressure of 6 bar shall be as follows:

a) 1.00 mm for vessel diameters up to and including 400 mm;

b) 1.75 mm for vessel diameters over 400 mm and up to and including 700 mm.

The minimum wall thickness t (in mm) of all finished vessels shall be calculated as follows:

cylindrical shells $t = \frac{pD}{20fJ\text{-}p} + c$

spherical shells $t = \frac{pD}{40fJ\text{-}p} + c$

where

p is the maximum vessel working pressure (in bar);

D is the inside diameter (in mm);

f is the design stress (in N/mm^2).

NOTE For carbon steels the design stress (in N/mm^2) is $\frac{\text{tensile strength}}{3}$

For stainless steels the design stress (in N/mm^2) is the lower of:

a) $\frac{\text{tensile strength}}{4.5}$

b) $\frac{\text{0.2 \% proof stress}}{1.75}$

J is the joint factor (see Table 1);

c is the corrosion allowance (in mm); $c = 0$ for vessels internally coated with rust inhibitor or made of stainless steel; $c = 0.5$ for all other conditions.

3.4.2 *Vessel ends thickness*

The following equations and values shall be used for design and calculation of the minimum thickness t (in mm) of material for hemispherical, semi-ellipsoidal, torispherical ends for use with cylindrical shells. Each, except the hemispherical end, shall incorporate a skirt[2)].

a) *Hemispherical ends.* [See Figure 1(a).]

$$t = \frac{pR}{20fJ\text{-}p} + c$$

b) *Semi-ellipsoidal ends.* An end of semi-ellipsoidal form, in which half the minor axis (inside depth of end minus the skirt length) equals one-quarter of the inside diameter of the skirt. [See Figure 1(b).]

$$t = \frac{pD_1}{20fJ\text{-}p} + c$$

c) *Torispherical ends.* An end in which the inside crown radius R is not greater than the outside diameter of the skirt and the inside knuckle (or corner) radius r is not less than 6 % of the inside crown radius. [See Figure 1(c).]

$$t = \frac{pRM}{20fJ\text{-}p} + c$$

where

p is the maximum vessel working pressure (in bar);

R is the inside radius (spherical or crown) (in mm);

f is the design stress (in N/mm^2);

NOTE For carbon steels the design stress (in N/mm^2) is $\frac{\text{tensile strength}}{3}$

For stainless steels the design stress (in N/mm^2) is the lower of:

a) $\frac{\text{tensile strength}}{4.5}$

b) $\frac{\text{0.2 \% proof stress}}{1.75}$

J is the joint factor as shown in Table 1 for any joint in the end, and the end-to-shell joint for hemispherical ends;

c is the corrosion allowance (in mm); $c = 0$ for ends internally coated or made of stainless steel;

D_1 is the inside diameter of end skirt (in mm);

M is the shape factor ¼ $\left(3 + \sqrt{\frac{R}{r}}\right)$

[2)] In the pressure vessel industry, a skirt is also known coloquially as a straight flange.

Table 1 — Values of joint factor

Type of seam and condition for welding	Joint factor, J
No welded seam (i.e. mechanical joints)	1.0
Machine welded seam with removable backing material or joggled joint, procedure approved, operator approved, a test coupon for each 300 m of welded seam	0.8
Machine welded seam with no backing material, procedure approved, operator approved	0.6
Manually welded seam, procedure approved, welder approved	0.5

3.5 Approval testing of welding procedures: welder and operator approval

Approval testing of welding procedures shall be conducted, recorded and reported in accordance with BS 4870-1.

Approval testing of welders and operators shall be conducted, recorded and reported in accordance with BS 4871-1.

3.6 Vessels with clench ring construction

The wall thickness of the two halves of the vessel at the clench ring junction shall be constructed in accordance with **3.4.1**.

The dimensions of the clench ring to enable the expansion vessel to sustain a maximum working pressure shall be obtained using the following formula in relation to Figure 2.

$$p = \frac{\frac{231}{1.3}\left[\frac{R}{3}\left(t_r^2 + t_v^2\right) + \cos\alpha L^2\left(t_r + t_v\right)\right]}{R^2 L \sin\alpha}$$

where

R is the $\frac{\text{radius of clench ring + radius of shell}}{2}$;

t_r is the thickness of clench ring;

t_v is the thickness of rim of vessel;

α is the angle of the rim in respect to vertical;

L is the length of rim;

p is the maximum vessel working pressure.

3.7 Alternative methods of construction

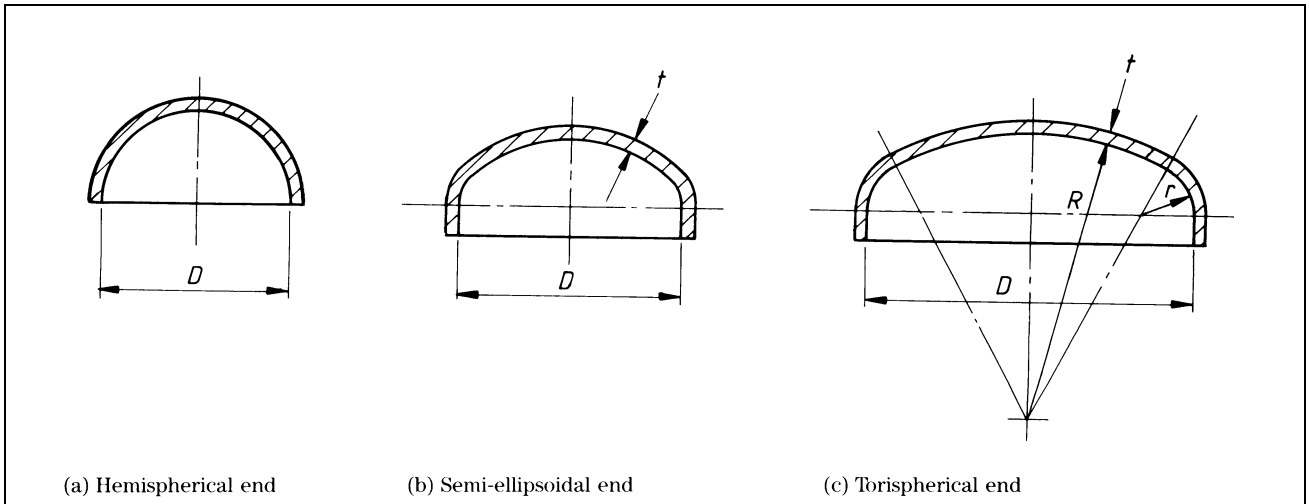
Vessels to designs which are not readily calculable to the formulae in **3.4** and **3.6** shall be subjected to a proof hydraulic test in accordance with **5.8.6** of BS 5500:1988 or ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 UG-101, in the presence of an inspector of an independent inspection authority.

3.8 Vessel mounting

Where the vessel mountings are attached to the vessel, the method of attachment shall not involve full penetration of the vessel shell.

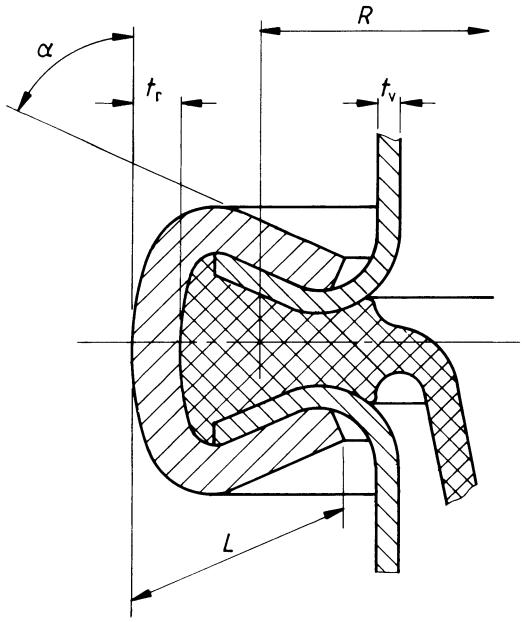
The manufacturer's instructions for mounting and positioning shall be specific and clearly stated, and shall be such that no distortion of the vessel occurs. These instructions shall be included with each vessel.

For vessels mounted directly on to a wall, a marking-out template shall be provided in order to reduce the possibility of causing distortion to the vessel.



(a) Hemispherical end (b) Semi-ellipsoidal end (c) Torispherical end

Figure 1 — Types of dished ends



NOTE 1 t_r should be not less than t_v.

NOTE 2 Care needs to be exercised when applying this formula to larger diameter vessels.

Figure 2 — A method of clench ring design

Manufacturers shall prescribe a means for mounting and positioning the expansion vessel that allows access to the water connection and the gas filling valve.

3.9 Water connection

Threaded water connections (male or female), shall comply with BS 21 and shall be designation R 3/4 for vessels up to and including 300 L total vessel volume, and a minimum of designation R 1 for vessels exceeding 300 L and up to 1 000 L total vessel volume. The thread shall be fitted with a cap or plug for protection during storage and handling.

The construction of the vessel and water connection shall be such that it is possible to make a watertight joint without distortion of the vessel.

The method of connection to the system shall be via a mechanical joint.

The water connection shall be welded in accordance with BS 5135. The sizing of weld fillets shall be as given in Figure 3.

The material used for connection bosses shall comply with BS 1387. The material used for connections for vessels manufactured from stainless steel shall have a composition compatible with BS 1449-2.

3.10 Air/gas filling valve

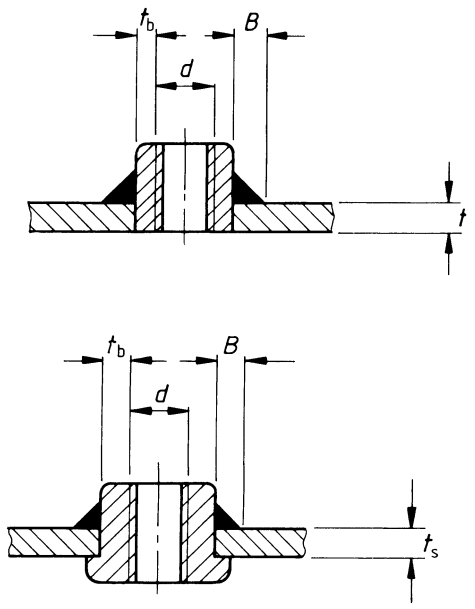
The filling valve shall be a non-return valve having a non-stick seat and shall be suitable for the stated maximum working pressure and temperature. It shall comply with BS AU 50-3. The working parts shall be replaceable, and the valve shall be fitted with a protecting cap in such a manner as to discourage unauthorized interference.

The filling valve shall be so constructed that the gas pressure can be adjusted.

3.11 Diaphragm

The diaphragm shall be of an impervious material as specified in **3.2**, suitable for the stated maximum vessel temperature. The manner of fixing of the diaphragm shall be suitable for the stated maximum vessel working pressure and temperature. The vessel and diaphragm shall be constructed in such a manner that damage to the diaphragm cannot occur through impingement on the water connection. If a diaphragm protector is attached to the water connection, then this shall have a minimum free area of 1.5 times the cross-sectional area of the water connection.

The vessel shall be so constructed that the diaphragm will not be extended beyond its elastic limit if a total loss of gas pressure occurs.



All dimensions are in millimetres.

t	3	5	6	8	9	11	13
B	6	8	9	13	14	16	17

NOTE t is the thickness of vessel shell (t_s) or boss (t_b) (where d is the diameter of thread) whichever is the smaller. B is the width of weld fillet.

Figure 3 — Sizing of weld fillet for typical water connection bosses

4 Workmanship

The quality of workmanship shall comply with the requirements of the appropriate British Standards referred to in this standard. Parts shall be so finished as to avoid injury, e.g. from burrs and sharp edges and to permit easy cleaning.

Filling compounds shall not be used.

5 Testing of vessels and diaphragms

5.1 Type test

Before production commences and in the presence of an independent inspecting authority, as defined in BS 5500, each shape and size of vessel shall be subjected to a vessel type test, comprising the diaphragm endurance test as described in **A.1**, and the combined distortion and pressure test as described in **A.2**.

5.2 Routine test

Every complete vessel shall be subjected to the pressure test given in **A.3**, and shall be inspected for visible defects.

5.3 Random test

Selected vessels shall be subjected to the diaphragm endurance test as described in **A.1** followed by the vessel pressure test as described in **A.3**.

NOTE It is recommended that the method of sampling should comply with BS 6001.

6 Performance

6.1 Diaphragm endurance test

When tested in accordance with **A.1**, the vessel shall be capable of sustaining the original gas charge, thus proving there has been no unacceptable deterioration of the diaphragm.

Vessels and diaphragms subjected to this test shall not be offered for sale.

6.2 Combined distortion and hydraulic pressure test

When tested in accordance with **A.2**, there shall be no leakage of the testing medium during the tests and no permanent distortion of the vessel after the test.

6.3 Vessel pressure test

When tested in accordance with a) of **A.3** for which the testing medium is water, the pressure readings shall not show a loss.

When tested in accordance with b) of **A.3** for which the testing medium is air or gas, the pressure readings shall not show a loss exceeding 0.1 bar.

WARNING NOTE. It should be borne in mind that pneumatic testing is potentially a much more dangerous operation than hydraulic testing in that, irrespective of vessel size, any failure during test is likely to be of a highly explosive nature. It should, therefore, be undertaken only after consultation with the inspecting authority and after ensuring that the safety measures taken comply with relevant legislation.

If the tests reveal a defect, then the vessel and diaphragm shall be discarded.

7 Marking

A label carrying the following information shall be firmly affixed to each vessel.

a) the number and date of this British Standard, i.e. BS 6144:1990;[3)]

b) the manufacturer's or agent's name and address;

c) the manufacturer's identification (to include a batch number or serial number);

d) the total vessel volume;

e) the manufacturer's charging pressure;

f) the maximum vessel working pressure;

g) the maximum vessel temperature.

NOTE Attention is drawn to the necessity to include any other information that may be required by legislation.

[3)] Marking BS 6144:1990 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

Appendix A Test procedures

A.1 Diaphragm endurance test

Assemble the expansion vessel for service and fill it on the gas side to a pressure equal to the minimum charging pressure appropriate to the design of the vessel being tested. Connect the water side of the vessel to a suitable pneumatic or hydraulic apparatus and subject the diaphragm to 100 000 total inverse flexings/inflations at a commencing temperature of 15 °C which shall not exceed 30 °C during the test. The flexing/inflation is to be caused by a pressure variation from the initial charging pressure to the stated maximum vessel working pressure.

A.2 Combined distortion and hydraulic pressure test

A.2.1 *Preliminary hydraulic pressure test*

Secure the expansion vessel to be tested on a suitable platform, completely fill it with cold water at atmospheric pressure, and connect it to a suitable hydraulic testing system.

Securely arrange suitable dial gauges of certified accuracy that have been adjusted to zero or to datum point, with the styli touching the surface at the weakest areas of the vessel.

Raise the pressure within the vessel under test to 0.5 bar.

Release the pressure to atmospheric pressure and return the dial gauge to zero or datum. Record the results of the test.

Repeat the above procedure at 0.5 bar increments up to test pressure and construct a graph to record the total deformation against pressure. The test pressure shall be 1.3 times the maximum vessel working pressure and shall be maintained for 10 min while the vessel is visually inspected.

A.2.2 *Testing for permanent distortion*

Reset the dial gauges to zero or datum with the styli touching the surface of the vessel at the same points as in the test given in **A.2.1**.

Repeat the procedure at 0.5 bar increments up to the test pressure of the vessel.

Release the pressure to atmospheric pressure and return the dial gauges to zero or datum. Record the results of the test.

A.3 Vessel pressure test

Subject the vessel to a test pressure of 1.3 times the maximum vessel working pressure. Tests for leakage shall be carried out as follows.

a) When the testing medium is water, allow the vessel to stand for a period of not less than 10 min, then examine it for leaks or obvious defects. Take pressure readings at both the beginning and end of this period.

b) When the testing medium is air or gas, examine the vessel:

1) by immersion in water; or

2) by application of a soap solution; or

3) allow it to stand for a minimum period of 24 h taking pressure readings at both the beginning and end of this period.

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Publications referred to

BS 21, *Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions).*

BS 1387, *Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads.*

BS 1449, *Steel plate, sheet and strip.*

BS 1449-1, *Specification for carbon and carbon-manganese plate, sheet and strip.*

BS 1449-2, *Specification for stainless and heat-resisting steel plate, sheet and strip.*

BS 1501, *Steels for pressure purposes: plates.*

BS 1501-1, *Specification for carbon and carbon manganese steels.*

BS 4814, *Specification for expansion vessels using an internal diaphragm, for sealed hot water heating systems.*

BS 4870, *Specification for approval testing of welding procedures.*

BS 4870-1, *Fusion welding of steel.*

BS 4871, *Specification for approval testing of welders working to approved welding procedures.*

BS 4871-1, *Fusion welding of steel.*

BS 5135, *Specification for arc welding of carbon and carbon manganese steels.*

BS 5169, *Specification for fusion welded steel air receivers.*

BS 5500, *Specification for unfired fusion welded pressure vessels.*

BS 5750, *Quality systems.*

BS 6001, *Sampling procedures for inspection by attributes.*

BS AU50, *Tyres and wheels.*

BS AU50-3, *Valves.*

American Society of Mechanical Engineers' (ASME) Boiler and Pressure Vessel Code[4].

European Economic Community Council Directive of 15 July 1980.

Official Journal L 229 pp 11 to 29[5].

List of Approved Chemicals and materials. The Technical Secretary Committee on Chemicals and materials of Construction for use in Public Water Supply and Swimming Pools. Department of the Environment, Water Division, Romney House, 43 Marsham Street, London SW1P 3PY[6].

UK Water Fittings Bye-laws Scheme Information and Guidance Note No. 5-01-02, ISBN 0267-0313, Water Research Centre, Water Bye-laws Advisory Service, 660 Ajax Avenue, Slough, Berks SL1 4BG[7].

World Health Organization. Guidelines for drinking water quality.

Volume 1: Recommendations (Geneva 1984)[4].

[4] Available from BSI Sales Department, Linford Wood, Milton Keynes, MK14 6LE.
[5] HMSO Available from HMSO, 49 High Street, Holborn, London, WC1 for personal callers, or by post from HMSO, P.O. Box 276, London SW8 5DT.
[6] Available from Department of the Environment, Water Division, Romney House, 43 Marsham Street, London SW1P 3PY.
[7] Available from Water Research Centre, Water Bye-laws Advisory Service, 660 Ajax Avenue, Slough, Berks SL1 4BG.

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