BRITISH STANDARD

BS 734-1:1973

Incorporating Amendment No. 1

Measurement of the

Density of milk using a hydrometer —

Part 1: Specification for hydrometers for use in milk

Confirmed November 2011

UDC 637.127:531.756

Co-operating organizations

The Dairying Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Chemical Society
Commonwealth Bureau of Dairy Science and Technology
Dairy Trade Federation*
Department of Health and Social Security
Department of Trade and Industry, Laboratory of the Government Chemist*
Institute of Food Science and Technology
Milk Marketing Board*
Milk Marketing Board for Northern Ireland*
Milking Machine Manufacturers' Association
Ministry of Agriculture, Fisheries and Food*
National Association of Creamery Proprietors and Wholesale Dairymen
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Society of Chemical Industry
Society of Dairy Technology*
United Kingdom Dairy Association*
West of Scotland Agricultural College

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this standard:

Association of British and Dominion Condensed Milk Manufacturers
Association of British Manufacturers of Milk Powder
Association of Butter Makers, Blenders and Packers
Association of Public Analysts
Association of Public Health Inspectors
British Food Manufacturing Industries Research Association
British Paper and Board Makers' Association
Hannah Research Institute
Ice Cream Alliance Ltd.
Ice Cream Federation Ltd.
Joint Committee of the Milk Marketing Board and the Dairy Trade Federation
London Provision Exchange
Ministry of Agriculture, Government of Northern Ireland
Society for Analytical Chemistry
University of Reading

This British Standard, having been approved by the Dairying Industry Standards Committee, was published under the authority of the Executive Board on
29 October 1973

First published May 1937
First revision March 1955
Second revision as Part I September 1960
Third revision October 1973

The following BSI references relate to the work on this standard:
Committee reference DAFA/3
Draft for comment 69/29084

ISBN 0 580 07074 3

Amendments issued since publication

Amd. No.	Date of issue	Comments
1963	May 1976	Indicated by a sideline in the margin

Contents

Foreword

BS 734 was first published, under the authority of the Dairying Industry Standards Committee, in 1937 and a revised edition was published in 1955. In 1959 the standard was again revised; Part 2 "Methods" was published in that year, and in 1960, Part 1, "Apparatus".

Part 1 of this British Standard specifies hydrometers of two sizes to meet the need of the dairying industry to deal with milk samples of differing volumes. Two scale ranges are provided for each size.

This revision has been based on draft International Standard ISO 2449, "*Milk and Liquid milk products — density hydrometers for use in products with a surface tension of approximately 45 mN/m*", to which the Nos. 1 and 1A hydrometers strictly conform. The smaller, less precise Nos. 2 and 2A hydrometers, which do not appear in the ISO document, have been retained in a modified form as their use is widespread in the United Kingdom. The Nos. 3 and 3A hydrometers specified in the 1960 edition have not, however, been retained.

The basis of adjustment of the hydrometers adopted in 1937 was density in grams (mass) per millilitre at 20 °C in a liquid with a surface tension of 46 dyn/cm. In this revision, however, the internationally accepted value of 45 mN/m (see **3.3**, Note) for the average surface tension at 20 °C of freshly formed surfaces of milk has been adopted as the basis of adjustment.

NOTE The system of units known as the International System of units (SI), and adopted by ISO [see BS 3763, "*The International System of units (SI)*"], has been used in this British Standard as follows.

1) Instead of the surface tension unit "dyne per centimetre" (dyn/cm) used in ISO R 387, "*Principles of construction and adjustment of hydrometers*", the unit adopted is the "millinewton per metre" (mN/m), the appropriate decimal multiple of the SI unit of surface tension "newton per metre" (N/m), where the newton (N), the SI unit of force, is defined as that force which, when applied to a body having a mass of 1 kg gives it an acceleration of 1 m/s^2. (1 mN/m = 1 dyn/cm.)

2) The SI unit of density, i.e. mass per unit volume, is the "kilogram per cubic metre" (kg/m^3), an appropriate decimal multiple being the "gram per cubic centimetre" (g/cm^3). As a convenient synonym for the latter unit, the SI system allows the use of "gram per millilitre" (g/ml), and this method of expressing density, accepted in ISO R387, has been adopted. It should be noted that "density (g/ml)", means "gram (mass) per millilitre" and not "gram (observed weight) per millilitre." (1 g/ml = 1 g/cm^3.)

Details of cylinders in which the hydrometers may be used are given in Appendix A, and suitable thermometers for use with them are described in Appendix B.

Notes on the verification of hydrometers are given in Appendix C, with two recommended procedures for comparison with similar reference hydrometers in order to determine corrections for hydrometer errors. For the benefit of users, these methods will also be included in the revision of the 1959 edition of Part 2 of this British Standard BS 734, "*Measurement of the density of milk using a hydrometer*", Part 2[1)], "*Method for the determination of milk density*".

Details of the facilities available for verification of the hydrometers are given in Appendix D.

[1)] In course of preparation

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Summary of pages

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

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

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1 Scope

This Part of this British Standard specifies requirements for glass hydrometers of constant mass, for use in milk having a surface tension of approximately 45 mN/m, which indicate density in grams per millilitre and which comply with ISO 387, "*Principles of construction and adjustment of hydrometers*".

Two sizes of hydrometer are specified, with two scale ranges for each size. The larger hydrometers, designated No. 1 and No. 1A to distinguish between the scale ranges, correspond to the precision types specified in draft International Standard ISO 2449, "*Milk and liquid milk products — Density hydrometers for use in products with a surface tension of approximately 45 mN/m*".

The smaller hydrometers, designated No. 2 and No. 2A to distinguish between the scale ranges, are more robust instruments intended to permit the density of smaller samples to be determined.

2 Scale ranges, subdivision of scales and tolerances

2.1 Scale ranges. The scale ranges shall be as follows:

1) 1.025 g/ml to 1.035 g/ml for the Nos. 1 and 2 hydrometers, for use in milks of normal density;

2) 1.015 g/ml to 1.025 g/ml for the Nos. 1A and 2A hydrometers, for use in milks of low density.

2.2 Sub division of scales. The scales for the hydrometers shall be sub divided at each 0.000 2 g/ml for the Nos. 1 and 1A hydrometers and at each 0.000 5 g/ml for the Nos 2 and 2A hydrometers.

2.3 Tolerances. The density indication of the hydrometers shall not be in error at any point on the scale by more than ± 0.000 2 g/ml for the Nos. 1 and 1A hydrometers, or by more than ± 0.000 3 g/ml for the Nos. 2 and 2A hydrometers.

3 Adjustment

3.1 Reading level. The hydrometers shall be adjusted to be read at the top of the liquid meniscus, i.e. where the meniscus appears to meet the stem [see **3.4** and **8** 2)].

3.2 Immersion. The hydrometers shall be adjusted to give correct readings when the emergent stem is wetted by the liquid to a level not more than 3 mm above the top of the meniscus.

3.3 Temperature and surface tension. The hydrometers shall be adjusted to indicate density in grams per millilitre at 20 °C when floating in a liquid at 20 °C with a surface tension of 45 mN/m.

NOTE The value 45 mN/m is taken as the average surface tension at 20 °C of freshly formed surfaces of cows' milk, i.e. the surface obtained by pouring milk into a vessel until some has overflowed.

3.4 Adjustment Level. A No. 1 (or 1A) hydrometer or a No. 2 (or 2A) hydrometer shall be regarded as being correctly adjusted when its reading at the level of the *flat surface of a transparent liquid* at 20 °C and with a surface tension of 45 mN/m (see Note 1), exceeds the density of the liquid by 0.000 3 g/ml or 0.000 4 g/ml, respectively, values that correspond to the height of each meniscus (see Note 2).

NOTE 1 It is not essential for the transparent liquid used for adjustment to have a temperature of 20 °C and a surface tension of 45 mN/m provided that appropriate corrections are applied.

NOTE 2 The quoted values of 0.000 3 g/ml and 0.000 4 g/ml were derived from a modification of Langberg's formula for meniscus height (see below), and also from experimental observations, for hydrometers whose scales and dimensions comply with the requirements of this British Standard.

$$h = \frac{\sigma i}{9.81 d \rho s} \left[\sqrt{\left(1 + \frac{19.62 d^2 \rho}{\sigma}\right)} - 1 \right]$$

Where h is the meniscus height in terms of "grams per millilitre",

σ is the surface tension of liquid (mN/m),

i is the scale range (g/ml) (i.e. 0.01 for No. 1, 1A, 2, or 2A hydrometers),

d is the external diameter of the stem (mm),

ρ is the density of the liquid (g/ml), and

s is the mean scale length (mm) (e.g. 64 for a No. 1 or No. 1A hydrometer).

4 Materials and construction

4.1 The bulb and stem of the hydrometer shall be made of transparent glass, and shall be as free as possible from strain and visible defects. In particular, the external surface shall be smooth and free from irregularities. The base of the bulb may be strengthened by internal thickening of the wall.

4.2 The loading material shall be lead shot securely embedded in a suitable cementing material in the bottom of the bulb. The loading material shall be such that, if the hydrometer is kept in a horizontal position for one hour at 40 °C, it shall subsequently float with its axis within 1.5° of the vertical (see **5.3**).

4.3 There shall be no loose material in the hydrometer.

4.4 The scale paper shall preferably be white, shall be of high quality and shall have a smooth surface that permits the graduation lines, numbers and inscriptions to be marked finely and clearly on it. All scale markings shall be permanent.

NOTE It is recommended that the paper should be an esparto paper (65 % to 75 % esparto is suitable) and that the scale strips should be cut with their length in the machine direction of the paper.

The scale paper in a hydrometer shall show no evidence of charting and when exposed to a temperature of 80 °C for 24 h shall not become discoloured or distorted.

4.5 The scale paper shall be securely fastened in place. The scale paper shall have a scale mark, a few millimetres above the top graduation line, consisting of a short horizontal line with a "V" at each end (thus: >——<). A fine reference line of uniform thickness shall be cleanly etched on the hydrometer stem at a position coincident with the horizontal portion of the scale mark so that the ends of the etched line project into the "V" at each end of the scale mark.

A hydrometer shall be deemed not to comply with the requirements of this British Standard if there is any displacement of the scale paper, i.e. if the scale mark and the reference line do not exactly coincide.

5 Form

5.1 The outer surface of the hydrometer shall be symmetrical about its axis and there shall be a smooth transition between the bulb and the stem and no other abrupt changes in cross-section.

5.2 The tapered designs shown in Figure 1 are preferred, but any similar design that does not permit air bubbles to be trapped is acceptable.

5.3 The hydrometer shall float so that its axis does not deviate by more than 1.5° from the vertical position.

6 Scales

Figure 2 shows the sequence and numbering of graduation lines which shall be followed, and illustrates acceptable scales.

6.1 General

6.1.1 The scale shall be straight and without twist.

6.1.2 There shall be no irregularities in the spacing of the graduation lines.

6.1.3 The graduation lines shall be at right angles to the axis of the hydrometer.

6.1.4 The graduation lines shall be of uniform thickness not exceeding 0.2 mm.

6.1.5 The scale shall extend at both ends beyond its nominal limits by at least two graduation lines.

6.1.6 All numbers shall be printed in black.

6.2 Nos. 1 and 1A hydrometer scales

6.2.1 The main graduation lines (density equivalent 0.001 g/ml) shall extend completely round the circumference of the stem, shall be numbered and shall be printed in black.

6.2.2 The minor graduation lines shall all be the same length, which shall be not less than 2 mm, shall extend at least one-fifth, and preferably between one-third and one-half, of the way round the circumference of the stem, and shall be printed in black, or preferably in red.

6.2.3 The ends of the minor graduation lines shall lie vertically above one another.

6.2.4 The numbers representing the nominal limits of the scale shall be written in full, and the remaining numbers shall be indicated by the second and third decimal digits only.

6.2.5 The numbers shall be placed immediately above the graduation lines to which they refer, and slightly to the side of the adjacent shorter lines.

6.3 Nos. 2 and 2A hydrometer scales

6.3.1 All graduation lines shall extend completely round the circumference of the stem.

6.3.2 The numbers representing the nominal limits of the scale shall be written in full, these representing the mid-points of the scale shall be indicated by the second and third decimal digits only, and the remaining numbers by the third decimal digit only.

6.3.3 The numbers shall be placed immediately above the graduation lines to which they refer.

6.3.4 The graduation lines marking full divisions (density equivalent 0.001 g/ml and numbered) shall be printed in black, and those marking sub-divisions (density equivalent 0.000 5 g/ml and unnumbered) shall be printed in black, or preferably in red. Lines beyond the nominal scale limits shall continue in this colour sequence.

7 Principal dimensions

The dimensions of the hydrometers shall be as given in Table 1 and as illustrated in Figure 1.

Table 1 — Principal Dimensions

	Nos. 1 and 1A	Nos. 2 and 2A
	mm	mm
Distance between top numbered graduation line and bottom of bulb, maximum	220	195
Distance between top numbered graduation line and top of stem, approximate	20	20
Distance between top and bottom numbered graduation lines (scale length)	60–68	37–43
Length of uniform stem below bottom graduation line, minimum	5	5
External diameter of stem, approximate	3.1	3.2
External diameter of bulb	24–26	19–21
Length of uniform stem, maximum	100	75
	ml	ml
Volume below bottom numbered graduation line	43–56	29–37

8 Inscriptions

The following information shall be marked on the paper bearing the scale. Except for the red band 2) all inscriptions shall be black.

1) The inscriptions “g/ml at 20 °C” and “45 mN/m”.

2) As an indication that the hydrometer is adjusted to be read at the top of the liquid meniscus, the top 3 mm of the scale paper shall be coloured red. As a further indication the inscription “Read at top of meniscus” or an abbreviation for this, e.g. “Rd menisc. top” or “Menisc. top” may be added.

3) An identification of the purpose of the hydrometer.

NOTE This may be the word “Milk” and the number of this British Standard, i.e. BS 734, or some other indication that the hydrometer is in accordance with the requirements of this British Standard.

4) An individual identification number for the hydrometer.

5) The maker’s or vendor’s name or mark.

NOTE Attention is drawn to the certification facilities offered by BSI; see the inside back cover of this standard.

Appendix A Suitable hydrometer cylinders

Cylindrical vessels of suitable rigid materials such as glass, plastics or metal having the following minimum dimensions are suitable for use with the hydrometers described in this British Standard.

	For hydrometer Nos. 1 and 1A	For hydrometer Nos. 2 and 2A
	mm	mm
Minimum internal diameter of cylinder	35	30
Minimum internal depth of cylinder	225	200

These dimensions are the smallest which ensure that any point on the scale of the hydrometers can conveniently be read and that the hydrometer will float freely.

If metal is used in the construction of the cylindrical vessel it should not be thicker than 0.7 mm, and the rim should be reinforced as illustrated in Figure 3 and Figure 4 to prevent damage, and also to prevent thickening, if the metal is plated.

Cylinders having diameters larger than the minimum figure quoted above may conveniently be used when the volume of the available milk sample is large enough.

The top edge should be circular (without a spout and in one plane). In use, the axis of the cylinder should be vertical, and the top edge horizontal.

The dimensions of the bases given in Figure 3 and Figure 4 are for guidance only.

Appendix B Thermometer

A thermometer having the following characteristics is suitable for determining the temperature of the milk in the hydrometer cylinder.

	mm
Overall length	255 ± 10
Scale length	100 ± 5
Distance between lowest graduation line and bottom of bulb	110 ± 5
Immersion	50
	°C
Scale range	10 to 45
Graduation interval	0.5
Scale accuracy	± 0.25

Appendix C Notes on verification of hydrometers

C.1 Introduction

In order to place confidence in the reading of a hydrometer, it is necessary to verify the scale after manufacture and possibly at intervals later, either to ensure that the scale errors are within the specified tolerance or, when working to closer limits, to ascertain the values of the corrections to be applied for scale error.

These notes are intended to offer guidance on the subject, but do not attempt to cover all possible methods in full detail.

Various methods may be used to verify a hydrometer, including the use of the following.

1) A hydrostatic balance, whereby the hydrometer is weighed while suspended in a liquid of known density and also in air. The scale errors of the hydrometer are calculated from the results of the weighings.

2) A pyknometer, by means of which an independent determination is made of the density of a sample of milk, or other liquid of known surface tension. The result of this determination is compared with the value obtained by using the hydrometer being verified.

3) A reference hydrometer, previously checked by methods **C.1** 1) or **C.1** 2) for example, which is floated in a suitable liquid together with the hydrometer being verified. The readings of the two hydrometers are directly compared. The reference hydrometer is a similar hydrometer which has been verified, preferably by an official standardizing laboratory, and for which the scale errors are known.

NOTE It cannot be assumed that the liquid used for verification by these methods will have a surface tension of 45 mN/m even if milk is used. The surface tension should, therefore, be checked and a correction for meniscus height applied if necessary (see **3.4**, Note 2). If in method **C.1** 3) the stem diameter of the reference hydrometer and the hydrometer being verified are the same, corrections for meniscus height will not be necessary.

The hydrostatic balance method is one suitable for the standardization of reference standard hydrometers by national standardizing laboratories. It is not a method which the ordinary user of hydrometers would find convenient to adopt, as it is unwieldy compared with the alternatives and involves specialized apparatus.

The methods involving the use of either a pyknometer or a reference hydrometer can readily be employed by the hydrometer user. The method of direct comparison with a reference hydrometer is simpler, particularly as the comparison can be made at the ambient temperature, and it is speedier. It is therefore recommended. The reference hydrometer to be used should be verified, however, at intervals of not greater than two years.

Where a reference hydrometer is not available, a pyknometer is a suitable alternative. Although the pyknometer method is more direct than the hydrometer method, it takes more time to carry out and it is essential to ensure that the liquid temperature is very nearly the same at the times of the two comparison measurements made with the pyknometer and the hydrometer, respectively.

In this British Standard, the adjustment level (see **3.4**) for reading is that of the level liquid surface. Therefore, although milk may be used for the comparison measurement, it is preferable to use a transparent working liquid of known and stable surface tension in which hydrometer readings can be taken at the level liquid surface. This technique avoids the introduction of errors arising, in particular, from the variability of surface tension and from the difficulty of estimating the reading at the level surface.

A suitable transparent liquid, having a stable surface tension of between 40 mN/m and 50 mN/n, may be made up for any density in the range 1.015 g/ml to 1.035 g/ml by dissolving the appropriate mass of sodium carbonate in a 10 % solution of ethanol 95 % (V/V) in distilled water. The approximate relationship between the mass of anhydrous sodium carbonate per litre of solution and a hydrometer reading at 20 °C at the level liquid surface is as follows:

Approximate hydrometer reading at level liquid surface at 20 °C	**Mass of anhydrous sodium carbonate per litre of solution**
g/ml	g
1.016	31.0
1.018	33.1
1.020	35.3
1.022	37.4
1.024	39.6
1.026	41.7
1.028	43.9
1.030	46.0
1.032	48.2
1.034	50.4

It is not usually feasible to check all the points on a hydrometer scale. Experience shows that verification at three evenly spaced points (e.g. 1.026 g/ml, 1.030 g/ml and 1.034 g/ml) is sufficient to ensure confidence in interpolating scale corrections for the remainder of the scale.

As verification by comparison with a reference hydrometer is the method recommended, two alternative procedures are given below.

C.2 Methods of verification using a reference hydrometer

C.2.1 *General.* Use a reference standard hydrometer made to the same specification as the one being tested, e.g. a No. 1 hydrometer to check another No. 1 hydrometer. This ensures that any difference between the surface tension of the liquid and the standard value of 45 mN/m will affect the reading of both hydrometers similarly.

Place the liquid in which the hydrometers are to be floated in a suitable transparent vessel with the front wall polished flat and free from visible defects. The vessel should be large enough for the two hydrometers to float freely side by side, neither touching each other nor the sides of the containers.

Stir the liquid well before inserting the hydrometers, which should be at nearly the same temperature as the liquid to avoid creating non-uniform conditions. The actual temperature of the liquid and the hydrometers is not important, however, since both instruments will be affected to the same extent by any departure from the standard temperature. Take care not to wet the hydrometer stems more than 2 mm or 3 mm above the level of reading.

Take the readings of the hydrometers as nearly as possible at the same moment and as soon as possible after the hydrometers have become steady, but not more than one minute after immersion.

C.2.2 *Procedure 1.* If a transparent liquid is used, take the readings at the level of the flat liquid surface. If milk is used take readings at the top of the meniscus. The correction for scale errors of the hydrometer under test is obtained by subtracting its reading from the corrected reading of the reference hydrometer.

C.2.3 *Procedure 2.* In this procedure, the container to be used is a transparent rectangular container of the following minimum internal dimensions: height 300 mm, width 100 mm and depth (front to rear) 75 mm. This container should be marked on the front and the rear faces with a fine horizontal line (thickness 0.1 mm to 0.2 mm) extending completely across each face and positioned at exactly the same distance (approximately 250 mm) from the bottom of the container.

Place the container on a level surface and fill it with the liquid at about 20 °C to an appropriate level below the horizontal line. Float the reference hydrometer with the hydrometer to be checked in the liquid and adjust the liquid surface so that the top of the liquid meniscus at the face of the container is just below but almost coincident with the horizontal line and is within 1 mm of this line.

With the eye at the level of the line on the front face of the container sight across to the rear line so that the two lines coincide. Note the readings of the two hydrometers at the level of the lines.

C.3 Example of the determination of the correction for a No. 1 hydrometer

	g/ml
Reading of reference hydrometer	1.030 4
Correction for scale error (from certificate)	− 0.000 2
Corrected reading of reference hydrometer	1.030 2 (a)
Reading of hydrometer being verified	1.030 0 (b)
Correction for scale error of hydrometer being verified, (a) minus (b)	+ 0.000 2

Appendix D Testing of British Standard hydrometers for use in milk

At its Hemel Hempstead Centre, the British Standards Institution is prepared to verify individual British Standard hydrometers marked with an identification number. Particulars of the test arrangements and fees charged can be obtained on application to the Manager, British Standards Institution, Maylands Avenue, Hemel Hempstead, Herts.

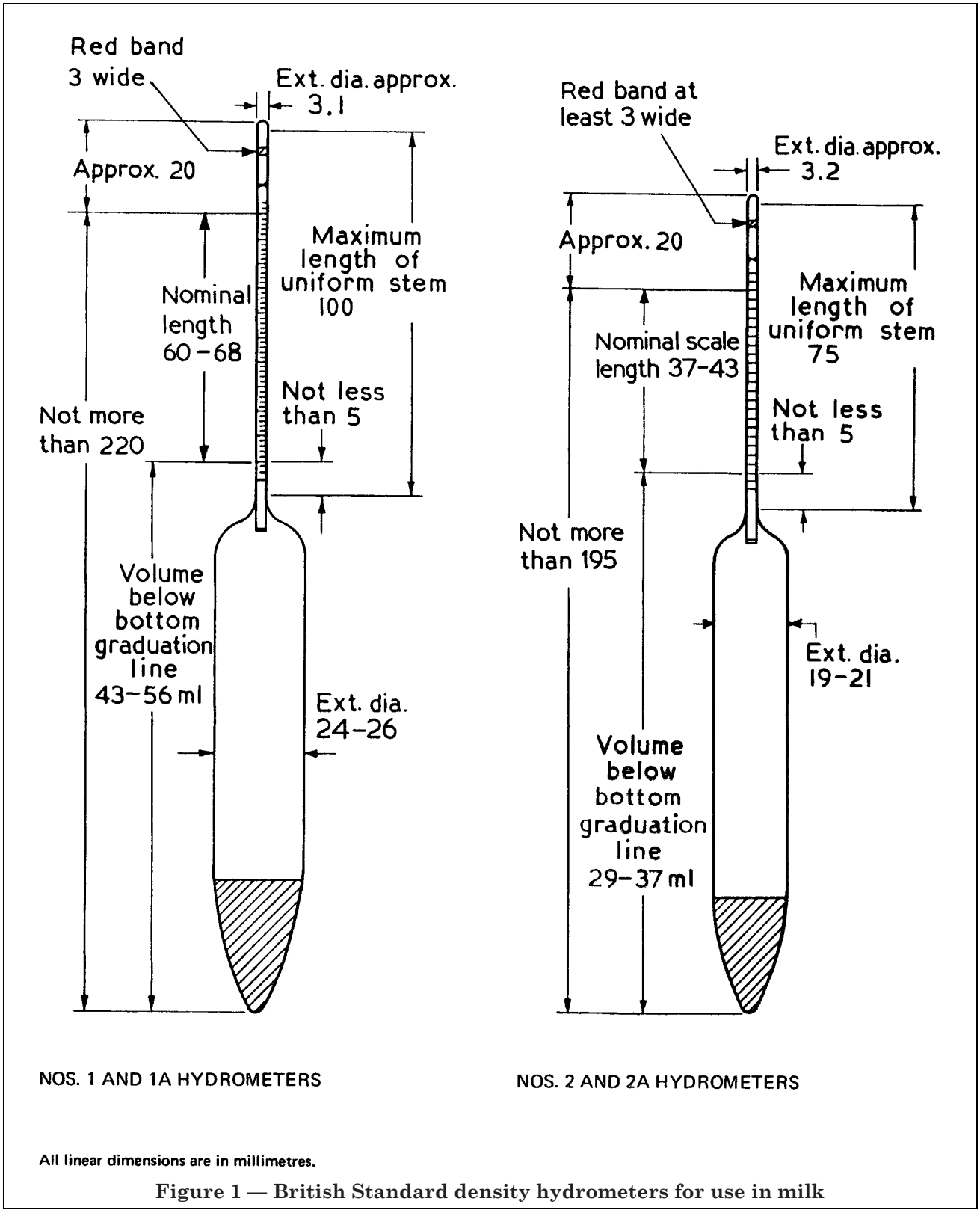
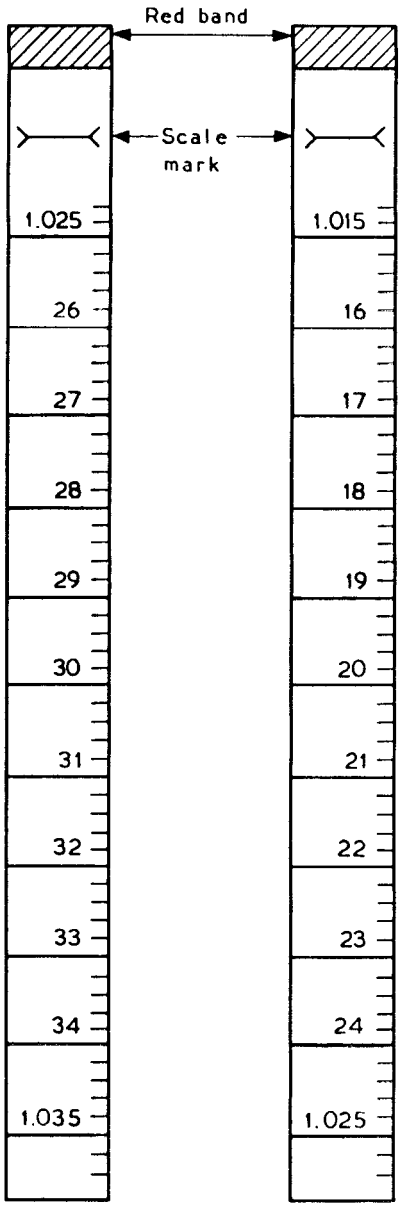


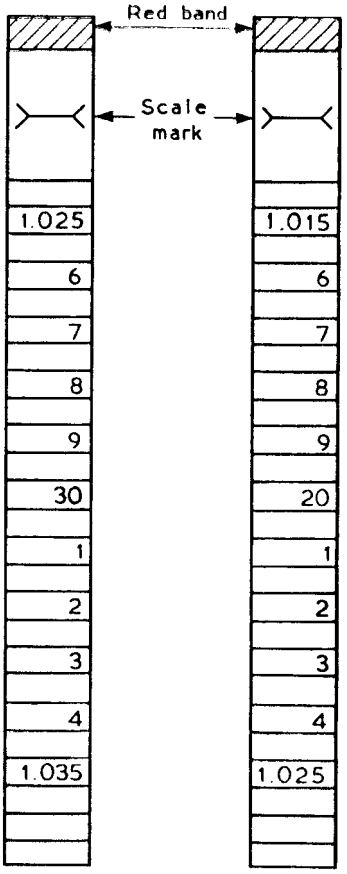
Figure 1 — British Standard density hydrometers for use in milk



No. 1 HYDROMETER

No. 1A HYDROMETER

NOTE Major (numbered) lines are black, minor lines are red or black.

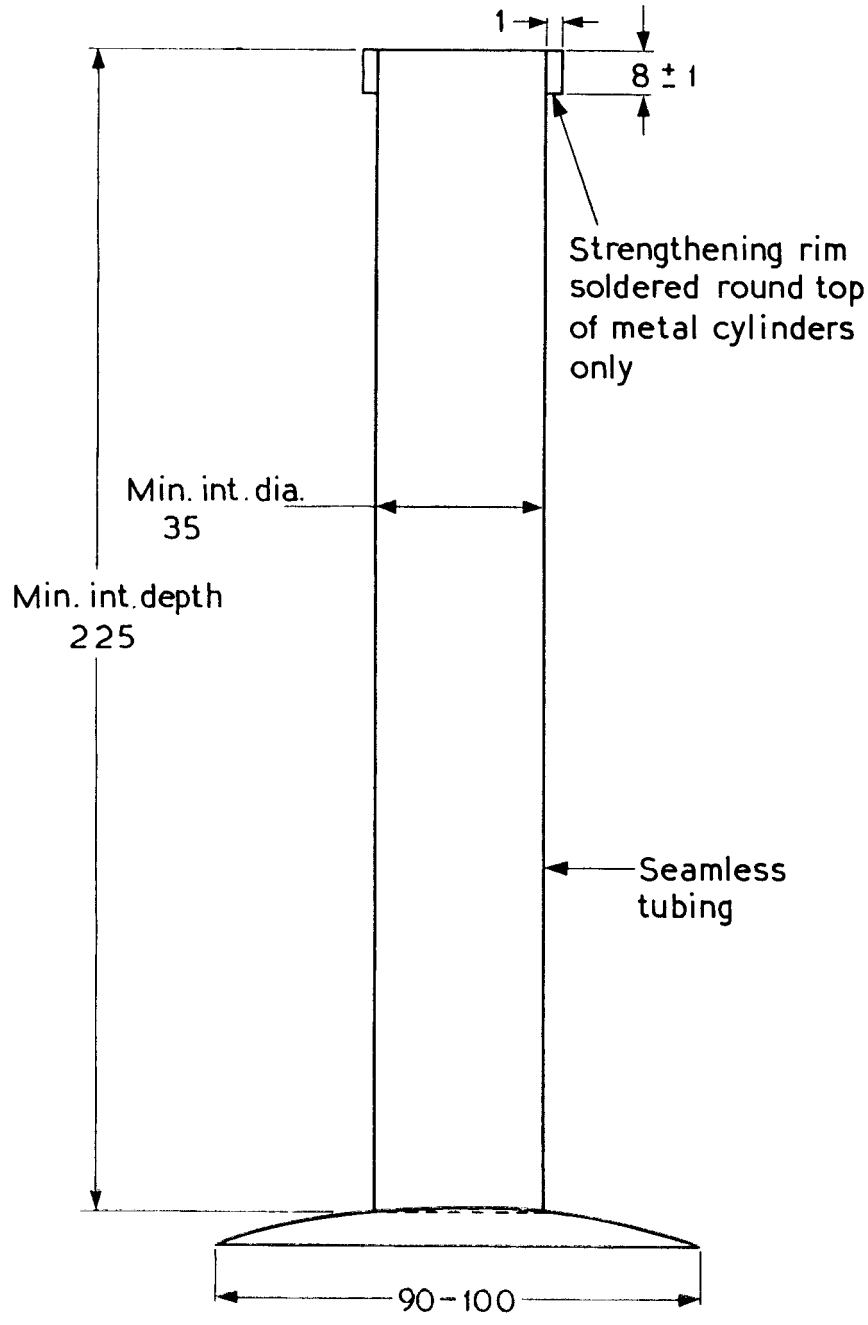


No. 2 HYDROMETER

No. 2A HYDROMETER

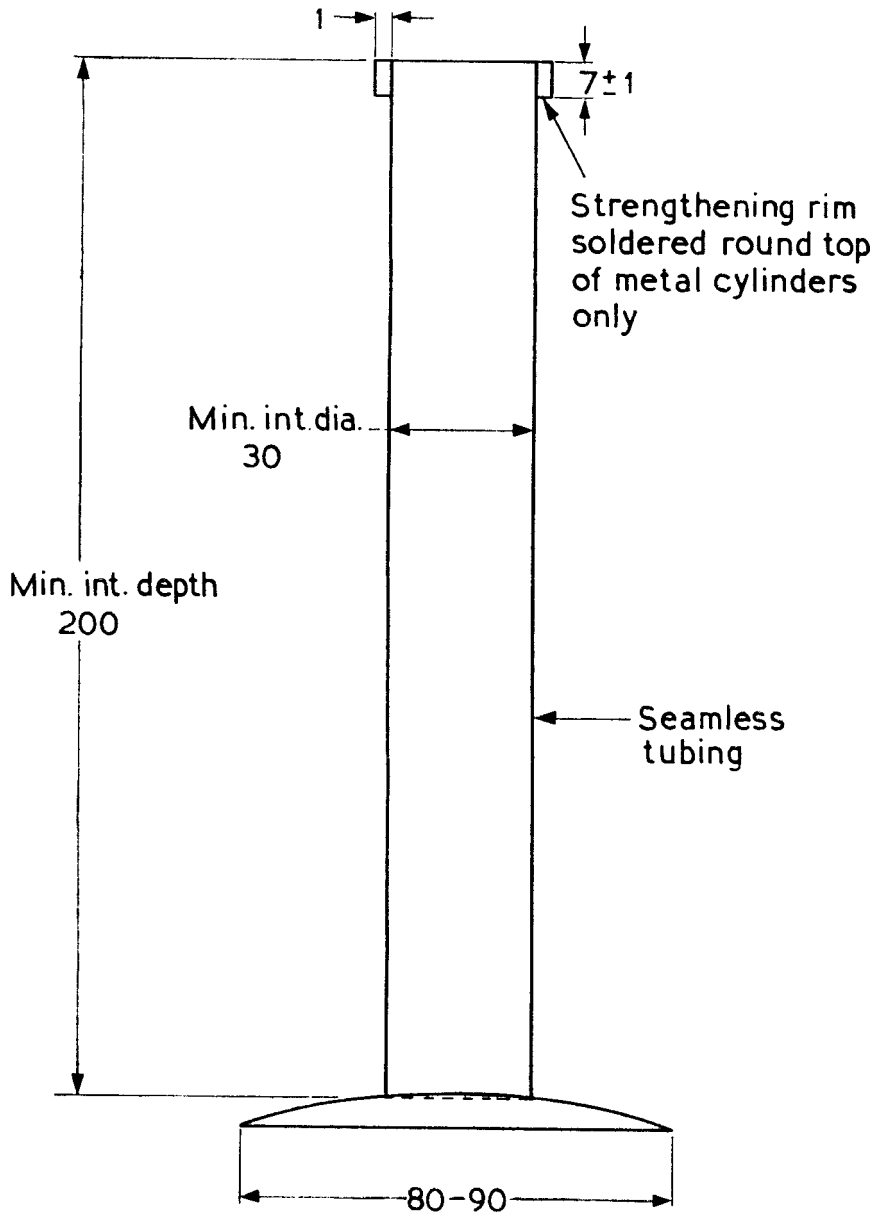
NOTE The numbered graduation lines are black. The other lines are red or black.

Figure 2 — Hydrometer scales



All dimensions are in millimetres.

Figure 3 — Cylinder for nos. 1 and 1A Hydrometers



All dimensions are in millimetres.

Figure 4 — Cylinder for nos. 2 and 2A Hydrometers

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