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Specification for

Density hydrometers

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Laboratory Apparatus Standards Policy Committee (LBC/-) to Technical Committee LBC/5, upon which the following bodies were represented:

British Laboratory Ware Association
Department of Trade and Industry (Laboratory of the Government Chemist)
Department of Trade and Industry (National Physical Laboratory)
Department of Trade and Industry (National Weights and Measures Laboratory)
Institute of Brewing
Institute of Petroleum
National Sulphuric Acid Association
Royal Society of Chemistry
Scotch Whisky Association
Society of Glass Technology

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Contents

Foreword

This British Standard has been prepared under the direction of the Laboratory Apparatus Standards Policy Committee. It supersedes BS 718:1979 which is withdrawn. BS 718:1979 was undertaken with the following objectives in view.

a) To align as nearly as practicable with ISO 387 and ISO 649 prepared by Technical Committee 48, Laboratory glassware and related apparatus, of the International Organization for Standardization (ISO).

b) To restrict the scales of density to the exclusion of relative density (formerly termed specific gravity)[1].

c) As a step to the full utilization of basic SI units, to introduce the option of scales marked in kg/m^3 as an alternative to g/ml.

In addition to the five series and two sub-series of hydrometers specified in the 1960 edition, a new sub-series (S50SP) was introduced which, like the other sub-series, is for use in the petroleum industry.

This edition introduces technical changes but it does not reflect a full review or revision of the standard which will be undertaken in due course.

This edition introduces an additional single range hydrometer in the sub-series particularly for use with petroleum fuels and updates the data for density of water in Appendix H to allow for changes in the International Temperature Scale in ITS-90.

In addition to the specification this standard contains a number of appendices. These include a table of the surface tension categories adopted for the hydrometers, a table of recommended stem diameters, information on the technique for using hydrometers, tables of temperature corrections, indications of the influence of surface tension on the various hydrometers, a table for correcting readings taken at the top of the meniscus in opaque liquids and tables facilitating the measurement of the volume of liquid in bulk on the basis of hydrometer observations[2]. Suitable vessels for use with the hydrometers are described. The relationship between density and weight per millilitre in air is indicated. A new table for the density of distilled water between 0 °C and 40 °C is included. Information enabling hydrometer and pyknometer readings to be interrelated (given in the 1960 edition of this British Standard) is given in BS 733.

Guide to intending purchasers of British Standard hydrometers

The following notes are provided to assist in the selection of the particular British Standard hydrometers which are the most suitable in any given circumstances. Intending purchasers are advised to state precisely, when enquiring or ordering from suppliers, which of the variants referred to are required. The references on the right are to the relevant portions of the standard.

[1] Users who may have a continuing need to use relative density (*d* 60/60 °F) hydrometers should refer to ISO 650 which is technically identical with the relevant parts of the 1953 and 1960 editions of this standard.

[2] Attention is drawn to the fact that in the petroleum industry a different method, of special applicability, is in use for the measurement of oil in bulk.

a) Series (which governs the size of the hydrometer and the precision of readings) — *Reference*: Table 1 and Table 2

Series		Nominal range of individual scales		Scale subdivision		Total length
		kg/m^3	g/ml	kg/m^3	g/ml	mm
L20	(long)	20	0.020	0.2	0.000 2	335
L50 or L50SP	(long)	50	0.050	0.5	0.000 5	335
M50 or M50SP	(medium)	50	0.050	1.0	0.001	270
M100	(medium)	100	0.100	2.0	0.002	250
S50	(short)	50	0.050	2.0	0.002	190
S50SP	(short)	50	0.050	1.0	0.001	190

b) Range of hydrometer required. Selection to be made according to application and range required from the 70 hydrometers in series L20, the 28 in series L50, M50 or S50, and the 14 in series M100; or from the 11 covering the range 0.6 g/ml to 1.1 g/ml in sub-series L50SP, M50SP or S50SP. — Clause **11**

c) Basis of scale. For sub-series L50SP, M50SP and S50SP only, select density at 15 °C or density at 20 °C. — Clause **3**

d) Surface tension category. Select low or medium or high according to the type of liquid and the method of use or for hydrometers of the highest precision, specify the liquid in which they will be used. — Clause **5**

e) Special requirements, where unavoidable, in accordance with the particular circumstances. For example, a smaller maximum error than that specified in the standard may be essential (Clause **13**); or it may be that the hydrometer will be used at a temperature higher than 70 °C, in which case either the loading material should have a softening point higher than 80 °C, or a hydrometer with mercury loading should be used. — Clause **8**

It may also be desired to order special hydrometer jars appropriate to the instruments which are being purchased. — Appendix G

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 to iv, pages 1 to 18, 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 requirements for five basic series of glass hydrometers of constant mass which are graduated to indicate density (kg/m^3 or g/ml) when used at 20 °C.

Each series comprises hydrometers which between them cover the interval 600 kg/m^3 to 2 000 kg/m^3 (0.6 g/ml to 2.0 g/ml). The hydrometers are graduated appropriately for use in liquids of low, medium or high surface tension.

The standard also specifies three sub-series of hydrometers which are graduated either to indicate density when used at 15 °C or to indicate density when used at 20 °C. They have smaller tolerances on scale error, are limited to the range 600 kg/m^3 to 1 100 kg/m^3 (0.6 g/ml to 1.1 g/ml) and are for use in liquids of low surface tension.

A single hydrometer principally suitable for the measurement of the density of petroleum fuels is included.

This British Standard does not cover hydrometers with a built-in thermometer (thermohydrometers).

2 References

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

3 Basis of scale

3.1 The basis of scale shall be density (mass per unit volume) in kilograms per cubic metre (kg/m^3). The use of grams per cubic centimetre (g/cm^3) or grams per millilitre (g/ml) is accepted.

NOTE The term millilitre (ml) is commonly used as a special name for the cubic centimetre (cm^3), in accordance with a decision of the twelfth Conférence Générale des Poids et Mesures. The term millilitre is acceptable, in general, for reference to capacities of volumetric glassware and is used in the present text.

4 Reference temperature

4.1 The standard reference temperature for density hydrometers excluding the special sub-series L50SP, M50SP and S50SP shall be 20 °C. When used in a liquid at this temperature, the hydrometer shall indicate the density of the liquid at 20 °C.

4.2 The standard reference temperature for density hydrometers of the special sub-series L50SP, M50SP and S50SP shall be either 15 °C or 20 °C. When used in a liquid at the appropriate temperature, the hydrometer shall indicate the density of the liquid at that temperature.

5 Surface tension

The adjustment in manufacture shall be related to specific capillary conditions as follows.

5.1 When the hydrometer is slightly displaced from its equilibrium position in a liquid, the stem passes through the liquid surface without causing any apparent alteration in the shape of the meniscus.

5.2 The hydrometer scale shall be adjusted either for a given liquid having a given surface tension or for one of the standard categories of surface tension given in Appendix A. Except where the highest precision is required, one of the standard categories of surface tension given in Appendix A shall be used.

For hydrometers of the highest precision, intended for use in particular liquids (e.g. alcohol solutions), the surface tension values appropriate to clean surfaces of these liquids and to the actual indications of the hydrometer shall be used: [see **14.2** c)].

5.3 The sub-series L50SP, M50SP and S50SP are limited to the low surface tension category.

6 Reference levels for adjustment and reading

6.1 The scales of the hydrometers shall be adjusted for readings taken at the level of the horizontal liquid surface.

NOTE If a hydrometer having a scale so adjusted is used in an opaque liquid, readings may be taken at the top of the meniscus where it appears to meet the stem, but an appropriate correction to the level of the horizontal liquid surface should then be made. (See Appendix B.)

6.2 The middle of the thickness of a scale line shall be taken as its definitive position.

7 Immersion

Hydrometers shall be graduated for use with the emergent stem dry, except in the immediate vicinity of the meniscus.

8 Materials and workmanship

8.1 The bulb and the stem shall be made of a suitable transparent glass selected and processed to be as free as possible from stress and visible defects, and having a thermal cubical expansion coefficient of $(25 \pm 2) \times 10^{-6}$ °C^{-1}.

NOTE The value of the thermal cubical expansion coefficient conforms with the conventional value quoted in ISO 1768 for use in the preparation of measurement tables for liquids.

8.2 The loading material shall be fixed in the bottom of the hydrometer. After the finished hydrometer has been kept in a horizontal position for 1 h at 80 °C, or any higher temperature at which the hydrometer is intended to be used, and subsequently cooled in that position, the instrument shall meet the requirements of **9.3**.

8.3 There shall be no loose material in the instrument.

8.4 The strip on which the scale and inscriptions are marked shall have a smooth matt surface. The strip shall show no evidence of charring. The strip bearing the scale shall not become discoloured or distorted when the stem is exposed for 1 h to a temperature of 80 °C, or any higher temperature at which the hydrometer is intended to be used.

9 Form

9.1 The outer surface shall be symmetrical about the main axis.

9.2 There shall be no abrupt changes in cross section. The tapered design shown in Figure 1 is preferred, but any design which does not permit air bubbles to be trapped is acceptable.

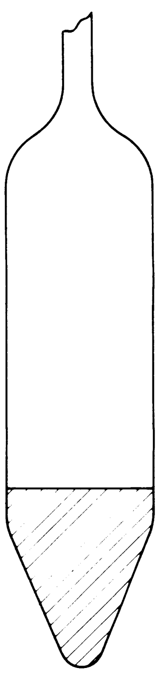


Figure 1 — Preferred design of hydrometer bulb

9.3 The hydrometer shall float with its axis vertical to within 1.5° of arc.

9.4 A thermometer shall not form part of the hydrometer.

10 Scale

Examples of recommended scales for BS hydrometers are illustrated in Figure 2.

10.1 General

10.1.1 The strip on which the scale and inscriptions are marked shall remain securely fastened in place at a temperature of 80 °C or any higher temperature at which the hydrometer is intended to be used.

10.1.2 Appropriate means shall be incorporated for ensuring that any displacement of the strip bearing the scale is readily apparent.

NOTE Any displacement renders the instrument unsuitable for use.

10.1.3 The scale shall be straight and without twist.

10.1.4 No hydrometer shall have more than one type of density scale. If a hydrometer has duplicate scales, the values indicated by them shall not differ.

10.1.5 The scale lines and inscriptions should preferably be black and shall be clearly and durably marked on the strip.

10.2 Graduation lines

10.2.1 The graduation lines shall be distinct and of uniform thickness not exceeding 0.2 mm or $^1/_5$ of the distance between the centres of adjacent lines, whichever is less. For the SP series, the thickness of the graduation lines shall not exceed 0.2 mm or $^1/_6$ of the distance between the centres of adjacent lines, whichever is less.

10.2.2 There shall be no evident local irregularities in the spacing of the graduation lines.

10.2.3 The graduation lines shall be perpendicular to the axis of the hydrometer.

10.2.4 Except in the case of duplicate scales, the short, medium and long scale lines shall extend, respectively, at least $^1/_5$, $^1/_3$ and $^1/_2$ of the way round the circumference of the stem.

10.2.5 The highest and lowest graduation lines indicating the nominal limits of the scale shall be long lines (see **10.3.1**, **10.3.2** and **10.3.3**).

10.2.6 The short, medium and long lines shall each be vertically disposed so that either the mid-points or the right hand ends or the left hand ends of all graduation lines shall lie on an imaginary vertical line parallel to the axis of the instrument. Alternatively in the latter two cases the vertical line may be marked.

10.3 Sequence of graduation lines

10.3.1 On hydrometers whose smallest scale division is 1 kg/m^3 or 0.001 g/ml, the graduation lines shall be as follows.

a) Every tenth graduation line shall be a long line.

b) There shall be a medium line between two consecutive long lines.

c) There shall be four short lines between consecutive medium and long lines.

10.3.2 On hydrometers whose smallest scale division is 2 kg/m^3 or 0.2 kg/m^3 or 0.002 g/ml or 0.000 2 g/ml, the graduation lines shall be as follows.

a) Every fifth graduation line shall be a long line.

b) There shall be four short lines between two consecutive long lines.

10.3.3 On hydrometers whose smallest scale division is 0.5 kg/m^3 or 0.000 5 g/ml, the graduation lines shall be as follows.

a) Every tenth graduation line shall be a long line.

b) There shall be four medium lines between two consecutive long lines.

c) There shall be one short line between two consecutive medium lines and between consecutive medium and long lines.

10.4 Figuring of graduation lines

10.4.1 Except in the case of duplicate scales, the scale shall have only one set of figures.

10.4.2 The scale shall be figured so as to enable the value corresponding to any graduation line to be readily identified.

10.4.3 The highest and lowest graduation lines of the nominal limits of the scale shall be figured in full.

10.4.4 At least every tenth line shall be figured.

10.4.5 The decimal marker shall be included for numbers expressed in full but may be omitted from abbreviated numbers.

10.5 Extension of scale. The scale shall be extended beyond the nominal scale limits as indicated in Table 1.

11 Ranges of the series of hydrometers (see Table 1)

Each of the five main series of hydrometers shall cover a total range of 600 kg/m^3 to 2 000 kg/m^3 (0.600 g/ml to 2.000 g/ml). Each hydrometer shall cover a range of either 20 kg/m^3, 50 kg/m^3 or 100 kg/m^3 (0.020 g/ml, 0.050 g/ml or 0.100 g/ml).

The lower nominal limits of the scales of individual hydrometers shall be as follows. L20 series: 600 (0.600), 620 (0.620), 640 (0.640) etc. L50, M50 and S50 series: 600 (0.600), 650 (0.650), 700 (0.700) etc. M100 series: 600 (0.600), 700 (0.700), 800 (0.800) etc. according to whether the scales are based on kg/m^3 or g/ml.

Each of the three sub-series of hydrometers shall cover a total range of 600 kg/m^3 to 1 100 kg/m^3 (0.600 g/ml to 1.100 g/ml), each hydrometer having a range of 50 kg/m^3 (0.050 g/ml).

The lower nominal limits of the scales of the series L50SP, M50SP and S50SP shall be 600, 650, 700, etc. (0.600, 0.650, 0.700, etc.), according to whether the scales are based on kg/m^3 or g/ml.

For the special single hydrometer principally suitable for the measurement of petroleum fuels the range shall be 50 kg/m^3 (0.050 g/ml) and the lower nominal limit shall be 775 (0.775) according to whether the scale is based on kg/m^3 or g/ml.

NOTE The special sub-series L50SP, M50SP and S50SP as well as this single hydrometer may be used for the measurement of petroleum fuels.

In all other respects the hydrometer shall comply with the requirements of Table 1 and the maximum permitted errors in Table 2 for the special sub-series L50SP or M50SP respectively.

12 Principal dimensions

12.1 The dimensions of the hydrometers shall conform to those given in Table 1.

12.2 The cross section of the stem shall remain unchanged over the length of the scale and for at least 5 mm below the lowest graduation line on the scale.

12.3 The stem shall extend unchanged in diameter at least 15 mm above the uppermost graduation line on the scale.

12.4 No hydrometer shall have a stem of diameter smaller than 4.0 mm.

NOTE For convenience in manufacture, it has been found advantageous to comply with the recommendations for stem diameter given in Appendix C.

Table 1 — Principal requirements for series of hydrometers

Series	Maximum total length	Nominal range of each hydrometer		Number of scale divisions and value of the scale interval		Minimum scale length (nominal range)	Bulb diameter		Volume below lowest graduation line of nominal range		Extension of scale at each end beyond upper and lower nominal limits
							min.	max	min.	max.	
	mm	kg/m³	g/ml	kg/m³	g/ml	mm	mm	mm	ml	ml	Graduation lines
L20	335	20	0.020	100 × 0.2	100 × 0.000 2	105	36	40	108[a]	132	5 to 10
L50	335	50	0.050	100 × 0.5	100 × 0.000 5	125	23	27	50[a]	65	2 to 5
M50	270	50	0.050	50 × 1	50 × 0.001	70	20	24	30	45	2 to 5
M100	250	100	0.100	50 × 2	50 × 0.002	85	18	20	18	26	2 to 5
S50	190	50	0.050	25 × 2	25 × 0.002	50	18	20	18[a]	26	2 or 3
Special sub-series[b]											
L50SP	335	50	0.050	100 × 0.5	100 × 0.000 5	125	23	27	50	65	2 to 5
M50SP	270	50	0.050	50 × 1	50 × 0.001	70	20	24	30	45	2 to 5
S50SP	190	50	0.050	50 × 1	50 × 0.001	50	18	20	18[a]	26	2 or 3

[a] For the diameter of the stem to exceed 4 mm (as required by **12.4**) these volumes, for hydrometers covering the range 1 700 kg/m³ to 2 000 kg/m³ or 1.7 g/ml to 2.0 g/ml, will be nearer the maximum value than the minimum value (see footnote to Table 4).

[b] See BS 4714.

13 Maximum permitted instrument errors

The maximum permitted instrument errors for the hydrometers are given in Table 2. It is recommended that the hydrometers in the special sub-series are supplied with certificates of correction when required for referee purposes.

For information on the testing of BS hydrometers, see Appendix D.

Table 2 — Maximum permitted instrument errors

Series	Maximum permitted error at any point on the scale	
	kg/m³	g/ml
L20	± 0.2	± 0.000 2
L50	± 0.5	± 0.000 5
M50	± 1.0	± 0.001
M100	± 2.0	± 0.002
S50	± 2.0	± 0.002
Special sub-series		
L50SP	± 0.3	± 0.000 3
M50SP	± 0.6	± 0.000 6
S50SP	± 1.0	± 0.001 0

14 Inscriptions

The following information shall be durably and legibly marked within the hydrometer.

14.1 An inscription to indicate the basis of the scale e.g. kg/m³ at 20 °C or g/ml at 15 °C.

14.2 One of the following.

a) The particular surface tension at which the scale has been adjusted, expressed in mN/m, e.g. 55 mN/m.

b) The surface tension category as defined in Appendix A for which the scale has been adjusted, e.g. low S.T.

c) If the instrument is calibrated for use with a particular liquid, the name of that liquid.

14.3 The series number, e.g. L50.

14.4 The maker's and/or vendor's name or readily identifiable mark.

14.5 An identification number of the instrument, the first two digits of which may indicate the year of manufacture e.g. 780001.

14.6 The number of this British Standard, i.e. BS 718.

Appendix A Standard categories of surface tension for hydrometers

The standard categories of surface tension are adopted for hydrometers for technical use, so as to provide a precise basis for calibration and verification and to permit the attainment of the appropriate accuracy in measurements in the liquids indicated. The adoption of these surface tension categories does not preclude the use of other surface tensions as the basis for the calibration of hydrometers, provided such surface tensions are marked, in mN/m, within the hydrometers. Attention is drawn to the requirements of **14.2** a) and **14.2** b).

Table 3 shows the surface tensions for the adjustment of hydrometers related to the minima of their density range.

If surfaces of aqueous solutions (except those of acetic acid and of nitric acid above a density of 1 300 kg/m^3 or 1.3 g/ml) are specially cleaned, e.g. by overflow, then the surface tension is increased to approximately 75 mN/m.

Table 3 — Standard categories of surface tension

Category	Density		g/ml	0.00	0.02	0.04	0.06	0.08	Examples of liquids to which the category is appropriate
	kg/m^3	g/ml	kg/m^3	0	20	40	60	80	
			Surface tension mN/m						
Low	600 700 800 900	0.6 0.7 0.8 0.9		15 20 25 30	16 21 26 31	17 22 27 32	18 23 28 33	19 24 29 34	Organic liquids generally (including ethers, petroleum distillates, coaltar distillates), and all types of oils Aqueous solutions of low molecular mass organic substances
	1 000 to 1 300 inclusive	1.00 to 1.30 inclusive				35			Acetic acid solutions, the free surfaces of which have not been specially cleaned
Medium	960 970 980 990	0.96 0.97 0.98 0.99				35 40 45 50			Aqueous solutions of low molecular mass organic substances (including those of ethyl and methyl alcohol, but excluding acetic acid solutions), the free surfaces of which have not been specially cleaned
	1 000 to 2 000 inclusive	1.00 to 2.00 inclusive				55			Nitric acid solutions of densities greater than 1 300 kg/m^3 or 1.3 g/m whether the free surfaces have been specially cleaned or not
High	1 000 to 2 000 inclusive	1.00 to 2.00 inclusive				75			Aqueous solutions, the surfaces of which have been specially cleaned, except: (a) nitric acid of density greater than 1 300 kg/m^3 or 1.3 g/ml; (b) acetic acid solutions[a].

[a] Acetic acid solutions show extreme variability of surface tension.

Appendix B Meniscus corrections

Table 4 gives the approximate amounts to be added to readings taken where the top of the meniscus appears to meet the stem, in order to obtain the corresponding indications at the level of the horizontal liquid surface (see **6.1**). They have been calculated for hydrometers having the recommended stem diameters given in the specification and are based on an equation due to Langberg, which, re-arranged, is equivalent to:

$$h = \frac{1000\,\sigma i}{d\rho s g}\left[\sqrt{\left(1 + \frac{2gd^2\rho}{1000\,\sigma}\right)} - 1\right]$$

where:

- h is the meniscus height (in kg/m^3)
- σ is the surface tension of the liquid (in mN/m)
- i is the nominal scale range (in kg/m^3)
- d is the external diameter of the stem (in mm)
- ρ is the reading at the top of the meniscus (in kg/m^3)
- s is the scale length (nominal range) (in mm)
- g is the acceleration due to gravity (9.81 m/s^2).

Table 4 has been calculated for the scale lengths indicated in the third row. The left-hand and right-hand entries refer, respectively, to the lower and upper limits of the range of scale lengths normally found in practice for hydrometers complying with the requirements of this British Standard.

The corrections in Table 4 have been rounded off to the nearest one-fifth of the smallest scale division (see Table 1).

More accurate corrections for meniscus height than can be obtained from Table 4 may be derived from Table 5, having regard to the diameter of the stem of the particular hydrometer concerned. Table 5 is also computed from Langberg's equation.

Table 4 — Average meniscus corrections expressed in units of density

Unit kg/m^3

Series of hydrometers			L20		L50 and L50SP		M50 and M50SP		M100		S50		S50SP	
Value of smallest scale division			0.2		0.5		1		2		2		1	
Assumed scale length (mm)			113	127	125	145	78	99	87	102	50	62	50	62
Density of liquid kg/m^3	g/ml	Surface tension (mN/m)												
600	0.600	15	0.32	0.28	0.8	0.7	1.2	1.0	2.0	2.0	2.0	1.6	1.8	1.6
800	0.800	25	0.36	0.32	0.8	0.7	1.4	1.0	2.4	2.0	2.0	1.6	2.0	1.6
1 000	1.000	35	0.36	0.32	0.8	0.7	1.4	1.0	2.4	2.0	2.0	1.6	2.2	1.6
		55	0.44	0.40	1.0	0.8	1.6	1.2	2.8	2.4	2.4	2.0		
		75	0.48	0.44	1.0	0.9	1.8	1.4	3.2	2.8	2.8	2.4		
1 500	1.500	35	0.32	0.28	0.7	0.6	1.0	0.8	2.0	1.6	2.0	1.2		
		55	0.36	0.32	0.8	0.7	1.2	1.0	2.4	2.0	2.0	1.6		
		75	0.40	0.36	0.9	0.8	1.4	1.0	2.8	2.4	2.4	2.0		
2 000	2.000	55	0.32	0.28	0.7	0.6	1.0	1.0	2.0	1.6	2.0	1.6		
		75	0.36	0.32	0.8	0.7	1.2	1.0	2.4	2.0	2.4	1.6		
NOTE For hydrometer scales graduated in g/ml, divide corrections shown by 1 000.														

Table 5 — Average meniscus corrections expressed in units of length

Unit: mm

Density of liquid		Surface tension	Stem diameter			
kg/m^3	g/ml	mN/m	4 mm	5 mm	6 mm	7 mm
600	0.6	15	1.7	1.8	1.9	1.9
700	0.7	20	1.8	1.9	2.0	2.0
800	0.8	25	1.9	2.0	2.0	2.1
900	0.9	30	1.9	2.0	2.1	2.2
1 000	1.0	35 55	1.9 2.2	2.1 2.4	2.1 2.5	2.2 2.6
1 300	1.3	35 55	1.8 2.1	1.9 2.2	1.9 2.3	2.0 2.4
1 500	1.5	55	2.0	2.1	2.2	2.3
2 000	2.0	55	1.8	1.9	1.9	2.0

Appendix C Recommended stem diameters for hydrometers

The diameters given in Table 6 are not mandatory. They are intended for guidance in manufacture.

Table 6 — Recommended stem diameters for hydrometers

Lower density limit of nominal range (top mark)		Series L20, L50 and L50SP	Series M50, M100 and M50SP	Series S50 and S50SP
kg/m^3	g/ml	mm	mm	mm
600	0.6	6.6	7.1	6.4
700	0.7	6.1	6.6	5.9
800	0.8	5.7	6.2	5.5
900	0.9	5.4	5.8	5.2
1 000	1.0	5.1	5.5	4.9
1 100	1.1	4.9	5.3	4.7
1 200	1.2	4.7	5.0	4.5
1 300	1.3	4.5	4.8	4.3
1 400	1.4	4.3	4.7	4.2
1 500	1.5	4.2	4.5	4.0[a]
1 600	1.6	4.0[a]	4.4	4.0[a]
1 700	1.7	4.0[a]	4.2	4.0[a]
1 800	1.8	4.0[a]	4.1	4.0[a]
1 900	1.9	4.0[a]	4.0[a]	4.0[a]

[a] 4.0 mm is the minimum stem diameter permitted in **12.4**

Appendix D Testing of BS hydrometers

The examination and calibration of hydrometers is undertaken by approved laboratories of the National Accreditation Service (NAMAS). Full details of services and fees can be obtained on application to individual laboratories. A list of NAMAS approved laboratories can be obtained from NAMAS, National Physical Laboratory, Teddington, Middlesex, TY 11 0LW.

Appendix E Method for determination of density by means of BS hydrometers

E.1 General

To obtain the highest precision when using a particular hydrometer the following general procedures should be adhered to.

E.1.1 Read the hydrometer in the liquid at a known temperature.

E.1.2 Apply corrections (when significant) to the observed reading for the following.

E.1.2.1 The meniscus height (if the test liquid is opaque [see **E.4.1**)].

E.1.2.2 The scale error of the hydrometer at the observed reading [see **E.4.2**)].

E.1.2.3 The difference between the temperature of the liquid and the standard temperature of the hydrometer (see **E.4.3**).

E.1.2.4 The difference between the surface tension of the liquid and that for which the hydrometer is graduated (see **E.4.4**).

E.2 Apparatus. The following apparatus is required.

E.2.1 *Hydrometer*. Select a hydrometer appropriate to the surface tension of the liquid to be examined. Table 3 gives a guide to the appropriate hydrometer category suitable for the range of liquids mentioned. Surface tensions of other liquids may be obtained from appropriate table of physical properties of substances, e.g. "International Critical Tables".

E.2.2 *Hydrometer vessel*. Select a hydrometer vessel as described in Appendix G.

E.2.3 *Thermometer*. For high precision work select a total immersion thermometer graduated in 0.1 °C, with a certificate of scale correction. A thermometer range of – 0.5 ° to 40.5 °C, designation no. A40C/Total or B60C/Total complying with the requirements of BS 593 is suitable. (Also IP39C; ASTM 63C; STPTC T5d.)

E.3 Procedure

E.3.1 ***Preliminaries***

E.3.1.1 Clean all apparatus before use.

E.3.1.2 Allow the liquid to attain thermal equilibrium with its surroundings and pour it into the hydrometer vessel allowing a small quantity to overflow if an overflow vessel is used. Avoid the formation of air bubbles in the liquid by pouring it down the side of the vessel. Stir the liquid vertically with a loop stirrer, again avoiding the formation of bubbles. Record the temperature of the liquid to the nearest 0.2 °C.

E.3.1.3 Examine the hydrometer to ascertain that the scale has not shifted since manufacture (see **10.1.2**).

E.3.1.4 Insert the hydrometer carefully into the liquid, holding it by the top of its stem. Release the hydrometer when it is approximately in its position of equilibrium and, if an overflow vessel is used, add a further amount of sample to the vessel by way of the filling tube until a volume approximately equal to 15 % of the nominal capacity has overflowed. A little experience soon enables the user to appreciate when the hydrometer is approaching equilibrium and to release it in such a position that the hydrometer rises or falls by only a small amount when released. This is important with viscous liquids for otherwise excess liquid will adhere to the stem and the hydrometer will thereby be weighted down.

E.3.1.5 When the hydrometer is steady, press the top of the stem downwards a few millimetres beyond the position of equilibrium or, if the liquid is viscous, only one scale division, gripping the stem very lightly with a finger and thumb. Withdraw the hand and observe the meniscus as the hydrometer oscillates to equilibrium. If the stem and liquid surface are clean the meniscus shape will remain unchanged as the hydrometer rises and falls. If the meniscus shape changes, e.g. if it wrinkles or is distorted by the motion of the hydrometer, lack of cleanliness is indicated and the hydrometer and vessel should be cleaned and the test repeated with a fresh sample. This precaution becomes increasingly important with increasing surface tension of the liquid.

E.3.2 *Reading the hydrometer*. When the hydrometer, which must not be touching the side of the vessel, has again settled down to its equilibrium position (in the case of viscous liquids this may take some time) record the reading as follows.

E.3.2.1 *Transparent liquids*. Record the scale reading corresponding to the plane of intersection of the horizontal liquid surface and the stem. When taking the reading, view the scale through the liquid, adjusting the line of sight so that it is in the plane of the liquid surface.

E.3.2.2 *Opaque liquids*. Record the scale reading where the meniscus merges into the stem of the hydrometer.

E.3.2.3 *Reading of temperature*. Immediately after taking the reading, measure the temperature of the liquid to the nearest 0.2 °C. The mean of this temperature and the initial temperature referred to in **E.3.1.2** should be used in the calculation of corrections (see **E.4**).

NOTE This procedure is particularly important in the case of liquids having high values of coefficient of thermal cubical expansion.

The difference between the two temperatures should not exceed 1 °C and if a larger difference is found, lack of thermal equilibrium is indicated, and the procedure should be repeated from **E.3.1.2**.

E.4 Application of the corrections

E.4.1 *Meniscus height*. If the hydrometer has been read in an opaque liquid (i.e. at the line where the liquid merges into the stem of the hydrometer) it is necessary to correct the reading for the meniscus height by adding the appropriate value from Table 4 or Table 5.

E.4.2 *Instrument error*. If known, the correction for instrument error may be algebraically applied with equal validity under all conditions of use. It is however additional to other corrections, for example those for temperature and surface tension, which vary according to conditions of use.

For many purposes it is sufficient to know that the instrument error does not exceed the maximum error permitted under the specification. Where greater accuracy is required the instrument error should be known and allowed for.

E.4.3 *Temperature of calibration*. If the hydrometer reading is taken at a temperature other than the standard temperature for the hydrometer, the reading will be in error due to the change in volume of the hydrometer between the two temperatures.

Appropriate corrections making allowance for this temperature effect are given in Table 7. If positive in sign the temperature correction given is to be added to, and if negative, subtracted from the hydrometer reading. The tables have been computed using a nominal coefficient of cubical expansion of the glass of the hydrometer and having a value of 25×10^{-6} °C^{-1}.

E.4.4 *Surface tension*. Attention has already been drawn to the fact that the reading of a hydrometer depends on the surface tension of the liquid in which it is used. In general it is possible, by choosing a hydrometer graduated for the most appropriate of the surface tension categories available (see Table 3) and having a suitably open scale (see Table 1), to avoid any necessity for surface tension corrections. Table 8 gives an indication of possible errors, in the form of corrections which may be applied on account of difference between the surface tension of the liquid and the surface tension for which the hydrometer is graduated. They relate to hydrometers of average dimensions permitted by the requirements of this standard (see Table 1), and are therefore not necessarily applicable to hydrometers complying with previous editions of this British Standard.

Table 7 — Corrections for temperature applicable to BS density hydrometers standardized at 20 °C or 15 °C

(Unit: kg/m^3 or 10^{-3} g/ml)

Reference temperature		Hydrometer reading							
20 °C	15 °C	600 kg/m^3	800 kg/m^3	1 000 kg/m^3	1 200 kg/m^3	1 400 kg/m^3	1 600 kg/m^3	1 800 kg/m^3	2 000 kg/m^3
Temperature of liquid, (°C)		0.6 g/ml	0.8 g/ml	1.0 g/ml	1.2 g/ml	1.4 g/ml	1.6 g/ml	1.8 g/ml	2.0 g/ml
0	—	+ 0.3	+ 0.4	+ 0.5	+ 0.6	+ 0.7	+ 0.8	+ 0.9	+ 1.0
5	0	+ 0.2	+ 0.3	+ 0.4	+ 0.5	+ 0.5	+ 0.6	+ 0.7	+ 0.8
10	5	+ 0.2	+ 0.2	+ 0.3	+ 0.3	+ 0.4	+ 0.4	+ 0.5	+ 0.5
15	10	+ 0.1	+ 0.1	+ 0.1	+ 0.2	+ 0.2	+ 0.2	+ 0.3	+ 0.3
20	15	0	0	0	0	0	0	0	0
25	20	– 0.1	– 0.1	– 0.1	– 0.2	– 0.2	– 0.2	– 0.2	– 0.3
30	25	– 0.2	– 0.2	– 0.3	– 0.3	– 0.4	– 0.4	– 0.5	– 0.5
35	30	– 0.2	– 0.3	– 0.4	– 0.5	– 0.5	– 0.6	– 0.7	– 0.8
40	35	– 0.3	– 0.4	– 0.5	– 0.6	– 0.7	– 0.8	– 0.9	– 1.0
45	40	– 0.4	– 0.5	– 0.6	– 0.8	– 0.9	– 1.0	– 1.1	– 1.3

NOTE These corrections when applied to the hydrometer reading at t °C give the density of the liquid in kg/m^3 or g/ml at t °C. They are based on the relationship:

$C = 0.000\,025\,R\,(t_s - t)$

where:

C is the correction

R is the observed reading

t_s is the reference temperature

t is the temperature of the liquid the density of which is to be determined

It is important to note that the density obtained by applying this correction is that of the liquid at the temperature of observation. If the density is then required at some other temperature an allowance must be made for the expansion or contraction of the liquid with change of temperature.

Table 8 — Surface tension corrections

(Unit: kg/m^3 or 10^{-3} g/ml)

Surface tension of liquid minus that for which the hydrometer is graduated (mN/m)	Series L20				Series L50 and L50 SP				Series M50 and M50 SP				Series M100				Series S50 and S50 SP			
	Hydrometer reading				Hydrometer reading				Hydrometer reading				Hydrometer reading				Hydrometer reading			
	600 kg/m^3 0.6 g/ml	1 000 kg/m^3 1.0 g/ml	1 500 kg/m^3 1.5 g/ml	2 000 kg/m^3 2.0 g/ml	600 kg/m^3 0.6 g/ml	1000 kg/m^3 1.0 g/ml	1 500 kg/m^3 1.5 g/ml	2 000 kg/m^3 2.0 g/ml	600 kg/m^3 0.6 g/ml	1 000 kg/m^3 1.0 g/ml	1 500 kg/m^3 1.5 g/ml	2 000 kg/m^3 2.0 g/ml	600 kg/m^3 0.6 g/ml	1 000 kg/m^3 1.0 g/ml	1 500 kg/m^3 1.5 g/ml	2 000 kg/m^3 2.0 g/ml	600 kg/m^3 0.6 g/ml	1 000 kg/m^3 1.0 g/ml	1 500 kg/m^3 1.5 g/ml	2 000 kg/m^3 2.0 g/m
– 40	—	– 0.54	– 0.45	– 0.39	—	– 1.2	– 0.9	– 0.8	—	– 1.9	– 1.5	– 1.4	—	– 3	– 3	– 2	—	– 2.5	– 2	– 2
– 30	—	– 0.41	– 0.34	– 0.30	—	– 0.9	– 0.7	– 0.6	—	– 1.4	– 1.1	– 1.0	—	– 2	– 2	– 2	—	– 2	– 1.5	– 1.5
– 20	—	– 0.27	– 0.22	– 0.20	—	– 0.6	– 0.5	– 0.4	—	– 0.9	– 0.8	– 0.7	—	– 2	– 1	– 1	—	– 1.5	– 1	– 1
– 10	– 0.18	– 0.14	– 0.11	– 0.10	– 0.3	– 0.3	– 0.2	– 0.2	– 0.6	– 0.5	– 0.4	– 0.3	– 1	– 1	– 1	– 1	– 1	– 0.5	– 0.5	– 0.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+ 10	+ 0.18	+ 0.14	+ 0.11	+ 0.10	+ 0.3	+ 0.3	+ 0.2	+ 0.2	+ 0.6	+ 0.5	+ 0.4	+ 0.3	+ 1	+ 1	+ 1	+ 1	+ 1	+ 0.5	+ 0.5	+ 0.5
+ 20	—	+ 0.27	+ 0.22	+ 0.20	—	+ 0.6	+ 0.5	+ 0.4	—	+ 0.9	+ 0.8	+ 0.7	—	+ 2	+ 1	+ 1	—	+ 1.5	+ 1	+ 1
+ 30	—	+ 0.41	+ 0.34	+ 0.30	—	+ 0.9	+ 0.7	+ 0.6	—	+ 1.4	+ 1.1	+ 1.0	—	+ 2	+ 2	+ 2	—	+ 2	+ 1.5	+ 1.5
+ 40	—	+ 0.54	+ 0.45	+ 0.39	—	+ 1.2	+ 0.9	+ 0.8	—	+ 1.9	+ 1.5	+ 1.4	—	+ 3	+ 3	+ 2	—	+ 2.5	+ 2	+ 2

NOTE For hydrometers of different dimensions permitted under this specification the surface tension allowances may vary from the above amounts by up to approximately ± 10 %.

Appendix F Table for use in calculating quantities of liquid in bulk

NOTE 1 It is essential that the correction referred to in **E.4.3** is carried out before that described in this appendix.

NOTE 2 In the petroleum industry special calculation procedures based on the standard reference temperature 15 °C are used, and the necessary tables for these and for reference temperature 60 °F are given in BS 6441. Tables for reference temperature 20 °C are given in Addendum 01 to ISO/R91.

At a given temperature t the volume V_t in cubic metres or millilitres of a quantity of liquid can be obtained by dividing its apparent mass in air, W kilograms or grams, by the apparent mass in air of the liquid per cubic metre or per millilitre respectively.

$$V_t\ (\mathrm{m}^3) = \frac{\text{apparent mass in air}(W\ \text{kg})}{\text{apparent mass in air per unit volume}(\text{kg/m}^3)\ \text{at}\ t}\ \text{or}$$

$$V_t\ (\text{ml}) = \frac{\text{apparent mass in air}(W\ \text{g})}{\text{apparent mass in air per unit volume}(\ \text{g/ml})\ \text{at}\ t}$$

Alternatively, the total apparent mass in air of the liquid at t, W kilograms or grams, can be found by multiplying together the total volume of the liquid, V_t cubic metres or millilitres, and the apparent mass in air at t, in kilograms per cubic metre or grams per millilitre respectively.

W (kg) = [V_t(m^3)] × [apparent mass in air per unit volume at t (kg/m^3)] or

W (g) = [V_t(ml)] × [apparent mass in air per unit volume at t (g/ml)]

In both instances, the apparent mass in air per unit volume at t is required and Table 9 enables these quantities to be obtained in a simple way from the density (kg/m^3 or g/ml) at t.

Table 9 — Conversion of density (kg/m^3 or g/ml) to apparent mass (in air) in kg or g of the liquid occupying 1 m^3 or 1 ml at a given temperature, *t*

The correction in the third or fourth column, whichever is appropriate, is to be applied to the corresponding value in the first or second column.

Density at any given temperature *t*		Correction to give apparent mass in air of the liquid	
		Occupying 1 m^3 at *t*	Occupying 1 ml at *t*
kg/m^3	g/ml	kg/m^3	g/ml
600 to 1 1 00	0.6 to 1.1	– 1.1	– 0.0011
1 200 to 1 700	1.2 to 1.7	– 1.0	– 0.001
1 800 to 2 000	1.8 to 2.0	– 0.9	– 0.0009

NOTE 1 These figures are based on the practice of the Standards Weights and Measures and Quality Assurance Division, Department of Prices and Consumer Protection, taking 0.001 217 g/ml and 8.136 g/ml for the densities of the atmosphere and of the weights used.

NOTE 2 The equivalence of the cubic decimetre and the litre (1964 CGPM definition) is assumed.

When the temperature of observation of the density is not the same as the temperature at which the volume of the liquid is required or measured, the expansion or contraction of the liquid between the two temperatures has to be taken into account. The volume V_t' at t' can be obtained from V_t (found as indicated above) by using the relationship:

$$V_t' = V_t\ [1 + \alpha\ (t' - t)]$$

where α is the mean coefficient of thermal cubical expansion of the liquid per degree Celsius over the temperature range t to t' expressed in °C.

Similarly, when the total apparent mass in air W is required, the density being known at t and the total volume V_t' at t', then the volume V_t at t can be found from V_t' by dividing it by $[1 + \alpha\ (t' - t)]$.

Appendix G Vessels for hydrometer observations

For all liquids, a cylindrical hydrometer vessel is normally suitable, but for results of the highest precision on liquids of high surface tension (see Table 3) an overflow vessel should be used so that the surface film can be removed.

G.1 Cylindrical vessels. The cylinder should stand firmly on its base and should be free from local irregularities producing distortion. In Table 10 the capacities of suitable graduated cylinders complying with the requirements of BS 604, are given. Graduated, or preferably ungraduated, cylinders of these sizes will doubtless be available to hydrometer users. Larger cylinders are of course at least equally satisfactory when sufficient liquid is available. Shorter cylinders can be used when the length of the hydrometer is not near the maximum permitted, or when the scale reading is not near the top of the stem. The diameter of the cylinder employed should be at least several millimetres greater than the hydrometer bulb diameter.

Table 10 — Cylinders complying with the requirements of BS 604 suitable for observations on BS hydrometers

Hydrometer series	Maximum bulb diameter	Maximum length of hydrometer to its top graduation mark	Nominal capacity of cylinder
	mm	mm	ml
L20	40	320	1 000
L50 and L50SP	27	320	1 000
M50 and M50SP	24	255	500
M100	20	235	250
S50 and S50SP	20	175	250

G.2 Overflow vessels. Overflow vessels suitable for use with British Standard hydrometers are shown in Figure 3. The internal diameter of the vessel and the distance of the overflow level from the top and bottom of the vessel should be kept within the limiting values shown, but small variations in the remaining dimensions are unimportant. The vessels illustrated can be made easily from glass tubing; they require a stand to hold them. Type A is suitable for series L20 and L50, type B for series M100 and type C for series S50 hydrometers.

Appendix H Density of air-free distilled water

H.1 Although the density of water is not a fundamental quantity in the International System of units, water is still used as a standard substance for precise volume and density measurements.

The tables for the density of water used in BS 718:1979 were calculated using the International Practical Temperature Scale of 1968 (IPTS-68). These tables have been recalculated using the new International Temperature Scale of 1990 (ITS-90). The new values which have been calculated by the Institute of Petroleum are given in Table 11 and are reproduced, together with the associated equations and comments on the uncertainty of the data, by permission of the Institute of Petroleum.

H.2 The density of water at various temperatures, set out in Table 11 has been calculated by the Institute of Petroleum, using an equation given by G. S. Kell reworked to incorporate the International Temperature Scale 1990 (ITS-90). Kell's equation together with the expected uncertainties of the densities are given in **H.3** and **H.4**.

Table 11 — Density of water (kg/m^3) Calculated by the Institute of Petroleum using Kell's equation

t_{90} °C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	999.840	9.846	9.853	9.859	9.865	9.871	9.877	9.883	9.888	9.893
1	999.898	9.904	9.908	9.913	9.917	9.921	9.925	9.929	9.933	9.937
2	999.940	9.943	9.946	9.949	9.952	9.954	9.956	9.959	9.961	9.962
3	999.964	9.966	9.967	9.968	9.969	9.970	9.971	9.971	9.972	9.972
4	999.972	9.972	9.972	9.971	9.971	9.970	9.969	9.968	9.967	9.965
5	999.964	9.962	9.960	9.958	9.956	9.954	9.951	9.949	9.946	9.943
6	999.940	9.937	9.934	9.930	9.926	9.923	9.919	9.915	9.910	9.906
7	999.901	9.897	9.892	9.887	9.882	9.877	9.871	9.866	9.860	9.854
8	999.848	9.842	9.836	9.829	9.823	9.816	9.809	9.802	9.795	9.788
9	999.781	9.773	9.765	9.758	9.750	9.742	9.734	9.725	9.717	9.708
10	999.699	9.691	9.682	9.672	9.663	9.654	9.644	9.634	9.625	9.615
11	999.605	9.595	9.584	9.574	9.563	9.553	9.542	9.531	9.520	9.508
12	999.497	9.486	9.474	9.462	9.450	9.439	9.426	9.414	9.402	9.389
13	999.377	9.364	9.351	9.338	9.325	9.312	9.299	9.285	9.271	9.258
14	999.244	9.230	9.216	9.202	9.187	9.173	9.158	9.144	9.129	9.114
15	999.099	9.084	9.069	9.053	9.038	9.022	9.006	8.991	8.975	8.959
16	998.943	8.926	8.910	8.893	8.876	8.860	8.843	8.826	8.809	8.792
17	998.774	8.757	8.739	8.722	8.704	8.686	8.668	8.650	8.632	8.613
18	998.595	8.576	8.557	8.539	8.520	8.501	8.482	8.463	8.443	8.424
19	998.404	8.385	8.365	8.345	8.325	8.305	8.285	8.265	8.244	8.224
20	998.203	8.182	8.162	8.141	8.120	8.099	8.077	8.056	8.035	8.013
21	997.991	7.970	7.948	7.926	7.904	7.882	7.859	7.837	7.815	7.792
22	997.769	7.747	7.724	7.701	7.678	7.655	7.631	7.608	7.584	7.561
23	997.537	7.513	7.490	7.466	7.442	7.417	7.393	7.369	7.344	7.320
24	997.295	7.270	7.246	7.221	7.195	7.170	7.145	7.120	7.094	7.069
25	997.043	7.018	6.992	6.966	6.940	6.914	6.888	6.861	6.835	6.809
26	996.782	6.755	6.729	6.702	6.675	6.648	6.621	6.594	6.566	6.539
27	996.511	6.484	6.456	6.428	6.401	6.373	6.344	6.316	6.288	6.260
28	996.231	6.203	6.174	6.146	6.117	6.088	6.059	6.030	6.001	5.972
29	995.943	5.913	5.884	5.854	5.825	5.795	5.765	5.735	5.705	5.675
30	995.645	5.615	5.584	5.554	5.523	5.493	5.462	5.431	5.401	5.370
31	995.339	5.307	5.276	5.245	5.214	5.182	5.151	5.119	5.087	5.055
32	995.024	4.992	4.960	4.927	4.895	4.863	4.831	4.798	4.766	4.733
33	994.700	4.667	4.635	4.602	4.569	4.535	4.502	4.469	4.436	4.402
34	994.369	4.335	4.301	4.267	4.234	4.200	4.166	4.132	4.098	4.063
35	994.029	3.994	3.960	3.925	3.891	3.856	3.821	3.786	3.751	3.716
36	993.681	3.646	3.610	3.575	3.540	3.504	3.469	3.433	3.397	3.361
37	993.325	3.289	3.253	3.217	3.181	3.144	3.108	3.072	3.035	2.999
38	992.962	2.925	2.888	2.851	2.814	2.777	2.740	2.703	2.665	2.628
39	992.591	2.553	2.516	2.478	2.440	2.402	2.364	2.326	2.288	2.250
40	992.212									

H.3 Equation (1) below was given by G. S: Kell in *Density, Thermal Expansivity, and Compressibility of Liquid Water from* 0 °C to 150 °C Journal of Chemical and Engineering Data, Vol. 20, No 1, 1975.

$$\rho_w \ (999.83952 + 16.945176 \cdot t_w - 7.9870401 \cdot 10^{-3} \cdot t_w^2 - 4.6170461 \cdot 10^{-5} \cdot t_w^3 + 1.0556302 \cdot 10^{-7} \cdot t_w^4 - 2.8054253 \cdot 10^{-10} \cdot t_w^5)/(1 + 1.687985 \cdot 10^{-2} \cdot t_w) \quad (1)$$

where

ρ_w = water density in kg/m^3 at a pressure of 101.325 kPa;

t_w = water temperature in °C (IPTS-68).

The two equations below which are also due to Kell may be used to calculate ρ_{tp} the density of water in kg/m^3 at pressures other than 101.325 kPa.

$$\rho_{tp} = \rho_w + (K_{tp} \cdot pressure \cdot \rho_w)$$

where

$$K_{tp} = K_{tw} - (5.85 \cdot 10^{-11} \cdot \rho)$$

where

ρ is the water pressure in kPa

K_{tw} is the compressibility coefficient at 101.325 kPa at temperature t_w;

$$K_{tw} = (50.88496 + 0.6163813 \cdot t_w + 1.459187 \cdot 10^{-3} \cdot t_w^2 + 2.008438 \cdot 10^{-5} \cdot t_w^3 - 5.847727 \cdot 10^{-8} \cdot t_w^4 + 4.10411 \cdot 10^{-10} \cdot t_w^5) \cdot 10^{-6}/(1 + 1.967348 \cdot 10^{-2} \cdot t_w)$$

H.4 The estimated uncertainty of Table 11 is 0.006 kg/m^3. When considering the density of a sample of water, the following sources of error should be considered.

a) Dissolved air. The density difference between 0 % and 100 % air saturated water is 0.0033 kg/m^3 at 15 °C and 0.0027 kg/m^3 at 20 °C.

b) Purity, 1 part per million dissolved solids (NaCl) gives a change in density of 0.0007 kg/m^3.

c) Isotopic ratios. The density of water is dependent on the H : D and $O^{16} : O^{17} : O^{18}$ ratios. It is reasonable to expect that water from different sources might vary in density by up to 0.006 kg/m^3. Care should be taken to avoid isotopic fractionation when purifying the water, since two additional distillations have been shown to change the water density by 0.005 kg/m^3.

d) Pressure. The normal range of ambient pressures from 940 to 1 030 mbar causes a density change of 0.004 kg/m^3.

e) Temperature. An error in temperature measurement of 10 mK (0.01 °C) is equivalent to a density error of 0.002 kg/m^3.

f) Hydrostatic head. A 250 mm head of water will cause a density increase of 0.001 kg/m^3.

When all these factors are taken into account, the uncertainty in the density of a sample of nominally pure water is probably about 0.01 kg/m^3. Further information on the subject is available from the Institute of Petroleum[3)].

3) The Institute of Petroleum, 61 New Cavendish Street, London W1M 8AR.

Appendix J Differences between readings on hydrometers graduated on various bases of scale

The data in Table 12 are of use when graduating or testing a British Standard hydrometer against a reference instrument not graduated on the required scale.

The tabulated values are the differences which should exist between the readings of similar instruments in the same surface tension category and having scales graduated in different units; they apply when the hydrometers are subject to the same conditions in the same liquid. The differences are independent of the temperature of the liquid, and are based on a nominal coefficient of cubical expansion of glass of 25×10^{-6} °C^{-1}.

Table 12 — Differences between readings on hydrometers graduated for density at 20 °C or 15 °C or relative density 60/60 °F

Unit: kg/m^3 or 10^{-3} g/ml or *d*. All values are positive

Indication of hydrometer		**Reading on relative density 60/60 °F scale *minus* reading on density at 20° scale**	**Reading on relative density 60/60 °F scale *minus* reading on density at 15 °C scale**	**Reading on density at 15 °C scale *minus* reading on density at 20 °C scale**
kg/m^3	g/ml or *d* 60/60			
600	0.6	0.7	0.6	0.1
700	0.7	0.8	0.7	0.1
800	0.8	0.9	0.8	0.1
900	0.9	1.0	0.9	0.1
1 000	1.0	1.1	1.0	0.1
1 100	1.1	1.2	1.1	0.1
1 200	1.2	1.3	—	—
1 300	1.3	1.4	—	—
1 400	1.4	1.5	—	—
1 500	1.5	1.6	—	—
1 600	1.6	1.7	—	—
1 700	1.7	1.9	—	—
1 800	1.8	2.0	—	—
1 900	1.9	2.1	—	—
2 000	2.0	2.2	—	—

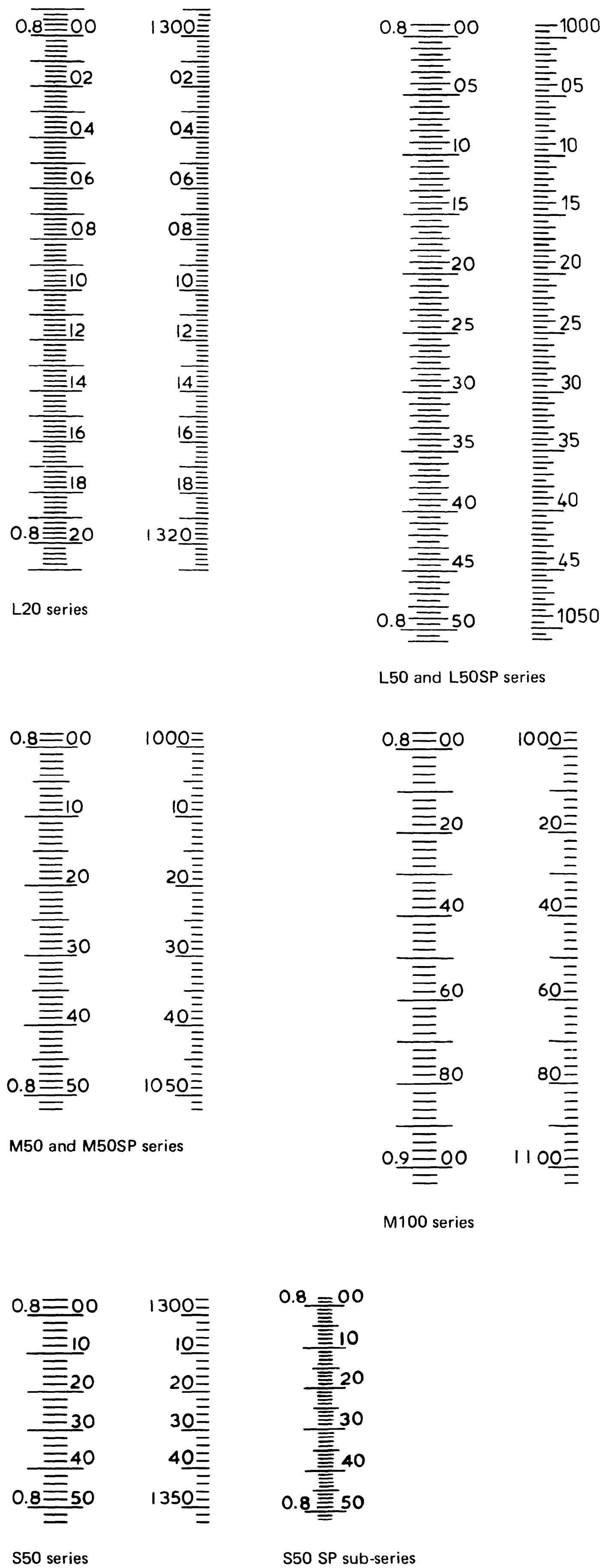
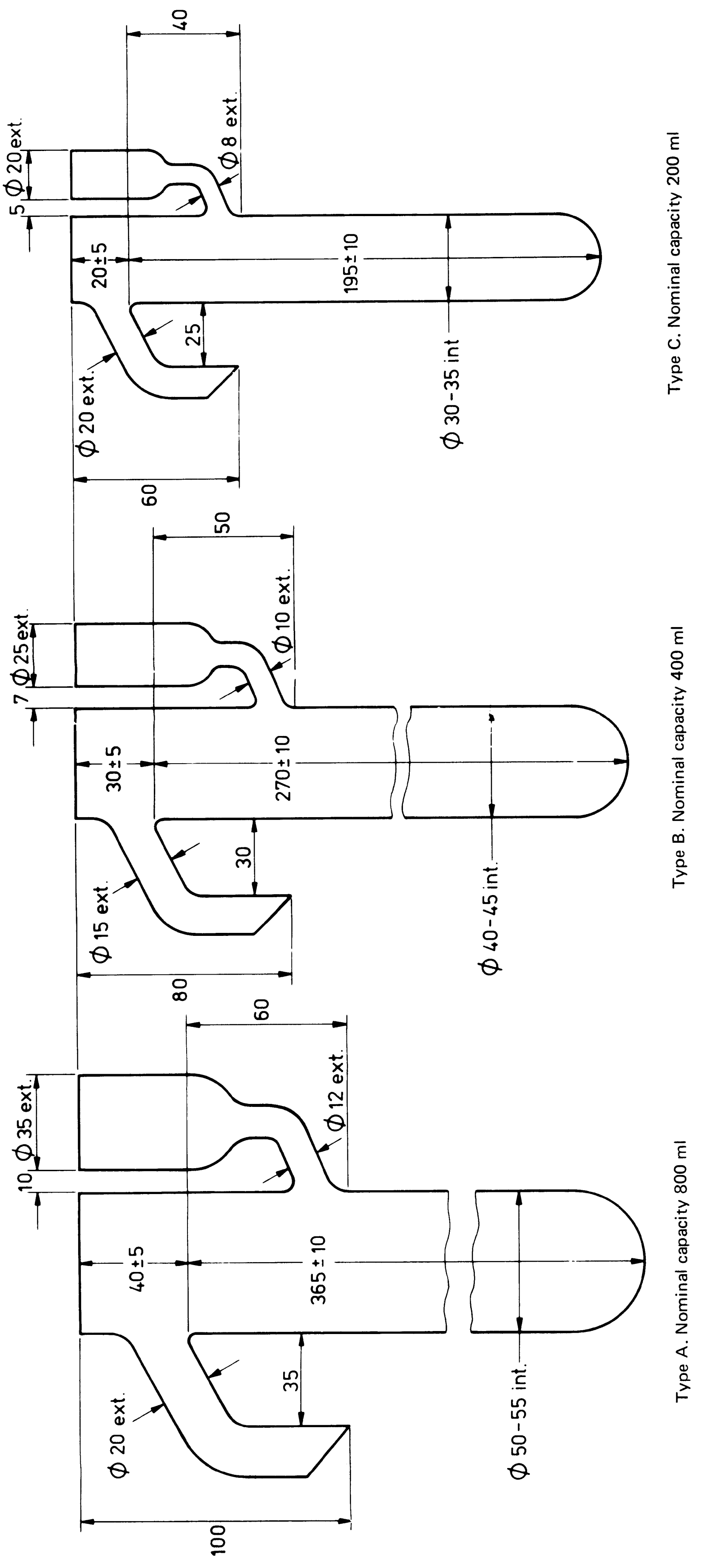


Figure 2 — Examples of hydrometer scales recommended in clause 10



All dimensions in millimetres.

Figure 3 — Overflow vessels suitable for observations on hydrometers

Publication(s) referred to

BS 593, *Specification for laboratory thermometers.*

BS 604, *Specification for graduated glass measuring cylinders.*

BS 733, *Pyknometers*[4].

BS 733-2, *Methods for calibration and use of pyknometers.*

BS 4714, *Method for laboratory determination of density or relative density of crude petroleum and liquid petroleum products (hydrometer method).*

BS 6441, *Schedule for petroleum measurement tables.*

ISO/R 91, *Petroleum measurement tables — Tables based on a reference temperature of 20 °C. Addendum 01.*

ISO 387, *Hydrometers — Principles of construction and adjustment*[4].

ISO 649, *Laboratory glassware — Density hydrometers for general purposes*[4].

ISO 649-1, *Specification.*

ISO 649-2, *Test methods and use.*

ISO 650, *Relative density 60/60 degrees F hydrometers for general purposes*[4].

[4] Referred to in the foreword only.

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