INTERNATIONAL STANDARD 650

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Relative density 60/60 °F hydrometers for general purposes

Aréomètres à densité relative 60/60 °F d'usage général

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 650 was developed by Technical Committee ISO/TC 48, *Laboratory glassware and related apparatus.*

It was submitted directly to the ISO Council, in accordance with clause 6.12.1 of the Directives for the technical work of ISO. It cancels and replaces ISO Recommendation R 650-1968, which had been approved by the member bodies of the following countries :

Australia	Egypt, Arab Rep. of	Poland
Austria	Greece	Spain
Belgium	Hungary	Switzerland
Brazil	India	Turkey
Bulgaria	Israel	United Kingdom
Chile	Korea, Rep. of	U.S.A.
Colombia	Netherlands	U.S.S.R.
Czechoslovakia	New Zealand	Yugoslavia

The member bodies of the following countries had expressed disapproval of the document on technical grounds :

France
Germany

Printed in Switzerland

Relative density 60/60 °F hydrometers for general purposes

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies requirements for five basic series of glass hydrometers of constant mass which indicate relative density 60/60 °F with reference to water and comply with ISO 387.

NOTE – The use of a scale other than one based on density (mass per unit volume) is not in general recommended, but in view of its importance in trade between various countries, the scale based on relative density with reference to water is accepted.

The dimensions of the hydrometers have been chosen in such a way as to lead to convenience in use and economy in manufacture.

2 REFERENCES

ISO 387, *Hydrometers – Principles of construction and adjustment.*[1)]

ISO 1768, *Glass hydrometers – Conventional value for the thermal cubic expansion coefficient (for use in the preparation of measurement tables for liquids).*

3 DEFINITION

relative density 60/60 °F of a liquid with reference to water[2)] : The ratio

$$\frac{\text{density of the liquid at 60 °F}}{\text{density of water at 60 °F}}$$

4 BASIS OF SCALE

The scale shall indicate relative density 60/60 °F with reference to water.

5 REFERENCE TEMPERATURE

The standard reference temperature for the hydrometers shall be 60 °F. When used in a liquid at this temperature, the hydrometer shall indicate the relative density of the liquid at 60 °F with reference to water at 60 °F.

NOTE – For the purposes of this International Standard, the standard reference temperature 60 °F can be taken as equal to 15,56 °C.

6 SURFACE TENSION

The adjustment shall be related to specific capillary conditions as follows :

6.1 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.

6.2 The hydrometer shall be adjusted with regard to surface tension. Except where the highest precision is required, one of the standard categories of surface tension given in table 3, annex A, shall be used.

For hydrometers of the highest precision, intended for use in particular liquids (for example 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 15 b) 3)].

7 REFERENCE LEVELS FOR ADJUSTMENT AND READING

7.1 Hydrometers should preferably be adjusted for readings taken at the level of the horizontal liquid surface. If a hydrometer 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 appropriate correction to the level of the horizontal liquid surface shall then be made.

To avoid the necessity for making such corrections, hydrometers intended for use in opaque liquids may alternatively be adjusted for readings taken at the top of the meniscus where it appears to meet the stem. If a hydrometer is so adjusted, this shall be clearly indicated on the scale [see 15 c)].

NOTE – Appropriate corrections are given in annex C.

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

1) At present at the stage of draft. (Revision of ISO/R 387.)

2) The expression "relative density" complies with ISO 31, Part III, *Quantities and units of mechanics.* The term "specific gravity" is often used in English instead of "relative density", when the reference substance is water.

8 IMMERSION

In order that the readings of the hydrometer should be correct, the emergent stem shall be dry, except in the immediate vicinity of the meniscus.

9 MATERIALS AND WORKMANSHIP

9.1 The bulb and the stem shall be made of transparent glass as free as possible from strain and visible defects, and shall have a coefficient of cubical thermal expansion of $(25 \pm 2) \times 10^{-6}\ °C^{-1}$.*

NOTE — Various measurement tables for liquids have been drawn up on the basis of using hydrometers made of glass having a particular thermal expansion coefficient. When the actual expansion of the hydrometer departs significantly from the particular value which underlies the measurement tables, an appropriate correction should be made.

9.2 The loading material shall be fixed in the bottom part of the hydrometer. When heated in a horizontal position for 1 h at 80 °C and subsequently cooled to room temperature in that position, the hydrometer shall meet the requirements of 10.3.

If, however, a hydrometer is likely to be used at a temperature higher than 70 °C, this test shall be carried out at a temperature which is higher than 80 °C. The material shall not deteriorate in use.

Mercury shall not be used as a loading material.

9.3 There shall be no loose material in the instrument.

9.4 The scale lines and inscriptions should preferably be black and shall be clearly and permanently marked.

9.5 The strip on which the scale and inscriptions are marked shall have a smooth 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 to any higher temperature at which the hydrometer will be used.

10 FORM

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

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

10.3 The hydrometer should float with its axis essentially vertical; 1,5° is recommended as the maximum permissible deviation.

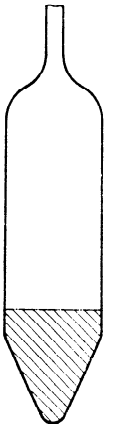

FIGURE — **Preferred design of hydrometer bulb**

10.4 A thermometer shall not form part of a hydrometer of high sensitivity.

10.5 The cross-section of the stem shall remain unchanged for at least 5 mm below the lowest graduation line of the scale.

10.6 The stem shall extend at least 15 mm above the uppermost graduation line of the scale.

11 SCALE

11.1 General

11.1.1 The strip on which the scale and inscriptions are marked shall remain securely fastened in place at the temperature of use (see 9.5).

11.1.2 Appropriate means shall be incorporated for ensuring that any displacement of the scale or of the strip bearing the scale is readily apparent. If the scale is displaced, the hydrometer shall be rejected.

11.1.3 No hydrometer shall have more than one type of scale. If a hydrometer has two scales of the same type, the values indicated by them shall not differ.

11.2 Graduation lines

11.2.1 The graduation lines shall be distinct and of uniform thickness not exceeding one-fifth of the distance between the centres of adjacent lines.

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

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

11.2.4 The scale shall be straight and without twist.

* This value complies with ISO 1768.

11.2.5 A line parallel to the axis of the instrument and indicating the front of the scale is permitted.

11.2.6 The highest and lowest graduation lines indicating the nominal limits of the scale shall be long lines [see 11.3.1 a), 11.3.2 a) and 11.3.3 a)].

11.2.7 The short scale lines shall extend at least one-fifth of the way round the circumference of the stem, the medium lines at least one-third, and the long lines at least one-half of the way round the circumference.

11.2.8 The distance between the centres of adjacent graduation lines shall exceed 0,8 mm but shall not exceed 3,0 mm, and should preferably be not less than 1,2 mm and not more than 2,0 mm.

11.2.9 The scale shall extend at each end beyond its nominal limits by at least two graduation lines.

11.3 Sequence of graduation lines

11.3.1 On the hydrometers whose smallest scale division is 0,001 relative density :

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.

11.3.2 On the hydrometers whose smallest scale division is 0,000 2 or 0,002 relative density :

a) every fifth graduation line shall be a long line;

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

11.3.3 On the hydrometers whose smallest scale division is 0,000 5 relative density :

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.

11.4 Figuring of graduation lines

11.4.1 The scale shall have only one set of numbers.

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

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

11.4.4 At least every tenth line shall be figured.

11.4.5 The decimal sign shall be included for numbers expressed in full, but may be omitted from abbreviated numbers.

12 SERIES OF HYDROMETERS (see table 1)

Each of the five series of hydrometers covers a total range of 0,600 to 2,000 relative density, each hydrometer having a range of 0,020 or 0,050 or 0,100 relative density. The lower nominal limits of the scales of the L20 series hydrometers shall be 0,600 – 0,620 – 0,640 – etc., those of the L50, M50 and S50 series hydrometers shall be 0,600 – 0,650 – 0,700 – etc., and those of the M100 series hydrometers shall be 0,600 – 0,700 – 0,800 – etc.

TABLE 1 – **Requirements for series of hydrometers**

Series	Maximum total length	Nominal range of each hydrometer	Number of scale divisions × 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	relative density	relative density	mm	mm	mm	ml	ml	graduation lines
L20	335	0,020	100 × 0,000 2	105	36	40	108*	132	5 to 10
L50	335	0,050	100 × 0,000 5	125	23	27	50*	65	2 to 5
M50	270	0,050	50 × 0,001	70	20	24	30	45**	2 to 5
M100	250	0,100	50 × 0,002	85	18	20	18	26	2 to 5
S50	190	0,050	25 × 0,002	40	18	20	18	26	2 or 3

* These minimum volumes below the scale are affected by the recommended limits on stem diameter (see annex B).

** In some countries and in special circumstances, the maximum volume below the scale may be that appropriate to the L50 series.

13 PRINCIPAL DIMENSIONS

13.1 The dimensions of the hydrometers shall conform to the requirements given in table 1.

13.2 No hydrometer shall have a stem of smaller diameter than 4,0 mm.

NOTE — For maximum ease and advantage in manufacture, it has been found preferable to comply with the stem diameters recommended in annex B.

14 ACCURACY

The maximum permitted errors in accuracy for the hydrometers are given in table 2.

TABLE 2 — **Maximum permitted errors**

Series	Maximum permitted error at any point on the scale
	relative density
L20	± 0,000 2
L50	± 0,000 5
M50	± 0,001
M100	± 0,002
S50	± 0,002

15 INSCRIPTIONS

The following information shall be permanently, legibly and unequivocally marked within the hydrometer :

a) an inscription to indicate the basis of the scale;

b) 1) either a particular surface tension expressed in millinewtons per metre (for example "55 mN/m");

2) or a surface tension category as defined in annex A (for example "low S.T.");

3) or a particular liquid;

c) if appropriate, that the hydrometer is adjusted for readings at the top of the meniscus (i.e. for use in opaque liquids);

d) the series number (for example "L50");

e) the marker's or vendor's name or mark;

f) an identification number of the instrument;

g) the number of this International Standard, or the number of the corresponding national standard.

ANNEX A

STANDARD CATEGORIES OF SURFACE TENSION FOR HYDROMETERS

The standard categories of surface tension shown in table 3 are adopted for hydrometers for technical use, so as to provide a precise basis of adjustment and verification and to permit the attainment of appropriate accuracy in hydrometric 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 adjustment of hydrometers, provided that such surface tensions are marked, in millinewtons per metre, within the hydrometer.

Attention is drawn to the provision that, if desired, the name of the liquid [see 15 b) 3)] for which the hydrometer is intended can be marked within the hydrometer, instead of a surface tension category or a precise surface tension.

TABLE 3 — **Standard surface tension categories**

Category	Relative density	Surface tension mN/m	Examples of liquids to which the category is appropriate
Low	increment 0,6 0,7 0,8 0,9	0,00 0,02 0,04 0,06 0,08 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	Organic liquids generally (including ethers, petroleum distillates, coaltar distillates), and all types of oils.
	1,00 to 1,30 inclusive	35	Acetic acid solutions, the surfaces of which have not been specially cleaned for example by overflow.
Medium	0,60 to 0,94 inclusive	As for the "low" category above	Aqueous solutions (including those of ethyl and methyl alcohol, but excluding acetic acid solutions), the surfaces of which have not been specially cleaned.
	0,96 0,97 0,98 0,99	35 40 45 50	
	1,00 to 2,00 inclusive	55	Nitric acid solutions of density greater than 1,3 g/ml, whether specially cleaned or not.
High	1,00 to 2,00 inclusive	75	Aqueous solutions, the surfaces of which have been specially cleaned, for example by overflow, except a) nitric acid solutions of density greater than 1,3 g/ml; b) acetic acid solutions.[1)]

1) Owing to the extreme variability of the surface tension of acetic acid solutions with clean surfaces, these solutions have not been included in the table.

ANNEX B

RECOMMENDED STEM DIAMETERS FOR HYDROMETERS

The diameters shown in table 4 are not mandatory. They are intended for guidance in manufacture.

TABLE 4 — **Recommended stem diameters**

Upper limit of nominal range	Series L20 and L50	Series M50, M100 and S50
	mm	mm
0,6	6,6	7,1
0,7	6,1	6,6
0,8	5,7	6,2
0,9	5,4	5,8
1,0	5,1	5,5
1,1	4,9	5,25
1,2	4,7	5,0
1,3	4,5	4,8
1,4	4,3	4,65
1,5	4,2	4,5
1,6	4,0	4,35
1,7	4,0*	4,2
1,8	4,0*	4,1
1,9	4,0*	4,0

* To avoid fragility in the hydrometers of the series L20 and L50 which extend above the indication 1,6, it is recommended that the stem diameter should not fall below 4,0 mm; this implies that it will not be possible for the volume below the scale of these hydrometers to fall to the minimum permitted by table 1.

ANNEX C

MENISCUS CORRECTIONS

Table 5 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. They have been calculated for hydrometers having the mean dimensions permitted by the specification and are based on an equation due to Langberg which, rearranged, is equivalent to

$$d - d_o = \frac{\Delta d\ \sigma}{g\ \Delta l\ D\ d_o} \left(\sqrt{1 + \frac{2\ g\ D^2\ d_o}{\sigma}} - 1 \right)$$

where

d is the relative density reading at the level of the horizontal liquid surface;

d_o is the relative density reading at the top of the meniscus;

Δd is the scale interval, in units of relative density;

σ is the surface tension, in millinewtons per metre;

g is the acceleration due to gravity, in metres per second squared, taken as the standard acceleration of 9,806 65 m/s^2;

D is the stem diameter, in millimetres;

Δl is the scale spacing, in millimetres.

NOTE — The equation is dimensionally correct if the relative density units are replaced by grams per cubic centimetre.

Those requiring to know the corrections for meniscus height more closely than can be obtained from average values given in table 5 may derive them, having regard to the diameter of the stem of the particular hydrometer concerned, from table 6, which is also deduced from Langberg's equation.

TABLE 5 — **Average meniscus corrections expressed in units of relative density**

Unit : 0,001 relative density

Relative density of liquid	**Surface tension**	**Series of hydrometers (and value of the smallest scale division)**			
	mN/m	**L20 (0,2)**	**L50 (0,5)**	**M50 (1)**	**M100 and S50 (2)**
0,6	15	0,32	0,7	1,2	2,0
0,8	25	0,36	0,7	1,4	2,4
1,0	35	0,36	0,7	1,4	2,4
	55	0,44	0,9	1,6	2,8
	75	0,48	1,0	1,8	3,2
1,5	35	0,28	0,6	1,2	2,0
	55	0,36	0,7	1,4	2,4
	75	0,40	0,8	1,6	2,4
2,0	55	0,32	0,6	1,2	2,0
	75	0,36	0,7	1,4	2,4
Corrections rounded off to nearest one-fifth of the smallest scale division		0,04	0,1	0,2	0,4