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Hydrometers — Principles of construction and adjustment

Aréomètres — Principes de construction et d'étalonnage

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FOREWORD

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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 387 was developed by Technical Committee ISO/TC 48, *Laboratory glassware and related apparatus*, and was circulated to the member bodies in May 1976.

It has been approved by the member bodies of the following countries :

Australia	India	Romania
Austria	Ireland	South Africa, Rep. of
Belgium	Israel	Spain
Canada	Italy	Turkey
Chile	Korea, Rep. of	United Kingdom
Czechoslovakia	Mexico	U.S.A.
France	Netherlands	U.S.S.R.
Germany	Philippines	
Hungary	Poland	

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Hydrometers — Principles of construction and adjustment

1 SCOPE AND FIELD OF APPLICATION

This International Standard sets out principles for the construction and adjustment of glass hydrometers of constant mass which do not incorporate a thermometer.

The corresponding International Standard for glass hydrometers with an incorporated thermometer is ISO . . .[1]

2 REFERENCE

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

3 BASIS OF SCALE

3.1 The scale shall indicate density (mass per unit volume) in kilograms per cubic metre (kg/m^3). The gram per cubic centimetre (g/cm^3) is an acceptable sub-multiple of the SI unit[2].

NOTE — The advantages of using density as the basis of hydrometer scales are explained in annex B.

3.2 The use of a scale other than one based on density is not recommended but, in view of its importance in trade between various countries, the scale based on relative density with reference to water is permitted.

$$\text{relative density} = \frac{\rho_1}{\rho_2}$$

where

ρ_1 is the density of a liquid at a specified temperature t_1;

ρ_2 is the density of water at a specified temperature t_2.

4 REFERENCE TEMPERATURE

4.1 The standard reference temperature for density hydrometers shall be 20 °C.

NOTE — In special circumstances, either 15 °C or 27 °C may be substituted for 20 °C. When it is necessary in tropical countries to work at an ambient temperature considerably above 20 °C, and these countries do not wish to use the standard reference temperature of 20 °C, it is recommended that they should adopt 27 °C.

4.2 Where the relative density scale is used, the reference temperature for the purposes of this International Standard shall be 60 °F (15,56 °C) for both t_1 and t_2, as defined in 3.2.

5 SURFACE TENSION

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 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 11 c) 3)].

6 REFERENCE LEVELS FOR ADJUSTMENT AND READING

6.1 Hydrometers intended for use in translucent liquids shall 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 11 d)].

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

1) In preparation.

2) The alternative g/ml is permitted.

7 CALIBRATION CONDITIONS

Hydrometers shall be adjusted for use under the following conditions :

a) the emergent stem being dry, except in the immediate vicinity of the meniscus;

b) when the hydrometer is slightly displaced from its equilibrium position in a liquid, the stem passing through the liquid surface without causing any apparent alteration in the shape of the meniscus.

8 MATERIALS AND WORKMANSHIP

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

NOTE — The value of this coefficient has been specified in order that various measurement tables and temperature correction tables which have been compiled using this value may be used without error.

8.2 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 9.3.

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.

8.3 There shall be no loose material in the instrument.

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

8.5 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 70 °C or to any higher temperature at which the hydrometer will be used.

9 SHAPE

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 the figure below is preferred, but any design which does not permit air bubbles to be trapped is acceptable.

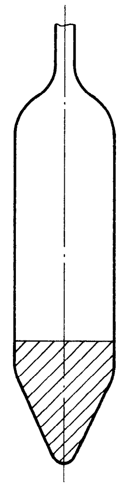

FIGURE — **Preferred design of hydrometer bulb**

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

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

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

10 SCALE

10.1 General

10.1.1 The strip on which the scale and inscriptions are marked shall remain securely fastened in place at the temperature of use (see 8.5).

10.1.2 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 instrument shall be rejected.

* This value complies with ISO 1768.

10.1.3 No hydrometer shall have more than one type of density or relative density scale. If a hydrometer bears duplicate scales of the same type, the values indicated by them shall not differ appreciably.

10.2 Graduation lines

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

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

10.2.3 The graduation lines shall lie in planes perpendicular to the axis of the hydrometer.

10.2.4 The scale shall be straight and without twist.

10.2.5 A line on the strip bearing the scale parallel to the axis of the instrument and indicating the front of the scale is permitted.

10.2.6 The graduation lines indicating the nominal limits of the scale shall be long lines [see 10.3.1 a), 10.3.2 a) and 10.3.3 a)].

10.2.7 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.

10.2.8 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 or more than 2,0 mm.

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

10.3 Sequence of graduation lines

10.3.1 On hydrometer scales whose smallest interval is 0,1 kg/m^3 (or 0,000 1 relative density) or a decimal multiple thereof :

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 hydrometer scales whose smallest interval is 0,2 kg/m^3 (or 0,000 2 relative density) or a decimal multiple thereof :

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 hydrometer scales whose smallest interval is 0,5 kg/m^3 (or 0,000 5 relative density) or a decimal multiple thereof :

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 The scale shall have only one set of numbers, and the last digits of the numbers shall be vertically aligned.

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 shall be figured in full.

10.4.4 At least every tenth line shall be figured.

10.4.5 For density values expressed in grams per cubic centimetre and for relative density values, the decimal sign shall be included for numbers expressed in full, but may be omitted from abbreviated numbers.

11 INSCRIPTIONS

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

a) the basis of the scale, for example "kg/m^3";

b) the standard reference temperature of the hydrometer, for example "20 °C";

c) 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, if the instrument is calibrated for use in a particular liquid, the name of that liquid;

d) whether the hydrometer is adjusted for readings at the top of the meniscus (i.e. for use in opaque liquids);

e) the maker's and/or vendor's name or readily identifiable mark;

f) 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 following standard categories of surface tension 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 [see 11 c) 3)] that, if desired, the name of the liquid for which the hydrometer is intended can be marked within the hydrometer, instead of a surface tension category or a precise surface tension.

TABLE – **Standard surface tension categories**

Category	**Indication** kg/m³	**Surface tension** mN/m	**Examples of liquids to which the category is appropriate**
Low	increment 600 700 800 900	0 20 40 60 80 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.
	1 000 to 1 300 inclusive	35	Acetic acid solutions, the free surfaces of which have not been specially cleaned for example by overflow.
Medium	600 to 940 inclusive 960 970 980 990	As for the category "low" above 35 40 45 50	Aqueous solutions (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	55	Nitric acid solutions of densities greater than 1 300 kg/m³ whether the free surface has been specially cleaned or not.
High	1 000 to 2 000 inclusive	75	Aqueous solutions, the surfaces of which have been specially cleaned, except : a) nitric acid solutions of densities greater than 1 300 kg/m³ 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

NOTES ON THE ADOPTION OF DENSITY AS THE PREFERRED BASIS FOR THE SCALES OF HYDROMETERS

The choice of density as the preferred basis for the scales of hydrometers rests on the following considerations :

The condition of static equilibrium of a floating hydrometer is that the level of the liquid surface intersects the stem so that the volume of liquid displaced by the instrument has a mass equal to that of the hydrometer[1]. The position of equilibrium, and therefore the scale indication, is thus directly determined by the mass per unit volume of the liquid, i.e. its density.

Consequently, density is the simplest and most logical basis for hydrometer scales.

Most purposes for which hydrometers are used are included under the following four headings :

a) to indicate the quality of a product;

b) to follow the progress of an operation, for example fermentation;

c) as a means of assessing the composition of a liquid or of preparing a liquid of known composition;

d) as a means of deducing the mass of a known volume or the volume of a known mass of a liquid.

For purposes a) and b), a hydrometer graduated in terms of density is as useful as any other. As regards c), since observations cannot always be taken at the same temperature, when using hydrometers showing percentage composition there is need for elaborate correction tables.

Once resort to correction tables is necessary, a density hydrometer has the advantage because, with appropriate tables, it can be used for any liquid. Such tables can be used not only with hydrometers, but also with other methods of determining density. Density hydrometers can also be used, in conjunction with very simple tables, for purpose d), the measurement of liquid in bulk.

Density hydrometers are therefore suitable for all these purposes. They are clearly more suitable than hydrometers with arbitrary scales; the latter came into use because, having scales with uniformly spaced graduation marks, they were easy to copy and produce, an advantage which is of little concern at the present day. The advantages of scales of density over composition scale have been mentioned. While relative density scales share these advantages, the conception of relative density, being related to water at various temperatures, is less fundamental than that of density, and is often ambiguous. Moreover, it is taken to be the ratio sometimes of masses (i.e. corrected for air buoyancy) and sometimes of apparent masses (uncorrected for air buoyancy). Density hydrometers, being based simply on mass per unit volume, are free from these causes of uncertainty and error.

1) The small forces of capillarity and air-buoyancy acting on the stem are neglected here, being irrelevant to the main argument.

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