INTERNATIONAL STANDARD ISO 384

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Laboratory glassware — Principles of design and construction of volumetric glassware

Verrerie de laboratoire — Principes de conception et de construction de la verrerie volumétrique

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

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

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

No member body expressed disapproval of the document.

This International Standard cancels and replaces ISO Recommendation R 384-1964, of which it constitutes a technical revision.

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CONTENTS

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Laboratory glassware — Principles of design and construction of volumetric glassware

1 SCOPE AND FIELD OF APPLICATION

This International Standard sets out principles for drawing up specifications for articles of volumetric glassware.

2 REFERENCES

ISO 383, *Laboratory glassware — Interchangeable conical ground joints.*

ISO 1769, *Laboratory glassware — Pipettes — Colour coding.*

ISO 4791/II, *Laboratory glassware — Vocabulary — Part II.*[1)]

3 UNIT OF VOLUME, AND REFERENCE TEMPERATURE

3.1 Unit of volume

The unit of volume shall be the cubic centimetre (cm^3) or, in special cases, the cubic decimetre (dm^3) or cubic millimetre (mm^3).

NOTE — The term millilitre (ml) is commonly used as a special name for the cubic centimetre (cm^3) and, similarly the litre (l) for the cubic decimetre (dm^3) and the microlitre (μl) for the cubic millimetre (mm^3), in accordance with the International System of units (SI).

3.2 Reference temperature

The standard reference temperature, i.e. the temperature at which the article of volumetric glassware is intended to contain or deliver its nominal volume (nominal capacity), shall be 20 °C.

NOTE — 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 adopt a temperature of 27 °C.

4 VOLUMETRIC ACCURACY

4.1 In a specification where two classes of accuracy are required,

- the higher grade shall be designated "class A";
- the lower grade shall be designated "class B".

4.2 Limits of volumetric error shall be specified for each type of article having regard to the method and purpose of use and the class of accuracy.

4.3 The numerical values of limits of volumetric error for articles of volumetric glassware for general purposes shall be chosen from the series 10 — 12 — 15 — 20 — 25 — 30 — 40 — 50 — 60 — 80, or a suitable decimal multiple thereof.[2)]

4.4 The limits of volumetric error specified for a series of sizes of an article should provide a reasonably uniform progression in relation to capacity when plotted on a logarithmic graph as shown in annex A. Such a graph should be included as an annex to all specifications in which a series of three or more sizes of an article is specified.

4.5 Where two classes of accuracy are specified, then the limits of volumetric error permitted for class B should, in general, be approximately twice those permitted for class A.

4.6 For all articles having a scale, the maximum permitted volumetric error for either class of accuracy shall not exceed the volume equivalent of the smallest scale division.

1) In preparation.

2) This is the R″ 10 series of preferred numbers and has been adopted because decimal sub-multiples of some of the unrounded numbers, for example 31,5, would appear to imply a degree of precision which is not intended and which could not be measured in practice.

4.7 Where two classes of accuracy are specified, the class A limit of volumetric error specified for any article shall not be smaller than that calculated from the maximum permitted diameter at the relevant graduation line by the formulae detailed in annex B; the corresponding class B limit shall be derived in accordance with 4.5.

Where only one class of accuracy is specified, the limit of volumetric error specified for any article shall be similarly determined, on the basis of a preliminary decision as to whether class A or class B accuracy is appropriate to the article in question.

A nomograph, plotted on a logarithmic scale as shown in annex B, should be included, as an annex, in all specifications for articles of volumetric glassware.

4.8 The limit of volumetric error specified for any article designed for delivery shall also be not less than four times the standard deviation (RMS) determined experimentally by an experienced operative from a series of at least twenty replicable determinations of delivered capacity on the same article, carried out strictly in accordance with the method specified for that article.

5 METHODS OF VERIFICATION AND USE

5.1 The method of verification should be clearly specified for each article of volumetric glassware.

5.2 Any difference between the method of verification and the method of use shall be clearly indicated.

5.3 Delivery times and, where applicable, waiting times for all articles intended for delivery of a liquid shall be specified.[1)]

5.4 Setting of the meniscus shall be performed by one of the two methods detailed below. Wherever practicable, the meniscus should descend to the position of setting.

a) The meniscus is set so that the plane of the upper edge of the graduation line is horizontally tangential to the lowest point of the meniscus, the line of sight being in the same plane. In the case of a mercury meniscus, however, the highest point of the meniscus is set to the lower edge of the graduation line.

b) The meniscus is set so that the plane of the centre of the graduation line is horizontally tangential to the lowest point of the meniscus. The eye is raised towards the plane and observes the front and back portions of the line apparently meeting the lowest point simultaneously. In the case of a mercury meniscus, the eye is lowered towards the plane of the centre of the graduation line.

NOTE — The difference between meniscus positions resulting from the alternative methods of setting is the volume equivalent to one-half the thickness of the graduation line. In the case of articles where the capacity is read as the difference between two meniscus readings (for example on a burette) then no error results if the article is manufactured using one method and is later used by the other method. Even in most unfavourable cases of single-mark articles (for example large flasks), when working to the highest attainable accuracy, the difference resulting from use of the two methods is unlikely to exceed 30 % of the class A limit of error, and a correction can be calculated where necessary.

5.5 When the article is used with opaque wetting liquids, the horizontal line of sight shall be taken through the upper edge of the meniscus, and where necessary an appropriate correction shall be applied.

6 CONSTRUCTION

6.1 Material

Volumetric glassware shall be constructed of glass of suitable chemical and thermal properties. It shall be as free as possible from visible defects and shall be reasonably free from internal stress.

6.2 Shape

All articles shall be of a shape which will facilitate emptying and drainage, and should preferably be of circular cross-section.

6.3 Capacity

6.3.1 The numerical values of capacity of articles of volumetric glassware for general purposes should preferably be chosen from the series 10 – 20 – 25 – 50, or a decimal multiple or submultiple thereof.

6.3.2 The numerical value of the volume equivalents of the smallest division on articles having a scale shall be chosen from the series 1 – 2 – 5, or a decimal multiple or submultiple thereof.

6.3.3 In the case of a special purpose article of volumetric glassware which is to be graduated for direct reading of capacity when used with a specific liquid other than water, the specification should also indicate the corresponding capacity when used with pure water so that the latter can be used for verification.

1) See definitions given in ISO 4791/II.

6.4 Stability

Vessels provided with a flat base shall stand firmly thereon without rocking when placed on a level surface and, unless specified otherwise, the axis of the graduated portion of the vessel should be vertical. Wherever practicable, vessels shall not topple when placed empty on a surface inclined at an angle to the horizontal to be specified for each article.

Vessels provided with a base which is not circular shall meet this requirement in all directions.

6.5 Delivery jets

6.5.1 Delivery jets should be strongly constructed with a smooth and gradual taper without any sudden constriction at the orifice.[1)]

6.5.2 The end of the jet shall be finished by one of the methods listed below in order of preference :

a) smoothly ground square with the axis, slightly bevelled on the outside and fire-polished;

b) smoothly ground square with the axis and slightly bevelled on the outside;

c) cut square with the axis and fire-polished.

A fire-polished finish reduces the danger of chipping in use, but should not result in constriction, as indicated in 6.5.1, or in undue stress.

6.5.3 The jet should form an integral part of an article intended for class A and should preferably form an integral part of an article intended for class B.

6.6 Stoppers

6.6.1 Glass stoppers should preferably be ground so as to be interchangeable, in which case the ground portions shall comply with ISO 383. If individually fitted, they shall be well ground so as to prevent leakage, preferably with a taper of approximately 1/10.

6.6.2 Stoppers of a suitably inert plastics material may be permitted as an alternative to glass. In such cases, the glass socket into which the stopper fits should preferably comply with ISO 383.

6.7 Stopcocks or similar devices

6.7.1 Stopcocks and similar devices shall be designed to permit smooth and precise control of outflow and to prevent a rate of leakage greater than that allowed in the specification for the article.

6.7.2 Stopcocks and similar devices shall be made from glass or from suitable inert plastics material.

6.7.3 All-glass stopcocks shall have the key and barrel finely ground preferably to a taper of 1/10 and shall comply with appropriate national or international specifications.

6.7.4 Glass stopcock barrels to receive plastics keys shall be polished internally.

6.7.5 Stopcock components may be fitted with suitable retaining devices.

7 LINEAR DIMENSIONS

7.1 Linear dimensional requirements shall be specified for all articles of volumetric glassware in such a way as to ensure that :

a) the article is convenient and satisfactory for its intended use;

b) in a series of sizes of an article, unnecessary inconsistencies in shape and proportions can be avoided;

c) a limitation is placed on the maximum internal diameter at the graduation line or lines (see 4.7 and annex B); this limitation may be a direct limitation on diameter or an indirect one by a minimum limitation on scale length;

d) the requirement for spacing of graduation lines specified in 9.1.2 is achieved;

e) the stability requirements of 6.4 can be achieved.[2)]

Linear dimensions shall be specified in millimetres.

7.2 Dimensional requirements should not be more restrictive than is necessary to achieve the aims listed in 7.1.

7.3 In order to permit maximum freedom in manufacture within the restrictions imposed by 7.1, dimensions may be divided into two categories of importance and classified as "essential dimensions" and "guidance dimensions".

1) A reason for not permitting a sudden constriction at the orifice is that such a shape could conceal the fact that the jet had been damaged, cut back and re-fired. Following such treatment the volume delivered by the article could have been altered beyond the specified limits of volumetric error without any visible evidence of this fact.

2) The stability requirement is controlled by the angle of displacement from the vertical at which the centre of gravity comes vertically above the edge of the base. The height of the centre of gravity is not only a function of the specified dimensions but is also affected by the distribution of mass in the various parts of the article. It is, however, important to ensure that the specified dimensions do not make it difficult or impossible to achieve the required stability.

7.4 In a specification where these two categories of dimensions are used, the requirements of 7.1 c) and d) shall be included as essential dimensions.

7.5 The requirements of 7.1 b) can in many cases be ensured sufficiently by guidance dimensions.

7.6 Essential dimensions shall be expressed in one of the following ways, whichever is the most suitable or convenient[1]:

a) a median figure with ± tolerance;

b) a maximum and minimum figure;

c) a maximum or a minimum figure, if the other limit is unimportant or is controlled by other factors in the specification.

7.7 A dual limitation on dimensional tolerances should be avoided wherever possible; for example, if an overall length is limited by the methods shown in 7.6 a) or 7.6 b) and there are two or more additive components of this length to be specified, then

– either the tolerance on overall length should be sufficient to accommodate the additive tolerance of all the components,

– or the least important component should be left undimensioned so that it is controlled only by the difference between overall length and the total length of the other components.

7.8 Guidance dimensions shall be expressed as median figures without tolerance, or as minima or maxima. If both limits are considered necessary, then the dimension in question shall be classed as an essential dimension.

8 GRADUATION LINES

8.1 Graduation lines shall be clean, permanent lines of uniform thickness.

8.2 A maximum thickness of graduation line shall be specified appropriate to the particular article and its class of accuracy. This thickness shall not exceed one-half of the linear equivalent of the limit of volumetric error (see annex C).

8.3 On articles having a scale, the specified maximum thickness of lines shall not exceed one-quarter of the minimum distance between centres of adjacent lines (see also annex C).

8.4 All graduation lines shall lie in planes at right angles to the longitudinal axis of the graduated portion of the article. On articles provided with a flat base, the graduation lines shall therefore lie in planes parallel to the base.

8.5 In general, graduation lines should be confined to cylindrical portions of an article's cross-section and should preferably be situated not less than 10 mm from any change in diameter. In special circumstances, preferably for class B articles only, graduation lines may be provided on a parallel side portion of non-circular cross-section or on a conical or tapered portion of the article.

8.6 On articles not having a scale, all graduation lines should extend completely round the circumference of the article, except that a gap, not exceeding 10 % of the circumference, may be permitted. In the case of an article which is restricted as to the normal direction of viewing in use, this gap should be at the right or left of the normal direction of view.

9 SCALES

9.1 Spacing of graduation lines

9.1.1 There should be no evident irregularity in the spacing of graduation lines (except in special cases where the scale is on a conical or tapered portion of the article and a change of subdivision takes place).

9.1.2 The minimum distance between the centres of adjacent graduation lines shall be not less, in relation to diameter, than that calculated from the formula

$(0{,}8 + 0{,}02\,D)$ mm

where D is the maximum permitted internal diameter of the tube in millimetres (see also annex C).

9.2 Length of graduation lines (see figure 2)

9.2.1 On articles of circular cross-section having a scale, the length of the graduation lines shall be varied so as to be clearly distinguishable and shall be in accordance with the provisions of 9.2.2, 9.2.3 or 9.2.4.

9.2.2 *Graduation pattern I*

a) The length of the short lines should be approximately, but not less than, 50 % of the circumference of the article.

b) The length of the medium lines should be approximately 65 % of the circumference of the article and should extend symmetrically at each end beyond the end of the short lines.

c) The long lines should extend completely round the circumference of the article, but a gap, not exceeding 10 % of the circumference, may be permitted (see 8.6).

1) The choice between 7.6 a) and 7.6 b) will often be guided by economy or simplicity of figures and sometimes by the avoidance of an implication of greater precision than is intended.

9.2.3 *Graduation pattern II*

a) The length of the short lines should be not less than 10 % and not more than 20 % of the circumference of the article.

b) The length of the medium lines should be approximately 1,5 times the length of the short lines and should extend symmetrically at each end beyond the end of the short lines.

c) The long lines should extend completely round the circumference of the article, but a gap, not exceeding 10 % of the circumference, may be permitted (see 8.6).

9.2.4 *Graduation pattern III*

a) The length of the short lines should be not less than 10 % and not more than 20 % of the circumference of the article.

b) The length of the medium lines should be approximately 1,5 times the length of the short lines and should extend symmetrically at each end beyond the ends of the short lines.

c) The length of the long lines should be not less than twice the length of the short lines and should extend symmetrically at each end beyond the ends of the short and medium lines.

9.2.5 In special cases where scales are required on non-circular cross-section or conical or tapered portions of an article, the requirements of 9.2.2, 9.2.3 or 9.2.4 should be appropriately modified.

9.3 Sequence of graduation lines (see figure 1)

9.3.1 On articles in which the volume equivalent of the smallest scale division is 1 ml (or a decimal multiple or submultiple thereof) :

a) every tenth graduation line is a long line;

b) there is a medium line midway between two consecutive long lines;

c) there are four short lines between consecutive medium and long lines.

9.3.2 On articles in which the volume equivalent of the smallest scale division is 2 ml (or a decimal multiple or submultiple thereof) :

a) every fifth graduation line is a long line;

b) there are four short lines between two consecutive long lines.

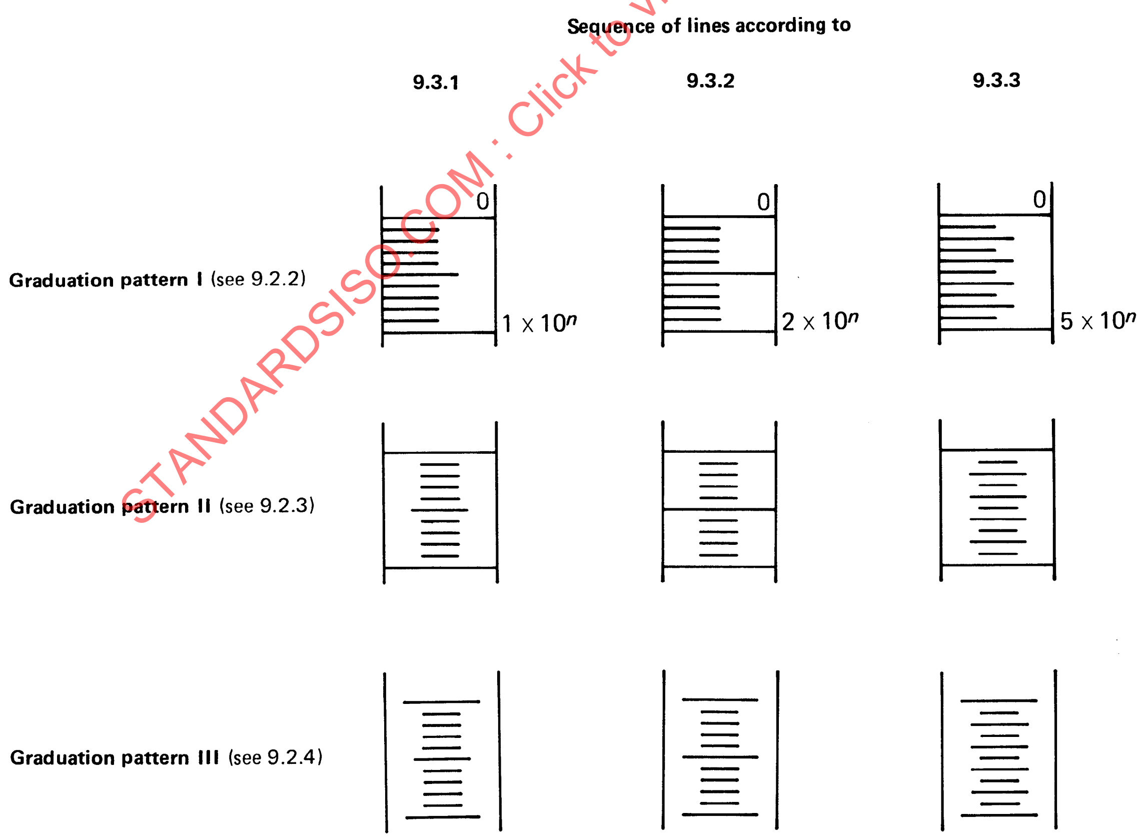

FIGURE 1 — **Length and sequence of graduation lines**

9.3.3 On articles in which the volume equivalent of the smallest scale division is 5 ml (or a decimal multiple or submultiple thereof) :

a) every tenth graduation line is a long line;

b) there are four medium lines equally spaced between two consecutive long lines;

c) there is one short line between two consecutive medium lines or between consecutive medium and long lines.

9.4 Position of graduation lines (see figure 2)

9.4.1 On articles graduated according to pattern I with vertical scales in accordance with 9.2.2, the ends of the short graduation lines shall lie on an imaginary vertical line down the centre of the front of the article, the lines themselves extending preferably to the left when the article is viewed from the front in the position of normal use.

9.4.2 On articles graduated according to pattern II or III, with vertical scales in accordance with 9.2.3 and 9.2.4, the mid-points of the short and medium graduation lines shall lie on an imaginary vertical line down the centre of the front of the article, when the article is viewed from the front in the position of normal use.

10 FIGURING OF GRADUATION LINES

10.1 On articles with one graduation line, the number representing nominal capacity may be included with the other inscriptions and need not be adjacent to the graduation line.

10.2 On articles having two or three graduation lines, the numbers representing nominal capacity need not be adjacent to the lines to which they relate, if some other more suitable method of identification is used (for example as covered by the note to 11.1 d)).

10.3 On articles having one principal graduation line and a small number of subsidiary lines, the number representing the principal capacity may be included with the other inscriptions as in 10.1 provided that the subsidiary graduation lines are suitably identified.

10.4 On articles having a scale :

a) the scale shall be so figured as to enable the value corresponding to each graduation line to be readily identified;

b) the scale should normally have only one set of figures;

c) at least every tenth line shall be figured;

d) figures shall be confined to long graduation lines and should be placed immediately above the line and slightly to the right of the adjacent shorter graduation lines;

NOTE — Where long lines complying with 9.2.3 are used (i.e. not extending completely round the article), an alternative scheme of figuring may be permitted, in which the figure is placed slightly to the right of the end of the long line in such a way that an extension of the line would bisect it.

e) where it is necessary in special cases to use a number relating to a medium or short graduation line, the number should be placed slightly to the right of the end of the line in such a way that an extension of the line would bisect it.

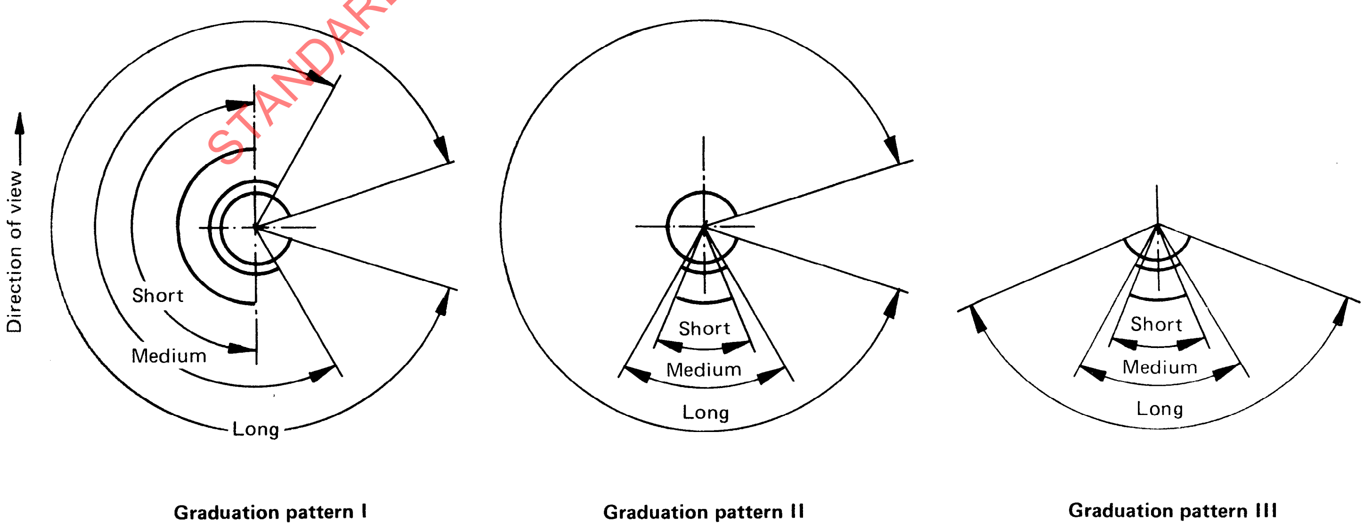

FIGURE 2 — **Position of graduation lines**

11 INSCRIPTIONS

11.1 The following inscriptions shall be permanently marked on each article :

a) a number indicating the nominal capacity (except for articles with graduation lines figured to indicate capacity);

b) the symbol "cm^3" or the symbol "ml" to indicate the unit in terms of which the article is graduated (see note to 3.1);

c) the inscription "20 °C" to indicate the standard reference temperature;

NOTE — Where, exceptionally, the reference temperature is 27 °C, this value should be substituted for 20 °C.

d) the letters "**In**" to indicate that the article has been constructed to **contain** its indicated capacity, or the letters "**Ex**" to indicate that the article has been constructed to **deliver** its indicated capacity;

NOTE — Where the article has graduation lines intended to indicate both content and delivery, the letters shall be close to the line to which they refer.

e) the inscription "A" or "B" to indicate the class of accuracy to which the article is intended to belong;

f) on articles intended for use with a specified waiting time, the waiting time shall be inscribed, for example : "Ex + 15 s";

g) the maker's or vendor's name or mark.

11.2 Such of the following additional inscriptions as are required by national regulations should be marked on class A articles intended for official verification or certification. They should preferably be marked on all class A articles and may be also used, if desired, on class B articles :

a) an identification number; the same number shall be marked on the handles of stopcocks, if required, and also on stoppers which are not interchangeable; if interchangeable glass stoppers are provided, then the stopper and neck should be marked with the joint size designation in accordance with ISO 383;

b) on articles intended for delivery through a jet, the time in seconds for unrestricted delivery of the contents, using pure water;

c) in the case of an article of volumetric glassware which has been specially constructed for direct reading of capacity when used with a specific liquid other than water, the name or chemical formula of the liquid in question;

d) the limit of volumetric error, valid for the article, for example ± . . . ml.

11.3 The following inscriptions shall also be marked on articles to which they apply :

a) in the case of an article made from a glass having a coefficient of (cubical) thermal expansion outside the range 25×10^{-6} K^{-1} to 30×10^{-6} K^{-1} (i.e. outside the range of the usual types of soda-lime glass), an indication to this effect, so that for certification purposes the appropriate correction table may be selected; this requirement will be met by the manufacturer's name or trade mark if the coefficient of thermal expansion is published in the corresponding catalogues;

b) in the case of pipettes constructed for delivery to include the last drop being blown out of the jet, the word BLOWOUT and/or a white enameled (or etched or sandblasted) band, 3 to 5 mm wide, approximately 15 to 20 mm from the top of the suction tube.

NOTE — In national standards, provision may be made for additional marking with equivalent terms in other languages (for example, "Ausblasen", "Inflatur", "À souffler").

12 VISIBILITY OF GRADUATION LINES, FIGURES AND INSCRIPTIONS

12.1 All figures and inscriptions shall be of such size and form as to be clearly legible under normal conditions of use.

12.2 All graduation lines, figures and inscriptions shall be clearly visible and permanent.

13 COLOUR CODING

In the case of pipettes, there should be a requirement that colour coding, if used, must comply with the requirements of ISO 1769.

ANNEX A

LIMIT OF VOLUMETRIC ERROR IN RELATION TO CAPACITY

Sub-clause 4.4 of this International Standard specifies a requirement that limits of volumetric error for each size of an article, when a series of three or more sizes are specified, should be chosen so as to provide a reasonably uniform progression in relation to the capacities of the articles.

The attainment of this requirement can most conveniently be checked by means of a graph of the form shown in figure 3.

The logarithmic decades on this graph can be scaled in tenths, tens, etc., as appropriate to the series of capacities of the article in question and their proposed limits of volumetric error.

The decade rulings shown include heavy lines for the preferred values of errors listed in 4.3 and of capacities listed in 6.3.1. Thin line rulings are shown for other capacities which may be required for special purposes.

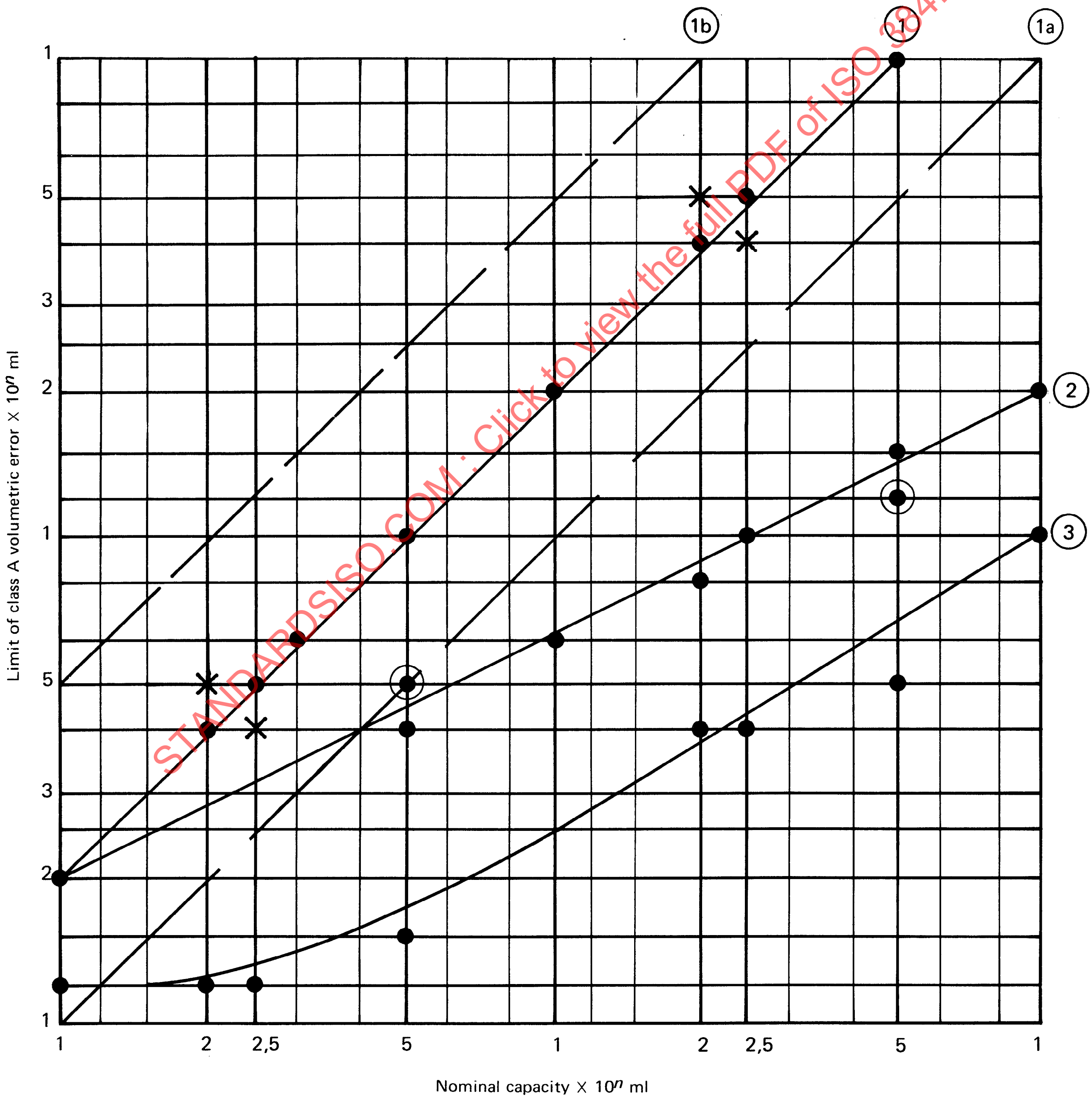

FIGURE 3

The three lines shown on the graph, by way of example, illustrate features as follows :

A.1 LINE (1)

A series of sizes in which the limits of error are directly proportional to capacity, i.e. errors which increase decade by decade with capacity. A proportion of this order of magnitude is likely to be applicable to a series of sizes of an article in which capacity and diameter are variables but the length is approximately constant throughout the range of sizes, for example graduated pipettes.

The slope of this line is 1, or 45° to the base line, and in the example shown would represent a limit of volumetric error constant at 2 % (or 0,2 % or 0,02 % according to the decade scales) of capacity throughout the range of sizes.

The broken lines of similar slope shown as (1a) and (1b) indicate a similar proportional relationship between error and capacity but of different magnitudes corresponding to 1 % (or 0,1 % etc.) and 5 % (or 0,5 % etc.) respectively.

The points X shown near line (1) illustrate less satisfactory limits of error which would have resulted if the 2 and 2,5 sizes (in either decade) had been allotted the same limits of error.

A.2 LINE (2)

A series of sizes in which the limits of error increase by one decade for two decades increase in capacity. A proportion of this order of magnitude is likely to be applicable to one-mark articles in which all three linear dimensions increase proportionately with increase of capacity, for example one-mark pipettes or flasks.

The slope of this line is 1 in 2, or approximately 26°30′ to the base line. A series of articles to which a graph with a slope of anything less than 45° applies will provide increasing precision with increasing capacity.

In such cases many of the plotted points will not lie exactly on a straight line. When a specification is being drafted, the aim should be to choose the line which provides the best possible fit to the plotted points and then to check that, for each capacity, the nearest available preferred limit of error has been selected. In the example illustrated, two alternative errors have been shown against capacity 5 in each decade, in each case the one marked with a circle being preferable.

A.3 LINE (3)

This illustrated the third possibility which may be required in certain cases where very small capacities are included in a series of sizes. The upper section is a straight line with an angle of slope between 26°30′ and 45° as described in the preceding clause, but the lower continuation of the line is a curve of reducing angle of slope which, in limiting cases, may become horizontal at the extreme end.

There are two potential causes for this reduction in angle of slope on very small articles :

a) It may be impracticable to reduce the diameter at the graduation line sufficiently to accommodate a smaller limit of error within the limitation of 4.7; for example, one-mark flasks below about 10 ml capacity are inconvenient if the neck is of such a small diameter that the flask cannot be readily filled or emptied, or will not permit the entry of a pipette of suitable capacity.

b) In the case of small articles intended for delivery, for example pipettes of capacities smaller than about 0,5 ml, the standard deviation requirements of 4.8 may be more restrictive than the diameter limitation of 4.7 in preventing the use of smaller limits of error.

The graph shown as an example in figure 3 is designed for explanatory purposes and includes two complete logarithmic decades on each of the axes. The numerals shown on these decades are only logarithmic and do not indicate any orders of magnitude.

The graph is recommended in 4.4 to be included in appropriate International Standards and should be fully figured so that the capacities and limits of error can be read directly. It should preferably include only the ranges of capacity and limit of error required in the individual specification to which it applies and should be drawn to the largest scale which can be accommodated within the size of the page, i.e. a limit of 150 mm.

In the case of specifications which included two classes of accuracy, it should be sufficient for the graph to show only the class A limits of error unless, in a special case, a ratio of errors different from that required by 4.5 has been adopted.

ANNEX B

LIMIT OF VOLUMETRIC ERROR IN RELATION TO DIAMETER AT THE MENISCUS

Sub-clause 4.7 of this International Standard specifies a requirement that the limit of volumetric error specified for any article shall not be less than that calculated for the maximum permitted diameter by means of a formula.

This requirement is designed to ensure that the intended precision of the article can be readily attained under normal conditions of use, i.e. that a volume equal to the limit of volumetric error should occupy a readily visible length of tube of the maximum diameter allowed.

The following symbols are used in deriving the formula :

V is the limit of volumetric error, in microlitres;

D is the internal diameter, in millimetres, of the tube at the meniscus;

L is the linear equivalent of V, in millimetres, i.e. the length of tube of diameter D occupied by a volume equal to V;

L can be considered to be made up of two components :

a) a basic minimum of 0,4 mm which is the lowest limit, even on tubes of very small diameter, which has proved to be satisfactory in normal use and practicable for economic routine manufacture;

b) an additional allowance for potential parallax error in reading, which is related to the diameter, and for which the symbol "p" is used.

The value for this parallax component can be derived as follows :

If θ is the angle between the operator's sight-line to the meniscus and the horizontal plane tangential to the meniscus, then :

$$\tan \theta = \frac{p}{D/2} = \frac{H}{d + D/2}$$

$$p = \frac{HD}{2d + D}$$

where

p is the error in reading, in millimetres;

d is the distance of the operator's eye from the scale, in millimetres;

H is the distance of the operator's eye above or below the horizontal plane tangential to the meniscus, in millimetres;

D is the diameter of tube, neck or column which carries the scale, in millimetres.

Example :

If $H = 5$ mm, and $d = 200$ mm, then

$$p = \frac{5D}{400 + D}$$ over the extreme range of diameters.

If $D = 1$ mm then $p = 0{,}012\,5$ mm $= 0{,}012\,5\,D$

$D = 100$ mm then $p = 1{,}0$ mm $= 0{,}010\,0\,D$

So without significant error a constant figure of 0,01 D can be substituted.[1)]

1) It should be noted that this formula tends to exaggerate the potential parallax error on a meniscus greater than about 25 mm diameter. In such a case the flat centre portion of the meniscus helps to minimize parallax error, but the effect does not significantly affect this formula.

The total linear equivalent of the limit of volumetric error is therefore given by

$$L \geqslant (0,4 + 0,01\,D)$$

$$V \geqslant \frac{\pi}{4} D^2\,(0,4 + 0,01\,D)$$

Again without significant error $\frac{\pi}{4}$ can be rounded to 0,8 and the result can be divided by 1 000 to convert to cm^3, thus :

$$V \geqslant \frac{0,8\,D^2}{1\,000}\,(0,4 + 0,01\,D)$$

where D is in millimetres.

For the series of limits of volumetric error specified in 4.3 of this International Standard, appropriate maximum diameters at the meniscus calculated by this formula are shown in the table.

TABLE – **Maximum internal diameter of tube at the graduation line appropriate to selected limits of volumetric error**

Limit of volumetric error ± µl	**Maximum internal diameter of tube at the graduation line** mm	**Limit of volumetric error** ± µl	**Maximum internal diameter of tube at the graduation line** mm
0,1	0,56	100	15
0,2	0,78	120	17
0,3	0,96	150	18
0,4	1,1	200	20
0,5	1,2	250	23
0,6	1,3		
0,8	1,5	300	25
		400	27
1	1,7	500	29
2	2,4	600	32
3	2,9	800	36
4	3,4		
5	3,8	1 000	40
6	4,2	1 200	44
8	4,7	1 500	47
		2 000	52
10	5,3	2 500	57
12	6,0	3 000	61
15	6,4	4 000	68
20	7,3	5 000	74
25	8,1	6 000	80
30	8,7	8 000	83
40	10	10 000	96
50	11		
60	12		
80	13,5		

The relationship between *V*, *L* and *D* can be clearly demonstrated by means of a nomograph prepared on a logarithmic scale as shown in figure 4.

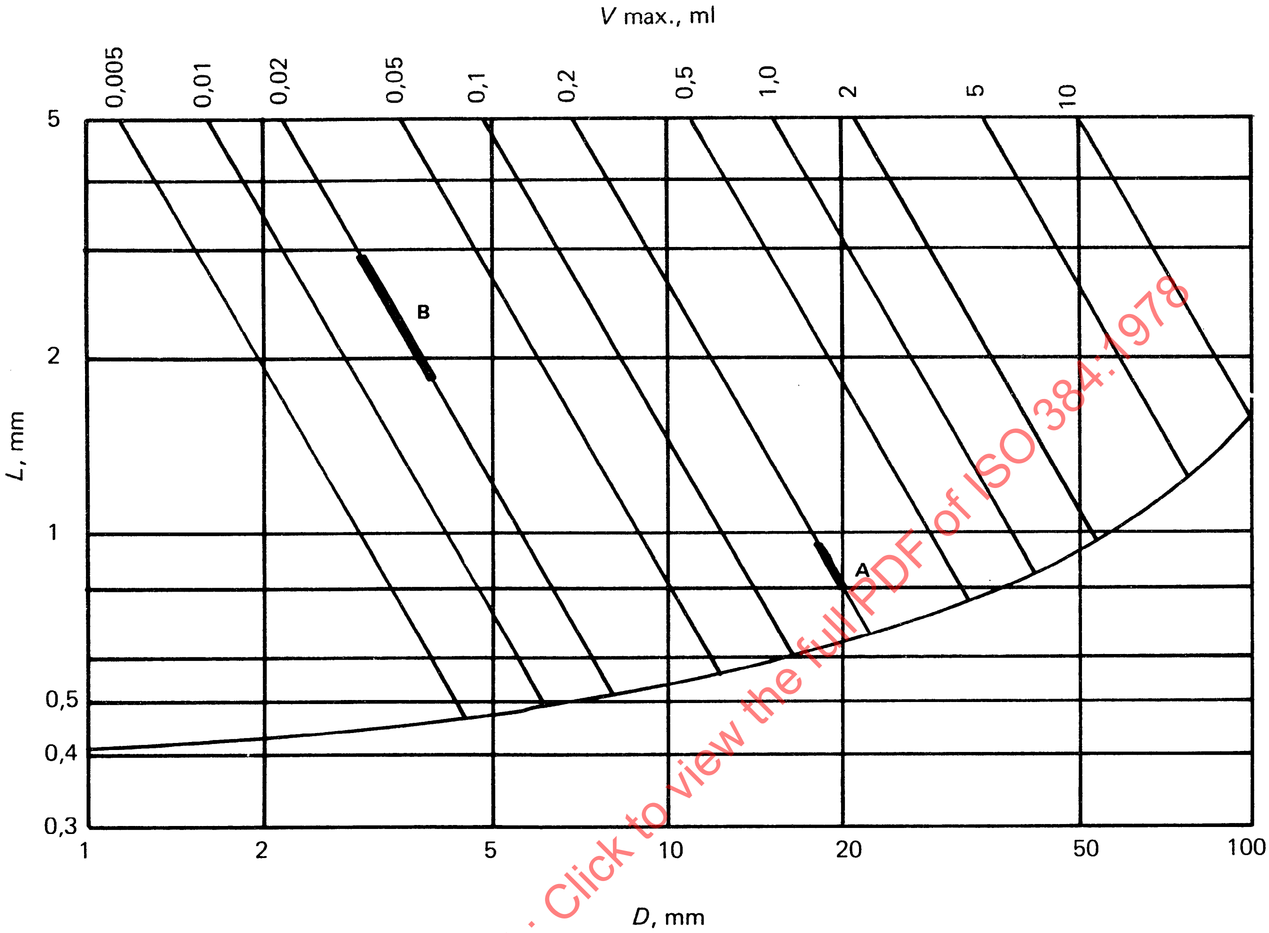

FIGURE 4

The curved line across the nomograph results from plotting the formula

$L = (0{,}4 + 0{,}01\ D)$

and thus oblique lines representing limits of volumetric error terminate on this curve at points which represent maximum appropriate diameters as given in the table.

The thicker portions on two of these oblique lines provide examples of the method of application of the nomograph as follows :

In line A the specification for an article gives

D to be 17 to 20 mm

V to be ± 0,2 ml

In this example, which could apply to a volumetric flask, the upper limit of *D* approaches very close to the limit curve.

In line B the application for an article gives

D to be 3 to 4 mm

V to be 0,02 ml

In this example, which could apply to a pipette, either a larger diameter or a smaller limit of error would appear to be possible. The inference is that in this case the limit of error is controlled by the standard deviation requirement of 4.8 rather than by the dimensional requirements of 4.7.