TECHNICAL REPORT

ISO/TR 3666

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Viscosity of water

Viscosité de l'eau

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established 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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 3666, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants.*

This second edition cancels and replaces the first edition (ISO/TR 3666:1977), which has been technically revised.

Annexes A and B of this Technical Report are for information only.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

Viscosity of water

1 Scope

This Technical Report gives values for the viscosity of water at several reference temperatures. The viscosity of water is commonly used throughout the world as the basis for the calibration of relative viscometers.

2 Values for the viscosity of water

The dynamic viscosity, η, and the kinematic viscosity, ν, of water at 20 °C and normal atmospheric pressure (0,101 325 MPa) are given by:

η = 1,001 6 mPa·s

ν = 1,003 4 mm²/s

The estimated relative uncertainty associated with both values is 0,17 %, as detailed in annex A.

NOTE 1 The viscosity values stated above are based on the value of 1,001 9 mPa·s reported by Swindells et al. in 1952 (see annex B) which was also the basis of ISO/TR 3666:1977 and corresponds to the IPTS-48 temperature scale. The change of this value by 0,000 3 mPa·s is due to the difference of 12 mK between the IPTS-48 and the ITS-90 temperature scale at 20 °C.

Based on a critical evaluation of the results of water viscosity measurements published between 1949 and 1994 (see annex A), the temperature dependence of the viscosity of water, expressed by the viscosity ratio $V_r = \eta(T)/\eta(20\ °C)$ for temperatures T between 15 °C and 40 °C, is given by the values listed in table 1.

Table 1 — Recommended values for the (dynamic) viscosity ratio $V_r = \eta(T)/\eta(20\ °C)$ of water at various reference temperatures; density ρ, temperature coefficients U_η, U_ν, and pressure coefficient γ

Temperature, T °C	Dynamic viscosity ratio, V_r	Density, ρ kg/m³	Temperature coefficient, U_η K^{-1}	Temperature coefficient, U_ν K^{-1}	Pressure coefficient, γ 10^{-4} MPa^{-1}
15	1,136 0 ± 0,000 6	999,10	0,026 5	0,026 4	-6,14
20	1,000 00	998,20	0,024 5	0,024 3	-4,28
23	0,930 6 ± 0,000 4	997,54	0,023 5	0,023 2	-3,28
25	0,888 5 ± 0,000 3	997,04	0,022 8	0,022 5	-2,65
30	0,795 8 ± 0,000 3	995,65	0,021 3	0,021 0	-1,22
40	0,651 4 ± 0,000 2	992,21	0,018 8	0,018 5	+1,20

For additional information the pressure coefficient, γ, is given by the following equation.

$$\gamma = \frac{1}{\eta} \cdot \frac{d\eta}{dp} \qquad (1)$$

where

p is the pressure, in megapascals.

The temperature coefficients U_η and U_ν are given by equations 2 and 3.

$$U_\eta = -\frac{1}{\eta} \cdot \frac{d\eta}{dT} \tag{2}$$

$$U_\nu = -\frac{1}{\nu} \cdot \frac{d\nu}{dT} \tag{3}$$

Uncertainties are stated as confidence interval at a 95 % confidence level. Temperatures are in accordance with the International Temperature Scale ITS-90.

3 Realization of the viscosity of water

The viscosity values reported in this Technical Report refer to freshly double-distilled water.

When using water for the calibration of viscometers, which are sensitive to surface tension effects (for example capillary viscometers), special care has to be taken to avoid any contamination with surfactants. In this case it is recommended to use equipment made from fused silica for the distillation and storage of water.

Annex A
(informative)

Results of water viscosity measurements

It is current practice throughout the world to use the viscosity of water at 20 °C and atmospheric pressure as the metrological basis of viscometry. Based on the value of η(20 °C) = 1,001 9 mPa·s as published by Swindells et al. [1] in 1952, the internationally accepted viscosity values of water as stated in ISO/TR 3666:1977 are η(20 °C) = 1,002 mPa·s for dynamic viscosity and ν(20 °C) = 1,003 8 mm²/s for kinematic viscosity, with an estimated uncertainty of 0,25 % for both values.

From the present standpoint, these values require updating for the following reasons:

a) according to the new International Temperature Scale, ITS-90, the viscosity value of 1,002 mPa·s, which was determined using the IPTS-48, is no longer valid for 20,000 °C, but applies to a temperature of 19,988 °C. The relative change in viscosity corresponding to this 12 mK temperature difference is 3×10^{-4} and cannot be neglected with respect to a repeatability of 1×10^{-4} which is achieved in precise measurements;

b) besides the viscosity at 20 °C, reference values of high precision should be available in a wider temperature range, especially at 23 °C and 25 °C, which are frequently used as reference temperatures;

c) it is inconsistent to state four valid digits for the dynamic viscosity and five for the kinematic viscosity while stating the same uncertainty for both;

d) with regard to the present knowledge of the viscosity of water [1- 6], the estimated uncertainty of 0,25 % is considered to be unrealistically high.

Since the work of Swindells et al., four other absolute viscosity determinations, performed directly on water and using different methods, have been published [2 - 5]. The uncertainties stated by the authors are not directly comparable with each other and also indicate the existance of undetected systematic deviations. Therefore, in the absence of other information, the unweighted average of all five results leads to a value of 1,002 0 mPa·s ± 0,001 4 mPa·s [6]. There are, however, strong reasons to consider the results of Swindells et al. [1] and Berstad et al. [5] to be more reliable than the other values. Since both results do not agree within the uncertainty stated by the authors, it does not seem appropriate to change the basic value (except for the adaption to the temperature scale changes) until new experimental results are available.

In spite of this, the available information shows that the uncertainty of the water viscosity is less than 0,25 %. As an estimate, a value of 0,17 %, which covers all five experimental results, is considered as an adequate representation of the present knowledge of the viscosity of water.

Annex B
(informative)

Bibliography

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