

# Viscosity of water

ICS 17.060

# National foreword

This British Standard reproduces verbatim ISO/TR 3666:1998 and implements it as the UK national standard.

The UK participation in its preparation was entrusted to Technical Committee PTI/13, Petroleum testing and terminology, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
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## Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the ISO/TR title page, page ii, pages 1 and 2 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.

## Amendments issued since publication

Amd. No.	Date	Comments

This British Standard, having been prepared under the direction of the Sector Committee for Materials and Chemicals, was published under the authority of the Standards Committee and comes into effect on 15 March 1999

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# Contents

	Page
National foreword	Inside front cover
Foreword	ii
1 Scope	1
2 Values for the viscosity of water	1
3 Realization of the viscosity of water	1
Annex A (informative) Results of water viscosity measurements	2
Annex B (informative) Bibliography	2
Table 1 — Recommended values for the (dynamic) viscosity ratio $V_r = \eta(T)/\eta(20\text{ °C})$ of water at various reference temperatures; density $\rho$ , temperature coefficients $U_\eta$ , $U_v$ , and pressure coefficient $\gamma$	1



**TECHNICAL  
REPORT**

**ISO/TR  
3666**

Second edition  
1998-12-15

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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.

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

## 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,  $\eta$ , and the kinematic viscosity,  $\nu$ , of water at 20 °C and normal atmospheric pressure (0,101 325 MPa) are given by:

$$\eta = 1,001\ 6\ \text{mPa}\cdot\text{s}$$

$$\nu = 1,003\ 4\ \text{mm}^2/\text{s}$$

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  $V_r = \eta(T)/\eta(20\ \text{°C})$  for temperatures  $T$  between 15 °C and 40 °C, is given by the values listed in Table 1.

For additional information the pressure coefficient,  $\gamma$ , is given by the following equation.

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

where

$p$  is the pressure, in megapascals.

The temperature coefficients  $U_\eta$  and  $U_\nu$  are given by equations 2 and 3.

$$U_\eta = -\frac{1}{\eta} \cdot \frac{d\eta}{dT} \quad (2)$$

$$U_\nu = -\frac{1}{\nu} \cdot \frac{d\nu}{dT} \quad (3)$$

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.

**Table 1 — Recommended values for the (dynamic) viscosity ratio  $V_r = \eta(T)/\eta(20\ \text{°C})$  of water at various reference temperatures; density  $\rho$ , temperature coefficients  $U_\eta$ ,  $U_\nu$ , and pressure coefficient  $\gamma$**

Temperature, $T$ °C	Dynamic viscosity ratio, $V_r$	Density, $\rho$ kg/m <sup>3</sup>	Temperature coefficient, $U_\eta$ K <sup>-1</sup>	Temperature coefficient, $U_\nu$ K <sup>-1</sup>	Pressure coefficient, $\gamma$ 10 <sup>-4</sup> MPa <sup>-1</sup>
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

## 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  $\eta(20\text{ °C}) = 1,001\ 9\ \text{mPa s}$  as published by Swindells et al. [1] in 1952, the internationally accepted viscosity values of water as stated in ISO/TR 3666:1977 are  $\eta(20\text{ °C}) = 1,002\ \text{mPa s}$  for dynamic viscosity and  $\nu(20\text{ °C}) = 1,003\ 8\ \text{mm}^2/\text{s}$  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  $3 \times 10^{-4}$  and cannot be neglected with respect to a repeatability of  $1 \times 10^{-4}$  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 existence of undetected systematic deviations. Therefore, in the absence of other information, the unweighted average of all five results leads to a value of  $1,002\ 0\ \text{mPa s} \pm 0,001\ 4\ \text{mPa s}$  [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 adaptation 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

- [1] Swindells, J. F.; Coe, J. R.; Godfrey, T. B.: Absolute Viscosity of water at 20 °C. In: J. Res. NBS 48 (1952), p. 1 – 31.
- [2] Roscoe, R.; Bainbridge, W.: Viscosity Determination by the Oscillating Vessel Method. II. The Viscosity of Water at 20 °C. In: Proc. Phys. Soc. 72 (1958), p. 585 – 595.
- [3] Malyarov, G. A.: Opređenje vyazkosti vody pri temperature 20 °C. (Determination of the viscosity of water at 20 °C.) In: Trudy Vses. Nauchno-Issled. Inst. Metrologii 37 (1959), p. 125 – 140.
- [4] Kestin, J.; Shankland, J. R.: The Free Disk as an Absolute Viscometer and the Viscosity of Water in the Range 25 °C – 150 °C. In: J. Non-Equil. Thermodyn. 6 (1981), p. 241 – 256.
- [5] Berstad, D. A.; Knapstad, B.; Lamvik, M., Skjølsvik, P.A., Tørklep, K. and Øye, H.A.: Accurate Measurements of the Viscosity of Water in the Temperature Range 19.5 – 25.5 °C. In: Physica A 151 (1988), p. 246 – 280.
- [6] Bauer, H.; Binas, E.; Broeke, H.; Völkel, L.: New recommended viscosity values for water as the metrological basis of viscometry. In: PTB-Mitteilungen 105 (1995), p. 99 – 105.





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