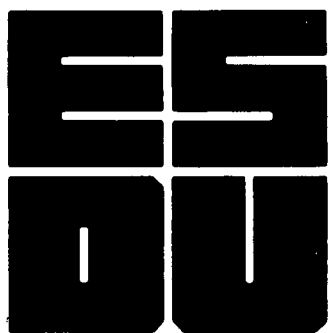


81016



Engineering Sciences Data
Item Number

81016

Approved for Issue
September 1981

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Institution of Chemical Engineers

Viscosity of liquid aromatic hydrocarbons

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81016

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The Physical Data and Reaction Kinetics Committee, which first met in May 1966, has the co-operation of many engineers and scientists in industry, research establishments and the universities from whom much assistance and information is being received. For this particular Item the initial assessment of the available information, the correlations and the tables calculated from them were prepared by the National Engineering Laboratory. The work was undertaken by Dr J.D.Isdale of the Thermal Systems Division and was sponsored by ESDU.

In order to assist the preparation of new work, and particularly to assist the periodic review and revision of work already issued, users are encouraged to make known their experience in using the information and procedures and to notify the Unit of any additional information which they can provide or to which reference can be made. Prepaid reply service cards are available for this purpose. Whenever an Item is revised, users who are Associates of ESDU (i.e. have a standing order for one or more Sub-series) automatically receive any material required to up-date Items in the Sub-series held. While it is always advisable to check by use of the current edition of the Engineering Sciences Data Index that Items held are the latest issue and incorporate the latest amendments, those who are not Associates are particularly advised to take this action at reasonable intervals since the Unit cannot undertake to supply them with an appropriate up-dating service. Any missing amendments can be supplied on request.

(Continued on inside back cover)

* Corresponding Member

VISCOSITY OF LIQUID AROMATIC HYDROCARBONS

1. INTRODUCTION

This Item presents values of viscosity at saturation pressure, in tabular form, for liquid aromatic hydrocarbons.

The data on which these values are based are the most reliable available and the range covered is from the melting point (or, where the melting point is not known, from a value believed to be near it) to approximately ten degrees below the critical temperature. In common with other ESDU Items, quantities are expressed in SI Units and conversion factors to other units are provided in Section 3.

Section 4 describes the procedure used to obtain the values of viscosity presented and indicates the effect of pressure. Section 5 gives an explanation of the Tables and indicates the uncertainties in the values presented in them.

In Section 6, References 1 to 6 are sources of additional information. For some of these liquids other reliable correlations are available but they are often restricted to values below the normal boiling point as in the API Tables⁴. The measured data considered in the preparation of this Item are given in Derivations 7 to 56.

For convenience when using these Tables a foldout flap, attached to the last page, indexes each compound name against the number used to identify it in the Tables and shows the number and page of the Table where its viscosity can be found.

2. NOTATION AND UNITS

The SI unit of dynamic viscosity is the Newton second per square metre (N s/m^2). The values presented in the tables are given in milli Newton seconds per square metre (mN s/m^2), a submultiple which is convenient for the magnitudes considered and which is equivalent to the c.g.s. centipoise.

A, B	non-dimensional constants for each liquid in Equation (1)	
C	constant for each liquid in Equation (2)	K
D	constant for each liquid in Equation (1)	mN s/m^2
p	pressure	Pa
T	thermodynamic temperature	K
t	Celsius temperature, $T - 273.15$	$^{\circ}\text{C}$
α	constant in Equation (3)	m^2/N
η	dynamic viscosity	mN s/m^2

Subscripts

b	denotes value at normal boiling point
c	denotes value at critical point
m	denotes value at melting point
r	denotes reduced quantity, e.g., $T_r = T/T_c$

3. CONVERSION FACTORS

$$\begin{aligned} 1 \text{ mN s/m}^2 &= 1 \text{ centipoise} \\ &= 145.04 \times 10^{-9} \text{ lbf s/in}^2 \\ &= 101.97 \times 10^{-6} \text{ kgf s/m}^2 \\ &= 10^{-3} \text{ kg/m s} \end{aligned}$$

$$\begin{aligned} 10^5 \text{ N/m}^2 &= 1 \text{ bar} \\ &= 14.5038 \text{ lbf/in}^2 \\ &= 1.0197 \text{ kgf/cm}^2 \\ &= 0.9869 \text{ atm} \\ &= 750.062 \text{ mmHg.} \end{aligned}$$

4. LIQUID VISCOSITY

4.1 Viscosity at Saturation Pressure

The two equations most commonly used to describe variations of the coefficient of viscosity with temperature at saturation pressure are:

$$\ln \eta = A' + \frac{B'}{T},$$

and
$$\ln \eta = A'' + \frac{B''}{T - C''}$$

Both of these can provide adequate representations of viscosity over limited temperature ranges but are unsatisfactory over the full range. The first form often produces large deviations near the melting point or at higher viscosities and neither equation has a realistic form for near-critical temperatures. Several similar forms are available which use volume as an independent variable but these are limited by the need for accurate volume data or an equation of state.

The following equation has been derived for the present work and has been found to give a good representation of the data from the melting point to $T_r = 0.9$:

$$\ln \frac{\eta}{D} = A(\theta - 1)^{1/3} + B(\theta - 1)^{4/3}, \quad (1)$$

where
$$\theta = \frac{T_c - C}{T - C}. \quad (2)$$

Relatively few reliable experimental data are available at reduced temperatures greater than 0.9; however the equation form is consistent with observed trends in that region and produces reasonable estimates up to the critical temperature.

The derived values of the coefficients A , B , C , and D are given in Table 1. The coefficient C has the dimensions of temperature and defines the temperature at which the liquid viscosity is assumed to tend to infinity: it has a magnitude similar to that of the glass transition temperature and is well below the melting point. The coefficient D is in effect a pseudocritical viscosity which is produced by the equation at $T_r = 1.0$. In most cases, values of A , C and D are calculated from the critical properties of each fluid. Only B is obtained by fitting the equation to viscosity data and it is also correlated with corresponding values for other members of each chemical series. This procedure helps to minimise coefficient variations caused by isolated sets of inaccurate

data or by data covering only short ranges of temperature, and it thus produces sets of viscosity values which vary in a consistent way throughout the series. Several sets of coefficients are also given which are derived entirely from the correlation and these are identified in Table I: no experimental measurements were found for these liquids. The values of the four coefficients and of t_c given in Table I have been used to calculate the viscosities presented in Tables II to IX.

4.2 Effect of Pressure

No accurate general expression is available for estimating the effect of pressure on these liquids; however the simple expression given for alkanes in Item No. 79027 may be applied to these fluids in a similar way and is given here as an approximate guide. Some of the Derivations and Reference 6 give values for a few of these fluids at elevated pressure based on individual sources. In these cases values at saturation pressure from the single source used may differ significantly from the values given here which are based on the most reliable measured data available at saturation pressure.

In most cases viscosity increases by about 1 per cent for a pressure increase of 1 MPa (10 bar). Below the normal boiling point the difference between values measured at atmospheric pressure and those at the true saturation pressure is therefore very small. The viscosity of liquids with a high viscosity at saturation pressure increases more rapidly than that of liquids with a low viscosity.

For temperatures from the melting point to reduced temperatures of about 0.75 the following relationship may be used as an approximate guide:

$$\ln \frac{\eta_p}{\eta} = \alpha p \quad (3)$$

where η_p is the viscosity at pressure p , η is the viscosity at saturation pressure, and α is a pressure-viscosity coefficient. An average value for α is $0.9 \times 10^{-8} \text{ m}^2/\text{N}$ for pressures up to 100 MPa.

5. EXPLANATION OF TABLES

5.1 Notes on Compounds Considered

The compounds are numbered from 1 to 71 in Table I and these numbers are used to identify the compounds in the Tables where space does not permit the use of the name. The compounds are identified by a systematic name but for some compounds alternative names are also given. The names in bold type are those based on BSI recommendations, see References 2 and 3.

Compounds for which no experimental data exist and for which A , B , C and D were estimated as described in Section 4.1 are indicated by an asterisk against their compound number in Table I.

Tables II to IX present values of viscosity at 10 °C intervals of temperature.

5.2 Accuracy of Data

For uniformity and ease of interpolation in Tables II to IX the data are presented and can be read to more significant digits than is warranted by their estimated accuracy; however the best interpolations are provided by using Equation (1) with the appropriate coefficients.

Experimental data from the most reliable individual sources can have an accuracy of about ± 0.2 per cent. However differences in technique and in sample purity often lead to discrepancies of ± 2 per cent or more even between apparently reliable sources, and larger discrepancies are not uncommon. Moreover, reliable data of this

standard are not available for all the compounds considered, and never cover the whole temperature range of interest. Although it is considered that the correlation procedures adopted keep the errors in the values presented to a minimum, the user should allow for an uncertainty in the values in Tables II to IX corresponding to the classification given in Table X.

For some of these fluids, anomalous transition temperatures have been reported at the low temperatures in the region of the melting point. The equation coefficients given here are, however, based on data showing normal behaviour at temperatures usually above the melting point.

The classification A, B, and C for each fluid are estimates of the maximum uncertainty which occurs in the stated temperature ranges, with A corresponding to an uncertainty of ± 1 per cent, B to ± 5 per cent, and C to ± 10 per cent. Values with a D classification may have an uncertainty of more than ± 10 per cent. Classifications which are not based on reliable experimental data are given in parentheses.

6. REFERENCES AND DERIVATION

6.1 References

The references given are recommended sources of information supplementary to that in this Item.

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