

NOV 21 1966

Viscosity of Isobutane

MARIO H. GONZALEZ and ANTHONY L. LEE
Institute of Gas Technology, Chicago, Ill.

Experimental viscosity data for isobutane are presented for temperatures from 100° to 340° F. and pressures from 100 to 8000 p.s.i.a. Experimental density values are reported for temperatures from 100° to 340° F. at 8000 p.s.i.a. The method for correlating the data is discussed, and the data are compared with literature values. A table of recommended viscosity values is presented.

DATA on the effects of temperature and pressure on the viscosity of isomeric paraffins are scarce. The effects of temperature on the viscosity of these compounds have been noted by Evans (3), Lambert *et al.* (7), Lipkin, Davidson, and Kurtz (10), Titani (15), Ishida (6), and Sage, Yale, and Lacey (12). The only data that report the pressure effect on viscosity are those presented by Sage, Yale, and Lacey (12) for the isobutane system.

Extensive study has been carried out on the viscosity of normal paraffins up to 10 carbons in chain length and for some of their binary mixtures (8). The study of the isomers of these hydrocarbons could be critical in the determination of the molecular configuration dependence of viscosity. This dependence appears to be an important factor in the behavior of mixtures of compounds with completely dissimilar configurations, as in the methane-*n*-decane system (5,8).

This paper presents experimental and recommended values for isobutane at temperatures from 100° to 460° F. and pressures from atmospheric to 8000 p.s.i.a. Experimental density data are reported for temperatures from 100° to 340° F. at 8000 p.s.i.a.

APPARATUS AND MATERIALS

The instrument used is a modified version of one described previously (4). A magnetically driven mixing pump and stainless steel pycnometers for density determinations have been added to the system.

The isobutane is a Phillips Petroleum Co. pure grade. Mass spectrometric analysis showed a composition of 99.7% *iso*-C₄, 0.2% N₂, and 0.1% O₂.

EXPERIMENTAL DATA

Most of the experimental data were obtained for the liquid phase, as only two of the isotherms investigated were above the critical temperature of isobutane. The determinations at 160° and 220° F. were extended to the saturated liquid locus. Isobars of viscosity are presented in Figure 1, and a cross-plot of viscosity vs. pressure is shown in Figure 2. The reported values are believed to be within $\pm 1\%$ of the true isobutane viscosity values at the 95% level of confidence (5).

The residual correlation represented all data satisfactorily. The determinations for the 100° and 160° F. isotherms were carried up to 8000 p.s.i.a., which defined the high-density section of the residual curve. The other isotherms were then studied only to the extent of defining the remaining section of the curve. Density values by Sage and Lacey (11) were used for pressures up to their highest reported values of 5000 p.s.i.a. To extend the residual correlation of all isotherms to 8000 p.s.i.a., density values were determined at these conditions. Table I presents the experimental

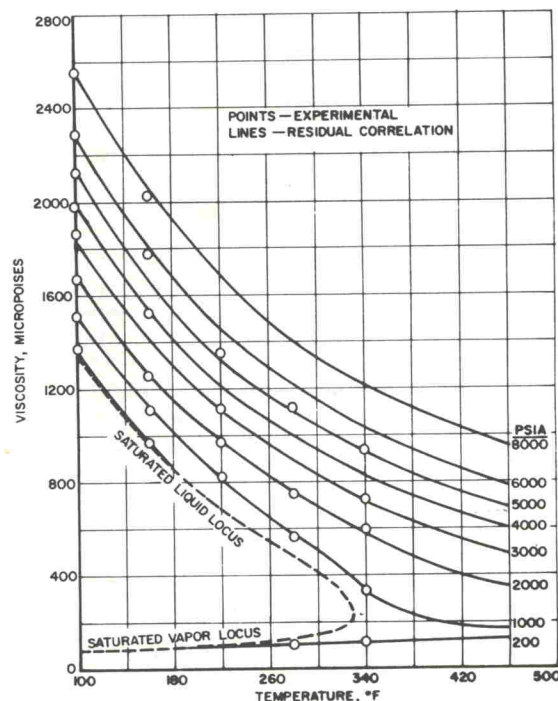


Figure 1. Viscosity vs. temperature for isobutane

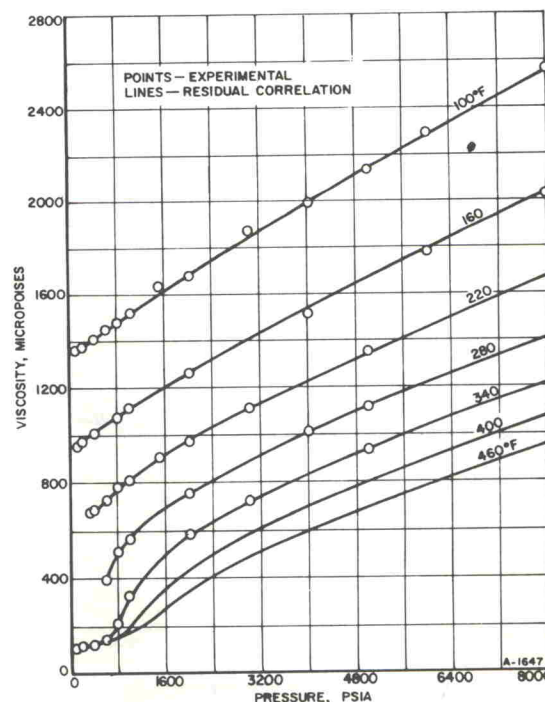


Figure 2. Viscosity vs. pressure for isobutane

density values obtained. The standard deviation of the experimental density values was $\pm 1.6\%$.

Detailed tables of experimental data have been prepared and are available from ADI.

COMPARISON WITH LITERATURE

The only available data on the viscosity behavior of isobutane for the range of temperatures and pressures studied in this paper are those reported by Sage, Yale, and Lacey (12). These authors reported data for isobutane for temperatures from 100° to 220° F. and pressures from atmospheric to 2000 p.s.i.a. which are consistently lower than those obtained in this investigation. Data are compared in Figure 3.

Values of isobutane viscosity were calculated with the equation proposed by Lee *et al.* (9), using the density data of Sage and Lacey. The resulting values had a standard deviation of -9% from the experimental points. This indicates a configuration effect which is not taken into consideration by the formula. This effect has been analyzed by the authors.

A survey of the literature shows that the reported values of the viscosity of isobutane at atmospheric pressure vary widely among authors. Data presented by Lambert *et al.* (7), the Thermophysical Properties Research Center "Data Book" (14), Sage *et al.* (12), Svehla (13), and values calculated with the equation of Lee *et al.* (9) were plotted. The μ_0 values used in the residual correlation were obtained from a least squares fit of the experimental data to Sutherland's equation. The small curvature of the calculated values at low temperatures was neglected since its effect on the recommended values was on the order of $\pm 0.1\%$. The values used and the experimental data are shown in Figure 4.

Table I. Density of Isobutane at 8000 P.S.I.A.

Temp., ° F.	Density, G./Cc.
100	0.6126
160	0.5882
220	0.5695
280	0.5451
340	0.5192

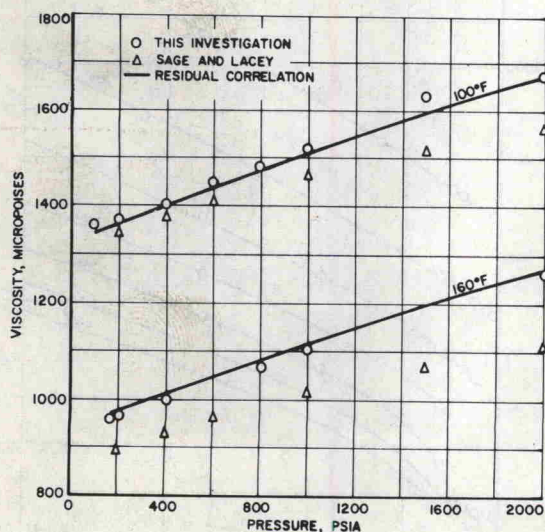


Figure 3. Comparison of viscosity values of isobutane

CORRELATION

The problem of predicting viscosity values that would agree with the experimental results, and for temperatures and pressures outside the range of experimental investigation, was solved by the correlation based on the residual viscosity concept (1). This correlation is defined as the difference between viscosity of a given pressure and temperature and μ_0 , the viscosity at 1 atm. and the same temperature, plotted against the density corresponding to the given temperature and pressure. The residual viscosity concept has been discussed in detail (1,2) and has predicted the viscosity of a number of materials which include the normal paraffins up to decane and at least the isomer reported in this investigation. The residual correlation of the isobutane data is shown in Figure 5.

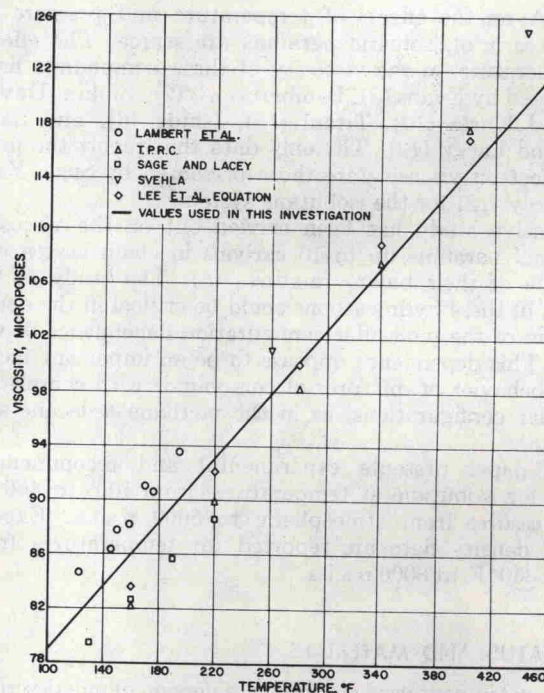


Figure 4. Viscosity of isobutane at atmospheric pressure

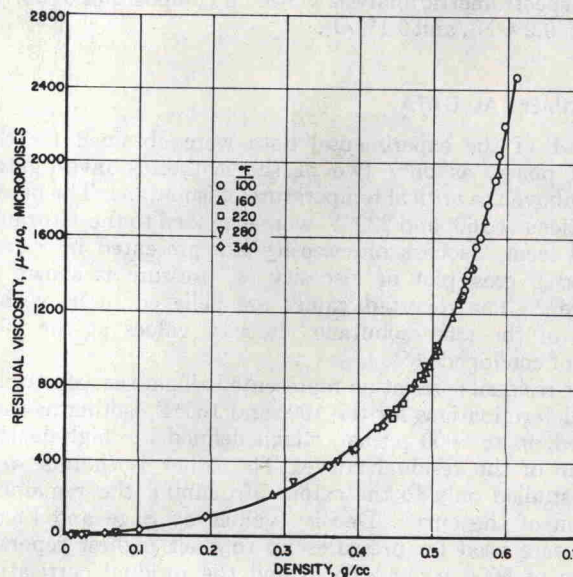


Figure 5. Residual viscosity vs. density for isobutane