For all but two of the 81 test points, runs were made for at least two different pressure differentials between the ends of the capillary tube. In general, two to five flow times were averaged for a given pressure differential. The deviations of trial flow times were usually less than 0.1% of the mean. The mean flow time for each run was used to calculate the viscosity and the average of these run values was recorded as the viscosity for the test point. Data obtained on different dates but under common test conditions were calculated as separate runs and then averaged. Deviations of individual run values from the mean were generally small. For 1000 p.s.i.a. or above, the average deviation was 0.14%; below 1000 p.s.i.a. it was 0.55%.

COMPARISON WITH LITERATURE VALUES

A number of investigations of the viscosity behavior of ethane have been reported. Two investigations (3, 16) extend to high pressures, one (19) determined saturated liquid values, and nine (2, 6, 7, 9, 10, 11, 20, 21, 23) were made at atmospheric pressure. Several methods were used to compare the various data sets and assess the validity of our results. Selected data were then correlated to permit development of a table of recommended values, believed accurate to within ±2% of the true value, and extending beyond the range of temperatures and pressures covered by existing data.

The data of the different investigations were plotted as isotherms of viscosity vs. pressure and as isobars of viscosity vs. temperature. These plots tested the continuity of the values and checked on the consistency of the data. In this manner inconsistent points were located and reconciled. As a further test, data from the several sets were plotted as residual viscosity vs. density. Residual viscosity is defined as the difference between the viscosity at a given pressure and temperature and the viscosity at 1 atm. and the same temperature. The residual concept was proposed by Predvoditelev (12), verified by Abas-Zade (1) for thermal conductivity, and extended by Thodos and others (4, 15) for viscosity. A residual viscosity–density plot was utilized in the study of the viscosity behavior of propane (17). Atmospheric pressure data were compared by use of Sutherland's equation. This permitted easy determination of differences in temperature dependence of sets of data, when the agreement between values was good for a narrow range of conditions.

Ethane viscosity data for the saturated liquid and for pressures slightly above the vapor pressure were obtained by Swift, Lohrenz, and Kurata (19). Their values agree almost perfectly with the saturated liquid locus estimated by extrapolating isotherm data of this investigation to the vapor pressure.

Ethane viscosity data at atmospheric pressure were obtained by Vogel (23), Ishida (9), Titani (20), Trautz and Sorg (21), Adzumi (2), Majumdar and Oka (11), Craven and Lambert (6), Lambert and others (10), and DeRocco and Halford (7). There is good agreement among all the data. However, Titani's and Adzumi's values show a greater temperature dependence than the values of Trautz and Sorg, Lambert and others, and DeRocco and Halford. To illustrate this, the constants in Sutherland's equation (18)

$$\mu_0 = CT^{3/2}/(T + S) \tag{1}$$

where μ_0 is in micropoises and T in ° K., determined from the reported data, can be compared. The values of the constants are

	C	S
Titani	10.7	287
Adzumi	10.6	280
Trautz and Sorg	10.0	259

The DeRocco and Halford values would be very close to Trautz and Sorg's. The obvious reason for the differences

is that constants fitted to data for different ranges of temperature may differ slightly. Certainly, at higher temperatures one would expect viscosity to become more nearly proportional to $T^{1/2}$. Thus, although agreement is good, the Sutherland constants differ mainly because the data of Trautz and Sorg and DeRocco and Halford extend to 250° and 200° C., respectively, while the highest temperatures of Titani's and Adzumi's investigations were 120° and 100° C.

Baron, Roof, and Wells (3) utilized a modified Rankine capillary tube viscometer to obtain data at four temperatures from 125° to 275° F. for pressures up to 8000 p.s.i.a. Their values and the experimental data of this investigation agree within 3% for most points. Smith and Brown (16) used a rolling ball viscometer to obtain data at 12 temperatures from 59° to 392° F. for pressures up to 5000 p.s.i.a. Their values are generally more than 3% lower than the data of this investigation and for many points the deviations exceed 10%.

The experimental data of this investigation, plotted as residual viscosity vs. density on linear coordinates, result in a smooth continuous curve at densities above 0.10 gram per cc., as shown in Figure 3. Density values used for constructing plots of residual viscosity vs. density are those reported by Sage and others (13, 14). The atmospheric
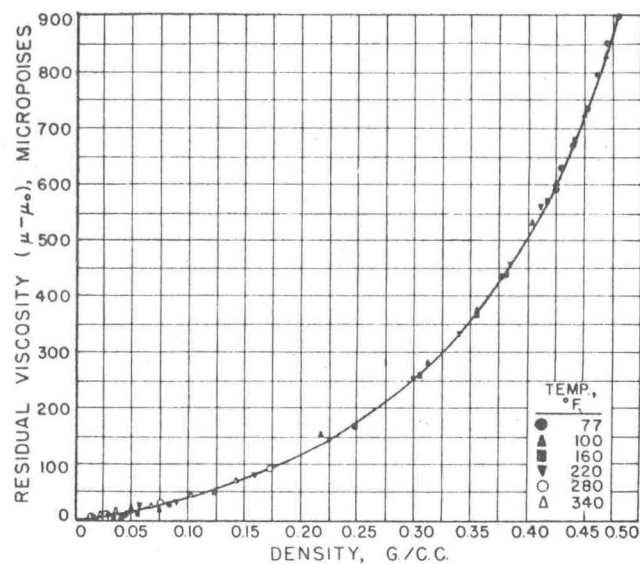

Figure 3. Residual ethane viscosity vs. density
Linear coordinates

pressure viscosity values were calculated by use of Sutherland's equation with the constants determined from the data of Trautz and Sorg. To expand the low density region, the residual viscosity–density data were plotted also on logarithmic coordinates. This plot (Figure 4) shows definite separation of the smooth curve into a family of isotherms at densities below 0.10 gram per cc. Correlation of this behavior may be possible for similar substances on a reduced basis and is being investigated. The separation in Figure 4 is therefore shown in terms of the reduced temperature, T_R. A curve for the reduced temperature corresponding to 220° F. ($T_R = 1.236$) is not present in Figure 4, because the 220° F. data at the lowest densities are probably about 1 micropoise high. Both the linear and logarithmic residual viscosity–density plots indicate that for densities above 0.10 gram per cc. all the IGT data are correlated by a single curve.

The data of Baron, Roof, and Wells, portions of the data of Smith and Brown, and the data of this investigation (the smooth curve) are directly compared in Figure 5. This