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VISCOSITY-DENSITY CORRELATION OF NEWTONIAN LIQUIDS

BY

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ABSTRACT

The viscosity of monatomic liquids was modeled by an equation derived from the kinetic theory of gases. Viscosities may be calculated from data on density and molecular weight of the liquid. In adapting this relationship to polyatomic liquids, a single correction factor was developed for each of five series of homologues; n-paraffins, n-1-alkenes, n-alkylcyclohexanes, n-alkylbenzenes and n-alcohols, to account for the deviations of the calculated viscosities from those reported, extending over a one- to three-hundred degree range. The factor is a function of reduced temperature relative to the normal boiling point, T_{rB}. A single equation for each of the series of homologues, n-paraffins to n-alcohols, was thus used as a predictor for the viscosities with an average error of 6.8, 4.9, 7.9, 4.9 and 29.5 per cent, respectively.

The correction factors for the hydrocarbon series, excluding the alcohols were sufficiently similar so that they were estimated to be identical. A combined correction factor for two series, n-paraffins and n-1-alkenes, was employed to extrapolate to the alkylbenzenes and alkylcyclohexanes with an accuracy in predicted viscosity of 10.1 and 18.4 per cent, respectively. The maximum error in both series was only 37.9 per cent. Thus predictions of liquid viscosity were performed over extended temperature ranges, with good accuracy without requiring viscosity data.

A further refinement of the correction factor for each of the five series of homologues was introduced by correlation with two parameters; T_{rB} and with the number of carbon atoms in the alkyl group, C. The use of the carbon parameter decreased the average error in predicted viscosity to 1.78, 1.95, 2.39, 3.46 and 14.5 per cent for the n-paraffins, n-1-alkenes, n-alkylcyclohexanes, n-alkylbenzenes and the n-alcohols, respectively.

The idealized liquid state model which is the basis of the present development does not adequately predict the viscous behavior of real liquids. It is significant, however, that the deviations from the model are relatively consistent, and may be taken into account by a relatively simple empirical function, applicable to a wide variety of liquids.

This study also describes the experimental determination of density and kinematic viscosity over wide ranges of temperature and of molecular weight for the n-alcohols. A density apparatus based on the hydrostatic weighing method was constructed and used for the measurement of n-alcohol densities from room temperature to near their normal boiling points. The apparatus permitted a density measurement every 30 minutes on 5 ml of liquid sample with an average accuracy of 1.4 x 10^{-4} g/ml, and a reproducibility of 1-4 x 10^{-4} g/ml.

APPROVAL OF DISSERTATION

VISCOSITY-DENSITY CORRELATION OF NEWTONIAN LIQUIDS

BY

MELVIN L. DRUIN

FOR

DEPARTMENT OF CHEMICAL ENGINEERING

NEWARK COLLEGE OF ENGINEERING

BY

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APPROVED: ______________________ CHAIRMAN

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NEWARK, NEW JERSEY

JUNE, 1968

DEDICATION

THE AUTHOR DEDICATES THIS DISSERATION
TO THE MEMORY OF HIS FATHER-IN-LAW,
LEWIS LEFKOWITZ

ACKNOWLEDGEMENTS

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INTRODUCTION

Viscosity implies resistance to flow. In a more classical statement, it can be considered as the resistance exhibited by a fluid to any forces tending to induce differential motion between adjacent layers of the fluid. When a fluid is subjected to a shearing stress, the fluid moves to produce a certain displacement. The resulting velocity gradient throughout the fluid will exhibit a maximum velocity at the point where the shearing stress is applied. This relationship of shearing stress to velocity gradient can be described by Newton's Law of Viscous Flow (15). It states that the shear force per unit area, resisting the tendency to flow is directly proportional to the velocity gradient. Thus, the value of the shear force per unit area is zero for zero velocity gradient, i.e., liquid at rest. The equation, provided the flow is laminar is expressed as

$$F/A' = \mu(dv/dx) \tag{1}$$

where: F = applied force

A' = area over which force is applied

dv/dx = velocity gradient

and where the constant of proportionality, μ, is the coefficient of viscosity, or more simply, the viscosity. Fluids that behave in this fashion are termed Newtonian fluids. All gases and most simple liquids are described by equation 1. Fluids that do not obey this simple law, i.e., for example, pastes, slurries and high polymers, are classified non-Newtonian. The units of viscosity can be determined by the application of dimensional analysis to equation 1:

$$\mu = (F/A') \ / \ (dx/dv) \tag{2}$$

where:
$F = f_1 \ (M'LT_i^{-2})$
$A' = f_2 \ (L^2)$
$x = f_3 \ (L)$
$v = f_4 \ (LT_i^{-1})$
M' = mass
L = length
T_i = time

Substituting the above dimensional functions in equation 2 gives

$$\mu = (M'LT_i^{-2})/L^2) \ / \ (L/LT_i^{-1}) \tag{3}$$

which simplifies to

$$\mu = M'/LT_i \tag{4}$$

Viscosity, thus has the dimensions of mass/(length) (time).

Viscosity may also be expressed by the force-length-time method of dimensional analysis by employing the following definitions to equation 2.

$A' = f_1\ (L^2)$

$x = f_2\ (L)$

$v = f_3\ (LT_i^{-1})$

F = force

L = length

T_i = time

Substitution of the above dimensional functions in equation 2 results in

$$\mu = (F/L^2)\ (L/LT_i^{-1}) \tag{5}$$

which simplifies to

$$\mu = FT_i/L^2 \tag{6}$$

Thus, viscosity also has the dimensions of (force-time)/(length)^2. Both of these groups of units, as determined above, to represent viscosity are used in the Literature, although most often, viscosities are expressed in terms of poises, centipoises, etc. A poise represents a viscosity of 1 dyne-sec/cm^2 or 1 g mass/sec-cm and 1.0 centipoise equals 0.01 poise.

Gas Viscosity

The theory of gas viscosity has been well established by both classical and modern kinetic theory. When a gas undergoes a shearing stress, there results some bulk motion, and the molecules at any one point have the bulk-velocity vector added to their own random-velocity vector. The resulting molecular collisions transfer momentum and produce frictional drag. The internal resistance to this drag is termed as viscosity.

Classical kinetic theory of ideal gases allows one to estimate the rate of momentum interchange and thus the gas viscosity. The approach assumes low pressures, rigid non-attracting spherical molecules, and movement in only three directions of the coordinate axes (15).

Modern kinetic theory is a more accurate approach because of the allowance for molecular forces of attraction and repulsion. Considerable success has been attained by the mathematical theory described by Chapman and Cowling (20). The theory assumes elastic collisions between rigid, smooth, spherical, non-polar molecules. The kinetic theory models have been verified experimentally and have been refined by Sutherland (73), to permit estimations of gas viscosities to an accuracy of two to three per cent.

Liquid Viscosity

The theories of liquid viscosity are considerably more involved than those of gas viscosity, and to date no single theory has been generally accepted. The majority of knowledge about the viscosity of liquids is largely empirical (15). In liquids, the viscosity is basically the result of strong intermolecular forces which hinder any relative motion between two adjacent segments in a liquid. With increasing temperature, the random kinetic energy of the molecules helps to overcome molecular forces, hence viscosity must decrease, contrary to the behavior of gases where an increase in temperature increases the rate of momentum transfer - hence the viscosity (34).

Associated liquids exhibit even greater variations. The higher viscosities of associated, or polar, liquids as compared to non-polar liquids are interpreted on the view that the activation energy of viscosity is utilized to break hydrogen bonds as well as to produce deformation, i.e., flow (5). Fewer molecules have received sufficient energy by collision to migrate and relieve the stress, thus the resulting higher viscosity.

The significance of reliable liquid viscosity correlations in chemical engineering is best shown by the effect of viscosity on the more important parameters in the fields of fluid flow, heat transfer and mass transfer. McGuire (51) studied the effects of accuracy in viscosity estimation on various correlations of chemical engineering parameters. Typical examples from his study indicated the required accuracy in viscosity estimation to limit the parameter uncertainty to less than five per cent due to viscosity alone. Some examples are presented below.

Calculation	Reference	Accuracy
1. Pressure drop of viscous fluids through beds of granular solids	$\Delta P = 53\ LV_oA_f/D_p^2$	5%
2. Coefficient of heat transfer of fluids in turbulent flow inside clean round pipes	$h_t = (.23K/D)\,(Du\rho/\mu)^{.8}(c\mu/K)^{.4}$	13%
3. Gas-Resistance HTU	$H_y \alpha (\mu/\rho D)^{.5}$	10%

It is apparent from the cited examples that the viscosity must be predictable within a reasonable accuracy.

The purpose of this thesis is to investigate homologous series of compounds and to develop an accurate correlation between viscosity, temperature, density and constitution over a wide temperature range. The adaptation of the correlation to various homologous series of compounds would indicate a wide applicability of the correlation. Both polar and non-polar liquids would be included in the relationship.

In general density and viscosity data required to test the basic correlation for the homologous series of compounds investigated are available with high accuracy in the literature (2, 21, 37, 42, 77). Literature data for the n-alcohols is insufficient and that which is available (22, 37, 42, 77, 78) shows scatter which may be attributed in part to lack of purity and to experimental error. Thus, this study describes in detail the experimental determination of density and kinematic viscosity over wide ranges of temperature and of molecular weight for the n-alcohols.

EXTENT OF PRESENT KNOWLEDGE

Correlation of Liquid Viscosity

Many empirical approaches have been tried between viscosity and parameters such as temperature, pressure, density, free volume, and molecular weight with varying degrees of success.

Poiseulle (60) published his classic work on the flow of liquids through fine tubes, in the middle of the nineteenth century. Through these studies, Poiseulle established that the variation of liquid water viscosity with temperature followed a quadratic relationship.

The reciprocal of viscosity, $1/\mu$, termed fluidity, was shown by Bingham (13) to be more susceptible to correlation with temperature. The resulting correlation indicated a much more linear relationship than did viscosity and temperature. The observations of Bingham were extended by Batschinski (11) in 1913 who presented an empirical equation between fluidity and specific volume. Data for sixty-six non-associated liquids produced a linear relationship.

McLeod (52) in 1923 related viscosity with free space within a liquid, and with a constant dependent upon the molecular structure. This work was never extended to the point of practical usage.

Bingham and Stookey (14), revived the work on fluidity and found correlations for some homologous series. In its most refined form the equation is

$$f_\ell/T = A_s + \alpha T(10)^{(\beta'/M - \gamma'/M^2)} \tag{7}$$

where: f_ℓ = $1/\mu$, fluidity
T = absolute temperature
M = molecular weight
A_s, α, β', γ' = constants for a particular homologous series

Equation 7 gives excellent agreement with experimental values for many compounds but cannot be used for associated fluids such as alcohols.

Doolittle (27) extended the free space theory of Batchinski with the following accurate, but extremely complex relationship

$$\ell n\,(\mu) = -A_b e^{500/T}\left(-\Sigma_i\,(-500/T) \right) - 4.66 + C_b e^{500/T} \tag{7A}$$

where: μ = liquid viscosity
A_b = constant
T = absolute temperature
$-\Sigma_i$ = $(-500/T)$ = logarithmic integral
C_b = constant of integration dependent on molecular weight

Doolittle later expanded his work (28) to demonstrate the application of the above equation to a homologous series, where molecular weight varied from 100 to 200. Although his calculations of viscosity fall within the range of experimental error, it is doubtful that this method will be accepted for common application.

A reference-substance type plot of viscosity versus temperature was proposed by Othmer, et al. (57, 58, 59). DiGeronimo (25) later demonstrated that within a homologous series there is a random distribution of the slopes of each member of the series. The intercepts of the lines failed to yield a definite relationship. Summarizing, the approach offers little advantage over the forementioned correlations.

In 1930 Andrade (4) presented one of the most useful contributions concerning the temperature dependence of viscosity. It is expressed as

$$\mu = Ae^{B'/T} \tag{8}$$

where: μ = liquid viscosity

T = absolute temperature

A, B' = constants

Various modifications of equation 8 have been proposed which introduce the effect of a variation in density (67). Andrade's equation, though mainly obtained by empirical means is basically of the same form that Eyring and his associates (5, 36), derived through the application of the theory of absolute reaction rates. Andrade's equation is applicable over practically the entire temperature range for a great many compounds giving excellent agreement with experimental results. The constants A and B' must be determined experimentally for each compound. Kierstead and Turkevitch (47) failed in an attempt to correlate A and B' with molecular structure for an entire homologous series. In 1964, Kreps and Signorelli (49), by means of a multiple regression analysis and a relationship similar to the Andrade equation, correlated the A and B' constants with the total number of carbon atoms in the individual compounds, for an entire homologous series. Accuracy when compared with experimental viscosities was excellent; the average error in calculated viscosity for the three homologous series investigated ranged from 1.49 to 3.95%.

Gambill (33), Reid and Sherwood (66, 67) and Reid (65) concisely present the available methods to estimate liquid viscosity when no experimental data are available and conclude that none are reliable. Most common reference is to the following three methods.

Souder's method (72), applicable for reduced temperatures, T_r, less than or equal to 0.70, is based on the empirical relationship

$$\log(\log(10\mu^o)) = (I\rho/M) - 2.9 \qquad (9)$$

where: μ^o = liquid viscosity at low pressure

I = constant calculated from empirically derived atomic and structural constant

ρ = liquid density

M = molecular weight

Thomas (76), in his relation, makes use of similar empirically determined structural contributions with comparable results. These two methods, are usually good to within ± 30% based on most compounds, but errors up to 90% may be expected.

The third method, termed the Rheochor (66) was developed by Friend and Hargreaves and is limited in scope being applicable only to determination of liquid viscosity at the normal boiling point. Average errors within 15 to 20% and common errors up to 50% may be expected.

In summary with respect to the extent of the present knowledge of the correlation of liquid viscosity with other physical properties, the following can be stated:

(a) Viscosity correlations most commonly employed are empirical in nature.

(b) The best correlations are generally limited to one compound, and at least two experimental points are required.

(c) Accuracy and simplicity are sacrificed when the correlations are extended to groups of compounds such as a homologous series.

(d) None of the better correlations have been extended to the point of employing one equation over an extended temperature range with the same set of constants, for a group of homologous series.

(e) No reliable method is available for the estimation of liquid viscosity in the absence of experimental data. The best methods are usually good to within 30%.

Measurement of Liquid Density

In general, the experimental determination of the density of liquids can be classified into two main groups:

(a) measurement of the weight of known volume

(b) buoyancy methods.

Measurement of Weight of a Known Volume

Pycnometers. The most common method of density determination consists in establishing the weight of liquid occupying a known volume which is defined by the shape of a given vessel. Since it is impracticable to determine this volume from the geometry of the vessel, calibration of the vessel is in terms of the weight of pure water which it will hold. A multitude of pycnometers have been used for defining a volume so that the filling and weighing of the vessel are reproducible and convenient. These include: the Gay-Lussac pycnometer, the Johnston and Adams pycnometer, the automatic leveling pycnometer of Brown and Land, the Sprengel-Ostwald pycnometer and the Lipkin bicapillary pycnometer. Detailed description of each pycnometer is given by Weissberger (75).

The Lipkin bicapillary pycnometer which requires about 5 ml of sample, has been recommended by the American Society for Testing Materials (ASTM) in a standard method of test for the density of hydrocarbon liquids. The ASTM reports an error of $\pm$ 1-4 x 10^{-4} in density. The chief disadvantages of this type pycnometer are that it is restricted to liquids having vapor pressures less than 600 mm of mercury at the test temperatures. The filling and adjusting of the pycnometer is quite involved. Trapping of air bubbles in the sample is a common occurrence and results in serious errors. Samples which are solids at room temperature are especially difficult to handle in a pycnometer.

Dilatometers. A detailed description of the different forms of the dilatometer is given by Gibson (35) and by Jones, et al. (43). In general, changes in volume as a function of temperature are determined by observing the change in level of the liquid in a capillary attached to a bulb (thermometer type), or by weighing the liquid displaced from a completely filled vessel when the test temperature is increased (weight type). Costello and Bowden (22) employed a sealed dilatometer as a pycnometer to determine the densities to within $\pm$ 0.0001 g/ml of some normal alcohols.

Buoyancy Methods

Many methods for measuring density are based on Archimedes' principle, which states that the upward buoyant force exerted on a body immersed in a liquid is equal to the weight of the displaced liquid.

Hydrostatic Weighing Method of Kohlrausch (48).

A sinker is suspended from a gravimetric balance and is weighed first in air, then submerged in the liquid. The apparent loss in true weight is equal to the mass of the displaced liquid which can be related to the density of the liquid. The method is rapid and lends itself to measurements of a given sample at a number of different temperatures and gives very precise results. Wirth (80) has demonstrated that the reproducibility of the measurements of density is as high as $\pm 2 \times 10^{-6}$ g/ml when sinkers of three-hundred ml were employed. Schulz (70) has described a vessel for immersing the sinker, which is suited to density measurement of solutions of volatile or hygroscopic organic liquids. An accuracy of $\pm 1 \times 10^{-5}$ was obtained using 50 ml of sample.

Forziati, et al. (31) present a density balance useful for hydrocarbons which allows a density measurement every 20 minutes on 9 ml of sample with an accuracy of 5×10^{-5} g/ml and a reproducibility of 2×10^{-5}.

Totally Immersed Hydrostatic Balance. The method proposed by Wagner, Bailey and Eversole (79) for measuring densities of either liquids or vapors makes use of a quartz bob of known volume suspended from a quartz helix and immersed in the phase whose density is being determined. Wagner, et al. (79) report that, with a bob of 1.35 ml, the density of liquid water was obtained to within ± 0.0003 g/ml over the temperature range from 10°C to 35°C. An accuracy of ± 0.0001 g/ml in density was obtained with liquid n-heptane by Gaines and Rutkowski (32) using an apparatus similar in design to that of Wagner. The main disadvantage in this method is the considerable amount of labor involved in the helix calibration.

Free Floats. Hydrometers are examples of free floats which are suitable only for rough determinations of liquid density. Even with large amounts of sample, 25-50 ml, the accuracy in density is not higher than ± 0.001 g/ml (75). Variations of the free float method, i.e., the magnetic float, the density gradient tube and the cartesian diver are described in detail by Weissberger (75).

Falling Drop. The falling drop method of Barbour and Hamilton (9) is described by Weissberger (75) and Hoiberg (40).

The method has many disadvantages (75), the chief being an accuracy in density of only ± 0.001 g/ml.

Measurement of Viscosity of Newtonian Liquids

The laws of fluid flow under generalized conditions can be extremely complex. The experimental conditions for viscometric work are so selected that the effects of all properties of the fluid other than its viscosity are eliminated or reduced to insignificant values, and the geometry of the experimental system is designed to give simple functions of space and time in the final equations. Considerations of accuracy, simplicity and susceptibility to mathematical treatment have resulted in the continued use and refinement of only a few methods of measuring the absolute viscosity of Newtonian liquids. An additional requirement common to the successful methods is that measurements be made in a system where flow is predominantly laminar, that is, flow where the individual particles of the fluid move in regular paths relative to the fluid boundaries. These systems and the respective classes of viscometers include:

(a) the isothermal flow of a fluid in straight long tubes of circular cross-section; capillary-tube viscometers;

(b) the flow in the annulus between two long concentric cylinders rotating at different speeds, around a common axis; rotational viscometers;

(c) the flow around a body in a relatively large expanse or fluid; falling body viscometers;

(d) the flow about a body of revolution set in oscillatory motion; oscillational viscometers.

Comprehensive discussions of viscometers of various types have been given by Reilly (68), Barr (10), Hatschek (38), and by Weissberger (75). Rotational viscometers have been described in detail by Bearden (12) and by Couette (23). Bridgman (17) and Hoppler (41) describe their designs of a falling-body viscometer. Neither viscometer is subject to exact mathematical treatment, and are therefore limited in accuracy. Oscillational viscometers employing simple shapes such as spheres (6), cylinders (55) and disks (46) are also limited in accuracy due to incomplete mathematical treatment.

The capillary-tube viscometer has been used in this work since it is the most accurate and widely used method (75). For convenient application to viscometry, the equation for laminar flow of a fluid through a cylindrical tube (41) may be written as

$$\mu = \pi r^4 P t_i / 8 v (\ell + nr) - s \rho v / 8 \pi (\ell + nr) t_i \qquad (10)$$

where: r = radius of capillary

P = mean effective pressure drop through capillary

v = volume of flow in time, t_i

ℓ = length of the capillary

n, s = coefficients associated with flow at the ends of the capillary

μ = absolute viscosity

ρ = density of the fluid

t_i = efflux time

Barr (10) presents the derivation of equation 10 from the theory. The first term is seen to include the laws determined by Poiseuille (60), while the second term, or kinetic energy term, arises from the work done in accelerating and decelerating the fluid at the ends of the capillary.

The most widely used type of capillary viscometer is one in which the pressure causing the flow results from the hydrostatic head of liquid in the viscometer. This type is called the kinematic viscometer and the kinematic viscosity is obtained directly. For this case the pressure causing flow is $h\rho g_o$, where h is a mean effective value of the head and g_o is the acceleration of gravity. Replacing $h\rho g_o$ for P in equation 10 gives the following

$$\mu/\rho = V_i = \pi r^4 h g_o t_i / 8v\,(\ell + nr) - sv/8\pi\,(\ell + nr)\,t_i \qquad (11)$$

or

$$V_i = C_1 t_i - B/t_i \qquad (12)$$

where

$$C_1 = \pi r^4 h g_o / 8v\,(\ell + nr) \text{ and } B = sv/8\pi(\ell + nr) \qquad (13)$$

EXPERIMENTAL STUDIES

Compounds

Paraffins

n-Decane and n-tridecane supplied by Wilkens Instrument and Research, Inc. were used without further purification.

Alcohols

Ten members of the homologous series of normal alcohols ranging from n-butanol to n-hexadecanol were obtained and purified if purity was found to be below 99.9 per cent. The history of the n-alcohols studied is presented in Table 1.

The purity of all the n-alcohols was determined by H. Kemme (45) by means of differential thermal analysis. Kemme found that only the alcohols having a purity of at least 99.9 per cent gave a vertical isotherm during the determination of the normal boiling point. This behavior was established as the criterion of purity of better than 99.9 per cent. n-Butanol, n-heptanol, n-nonanol, n-tetradecanol and n-hexadecanol were found to be impure as obtained from the suppliers. These were further purified by either of two methods:

(a) gas liquid chromatography (GLC) or

(b) distillation with the Nester-Faust Spinning Band Distillation Column

TABLE 1

HISTORY OF n-ALCOHOLS STUDIED

Compound	Supplier	Purity Claimed %	Method Of Purification Used Here	Normal Boiling Point Found °C	Purity Found %
n-Butanol	Union Carbide	none	GLC*	117.89	99.9
n-Pentanol	Wilkens	99.9	none	138.06	99.9
n-Hexanol	Wilkens	99.9	none	157.14	99.9
n-Heptanol	K and K Lab.	none	DIST*	176.26	99.9
n-Octanol	Wilkens	99.9	none	195.26	99.9
n-Nonanol	K and K Lab.	95-99	DIST	213.56	99.9
n-Decanol	Wilkens	99.9	none	231.0	99.9
n-Dodecanol	Wilkens	99.9	none	260.70	99.9
n-Tetradecanol	Conco Co.	97	DIST	263.26	99.9
n-Hexadecanol	Conco Co.	95	DIST	344.06	99.9

---

*GLC - gas liquid chromatography
DIST - distillation

Equipment

Density Apparatus

The density apparatus used was based on the hydrostatic weighing method of Kohlrausch (48) and was constructed to meet the following design criteria:

(a) establishment, control and measurement of the temperature of the liquid

(b) obtaining a high degree of reproducibility and precision in measured density over an extended temperature interval

(c) convenience in operation involving the insertion and removal of the plummet from the liquid sample and the inspection and control of the surface of the liquid in relation to the immersed plummet

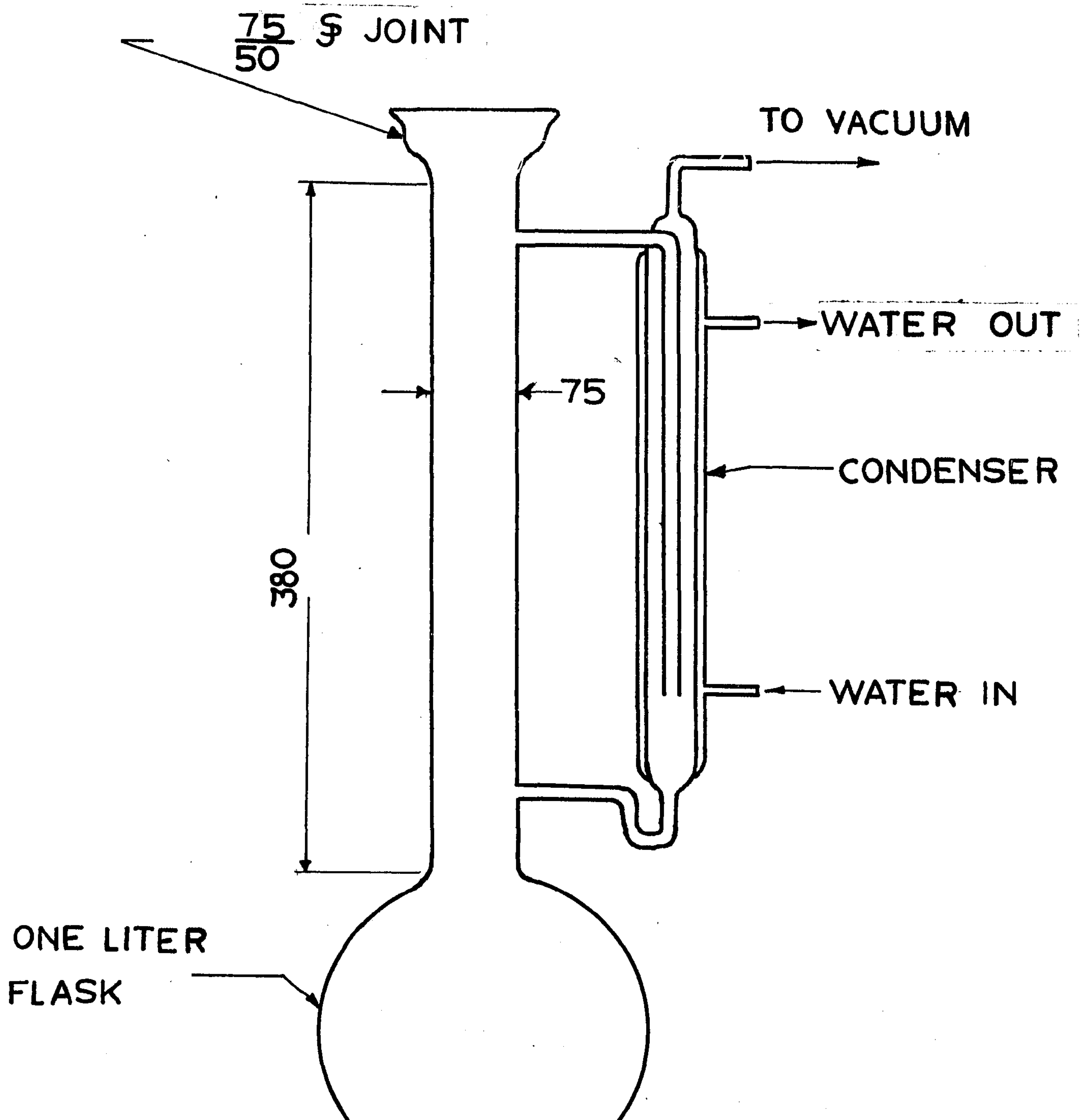
(d) measurements on a number of liquids in a minimum length of time

(e) employing the smallest amount of liquid sample while maintaining a high degree of accuracy

Vapor Bath. A vapor bath supplied by Cannon Instrument Co. (8) conforming to the dimensions shown in Figure 1, was used in this work. The column of the vapor bath was insulated with a covering of aluminum foil, and 1-inch thick corrugated cardboard in which holes

FIGURE I

VAPOR BATH



ALL DIMENSIONS IN MILLIMETERS

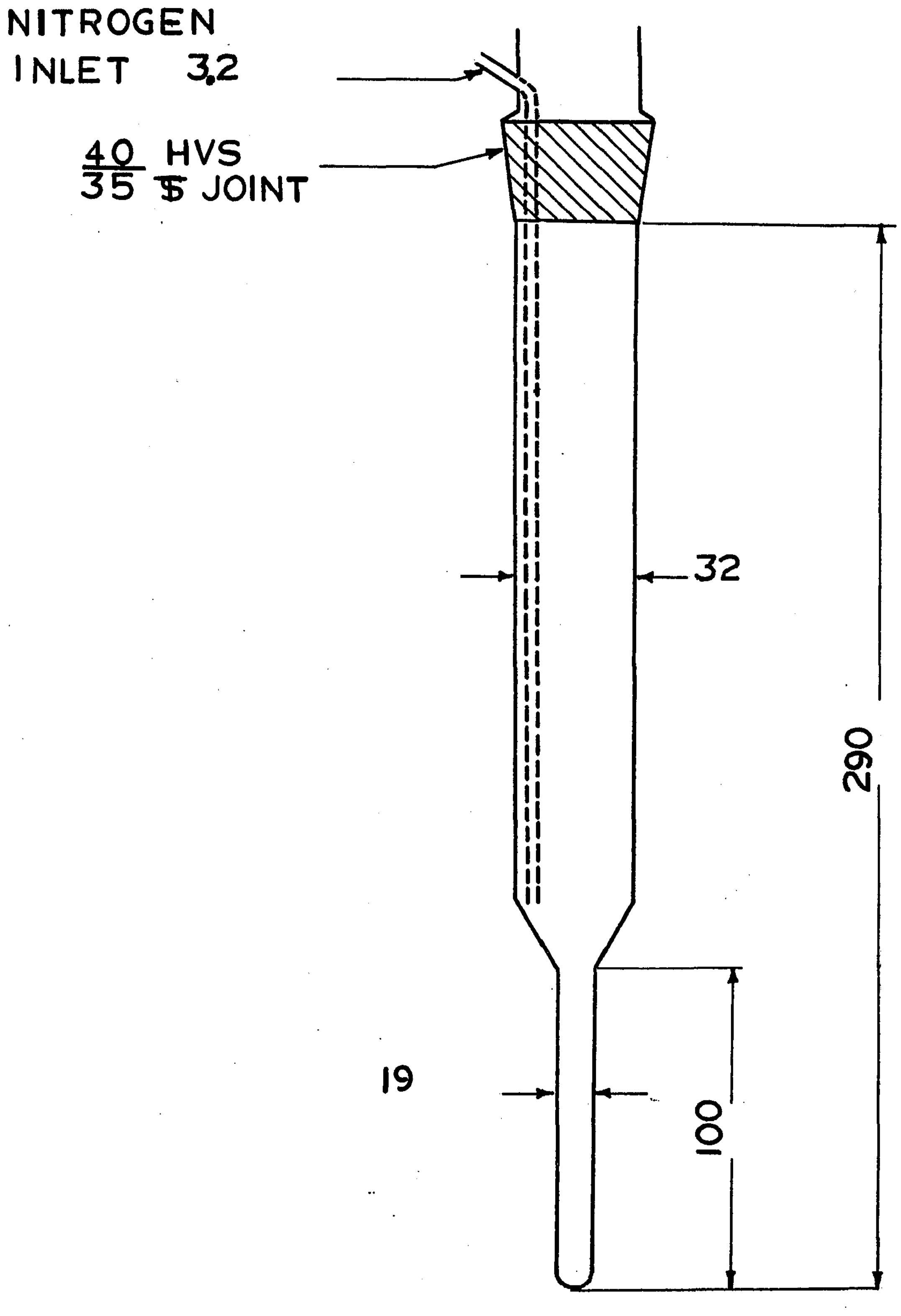
were cut to permit observation of the immersed plummet. The density measurements were made in the density sample tube shown in Figure 2, which was placed inside tube A of the removable density adapter (Figure 3). This adapter was set on top of the vapor bath so that the density sample tube was suspended inside the bath. The thermocouple holder tube, shown in Figure 4, was placed inside tube B of the removable density adapter. The assembled vapor bath is presented in Figures 5 and 6.

Heater. Heat was supplied to the 1000-ml round-bottom flask of the vapor bath by means of a cylindrical heating mantle. Voltage to the heater was controlled by a variable transformer.

Balance. A Sartorius Balance modified for below-the-base weighing (Model 2413, Scientific Glass Co.), was employed for all weight measurements. The balance was supported above the vapor bath on two 1/4-inch thick lead plates sandwiched between two 1/4-inch thick wood plates. These plates insulated the balance from the effects of rising convection currents and also dampened out vibrations. The plates were set on an Unistrut frame which was completely enclosed by a 1/4-inch thick plexiglass shield. The shielding prevented air currents from disturbing the suspended plummet. The balance assembly is shown in Figure 7.

FIGURE 2

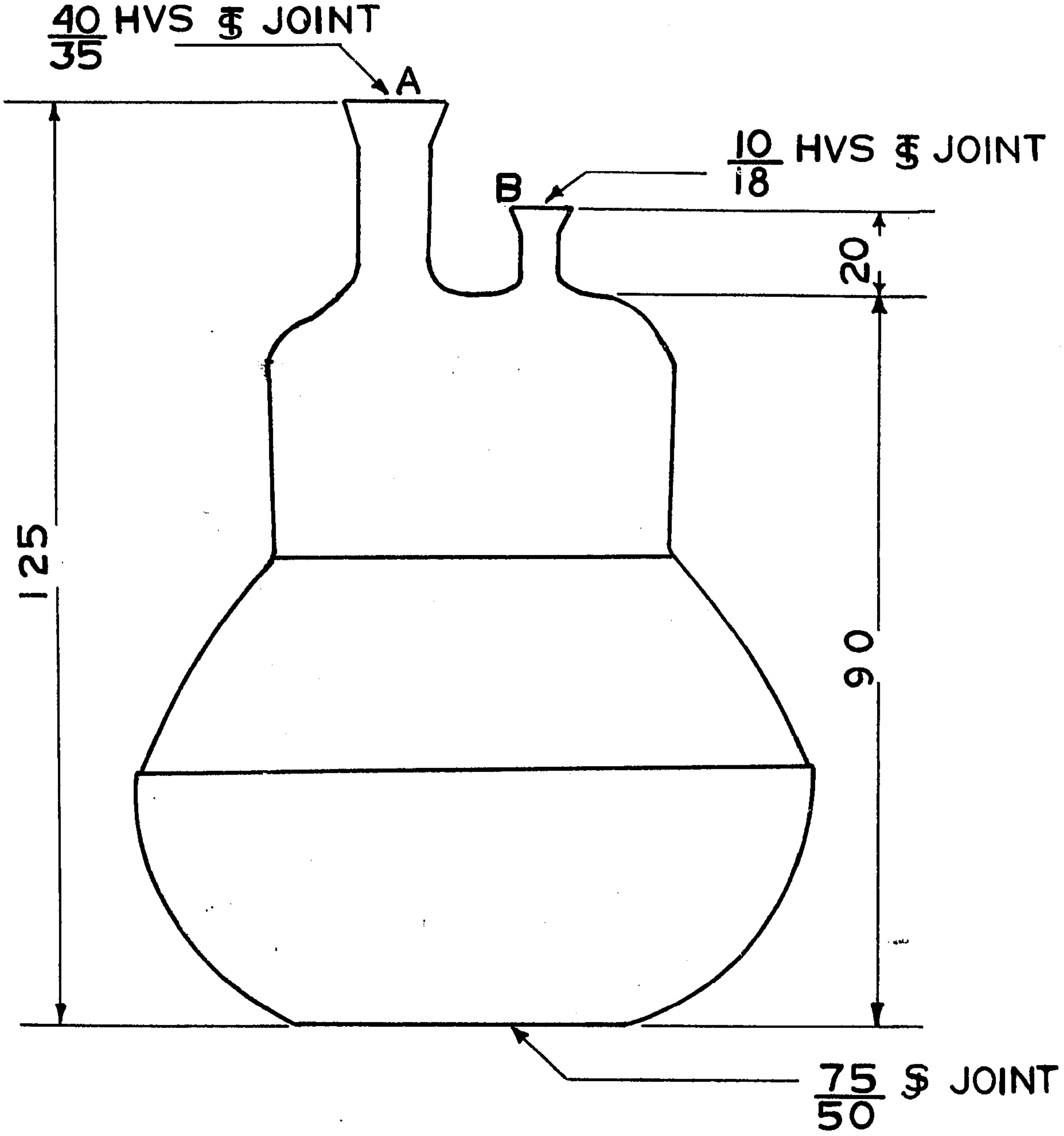
DENSITY SAMPLE TUBE



ALL DIMENSIONS IN MILLIMETERS

FIGURE 3

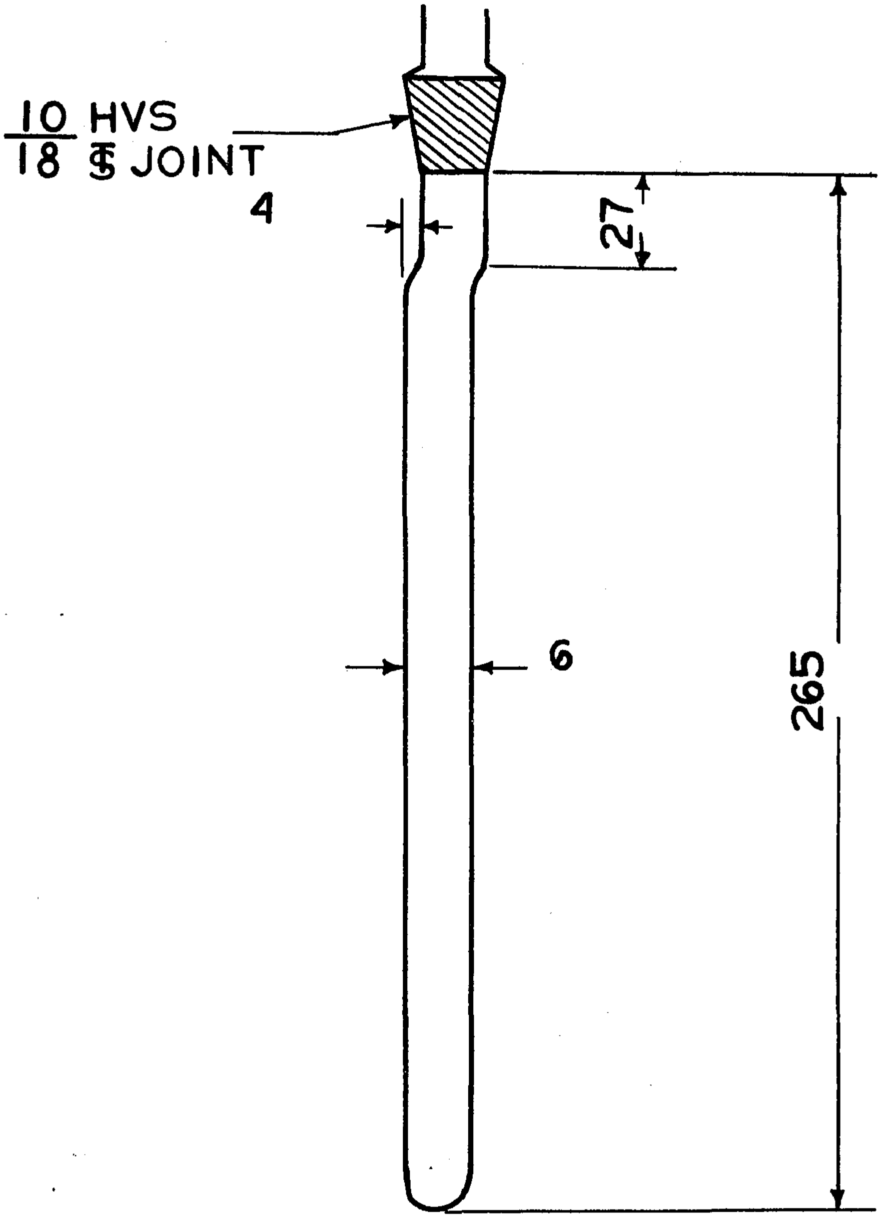
REMOVABLE DENSITY ADAPTER



ALL DIMENSIONS IN MILLIMETERS

FIGURE 4

THERMOCOUPLE HOLDER TUBE



ALL DIMENSIONS IN MILLIMETERS

Figure 5

ASSEMBLED DENSITY APPARATUS

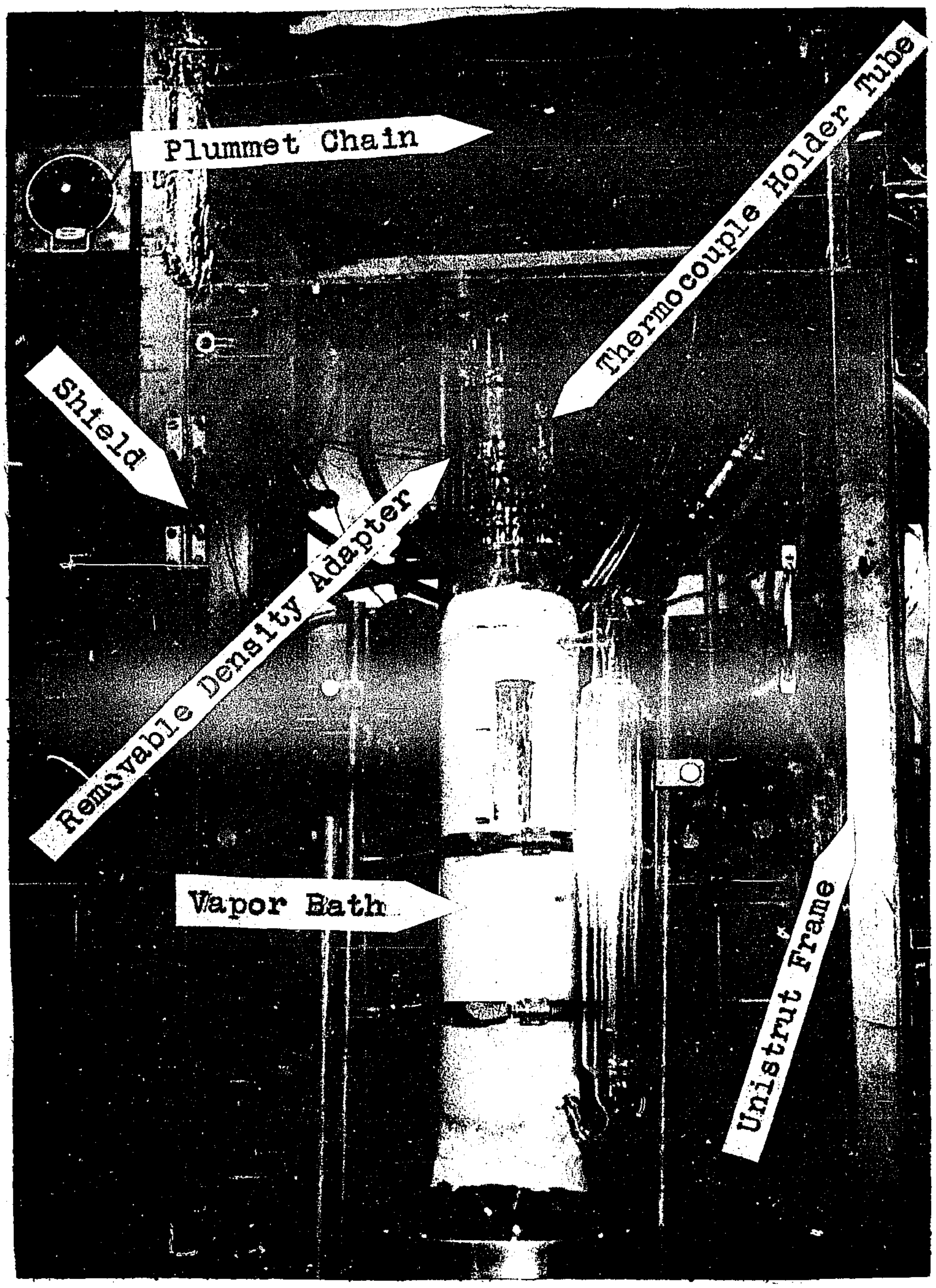


Figure 6

ASSEMBLED DENSITY APPARATUS
WITH PLUMMET

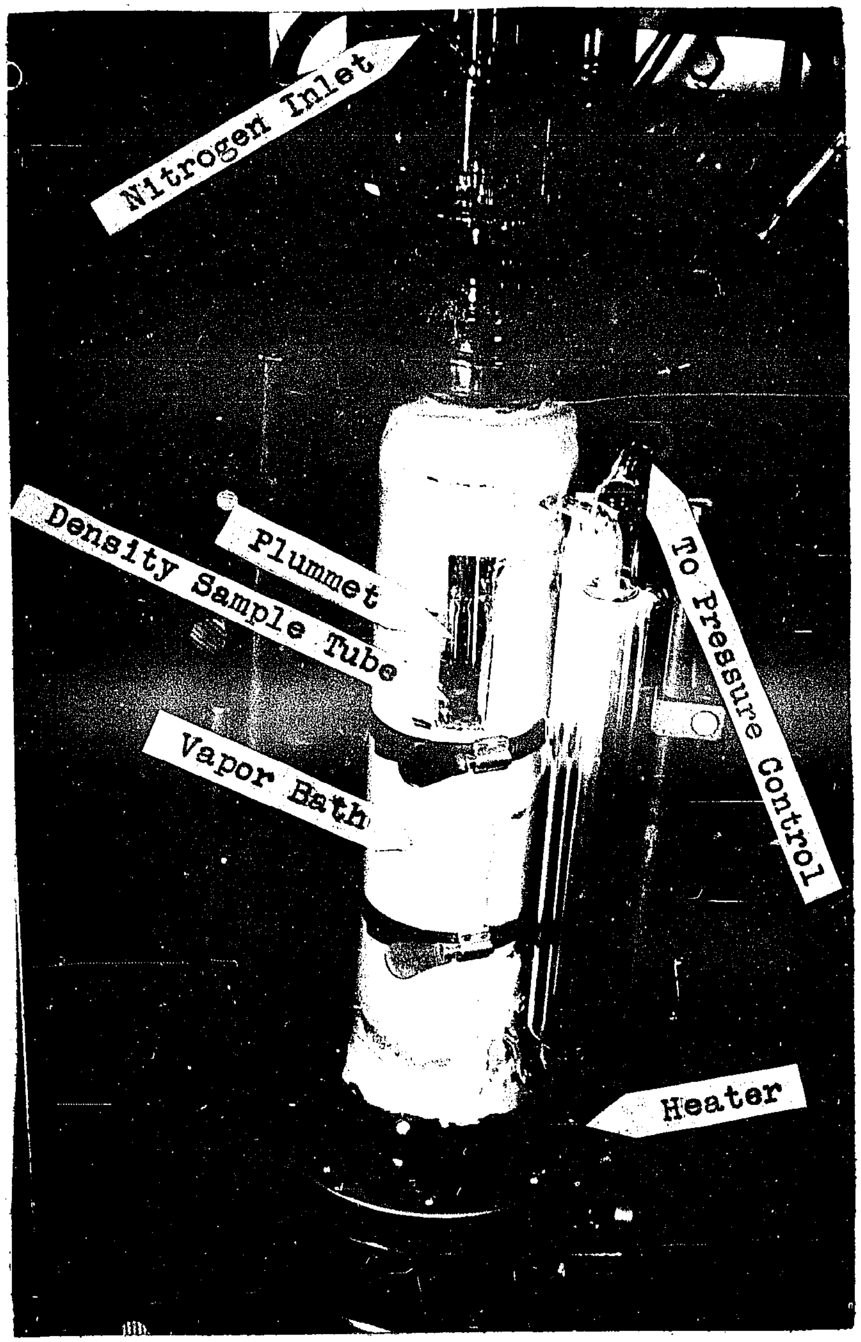
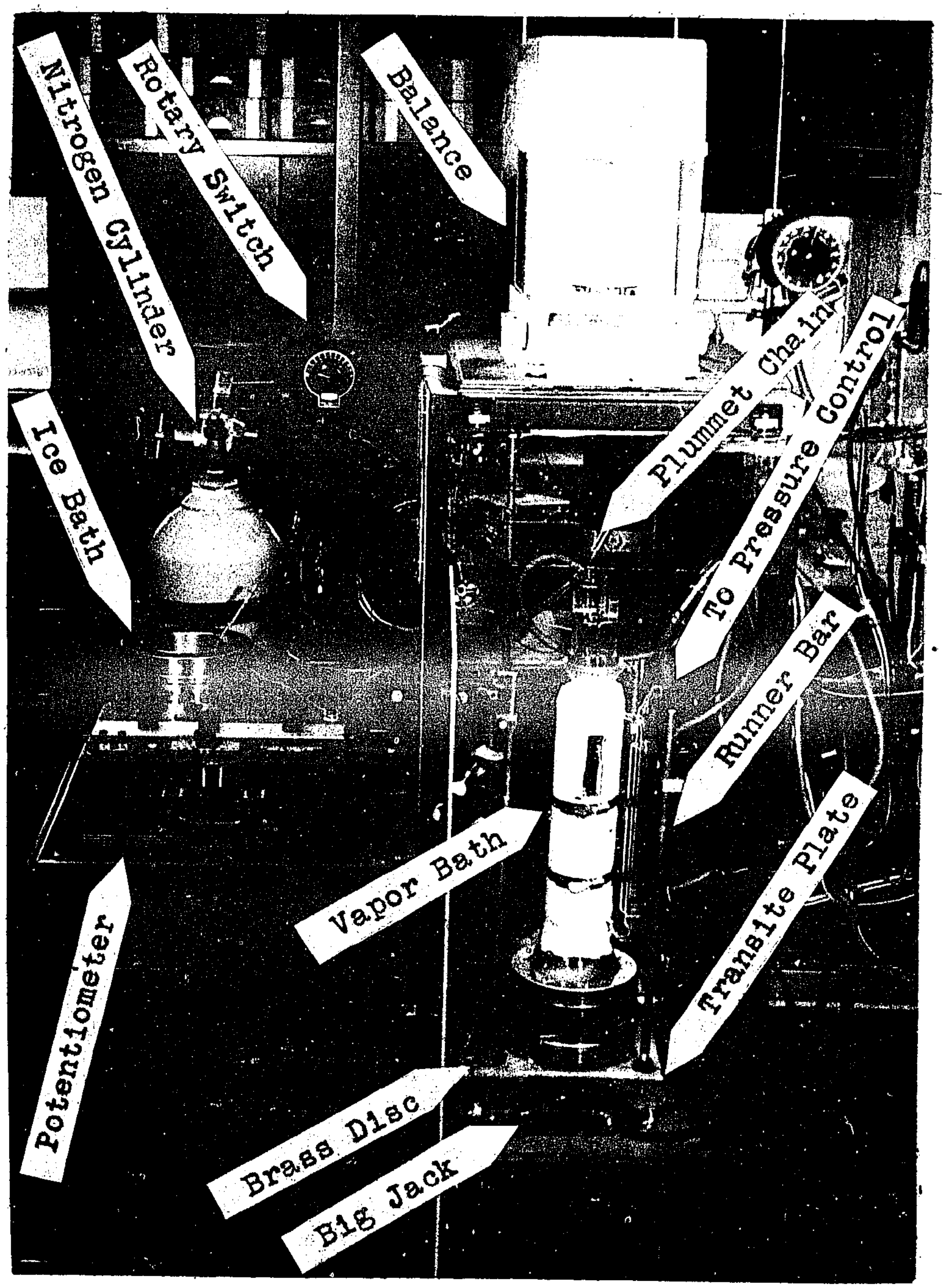


Figure 7

DENSITY APPARATUS WITH BALANCE

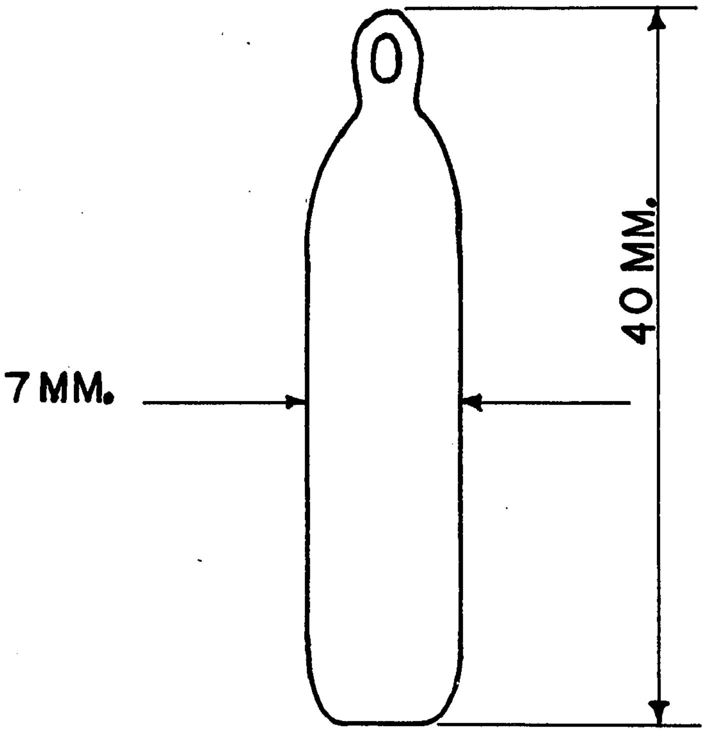


Plummet. A solid cigar-shaped pyrex rod of 7 mm O. D. served as the plummet and is shown in Figures 6 and 8. The volume of the plummet, 2 cc, was limited by the inconvenience of preparing or purchasing large amounts of highly purified samples and also by the design of the density sample tube. To prevent contact between the plummet and walls of the density sample tube a minimum annular spacing of 3 mm was selected. Careful alignment of the plummet and the density sample tube with respect to annular spacing and vertical mounting was required. The plummet was suspended from the balance by means of an 18 inch long fine 14 karat gold chain which was then attached to a 27 gage platinum wire. The platinum wire passed through the liquid surface and was used to minimize surface tension effects on the hydrostatic weighings (62).

Plummet Level Control. Because of evaporation and expansion of the liquid sample, the immersion level of the plummet would tend to change during and between runs. A mechanism which permitted raising or lowering the vapor bath was constructed, to maintain a constant immersion level of the plummet in the liquid sample. This level control permitted the surface of the liquid sample to be brought always to a mark on the platinum wire. The wire was selected for the reference mark since it always contributed the same, small amount to the total volume of immersed solid.

FIGURE 8

PLUMMET



2 CC VOLUME

The immersion level control mechanism is shown in Figure 7. The density apparatus was supported on a 15" x 11" x 1/4" transite plate which was bolted onto an adjustable elevating support (Big Jack, Type B). The transite plate had four mounting holes for $\frac{1}{2}$-inch aluminum rods which supported the density apparatus. The jack was seated on a $\frac{1}{2}$-inch thick plywood board which rested on the supporting Unistrut frame for the Sartorius Balance. The entire density apparatus was thus raised or lowered by turning the screw of the jack.

The vertical and horizontal alignment of the density apparatus was established by means of a "runner" bar which extended through both the transite and plywood plates. Two circular brass discs were clamped to this bar; one above and the other below the transite plate, by means of set screws. The "runner" bar also prevented movement, i.e., tilting, of the density apparatus during a run. A level indicator was used to determine whether the density apparatus was properly aligned.

The use of the plummet level control mechanism also served for convenient means for insertion and removal of the plummet from the liquid sample.

Temperature Measurements. Temperature measurements inside the vapor bath were made by a 24 gage iron-constantan thermocouple insulated with fiberglass. The thermocouple was inserted into the thermocouple holder tube and temperatures were determined with a Leeds and Northrup (Model 8686) millivolt potentiometer.

Pressure Control System. Constant temperature was maintained within the vapor bath by controlling the pressure over a boiling liquid. Either toluene or dimethylphthalate were employed as the bath liquid in this work. The pressure control system is shown in Figures 9, 11 and schematically in Figure 10. The system is similar to the one designed and used by Kemme (45). Lunkenheimer ball valves, B_1 and B_2, served three purposes:

(a) Opening both valves achieved a by-pass of the control manostat and a rapid pressure evacuation of the vapor bath.

(b) Closing valve B_2 and opening valve B_1 placed the control manostat in operation.

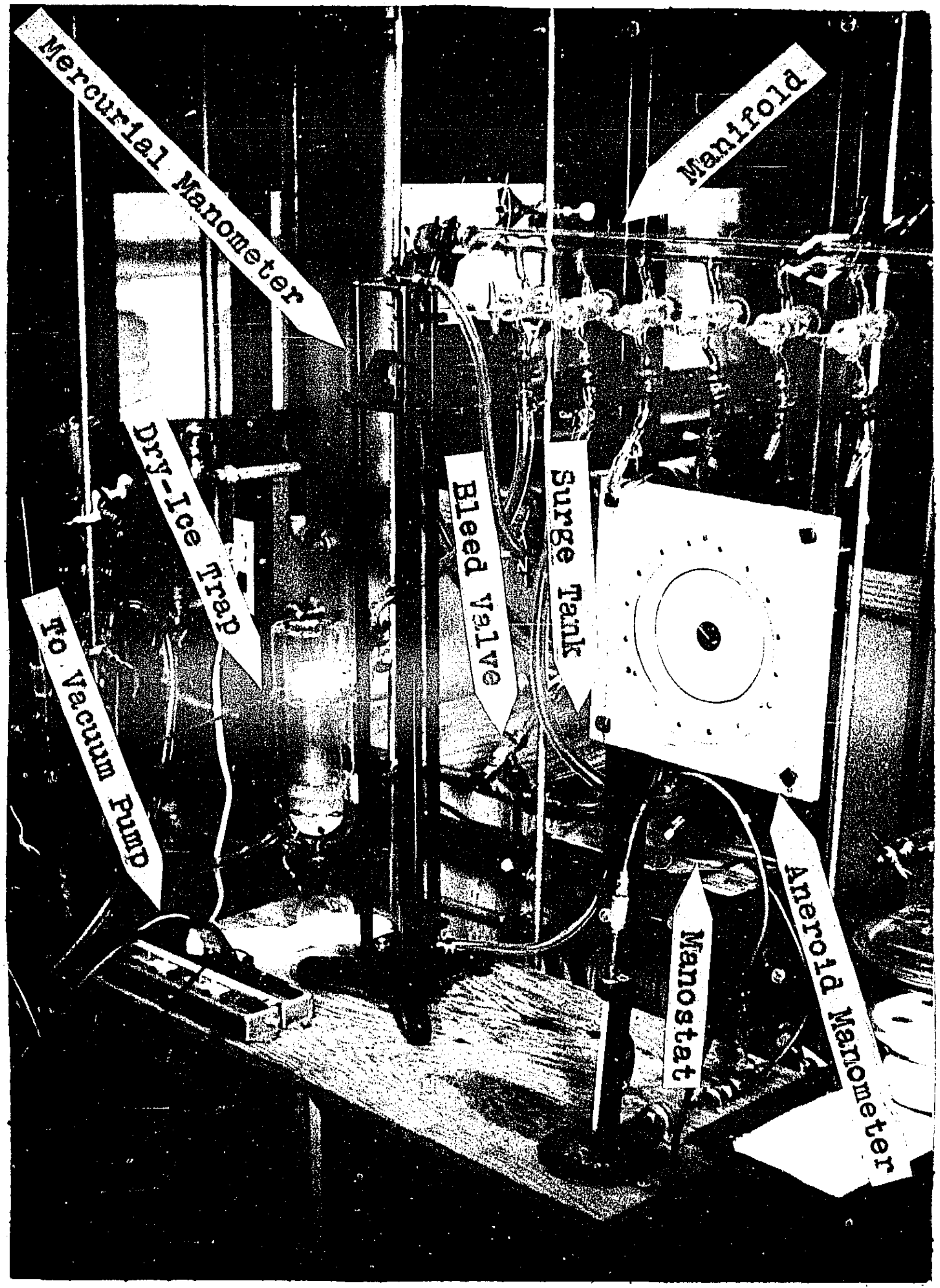
(c) Closing both valves produced a closed system and permitted shut down of the vacuum pump without loss of vacuum.

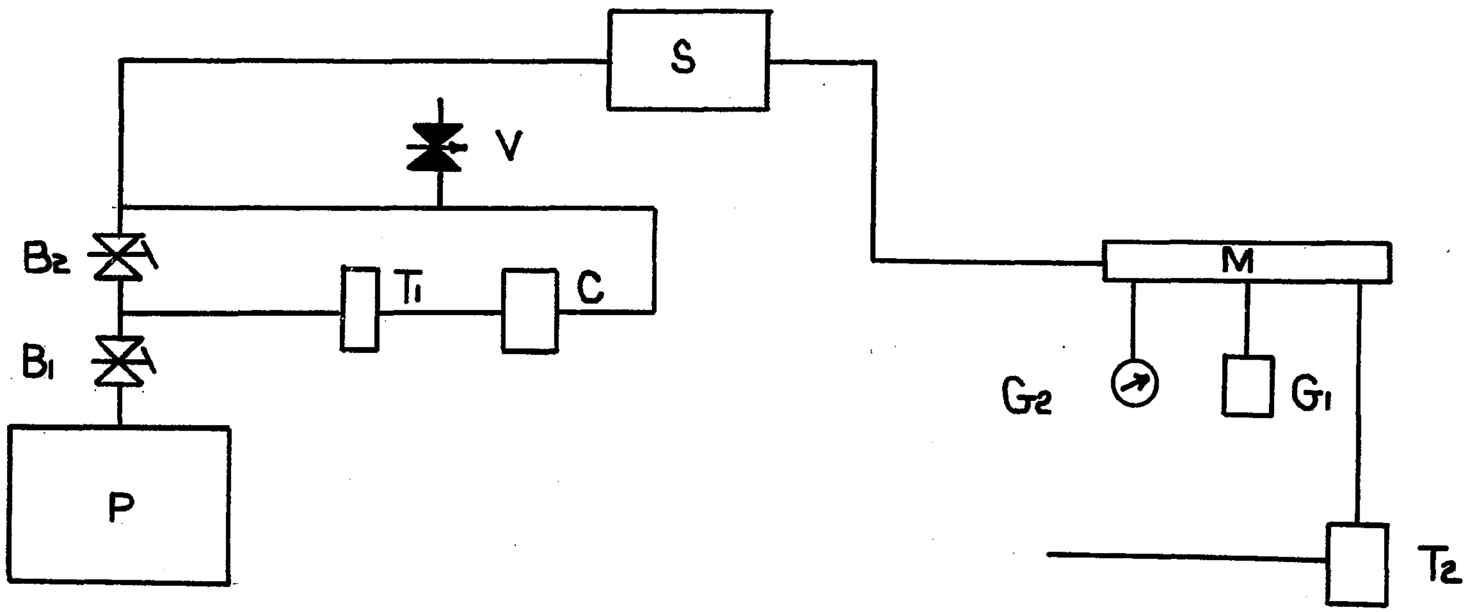
Complete specifications for the pressure control system are given in Table 2.

The surge tank, S, was placed in a wooden box packed with excelsior as a safety precaution. Pyrex joints employed in the

Figure 9

PRESSURE CONTROL SYSTEM





CODE

B	BALL VALVE
C	MANOSTAT
G	MANOMETER
M	MANIFOLD
P	PUMP VACUUM
S	SURGE TANK
T	TRAP
V	BLEED VALVE

FIGURE 10

PRESSURE CONTROL SYSTEM

Figure 11

DENSITY APPARATUS WITH AUXILIARY EQUIPMENT

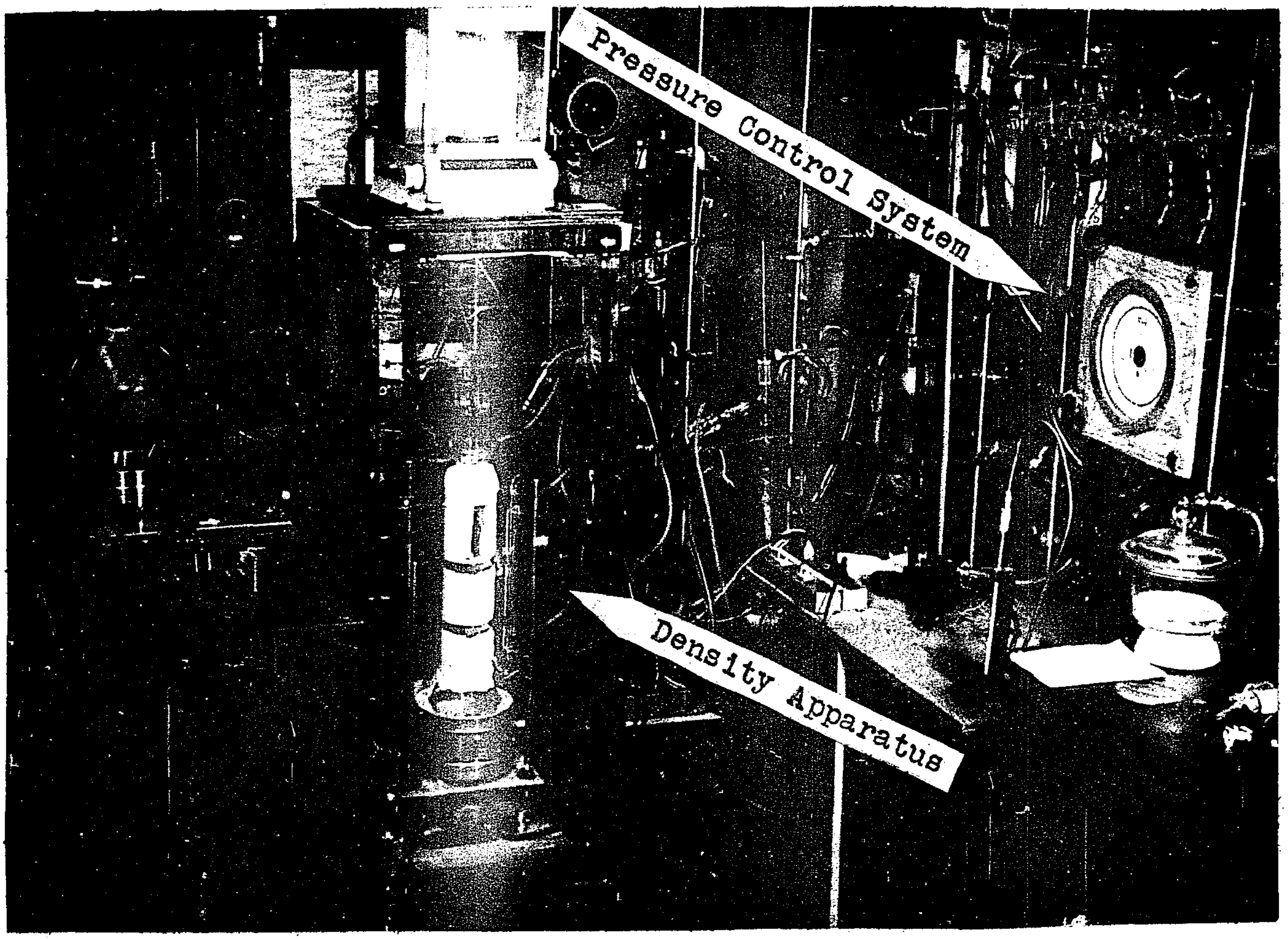


TABLE 2

PRESSURE CONTROL SYSTEM

PART NO.	SPECIFICATIONS
B_1, B_2	700-B bronze, 3/4-inch Buna N seat Lunkenheimer ball valves, Jones and Auerbacker
C	Cartesian manostat No. 8, 4 mm orifice, Manostat Corporation, Catalog No. 50-580
G_1	Precision mercurial manometer, type FA-135, Wallace and Tiernan
G_2	Precision aneroid Manometer, type FA-129-160, Wallace and Tiernan
M	Manifold, Pyrex, see Kemme (45)
P	Duo seal vacuum pump, model 1402, W. M. Welch Scientific Co.
S	Surge tank, 22 liter Pyrex round-bottom flask, 3-neck with vertical side necks, all joints high vacuum spherical (H. V. S.), Scientific Glass Co.
T_1	Vacuum trap, Pyrex, Catalog No. JV-7810, Scientific Glass Co.
T_2	Dry-ice trap, Pyrex, see Kemme (45)
V	1/4 - inch Hoke bleed valve

pressure control system were high vacuum (H. V. S.) ball joints. Piping consisted mainly of tygon tubing except for the loop between the vacuum pump and the surge tank which consisted of metal pipe. Details of the assembled density apparatus and the auxiliary equipment are presented in Figure 11.

Viscosity Apparatus

Cannon-Ubbelhode (19) semi-micro capillary viscometers were used for all kinematic viscosity determinations. These viscometers have been designed with "trumpet-shaped" capillary entrances and exits to minimize capillary entrance and exit kinetic energy effects. During operation, the viscometer had a constant liquid driving head at all temperatures, and, therefore, the viscometer constant was not effected by temperature.

A water bath (Fisher Isotemp Bath), constant to ± 0.01°C was used in the temperature range 20 to 80°C. At temperatures below 40°C chilled ethylene glycol-water solution was circulated through a cooling coil placed in the bath. A refrigerated circulating bath pumped the refrigerant through copper tubing to the coil. The Cannon Instrument Company's (Model H-1) high temperature bath, filled with five gallons of methyl phenyl silicone fluid (General Electric SF-1017), was employed for ± 0.1°C control at temperatures from 90 to 250°C. Temperature was automatically controlled by a mercury-glass thermoregulator.

The temperatures of the constant temperature baths were determined with 0.1°C graduated, adjustatherm thermometers. Thermometers were calibrated, up to 100°C, against a National Bureau of Standards calibrated thermometer with a maximum deviation of ± 0.1°C. Four electric timers (Standard Co., Model S-10), graduated in divisions of 0.1 seconds, and supplied with a guaranteed accuracy to within 0.05 per cent when tested over a 10 minute period, were used to measure the efflux time. Details of the entire viscosity apparatus are shown in Figure 12.

Procedures

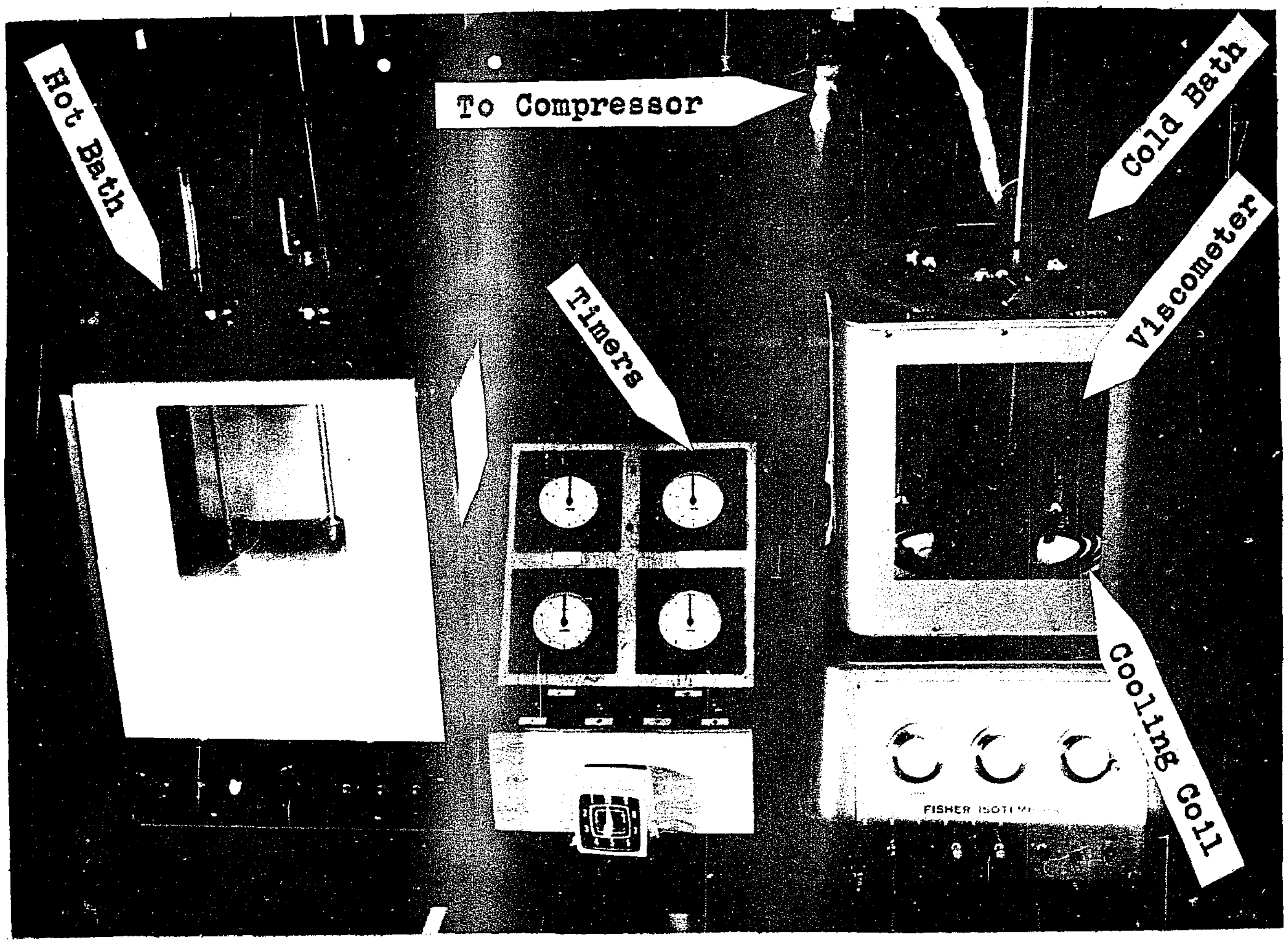
Density Measurements

Loading Density Sample Tube. The Pyrex plummet and the density sample tube were thoroughly cleaned prior to each run. Five milliliters of liquid sample were introduced by pipet into the density sample tube, with caution to avoid wetting the upper walls. If at any time during a run, the suspension chain were to become wet, an error in the observed weight would be created. Solid samples, at room temperature were melted by a heat gun, then charged as a liquid by pipet as described above.

Assembling the Density Apparatus. The bath liquid was introduced, with boiling chips, into the one-liter flask of the vapor bath to a level slightly above the rim of the heating mantle. The

Figure 12

VISCOSITY APPARATUS



density sample tube and the thermocouple holder tube were then placed inside tube A and tube B, respectively, of the removable density adapter. This adapter was then positioned on top of the vapor bath so that the density sample tube was suspended inside the bath. All ground joints were lightly greased with high vacuum silicone grease. Pyrex glass wool, was packed around the exposed section of the one-liter flask to prevent heat losses. Prepurified nitrogen gas was admitted through the nitrogen inlet tube of the density sample tube for a period of two minutes to flush out air above the liquid sample. The assembled density apparatus was placed inside the shield on the adjustable elevating support and aligned so that the suspended plummet was hanging freely in air outside the density apparatus.

Weighing Plummet in Air. The suspended plummet was first weighed in air, outside the density apparatus, by setting the zero point of the balance and recording the weight at two minute intervals until three successive readings agreed within ± 0.0001 grams.

Insertion of Plummet Into Density Sample Tube. The density apparatus was lowered by the jack until the plummet was easily inserted into the liquid sample and then positioned such that the surface of the liquid was approximately at the scratched reference mark on the platinum wire. The vertical and horizontal alignment of the density apparatus was fixed by means of the runner bar and the two brass discs.

Weighing Plummet Immersed in Liquid Sample. Power to the heating mantle was set to obtain a low rate of reflux. The bleed valve V and the ball valve B_2 were closed, ball valve B_1 was opened, the needle valve of the manostat C was opened and the vacuum pump P was turned on until the absolute pressure in the system was reduced to the desired value as determined by the manometers. As this pressure was approached, the needle valve of the manostat was partially closed so that the desire value of the pressure was gradually attained. When this value was obtained, the needle valve of the manostat was then completely closed. Final adjustment of the exact pressure was made on the basis of temperature when reflux had started. If the pressure was too low, the ball valve B_1 was closed, the needle valve of the manostat was opened, and the bleed valve V was then adjusted so that the pressure was higher than the desired value. The needle valve of the manostat was then closed, the ball valve B_1 was opened, and then the needle valve of the manostat was alternately opened and closed until the exact pressure was reached. A period of 15-20 minutes was generally sufficient to insure that steady state had indeed been reached. The ball valve B_1 was then closed and the vacuum pump turned off in order to weigh the immersed plummet. This was necessary because vibrations from the vacuum pump caused the balance to fluctuate. Prior to obtaining a weight, the surface of the liquid sample was set exactly at the scratched reference mark on the platinum wire by the procedure outlined on page 32. The zero point of the balance had to be reset at this time since it was found that the zero point varied with changes in temperature and shifting loads in the building.

The weight of the immersed plummet, the pressure and the temperature were recorded at 2 minute intervals until three successive readings agreed within ± 0.0001 grams. Recording multiple readings was insurance that temperature steady state had indeed been reached, and that the plummet was not touching the sides of the density sample tube. This procedure was employed to measure the density of the normal alcohols, n-butanol to n-hexadecanol, at temperatures from 25°C to close to their normal boiling points.

Calculation of Density. A force balance in the vertical direction on an object immersed in a liquid gives

$$B_F = \rho g_o V_t \tag{14}$$

where: B_F = bouoyant force

ρ = mass density of the liquid

g_o = acceleration of gravity

V_t = volume of the immersed object at test temperature.

The apparent loss in the true weight of the plummet and the wire is equal to the mass of displaced liquid. Thus

$$B_F = g_o (W_A - W_L) \tag{15}$$

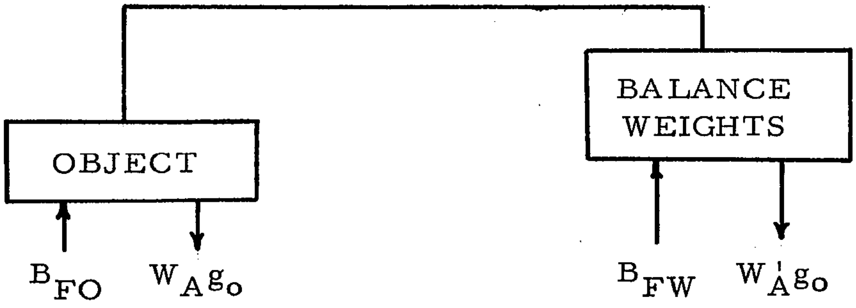
where: W_A = true (vacuum-corrected) weight in air

W_L = true weight in liquid

Combining equations 14 and 15 gives

$$\rho = (W_A - W_L)/V_t \tag{16}$$

The equation for calculating the true weight W_A from the weight W_A', which is required to balance the suspended plummet and wire in air, is obtained from a force balance



$$W_A g_o - B_{FO} = W_A' g_o - B_{FW} \tag{17}$$

Here B_{FO} and B_{FW} are the buoyant forces on the object and balance weights respectively. The buoyant force on the object is given by

$$B_{FO} = g_o V_o D_{air} \tag{18}$$

where: V_o = volume of object

D_{air} = density of air

and

$$V_o \approx W'_A \,/\, D_o \tag{19}$$

where D_o is the density of the object.

The buoyant force on the balance weights is

$$B_{FW} = g_o \, V_W \, D_{air} \tag{20}$$

where $V_W = W'_A \,/\, D_W$ is the volume occupied by the W'_A balance weights consisting of a material having a density D_W. Combining equations 17 to 20 gives

$$W_A = W'_A - (W'_A/D_W)\, D_{air} + (W'_A \,/\, D_o)\, D_{air} \tag{21}$$

Similarly a force balance on the plummet and wire immersed in a liquid, and the balance weights in air, gives the true weight of the object in liquid as

$$W_L = W'_L - D_{air}\, (W'_L / D_W) \tag{22}$$

The volume of the immersed object, V_t, is determined at a given temperature t_c by calibration with distilled water and equations 16, 21 and 22. Though the surface of the liquid is brought to a constant level on the platinum wire each time, V_t varies with temperature because of expansion of the Pyrex plummet. The immersed volume at any temperature, t, is calculated using the following equation:

$$V_t = V_c\ (1 + C_e\ \Delta t) \tag{23}$$

where: V_t = immersed volume of object at test temperature, t

V_c = immersed volume of object at calibration temperature, t_c

C_e = cubical coefficient of expansion of Pyrex glass, 9.9×10^{-6} per degree centigrade

Δt = $(t - t_c)$

In the calculation procedure presented above, the density of air was assumed constant, i.e., 0.0012 g/ml. This assumption does not effect 4th decimal accuracy in the experimental density (75). All calculations of liquid density were determined by Computer Program No. 1 which appears in the Appendix.

Kinematic Viscosity

The Cannon-Ubbelhode semi-micro capillary viscometer was cleaned prior to each run. Kinematic viscosity was determined via the procedure recommended by ASTM D445-53T. If the efflux time was less than 200 seconds, a smaller capillary viscometer was required. The procedure was repeated at the same temperature, without recharging the viscometer, until two successive measurements agreed within $\pm$ 0.1 per cent of the measure efflux time. This procedure was employed to measure the kinematic viscosity of the normal alcohols, n-butanol to n-hexadecanol, at temperatures from 25°C to close to their normal boiling points.

Calculation of Kinematic Viscosity. The kinematic viscosities of the n-alcohols were calculated by an equation of the following form

$$\mu/\rho = V_i = C_1 t_i - B/t_i \tag{24}$$

where: V_i = kinematic viscosity

μ = absolute viscosity

ρ = density

t_i = efflux time

C_1 = viscometer constant

B = kinetic energy correction constant

The constant C_1, was assumed to be constant over the entire range of temperatures, since mathematical treatment of the Poiseuille equation for capillary flow indicated that this was the case if expansion of the viscometer glass was linear with temperature (29). This assumption has been verified experimentally by Doolittle and Peterson (29). The quantity, B/t_i, was usually a small fraction of the term $C_1 t_i$, but was applied in all calculations of kinematic viscosity. The B/t_i quantity can not be neglected unless it is 0.1 per cent of the $C_1 t_i$ term, or less (7). The kinetic energy correction constant, B, is not a true constant in capillary viscometers. It increases with increasing Reynolds Numbers up to the range of 2000 (7). Over the range of kinematic viscosities studied it was assumed that B was a constant for each viscometer. All calculations of kinematic viscosity were carried out by means of Computer Program No. 2, which appears in the Appendix.

Calibrations

Density Apparatus

Vapor Bath, Pressure-Temperature. The temperature inside the vapor bath was calibrated as a function of pressure for the two bath liquids employed. Toluene was used for room temperature to 110°C, and dimethylphthalate for 130 to 280°C runs. The pressure was controlled by the manostat while heat input to the vapor bath and the condenser duty were manually adjusted until the boiling liquid and the refluxing vapor were neither subcooled nor superheated. The criterion for the latter was a vapor temperature that did not vary with changes in heat input. Reflux rates were about 30 to 50 drops per minute. System pressure and vapor temperature were recorded at regular intervals until thermal equilibrium was reached. Readings were then continued for one hour, and the average values with ranges are presented in Table 3. Average temperature and pressure fluctuations were 0.18°C and 0.2 mm Hg., and 0.05°C and 0.2 mm Hg. for dimethylphthalate and toluene, respectively.

Plummets. The calibration of two Pyrex plummets was performed with freshly distilled water at 30°C. The experimental procedure and method of calculation was idential to the description on pages 39 to 43. In this case, the density of the liquid was accurately known (21) and the loss in true weight of the plummet, $W_A - W_L$, was used to determine the immersed volume V_c of the plummet and wire at the calibration temperature. Thus, the immersed volume is

$$V_c = (W_A - W_L)/\rho \tag{25}$$

The calibration results for the two Pyrex plummets appears in Table 4. In each case the immersed volume, V_c, of the plummet and wire are given at the calibration temperature.

To determine the accuracy of the density apparatus, the density of freshly distilled water was experimentally determined at three temperatures by employing the above calibration data. The results are given in Table 5. The experimental densities of water are in agreement with literature values (21) within 1.4×10^{-4} g/ml.

TABLE 3

VAPOR BATH CALIBRATION
PRESSURE-TEMPERATURE

AVERAGE PRESSURE mm Hg	PRESSURE FLUCTUATION mm Hg	AVERAGE TEMPERATURE °C	TEMPERATURE FLUCTUATION °C
Dimethylphthalate			
4.0	± 0.1	127.30	± 0.20
19.0	± 0.1	161.73	± 0.10
60.0	± 0.1	191.90	± 0.22
149.7	± 0.2	219.49	± 0.30
340.3	± 0.3	250.34	± 0.10
685.5	± 0.4	279.25	± 0.19
	Average = ± 0.2		Average = ± 0.18
Toluene			
70.1	± 0.1	43.92	± 0.08
199.2	± 0.2	69.52	± 0.02
409.9	± 0.3	90.39	± 0.06
688.6	± 0.2	107.50	± 0.04
	Average = ± 0.2		Average = ± 0.05

TABLE 4

CALIBRATION OF PLUMMETS WITH DISTILLED WATER

PLUMMET NUMBER	APPARENT WEIGHT		TRUE WEIGHT		TEMP. °C	DENSITY (21) g/ml	IMMERSED VOLUME, ml
	W'_A	W'_L	W_A	W_L			
1	5.0665	3.0713	5.0682	3.0708	30.20	0.99562	2.00611
2	5.0781	3.0815	5.0797	3.0810	30.32	0.99558	2.00760

TABLE 5

ACCURACY OF DENSITY APPARATUS

		WATER DENSITY, g/ml		
PLUMMET NUMBER	TEMPERATURE °C	EXPERIMENTAL ρ	LITERATURE (21) ρ_L	DEVIATION $(\rho - \rho_L)$
1	40.24	0.99233	0.99216	+ 0.00017
1	59.80	0.98323	0.98333	- 0.00010
1	79.78	0.97181	0.97195	- 0.00014

Average Deviation = 0.00014 g/ml

With the same plummet, the densities of two pure hydrocarbons, n-decane and n-tridecane, were measured at temperatures from near room temperature to close to their normal boiling points. The purpose of this investigation was to establish whether the accuracy in density, based on the above calibration data, varied with temperature. The experimentally determined densities of n-decane and n-tridecane are given in Tables 6 and 7, respectively. The average deviation between the experimental and the literature densities (2) are 3.1×10^{-4} and 4.6×10^{-4} g/ml for n-decane and n-tridecane, respectively. The deviations exhibit no relationship with temperature.

Viscometers

The viscometers were calibrated in accordance with the procedure recommended by ASTM D445-53T (7), using two viscosity standard oils, supplied by Cannon Instrument Co. The kinematic viscosities of the standards were established in Master Viscometers, by the Cannon Instrument Co., as described by M. R. Cannon (18).

The kinetic energy correction constant, B, was calculated from measurements of the efflux time of the two standard oils at the same test temperature by use of the following equation:

$$B = t_1 t_2 \, (V_2 t_1 - V_1 t_2) \, / \, (t_2^2 - t_1^2) \tag{26}$$

TABLE 6

ACCURACY OF n-DECANE DENSITY AS FUNCTION OF TEMPERATURE

PLUMMET NUMBER	TEMPERATURE °C	DENSITY, g/ml		DEVIATION
		EXPERIMENTAL ρ	LITERATURE (2) ρ_L	$(\rho - \rho_L)$
1	30.18	0.7226	0.7223	+ 0.0003
1	40.20	0.7148	0.7148	0.0000
1	59.90	0.7002	0.6997	+ 0.0005
1	80.80	0.6840	0.6840	0.0000
1	99.92	0.6685	0.6682	+ 0.0003
1	143.89	0.6317	0.6314	+ 0.0003
1	151.28	0.6253	0.6249	+ 0.0004
1	160.97	0.6167	0.6160	+ 0.0007

Average Deviation = 0.00031 g/ml

TABLE 7

ACCURACY OF n-TRIDECANE DENSITY AS FUNCTION OF TEMPERATURE

PLUMMET NUMBER	TEMPERATURE °C	DENSITY, g/ml EXPERIMENTAL ρ	 LITERATURE (2) ρ_L	DEVIATION $(\rho - \rho_L)$
1	30.11	0.7486	0.7491	- 0.0005
1	40.18	0.7413	0.7420	- 0.0007
1	59.88	0.7274	0.7278	- 0.0004
1	80.08	0.7128	0.7131	- 0.0003
1	170.10	0.6449	0.6445	+ 0.0004

Average Deviation = 0.00046 g/ml

where: V_1, V_2 = kinematic viscosities of standard oils 1 and 2 respectively at test temperature, centistokes

t_1, t_2 = efflux times for standard oils 1 and 2, respectively

The viscometer constant, C_1, was determined by the following relationship

$$C_1 = (V_1 + B/t_1) / t_1 \tag{27}$$

The calibration results for each viscometer at 100°F with standard oils appears in Table 8. The last four viscometers listed in Table 8 were supplied with a certificate of calibration containing the listed results.

Results

Density Data of n-Alcohols

The densities of ten normal alcohols at temperatures from near room temperature to close to their normal boiling points are presented in Table A-1 (Appendix). The densities are plotted versus temperature, °C, in Figures 13 and 14. The data do not define straight lines for any of the n-alcohols measured over a wide temperature range. During the density determinations, temperatures did not vary by more than 0.03°C and 0.10°C while in the ranges 25°C to 110°C, and 130°C to 280°C, respectively. The reproducibility as determined by replicate

TABLE 8

VISCOMETER CALIBRATION AT 100°F

VISCOMETER*	t_1 (sec)	t_2 (sec)	V_1 (cs)	V_2 (cs)	B	$C_1 (10^3)$
150K233	144.4	489.8	6.184	20.43	- 25.6578	41.601
100K353	468.5	1558.7	6.184	20.43	- 22.1381	13.098
25K330	1796.5	3503.2	3.126	6.184	110.2326	1.774
25K329	2331.9	4530.9	3.126	6.184	179.7310	1.374
25K326	1333.7	2650.3	3.126	6.184	- 25.0940	2.329
75K881**	269.2	384.5	2.190	3.123	- 1.8449	8.110
75K879**	272.8	389.1	2.190	3.123	- 0.2408	8.025
25K451**	417.2	631.6	0.7689	1.1639	- 0.0682	1.843
25K456**	359.9	544.9	0.7690	1.1639	- 0.01646	2.135

---

* Subscript 1: Standard oil 1
Subscript 2: Standard oil 2
** Calibrated by Cannon Instrument Co.

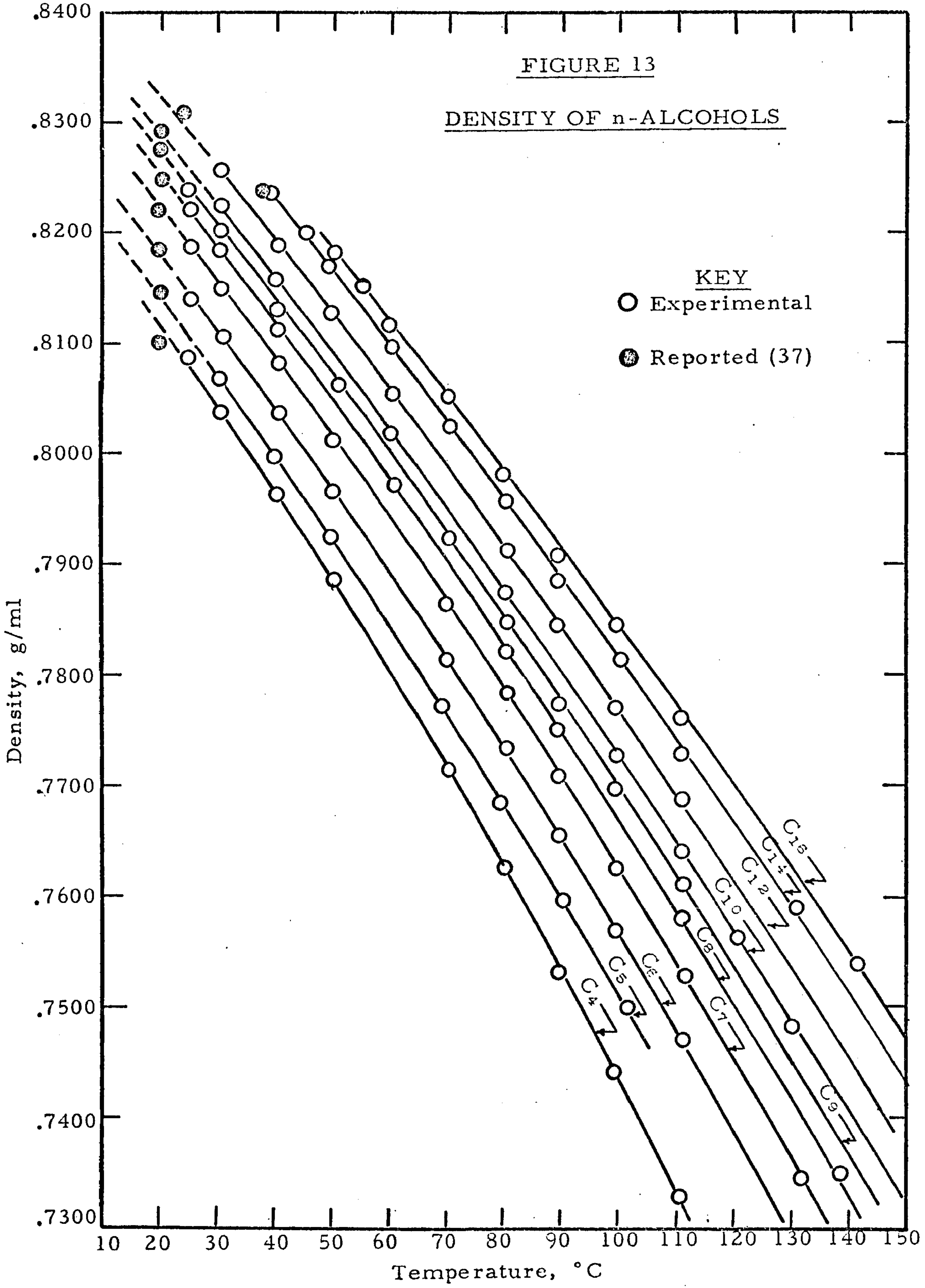


FIGURE 13

DENSITY OF n-ALCOHOLS

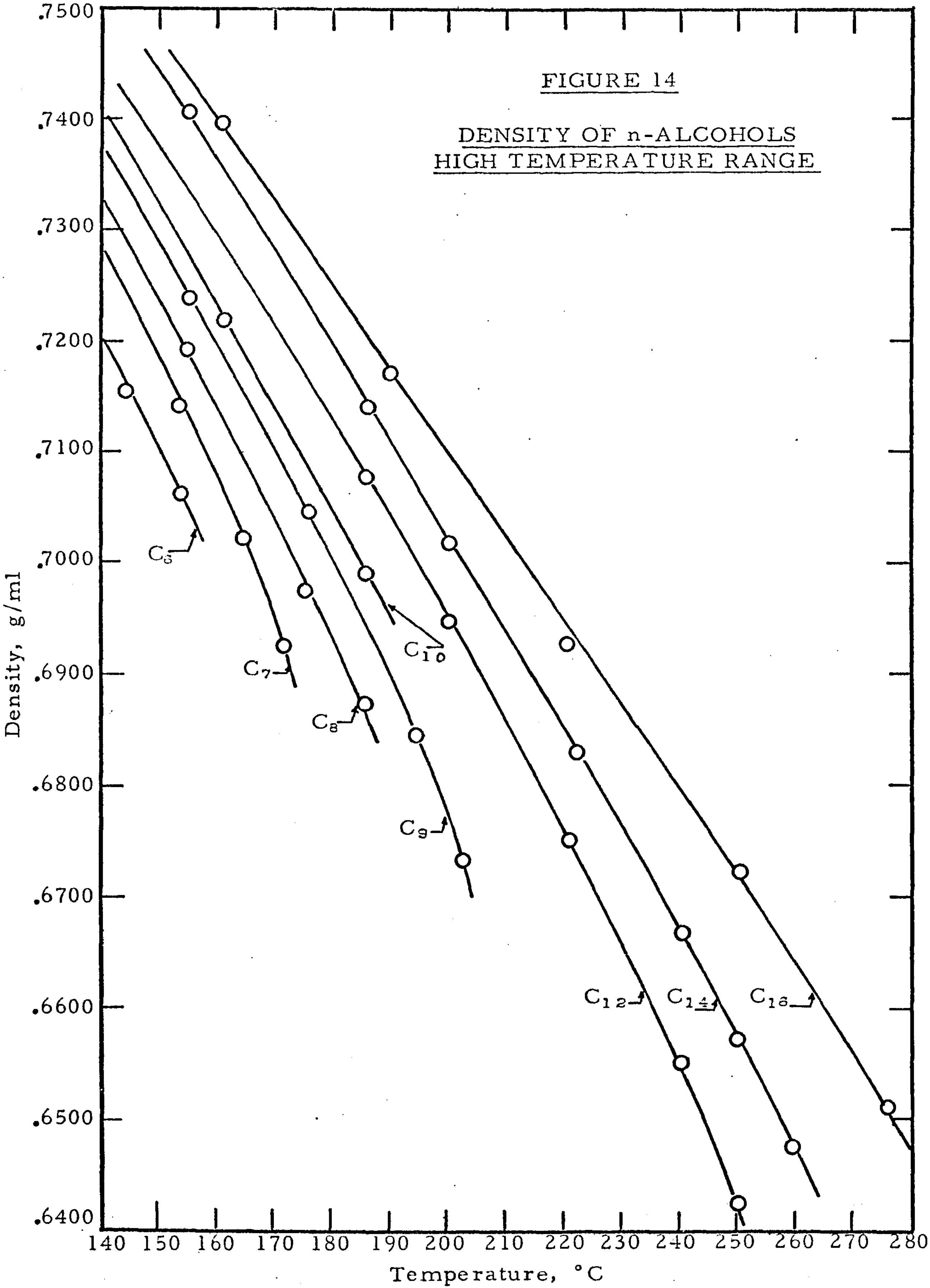


FIGURE 14

DENSITY OF n-ALCOHOLS
HIGH TEMPERATURE RANGE

measurements at the same temperature for n-octanol and n-tetradecanol is summarized in Table 9. The average reproducibility of density is 1 x 10^{-4} and 4 x 10^{-4} g/ml for n-octanol from 40° to 89°C and n-tetradecanol from 240 to 260°C, respectively. At temperatures approaching the normal boiling point, reproducibility decreased due to condensation of alcohol vapors on the suspension chain. All replicate measurements of density, at a given temperature, were performed on the same sample during different runs. The average time required for the experimental determination of one density point was 30 minutes, i.e., 15-20 minutes to reach temperature equilibrium and 10-15 minutes to collect the necessary data.

The only extensive work previously reported on the density of a series of normal alcohols was that of Costello and Bowden (22) using a sealed dilatometer. Their data is included in Table A-1, and is not in agreement with the experimental densities. The deviations between the densities of the n-alcohols reported by Costello and Bowden and the experimental densities are of the order of 2 to 3 in the third decimal place. In general, when the experimental density versus temperature curves, Figure 13, are extrapolated to temperatures (20 to 25°C) where the densities are reported in the Handbook of Physics and Chemistry (37) excellent agreement is obtained. Differences between the purities of the alcohols used by Costello and Bowden and the material employed in the present work may have caused the

TABLE 9

REPRODUCIBILITY OF EXPERIMENTAL DENSITY OF n-ALCOHOLS

COMPOUND	TEMP. °C	DENSITY g/ml	REPRODUCIBILITY OF DENSITY g/ml
n-Octanol	40.28	0.8112	
	40.32	0.8114	+ 0.0002
	80.32	0.7820	
	80.34	0.7820	0.0000
	89.48	0.7750	
	89.49	0.7751	+ 0.0001
		Average Reproducibility	= 0.0001
n-Tetradecanol	240.68	0.6664	
	240.68	0.6668	+ 0.0004
	250.08	0.6570	
	250.08	0.6574	+ 0.0004
	259.83	0.6473	
	259.83	0.6477	+ 0.0004
		Average Reproducibility	= 0.0004

disagreement in densities. A good criterion for purity (45) is the boiling point of the alcohol. Comparisons of the experimental normal boiling points and those reported by Costello and Bowden are given in Table 10. A survey of the literature boiling points is also included in Table 10 and indicates that the alcohols used by Costello and Bowden were not of the highest quality.

Interpolation of Density. The experimental densities of the n-alcohols exhibit little random scatter in the data. Least squares coefficients for the polynomial

$$\rho = a_1 + a_2 / t + a_3 / t^2 + a_4 / t^3 \tag{28}$$

where: t = temperature, °C

were developed for each compound using a least squares non-linear procedure. Computer Program No. 3 was employed to perform the calculations and appears in the Appendix. The constants, and the average deviations in the approximation of density are tabulated in Table 11. In most cases, the density data for a compound was split into two temperature ranges to obtain a better fit. The temperature range selected for each set of constants was based on the availability and distribution of experimental densities over the given range.

Equation 28 is quite good for purposes of interpolation. A quadratic equation yields a much poorer fit; increasing the number

TABLE 10

NORMAL BOILING POINTS OF THE n-ALCOHOLS

COMPOUND	BOILING POINT PRESENT WORK °C	BOILING POINT COSTELLO & BOWDEN °C	BOILING POINT LITERATURE °C	REFERENCE
n-Butanol	117.89	117.0	117.5	42
			117.7	37, 31
			117.8	74
n-Pentanol	138.06	138.10	137.75	42
			137.8	37
			137.8	53
n-Hexanol	157.14	157.5	156.5	30
			157.2	1, 37
			157.1	53
			157.1	74
n-Heptanol	176.26	-	176.3	30
			176.35	24
			176.3	1, 74
n-Octanol	195.26	195.0	195.1	74

TABLE 10 (Cont'd)

COMPOUND	BOILING POINT		BOILING POINT LITERATURE °C	REFERENCE
	PRESENT WORK °C	COSTELLO & BOWDEN °C		
n-Nonanol	213.56	-	213.5	30
			213.5	74
			213.5	44
n-Decanol	231.0	229.0	231.0	44, 37
			231.0	74
n-Dodecanol	260.70	257.0	259.0	44
			259.0	1
			263.5	74
n-Tetradecanol	263.26	282.0	293.0	74
			263.2	37
n-Hexadecanol	344.06	305.0	322.3	74
			344.0	44
			344.0	37

TABLE 11

INTERPOLATION OF DENSITY BY EQUATION 28

COMPOUND	TEMP. RANGE °C	NOS. OF POINTS	CONSTANTS				AVG. DEVIATION g/ml
			a_1	a_2	a_3	a_4	
n-Butanol	30-110	9	0.62232	17.00	- 549.8	6039	0.0015
n-Pentanol	30-101	7	0.62847	17.97	- 649.2	8126	0.0005
n-Hexanol	25-111	9	0.65112	14.76	- 474.3	5200	0.0013
n-Heptanol	25-111	9	0.65925	14.41	- 463.4	5097	0.0012
n-Octanol	25-111	11	0.67070	13.42	- 423.7	4588	0.0012
n-Octanol	138-186	4	-0.93158	702.4	-102000.	5080000	0.0003
n-Nonanol	25-111	9	0.67427	13.25	- 418.0	4517	0.0012
n-Nonanol	155-202	4	0.44571	7.68	15500.	-1547000	0.0006
n-Decanol	30-110	6	0.65954	16.40	- 591.4	7382	0.00066
n-Decanol	121-186	5	0.33961	112.5	- 10280	333300	0.00024
n-Dodecanol	30-111	8	0.66596	16.25	- 596.1	7597	0.00059
n-Dodecanol	186-250	5	0.05302	234.6	- 23920.	542900	0.00064
n-Tetradecanol	40-111	9	0.65432	19.59	- 815.9	12110	0.00028
n-Tetradecanol	131-260	11	0.13541	225.6	- 29210.	1358000	0.00060
n-Hexadecanol	50-111	8	0.63961	23.82	- 1137.	19660	0.00011
n-Hexadecanol	141-276	6	0.27138	168.72	- 21070.	971100	0.00058

Overall Average Deviation = 0.0007

of terms beyond the cubic makes no significant improvement. For these reasons a third-order polynomial was chosen as the fundamental function without further investigation. The overall average deviation between the experimental density and the density approximated by equation 28 at the same temperature, is 7×10^{-4} g/ml over the whole set of alcohol data. At temperatures where experimental densities were not determined, equation 28 and constants presented in Table 11 were used to interpolate density values. These interpolated densities are listed in Table A-2 (Appendix) with the reported densities of Costello and Bowden.

Kinematic Viscosity Data of n-Alcohols

The experimental kinematic viscosities of the n-alcohols are listed in Table A-3 (Appendix) along with the temperature of measurement. The per cent deviation for the efflux times was within ± 0.10 per cent and is an indication of the precision of the determinations. The logarithms of the experimental kinematic viscosities are plotted versus the reciprocal absolute temperature in Figure 15. The data do not define straight lines over a wide temperature range for any of the compounds studied. At high temperatures, approaching the normal boiling point, the behavior of the individual members of the n-alcohols can be divided into two classes; in one case the slope of curve, $\mathrm{Log}_{10}\ V_i$ versus $1/T$, increases rapidly and in the second case the slope of the curve decreases. The behavior of n-butanol, n-heptanol,

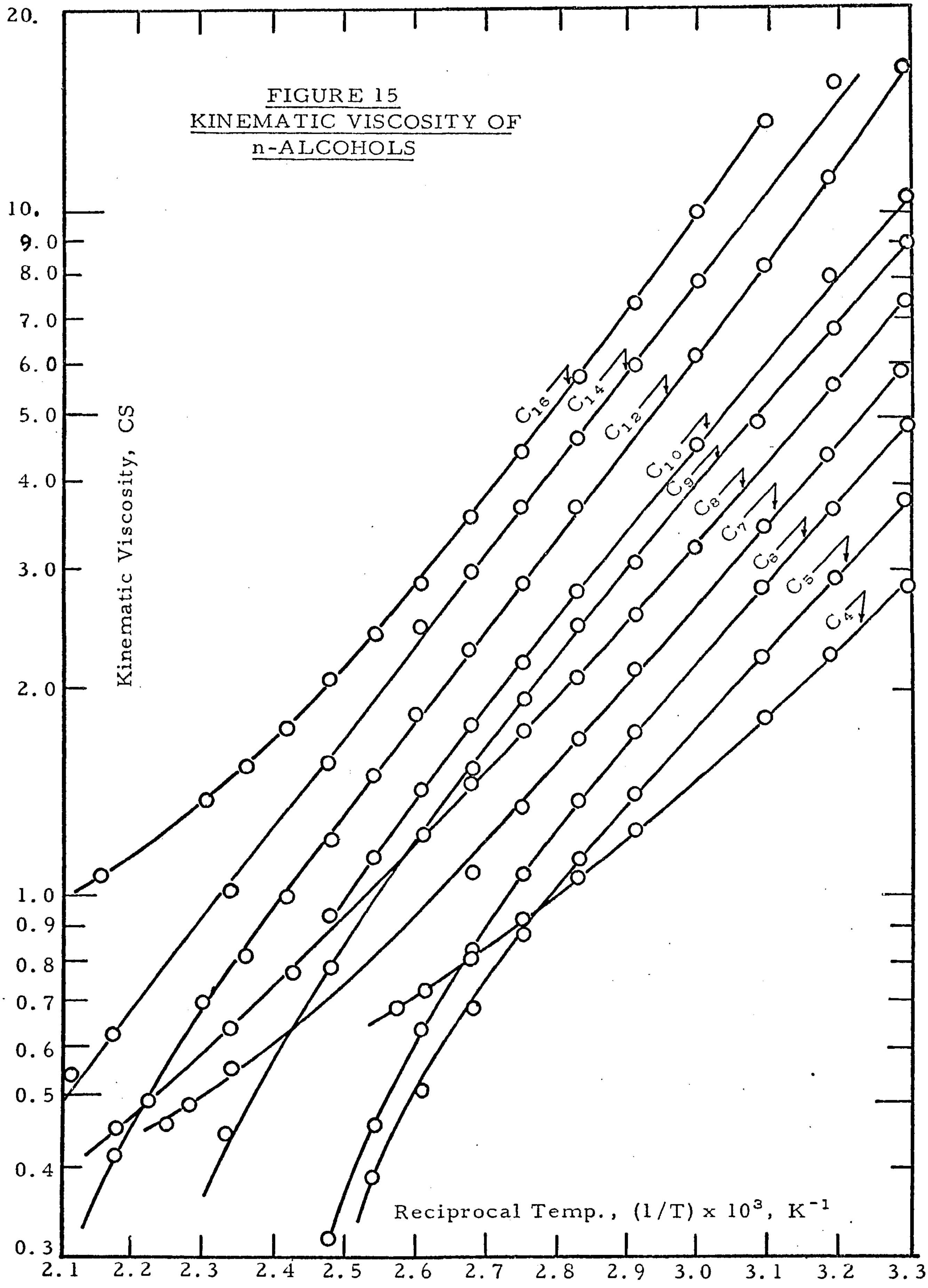


FIGURE 15
KINEMATIC VISCOSITY OF
n-ALCOHOLS

n-octanol, and n-hecadecanol is similar to the reported behavior (33) of the normal hydrocarbons, i.e., the kinematic viscosity of a normal hydrocarbon approaches a constant value at temperatures near the normal boiling point.

The unusual behavior of the remaining n-alcohols has not been reported prior to this work and can not be fully explained as yet. The behavior is not due to experimental procedure since the following precautions were employed during the measurements to insure that the results were precise and accurate:

(a) In all cases at least two capillary viscometers of different capillary bore were employed for the various regions of the temperature interval studied. This precaution was used as a double check on the calibration of the viscometer.

(b) The measurements of kinematic viscosity for each compound were collected in three separate runs at cold temperature, medium and high temperature runs. The results for each compound gave a smooth continuous curve of $\text{Log}_{10} V_i$ versus 1/T which indicate that decomposition and oxidation are negligible.

(c) All experimental kinematic viscosities were determined from measured efflux times which agreed within ± 0.1 per cent.

(d) All measured efflux times were greater than 200 seconds. This stated minimum efflux time was specified in order to obtain the required timing precision and to minimize the kinetic energy correction, B/t_i (7).

VISCOSITY-DENSITY CORRELATION

Development of Correlation

Viscosity of Monatomic Liquids

From the kinetic theory of gases it has been shown (15) that the viscosity of a monatomic gas is given by the relationship

$$\mu = 1/3\ \bar{u}\rho\lambda \tag{29}$$

where: μ = absolute viscosity

$\bar{u}$ = mean molecular speed of the molecules

ρ = mass density of the gas

λ = mean free path

In adapting this relationship for liquids, it is here assumed that the liquid molecules are arranged in a cubic lattice, with center-to-center spacing equivalent to

$$\Delta = (V/N)^{1/3} \tag{30}$$

where: V = molar volume

N = Avogadro's number

It is further postulated that momentum is transferred from one lattice plane to an adjacent plane at the sonic velocity, v_s, for the liquid. This is similar to a model for energy transport proposed by Bridgman (16) which serves to predict the thermal conductivity of pure liquids, with a cubic lattice similar to that of the solid state. Energy is transferred from plane to plane at the sonic velocity by collisions arising out of molecular vibrations about the equilibrium lattice positions. Bridgman's equation for the thermal conductivity is given as

$$K = 3\ (N/V)^{2/3}\ kv_s \tag{31}$$

where: K = thermal conductivity of the liquid

k = Boltzmann constant

v_s = speed of sound in the liquid

In the case of momentum transfer, molecules reaching a given plane have, on the average, suffered their last collision at a distance Δ from that position, where

$$\Delta = 2/3\ \lambda = (V/N)^{1/3} \tag{32}$$

The mean molecular speed is

$$\bar{u} = 2 \left| \bar{\underline{u}}_y \right| \tag{33}$$

where $\left|\bar{\underline{u}}_y\right|$ is the absolute value of the y component of the mean molecular velocity. Similar relationships apply to the velocity components in the x and z directions.

The proof of equation 33 involves the Maxwell-Boltzman distribution (15) of molecular velocities at rest,

$$f(\underline{u}_x, \underline{u}_y, \underline{u}_z) = f(\underline{u}) = (m/2\pi kT)^{3/2} e^{-m\underline{u}^2/2kT} \qquad (34)$$

where: $\underline{u}$ = individual molecular velocity

$\underline{u}_x, \underline{u}_y, \underline{u}_z$ = individual molecular velocity components

m = mass of a molecule

T = absolute temperature

and $f(\underline{u}_x, \underline{u}_y, \underline{u}_z)\, d\underline{u}_x d\underline{u}_y d\underline{u}_z$ is the fraction of the total molecules that is expected to have velocities along the three coordinates between $\underline{u}_x$ and $(\underline{u}_x + d\underline{u}_x)$, etc. at any instant. It follows from equation 34 that the distribution of molecular speed, u, is

$$f(u) = 4\pi u^2 (m/2\pi kT)^{3/2} e^{-mu^2/2kT} \qquad (35)$$

The mean molecular speed $\bar{u}$ is obtained by

$$\bar{u} = \int_0^\infty u\, f(u) du / \int_0^\infty f(u) du \qquad (36)$$

Combination of equations 35 and 36, letting $a' = m/2kT$ gives

$$\bar{u} = \int_0^\infty u^3\, e^{-a'u^2} du / \int_0^\infty u^2\, e^{-a'u^2} du \qquad (37)$$

where

$$\int_0^\infty u^2\, e^{-a'u^2}\, du = (\pi/a')^{\frac{1}{2}}/4a' \qquad (38)$$

and where

$$\int_0^{\infty} u^3 e^{-a'u^2} du = 1/2a'^2 \tag{39}$$

Combining equations 37, 38 and 39 and substituting $m/2kT = a'$

$$\bar{u} = (8kT/\pi m)^{\frac{1}{2}} \tag{40}$$

The positive value of the y component, $\bar{\underline{u}}_y^+$ of the mean molecular velocity $\bar{\underline{u}}$ is obtained by integration of the components of $\underline{u}f(\underline{u})$ throughout velocity space. The integral is

$$\bar{\underline{u}}_y^+ = \int_{-\infty}^{\infty}\int_0^{\infty}\int_{-\infty}^{\infty}\underline{u}_y f(\underline{u}_x, \underline{u}_y, \underline{u}_z) d\underline{u}_x d\underline{u}_y d\underline{u}_z \Big/ \int_{-\infty}^{\infty}\int_0^{\infty}\int_{-\infty}^{\infty} f(\underline{u}_x, \underline{u}_y, \underline{u}_z) d\underline{u}_x d\underline{u}_y d\underline{u}_z \tag{41}$$

Combination of equations 34 and 41, letting $\underline{u}_x^2 + \underline{u}_y^2 + \underline{u}_z^2 = \underline{u}^2$ gives

$$\bar{\underline{u}}_y^+ = H_d/H_n \tag{42}$$

where

$$H_d = \int_{-\infty}^{\infty}\int_0^{\infty}\int_{-\infty}^{\infty}\underline{u}_y (m/2\pi kT)^{3/2} e^{-m(\underline{u}_x^2 + \underline{u}_y^2 + \underline{u}_z^2)/2kT} d\underline{u}_x d\underline{u}_y d\underline{u}_z \tag{43}$$

and

$$H_n = \int_{-\infty}^{\infty}\int_0^{\infty}\int_{-\infty}^{\infty}(m/2\pi kT)^{3/2} e^{-m(\underline{u}_x^2 + \underline{u}_y^2 + \underline{u}_z^2)/2kT} d\underline{u}_x d\underline{u}_y d\underline{u}_z \tag{44}$$

Letting $a' = m/2kT$, equation 42 becomes

$$\bar{\underline{u}}_y^+ = L_d \Big/ \int_{-\infty}^{\infty} e^{-a'\underline{u}_x^2} d\underline{u}_x \int_0^{\infty} e^{-a'\underline{u}_y^2} d\underline{u}_y \int_{-\infty}^{\infty} e^{-a'\underline{u}_z^2} d\underline{u}_z \tag{45}$$

where

$$L_d = \int_{-\infty}^{\infty} e^{-a'\underline{u}_x^2}\, d\underline{u}_x \int_{o}^{\infty} \underline{u}_y e^{-a'\underline{u}_y^2}\, d\underline{u}_y \int_{-\infty}^{\infty} e^{-a'\underline{u}_z^2}\, d\underline{u}_z \tag{46}$$

which simplifies to

$$\bar{\underline{u}}_y^+ = \int_{o}^{\infty} \underline{u}_y e^{-a'\underline{u}_y^2}\, d\underline{u}_y \Big/ \int_{o}^{\infty} e^{-a'\underline{u}_y^2}\, d\underline{u}_y \tag{47}$$

The numerator of equation 47 is

$$\int_{o}^{\infty} \underline{u}_y e^{-a'\underline{u}_y^2}\, d\underline{u}_y = 1/a' \tag{48}$$

and the denominator is

$$\int_{o}^{\infty} e^{-a'\underline{u}_y^2}\, d\underline{u}_y = (\pi/a')^{\frac{1}{2}} \tag{49}$$

Combination of equations 47, 48 and 49 results in

$$\bar{\underline{u}}_y^+ = 1/(\pi a')^{\frac{1}{2}} \tag{50}$$

Substituting $m/2kT = a'$, gives

$$\bar{\underline{u}}_y^+ = (2kT/\pi m)^{\frac{1}{2}} \tag{51}$$

Combination of equations 40 and 51 gives

$$\bar{u} = 2\bar{\underline{u}}_y^+ \tag{52}$$

Since $\underline{u}_y$ is symmetrical around zero, the mean value $\bar{\underline{u}}_y^+$ yields the same mean value as $|\bar{\underline{u}}_y|$. Thus

$$\bar{u} = 2|\bar{\underline{u}}_y| \tag{53}$$

Combination of equations 29, 32 and 33 and replacing $|\bar{u}_y|$ by the sonic velocity results in

$$\mu = \rho v_s (V/N)^{1/3} \tag{54}$$

Rao (64) and Sakiadis and Coates (69) show that the velocity of sound in a liquid may be calculated by

$$v_s = (\beta\rho/M)^3 \tag{55}$$

where β is an empirical structural contribution factor (66) and M is the molecular weight. Using equation 55 to replace v_s in equation 54 and replacing the molar volume, V, by M/ρ gives

$$\mu = \rho^4 \beta^3 M^{1/3}/(M^3 N^{1/3} \rho^{1/3}) \tag{56}$$

which simplifies to

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3} \tag{57}$$

The Ratio K/μ

If Bridgman's equation for thermal conductivity is divided by equation 54, the ratio K/μ is given as

$$K/\mu = 3kN/V\rho \tag{58}$$

Since $k = R/N$ and $V = M/\rho$, there results

$$M(K/\mu) = 3R \tag{59}$$

When the viscosity, μ, is in poise and k is in calories per second per centimeter per degree Kelvin, the gas constant, R, is very nearly 2 calories per gram mole per degree Kelvin. Substitution of this value into equation 59 results in

$$M(K/\mu) = 6 \tag{60}$$

This result is identical with an equation developed by Mohanty (54) who combined the Andrade (3) viscosity equation with the thermal conductivity equation of Osida (56). The works of both Andrade and Osida are based on liquid models similar to that presently postulated.

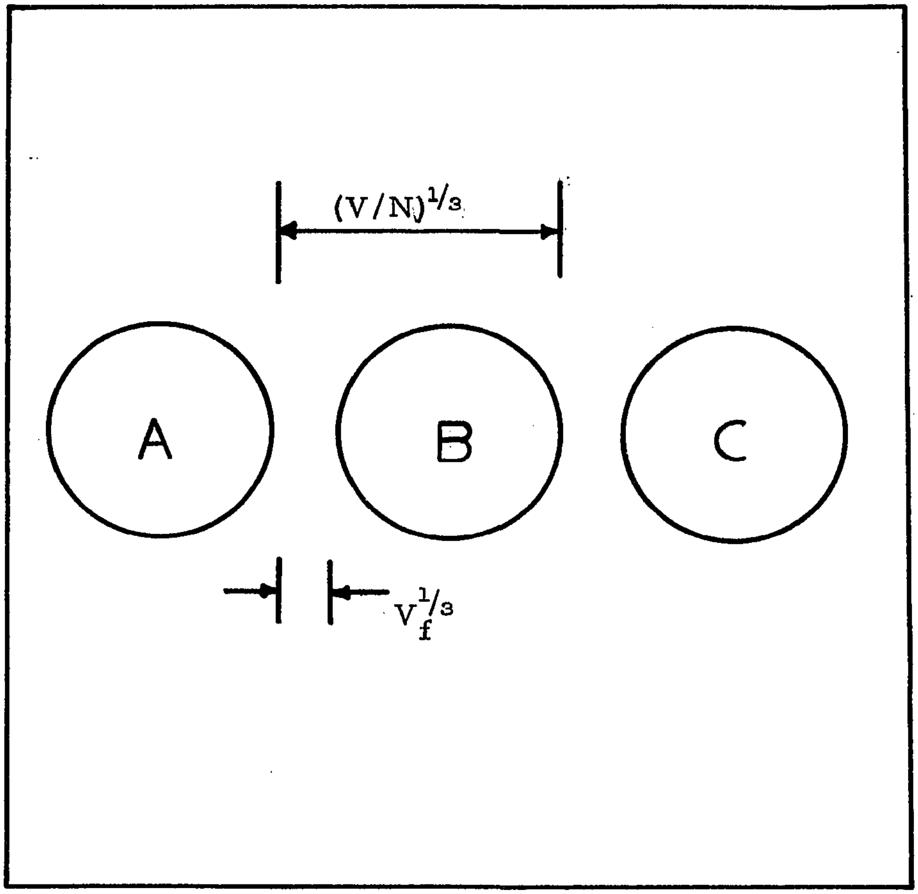
Viscosity and the Sonic Velocity

Equation 57 can be developed by a second method. The method used by Powell, Roseveare and Eyring (61) for estimating the thermal conductivity of pure liquids has been employed here for developing the viscosity-density correlation. The expression presented below, differs from equation 57 only by the numerical coefficients.

Powell, et al. (61) have shown that v_s in liquids is from five to ten times greater than the mean speed of the molecules. Upon collision of two molecules, sound is transferred between molecules almost instantaneously. Figure 16 illustrates the mechanism for the transfer of sound in liquids. The signal is transmitted from molecule A to molecule B with the velocity of sound in an ideal gas, then across

FIGURE 16

MODEL FOR THE TRANSFER OF SOUND



molecule B almost instantaneously. The free volume of a liquid can be considered as a force-free space, i.e., similar to an ideal gas (39). In terms of intermolecular distances

$$v_s = v_s' \, (V/NV_f)^{1/3} \tag{61}$$

where: v_s = speed of sound in liquid

v_s' = speed of sound in an ideal gas

V_f = molecular free volume

It is reported (39) that equation 61 gives excellent agreement with the observed speed of sound for a large number of liquids.

Analogously for a liquid, equation 29 must be modified by replacing the mean free path, λ, by 3/2 $(V/N)^{1/3}$. In accord with the speed of sound arguments, the mean molecular speed of the liquid molecules should be designated

$$\bar{u}_L = \bar{u}(V/NV_f)^{1/3} \tag{62}$$

Combination of equations 40 and 62 gives

$$\bar{u}_L = (8kT/m\pi)^{\frac{1}{2}} \, (V/NV_f)^{1/3} \tag{63}$$

From this, the viscosity of a monatomic liquid is

$$\mu = \tfrac{1}{2}\rho\,(V/N)^{1/3}(8kT/m\pi)^{\frac{1}{2}}(V/NV_f)^{1/3} \tag{64}$$

The free volume, V_f, is eliminated by combining equations 61 and 64 with

$$v_s' = (\gamma kT/m)^{\frac{1}{2}} \tag{65}$$

where γ is the specific heat ratio. Thus

$$\mu = 0.80\ v_s\rho(V/N)^{1/3}\gamma^{-\frac{1}{2}} \tag{66}$$

For liquids, γ is nearly unity except near the critical point. Accordingly, the viscosity of a monatomic liquid is

$$\mu = 0.80\ v_s\rho(V/N)^{1/3} \tag{67}$$

Equations 54 and 67 differ only in the value of the constant coefficients, 1.0 and 0.8, respectively.

Application of Correlation

Equation 57 was used to compute the viscosities of normal paraffins, 1-alkenes, monoalkycyclohexanes, monoalkylbenzenes and alcohols at each ten-degree Kelvin interval extending over a one to three hundred degree range. Densities of the hydrocarbons were taken from the A.P.I. compilations (2) while the densities of the alcohols were measured experimentally and are listed in Tables A-1 and A-2. The necessary values of the additive constitutive constant, β, were obtained from Reid and Sherwood (66) and are given in Table 12.

TABLE 12

ADDITIVE CONSTITUTIVE CONSTANT, β

BASIC STRUCTURE	β/GROUP
Methane	1850
$-CH_2-$, $-CH_3$	872
Double Bond	- 254
Cyclohexane	5363
-OH	137
Isopropyl	2616
Benzene	4534
"o" Position	0
"m" Position	59
"p" Position	117

An illustration of the calculations necessary for equation 57 is shown in the Appendix. Computer Program No. 4, used to calculate all viscosities, is presented in the Appendix. The viscosities of the normal paraffins, as calculated by equation 57, are listed with the reported values in Table A-4. The average error of the calculated viscosities with respect to reported or experimental values for the individual compounds in each of the above homologous series is given in Table 13. The results are summarized in Table 14. The precision of the calculated viscosities is about the same order as is provided by the methods of Thomas (76) and Souders (72).

Empirical Corrections to the Model

When the individual point deviations,

$$Z = \mu/\mu_r \tag{68}$$

where: μ = calculated viscosity by equation 57

μ_r = reported or experimental viscosity

are plotted against the reduced temperature with respect to the normal boiling point,

$$T_{rB} = T/T_B \tag{69}$$

where: T = absolute temperature

T_B = normal boiling point

TABLE 13

AVERAGE ERRORS FOR VISCOSITY PREDICTIONS BY EQUATION 57

	AVERAGE PER CENT ERROR*				
CARBON ATOMS	n-PARAFFINS	n-1-ALKENES	n-ALKYL CYCLOHEXANES	n-ALKYL BENZENES	n-ALCOHOLS
1	50.8				
2	40.7	49.3			
3	42.7	42.0			
4	27.3	29.9			54.2
5	38.2	34.0			53.4
6	34.1	47.6	26.7	22.7	49.1
7	37.0	51.9	24.6	37.0	49.1
8	30.9	36.3	23.0	40.8	50.6
9	34.3	25.9	26.5	37.7	64.1
10	32.3	21.5	32.3	36.9	52.2
11	32.1	22.7	37.9	34.8	
12	29.7	26.6	46.2	36.2	65.5
13	31.1	32.5	52.9	38.3	
14	30.4	39.8	58.5	41.2	66.6
15	31.4	46.8	63.1	45.1	
16	30.4	49.9	65.2	49.0	68.1
17	31.3	55.2	66.5	50.4	
18	30.1	57.5	69.7	52.2	
19	29.4	59.3	70.5	56.3	
20	29.7	63.1	71.1	57.6	
21			73.3	58.6	
22			73.5	59.1	

---

*Average % error = $(\mu - \mu_r)100/\mu_r$

TABLE 14

ACCURACY OF VISCOSITY PREDICTIONS BY EQUATION 57

SERIES	NUMBER OF CARBON ATOMS	AVERAGE % ERROR*
n-Paraffins	1-20	33.6
n-1-Alkenes	1-20	39.9
Mono-n-Alkyl Cyclohexanes	6-22	51.8
Mono-n-Alkyl Benzenes	6-22	44.3
n-Alcohols	4-16	57.3

---

* Average % error = $(\mu - \mu_r)100/\mu_r$

on log-log coordinates, it is seen, Figures 17, 18, 19, 20 and 21, that the predicted viscosities for each series of homologues differ from the reported values in a regular manner. For each series, a family of curves, parametric in the number of carbon atoms, may be drawn through these Z points. The Z function approaches a limiting value at about twenty carbon atoms.

The parametric curves for each series of homologues may be approximated by a single line of best fit in the form,

$$Z = \exp(a + b\ \ell n(T_{rB}) + c\ \ell n^2(T_{rB})\ ) \tag{70}$$

Coefficients for equation 70 were obtained by non-linear regression techniques. Computer Program No. 5 utilized in this procedure appears in the Appendix. The Z functions for the five series of homologues are plotted in Figure 22, and the coefficients for equation 70 are listed in Table 16. Either the graph or the equation may be used to determine the appropriate value of Z to correct the estimate provided by equation 57. The corrected viscosity is

$$\mu = \rho^{11/3} \beta^3 / (M^{8/3} N^{1/3} Z) \tag{71}$$

The calculations necessary for equation 71 are illustrated in the Appendix. Computer Program No. 6, used to calculate all corrected viscosities, appears in the Appendix. The results for the five series of homologues are tabulated in Tables A-5, A-6, A-7, A-8 and A-9,

FIGURE 17

Z AS A FUNCTION OF T_{rB}, n-PARAFFINS

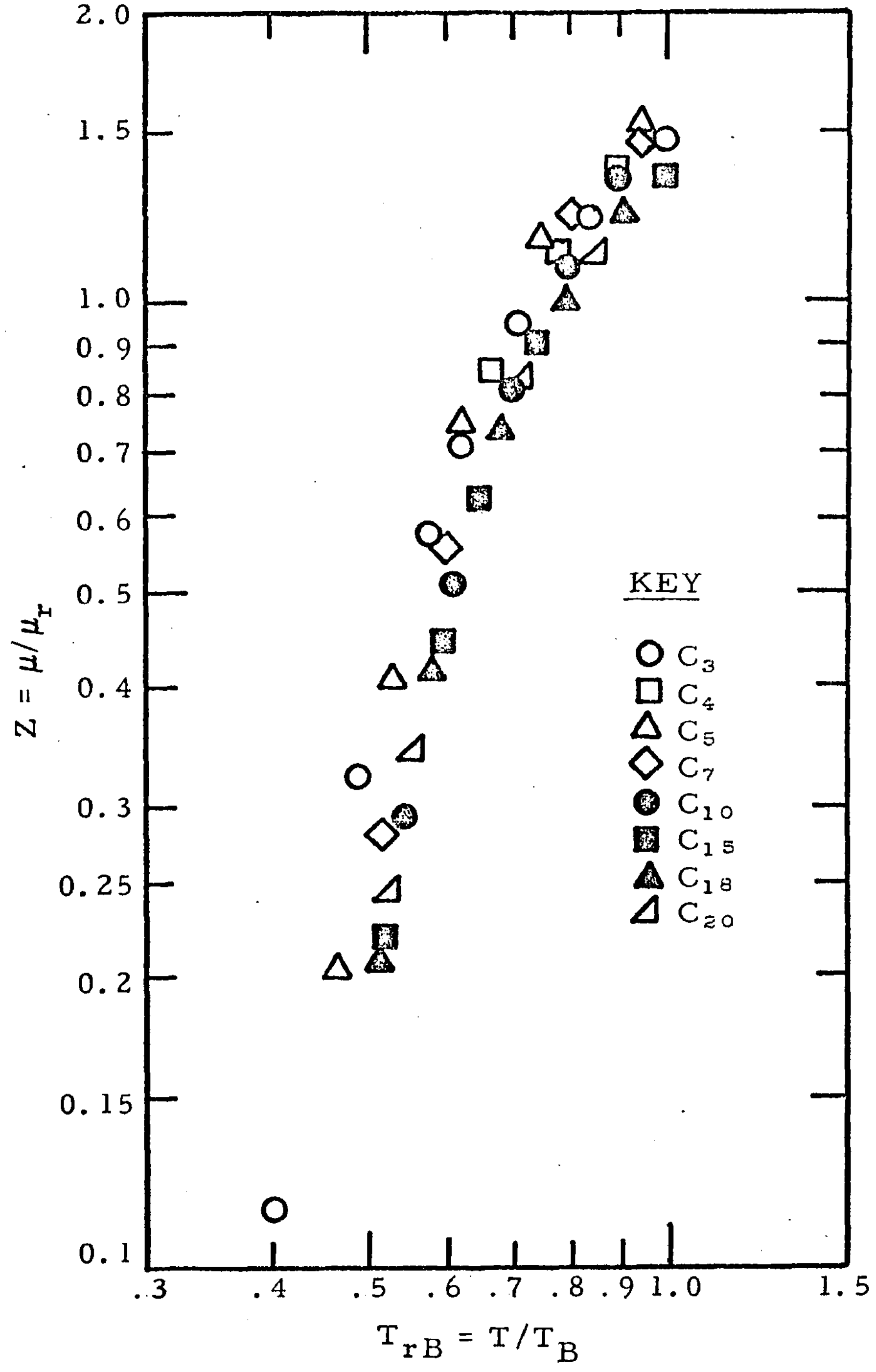


FIGURE 18

Z AS A FUNCTION OF T_{rB}
n-1-ALKENES

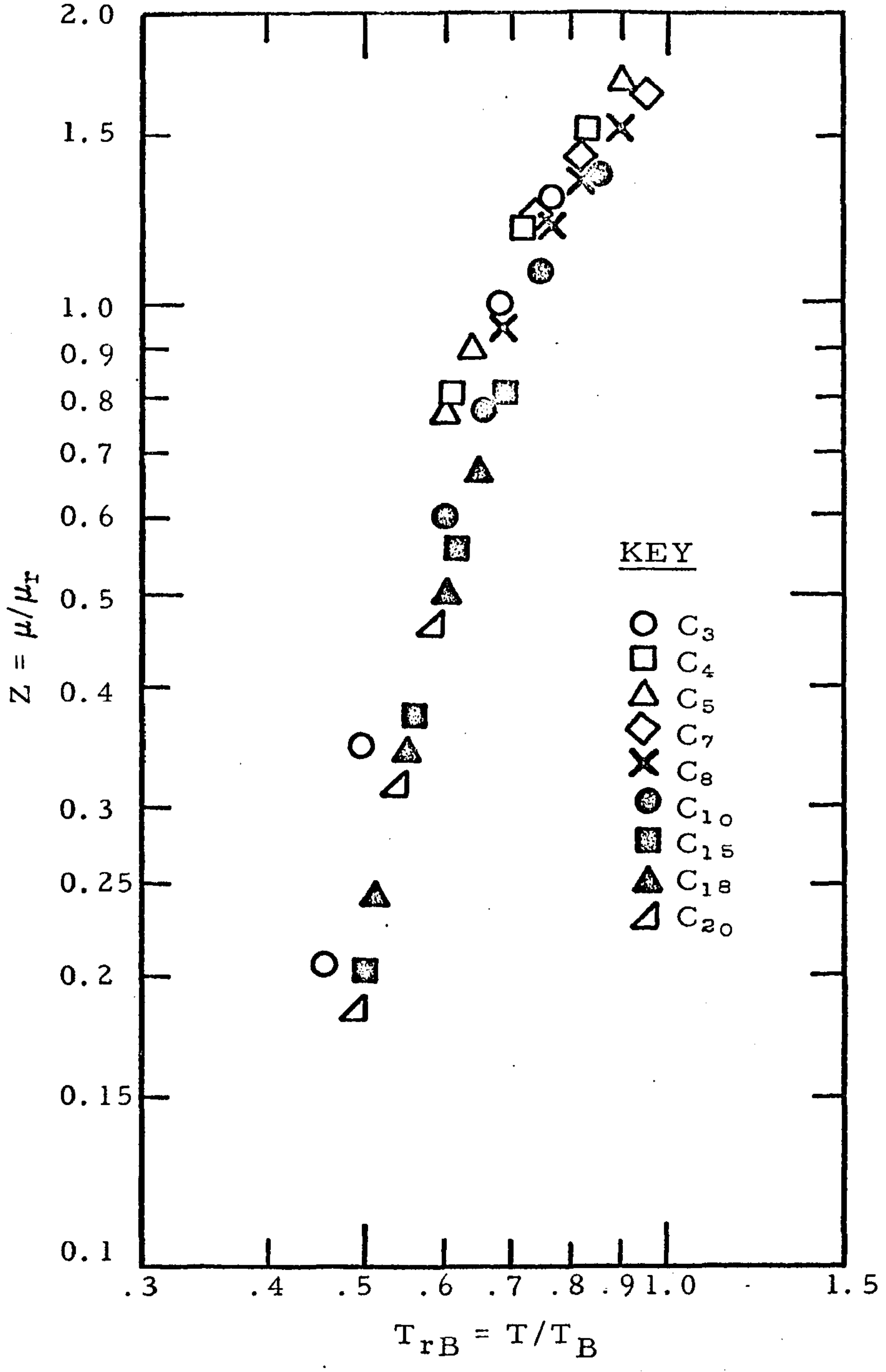


FIGURE 19

Z AS A FUNCTION OF T_{rB}
n-ALKYL CYCLOHEXANES

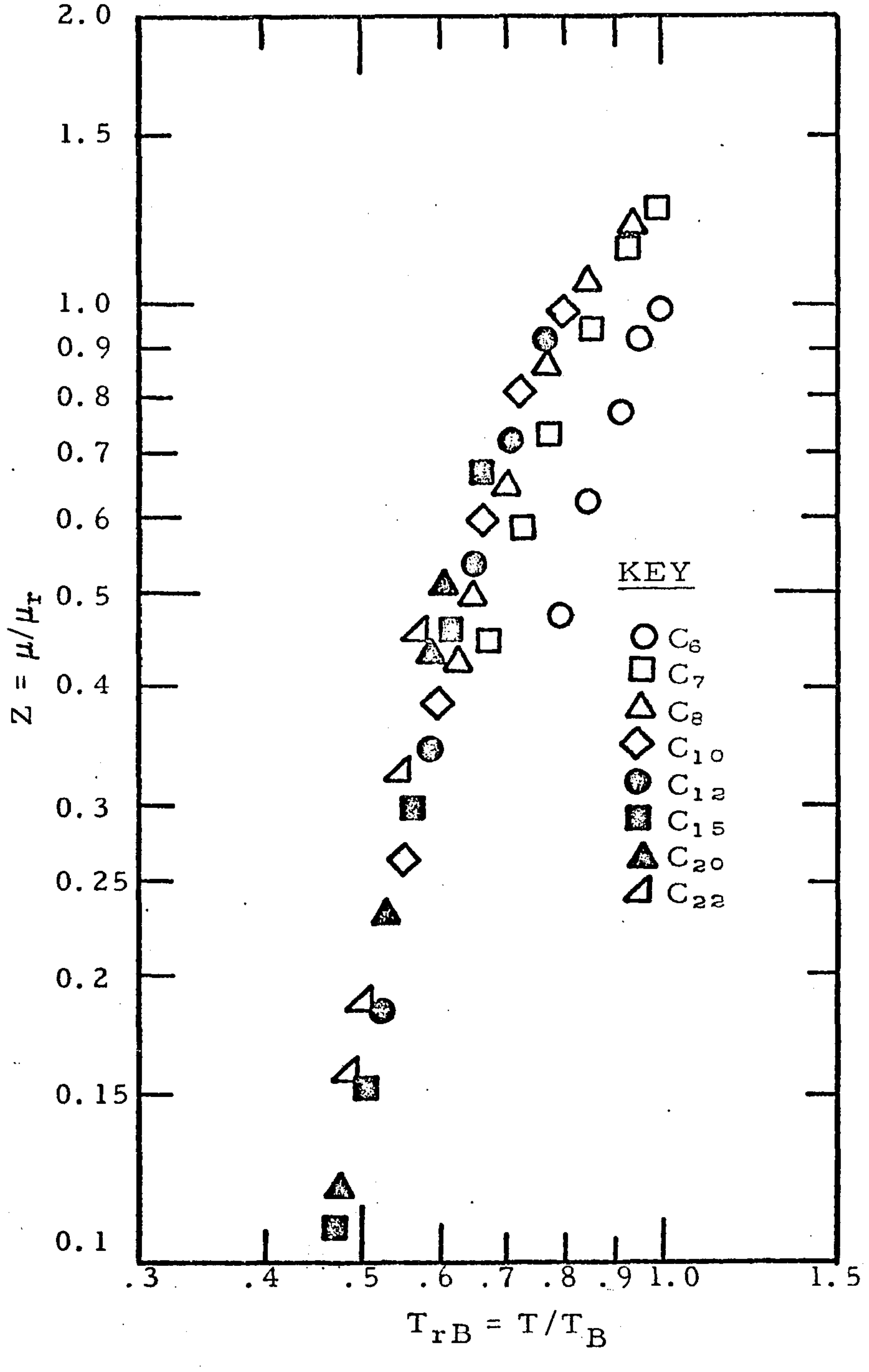


FIGURE 20

Z AS A FUNCTION OF T_{rB}
n-ALKYL BENZENES

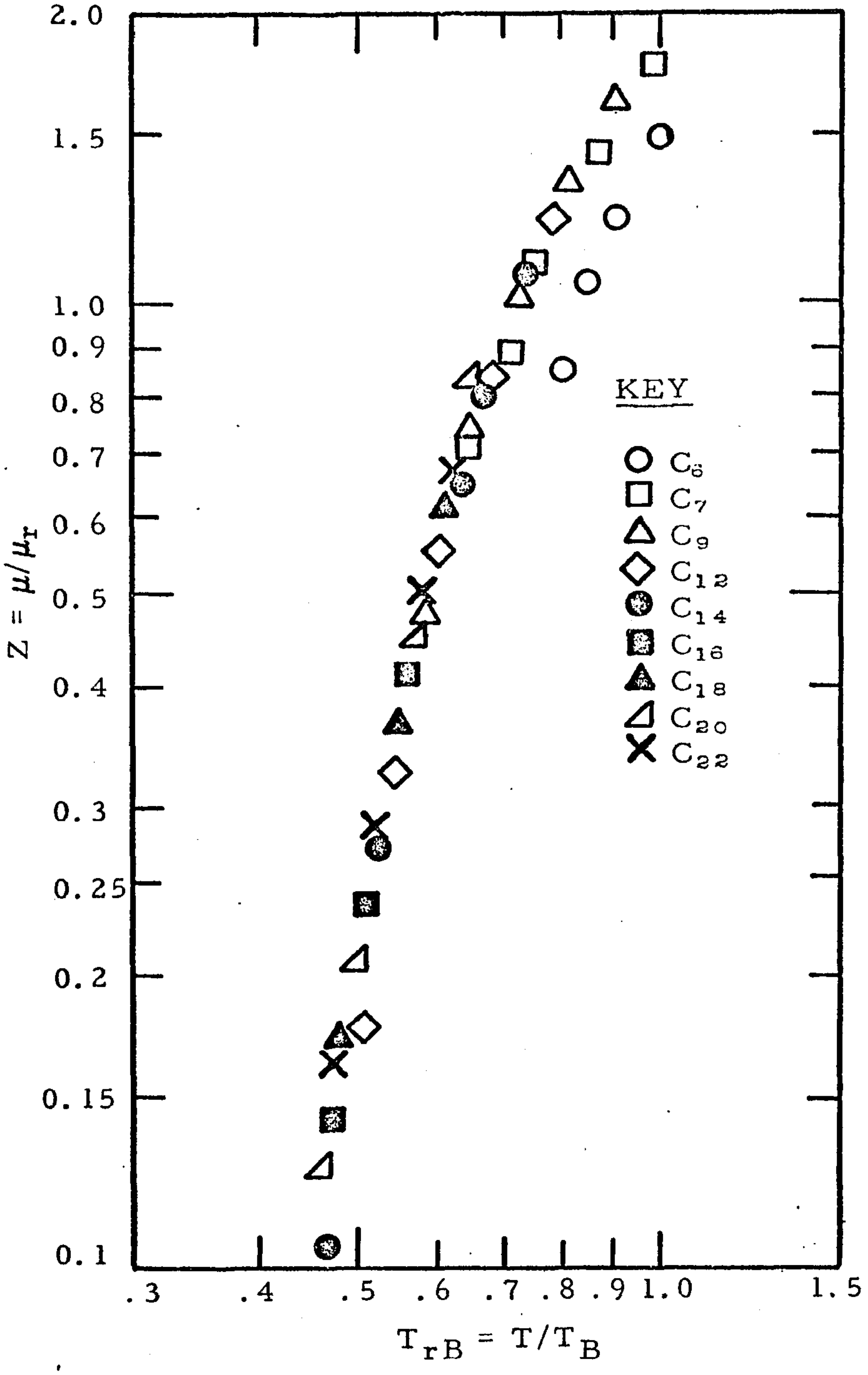


FIGURE 21

Z AS A FUNCTION OF T_{rB}
n-ALCOHOLS

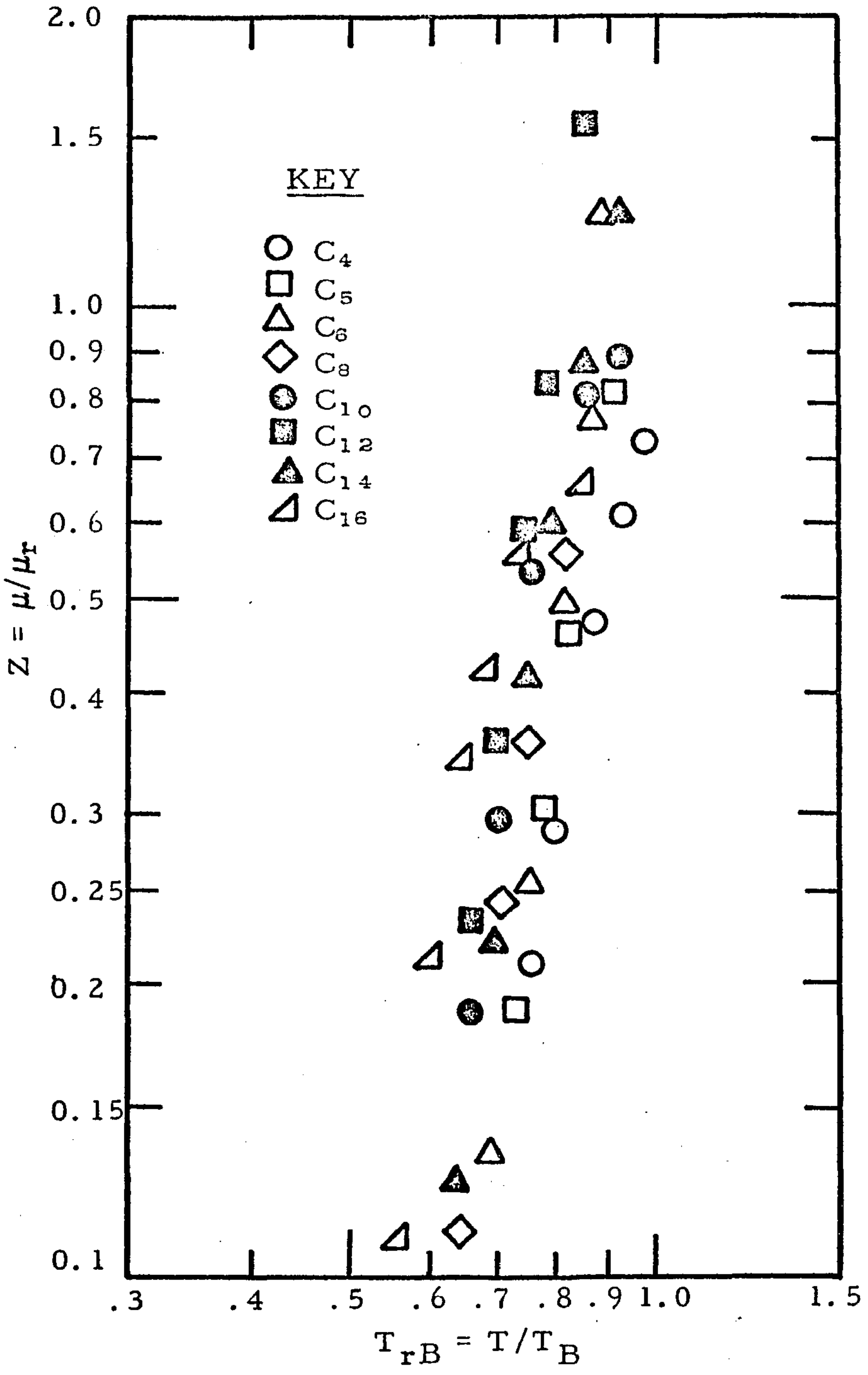
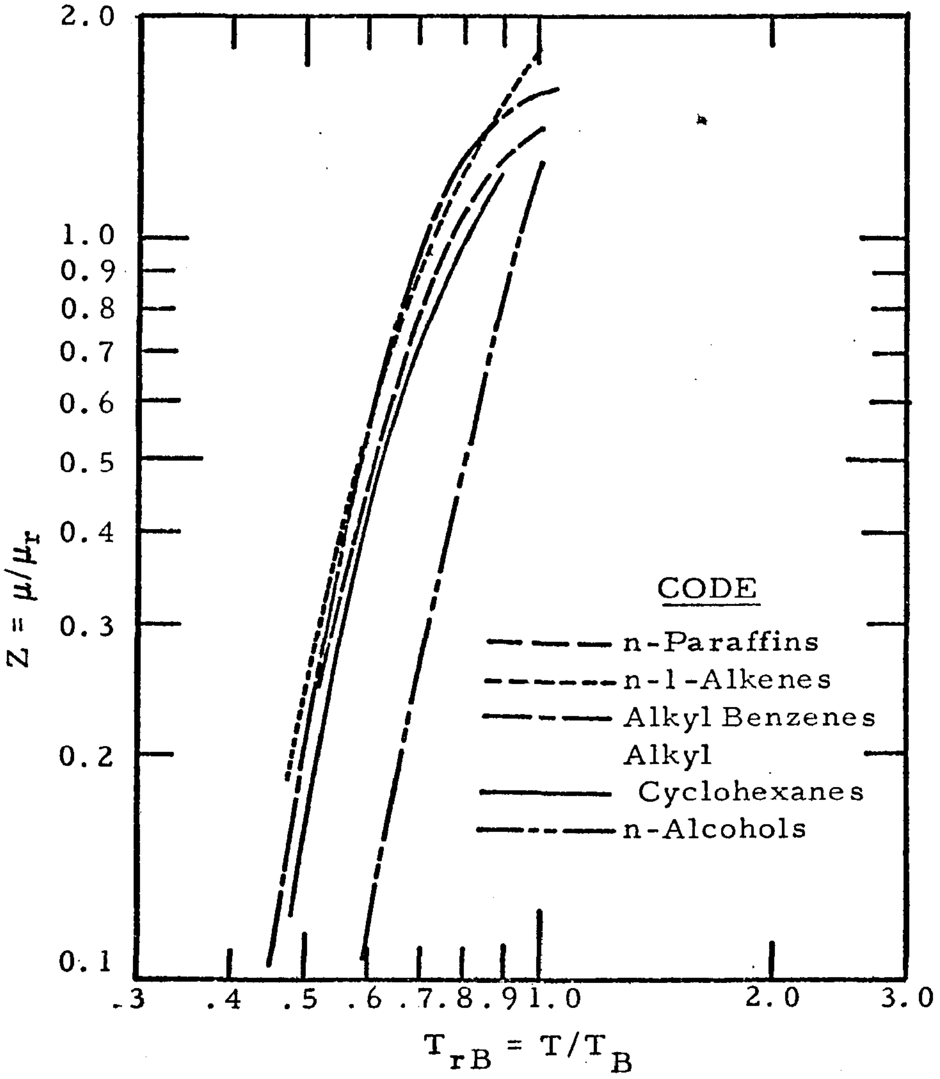


FIGURE 22

NON-LINEAR LEAST SQUARE FITS, AS A FUNCTION OF T_{rB}, FIVE SERIES OF HOMOLOGUES



respectively. Table 15 indicates the error experienced in using equation 71 as a viscosity predictor. The error analysis is summarized in Table 16. The improvement in quality of viscosity prediction provided by equation 71 is evidenced by the ratio of average errors for equations 57 and 71; in the case of the hydrocarbon series, the Z factor reduces the average errors by a factor of 4.9 to 9.0 for the individual series. The maximum errors are generally produced by predictions at or near to the freezing points of the hydrocarbons; equation 71 rapidly gives much more accurate results even only 10 degrees above the freezing point. Equation 71 gives relatively poor results for the n-alcohols as compared to the hydrocarbon series. The accuracy of approximately 30 per cent for these correlations represents a high deviation. The Z factor reduces average errors by a factor of only 1.94 for the n-alcohols.

Prediction of Viscosities. Equation 71 was further tested by prediction of the viscosities of octacosane, $C_{28}H_{58}$, and hexatriacontane, $C_{36}H_{74}$. The predictions were compared with the experimental data of Doolittle (29) and are presented in Table A-5. Average errors were 8.96 per cent for $C_{28}H_{58}$ and 8.0 per cent for $C_{36}H_{74}$. Thus equation 71 may be used for extrapolation to compounds of moderately high molecular weight with fair precision.

Equation 71 was also used to predict the viscosities of five

TABLE 15

AVERAGE ERRORS FOR VISCOSITY PREDICTIONS BY EQUATION 71

CARBON ATOMS	AVERAGE PER CENT ERROR*				
	n-PARAFFINS	n-1-ALKENES	n-ALKYL CYCLOHEXANES	n-ALKYL BENZENES	n-ALCOHOLS
4					38.4
5	26.3	19.9			23.4
6	16.8	11.8			31.8
7	9.7	4.11		6.97	15.9
8	6.9	3.64	6.59	6.43	11.5
9	4.2	3.78	1.56	3.35	23.1
10	2.7	4.53	2.73	4.59	30.3
11	2.4	4.25	3.96	3.06	
12	2.1	3.85	5.17	3.87	42.3
13	2.7	3.51	6.68	3.82	
14	3.3	3.33	8.05	4.27	25.8
15	4.1	3.05	8.73	4.16	
16	4.2	2.68	9.36	4.45	55.2
17	5.0	2.40	9.43	2.96	
18	5.0	2.30	10.5	3.06	
19	5.1	2.25	10.8	4.49	
20	5.7	1.98	11.0	5.30	
21			11.1	7.93	
22			13.3	9.75	

---

*Average % error = $(\mu - \mu_r)100/\mu_r$

TABLE 16

PREDICTION OF VISCOSITY BY EQUATION 71

SERIES	n-PARAFFINS	n-1-ALKENES	MONO-n-ALKYL CYCLOHEXANES	MONO-n-ALKYL BENZENES	n-ALCOHOLS
No. of Carbon Atoms	5-20	5-20	8-22	7-22	4-16
COEFFICIENTS FOR EQUATION 70					
a	0.323	0.552	0.337	0.422	0.234
b	0.239	0.405	0.842	-0.270	4.01
c	-3.56	-3.88	-3.20	-4.60	-1.19
VISCOSITY CALCULATED BY EQUATION 71					
No. of Points	378	177	177	265	109
Average % Error	6.8	4.9	7.9	4.9	29.5
Maximum % Error	49.6	47.5	29.0	27.8	88.2
Fraction of Errors >10%	.143	.074	.282	.121	.735 (.44 >30%)
Relative Average Error Eq. 57: Eq. 71	4.9	8.1	6.6	9.0	1.94

branched chained alkylbenzenes. The predictions were made without the use of any experimental values of viscosities. The results for 58 data points were compared with the reported values in the A. P. I. compilations (2) and are given in Table A-10. Average errors for each compound, tabulated in Table 17, ranged from 1.48 to 23.8 per cent, with a maximum error of only 31.2 per cent. Thus, equation 71 has been used for extrapolation to compounds differing in the basic structure from the original homologous series employed in the correlation of the Z function.

Single Viscosity Equation For Normal Hydrocarbons

The Z functions for the hydrocarbon series, excluding the n-alcohols, are sufficiently similar (Figure 22) so that they might be estimated to be identical, and all of the data available can be used to evaluate the coefficients for equation 70. Alternatively, the data for two or three of the series can be used for the correlation, and this data can then be extrapolated to any other series of hydrocarbons to predict the viscosities. Both of these propositions were tested, using Computer Programs No. 5 and 6, and the results are summarized in Table 18. The constants listed in this table for the case where all four series were correlated represent the equation of best fit to all the data used, based on a total of 997 points for 63 hydrocarbons in the four homologous series. The complete results for the case where two series were correlated are given in Tables A-11, A-12, A-13 and A-14.

TABLE 17

PREDICTION OF VISCOSITIES OF BRANCHED ALKYLBENZENES BY EQUATION 71

COMPOUND	NO. OF PREDICTIONS	MAXIMUM % ERROR	AVERAGE % ERROR*
o-Xylene	15	17.5	6.0
m-Xylene	15	30.4	18.1
p-Xylene	13	31.2	17.0
Isopropylbenzene	7	2.34	1.48
1-Methyl-4-ethylbenzene	8	30.9	23.8

---

* Average % error = $(\mu - \mu_r)100/\mu_r$

TABLE 18

PREDICTION OF VISCOSITIES FOR SERIES OF HOMOLOGUES

SERIES	METHOD	AVERAGE % ERROR	MAXIMUM % ERROR	FRACTION ERRORS >10%	CONSTANTS FOR EQ. 70		
					a	b	c
n-Paraffins	Correlated	7.59	54.2	.159	.341	.0157	-3.97
n-1-Alkenes	Correlated	8.53	52.8	.310			
Alkyl benzenes	Predicted	10.1	35.2	.426			
Alkyl cyclohexanes	Predicted	18.4	37.9	1.000			
				(.22>25%)			
n-Paraffins	Correlated	8.60	61.6	.318	.338	-.231	-4.36
n-1-Alkenes	Correlated	6.98	49.6	.254			
Alkyl benzenes	Correlated	8.07	31.1	.253			
Alkyl cyclohexanes	Predicted	19.4	36.1	1.000			
				(.23>25%)			
n-Paraffins	Correlated	7.51	77.6	.180	.337	-.161	-4.43
n-1-Alkenes	Correlated	10.2	57.8	.305			
Alkyl benzenes	Correlated	12.1	31.1	.590			
Alkyl cyclohexanes	Correlated	15.2	30.4	1.000			
				(.096>25%)			

From the results presented above, it is seen that equation 71 can be used for prediction of viscosities of hydrocarbons where no experimental data exists, with fair accuracy. Prior to this work, there was no reliable method available for the estimation of the viscosity of a liquid in the absence of even a single viscosity measurement (66). If a few experimental data points are available, for even one compound the Z function line might thereby be located with better precision, and considerably better predictions of viscosity should result for the entire series of homologues.

Parametric Predictor Equations

A further refinement of the Z function was accomplished by introducing a second variable, C, representing the number of carbon atoms in each compound.

$$Z = Z(T_{rB}, C) \tag{72}$$

Thus, the constants of equation 70 were correlated with C, using a least squares non-linear regression procedure, and the polynomial of best fit was developed by means of Computer Programs No. 7 and 8. These are in the form

$$a = a_1' + b'C + d'C^2 \tag{73}$$

$$b = e' + f'C + g'C^2 \tag{74}$$

$$c = h' + j'C + k'C^2 \tag{75}$$

Constants are listed in Table 19.

Equations 73, 74 and 75 were used together with equations 70 and 71 to predict the viscosities of the five series of homologues considered here. The calculations necessary for the parametric predictor equations are illustrated in the Appendix. The alkyl benzenes and alkyl cyclohexanes were correlated with slightly greater accuracy by using the number of carbon atoms in the alkyl side chain rather than through the use of the total number of carbon atoms. The results for each series of homologues are presented in Tables A-15, A-16, A-17, A-18 and A-19, respectively. The average errors for the individual compounds are given in Table 20. The results are summarized in Table 21. Computer Program No. 9 was utilized for all of the above calculations. The use of the carbon parameter decreases the average error for the series of homologues by factors ranging between 1.4 to 3.8. The results for the alcohols show fair correlation, i.e., only 1/4 of the predictions have errors greater than 25 per cent.

The parametric equations for the paraffins were tested by extrapolation of the equations to the lower paraffin hydrocarbons, methane to butane, which were not used in the original correlations. The results are included in Table A-15. Average errors for each compound, listed in Table 20, resulted in an overall average error for

TABLE 19

CONSTANTS FOR EQUATIONS 73, 74 and 75

SERIES	n-PARAFFINS*	n-1-ALKENES*	MONO-n-ALKYL CYCLOHEXANES**	MONO-n-ALKYL BENZENES**	n-ALCOHOLS*
No. of Carbon Atoms	5-20	5-20	8-22	9-22	4-16
a_1'	0.496	1.01	0.573	1.32	-2.808
b'	-0.0147	-0.0642	-0.141	-0.240	0.751
d'	0.0	0.0	0.00988	0.0103	-0.0378
e'	-0.279	1.94	2.00	3.76	-5.563
f'	0.0978	-0.213	-0.705	-1.08	2.31
g'	-0.00498	0.0	0.0406	0.0472	-0.130
h'	-3.15	0.950	-2.26	-0.0534	-17.46
j'	-0.0573	-0.634	-0.810	-1.22	2.38
k'	0.0	0.0144	0.0449	0.0564	- 0.115

---

* C represents the total number of carbon atoms in the compound.

** C represents only the number of carbon atoms in the alkyl side chain.

TABLE 20

AVERAGE ERRORS FOR VISCOSITY PREDICTIONS BY PARAMETRIC EQUATIONS

CARBON ATOMS	AVERAGE PER CENT ERROR**				
	n-PARAFFINS	n-ALKENES	ALKYL CYCLOHEXANES	ALKYL BENZENES	n-ALCOHOLS
1	7.39*				
2	8.48*				
3	8.85*				
4	6.64*				5.69
5	5.48	2.44			6.31
6	3.05	1.17			13.8
7	1.73	1.18			12.5
8	.934	.614	4.40		18.3
9	2.11	1.55	3.03	5.51	10.1
10	1.73	1.38	2.18	3.05	14.8
11	1.37	1.64	2.00	3.12	
12	.826	.836	2.55	3.93	16.8
13	.983	1.23	3.12	3.40	
14	1.03	2.21	1.97	3.51	26.5
15	1.33	2.82	2.73	3.80	
16	1.48	3.29	.993	4.95	20.0
17	1.53	2.73	1.90	3.85	
18	1.60	1.08	1.69	3.89	
19	1.59	1.67	2.44	3.15	
20	1.70	5.14	2.21	1.62	
21			1.82	1.01	
22			2.83	3.66	

---

* Results of extrapolation

** Average % error = $(\mu - \mu_r)100/\mu_r$

TABLE 21

ACCURACY OF VISCOSITY PREDICTION FOR THE PARAMETRIC EQUATIONS

SERIES	n-PARAFFINS*	n-1-ALKENES*	MONO-n-ALKYL CYCLOHEXANES**	MONO-n-ALKYL BENZENES**	n-ALCOHOLS*
No. of Points	378	177	177	234	109
No. of Carbon Atoms	5-20	5-20	8-22	9-22	4-16
Average % Error	1.78	1.95	2.39	3.46	14.5
Maximum % Error	14.8	6.29	19.5	17.1	62.0
Fraction of Errors >10%	0.0132	0.0	0.0057	0.047	0.66 (.25 >25%)
Relative Average % Error $Z(T_{rB})$: $Z(T_{rB}, C)$	3.82	2.51	3.31	1.42	1.88

---

* C represents the total number of carbon atoms in the compound.

** C represents the number of carbon atoms in the alkyl side chain.

the extrapolated region of 7.9 per cent. Extrapolations to the higher hydrocarbons were not successful when the true parametric value for the number of carbon atoms was used. The parameter approaches a limiting value at about 20 carbon atoms.

The parametric equations for the monoalkylbenzenes were employed to predict the viscosities of five branched chained alkylbenzenes. These predictions were accomplished without the use of experimental viscosities. The results are given in Table A-20. Average errors for each compound are listed in Table 22, and the overall average error was only 11.1 per cent.

Significance of Z Function

The Z function employed here to correct the viscosity predictions corresponds, in principle, to the compressibility factor for real gases and liquids. The idealized liquid state model which is the basis of the present development, like the ideal gas law, does not adequately predict the viscous behavior of real liquids. It is significant, however, that the deviations from the model are relatively consistent, and may be taken into account by a relatively simple empirical function, applicable to a wide variety of liquids. It is proposed that the Z function varies with T_{rB} in the reported manner because the development employed here was based on a reinterpretation of the rigid-sphere gas theory to apply to a mon-

TABLE 22

PREDICTION OF VISCOSITIES OF BRANCHED ALKYLBENZENES* BY PARAMETRIC EQUATIONS

COMPOUND	NO. OF PREDICTIONS	MAXIMUM % ERROR	AVERAGE % ERROR**
o-Xylene	15	24.0	13.7
m-Xylene	15	19.1	10.3
p-Xylene	13	17.6	8.6
Isopropylbenzene	7	3.1	1.8
1-Methyl-4-ethylbenzene	8	31.7	21.0

---

* C represents the number of carbon atoms in branched chain

** Average % error = $(\mu - \mu_r)100/\mu_r$

atomic liquid. Thus, the maximum deviations from the idealized liquid state model generally occur near to or at the freezing point. The variation of Z with carbon number, C, may be due to variations in molecular shape, size and forces which are not considered in the idealized liquid state model (monatomic liquid). At low carbon numbers, it is proposed that small increases in C significantly effect the magnitude of molecular forces. This effect diminishes as C increases until, it approaches a limiting value. The Z function employed here approaches a limiting value at about twenty carbon atoms.

The introduction of the factor Z into equation 54 results in the relationship

$$M\,(K/\mu) = 6Z \tag{76}$$

Mohanty tested his relationship, equation 60, at the boiling point for a group of chemically unrelated compounds and he showed the mean value of the constant to be 10.8. Thus, he, in effect, demonstrated deviations equivalent to an average value of Z of 1.8 at $T_{rB} = 1$. For the n-paraffins, the present work shows Z at the boiling point is 1.4, and this varies from a high of 1.75 for the n-1-alkenes to a low of approximately 1.24 for the n-alcohols.

In explaining his results, Mohanty discusses his relationship ("equation 3"), which is identical to equation 60 developed in the present work. He says,

> "The mean value of the constant is 10.8. It is evident from this that, to be applicable at the boiling point, the numerical coefficient in equation 3 requires modification. This can be done, satisfactorily enough, only on examination of a number of liquids." (54)

The members of the series of homologues tested here all show essentially similar deviation factors, Z, when examined at corresponding conditions of reduced temperature. Thus, equation 76 is applicable over a wide temperature range.

CONCLUSIONS

A density apparatus based on the hydrostatic weighing method of Kohlrausch was constructed and used for the determination of liquid densities between 25° C to 280° C. Temperatures were established and controlled by means of a boiling vapor bath and a precise pressure control system. The apparatus permitted a density measurement every 30 minutes on 5 ml of liquid sample with an accuracy of 1.4×10^{-4} g/ml, when a plummet of 2 cc was employed. The deviations between the experimental and the reported densities of n-decane and n-tridecane showed no relationship with temperature.

The densities of ten alcohols, each at least 99.9 per cent pure, were investigated with this density apparatus, from room temperature to near their normal boiling points. The reproducibility of density varied from 1.0×10^{-4} g/ml (to 100° C) to 4×10^{-4} g/ml at high temperatures approaching the boiling point. Reproducibility decreased at the high temperatures because of condensation of alcohol vapors on the suspension chain. The densities of the alcohols determined here are more reliable than the values reported by Costello and Bowden. This is based on boiling point comparisons, which indicated that their alcohols were not of the highest quality. The deviations between the densities of the alcohols reported by Costello and Bowden and the experimental values are of the order 2 to 3 in the third decimal place. The experimental densities exhibit little scatter in the data and, for purposes of interpolation, were fitted to third-order polynomials with an average deviation of 0.0007 g/ml.

Cannon-Ubbelhode semi-micro capillary viscometers were used to measure the kinematic viscosities of the ten alcohols from room temperature to 250° C. The per cent deviation for the efflux times was within 0.10 per cent, and is an indication of the precision of the determinations.

The viscosity of monatomic liquids was modeled by a relationship derived from the kinetic theory of gases. The expression takes the form

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3}$$

and there is only one independently adjustable parameter, β. This distinguishes the correlation of liquid viscosity presented here from the most widely used correlations, of Souders (72) and Thomas (76), which are entirely empirical in nature.

Viscosities were calculated from data on density and molecular weight of the liquids. The average deviations between the calculated and reported (or experimental) values of the viscosity are 32.0% for the n-paraffins, 39.8% for the n-1-alkenes, 53.4% for the n-alkylcyclohexanes, 46.3% for the n-alkylbenzenes and 57.3% for the n-alcohols.

A single correction factor, Z, was developed for each of the five series of homologues to account for the deviations of the calculated viscosities from those reported, extending over a one to three-hundred degree range. The factor is a function of reduced temperature relative to the normal boiling point, T_{rB}. The individual point viscosity deviations, Z, for each series, as a function of the T_{rB}, on log-log coordinates varies in a regular manner. For each series, a family of curves, parametric in the number of carbon atoms was drawn through these Z points, and could be approximated by a single line of best fit which takes the form

$$Z = \exp(a + b \ln(T_{rB}) + c \ln^2(T_{rB}))$$

A single equation for each series was thus used in the form

$$\mu = \rho^{11/3}\beta^3/M^{8/3}N^{1/3}Z$$

as a predictor for the viscosities of liquid n-paraffins, n-1-alkenes, n-alkylcyclohexanes, n-alkylbenzenes and n-alcohols, over an extended temperature range with an average error of 6.8%, 4.9%, 7.9%, 4.9% and 29.5%, respectively.

The Z functions for the hydrocarbon series, excluding the alcohols were sufficiently similar so that they were estimated to be identical. The data for two of the series, n-paraffins and n-1-alkenes, were combined for purposes of correlation, and this combined Z function was employed to extrapolate to the alkylbenzenes and the alkylcyclohexanes with an accuracy in predicted viscosity of 10.1% and 18.4%, respectively. The maximum error in both series was only 37.9%. Thus, predictions of liquid viscosity were performed over extended temperature ranges, with good accuracy without requiring viscosity data. Prior to this work, a reliable method available for the estimation of the viscosity of a liquid in the absence of even a single viscosity measurement did not exist.

Through correlation of the Z function, for each of the five series of homologues, with T_{rB} and with C, the number of carbon atoms in the alkyl group, a more accurate relationship of the Z function was accomplished. The use of the carbon parameter decreased the average error in predicted viscosity to 1.78%, 1.95%, 2.39%, 3.46% and 14.5% for the n-paraffins, n-1-alkenes, alkylcyclohexanes, alkylbenzenes and the n-alcohols, respectively. Extrapolation of the parametric equations for the paraffins to lower molecular weight paraffins gave average errors of 7.9%, while extrapolations to higher paraffins were not successful. The parameter approaches a limiting value at about 20 carbon atoms. The parametric equations for the alkylbenzenes were successfully employed to predict the viscosities of a number of branched chained alkylbenzenes with an average error of only 11.1%.

The function employed here to correct the viscosity predictions corresponds, in principle, to the compressibility factor for real gases and liquids. The idealized liquid state model which is the basis of the present development, like the ideal gas law, does not adequately predict the viscous behavior of real liquids. It is significant, however, that the deviations from the model are relatively consistent, and may be taken into account by a relatively simple empirical function, applicable to a wide variety of liquids.

NOMENCLATURE

a, b, c = disposable constants in equation 70

a_1, a_2, a_3, a_4 = disposable constants in equation 28

a' = constant in equation 37

$a_1', b', d', e', f', g', h', j', k',$ = disposable constants in equations 73, 74 and 75

A, B' = constants in equation 8

A_b, C_b = constants in equation 7A

A_s = constant in equation 7

A' = area over which force is applied

B_F, B_{FO}, B_{FW} = bouoyant forces

C = number of carbon atoms in the alkyl group of a compound

C_e = cubical coefficient of expansion, $°C^{-1}$

C_1, B = viscometer coefficients

dv = differential velocity change

dx = differential distance

D_{air}, D_o, D_W = density of air, object, weights, g/ml

e = 2.71828

f_1, f_2, f_3, f_4 = dimensional functions

f_ℓ = fluidity

F = applied force

g_o = acceleration of gravity

NOMENCLATURE (Continued)

h = mean effective hydrostatic head

H_d = numerator of equation 42

H_n = denominator of equation 42

I = constant in equation 9

k = Boltzmann constant, R/N

K = thermal conductivity coefficient, cal/(sec) (cm) (°C)

ℓ = length of capillary

L = length

M = molecular weight

M' = mass

m = mass of a molecule, g

n, s = coefficients in equation 10

N = Avogadro number, 6.0238×10^{23} molecules/g mole

P = pressure drop

r = radius of capillary

R = gas constant, 1.987 cal/(g mole) (°K)

T = absolute temperature, °K

T_i = time

T_B = absolute normal boiling point, °K

T_{rB} = reduced temperature with respect to boiling point, T/T_B

NOMENCLATURE (Continued)

t, t_1, t_2 = temperature, °C

t_c = calibration temperature, °C

t_i = efflux time

u = molecular speed of gas, cm/sec

$\bar{u}, \bar{u}_L$ = mean molecular speed of gas, liquid molecules, cm/sec

$\underline{u}$ = individual molecular velocity, cm/sec

$\underline{u}_x, \underline{u}_y, \underline{u}_z$ = individual molecular velocity components, cm/sec

$\underline{\bar{u}}$ = mean molecular velocity, cm/sec

$|\underline{\bar{u}}_y|$ = absolute value of the y component of the mean molecular velocity, cm/sec

$\underline{\bar{u}}_y^+$ = positive value of the y component of the mean molecular velocity, cm/sec

v = volume of flow in time, t_i

v_s, v_s' = speed of sound in liquid, gas, cm/sec

V = molar volume, cm^3/g mole

V_c, V_t = volume of immersed object at calibration temperature, test temperature, ml

V_f = molecular free volume, cm^3/molecule

V_i, V_1, V_2 = kinematic viscosity

V_o, V_W = volume object, weights, ml

NOMENCLATURE (Continued)

W_A, W_L = true weight in air, liquid, g

W'_A W'_L = apparent weight in air, liquid, g

Z = deviation, μ/μ_r

GREEK LETTERS

α, β', γ' = constants in equation 7

β = empirical structural contribution factor

Δ = mean intermolecular distance, cm

ρ = density, g/cm^3

γ = specific heat ratio

λ = mean free path, cm

π = 3.14159

μ = viscosity, g/(cm) (sec) or poise

μ^o = viscosity at low pressure, centipoise

μ_r = reported or experimental viscosity, g/(cm) (sec)

TABLE A-1

DENSITY OF n-ALCOHOLS

	EXPERIMENTAL		LITERATURE		
	TEMP. °C	DENSITY g/ml	TEMP. °C	DENSITY g/ml	REFERENCE
n-Butanol T_B = 117.89°C					
			20	0.8104	78
	24.98	0.8087	20	0.80978	37
	30.82	0.8037	20	0.8086	22
	40.30	0.7964	40	0.7936	22
	50.05	0.7887	80	0.7617	22
	70.60	0.7714	100	0.7434	22
	80.18	0.7625			
	89.85	0.7531			
	99.53	0.7440			
	110.72	0.7329			
n-Hexanol T_B = 157.14°C					
	25.30	0.8141	0	0.83284	77
	30.60	0.8105	0	0.8359	22
	40.24	0.8036	20	0.8186	37
	50.07	0.7964	20	0.8217	22
	69.88	0.7813	40	0.8076	22
	80.14	0.7735	80	0.7766	22
	89.67	0.7653	100	0.7599	22
	99.78	0.7569	140	0.7247	22
	111.18	0.7470			
	144.12	0.7157			
	153.92	0.7063			

TABLE A-1 (CONTINUED)

	EXPERIMENTAL		LITERATURE		
	TEMP. °C	DENSITY g/ml	TEMP. °C	DENSITY g/ml	REFERENCE
n-Heptanol T_B = 176.26°C					
	25.39	0.8188	20	0.8219	37, 78
	30.68	0.8150			
	40.40	0.8081			
	49.99	0.8012			
	69.90	0.7863			
	80.20	0.7783			
	89.68	0.7707			
	99.80	0.7624			
	111.22	0.7529			
	131.90	0.7346			
	153.87	0.7141			
	165.12	0.7024			
	171.28	0.6924			
n-Octanol T_B = 195.26°C					
	25.14	0.8220	20	0.8246	37
	30.51	0.8184	20	0.8227	22
	30.58	0.8180	40	0.8091	22
	40.28	0.8112	60	0.7948	22
	40.32	0.8114	80	0.7804	22
	60.56	0.7971	140	0.7305	22
	80.32	0.7820	180	0.6951	22
	80.34	0.7820			
	89.48	0.7750			
	89.49	0.7751			
	111.01	0.7579			
	138.43	0.7347			
	155.10	0.7192			
	175.92	0.6973			
	185.50	0.6873			

TABLE A-1 (CONTINUED)

	EXPERIMENTAL		LITERATURE		
	TEMP. °C	DENSITY g/ml	TEMP. °C	DENSITY g/ml	REFERENCE
n-Nonanol T_B = 213.56°C					
	24.93	0.8239	20	0.8274	37
	30.35	0.8202	20	0.8273	78
	40.55	0.8131			
	50.35	0.8063			
	70.18	0.7923			
	80.24	0.7846			
	89.72	0.7774			
	99.83	0.7695			
	110.96	0.7610			
	155.18	0.7237			
	175.93	0.7046			
	194.90	0.6845			
	202.71	0.6736			
n-Decanol T_B = 231.0°C					
	30.08	0.8224	20	0.8292	37
	39.98	0.8157	20	0.8260	22
	60.10	0.8017	40	0.8127	22
	80.32	0.7874	60	0.7998	22
	99.78	0.7726	80	0.7858	22
	110.84	0.7640	100	0.7705	22
	120.93	0.7562	120	0.7550	22
	130.29	0.7483	160	0.7224	22
	161.36	0.7218	180	0.7053	22
	162.14	0.7212			
	185.87	0.6993			

TABLE A-1 (CONTINUED)

n-Dodecanol
T_B = 260.70°C

EXPERIMENTAL		LITERATURE		
TEMP. °C	DENSITY g/ml	TEMP. °C	DENSITY g/ml	REFERENCE
30.31	0.8258	24	0.8309	37
40.44	0.8188	40	0.8196	22
49.88	0.8126	60	0.8057	22
60.49	0.8053	80	0.7920	22
80.20	0.7911	100	0.7774	22
89.68	0.7844	180	0.7144	22
99.73	0.7769	200	0.6982	22
111.12	0.7685	220	0.6810	22
185.95	0.7077	240	0.6635	22
200.43	0.6949	260	0.6457	22
221.12	0.6751			
240.65	0.6551			
250.12	0.6424			

n-Tetradecanol
T_B = 263.26°C

EXPERIMENTAL		LITERATURE		
TEMP. °C	DENSITY g/ml	TEMP. °C	DENSITY g/ml	REFERENCE
		38	0.8236	37
39.75	0.8236	40	0.8227	22
45.20	0.8199	60	0.8079	22
49.81	0.8170	80	0.7931	22
60.26	0.8098	100	0.7784	22
70.34	0.8025	120	0.7636	22
80.01	0.7955	140	0.7488	22
89.89	0.7884	180	0.7188	22
100.00	0.7811	200	0.7032	22
111.12	0.7729	220	0.6865	22
130.95	0.7589	240	0.6700	22
154.07	0.7406	260	0.6534	22
186.08	0.7138			
200.08	0.7020			

TABLE A-1 (CONTINUED)

	EXPERIMENTAL		LITERATURE		
	TEMP. °C	DENSITY g/ml	TEMP. °C	DENSITY g/ml	REFERENCE
n-Tetradecanol (Cont'd) T_B = 263.26°C					
	222.57	0.6830			
	240.68	0.6664			
	240.68	0.6668			
	250.08	0.6570			
	250.08	0.6574			
	259.83	0.6473			
	259.83	0.6477			
n-Hexadecanol T_B = 344.06°C					
	50.12	0.8184	50	0.8176	37
	55.02	0.8150	60	0.8105	22
	60.20	0.8118	100	0.7830	22
	70.10	0.8050	140	0.7537	22
	80.14	0.7979	160	0.7387	22
	89.82	0.7910	220	0.7082	22
	99.80	0.7842	260	0.6607	22
	111.07	0.7761			
	141.37	0.7539			
	160.67	0.7396			
	189.88	0.7172			
	220.38	0.6928			
	250.22	0.6724			
	276.45	0.6513			

TABLE A-2

INTERPOLATED DENSITIES OF n-ALCOHOLS

COMPOUND	TEMP. °C	DENSITY INTERPOLATED g/ml	LITERATURE (22) g/ml
n-Butanol	30.03	0.8019	
	70.00	0.7706	
	110.00	0.7360	
n-Pentanol	50.05	0.7932	
	69.96	0.7764	
	80.00	0.7676	0.7680
	100.00	0.7514	0.7515
n-Hexanol	24.94	0.8157	
	30.03	0.8088	
	110.00	0.7500	
	120.05	0.7347	0.7432
	130.02	0.7272	
n-Heptanol	110.00	0.7558	
n-Octanol	30.07	0.8171	
	60.10	0.7978	0.7948
	70.00	0.7893	
	90.00	0.7738	
	100.00	0.7671	0.7643
	110.00	0.7611	
	130.00	0.7331	
n-Nonanol	40.05	0.8147	
	110.00	0.7635	
	130.00	0.7334	
n-Decanol	110.00	0.7653	
	120.00	0.7567	0.7550
n-Dodecanol	90.05	0.7833	
	100.00	0.7764	0.7774
	120.00	0.7512	0.7622
	129.85	0.7409	
	140.10	0.7308	0.7468
	150.00	0.7217	
	161.55	0.7120	0.7307

TABLE A-2(CONTINUED)

COMPOUND	TEMP. °C	DENSITY INTERPOLATED g/ml	DENSITY LITERATURE (22) g/ml
n-Tetradecanol	90.05	0.7879	
n-Hexadecanol	90.05	0.7908	
	110.09	0.7769	
	120.00	0.7709	
	129.85	0.7619	
	140.10	0.7526	0.7537
	150.00	0.7437	

TABLE A-3

KINEMATIC VISCOSITY OF n-ALCOHOLS

	TEMPERATURE °C	KINEMATIC VISCOSITY CS
n-Butanol T_B = 117.89°C		
	24.98	3.200
	30.03	2.807
	40.03	2.227
	50.00	1.805
	70.00	1.243
	80.00	1.060
	90.00	0.9167
	100.00	0.8057
	110.00	0.7191
	115.00	0.6859
n-Pentanol T_B = 138.06°C		
	24.94	4.366
	30.03	3.786
	40.03	2.901
	50.05	2.236
	69.96	1.399
	80.00	1.104
	90.01	0.8706
	100.00	0.6802
	110.00	0.5151
	120.05	0.3835
	130.01	0.2505

TABLE A-3 (CONTINUED)

	TEMPERATURE °C	KINEMATIC VISCOSITY CS
n-Hexanol T_B = 157.14°C		
	24.94	5.718
	30.03	4.862
	40.15	3.660
	50.00	2.812
	69.98	1.736
	80.00	1.353
	90.00	1.067
	100.05	0.8276
	110.00	0.6337
	120.05	0.4575
	130.02	0.3114
n-Heptanol T_B = 176.26°C		
	25.45	6.872
	30.74	5.844
	40.51	4.419
	50.05	3.450
	70.00	2.113
	80.00	1.678
	90.00	1.341
	100.00	1.073
	154.00	0.5586
	165.15	0.4926
	171.30	0.4634

TABLE A-3 (CONTINUED)

TEMPERATURE °C	KINEMATIC VISCOSITY CS
n-Octanol T_B = 195.26°C	
25.00	8.775
30.07	7.422
40.05	5.532
60.10	3.206
70.00	2.582
80.00	2.084
90.00	1.718
100.00	1.439
110.00	1.229
130.00	0.9326
138.85	0.7664
154.00	0.6347
175.75	0.4989
185.65	0.4539
n-Nonanol T_B = 213.56°C	
25.00	10.86
30.07	9.066
40.05	6.765
50.60	4.939
70.00	3.085
80.00	2.417
90.00	1.919
100.00	1.533
110.00	1.229
130.00	0.7824
155.20	0.4442
175.65	0.2258

TABLE A-3 (CONTINUED)

	TEMPERATURE °C	KINEMATIC VISCOSITY CS
n-Decanol T_B = 231.0°C		
	30.07	10.59
	40.05	8.111
	60.10	4.527
	80.00	2.755
	90.00	2.183
	100.00	1.751
	110.00	1.407
	120.00	1.137
	129.95	0.9158
n-Dodecanol T_B = 260.70°C		
	30.20	16.36
	40.70	11.23
	49.75	8.370
	60.17	6.117
	80.10	3.680
	90.05	2.822
	100.00	2.280
	111.07	1.833
	120.00	1.490
	129.85	1.220
	140.10	0.9931
	150.00	0.8085
	161.55	0.6927
	185.80	0.4127
	199.80	0.2889
	220.61	0.1343

TABLE A-3 (CONTINUED)

	TEMPERATURE °C	KINEMATIC VISCOSITY CS
n-Tetradecanol T_B = 263.26°C	40.00	15.45
	60.00	7.912
	70.00	5.969
	80.03	4.624
	90.05	3.666
	100.00	2.994
	110.09	2.450
	130.20	1.542
	154.00	1.006
	186.17	0.6214
	199.95	0.5417
	222.46	0.3660
	249.80	0.1912
n-Hexadecanol T_B = 344.06°C	50.00	13.64
	60.00	9.864
	70.00	7.368
	80.00	5.682
	90.05	4.407
	100.00	3.550
	110.09	2.848
	120.00	2.390
	129.85	2.033
	140.10	1.752
	150.00	1.532
	160.50	1.368
	190.05	1.063
	222.46	0.8781
	249.80	0.7552

TABLE A-4

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-PARAFFINS

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3}$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Methane	93	.188	.245	30.1
	103	.142	.219	54.0
	113	.115	.193	68.2
Ethane	103	.805	.538	-33.2
	113	.574	.505	-12.1
	123	.442	.473	7.08
	133	.359	.442	23.2
	143	.301	.413	37.1
	153	.257	.384	49.4
	163	.222	.356	60.4
	173	.195	.329	68.6
	183	.172	.301	75.2
Propane	83	13.8	.722	-94.7
	93	5.96	.690	-88.4
	103	3.18	.659	-79.3
	113	1.96	.629	-67.9
	123	1.34	.600	-55.2
	133	.984	.569	-42.2
	143	.762	.539	-29.3
	153	.614	.510	-16.7
	163	.510	.483	- 5.31
	173	.433	.456	5.42
	183	.374	.429	14.6
	193	.327	.402	23.0
	203	.288	.377	30.8
	213	.256	.352	37.4
	223	.228	.327	43.6
	233	.205	.304	48.5

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Butane	183	.630	.534	-15.3
	193	.536	.506	- 5.55
	203	.462	.480	3.90
	213	.403	.455	12.9
	223	.355	.432	21.6
	233	.315	.409	29.8
	243	.282	.386	37.0
	253	.253	.364	44.1
	263	.229	.342	49.7
	273	.210	.322	53.3
Pentane	143	3.63	.737	-79.7
	153	2.35	.705	-70.0
	163	1.66	.675	-59.3
	173	1.24	.646	-47.9
	183	.973	.616	-36.6
	193	.791	.590	-25.4
	203	.659	.564	-13.2
	213	.562	.539	- 4.14
	223	.487	.514	5.60
	233	.428	.491	14.6
	243	.380	.468	23.1
	253	.341	.445	30.4
	263	.307	.422	37.5
	273	.279	.400	43.5
	283	.255	.379	48.7
	293	.235	.359	52.7
	303	.216	.338	56.3
Hexane	183	1.83	.693	-62.1
	193	1.38	.666	-51.8
	203	1.09	.639	-41.4
	213	.888	.613	-31.0
	223	.741	.587	-20.8
	233	.632	.563	-11.0
	243	.547	.538	- 1.59
	253	.480	.515	7.20
	263	.426	.491	15.3
	273	.381	.468	22.9
	283	.3436	.446	29.7
	293	.3126	.425	36.0
	303	.2854	.404	41.5
	313	.2619	.384	46.4
	323	.2411	.363	50.6
	333	.2223	.342	53.9
	343	.2050	.320	56.1

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Heptane	183	3.77	.759	-79.9
	193	2.61	.731	-72.0
	203	1.918	.703	-63.3
	213	1.476	.677	-54.2
	223	1.177	.650	-44.8
	233	.9653	.625	-35.3
	243	.8098	.600	-26.0
	253	.6916	.575	-16.9
	263	.5995	.551	- 8.16
	273	.5262	.527	.105
	283	.4666	.503	7.89
	293	.4181	.482	15.3
	303	.3772	.460	22.0
	313	.3426	.440	28.3
	323	.3128	.419	34.0
	333	.2867	.399	39.0
	343	.2635	.378	43.3
	353	.2431	.357	47.0
	363	.2250	.338	50.2
	373	.2086	.319	52.9
Octane	223	1.86	.706	-62.0
	233	1.46	.679	-53.5
	243	1.183	.653	-44.8
	253	.981	.686	-30.0
	263	.829	.603	-27.3
	273	.7125	.578	-18.8
	283	.6203	.554	-10.6
	293	.5466	.532	- 2.75
	303	.4865	.510	4.77
	313	.4368	.489	11.9
	323	.3946	.468	18.5
	333	.3578	.447	24.9
	343	.3274	.426	30.2
	353	.3004	.406	35.2
	363	.2765	.387	39.9
	373	.2555	.367	43.8
	383	.2366	.348	47.3
	393	.2195	.329	50.1

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Nonane	223	2.99	.755	-74.7
	233	2.24	.728	-67.5
	243	1.784	.702	-60.7
	253	1.403	.675	-51.9
	263	1.154	.650	-43.7
	273	.9688	.625	-35.5
	283	.8267	.599	-27.4
	293	.7160	.576	-19.5
	303	.6279	.554	-11.6
	313	.5562	.532	- 4.28
	323	.4970	.511	2.82
	333	.4472	.490	9.52
	343	.4047	.468	15.7
	353	.3687	.448	21.6
	363	.3375	.429	27.1
	373	.3100	.409	32.0
	383	.2858	.390	36.5
	393	.2641	.371	40.5
	403	.2445	.351	43.7
	413	.2271	.331	45.7
	423	.2115	.316	49.3
Decane	243	2.559	.745	-70.9
	253	1.987	.718	-63.9
	263	1.590	.692	-56.5
	273	1.304	.666	-48.9
	283	1.091	.641	-41.2
	293	.9284	.617	-33.5
	303	.8018	.594	-25.9
	313	.7010	.572	-18.5
	323	.6192	.550	-11.2
	333	.5517	.528	- 4.29
	343	.4951	.507	2.31
	353	.4476	.486	8.61
	363	.4068	.466	14.5
	373	.3715	.446	20.0
	383	.3408	.426	25.1
	393	.3137	.407	29.8
	403	.2896	.388	34.0
	413	.2683	.370	37.8
	423	.2489	.351	41.1
	433	.2313	.333	43.9
	443	.2152	.315	46.1

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Undecane	253	2.779	.758	-72.7
	263	2.163	.731	-66.2
	273	1.733	.705	-59.3
	283	1.421	.679	-52.2
	293	1.189	.655	-44.9
	303	1.012	.631	-37.6
	313	.8733	.608	-30.4
	323	.7627	.586	-23.2
	333	.6731	.564	-16.2
	343	.5988	.542	- 9.54
	353	.5371	.521	- 3.04
	363	.4850	.500	3.14
	373	.4403	.480	8.96
	383	.4018	.460	14.5
	393	.3680	.440	19.5
	403	.3385	.421	24.2
	413	.3124	.402	28.6
	423	.2892	.383	32.5
	433	.2683	.365	36.0
	443	.2493	.347	39.0
	453	.2320	.329	41.6
	463	.2161	.311	43.8
Dodecane	273	2.278	.740	-67.5
	283	1.833	.714	-61.0
	293	1.508	.689	-54.3
	303	1.265	.665	-47.4
	313	1.079	.642	-40.5
	323	.9321	.618	-33.6
	333	.8147	.596	-26.8
	343	.7188	.574	-20.2
	353	.6398	.552	-13.8
	363	.5743	.531	- 7.49
	373	.5183	.510	- 1.53
	383	.4706	.490	4.14
	393	.4291	.470	9.44
	403	.3932	.450	14.4
	413	.3617	.431	19.2
	423	.3338	.412	23.5
	433	.3089	.393	27.4
	443	.2865	.375	30.9
	453	.2664	.357	34.1
	463	.2480	.339	36.8
	473	.2311	.321	39.0
	483	.2153	.303	40.7

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Tridecane	273	2.950	.773	-73.8
	283	2.328	.747	-67.9
	293	1.886	.722	-61.7
	303	1.560	.697	-55.3
	313	1.314	.673	-48.8
	323	1.123	.649	-42.2
	333	.9725	.626	-35.6
	343	.8513	.603	-29.1
	353	.7527	.582	-22.7
	363	.6709	.560	-16.5
	373	.6022	.539	-10.5
	383	.5441	.518	- 4.75
	393	.4940	.497	.684
	403	.4508	.477	5.84
	413	.4133	.458	10.8
	423	.3803	.439	15.4
	433	.3511	.420	19.6
	443	.3251	.401	23.5
	453	.3017	.383	27.0
	463	.2807	.365	30.2
	473	.2616	.348	33.1
	483	.2435	.329	35.2
	493	.2268	.311	36.9
	503	.2114	.292	38.1
Tetradecane	283	2.940	.777	-73.6
	293	2.342	.751	-67.9
	303	1.910	.726	-62.0
	313	1.590	.702	-55.9
	323	1.345	.678	-49.6
	333	1.154	.655	-43.3
	343	1.002	.631	-37.0
	353	.8798	.609	-30.8
	363	.7795	.587	-24.7
	373	.6958	.566	-18.7
	383	.6251	.544	-13.0
	393	.5654	.523	- 7.45
	403	.5140	.503	- 2.19
	413	.4696	.483	2.81
	423	.4307	.463	7.55
	433	.3966	.444	12.0
	443	.3664	.426	16.1
	453	.3395	.407	19.9
	463	.3153	.389	23.4
	473	.2935	.372	26.6

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	483	.2733	.353	29.3
	493	.2547	.335	31.5
	503	.2375	.317	33.3
	513	.2218	.299	34.8
	523	.2074	.282	36.0
Pentadecane	283	3.663	.806	-78.0
	293	2.872	.780	-72.8
	303	2.310	.754	-67.4
	313	1.900	.729	-61.6
	323	1.591	.705	-55.7
	333	1.353	.681	-49.7
	343	1.166	.657	-43.6
	353	1.017	.635	-37.6
	363	.8953	.613	-31.6
	373	.7949	.590	-25.7
	383	.7112	.569	-20.0
	393	.6403	.547	-14.5
	403	.5800	.527	- 9.20
	413	.5280	.506	- 4.15
	423	.4830	.486	.681
	433	.4437	.467	5.26
	443	.4088	.448	9.55
	453	.3781	.429	13.6
	463	.3506	.411	17.3
	473	.3261	.394	20.7
	483	.3034	.375	23.8
	493	.2827	.357	26.4
	503	.2638	.339	28.6
	513	.2464	.322	30.6
	523	.2307	.305	32.2
	533	.216	.288	33.5
	543	.202	.272	34.7
Hexadecane	293	3.484	.806	-76.9
	303	2.766	.780	-71.8
	313	2.250	.755	-66.4
	323	1.866	.730	-60.9
	333	1.573	.706	-55.1
	343	1.346	.682	-49.3
	353	1.166	.659	-43.5
	363	1.021	.637	-37.6
	373	.9019	.614	-31.9
	383	.8033	.592	-26.3
	393	.7203	.570	-20.9
	403	.6499	.549	-15.6
	413	.5900	.528	-10.5

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	423	.5383	.508	- 5.6
	433	.4930	.488	- .954
	443	.4535	.469	3.46
	453	.4186	.450	7.60
	463	.3875	.432	11.5
	473	.3597	.414	15.0
	483	.3346	.396	18.3
	493	.3116	.378	21.2
	503	.2907	.360	23.8
	513	.2718	.343	26.1
	523	.2544	.326	28.1
	533	.238	.309	29.9
	543	.223	.293	31.4
	553	.210	.277	31.9
Heptadecane	293	4.209	.832	-80.2
	303	3.296	.805	-75.6
	313	2.650	.780	-70.6
	323	2.176	.755	-65.3
	333	1.820	.730	-59.9
	343	1.546	.706	-54.3
	353	1.330	.682	-48.7
	363	1.158	.659	-43.1
	373	1.018	.636	-37.5
	383	.9026	.614	-32.0
	393	.8064	.592	-26.6
	403	.7251	.570	-21.4
	413	.6560	.549	-16.3
	423	.5968	.529	-11.4
	433	.5454	.509	- 6.74
	443	.5006	.489	- 2.28
	453	.4611	.470	1.93
	463	.4262	.451	5.91
	473	.3951	.433	9.61
	483	.3671	.415	13.1
	493	.3417	.397	16.2
	503	.3187	.379	18.9
	513	.2978	.362	21.5
	523	.2787	.345	23.8
	533	.261	.328	25.8
	543	.245	.312	27.4
	553	.230	.296	28.8
	563	.216	.280	29.7
	573	.202	.264	30.5

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Octadecane	303	3.891	.829	-78.7
	313	3.093	.803	-74.0
	323	2.516	.778	-69.1
	333	2.087	.752	-63.9
	343	1.760	.728	-58.6
	353	1.505	.704	-53.2
	363	1.303	.681	-47.7
	373	1.140	.658	-42.3
	383	1.006	.635	-36.9
	393	.896	.613	-31.6
	403	.803	.590	-26.5
	413	.724	.569	-21.4
	423	.657	.548	-16.5
	433	.599	.528	-11.8
	443	.548	.508	- 7.3
	453	.504	.489	- 3.0
	463	.465	.470	1.03
	473	.431	.451	4.73
	483	.400	.433	8.25
	493	.372	.415	11.5
	503	.347	.397	14.4
	513	.324	.380	17.2
	523	.303	.363	19.8
	533	.28	.346	23.7
	543	.27	.330	22.2
	553	.25	.314	25.6
	563	.23	.298	29.5
	573	.22	.281	27.7
	583	.21	.264	25.6
Nonadecane	313	3.588	.825	-77.0
	323	2.891	.800	-72.3
	333	2.379	.774	-67.4
	343	1.992	.750	-62.4
	353	1.693	.725	-57.2
	363	1.458	.701	-51.9
	373	1.269	.678	-46.6
	383	1.116	.655	-41.3
	393	.989	.632	-36.1
	403	.884	.610	-31.0
	413	.795	.588	-26.0
	423	.719	.567	-21.2
	433	.654	.546	-16.5
	443	.598	.526	-12.0

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	453	.549	.506	- 7.77
	463	.506	.487	- 3.7
	473	.468	.469	.203
	483	.433	.450	3.93
	493	.402	.432	7.37
	503	.375	.414	10.3
	513	.350	.397	13.3
	523	.327	.380	16.1
	533	.31	.363	17.1
	543	.29	.346	19.4
	553	.27	.330	22.3
	563	.25	.314	25.7
	573	.24	.298	24.0
	583	.22	.280	27.4
	593	.21	.264	25.5
Eicosane	313	4.156	.847	-79.6
	323	3.316	.821	-75.2
	333	2.706	.795	-70.6
	343	2.249	.770	-65.8
	353	1.900	.745	-60.8
	363	1.627	.721	-55.7
	373	1.410	.697	-50.5
	383	1.235	.674	-45.4
	393	1.091	.651	-40.3
	403	.971	.628	-35.3
	413	.871	.606	-30.4
	423	.786	.585	-25.6
	433	.713	.564	-20.9
	443	.650	.543	-16.4
	453	.596	.523	-12.2
	463	.548	.504	- 8.1
	473	.506	.485	- 4.1
	483	.468	.466	- .38
	493	.435	.448	2.94
	503	.404	.430	6.36
	513	.377	.412	9.4
	523	.353	.395	12.0
	533	.33	.378	14.6
	543	.31	.362	16.7
	553	.29	.346	19.1
	563	.27	.329	21.9
	573	.26	.313	20.2
	583	.24	.296	23.3
	593	.23	.280	21.5
	603	.21	.263	25.4

TABLE A-4 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Octacosane	323	5.965	.964	-83.8
	373	2.898	.827	-71.5
	423	1.462	.706	-51.7
	473	.8743	.596	-31.8
	523	.5994	.498	-16.9
	573	.4156	.407	- 2.08
Hexatriacontane	373	4.892	.928	-81.0
	423	2.315	.798	-65.5
	473	1.3309	.682	-48.8
	523	.8889	.575	-35.3
	573	.6068	.478	-21.2

TABLE A-5

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-PARAFFINS, WITH Z FUNCTION ($Z(T_{rB})$)

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentane	143	3.63	5.32	46.6
	153	2.35	3.52	49.6
	163	1.66	2.45	47.4
	173	1.24	1.78	43.7
	183	.973	1.35	38.3
	193	.791	1.05	33.1
	203	.659	.847	28.6
	213	.562	.699	24.3
	223	.487	.589	20.9
	233	.428	.505	18.0
	243	.380	.441	16.0
	253	.341	.390	14.3
	263	.307	.349	13.6
	273	.279	.316	13.1
	283	.255	.288	13.1
	293	.235	.266	13.2
	303	.216	.246	13.9
Hexane	183	1.83	2.33	27.6
	193	1.38	1.77	27.9
	203	1.09	1.38	26.2
	213	.888	1.10	23.9
	223	.741	.901	21.6
	233	.632	.752	19.1
	243	.547	.640	16.9
	253	.480	.552	15.1
	263	.426	.483	13.4
	273	.381	.428	12.3
	283	.3436	.383	11.5
	293	.3126	.348	11.2
	303	.2854	.317	11.1
	313	.2619	.292	11.3
	323	.2411	.270	11.8
	333	.2223	.250	12.4
	343	.2050	.232	13.0

TABLE A-5 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Heptane	183	3.77	3.87	2.71
	193	2.61	2.84	8.99
	203	1.918	2.16	12.5
	213	1.476	1.68	14.0
	223	1.177	1.34	14.1
	233	.9653	1.10	13.6
	243	.8098	.912	12.6
	253	.6916	.771	11.5
	263	.5995	.662	10.4
	273	.5262	.575	9.34
	283	.4666	.506	8.48
	293	.4181	.451	7.92
	303	.3772	.406	7.54
	313	.3426	.368	7.46
	323	.3128	.336	7.58
	333	.2867	.309	7.83
	343	.2635	.285	8.20
	353	.2431	.264	8.80
	363	.2250	.247	9.57
	373	.2086	.231	10.6
Octane	223	1.86	1.95	5.04
	233	1.46	1.56	7.02
	243	1.183	1.28	7.79
	253	.981	1.06	7.95
	263	.829	.893	7.77
	273	.7125	.764	7.27
	283	.6203	.662	6.74
	293	.5466	.581	6.28
	303	.4865	.515	5.95
	313	.4368	.462	5.77
	323	.3946	.417	5.71
	333	.3578	.379	6.03
	343	.3274	.347	5.93
	353	.3004	.319	6.28
	363	.2765	.296	6.94
	373	.2555	.275	7.52
	383	.2366	.256	8.34
	393	.2195	.240	9.18

TABLE A-5 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Nonane	223	2.99	2.77	- 7.48
	233	2.24	2.18	- 2.90
	243	1.784	1.18	- 2.14
	253	1.403	1.42	1.23
	263	1.154	1.19	2.77
	273	.9688	1.00	3.28
	283	.8267	.855	3.41
	293	.7160	.741	3.44
	303	.6279	.649	3.39
	313	.5562	.575	3.36
	323	.4970	.514	3.33
	333	.4472	.462	3.35
	343	.4047	.418	3.40
	353	.3687	.382	3.65
	363	.3375	.351	4.02
	373	.3100	.324	4.48
	383	.2858	.300	5.04
	393	.2641	.279	5.70
	403	.2445	.260	6.32
	413	.2271	.243	7.21
	423	.2115	.229	8.21
Decane	243	2.559	2.34	- 8.40
	253	1.987	1.89	- 4.88
	263	1.590	1.55	- 2.52
	273	1.304	1.29	- .982
	283	1.091	1.09	- .044
	293	.9284	.934	.591
	303	.8018	.809	.918
	313	.7010	.709	1.13
	323	.6192	.627	1.24
	333	.5517	.559	1.32
	343	.4951	.502	1.37
	353	.4476	.455	1.54
	363	.4068	.414	1.76
	373	.3715	.379	2.06
	383	.3408	.349	2.42
	393	.3137	.323	2.86
	403	.2896	.299	3.37
	413	.2683	.279	4.03
	423	.2489	.261	4.73
	433	.2313	.244	5.44
	443	.2152	.228	6.12

TABLE A-5 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Undecane	253	2.779	2.47	-11.3
	263	2.163	2.00	- 7.58
	273	1.733	1.65	- 4.97
	283	1.421	1.38	- 3.16
	293	1.189	1.17	- 1.95
	303	1.012	1.00	- 1.17
	313	.8733	.868	- .648
	323	.7627	.760	- .317
	333	.6731	.672	- .108
	343	.5988	.599	.022
	353	.5371	.538	.140
	363	.4850	.486	.278
	373	.4403	.442	.427
	383	.4018	.404	.656
	393	.3680	.371	.907
	403	.3385	.343	1.23
	413	.3124	.318	1.69
	423	.2892	.295	2.16
	433	.2683	.276	2.69
	443	.2493	.257	3.25
	453	.2320	.241	3.86
	463	.2161	.226	4.50
Dodecane	273	2.278	2.07	- 9.05
	283	1.833	1.71	- 6.49
	293	1.508	1.44	- 4.68
	303	1.265	1.22	- 3.31
	313	1.079	1.05	- 2.49
	323	.9321	.914	- 1.93
	333	.8147	.802	- 1.59
	343	.7188	.709	- 1.41
	353	.6398	.631	- 1.31
	363	.5743	.568	- 1.16
	373	.5183	.513	- 1.08
	383	.4706	.466	- .989
	393	.4291	.425	- .898
	403	.3932	.390	- .723
	413	.3617	.360	- .447
	423	.3338	.333	- .155
	433	.3089	.309	- .163
	443	.2865	.288	.580
	453	.2664	.269	1.04
	463	.2480	.252	1.52
	473	.2311	.236	1.95
	483	.2153	.220	2.29

TABLE A-5 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Tridecane	273	2.950	2.57	-12.8
	283	2.328	2.11	- 9.33
	293	1.886	1.76	- 6.80
	303	1.560	1.48	- 5.02
	313	1.314	1.26	- 3.77
	323	1.123	1.09	- 2.93
	333	.9725	.949	- 2.41
	343	.8513	.833	- 2.11
	353	.7527	.738	- 1.93
	363	.6709	.659	- 1.84
	373	.6022	.591	- 1.81
	383	.5441	.534	- 1.79
	393	.4940	.485	- 1.81
	403	.4508	.443	- 1.80
	413	.4133	.406	- 1.69
	423	.3803	.374	- 1.53
	433	.3511	.346	- 1.37
	443	.3251	.321	- 1.12
	453	.3017	.299	- .833
	463	.2807	.279	- .520
	473	.2616	.261	- .121
	483	.2435	.244	.089
	493	.2268	.227	.236
	503	.2114	.212	.340
Tetradecane	283	2.940	2.58	-12.4
	293	2.342	2.13	- 9.12
	303	1.910	1.78	- 6.77
	313	1.590	1.51	- 5.13
	323	1.345	1.29	- 3.94
	333	1.154	1.12	- 3.18
	343	1.002	.975	- 2.74
	353	.8798	.858	- 2.50
	363	.7795	.761	- 2.38
	373	.6958	.679	- 2.38
	383	.6251	.610	- 2.46
	393	.5654	.551	- 2.49
	403	.5140	.501	- 2.57
	413	.4696	.457	- 2.62
	423	.4307	.419	- 2.63
	433	.3966	.386	- 2.58
	443	.3664	.357	- 2.50
	453	.3395	.331	- 2.38
	463	.3153	.308	- 2.20
	473	.2935	.288	- 1.98

TABLE A-5 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	483	.2733	.268	- 1.84
	493	.2547	.250	- 1.74
	503	.2375	.234	- 1.65
	513	.2218	.218	- 1.49
	523	.2074	.205	- 1.32
Pentadecane	283	3.663	3.11	-15.1
	293	2.872	2.55	-11.2
	303	2.310	2.12	- 8.25
	313	1.900	1.78	- 6.17
	323	1.591	1.52	- 4.64
	333	1.353	1.30	- 3.63
	343	1.166	1.13	- 3.03
	353	1.017	.990	- 2.69
	363	.8953	.873	- 2.48
	373	.7949	.775	- 2.47
	383	.7112	.693	- 3.55
	393	.6403	.623	- 2.72
	403	.5800	.563	- 2.86
	413	.5280	.512	- 3.00
	423	.4830	.468	- 3.14
	433	.4437	.429	- 3.22
	443	.4088	.395	- 3.28
	453	.3781	.366	- 3.27
	463	.3506	.339	- 3.25
	473	.3261	.316	- 3.14
	483	.3034	.294	- 3.09
	493	.2827	.274	- 3.07
	503	.2638	.256	- 3.06
	513	.2464	.239	- 2.96
	523	.2307	.224	- 2.83
	533	.216	.210	- 2.75
	543	.202	.197	- 2.44
Hexadecane	293	3.484	3.03	-13.0
	303	2.766	2.50	- 9.51
	313	2.250	2.09	- 6.95
	323	1.866	1.77	- 5.12
	333	1.573	1.51	- 3.81
	343	1.346	1.31	- 3.05
	353	1.166	1.14	- 2.56
	363	1.021	.997	- 2.32
	373	.9019	.881	- 2.29
	383	.8033	.784	- 2.39

TABLE A-5 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	393	.7203	.702	- 2.60
	403	.6499	.631	- 2.84
	413	.5900	.572	- 3.08
	423	.5383	.521	- 3.30
	433	.4930	.476	- 3.53
	443	.4535	.437	- 3.70
	453	.4186	.402	- 3.85
	463	.3875	.372	- 3.96
	473	.3597	.345	- 4.04
	483	.3346	.321	- 4.07
	493	.3116	.299	- 4.13
	503	.2907	.278	- 4.21
	513	.2718	.260	- 4.19
	523	.2544	.244	- 4.11
	533	.238	.229	- 3.95
	543	.223	.214	- 3.82
	553	.210	.201	- 4.11
Heptadecane	293	4.209	3.57	-15.3
	303	3.296	2.93	-11.3
	313	2.650	2.43	- 8.17
	323	2.176	2.05	- 5.92
	333	1.820	1.74	- 4.41
	343	1.546	1.49	- 3.36
	353	1.330	1.29	- 2.71
	363	1.158	1.13	- 2.40
	373	1.018	.994	- 2.33
	383	.9026	.881	- 2.40
	393	.8064	.785	- 2.60
	403	.7251	.704	- 2.89
	413	.6560	.635	- 3.22
	423	.5968	.576	- 3.51
	433	.5454	.525	- 3.82
	443	.5006	.480	- 4.11
	453	.4611	.441	- 4.37
	463	.4262	.407	- 4.58
	473	.3951	.376	- 4.78
	483	.3671	.349	- 4.92
	493	.3417	.324	- 5.09
	503	.3187	.302	- 5.23
	513	.2978	.282	- 5.29
	523	.2787	.264	- 5.31
	533	.261	.247	- 5.30
	543	.245	.232	- 5.36
	553	.230	.218	- 5.32
	563	.216	.204	- 5.44
	573	.202	.191	- 5.38

TABLE A-5 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Octadecane	303	3.891	3.40	-12.7
	313	3.093	2.81	- 9.14
	323	2.516	2.35	- 6.53
	333	2.087	1.99	- 4.68
	343	1.760	1.70	- 3.38
	353	1.505	1.47	- 2.56
	363	1.303	1.28	- 2.11
	373	1.140	1.12	- 1.96
	383	1.006	.986	- 2.00
	393	.896	.876	- 2.27
	403	.803	.782	- 2.59
	413	.724	.703	- 2.92
	423	.657	.635	- 3.30
	433	.599	.577	- 3.70
	443	.548	.526	- 4.03
	453	.504	.482	- 4.39
	463	.465	.443	- 4.71
	473	.431	.409	- 5.11
	483	.400	.378	- 5.39
	493	.372	.351	- 5.68
	503	.347	.326	- 5.95
	513	.324	.304	- 6.06
	523	.303	.284	- 6.12
	533	.28	.266	- 4.93
	543	.27	.249	- 7.60
	553	.25	.234	- 6.33
	563	.23	.220	- 4.50
	573	.22	.205	- 6.61
	583	.21	.192	- 8.77
Nonadecane	313	3.588	3.22	-10.2
	323	2.891	2.69	- 7.08
	333	2.379	2.26	- 4.89
	343	1.992	1.93	- 3.35
	353	1.693	1.65	- 2.37
	363	1.458	1.43	- 1.78
	373	1.269	1.25	- 1.49
	383	1.116	1.10	- 1.54
	393	.989	.972	- 1.71
	403	.884	.865	- 2.10
	413	.795	.775	- 2.51
	423	.719	.698	- 2.92
	433	.654	.632	- 3.38
	443	.598	.575	- 3.89

TABLE A-5 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	453	.549	.525	- 4.40
	463	.506	.482	- 4.83
	473	.468	.444	- 5.22
	483	.433	.409	- 5.50
	493	.402	.379	- 5.80
	503	.375	.352	- 6.25
	513	.350	.327	- 6.47
	523	.327	.305	- 6.58
	533	.31	.286	- 7.87
	543	.29	.267	- 7.82
	553	.27	.251	- 7.18
	563	.25	.235	- 5.95
	573	.24	.220	- 8.28
	583	.22	.206	- 6.58
	593	.21	.192	- 8.64
Eicosane	313	4.156	3.68	-11.5
	323	3.316	3.05	- 7.98
	333	2.706	2.56	- 5.40
	343	2.249	2.17	- 3.62
	353	1.900	1.85	- 2.37
	363	1.627	1.60	- 1.63
	373	1.410	1.39	- 1.25
	383	1.235	1.22	- 1.23
	393	1.091	1.08	- 1.41
	403	.971	.954	- 1.73
	413	.871	.852	- 2.18
	423	.786	.765	- 2.66
	433	.713	.690	- 3.19
	443	.650	.626	- 3.67
	453	.596	.570	- 4.31
	463	.548	.522	- 4.81
	473	.506	.479	- 5.27
	483	.468	.441	- 5.70
	493	.435	.408	- 6.26
	503	.404	.378	- 6.49
	513	.377	.351	- 6.84
	523	.353	.327	- 7.29
	533	.33	.305	- 7.45
	543	.31	.286	- 7.84
	553	.29	.268	- 7.75
	563	.27	.251	- 7.20
	573	.26	.235	- 9.79
	583	.24	.219	- 8.54
	593	.23	.205	-10.7
	603	.21	.192	- 8.61

TABLE A-5 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Octacosane	323	5.965	7.16	20.0
	373	2.898	2.89	- .368
	423	1.462	1.44	- 1.74
	473	.8743	.826	- 5.55
	523	.5994	.526	-12.2
	573	.4156	.358	-13.8
Hexatriacontane	373	4.892	5.04	3.10
	423	2.315	2.34	.915
	473	1.3309	1.27	- 4.81
	523	.8889	.767	-13.7
	573	.6068	.501	-17.4

TABLE A-6

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-1-ALKENES WITH Z FUNCTION ($Z(T_{rB})$)

$$\mu = \rho^{11/3} \beta^{3} / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentene	183	.85	1.25	47.5
	193	.70	.959	37.0
	203	.59	.757	28.3
	213	.50	.610	22.0
	223	.43	.506	17.6
	233	.38	.426	12.1
	243	.33	.367	11.3
	253	.30	.332	10.7
	263	.27	.286	5.81
	273	.24	.256	6.61
Hexene	223	.63	.797	26.6
	233	.54	.656	21.5
	243	.47	.547	16.5
	253	.42	.467	11.3
	273	.33	.354	7.41
	283	.29	.315	8.60
	293	.26	.283	8.84
	303	.24	.257	6.96
	313	.22	.235	6.87
	323	.20	.217	8.55
	333	.19	.202	6.23
Heptene	273	.44	.488	10.9
	283	.39	.425	9.05
	293	.35	.375	7.21
	303	.32	.335	4.59
	313	.29	.301	3.91
	323	.27	.274	1.46
	333	.25	.251	.418
	343	.23	.232	.717
	353	.22	.215	- 2.13
	363	.20	.201	.680
Octene	273	.613	.663	8.22
	283	.533	.569	6.68
	293	.470	.493	5.00
	303	.425	.434	2.01
	313	.383	.385	.461
	323	.347	.345	- .587

TABLE A-6 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	333	.317	.312	- 1.57
	343	.292	.284	- 2.63
	353	.271	.261	- 3.64
	363	.251	.241	- 3.86
	373	.235	.224	- 4.47
	383	.22	.210	- 4.49
Nonene	273	.839	.891	6.19
	283	.715	.752	5.23
	293	.620	.644	3.89
	303	.554	.558	.778
	313	.492	.490	- .481
	323	.440	.434	- 1.45
	333	.398	.388	- 2.62
	343	.363	.349	- 3.74
	353	.334	.317	- 4.94
	363	.307	.291	- 5.31
	373	.285	.268	- 6.04
	383	.26	.248	- 4.72
Decene	273	1.130	1.18	4.62
	283	.945	.984	4.15
	293	.805	.831	3.25
	303	.709	.711	.278
	313	.622	.616	- 1.02
	323	.551	.539	- 2.26
	333	.493	.476	- 3.50
	343	.445	.424	- 4.65
	353	.406	.381	- 6.09
	363	.371	.345	- 6.94
	373	.342	.315	- 7.96
	383	.32	.289	- 9.64
Undecane	273	1.50	1.47	- 1.98
	283	1.229	1.27	3.31
	293	1.031	1.06	2.79
	303	.895	.897	.208
	313	.777	.768	- 1.17
	323	.680	.665	- 2.22
	333	.603	.582	- 3.51
	343	.541	.514	- 5.05
	353	.489	.458	- 6.41
	363	.443	.411	- 7.29
	373	.405	.371	- 8.33
	383	.37	.338	- 8.78

TABLE A-6 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Dodecene	273	1.96	1.99	1.39
	283	1.58	1.62	2.38
	293	1.30	1.34	2.84
	303	1.12	1.12	.00
	313	.959	.950	- .936
	323	.831	.815	- 1.87
	333	.730	.707	- 3.16
	343	.647	.619	- 4.30
	353	.581	.547	- 5.83
	363	.523	.487	- 6.85
	373	.476	.437	- 8.13
	383	.43	.394	- 8.27
Tridecene	273	2.53	2.53	.00
	283	2.00	2.04	1.90
	293	1.63	1.67	2.28
	303	1.38	1.38	.00
	313	1.17	1.16	- .674
	323	1.01	.990	- 1.53
	333	.875	.851	- 2.77
	343	.769	.739	- 3.93
	353	.686	.648	- 5.58
	363	.614	.573	- 6.73
	373	.554	.510	- 7.94
	383	.50	.458	- 8.50
Tetradecene	273	3.23	3.18	- 1.65
	283	2.51	2.54	1.05
	293	2.01	2.06	2.32
	303	1.68	1.69	.709
	313	1.41	1.41	.00
	323	1.20	1.19	- 1.03
	333	1.04	1.02	- 2.27
	343	.906	.876	- 3.30
	353	.802	.762	- 4.95
	363	.714	.669	- 6.25
	373	.640	.592	- 7.46
	383	.58	.528	- 8.89
Pentadecene	273	4.09	3.94	- 3.63
	283	3.12	3.12	.00
	293	2.47	2.51	1.59
	303	2.04	2.05	.419
	313	1.70	1.70	.00
	323	1.43	1.42	- .690

TABLE A-6 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	333	1.23	1.20	- 1.77
	343	1.06	1.03	- 2.98
	353	.933	.891	- 4.50
	363	.824	.777	- 5.66
	373	.735	.684	- 6.98
	383	.66	.607	- 8.06
Hexadecene	283	3.82	3.80	- .529
	293	3.00	3.03	1.09
	303	2.44	2.46	.761
	313	2.02	2.02	.00
	323	1.69	1.68	- .529
	333	1.43	1.42	- 1.01
	343	1.234	1.20	- 2.37
	353	1.078	1.03	- 4.00
	363	.945	.898	- 5.02
	373	.839	.785	- 6.43
	383	.75	.692	- 7.68
Heptadecene	283	4.70	4.58	- 2.58
	293	3.61	3.63	.566
	303	2.93	2.92	- .245
	313	2.38	2.39	.265
	323	1.97	1.97	.00
	333	1.66	1.65	- .517
	343	1.42	1.40	- 1.62
	353	1.238	1.19	- 3.53
	363	1.077	1.03	- 4.36
	373	.952	.896	- 5.89
	383	.84	.784	- 6.63
Octadecene	293	4.32	4.31	- .316
	303	3.46	3.44	- .434
	313	2.79	2.80	.240
	323	2.29	2.30	.399
	333	1.92	1.91	- .322
	343	1.65	1.61	- 2.42
	353	1.41	1.37	- 2.96
	363	1.221	1.17	- 3.81
	373	1.074	1.02	- 5.37
	383	.95	.886	- 6.71

TABLE A-6 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Nonadecene	303	4.08	4.03	- 1.17
	313	3.26	3.25	- .202
	323	2.65	2.66	.419
	333	2.21	2.20	- .304
	343	1.87	1.84	- 1.35
	353	1.60	1.56	- 2.50
	363	1.38	1.33	- 3.45
	373	1.21	1.15	- 5.11
	383	1.06	.999	- 5.74
Eicosene	303	4.77	4.69	- 1.69
	313	3.77	3.77	.00
	323	3.05	3.06	.451
	333	2.52	2.52	.00
	343	2.12	2.10	- .798
	353	1.81	1.77	- 2.16
	363	1.55	1.51	- 2.86
	373	1.35	1.29	- 4.31
	383	1.18	1.12	- 5.24

TABLE A-7

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-ALKYL CYCLOHEXANES WITH Z FUNCTION ($Z(T_{rB})$)

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Ethyl-cyclohexane	253	1.63	1.50	- 7.81
	263	1.356	1.26	- 7.11
	273	1.142	1.07	- 6.73
	283	.976	.915	- 6.22
	293	.843	.796	- 5.58
	303	.737	.696	- 5.61
	313	.651	.617	- 5.26
	323	.581	.551	- 5.11
	333	.523	.495	- 5.45
	343	.475	.451	- 4.96
	353	.43	.387	- 9.93
	363	.40	.367	- 8.20
	373	.37	.350	- 5.46
	383	.34	.310	- 8.90
Propyl-cyclohexane	253	2.10	2.02	- 3.93
	263	1.705	1.66	- 2.53
	273	1.408	1.39	- 1.03
	283	1.182	1.182	.00
	293	1.006	1.01	.665
	303	.870	.879	1.03
	313	.760	.771	1.51
	323	.672	.681	1.29
	333	.601	.609	1.27
	343	.542	.546	.826
	353	.49	.480	- 1.99
	363	.45	.444	- 1.44
	373	.42	.420	.00
	383	.39	.374	- 4.22
Butyl-cyclohexane	253	2.94	2.70	- 8.06
	263	2.35	2.21	- 5.99
	273	1.91	1.84	- 3.55
	283	1.574	1.53	- 2.65
	293	1.314	1.30	- 1.28
	303	1.114	1.12	.148
	313	.955	.967	1.22
	323	.830	.843	1.54

TABLE A-7 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	333	.734	.746	1.58
	343	.658	.665	1.10
	353	.60	.610	1.60
	363	.55	.554	.744
	373	.51	.487	- 4.57
	383	.47	.451	- 4.12
Pentyl-cyclohexane	263	3.33	2.86	-14.0
	273	2.64	2.32	-12.0
	283	2.12	1.95	- 8.16
	293	1.723	1.64	- 4.96
	303	1.418	1.39	- 2.15
	313	1.191	1.192	.119
	323	1.026	1.04	.923
	333	.898	.908	1.06
	343	.79	.786	- .557
	353	.71	.722	1.68
	363	.63	.628	- .339
	373	.57	.587	2.95
	383	.51	.523	2.58
Hexyl-cyclohexane	263	4.49	3.68	-18.1
	273	3.52	3.00	-14.8
	283	2.77	2.44	-12.0
	293	2.22	2.05	- 7.47
	303	1.80	1.71	- 5.12
	313	1.492	1.46	- 2.09
	323	1.268	1.26	- .514
	333	1.097	1.097	.00
	343	.96	.967	.778
	353	.84	.841	.114
	363	.75	.781	4.11
	373	.66	.673	1.90
	383	.59	.590	.00
Heptyl-cyclohexane	263	5.94	4.66	-21.6
	273	4.58	3.73	-18.7
	283	3.56	3.04	-14.6
	293	2.81	2.52	-10.3
	303	2.25	2.12	- 5.76
	313	1.83	1.79	- 2.10
	323	1.544	1.53	- .935
	333	1.320	1.32	.00
	343	1.14	1.14	.00

TABLE A-7 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	353	.99	.994	.350
	363	.87	.890	2.32
	373	.77	.817	6.10
	383	.68	.704	3.53
Octylcyclohexane	263	7.72	5.88	-23.8
	273	5.88	4.70	-20.1
	283	4.51	3.78	-16.1
	293	3.51	3.13	-11.0
	303	2.77	2.60	- 6.09
	313	2.24	2.18	- 2.52
	323	1.86	1.84	- .825
	333	1.571	1.59	1.36
	343	1.34	1.36	1.15
	353	1.16	1.19	2.49
	363	1.00	1.03	2.98
	373	.88	.951	8.05
	383	.77	.834	8.27
Nonylcyclohexane	263	9.89	8.54	-13.6
	273	7.42	5.75	-22.5
	283	5.62	4.61	-17.9
	293	4.32	3.77	-12.7
	303	3.37	3.12	- 7.36
	313	2.68	2.57	- 4.02
	323	2.20	2.19	- .649
	333	1.85	1.87	.840
	343	1.57	1.61	2.79
	353	1.34	1.41	4.92
	363	1.15	1.23	6.69
	373	1.00	1.10	10.3
	383	.87	.951	9.27
Decylcyclohexane	273	9.26	7.00	-24.4
	283	6.93	5.59	-19.4
	293	5.26	4.53	-13.9
	303	4.05	3.70	- 8.61
	313	3.19	3.06	- 4.13
	323	2.59	2.57	- .672
	333	2.16	2.20	1.65
	343	1.81	1.88	3.60
	353	1.53	1.62	5.98
	363	1.31	1.42	8.35
	373	1.12	1.24	10.4
	383	.97	1.08	11.1

TABLE A-7 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Undecyl-cyclohexane	283	8.44	6.74	-20.2
	293	6.34	5.41	-14.6
	303	4.81	4.41	- 8.42
	313	3.76	3.64	- 3.32
	323	3.03	3.06	.929
	333	2.49	2.56	2.84
	343	2.08	2.20	5.79
	353	1.74	1.86	6.64
	363	1.47	1.61	9.34
	373	1.26	1.44	14.5
	383	1.08	1.27	17.2
Dodecyl-cyclohexane	283	10.19	7.94	-22.0
	293	7.54	6.36	-15.7
	303	5.68	5.15	- 9.28
	313	4.38	4.24	- 3.20
	323	3.50	3.52	.658
	333	2.86	2.97	3.82
	343	2.36	2.51	6.48
	353	1.96	2.14	8.97
	363	1.65	1.85	12.1
	373	1.40	1.62	15.8
	383	1.19	1.39	17.0
Tridecyl-cyclohexane	293	8.92	7.45	-16.5
	303	6.64	6.01	- 9.45
	313	5.08	4.90	- 3.59
	323	4.02	4.06	1.03
	333	3.26	3.42	5.02
	343	2.67	2.86	7.15
	353	2.21	2.48	12.1
	363	1.84	2.10	14.0
	373	1.55	1.83	18.2
	383	1.31	1.58	20.6
Tetradecyl-cyclohexane	303	7.71	6.95	- 9.84
	313	5.85	5.65	- 3.35
	323	4.59	4.65	1.20
	333	3.69	3.90	5.72
	343	3.00	3.25	8.30
	353	2.46	2.74	11.4
	363	2.04	2.37	16.1
	373	1.70	2.02	18.9
	383	1.44	1.79	24.2

TABLE A-7 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentadecyl-cyclohexane	303	8.91	7.97	-10.5
	313	6.69	6.44	- 3.68
	323	5.21	5.30	1.71
	333	4.15	4.37	5.20
	343	3.36	3.68	9.59
	353	2.74	3.11	13.6
	363	2.25	2.63	16.9
	383	1.57	2.01	27.8
Hexadecyl cyclohexane	313	7.61	7.27	- 4.53
	323	5.88	5.96	1.29
	333	4.66	4.92	5.60
	343	3.74	4.12	10.0
	353	3.03	3.47	14.5
	363	2.48	2.95	19.0
	373	2.04	2.50	22.5
	383	1.70	2.19	29.0

TABLE A-8

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-ALKYL BENZENES WITH Z FUNCTION ($Z(T_{rB})$)

$$\mu = \rho^{11/3} \beta^{3} / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Methyl-benzene	253	1.07	.983	- 8.16
	263	.904	.822	- 9.10
	273	.773	.705	- 8.75
	283	.6698	.616	- 8.07
	293	.5866	.545	- 7.03
	303	.5203	.490	- 5.89
	313	.4650	.444	- 4.44
	323	.4189	.408	- 2.60
	333	.380	.377	- .697
	343	.346	.352	+ 1.68
	353	.317	.332	4.59
	363	.291	.315	8.20
	373	.269	.302	12.4
	383	.249	.289	16.0
Ethyl-benzene	253	1.24	1.34	8.35
	263	1.045	1.10	5.29
	273	.895	.927	3.61
	283	.7751	.793	2.27
	293	.6783	.689	1.54
	303	.6003	.606	1.03
	313	.5354	.541	1.03
	323	.4814	.489	1.62
	333	.436	.443	1.57
	343	.397	.408	2.77
	353	.364	.381	4.57
	363	.334	.352	5.34
	373	.308	.331	7.48
	383	.286	.318	11.2
	393	.265	.301	13.5
	403	.247	.290	17.5
	413	.231	.279	20.7
Propyl-benzene	253	1.72	1.75	1.58
	263	1.416	1.41	- .121
	273	1.182	1.17	- .729
	283	.9996	.986	- 1.31
	293	.8571	.845	- 1.38

TABLE A-8 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	303	.7466	.734	- 1.65
	313	.6570	.646	- 1.66
	323	.5842	.575	- 1.65
	333	.524	.515	- 1.78
	343	.473	.468	- 1.04
	353	.430	.432	.428
	363	.392	.397	1.25
	373	.360	.372	3.39
	383	.331	.346	4.53
	393	.306	.328	7.10
	403	.284	.313	10.3
	413	.26	.271	4.10
	423	.25	.291	16.2
Butyl-benzene	253	2.23	2.36	5.85
	263	1.790	1.90	6.13
	273	1.466	1.53	4.64
	283	1.220	1.27	3.95
	293	1.035	1.07	3.48
	303	.894	.915	2.37
	313	.781	.793	1.57
	323	.684	.695	1.68
	333	.614	.618	.685
	343	.550	.552	.338
	353	.497	.503	1.28
	363	.450	.456	1.26
	373	.411	.421	2.46
	383	.38	.396	4.25
	393	.35	.391	11.6
	403	.32	.355	11.1
	413	.30	.331	10.2
	423	.28	.308	9.82
Pentyl-benzene	253	3.82	3.14	-17.9
	263	2.64	2.46	- 6.99
	273	2.01	2.01	.00
	283	1.608	1.62	.714
	293	1.334	1.35	.970
	303	1.132	1.14	.300
	313	.976	.972	- .430
	323	.853	.841	- 1.47
	333	.756	.738	- 2.41
	343	.674	.653	- 3.18
	353	.602	.584	- 2.92
	363	.543	.527	- 2.92

TABLE A-8 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	373	.492	.482	- 2.13
	383	.45	.441	- 1.90
	393	.41	.421	2.67
	403	.37	.374	1.04
	413	.34	.337	- .782
	423	.32	.340	6.20
Hexyl-benzene	253	5.17	4.17	-19.4
	263	3.66	3.24	-11.5
	273	2.60	2.54	- 2.25
	283	2.05	2.05	.00
	293	1.675	1.68	.374
	303	1.403	1.40	- .087
	313	1.196	1.19	- .899
	323	1.035	1.02	- 1.90
	333	.909	.880	- 3.15
	343	.804	.772	- 3.98
	353	.712	.683	- 4.01
	363	.638	.612	- 4.10
	373	.574	.550	- 4.23
	383	.52	.496	- 4.70
	393	.47	.460	- 2.09
	403	.43	.437	1.53
	413	.39	.387	- .722
	423	.36	.377	4.72
Heptyl-benzene	253	6.93	5.44	-21.6
	263	4.57	4.14	- 9.51
	273	3.34	3.24	- 3.09
	283	2.59	2.59	.00
	293	2.08	2.08	.00
	303	1.722	1.71	- .750
	313	1.451	1.44	- .765
	323	1.243	1.22	- 1.76
	333	1.081	1.05	- 2.88
	343	.949	.908	- 4.28
	353	.834	.800	- 4.09
	363	.742	.709	- 4.39
	373	.664	.634	- 4.54
	383	.60	.594	- 1.04
	393	.54	.515	- 4.64
	403	.49	.477	- 2.71
	413	.45	.451	.113
	423	.40	.391	- 2.31

TABLE A-8 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Octyl-benzene	253	9.23	7.05	-23.6
	263	5.94	5.32	-10.4
	273	4.25	4.13	- 2.85
	283	3.24	3.24	.00
	293	2.57	2.62	2.00
	303	2.09	2.11	1.08
	313	1.744	1.75	.346
	323	1.479	1.47	- .744
	333	1.274	1.25	- 2.07
	343	1.111	1.08	- 3.15
	353	.968	.934	- 3.53
	363	.856	.820	- 4.26
	373	.761	.728	- 4.28
	383	.68	.647	- 4.86
	393	.61	.579	- 5.05
	403	.55	.525	- 4.49
	413	.50	.484	- 3.14
	423	.45	.447	- .666
Nonyl-benzene	253	12.20	8.99	-26.3
	263	7.66	6.71	-12.5
	273	5.36	5.12	- 4.55
	283	4.02	4.01	- .175
	293	3.14	3.19	1.71
	303	2.53	2.59	2.42
	313	2.08	2.10	1.05
	323	1.745	1.75	.193
	333	1.490	1.47	- 1.09
	343	1.289	1.26	- 2.29
	353	1.115	1.09	- 2.56
	363	.978	.945	- 3.39
	373	.865	.833	- 3.76
	383	.77	.744	- 3.36
	393	.69	.658	- 4.66
	403	.62	.615	- .744
	413	.56	.559	- .150
	423	.50	.480	- 3.98
Decyl-benzene	253	16.0	11.6	-27.8
	263	9.81	8.55	-12.9
	273	6.72	6.46	- 3.90
	283	4.94	4.99	.942
	293	3.80	3.91	2.85
	303	3.02	3.12	3.31
	313	2.46	2.55	3.62

TABLE A-8 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	323	2.00	2.12	5.76
	333	1.730	1.75	1.28
	343	1.486	1.49	.102
	353	1.275	1.18	- 7.60
	363	1.112	1.10	- .908
	373	.977	.958	- 1.96
	383	.86	.830	- 3.43
	393	.77	.751	- 2.49
	403	.69	.690	.00
	413	.62	.616	- .638
	423	.56	.557	- .506
Undecyl-benzene	263	12.48	10.64	-14.7
	273	8.36	7.94	- 5.01
	283	6.04	6.07	.495
	293	4.58	4.77	4.11
	303	3.59	3.75	4.49
	313	2.89	3.04	5.05
	323	2.38	2.48	4.17
	333	1.995	2.05	2.96
	343	1.701	1.73	1.86
	353	1.449	1.47	1.50
	363	1.255	1.26	.460
	373	1.098	1.098	.00
	383	.97	.966	- .385
	393	.86	.857	- .374
	403	.76	.740	- 2.68
	413	.68	.676	- .535
	423	.61	.601	- 1.45
Dodecyl-benzene	273	10.34	9.69	- 6.26
	283	7.33	7.32	- .167
	293	5.47	5.67	3.74
	303	4.24	4.48	5.67
	313	3.37	3.58	6.30
	323	2.75	2.92	6.00
	333	2.29	2.41	5.25
	343	1.935	1.99	2.63
	353	1.637	1.69	3.10
	363	1.410	1.44	2.21
	373	1.226	1.24	1.43
	383	1.07	1.08	.567
	393	.95	.971	2.25
	403	.84	.832	- .918
	413	.75	.750	.00
	423	.67	.686	2.44

TABLE A-8 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Tridecyl-benzene	273	12.69	11.7	- 7.43
	283	8.84	8.84	.00
	293	6.50	6.78	4.32
	303	4.97	5.33	7.19
	313	3.91	4.20	7.44
	323	3.16	3.42	8.23
	333	2.61	2.79	7.01
	343	2.19	2.30	5.06
	353	1.839	1.93	5.16
	363	1.575	1.65	4.58
	373	1.362	1.41	3.61
	383	1.19	1.22	2.39
	393	1.04	1.07	2.97
	403	.92	.937	1.82
	413	.82	.834	1.72
	423	.73	.751	2.92
Tetradecyl-benzene	283	10.60	10.4	- 1.71
	293	7.68	7.96	3.59
	303	5.80	6.20	6.92
	313	4.51	4.88	8.20
	323	3.61	3.93	8.97
	333	2.95	3.17	7.34
	343	2.47	2.66	7.54
	353	2.06	2.19	6.55
	363	1.751	1.85	5.58
	373	1.507	1.58	5.16
	383	1.31	1.36	3.99
	393	1.14	1.18	3.41
	403	1.01	1.05	4.00
	413	.89	.918	3.15
	423	.79	.816	3.32
Pentadecyl-benzene	293	9.02	9.46	4.86
	303	6.72	7.28	8.38
	313	5.18	5.73	10.7
	323	4.11	4.57	11.2
	333	3.33	3.69	10.9
	343	2.76	3.03	9.65
	353	2.29	2.52	9.85
	363	1.938	2.11	8.65
	373	1.660	1.80	8.23
	383	1.43	1.53	7.30

TABLE A-8 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	393	1.25	1.32	5.40
	403	1.09	1.14	5.00
	413	.97	1.03	5.79
	423	.85	.894	5.16
Hexadecylbenzene	303	7.76	8.39	8.12
	313	5.92	6.57	11.0
	323	4.65	5.20	11.9
	333	3.74	4.18	11.7
	343	3.08	3.42	11.0
	353	2.54	2.82	10.9
	363	2.14	2.36	10.1
	373	1.822	2.01	10.2
	383	1.57	1.72	9.65
	393	1.36	1.49	9.25
	403	1.19	1.28	7.92
	413	1.04	1.09	5.19
	423	.92	1.01	9.72

TABLE A-9

CALCULATED AND EXPERIMENTAL VALUES OF VISCOSITIES OF n-ALCOHOLS WITH Z FUNCTION ($Z(T_{rB})$)

$$\mu = \rho^{11/3} \beta^{3} / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY EXPERIMENTAL CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Butanol	298.14	2.587	1.40	-45.9
	303.19	2.251	1.26	-44.2
	313.19	1.773	1.06	-40.5
	323.16	1.424	.885	-37.9
	343.16	.9578	.624	-34.8
	353.16	.8082	.531	-34.3
	363.16	.6904	.451	-34.7
	373.16	.5995	.385	-35.7
	383.16	.5292	.332	-37.2
Pentanol	303.19	3.055	1.72	-43.5
	313.19	2.320	1.43	-38.2
	323.21	1.774	1.20	-32.2
	343.12	1.086	.849	-21.8
	353.16	.8476	.717	-15.4
	363.17	.6613	.611	- 7.58
	373.16	.4975	.474	- 4.78
Hexanol	298.10	4.665	2.55	-45.4
	303.19	3.932	2.27	-42.2
	313.31	2.941	1.89	-35.6
	323.16	2.240	1.58	-29.3
	343.14	1.356	1.12	-17.5
	353.16	1.047	.947	- 9.51
	363.16	.8162	.804	- 1.44
	373.21	.6264	.685	9.43
	383.16	.4753	.592	24.5
	393.21	.3361	.491	46.2
	403.18	.2264	.426	88.2
Heptanol	298.61	5.627	3.31	-41.2
	303.90	4.763	2.98	-37.4
	313.67	3.571	2.476	-30.7
	323.21	2.764	2.08	-24.9
	343.16	1.661	1.46	-12.1
	353.16	1.306	1.23	- 5.67
	363.16	1.034	1.05	1.24

TABLE A-9 (CONTINUED

COMPOUND	TEMP. °K	VISCOSITY EXPERIMENTAL CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	373.16	.818	.890	8.87
	427.16	.3989	.392	- 1.69
	438.31	.3460	.332	- 4.02
	444.46	.3209	.298	- 7.18
Octanol	298.16	7.213	4.33	-40.0
	303.23	6.064	3.89	-35.9
	313.21	4.488	3.22	-28.2
	333.26	2.558	2.24	-12.6
	343.16	2.038	1.87	- 8.30
	353.16	1.630	1.57	- 3.19
	363.16	1.329	1.33	.252
	373.16	1.104	1.14	3.26
	383.16	.9352	.983	5.10
	403.16	.6836	.684	.020
	412.01	.5631	.627	11.4
	427.16	.4564	.497	8.93
	448.91	.3479	.361	3.76
	458.81	.3120	.313	.339
Nonanol	298.16	8.948	5.50	-38.5
	303.23	7.436	4.96	-33.3
	313.21	5.512	4.10	-25.6
	323.76	3.983	3.35	-16.0
	343.16	2.444	2.36	- 3.55
	353.16	1.896	1.98	4.46
	363.16	1.492	1.68	12.4
	373.16	1.180	1.42	20.6
	383.16	.9387	1.22	30.4
	403.16	.5738	.839	46.3
Decanol	303.23	8.708	6.14	-29.5
	313.21	6.616	5.04	-23.8
	333.26	3.630	3.46	- 4.80
	353.26	2.170	2.43	12.1
	373.16	1.353	1.74	28.8
	383.16	1.077	1.49	38.0
	393.16	.8600	1.27	47.1
	403.11	.6853	1.08	58.1
Dodecanol	303.36	13.51	8.98	-33.5
	313.86	9.197	7.26	-21.0
	322.91	6.802	6.09	-10.5
	333.33	4.926	5.00	1.45
	353.26	2.911	3.49	19.9

TABLE A-9 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY EXPERIMENTAL CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	363.21	2.210	2.93	32.6
	373.16	1.771	2.49	40.4
	384.23	1.408	2.08	47.6
	393.16	1.119	1.71	53.2
	403.01	.9041	1.45	60.4
	413.26	.7257	1.23	69.0
	423.15	.5835	1.05	80.2
	434.71	.4932	.885	79.5
Tetradecanol	313.16	12.73	6.39	-49.8
	333.16	6.407	4.35	-32.2
	343.16	4.791	3.61	-24.5
	353.19	3.679	3.027	-17.7
	363.21	2.888	2.54	-12.0
	373.16	2.339	2.16	- 7.74
	383.25	1.787	1.47	-17.5
	403.36	1.170	1.34	14.3
	427.16	.7452	.939	26.0
	459.33	.4436	.593	33.7
	473.11	.3803	.491	29.0
	495.62	.2500	.364	45.6
Hexadecanol	323.16	11.16	12.1	8.09
	333.16	8.01	9.90	23.6
	343.16	5.931	8.17	37.8
	353.16	4.533	6.78	49.6
	363.21	3.485	5.65	62.2
	373.16	2.784	4.76	70.9
	383.25	2.206	4.00	81.5
	393.16	1.842	3.42	85.5
	403.01	1.549	2.89	86.4
	413.26	1.318	2.43	84.7
	423.16	1.139	2.074	82.0
	433.66	1.021	1.80	76.7
	463.21	.7626	1.18	54.2
	495.62	.6084	.758	24.7
	522.96	.5078	.535	5.29

TABLE A-10

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF BRANCHED ALKYL BENZENES WITH Z FUNCTION OF n-ALKYL BENZENES ($Z(T_{rB})$)

$$\mu = \rho^{11/3}\beta^{3}/M^{8/3}N^{1/3}\,Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
o-Xylene	273	1.108	1.04	- 5.88
	283	.939	.890	- 5.26
	293	.809	.770	- 4.78
	303	.708	.677	- 4.44
	313	.625	.601	- 3.79
	323	.557	.541	- 2.95
	333	.501	.491	- 1.99
	343	.453	.450	- .624
	353	.412	.416	1.05
	363	.376	.388	3.13
	373	.345	.364	5.46
	383	.318	.343	7.98
	393	.294	.326	10.9
	403	.272	.311	14.4
	413	.254	.298	17.5
m-Xylene	273	.808	.960	18.8
	283	.702	.821	17.0
	293	.617	.714	15.6
	303	.549	.628	14.4
	313	.492	.560	13.7
	323	.445	.504	13.3
	333	.405	.459	13.3
	343	.370	.422	14.0
	353	.340	.391	14.9
	363	.314	.365	16.1
	373	.290	.343	18.2
	383	.269	.324	20.6
	393	.250	.309	23.5
	403	.233	.296	26.8
	413	.218	.284	30.4
p-Xylene	293	.644	.720	11.8
	303	.570	.634	11.2
	313	.508	.565	11.2
	323	.457	.509	11.4
	333	.415	.463	11.6

TABLE A-10 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	343	.377	.425	12.8
	353	.346	.394	13.8
	363	.318	.367	15.5
	373	.293	.345	17.8
	383	.270	.326	20.8
	393	.250	.310	24.1
	403	.233	.296	27.2
	413	.217	.285	31.2
Isopropylbenzene	273	1.076	1.10	2.34
	283	.917	.932	1.68
	293	.791	.802	1.37
	303	.693	.699	.917
	313	.612	.618	.948
	323	.545	.552	1.31
	333	.490	.499	1.83
1-Methyl 4-ethylbenzene	283	.808	1.06	30.9
	293	.705	.904	28.2
	303	.623	.783	25.8
	313	.556	.688	23.7
	323	.500	.611	22.2
	333	.454	.549	20.8
	343	.415	.497	19.8
	353	.382	.455	19.1

TABLE A-11

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-PARAFFINS WITH COMBINED Z FUNCTION TWO SERIES ($Z(T_{rB})$)

$$\mu = \rho^{11/3}\beta^3/M^{8/3}N^{1/3}\ Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentane	143	3.63	5.60	54.2
	153	2.35	3.61	53.5
	163	1.66	2.46	48.2
	173	1.24	1.76	42.1
	183	.973	1.31	35.0
	193	.791	1.02	28.7
	203	.659	.814	23.5
	213	.562	.668	18.8
	223	.487	.561	15.2
	233	.428	.481	12.4
	243	.380	.420	10.5
	253	.341	.372	9.05
	263	.307	.334	8.67
	273	.279	.303	8.64
	283	.255	.278	9.15
	293	.235	.258	9.85
	303	.216	.240	11.3
Hexane	183	1.83	2.34	27.6
	193	1.38	1.74	26.2
	203	1.09	1.34	23.1
	213	.888	1.06	19.9
	223	.741	.865	16.8
	233	.632	.720	13.9
	243	.547	.610	11.5
	253	.480	.526	9.54
	263	.426	.460	7.96
	273	.381	.408	7.01
	283	.3436	.366	6.45
	293	.3126	.333	6.44
	303	.2854	.305	6.71
	313	.2619	.281	7.45
	323	.2411	.262	8.48
	333	.2223	.244	9.69
	343	.2050	.227	10.9

TABLE A-11 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Heptane	183	3.77	3.98	5.54
	193	2.61	2.87	10.0
	203	1.918	2.15	11.9
	213	1.476	1.65	12.0
	223	1.177	1.31	11.1
	233	.9653	1.06	9.73
	243	.8098	.876	8.19
	253	.6916	.738	6.65
	263	.5995	.631	5.27
	273	.5262	.548	4.11
	283	.4666	.482	3.25
	293	.4181	.430	2.77
	303	.3772	.387	2.55
	313	.3426	.352	2.71
	323	.3128	.323	3.14
	333	.2867	.298	3.77
	343	.2635	.276	4.57
	353	.2431	.257	5.67
	363	.2250	.241	7.00
	373	.2086	.227	8.67
Octane	223	1.86	1.93	3.89
	233	1.46	1.53	4.77
	243	1.183	1.24	4.65
	253	.981	1.02	4.12
	263	.829	.857	3.42
	273	.7125	.731	2.55
	283	.6203	.631	1.78
	293	.5466	.553	1.20
	303	.4865	.491	.835
	313	.4368	.440	.711
	323	.3946	.398	.771
	333	.3578	.362	1.28
	343	.3274	.332	1.44
	353	.3004	.307	2.11
	363	.2765	.285	3.13
	373	.2555	.266	4.14
	383	.2366	.249	5.43
	393	.2195	.234	6.80

TABLE A-11 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Nonane	223	2.99	2.78	- 6.95
	233	2.24	2.16	- 3.54
	243	1.784	1.72	- 3.79
	253	1.403	1.38	- 1.33
	263	1.154	1.15	- .531
	273	.9688	.963	- .599
	283	.8267	.819	- .902
	293	.7160	.707	- 1.19
	303	.6279	.619	- 1.45
	313	.5562	.547	- 1.59
	323	.4970	.489	- 1.65
	333	.4472	.440	- 1.60
	343	.4047	.399	- 1.43
	353	.3687	.365	- 1.01
	363	.3375	.336	- .422
	373	.3100	.311	.306
	383	.2858	.289	1.20
	393	.2641	.270	2.23
	403	.2445	.253	3.27
	413	.2271	.238	4.63
	423	.2115	.224	6.14
Decane	243	2.559	2.34	- 8.72
	253	1.987	1.86	- 6.20
	263	1.590	1.52	- 4.70
	273	1.304	1.25	- 3.89
	283	1.091	1.05	- 3.56
	293	.9284	.897	- 3.40
	303	.8018	.774	- 3.43
	313	.7010	.677	- 3.48
	323	.6192	.597	- 3.54
	333	.5517	.532	- 3.56
	343	.4951	.478	- 3.51
	353	.4476	.433	- 3.30
	363	.4068	.395	- 2.99
	373	.3715	.362	- 2.53
	383	.3408	.334	- 1.96
	393	.3137	.310	- 1.26
	403	.2896	.288	- .451
	413	.2683	.270	.549
	423	.2489	.253	1.63
	433	.2313	.238	2.77
	443	.2152	.224	3.93

TABLE A-11 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Undecane	253	2.779	2.46	-11.4
	263	2.163	1.98	- 8.66
	273	1.733	1.61	- 6.90
	283	1.421	1.34	- 5.81
	293	1.189	1.13	- 5.21
	303	1.012	.962	- 4.92
	313	.8733	.832	- 4.79
	323	.7627	.726	- 4.75
	333	.6731	.641	- 4.75
	343	.5988	.570	- 4.78
	353	.5371	.512	- 4.69
	363	.4850	.463	- 4.55
	373	.4403	.421	- 4.34
	383	.4018	.386	- 4.00
	393	.3680	.355	- 3.59
	403	.3385	.328	- 3.06
	413	.3124	.305	- 2.36
	423	.2892	.285	- 1.60
	433	.2683	.266	- .749
	443	.2493	.250	.172
	453	.2320	.235	1.19
	463	.2161	.221	2.26
Dodecane	273	2.278	2.05	- 9.99
	283	1.833	1.68	- 8.25
	293	1.508	1.40	- 7.14
	303	1.265	1.18	- 6.38
	313	1.079	1.01	- 6.06
	323	.9321	.877	- 5.90
	333	.8147	.767	- 5.87
	343	.7188	.676	- 5.92
	353	.6398	.602	- 5.97
	363	.5743	.540	- 5.91
	373	.5183	.488	- 5.86
	383	.4706	.444	- 5.73
	393	.4291	.405	- 5.56
	403	.3932	.372	- 5.27
	413	.3617	.344	- 4.83
	423	.3338	.319	- 4.33
	433	.3089	.297	- 3.77
	443	.2865	.278	- 3.08
	453	.2664	.260	- 2.31
	463	.2480	.244	- 1.48
	473	.2311	.230	- .668
	483	.2153	.2155	.095

TABLE A-11 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Tridecane	273	2.950	2.57	-12.8
	283	2.328	2.09	-10.2
	293	1.886	1.73	- 8.48
	303	1.560	1.44	- 7.39
	313	1.314	1.23	- 6.73
	323	1.123	1.05	- 6.39
	333	.9725	.912	- 6.27
	343	.8513	.798	- 6.29
	353	.7527	.705	- 6.35
	363	.6709	.628	- 6.43
	373	.6022	.563	- 6.50
	383	.5441	.509	- 6.52
	393	.4940	.462	- 6.54
	403	.4508	.422	- 6.47
	413	.4133	.387	- 6.26
	423	.3803	.358	- 5.97
	433	.3511	.331	- 5.64
	443	.3251	.308	- 5.18
	453	.3017	.288	- 4.65
	463	.2807	.269	- 4.06
	473	.2616	.253	- 3.35
	483	.2435	.237	- 2.80
	493	.2268	.222	- 2.28
	503	.2114	.208	- 1.77
Tetradecane	283	2.940	2.58	-12.4
	293	2.342	2.11	-10.0
	303	1.910	1.75	- 8.42
	313	1.590	1.47	- 7.45
	323	1.345	1.25	- 6.84
	333	1.154	1.08	- 6.58
	343	1.002	.937	- 6.53
	353	.8798	.822	- 6.61
	363	.7795	.727	- 6.73
	373	.6958	.648	- 6.90
	383	.6251	.581	- 7.09
	393	.5654	.525	- 7.18
	403	.5140	.477	- 7.27
	413	.4696	.435	- 7.28
	423	.4307	.400	- 7.21
	433	.3966	.369	- 7.05
	443	.3664	.341	- 6.82
	453	.3395	.317	- 6.52
	463	.3153	.296	- 6.12

TABLE A-11 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	473	.2935	.277	- 5.65
	483	.2733	.259	- 5.23
	493	.2547	.242	- 4.82
	503	.2375	.227	- 4.39
	513	.2218	.213	- 3.87
	523	.2074	.201	- 3.32
Pentadecane	283	3.663	3.14	-14.3
	293	2.872	2.55	-11.3
	303	2.310	2.10	- 9.18
	313	1.900	1.75	- 7.85
	323	1.591	1.48	- 6.97
	333	1.353	1.26	- 6.52
	343	1.166	1.09	- 6.39
	353	1.017	.951	- 6.45
	363	.8953	.837	- 6.55
	373	.7949	.741	- 6.78
	383	.7112	.661	- 7.03
	393	.6403	.593	- 7.31
	403	.5800	.536	- 7.52
	413	.5280	.487	- 7.68
	423	.4830	.445	- 7.79
	433	.4437	.409	- 7.81
	443	.4088	.377	- 7.76
	453	.3781	.349	- 7.62
	463	.3506	.325	- 7.43
	473	.3261	.303	- 7.13
	483	.3034	.283	- 6.85
	493	.2827	.264	- 6.57
	503	.2638	.247	- 6.28
	513	.2464	.232	- 5.88
	523	.2307	.218	- 5.41
	533	.216	.205	- 4.97
	543	.202	.193	- 4.29
Hexadecane	293	3.484	3.05	-12.3
	303	2.766	2.50	- 9.73
	313	2.250	2.07	- 7.96
	323	1.866	1.74	- 6.85
	333	1.573	1.48	- 6.18
	343	1.346	1.27	- 5.96
	353	1.166	1.10	- 5.93
	363	1.021	.959	- 6.07
	373	.9019	.845	- 6.34
	383	.8033	.750	- 6.67

TABLE A-11 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	393	.7203	.669	- 7.06
	403	.6499	.602	- 7.42
	413	.5900	.544	- 7.72
	423	.5383	.495	- 7.97
	433	.4930	.453	- 8.17
	443	.4535	.416	- 8.28
	453	.4186	.384	- 8.34
	463	.3875	.355	- 8.33
	473	.3597	.330	- 8.26
	483	.3346	.307	- 8.10
	493	.3116	.287	- 7.95
	503	.2907	.268	- 7.79
	513	.2718	.251	- 7.51
	523	.2544	.236	- 7.15
	533	.238	.222	- 6.69
	543	.223	.209	- 6.22
	553	.210	.197	- 6.16
Heptadecane	293	4.209	3.62	-13.9
	303	3.296	2.94	-10.8
	313	2.650	2.42	- 8.55
	323	2.176	2.02	- 7.07
	333	1.820	1.71	- 6.24
	343	1.546	1.46	- 5.80
	353	1.330	1.25	- 5.67
	363	1.158	1.09	- 5.80
	373	1.018	.956	- 6.09
	383	.9026	.844	- 6.44
	393	.8064	.751	- 6.88
	403	.7251	.672	- 7.33
	413	.6560	.605	- 7.76
	423	.5968	.548	- 8.13
	433	.5454	.499	- 8.46
	443	.5006	.457	- 8.73
	453	.4611	.420	- 8.93
	463	.4262	.388	- 9.07
	473	.3951	.359	- 9.14
	483	.3671	.334	- 9.14
	493	.3417	.310	- 9.13
	503	.3187	.290	- 9.08
	513	.2978	.271	- 8.91
	523	.2787	.254	- 8.69
	533	.261	.239	- 8.41
	543	.245	.225	- 8.19

TABLE A-11 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	553	.230	.212	- 7.83
	563	.216	.200	- 7.62
	573	.202	.187	- 7.22
Octadecane	303	3.891	3.44	-11.6
	313	3.093	2.82	- 8.88
	323	2.516	2.34	- 7.08
	333	2.087	1.96	- 5.97
	343	1.760	1.67	- 5.33
	353	1.505	1.43	- 5.09
	363	1.303	1.24	- 5.14
	373	1.140	1.08	- 5.41
	383	1.006	.948	- 5.79
	393	.896	.839	- 6.33
	403	.803	.748	- 6.86
	413	.724	.671	- 7.36
	423	.657	.605	- 7.85
	433	.599	.549	- 8.30
	443	.548	.501	- 8.65
	453	.504	.459	- 8.99
	463	.465	.422	- 9.26
	473	.431	.390	- 9.57
	483	.400	.361	- 9.75
	493	.372	.335	- 9.89
	503	.347	.312	-10.0
	513	.324	.292	- 9.92
	523	.303	.273	- 9.77
	533	.28	.256	- 8.40
	543	.27	.241	-10.7
	553	.25	.227	- 9.23
	563	.23	.214	- 7.15
	573	.22	.200	- 8.89
	583	.21	.188	-10.7
Nonadecane	313	3.588	3.25	- 9.29
	323	2.891	2.69	- 7.05
	333	2.379	2.24	- 5.65
	343	1.992	1.90	- 4.82
	353	1.693	1.62	- 4.47
	363	1.458	1.39	- 4.43
	373	1.269	1.21	- 4.61
	383	1.116	1.06	- 5.05
	393	.989	.934	- 5.55
	403	.884	.829	- 6.20

TABLE A-11 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	413	.795	.741	- 6.80
	423	.719	.666	- 7.36
	433	.654	.602	- 7.92
	443	.598	.547	- 8.48
	453	.549	.500	- 9.00
	463	.506	.458	- 9.42
	473	.468	.422	- 9.76
	483	.433	.390	- 9.96
	493	.402	.361	-10.2
	503	.375	.336	-10.5
	513	.350	.313	-10.5
	523	.327	.293	-10.5
	533	.31	.274	-11.5
	543	.29	.257	-11.2
	553	.27	.242	-10.4
	563	.25	.228	- 8.94
	573	.24	.214	-10.9
	583	.22	.200	- 8.97
	593	.21	.188	-10.7
Eicosane	313	4.156	3.74	-10.0
	323	3.316	3.07	- 7.37
	333	2.706	2.55	- 5.61
	343	2.249	2.15	- 4.58
	353	1.900	1.82	- 4.02
	363	1.627	1.56	- 3.87
	373	1.410	1.35	- 4.02
	383	1.235	1.18	- 4.44
	393	1.091	1.04	- 4.99
	403	.971	.916	- 5.62
	413	.871	.816	- 6.30
	423	.786	.731	- 6.97
	433	.713	.659	- 7.63
	443	.650	.597	- 8.20
	453	.596	.543	- 8.89
	463	.548	.497	- 9.39
	473	.506	.456	- 9.84
	483	.468	.420	-10.2
	493	.435	.389	-10.7
	503	.404	.360	-10.8
	513	.377	.335	-11.0
	523	.353	.313	-11.3
	533	.33	.293	-11.3
	543	.31	.274	-11.5
	553	.29	.258	-11.2

TABLE A-11 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	563	.27	.242	-10.4
	573	.26	.227	-12.7
	583	.24	.213	-11.2
	593	.23	.200	-13.1
	603	.21	.187	-10.7
Octacosane	323	5.965	7.55	26.6
	373	2.898	2.895	- .098
	423	1.462	1.40	- 4.40
	473	.8743	.791	- 9.58
	523	.5994	.501	-16.4
	573	.4156	.341	-17.8
Hexatriacontane	373	4.892	5.20	6.38
	423	2.315	2.32	.129
	473	1.3309	1.23	- 7.79
	523	.8889	.733	-17.5
	573	.6068	.477	-21.4

TABLE A-12

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-1-ALKENES WITH COMBINED Z FUNCTION TWO SERIES (Z(TrB))

$$\mu = \rho^{11/3}\beta^3/M^{8/3}N^{1/3}\,Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentene	183	.85	1.30	52.8
	193	.70	1.01	44.3
	203	.59	.810	37.2
	213	.50	.663	32.6
	223	.43	.558	29.8
	233	.38	.477	25.6
	243	.33	.417	26.5
	253	.30	.383	27.7
	263	.27	.334	23.8
	273	.24	.303	26.4
Hexene	223	.63	.850	35.0
	233	.54	.709	31.4
	243	.47	.600	27.7
	253	.42	.519	23.7
	273	.33	.405	22.6
	283	.29	.364	25.6
	293	.26	.331	27.4
	303	.24	.304	26.8
	313	.22	.282	28.2
	323	.20	.264	31.8
	333	.19	.248	30.5
Heptene	273	.44	.541	22.9
	283	.39	.477	22.3
	293	.35	.426	21.7
	303	.32	.385	20.2
	313	.29	.350	20.8
	323	.27	.322	19.3
	333	.25	.299	19.4
	343	.23	.279	21.1
	353	.22	.262	19.0
	363	.20	.247	23.7
Octene	273	.613	.717	17.0
	283	.533	.622	16.8
	293	.470	.546	16.3

TABLE A-12 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	303	.425	.486	14.3
	313	.383	.436	13.8
	323	.347	.395	13.9
	333	.317	.361	14.0
	343	.292	.333	14.0
	353	.271	.309	14.0
	363	.251	.288	14.9
	373	.235	.271	15.4
	383	.22	.256	16.5
Nonene	273	.839	.944	12.5
	283	.715	.807	12.8
	293	.620	.698	12.7
	303	.554	.612	10.5
	313	.492	.543	10.3
	323	.440	.486	10.4
	333	.398	.439	10.3
	343	.363	.400	10.2
	353	.334	.367	9.9
	363	.307	.340	10.6
	373	.285	.316	10.8
	383	.26	.295	13.5
Decene	273	1.130	1.23	8.99
	283	.945	1.04	9.72
	293	.805	.885	9.98
	303	.709	.766	7.97
	313	.622	.670	7.72
	323	.551	.592	7.49
	333	.493	.529	7.23
	343	.445	.476	7.03
	353	.406	.432	6.48
	363	.371	.395	6.56
	373	.342	.364	6.42
	383	.32	.338	5.48
Undecene	273	1.50	1.51	.614
	283	1.229	1.32	7.21
	293	1.031	1.11	7.82
	303	.895	.951	6.23
	313	.777	.823	5.86
	323	.680	.719	5.81
	333	.603	.636	5.47
	343	.541	.567	4.83

TABLE A-12 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	353	.489	.510	4.34
	363	.443	.463	4.36
	373	.405	.422	4.18
	383	.37	.387	4.64
Dodecene	273	1.96	2.01	2.74
	283	1.58	1.66	4.85
	293	1.30	1.38	6.43
	303	1.12	1.17	4.82
	313	.959	1.00	4.65
	323	.831	.870	4.70
	333	.730	.762	4.35
	343	.647	.674	4.13
	353	.581	.601	3.45
	363	.523	.540	3.30
	373	.476	.489	2.84
	383	.43	.446	3.63
Tridecene	273	2.53	2.53	.00
	283	2.00	2.06	3.17
	293	1.63	1.71	4.62
	303	1.38	1.43	3.56
	313	1.17	1.21	3.65
	323	1.01	1.04	3.77
	333	.875	.905	3.46
	343	.769	.794	3.20
	353	.686	.702	2.38
	363	.614	.627	2.07
	373	.554	.563	1.68
	383	.50	.510	1.98
Tetradecene	273	3.23	3.15	- 2.45
	283	2.51	2.54	1.26
	293	2.01	2.08	3.57
	303	1.68	1.73	2.95
	313	1.41	1.46	3.31
	323	1.20	1.24	3.16
	333	1.04	1.07	2.83
	343	.906	.930	2.70
	353	.802	.817	1.88
	363	.714	.724	1.41
	373	.640	.646	.999
	383	.58	.582	.322

TABLE A-12 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentadecene	273	4.09	3.87	- 5.26
	283	3.12	3.10	- .720
	293	2.47	2.52	1.88
	303	2.04	2.07	1.68
	313	1.70	1.73	1.94
	323	1.43	1.47	2.49
	333	1.23	1.25	2.33
	343	1.06	1.08	2.00
	353	.933	.946	1.32
	363	.824	.832	.987
	373	.735	.738	.450
	383	.66	.661	.152
Hexadecene	283	3.82	3.74	- 2.04
	293	3.00	3.02	.528
	303	2.44	2.47	1.16
	313	2.02	2.05	1.38
	323	1.69	1.72	1.75
	333	1.43	1.46	2.19
	343	1.234	1.25	1.70
	353	1.078	1.09	.904
	363	.945	.952	.717
	373	.839	.840	.087
	383	.75	.747	- .406
Heptadecene	283	4.70	4.48	- 4.77
	293	3.61	3.58	- .752
	303	2.93	2.91	- .623
	313	2.38	2.40	.817
	323	1.97	2.00	1.65
	333	1.66	1.69	1.87
	343	1.42	1.44	1.64
	353	1.238	1.24	.546
	363	1.077	1.08	.545
	373	.952	.950	- .207
	383	.84	.839	- .149
Octadecene	293	4.32	4.22	- 2.30
	303	3.46	3.41	- 1.51
	313	2.79	2.79	.00
	323	2.29	2.32	1.14
	333	1.92	1.95	1.31
	343	1.65	1.65	.00
	353	1.41	1.42	.369
	363	1.221	1.23	.341
	373	1.074	1.07	- .439
	383	.95	.940	- 1.03

TABLE A-12 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Nonadecene	303	4.08	3.96	- 2.86
	313	3.26	3.23	- 1.02
	323	2.65	2.66	.486
	333	2.21	2.22	.643
	343	1.87	1.88	.457
	353	1.60	1.60	.00
	363	1.38	1.38	.00
	373	1.21	1.20	- .886
	383	1.06	1.05	- .733
Eicosene	303	4.77	4.58	- 3.94
	313	3.77	3.71	- 1.55
	323	3.05	3.05	.00
	333	2.52	2.53	.477
	343	2.12	2.13	.374
	353	1.81	1.81	.00
	363	1.55	1.55	.00
	373	1.35	1.34	- .723
	383	1.18	1.17	- .885

TABLE A-13

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-ALKYL BENZENES WITH COMBINED Z FUNCTION TWO SERIES ($Z(T_{rB})$)

$$\mu = \rho^{11/3}\beta^3/M^{8/3}N^{1/3}\,Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Methyl-benzene	253	1.07	1.08	.432
	263	.904	.906	.239
	273	.773	.783	1.26
	283	.6698	.686	2.47
	293	.5866	.610	3.91
	303	.5203	.548	5.29
	313	.4650	.497	6.88
	323	.4189	.456	8.78
	333	.380	.420	10.6
	343	.346	.390	12.8
	353	.317	.366	15.5
	363	.291	.346	18.9
	373	.269	.330	22.7
	383	.249	.313	25.8
Ethyl-benzene	253	1.24	1.44	16.4
	263	1.045	1.20	14.4
	273	.895	1.02	13.6
	283	.7751	.876	13.0
	293	.6783	.765	12.8
	303	.6003	.676	12.6
	313	.5354	.605	12.9
	323	.4814	.547	13.7
	333	.436	.495	13.6
	343	.397	.456	14.8
	353	.364	.424	16.6
	363	.334	.391	17.0
	373	.308	.366	18.9
	383	.286	.350	22.5
	393	.265	.329	24.3
	403	.247	.316	27.8
	413	.231	.301	30.4
Proply-benzene	253	1.72	1.84	6.98
	263	1.416	1.51	6.69
	273	1.182	1.27	7.31
	283	.9996	1.08	7.73

TABLE A-13 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	293	.8571	.930	8.51
	303	.7466	.813	8.88
	313	.6570	.719	9.39
	323	.5842	.641	9.75
	333	.524	.575	9.81
	343	.473	.524	10.7
	353	.430	.483	12.3
	363	.392	.443	13.1
	373	.360	.415	15.2
	383	.331	.384	16.2
	393	.306	.363	18.5
	403	.284	.345	21.6
	413	.26	.297	14.1
	423	.25	.317	26.7
Butyl-benzene	253	2.23	2.43	8.93
	263	1.790	1.99	11.1
	273	1.466	1.63	11.1
	283	1.220	1.36	11.7
	293	1.035	1.16	12.4
	303	.894	1.00	12.1
	313	.781	.875	12.0
	323	.684	.771	12.7
	333	.614	.688	12.1
	343	.550	.616	12.0
	353	.497	.563	13.3
	363	.450	.510	13.3
	373	.411	.471	14.6
	383	.38	.443	16.5
	393	.35	.435	24.4
	403	.32	.395	23.5
	413	.30	.366	22.1
	423	.28	.339	21.1
Pentyl-benzene	253	3.82	3.15	-17.5
	263	2.64	2.52	- 4.66
	273	2.01	2.10	4.41
	283	1.608	1.71	6.50
	293	1.334	1.44	8.10
	303	1.132	1.23	8.51
	313	.976	1.06	8.67
	323	.853	.924	8.33
	333	.756	.816	7.91
	343	.674	.725	7.56
	353	.602	.651	8.21

TABLE A-13 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	363	.543	.589	8.45
	373	.492	.539	9.47
	383	.45	.494	9.76
	393	.41	.471	14.8
	403	.37	.418	12.8
	413	.34	.376	10.6
	423	.32	.378	18.0
Hexyl-benzene	253	5.17	4.09	-20.8
	263	3.66	3.25	-11.1
	273	2.60	2.60	.00
	283	2.05	2.13	3.87
	293	1.675	1.77	5.83
	303	1.403	1.50	6.64
	313	1.196	1.28	6.90
	323	1.035	1.11	6.77
	333	.909	.965	6.20
	343	.804	.852	5.94
	353	.712	.758	6.42
	363	.638	.681	6.72
	373	.574	.613	6.87
	383	.52	.554	6.53
	393	.47	.515	9.54
	403	.43	.488	13.6
	413	.39	.433	11.0
	423	.36	.421	16.9
Heptyl-benzene	253	6.93	5.22	-24.6
	263	4.57	4.06	-11.1
	273	3.34	3.25	- 2.78
	283	2.59	2.65	2.32
	293	2.08	2.16	3.66
	303	1.722	1.80	4.46
	313	1.451	1.53	5.71
	323	1.243	1.31	5.75
	333	1.081	1.14	5.48
	343	.949	.994	4.76
	353	.834	.881	5.63
	363	.742	.785	5.83
	373	.664	.704	6.10
	383	.60	.662	10.3
	393	.54	.575	6.52
	403	.49	.533	8.81
	413	.45	.504	12.0
	423	.40	.437	9.27

TABLE A-13 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Octyl-benzene	253	9.23	6.62	-28.3
	263	5.94	5.12	-13.8
	273	4.25	4.06	- 4.44
	283	3.24	3.24	.00
	293	2.57	2.68	4.14
	303	2.09	2.19	4.81
	313	1.744	1.84	5.46
	323	1.479	1.56	5.56
	333	1.274	1.34	5.24
	343	1.111	1.17	5.01
	353	.968	1.02	5.39
	363	.856	.901	5.26
	373	.761	.805	5.80
	383	.68	.718	5.60
	393	.61	.645	5.73
	403	.55	.586	6.61
	413	.50	.541	8.28
	423	.45	.500	11.1
Nonyl-benzene	253	12.20	8.25	-32.4
	263	7.66	6.32	-17.5
	273	5.36	4.94	- 7.86
	283	4.02	3.96	- 1.58
	293	3.14	3.21	2.19
	303	2.53	2.65	4.64
	313	2.08	2.18	4.79
	323	1.745	1.84	5.28
	333	1.490	1.57	5.14
	343	1.289	1.35	4.91
	353	1.115	1.18	5.54
	363	.978	1.03	5.44
	373	.865	.914	5.71
	383	.77	.822	6.70
	393	.69	.730	5.73
	403	.62	.685	10.4
	413	.56	.624	11.4
	423	.50	.536	7.29
Decyl-benzene	253	16.0	10.4	-35.2
	263	9.81	7.88	-19.6
	273	6.72	6.11	- 9.09
	283	4.94	4.83	- 2.32
	293	3.80	3.86	1.56
	303	3.02	3.14	3.88
	313	2.46	2.60	5.89

TABLE A-13 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	323	2.00	2.19	9.65
	333	1.730	1.84	6.36
	343	1.486	1.58	6.32
	353	1.275	1.26	- .886
	363	1.112	1.19	7.21
	373	.977	1.04	6.87
	383	.86	.911	5.93
	393	.77	.828	7.54
	403	.69	.764	10.7
	413	.62	.685	10.5
	423	.56	.621	10.9
Undecyl-benzene	263	12.48	9.62	-22.9
	273	8.36	7.38	-11.8
	283	6.04	5.77	- 4.41
	293	4.58	4.63	1.18
	303	3.59	3.72	3.53
	313	2.89	3.06	5.90
	323	2.38	2.54	6.66
	333	1.995	2.13	6.89
	343	1.701	1.82	7.05
	353	1.449	1.56	7.85
	363	1.255	1.35	7.77
	373	1.098	1.19	8.15
	383	.97	1.05	8.55
	393	.86	.940	9.25
	403	.76	.815	7.28
	413	.68	.749	10.1
	423	.61	.668	9.50
Dodecyl-benzene	273	10.34	8.84	-14.5
	283	7.33	6.85	- 6.60
	293	5.47	5.43	- .722
	303	4.24	4.38	3.20
	313	3.37	3.56	5.75
	323	2.75	2.95	7.21
	333	2.29	2.47	8.03
	343	1.935	2.07	6.75
	353	1.637	1.78	8.52
	363	1.410	1.53	8.71
	373	1.226	1.33	8.89
	383	1.07	1.16	8.84
	393	.95	1.06	11.4
	403	.84	.913	8.65
	413	.75	.827	10.3
	423	.67	.760	13.4

TABLE A-13 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Tridecyl-benzene	273	12.69	10.5	-17.0
	283	8.84	8.14	- 7.96
	293	6.50	6.39	- 1.74
	303	4.97	5.13	3.16
	313	3.91	4.12	5.42
	323	3.16	3.42	8.07
	333	2.61	2.83	8.55
	343	2.19	2.37	8.09
	353	1.839	2.02	9.57
	363	1.575	1.74	10.2
	373	1.362	1.50	10.3
	383	1.19	1.31	9.99
	393	1.04	1.16	11.5
	403	.92	1.02	11.0
	413	.82	.915	11.5
	423	.73	.828	13.4
Tetradecyl-benzene	283	10.60	9.44	-10.9
	293	7.68	7.39	- 3.78
	303	5.80	5.89	1.56
	313	4.51	4.73	4.87
	323	3.61	3.88	7.57
	333	2.95	3.18	7.74
	343	2.47	2.71	9.56
	353	2.06	2.27	10.0
	363	1.751	1.93	10.3
	373	1.507	1.67	11.1
	383	1.31	1.45	10.9
	393	1.14	1.27	11.3
	403	1.01	1.14	12.7
	413	.89	1.00	12.5
	423	.79	.896	13.4
Pentadecyl-benzene	293	9.02	8.65	- 4.08
	303	6.72	6.82	1.48
	313	5.18	5.48	5.82
	323	4.11	4.45	8.37
	333	3.33	3.66	10.0
	343	2.76	3.05	10.5
	353	2.29	2.57	12.3
	363	1.938	2.18	12.5
	373	1.660	1.88	13.4
	383	1.43	1.62	13.6
	393	1.25	1.41	12.6
	403	1.09	1.23	13.1
	413	.97	1.11	14.8
	423	.85	.976	14.8

TABLE A-13 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Hexadecyl-benzene	303	7.76	7.76	.00
	313	5.92	6.21	4.93
	323	4.65	5.02	7.87
	333	3.74	4.10	9.63
	343	3.08	3.41	10.7
	353	2.54	2.85	12.4
	363	2.14	2.42	13.1
	373	1.822	2.09	14.5
	383	1.57	1.81	15.2
	393	1.36	1.58	15.9
	403	1.19	1.37	15.5
	413	1.04	1.18	13.5
	423	.92	1.10	19.2

TABLE A-14

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-ALKYL CYCLOHEXANES WITH COMBINED Z FUNCTION TWO SERIES ($Z(T_{rB})$)

$$\mu = \rho^{11/3}\beta^3/M^{8/3}N^{1/3}\ Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Ethylcyclohexane	253	1.63	1.20	-26.3
	263	1.356	1.01	-25.3
	273	1.142	.862	-24.5
	283	.976	.748	-23.4
	293	.843	.657	-22.0
	303	.737	.581	-21.1
	313	.651	.522	-19.8
	323	.581	.473	-18.5
	333	.523	.431	-17.5
	343	.475	.400	-15.8
	353	.43	.349	-18.8
	363	.40	.337	-15.8
	373	.37	.327	-11.6
	383	.34	.295	-13.2
Propylcyclohexane	253	2.10	1.61	-23.4
	263	1.705	1.33	-22.2
	273	1.408	1.12	-20.7
	283	1.182	.953	-19.4
	293	1.006	.822	-18.3
	303	.870	.720	-17.3
	313	.760	.638	-16.0
	323	.672	.570	-15.2
	333	.601	.516	-14.2
	343	.542	.469	-13.4
	353	.49	.418	-14.6
	363	.45	.392	-12.8
	373	.42	.378	-10.1
	383	.39	.341	-12.5
Butylcyclohexane	253	2.94	2.16	-26.6
	263	2.35	1.76	-25.1
	273	1.91	1.47	-23.1
	283	1.574	1.22	-22.2
	293	1.314	1.04	-20.7
	303	1.114	.901	-19.1
	313	.955	.787	-17.6

TABLE A-14 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	323	.830	.692	-16.6
	333	.734	.618	-15.8
	343	.658	.558	-15.2
	353	.60	.517	-13.8
	363	.55	.476	-13.4
	373	.51	.424	-16.8
	383	.47	.398	-15.2
Pentyl-cyclohexane	263	3.33	2.29	-31.3
	273	2.64	1.85	-29.8
	283	2.12	1.55	-26.8
	293	1.723	1.31	-24.1
	303	1.418	1.11	-21.6
	313	1.191	.961	-19.3
	323	1.026	.840	-18.2
	333	.898	.742	-17.4
	343	.79	.648	-18.0
	353	.71	.601	-15.3
	363	.63	.529	-16.1
	373	.57	.500	-12.3
	383	.51	.451	-11.5
Hexyl-cyclohexane	263	4.49	2.95	-34.3
	273	3.52	2.40	-31.9
	283	2.77	1.94	-29.9
	293	2.22	1.64	-26.3
	303	1.80	1.36	-24.3
	313	1.492	1.17	-21.6
	323	1.268	1.01	-20.0
	333	1.097	.888	-19.1
	343	.96	.788	-18.0
	353	.84	.690	-17.8
	363	.75	.647	-13.8
	373	.66	.562	-14.8
	383	.59	.499	-15.4
Heptyl-cyclohexane	263	5.94	3.77	-36.6
	273	4.58	2.99	-34.7
	283	3.56	2.43	-31.8
	293	2.81	2.01	-28.5
	303	2.25	1.69	-24.9
	313	1.83	1.43	-21.9
	323	1.544	1.22	-20.8
	333	1.320	1.06	-19.9

TABLE A-14 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	343	1.14	.922	-19.1
	353	.99	.807	-18.5
	363	.87	.728	-16.3
	373	.77	.674	-12.5
	383	.68	.586	-13.8
Octyl-cyclohexane	263	7.72	4.80	-37.8
	273	5.88	3.80	-35.4
	283	4.51	3.04	-32.6
	293	3.51	2.50	-28.8
	303	2.77	2.07	-25.1
	313	2.24	1.74	-22.3
	323	1.86	1.47	-20.9
	333	1.571	1.27	-19.0
	343	1.34	1.09	-18.9
	353	1.16	.958	-17.4
	363	1.00	.834	-16.6
	373	.88	.775	-11.9
	383	.77	.685	-11.0
Nonyl-cyclohexane	263	9.89	7.04	-28.8
	273	7.42	4.69	-36.8
	283	5.62	3.73	-33.6
	293	4.32	3.03	-29.9
	303	3.37	2.50	-25.9
	313	2.68	2.05	-23.4
	323	2.20	1.74	-20.8
	333	1.85	1.49	-19.6
	343	1.57	1.29	-17.9
	353	1.34	1.13	-15.9
	363	1.15	.987	-14.1
	373	1.00	.892	-10.8
	383	.87	.774	-11.0
Decyl-cyclohexane	273	9.26	5.75	-37.9
	283	6.93	4.55	-34.4
	293	5.26	3.65	-30.5
	303	4.05	2.97	-26.6
	313	3.19	2.44	-23.4
	323	2.59	2.05	-20.8
	333	2.16	1.75	-19.0
	343	1.81	1.49	-17.4
	353	1.53	1.30	-15.4
	363	1.31	1.14	-13.2
	373	1.12	.995	-11.2
	383	.97	.872	-10.2

TABLE A-14 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Undecylcyclohexane	283	8.44	5.53	-34.5
	293	6.34	4.40	-30.6
	303	4.81	3.55	-26.1
	313	3.76	2.92	-22.4
	323	3.03	2.44	-19.3
	333	2.49	2.04	-18.0
	343	2.08	1.75	-15.7
	353	1.74	1.48	-15.0
	363	1.47	1.28	-12.7
	373	1.26	1.16	- 8.29
	383	1.08	1.02	- 5.79
Dodecylcyclohexane	283	10.19	6.57	-35.5
	293	7.54	5.20	-31.0
	303	5.68	4.18	-26.4
	313	4.38	3.42	-22.0
	323	3.50	2.82	-19.3
	333	2.86	2.37	-17.1
	343	2.36	2.00	-15.1
	353	1.96	1.70	-13.2
	363	1.65	1.47	-10.6
	373	1.40	1.29	- 7.51
	383	1.19	1.11	- 6.32
Tridecylcyclohexane	293	8.92	6.14	-31.2
	303	6.64	4.91	-26.1
	313	5.08	3.97	-21.9
	323	4.02	3.27	-18.7
	333	3.26	2.74	-15.9
	343	2.67	2.28	-14.4
	353	2.21	1.97	-10.6
	363	1.84	1.67	- 9.17
	373	1.55	1.46	- 5.76
	383	1.31	1.26	- 3.68
Tetradecylcyclohexane	303	7.71	5.71	-25.9
	313	5.85	4.60	-21.3
	323	4.59	3.75	-18.2
	333	3.69	3.13	-15.1
	343	3.00	2.60	-13.3
	353	2.46	2.19	-11.1
	363	2.04	1.89	- 7.44
	373	1.70	1.61	- 5.28
	383	1.44	1.43	- .965

TABLE A-14 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentadecyl-cyclohexane	303	8.91	6.59	-26.0
	313	6.69	5.27	-21.2
	323	5.21	4.30	-17.4
	333	4.15	3.52	-15.2
	343	3.36	2.95	-12.1
	353	2.74	2.49	- 9.21
	363	2.25	2.10	- 6.77
	383	1.57	1.60	1.81
Hexadecyl-cyclohexane	313	7.61	5.98	-21.4
	323	5.88	4.86	-17.4
	333	4.66	3.98	-14.5
	343	3.74	3.31	-11.4
	353	3.03	2.78	- 8.23
	363	2.48	2.36	- 4.91
	373	2.04	1.99	- 2.35
	383	1.70	1.75	2.82

TABLE A-15

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-PARAFFINS WITH Z FUNCTION ($Z(T_{rB}, C)$)

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Methane	93	.188	.162	-13.6
	103	.142	.136	- 4.32
	113	.115	.120	4.21
Ethane	103	.805	.960	19.2
	113	.574	.658	14.6
	123	.442	.486	9.91
	133	.359	.380	5.76
	143	.301	.311	3.35
	153	.257	.265	2.93
	163	.222	.232	4.34
	173	.195	.207	6.38
	183	.172	.189	9.80
Propane	83	13.8	14.4	4.12
	93	5.96	6.64	11.5
	103	3.18	3.56	11.8
	113	1.96	2.13	8.78
	123	1.34	1.40	4.24
	133	.984	.977	- .683
	143	.762	.724	- 4.96
	153	.614	.563	- 8.36
	163	.510	.455	-10.9
	173	.433	.380	-12.3
	183	.374	.324	-13.4
	193	.327	.283	-13.4
	203	.288	.252	-12.4
	213	.256	.228	-10.9
	223	.228	.209	- 8.39
	233	.205	.194	- 5.49
Butane	183	.630	.596	- 5.41
	193	.536	.494	- 7.84
	203	.462	.419	- 9.25
	213	.403	.363	- 9.86
	223	.355	.321	- 9.48
	233	.315	.288	- 8.50

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	243	.282	.262	- 7.18
	253	.253	.240	- 5.02
	263	.229	.223	- 2.83
	273	.210	.208	- 1.04
Pentane	143	3.63	3.97	9.25
	153	2.35	2.68	14.1
	163	1.66	1.91	14.8
	173	1.24	1.41	13.9
	183	.973	1.08	11.5
	193	.791	.861	8.92
	203	.659	.703	6.64
	213	.562	.586	4.36
	223	.487	.500	2.58
	233	.428	.433	1.22
	243	.380	.381	.380
	253	.341	.340	- .232
	263	.307	.307	.00
	273	.279	.279	.00
	283	.255	.257	.804
	293	.235	.238	1.47
	303	.216	.222	2.71
Hexane	183	1.83	1.95	6.37
	193	1.38	1.49	7.79
	203	1.09	1.17	7.33
	213	.888	.994	6.32
	223	.741	.779	5.10
	233	.632	.655	3.69
	243	.547	.561	2.54
	253	.480	.487	1.52
	263	.426	.429	.665
	273	.381	.382	.223
	283	.3436	.3436	.00
	293	.3126	.313	.163
	303	.2854	.287	.475
	313	.2619	.265	1.13
	323	.2411	.246	1.96
	333	.2223	.229	2.86
	343	.2050	.213	3.72
Heptane	183	3.77	3.39	- 9.97
	193	2.61	2.51	- 3.99
	203	1.918	1.91	- .443
	213	1.476	1.50	+ 1.30

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	223	1.177	1.20	1.87
	233	.9653	.982	1.77
	243	.8098	.820	1.30
	253	.6916	.696	.638
	263	.5995	.599	- .044
	273	.5262	.522	- .670
	283	.4666	.461	- 1.15
	293	.4181	.412	- 1.38
	303	.3772	.372	- 1.46
	313	.3426	.338	- 1.27
	323	.3128	.310	- .908
	333	.2867	.286	- .430
	343	.2635	.264	.144
	353	.2431	.245	.928
	363	.2250	.229	1.87
	373	.2086	.215	3.07
Octane	223	1.86	1.82	- 2.32
	233	1.46	1.45	- .461
	243	1.183	1.19	.283
	253	.981	.986	.482
	263	.829	.832	.367
	273	.7125	.712	- .031
	283	.6203	.618	- .452
	293	.5466	.542	- .794
	303	.4865	.482	- 1.01
	313	.4368	.432	- 1.08
	323	.3946	.391	- 1.03
	333	.3578	.356	- .618
	343	.3274	.325	- .603
	353	.3004	.300	- .148
	363	.2765	.279	.595
	373	.2555	.259	1.27
	383	.2366	.242	2.17
	393	.2195	.226	3.11
Nonane	223	2.99	2.70	- 9.85
	233	2.24	2.11	- 5.74
	243	1.784	1.69	- 5.31
	253	1.403	1.37	- 2.32
	263	1.154	1.14	- 1.07
	273	.9688	.961	- .777
	283	.8267	.820	- .814
	293	.7160	.709	- .918
	303	.6279	.621	- 1.07

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	313	.5562	.550	- 1.17
	323	.4970	.491	- 1.25
	333	.4472	.441	- 1.28
	343	.4047	.400	- 1.24
	353	.3687	.365	- 1.00
	363	.3375	.335	- .627
	373	.3100	.309	- .162
	383	.2858	.287	.427
	393	.2641	.267	1.11
	403	.2445	.249	1.78
	413	.2271	.233	2.72
	423	.2115	.219	3.77
Decane	243	2.559	2.37	- 7.56
	253	1.987	1.90	- 4.59
	263	1.590	1.55	- 2.74
	273	1.304	1.28	- 1.67
	283	1.091	1.08	- 1.15
	293	.9284	.920	- .873
	303	.8018	.795	- .857
	313	.7010	.695	- .907
	323	.6192	.613	- 1.02
	333	.5517	.545	- 1.14
	343	.4951	.489	- 1.23
	353	.4476	.442	- 1.19
	363	.4068	.402	- 1.07
	373	.3715	.368	- .844
	383	.3408	.339	- .531
	393	.3137	.313	- .125
	403	.2896	.291	.375
	413	.2683	.271	1.04
	423	.2489	.253	1.75
	433	.2313	.237	2.50
	443	.2152	.222	3.24
Undecane	253	2.779	2.57	- 7.40
	263	2.163	2.07	- 4.37
	273	1.733	1.69	- 2.39
	283	1.421	1.40	- 1.19
	293	1.189	1.18	- .527
	303	1.012	1.01	- .241
	313	.8733	.872	- .165
	323	.7627	.761	- .223
	333	.6731	.671	- .350

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	343	.5988	.596	- .541
	353	.5371	.534	- .633
	363	.4850	.482	- .697
	373	.4403	.437	- .714
	383	.4018	.399	- .616
	393	.3680	.366	- .464
	403	.3385	.338	- .210
	413	.3124	.313	.205
	423	.2892	.291	.654
	433	.2683	.271	1.19
	443	.2493	.254	1.77
	453	.2320	.238	2.43
	463	.2161	.223	3.14
Dodecane	273	2.278	2.20	- 3.46
	283	1.833	1.80	- 1.63
	293	1.508	1.50	- .517
	303	1.265	1.27	.198
	313	1.079	1.08	.419
	323	.9321	.936	.438
	333	.8147	.817	.304
	343	.7188	.719	.065
	353	.6398	.639	- .195
	363	.5743	.572	- .350
	373	.5183	.516	- .527
	383	.4706	.468	- .640
	393	.4291	.426	- .721
	403	.3932	.390	- .675
	413	.3617	.360	- .493
	423	.3338	.333	- .260
	433	.3089	.309	.029
	443	.2865	.288	.447
	453	.2664	.269	.931
	463	.2480	.252	1.47
	473	.2311	.236	1.98
	483	.2153	.221	2.43
Tridecane	273	2.950	2.82	- 4.54
	283	2.328	2.28	- 1.89
	293	1.886	1.88	- .163
	303	1.560	1.57	.848
	313	1.314	1.33	1.37
	323	1.123	1.14	1.54
	333	.9725	.987	1.45
	343	.8513	.862	1.21

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	353	.7527	.760	.923
	363	.6709	.675	.604
	373	.6022	.604	.295
	383	.5441	.5440	.00
	393	.4940	.493	- .228
	403	.4508	.449	- .399
	413	.4133	.412	- .429
	423	.3803	.379	- .365
	433	.3511	.350	- .273
	443	.3251	.3251	.00
	453	.3017	.302	.260
	463	.2807	.282	.618
	473	.2616	.265	1.09
	483	.2435	.247	1.41
	493	.2268	.231	1.68
	503	.2114	.216	1.94
Tetradecane	283	2.940	2.86	- 2.78
	293	2.342	2.33	- .382
	303	1.910	1.93	1.11
	313	1.590	1.62	1.92
	323	1.345	1.38	2.32
	333	1.154	1.18	2.36
	343	1.002	1.02	2.17
	353	.8798	.896	1.84
	363	.7795	.791	1.47
	373	.6958	.703	1.05
	383	.6251	.629	.615
	393	.5654	.567	.286
	403	.5140	.514	.00
	413	.4696	.468	- .259
	423	.4307	.429	- .394
	433	.3966	.395	- .431
	443	.3664	.365	- .391
	453	.3395	.339	- .276
	463	.3153	.315	- .054
	473	.2955	.294	- .246
	483	.2733	.275	.495
	493	.2547	.257	.725
	503	.2375	.240	.989
	513	.2218	.225	1.35
	523	.2074	.211	1.74

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentadecane	283	3.663	3.52	- 3.88
	293	2.872	2.85	- .822
	303	2.310	2.34	1.21
	313	1.900	1.95	2.38
	323	1.591	1.64	3.05
	333	1.353	1.40	3.26
	343	1.166	1.20	3.14
	353	1.017	1.05	2.82
	363	.8953	.917	2.46
	373	.7949	.811	1.98
	383	.7112	.722	1.49
	393	.6403	.647	.980
	403	.5800	.583	.564
	413	.5280	.529	.203
	423	.4830	.483	.00
	433	.4437	.443	- .268
	443	.4088	.407	- .375
	453	.3781	.377	- .366
	463	.3506	.350	- .308
	473	.3261	.326	- .116
	483	.3034	.304	.057
	493	.2827	.283	.230
	503	.2638	.265	.433
	513	.2464	.248	.750
	523	.2307	.233	1.14
	533	.216	.219	1.51
	543	.202	.206	2.13
Hexadecane	293	3.484	3.43	- 1.51
	303	2.766	2.79	1.04
	313	2.250	2.31	2.65
	323	1.866	1.93	3.55
	333	1.573	1.64	3.99
	343	1.346	1.40	3.95
	353	1.166	1.21	3.72
	363	1.021	1.06	3.33
	373	.9019	.927	2.82
	383	.8033	.821	2.26
	393	.7203	.732	1.67
	403	.6499	.657	1.13
	413	.5900	.594	.651
	423	.5383	.540	.263
	433	.4930	.493	.00
	443	.4535	.452	- .288

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	453	.4186	.417	- .435
	463	.3875	.386	- .492
	473	.3597	.358	- .478
	483	.3346	.333	- .360
	493	.3116	.311	- .239
	503	.2907	.290	- .099
	513	.2718	.272	.172
	523	.2544	.256	.548
	533	.238	.240	1.04
	543	.223	.226	1.54
	553	.210	.213	1.61
Heptadecane	293	4.209	4.07	- 3.39
	303	3.296	3.29	- .297
	313	2.650	2.70	1.81
	323	2.176	2.24	3.10
	333	1.820	1.89	3.70
	343	1.546	1.61	3.91
	353	1.330	1.38	3.81
	363	1.158	1.20	3.45
	373	1.018	1.05	2.95
	383	.9026	.924	2.40
	393	.8064	.821	1.80
	403	.7251	.734	1.20
	413	.6560	.660	.643
	423	.5968	.598	.183
	433	.5454	.544	- .221
	443	.5006	.498	- .538
	453	.4611	.458	- .777
	463	.4262	.422	- .914
	473	.3951	.391	- .982
	483	.3671	.364	- .944
	493	.3417	.339	- .896
	503	.3187	.316	- .776
	513	.2978	.296	- .532
	523	.2787	.278	- .215
	533	.261	.261	.00
	543	.245	.246	.521
	553	.230	.232	1.02
	563	.216	.219	1.36
	573	.202	.206	1.92

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Octadecane	303	3.891	3.82	- 1.94
	313	3.093	3.11	.640
	323	2.516	2.57	2.62
	333	2.087	2.15	3.17
	343	1.760	1.82	3.61
	353	1.505	1.56	3.66
	363	1.303	1.35	3.42
	373	1.140	1.17	2.99
	383	1.006	1.03	2.47
	393	.896	.912	1.81
	403	.803	.813	1.19
	413	.724	.729	.634
	423	.657	.658	.111
	433	.599	.597	- .355
	443	.548	.544	- .680
	453	.504	.499	- .979
	463	.465	.459	- 1.18
	473	.431	.425	- 1.41
	483	.400	.394	- 1.48
	493	.372	.366	- 1.49
	503	.347	.342	- 1.46
	513	.324	.321	- 1.20
	523	.303	.300	- .859
	533	.28	.282	.841
	543	.27	.266	- 1.51
	553	.25	.251	.352
	563	.23	.237	2.88
	573	.22	.223	1.19
	583	.21	.208	- .559
Nonadecane	313	3.588	3.54	- 1.27
	323	2.891	2.91	+ .825
	333	2.379	2.43	2.06
	343	1.992	2.05	2.73
	353	1.693	1.74	2.92
	363	1.458	1.50	2.84
	373	1.269	1.30	2.56
	383	1.116	1.14	2.04
	393	.989	1.00	1.50
	403	.884	.891	.884
	413	.795	.797	.258
	423	.719	.717	- .252
	433	.654	.649	- .741
	443	.598	.591	- 1.20

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	453	.549	.540	- 1.60
	463	.506	.497	- 1.86
	473	.468	.459	- 2.01
	483	.433	.424	- 2.02
	493	.402	.394	- 1.97
	503	.375	.397	- 2.05
	513	.350	.344	- 1.84
	523	.327	.322	- 1.48
	533	.31	.303	- 2.32
	543	.29	.285	- 1.71
	553	.27	.269	- .432
	563	.25	.254	1.52
	573	.24	.239	- .321
	583	.22	.225	2.23
	593	.21	.211	.700
Eicosane	313	4.156	3.98	- 4.18
	323	3.316	3.26	- 1.66
	333	2.706	2.706	.00
	343	2.249	2.27	.879
	353	1.900	1.93	1.36
	363	1.627	1.65	1.45
	373	1.410	1.43	1.28
	383	1.235	1.25	.876
	393	1.091	1.10	.375
	403	.971	.969	- .168
	413	.871	.865	- .741
	423	.786	.776	- 1.26
	433	.713	.701	- 1.74
	443	.650	.636	- 2.11
	453	.596	.581	- 2.57
	463	.548	.533	- 2.82
	473	.506	.491	- 2.97
	483	.468	.454	- 3.04
	493	.435	.421	- 3.19
	503	.404	.392	- 2.96
	513	.377	.366	- 2.70
	523	.353	.343	- 2.70
	533	.33	.323	- 2.27
	543	.31	.304	- 2.03
	553	.29	.286	- 1.25
	563	.27	.270	.00
	573	.26	.255	- 1.97
	583	.24	.240	.00
	593	.23	.227	- 1.40
	603	.21	.214	1.82

TABLE A-15 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Octacosane	323	5.965	5.02	-15.8
	373	2.898	2.03	-30.0
	423	1.462	1.05	-28.0
	473	.8743	.648	-25.9
	523	.5994	.450	-24.9
	573	.4156	.338	-18.6
Hexatriacontane	373	4.892	1.41	-71.3
	423	2.315	.765	-66.9
	473	1.3309	.501	-62.4
	523	.8889	.372	-58.2
	573	.6068	.301	-50.4

TABLE A-16

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-1-ALKENES WITH Z FUNCTION ($Z(T_{rB},C)$)

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentene	183	.85	.833	- 2.01
	193	.70	.689	- 1.63
	203	.59	.579	- 1.93
	213	.50	.491	- 1.88
	223	.43	.423	- 1.56
	233	.38	.367	- 3.35
	243	.33	.323	- 2.01
	253	.30	.297	- 1.16
	263	.27	.257	- 4.86
	273	.24	.230	- 4.05
Hexene	223	.63	.637	1.18
	233	.54	.546	1.20
	243	.47	.472	.415
	253	.42	.414	- 1.38
	273	.33	.327	- 1.05
	283	.29	.294	+ 1.26
	293	.26	.266	2.27
	303	.24	.242	.904
	313	.22	.222	.871
	323	.20	.204	2.19
	333	.19	.189	- .534
Heptene	273	.44	.448	1.72
	283	.39	.398	2.07
	293	.35	.357	2.05
	303	.32	.323	.941
	313	.29	.294	1.40
	323	.27	.270	.00
	333	.25	.249	- .583
	343	.23	.230	.00
	353	.22	.214	- 2.52
	363	.20	.201	.294
Octene	273	.613	.604	- 1.45
	283	.533	.530	- .574
	293	.470	.470	.00
	303	.425	.420	- 1.14

TABLE A-16 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	313	.383	.379	- 1.04
	323	.347	.345	- .639
	333	.317	.316	- .362
	343	.292	.291	- .323
	353	.271	.270	- .396
	363	.251	.252	.211
	373	.235	.236	.281
	383	.22	.222	.864
Nonene	273	.839	.811	- 3.29
	283	.715	.701	- 2.00
	293	.620	.612	- 1.21
	303	.554	.541	- 2.29
	313	.492	.483	- 1.74
	323	.440	.435	- 1.03
	333	.398	.396	- .618
	343	.363	.362	- .282
	353	.334	.334	.00
	363	.307	.309	.806
	373	.285	.289	1.28
	383	.26	.270	3.91
Decene	273	1.130	1.09	- 3.73
	283	.945	.923	- 2.32
	293	.805	.794	- 1.36
	303	.709	.692	- 2.46
	313	.622	.610	- 2.01
	323	.551	.542	- 1.55
	333	.493	.487	- 1.16
	343	.445	.442	- .726
	353	.406	.403	- .632
	363	.371	.371	.00
	373	.342	.344	.465
	383	.32	.320	.00
Undecane	273	1.50	1.38	- 8.00
	283	1.229	1.21	- 1.66
	293	1.031	1.02	- .720
	303	.895	.879	- 1.75
	313	.777	.765	- 1.59
	323	.680	.672	- 1.11
	333	.603	.598	- .834
	343	.541	.537	- .822
	353	.489	.486	- .627
	363	.443	.443	.00
	373	.405	.408	.648
	383	.37	.377	1.86

TABLE A-16 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Dodecane	273	1.96	1.92	- 2.26
	283	1.58	1.57	- .482
	293	1.30	1.31	.936
	303	1.12	1.11	- .527
	313	.959	.954	- .488
	323	.831	.830	- .121
	333	.730	.730	.00
	343	.647	.649	.282
	353	.581	.582	.242
	363	.523	.527	.796
	373	.476	.481	1.12
	383	.43	.442	2.75
Tridecene	273	2.53	2.51	- .658
	283	2.00	2.03	1.48
	293	1.63	1.67	2.31
	303	1.38	1.39	.919
	313	1.17	1.18	.852
	323	1.01	1.02	1.00
	333	.875	.883	.907
	343	.769	.777	1.01
	353	.686	.691	.705
	363	.614	.620	1.03
	373	.554	.562	1.39
	383	.50	.513	2.55
Tetradecene	273	3.23	3.25	.722
	283	2.51	2.59	3.09
	293	2.01	2.10	4.30
	303	1.68	1.73	2.87
	313	1.41	1.45	2.70
	323	1.20	1.23	2.27
	333	1.04	1.06	1.90
	343	.906	.924	1.94
	353	.802	.814	1.48
	363	.714	.725	1.53
	373	.640	.652	1.80
	383	.58	.591	1.95
Pentadecene	273	4.09	4.14	1.32
	283	3.12	3.25	4.13
	293	2.47	2.60	5.21
	303	2.04	2.12	3.77
	313	1.70	1.75	3.15
	323	1.43	1.47	3.13

TABLE A-16 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	333	1.23	1.26	2.68
	343	1.06	1.09	2.31
	353	.933	.950	1.83
	363	.824	.840	1.91
	373	.735	.750	1.98
	383	.66	.676	2.47
Hexadecene	283	3.82	4.01	5.02
	293	3.00	3.17	5.70
	303	2.44	2.56	4.74
	313	2.02	2.10	3.77
	323	1.69	1.75	3.32
	333	1.43	1.48	3.26
	343	1.234	1.27	2.57
	353	1.078	1.10	1.84
	363	.945	.964	1.96
	373	.839	.855	1.87
	383	.75	.766	2.12
Heptadecene	283	4.70	4.85	3.23
	293	3.61	3.80	5.18
	303	2.93	3.03	3.44
	313	2.38	2.46	3.51
	323	1.97	2.04	3.34
	333	1.66	1.71	2.91
	343	1.42	1.45	2.36
	353	1.238	1.25	1.24
	363	1.077	1.09	1.50
	373	.952	.964	1.25
	383	.84	.857	2.05
Octadecene	293	4.32	4.45	3.03
	303	3.46	3.52	1.85
	313	2.79	2.84	1.93
	323	2.29	2.33	1.91
	333	1.92	1.95	1.36
	343	1.65	1.65	.00
	353	1.41	1.41	.00
	363	1.22	1.22	.00
	373	1.074	1.074	.00
	383	.95	.951	.148
Nonadecene	303	4.08	4.01	- 1.63
	313	3.26	3.22	- 1.29
	323	2.65	2.63	- .875

TABLE A-16 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	333	2.21	2.18	- 1.41
	343	1.87	1.83	- 1.91
	353	1.60	1.56	- 2.22
	363	1.38	1.35	- 2.04
	373	1.21	1.18	- 2.33
	383	1.06	1.05	- 1.34
Eicosene	303	4.77	4.47	- 6.29
	313	3.77	3.57	- 5.33
	323	3.05	2.90	- 4.89
	333	2.52	2.40	- 4.89
	343	2.12	2.01	- 5.18
	353	1.81	1.71	- 5.56
	363	1.55	1.47	- 5.02
	373	1.35	1.28	- 4.96
	383	1.18	1.13	- 4.16

TABLE A-17

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-ALKYL CYCLOHEXANES WITH Z FUNCTION ($Z(T_{rB},C)$)

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Ethyl-cyclohexane	253	1.63	1.62	- .752
	263	1.356	1.34	- 1.38
	273	1.142	1.12	- 2.15
	283	.976	.950	- 2.61
	293	.843	.820	- 2.79
	303	.737	.711	- 3.52
	313	.651	.627	- 3.73
	323	.581	.558	- 4.03
	333	.523	.498	- 4.71
	343	.475	.454	- 4.47
	353	.43	.389	- 9.62
	363	.40	.368	- 7.97
	373	.37	.351	- 5.23
	383	.34	.311	- 8.63
Propyl-cyclohexane	253	2.10	2.20	4.90
	263	1.705	1.78	4.33
	273	1.408	1.47	4.24
	283	1.182	1.23	4.05
	293	1.006	1.04	3.71
	303	.870	.899	3.39
	313	.760	.786	3.44
	323	.672	.692	3.02
	333	.601	.619	3.03
	343	.542	.557	2.80
	353	.49	.492	.322
	363	.45	.456	1.44
	373	.42	.435	3.67
	383	.39	.390	.00
Butyl-cyclohexane	253	2.94	3.04	3.32
	263	2.35	2.41	2.54
	273	1.91	1.96	2.67
	283	1.574	1.60	1.65
	293	1.314	1.33	1.58
	303	1.114	1.14	1.96
	313	.955	.977	2.34
	323	.830	.849	2.31
	333	.734	.751	2.31

TABLE A-17 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	343	.658	.672	2.08
	353	.60	.619	3.09
	363	.55	.566	2.98
	373	.51	.502	- 1.52
	383	.47	.470	.00
Pentylcyclohexane	263	3.33	3.22	- 3.36
	273	2.64	2.52	- 4.41
	283	2.12	2.06	- 3.03
	293	1.723	1.69	- 1.86
	303	1.418	1.41	- .664
	313	1.191	1.20	.420
	323	1.026	1.03	.444
	333	.898	.900	.202
	343	.79	.779	- 1.42
	353	.71	.718	1.12
	363	.63	.628	- .263
	373	.57	.593	3.97
	383	.51	.535	4.80
Hexylcyclohexane	263	4.49	4.31	- 3.91
	273	3.52	3.36	- 4.52
	283	2.77	2.63	- 5.08
	293	2.22	2.15	- 3.24
	303	1.80	1.74	- 3.23
	313	1.492	1.46	- 2.04
	323	1.268	1.24	- 1.84
	333	1.097	1.07	- 2.16
	343	.96	.941	- 1.95
	353	.84	.818	- 2.67
	363	.75	.761	1.50
	373	.66	.660	.00
	383	.59	.585	- .920
Heptylcyclohexane	263	5.94	5.76	- 3.11
	273	4.58	4.35	- 5.07
	283	3.56	3.38	- 5.09
	293	2.81	2.69	- 4.28
	303	2.25	2.19	- 2.70
	313	1.83	1.80	- 1.60
	323	1.544	1.51	- 2.51
	333	1.320	1.28	- 3.31
	343	1.14	1.10	- 3.87
	353	.99	.947	- 4.39
	363	.87	.847	- 2.70
	373	.77	.778	+ 1.09
	383	.68	.674	- .821

TABLE A-17 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Octyl-cyclohexane	263	7.72	7.71	- .104
	273	5.88	5.76	- 2.10
	283	4.51	4.37	- 3.07
	293	3.51	3.44	- 2.12
	303	2.77	2.74	- 1.01
	313	2.24	2.22	- .780
	323	1.86	1.82	- 1.90
	333	1.571	1.54	- 1.97
	343	1.34	1.29	- 3.85
	353	1.16	1.12	- 3.77
	363	1.00	.960	- 4.05
	373	.88	.883	.329
	383	.77	.774	.567
Nonyl-cyclohexane	263	9.89	11.82	19.5
	273	7.42	7.37	- .662
	283	5.62	5.54	- 1.51
	293	4.32	4.27	- 1.09
	303	3.37	3.36	- .151
	313	2.68	2.66	- .797
	323	2.20	2.18	- .872
	333	1.85	1.81	- 2.26
	343	1.57	1.53	- 2.67
	353	1.34	1.31	- 2.44
	363	1.15	1.13	- 2.11
	373	1.00	1.00	.00
	383	.87	.860	- 1.11
Decyl-cyclohexane	273	9.26	9.33	.797
	283	6.93	6.93	.00
	293	5.26	5.27	.210
	303	4.05	4.08	.702
	313	3.19	3.21	.710
	323	2.59	2.59	.00
	333	2.16	2.14	- .973
	343	1.81	1.77	- 1.94
	353	1.53	1.50	- 2.01
	363	1.31	1.29	- 1.67
	373	1.12	1.11	- 1.20
	383	.97	.955	- 1.53

TABLE A-17 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Undecyl-cyclohexane	283	8.44	8.60	1.89
	293	6.34	6.46	1.92
	303	4.81	4.95	3.01
	313	3.76	3.88	3.23
	323	3.03	3.12	3.01
	333	2.49	2.51	.939
	343	2.08	2.09	.423
	353	1.74	1.71	- 1.59
	363	1.47	1.45	- 1.43
	373	1.26	1.28	1.29
	383	1.08	1.10	2.13
Dodecyl-cyclohexane	283	10.19	10.3	.684
	293	7.54	7.67	1.74
	303	5.68	5.85	3.00
	313	4.38	4.56	4.14
	323	3.50	3.61	3.28
	333	2.86	2.92	2.18
	343	2.36	2.39	1.06
	353	1.96	1.96	.00
	363	1.65	1.66	.384
	373	1.40	1.42	1.37
	383	1.19	1.20	.483
Tridecyl-cyclohexane	293	8.92	8.97	.551
	303	6.64	6.82	2.76
	313	5.08	5.27	3.73
	323	4.02	4.17	3.64
	333	3.26	3.37	3.26
	343	2.67	2.71	1.47
	353	2.21	2.27	2.68
	363	1.84	1.87	1.42
	373	1.55	1.59	2.53
	383	1.31	1.34	2.34
Tetradecyl-cyclohexane	303	7.71	7.76	.598
	313	5.85	6.00	2.56
	323	4.59	4.71	2.64
	333	3.69	3.80	2.92
	343	3.00	3.05	1.62
	353	2.46	2.49	1.14
	363	2.04	2.09	2.34
	373	1.70	1.73	2.00
	383	1.44	1.50	4.07

TABLE A-17 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentadecyl-cyclohexane	303	8.91	8.57	- 3.79
	313	6.69	6.63	- .892
	323	5.21	5.24	.524
	333	4.15	4.16	.206
	343	3.36	3.39	.905
	353	2.74	2.78	1.36
	363	2.25	2.28	1.40
	383	1.57	1.66	5.45
Hexadecyl-cyclohexane	313	7.61	7.10	- 6.64
	323	5.88	5.64	- 4.10
	333	4.66	4.52	- 3.01
	343	3.74	3.67	- 1.76
	353	3.03	3.02	- .458
	363	2.48	2.50	.878
	373	2.04	2.07	1.34
	383	1.70	1.77	4.41

TABLE A-18

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF n-ALKYL BENZENES WITH Z FUNCTION ($Z(T_{rB},C)$)

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Propyl-benzene	253	1.72	1.74	1.11
	263	1.416	1.42	.172
	273	1.182	1.18	- .103
	283	.9996	.992	- .731
	293	.8571	.847	- 1.18
	303	.7466	.731	- 2.12
	313	.6570	.637	- 3.06
	323	.5842	.560	- 4.21
	333	.524	.494	- 5.70
	343	.473	.442	- 6.52
	353	.430	.401	- 6.85
	363	.392	.361	- 7.93
	373	.360	.331	- 7.97
	383	.331	.301	- 9.05
	393	.306	.278	- 9.04
	403	.284	.259	- 8.63
	413	.26	.218	-16.0
	423	.25	.228	- 8.76
Butyl-benzene	253	2.23	2.35	5.30
	263	1.790	1.90	6.17
	273	1.466	1.54	5.08
	283	1.220	1.28	4.62
	293	1.035	1.08	4.23
	303	.894	.921	3.05
	313	.781	.797	2.07
	323	.684	.697	1.90
	333	.614	.617	.528
	343	.550	.548	- .278
	353	.497	.498	.115
	363	.450	.448	- .514
	373	.411	.411	.00
	383	.38	.384	.986
	393	.35	.375	7.26
	403	.32	.339	5.84
	413	.30	.312	4.12
	423	.28	.288	2.76

TABLE A-18 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Pentyl-benzene	253	3.82	3.17	-17.1
	263	2.64	2.47	- 6.25
	273	2.01	2.03	.869
	283	1.608	1.63	1.36
	293	1.334	1.36	1.61
	303	1.132	1.14	.965
	313	.976	.979	.291
	323	.853	.847	- .658
	333	.756	.745	- 1.50
	343	.674	.660	- 2.12
	353	.602	.592	- 1.69
	363	.543	.535	- 1.51
	373	.492	.490	- .502
	383	.45	.450	.00
	393	.41	.430	4.88
	403	.37	.383	3.47
	413	.34	.346	1.88
	423	.32	.350	9.36
Hexyl-benzene	253	5.17	4.33	-16.2
	263	3.66	3.33	- 8.97
	273	2.60	2.59	- .379
	283	2.05	2.07	1.18
	293	1.675	1.70	1.20
	303	1.403	1.41	.487
	313	1.196	1.19	- .400
	323	1.035	1.02	- 1.32
	333	.909	.888	- 2.35
	343	.804	.781	- 2.84
	353	.712	.695	- 2.41
	363	.638	.626	- 1.93
	373	.574	.566	- 1.39
	383	.52	.514	- 1.12
	393	.47	.482	2.46
	403	.43	.461	7.24
	413	.39	.413	5.92
	423	.36	.407	12.9
Heptyl-benzene	253	6.93	5.89	-15.0
	263	4.57	4.38	- 4.15
	273	3.34	3.37	.834
	283	2.59	2.66	2.77
	293	2.08	2.11	1.42
	303	1.722	1.723	.071

TABLE A-18 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	313	1.451	1.45	- .367
	323	1.243	1.22	- 1.52
	333	1.081	1.05	- 2.56
	343	.949	.914	- 3.67
	353	.834	.809	- 2.98
	363	.742	.723	- 2.61
	373	.664	.651	- 1.92
	383	.60	.616	2.70
	393	.54	.541	.122
	403	.49	.507	3.48
	413	.45	.486	8.00
	423	.40	.428	7.00
Octyl-benzene	253	9.23	8.01	-13.3
	263	5.94	5.85	- 1.53
	273	4.25	4.41	3.88
	283	3.24	3.38	4.31
	293	2.57	2.70	4.88
	303	2.09	2.14	2.62
	313	1.744	1.76	.962
	323	1.479	1.47	- .668
	333	1.274	1.25	- 2.20
	343	1.111	1.08	- 3.20
	353	.968	.937	- 3.23
	363	.856	.827	- 3.38
	373	.761	.741	- 2.59
	383	.68	.665	- 2.16
	393	.61	.603	- 1.14
	403	.55	.555	.866
	413	.50	.520	3.92
	423	.45	.488	8.43
Nonyl-benzene	253	12.20	10.7	-12.4
	263	7.66	7.64	- .284
	273	5.36	5.62	4.94
	283	4.02	4.29	6.60
	293	3.14	3.33	6.10
	303	2.53	2.65	4.91
	313	2.08	2.12	2.10
	323	1.745	1.75	.291
	333	1.490	1.47	- 1.54
	343	1.289	1.25	- 2.92
	353	1.115	1.08	- 3.07
	363	.978	.944	- 3.48
	373	.865	.838	- 3.17

TABLE A-18 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	383	.77	.756	- 1.85
	393	.69	.676	- 2.01
	403	.62	.641	3.44
	413	.56	.592	5.73
	423	.50	.517	3.49
Decyl-benzene	253	16.0	14.3	-10.8
	263	9.81	10.1	2.48
	273	6.72	7.28	8.40
	283	4.94	5.43	9.94
	293	3.80	4.14	8.84
	303	3.02	3.23	6.83
	313	2.46	2.59	5.25
	323	2.00	2.12	6.01
	333	1.730	1.74	.620
	343	1.486	1.47	- 1.05
	353	1.275	1.16	- 8.80
	363	1.112	1.09	- 2.02
	373	.977	.952	- 2.59
	383	.86	.831	- 3.32
	393	.77	.759	- 1.37
	403	.69	.706	2.37
	413	.62	.640	3.29
	423	.56	.589	5.18
Undecyl-benzene	263	12.48	12.72	1.93
	273	8.36	9.07	8.52
	283	6.04	6.67	10.5
	293	4.58	5.08	10.9
	303	3.59	3.89	8.46
	313	2.89	3.09	6.82
	323	2.38	2.48	4.28
	333	1.995	2.03	1.91
	343	1.701	1.701	.00
	353	1.449	1.44	- .605
	363	1.255	1.23	- 1.63
	373	1.098	1.08	- 1.82
	383	.97	.955	- 1.58
	393	.86	.854	- .724
	403	.76	.745	- 1.95
	413	.68	.691	1.56
	423	.61	.623	2.19

TABLE A-18 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Dodecyl-benzene	273	10.34	11.0	6.55
	283	7.33	8.00	9.21
	293	5.47	6.01	9.91
	303	4.24	4.62	9.05
	313	3.37	3.62	7.41
	323	2.75	2.90	5.36
	333	2.29	2.37	3.36
	343	1.935	1.934	- .032
	353	1.637	1.637	.00
	363	1.410	1.40	- 1.01
	373	1.226	1.21	- 1.58
	383	1.07	1.05	- 1.97
	393	.95	.954	.404
	403	.84	.825	- 1.77
	413	.75	.753	.385
	423	.67	.698	4.22
Tridecyl-benzene	273	12.69	13.0	2.38
	283	8.84	9.45	6.85
	293	6.50	7.03	8.20
	303	4.97	5.39	8.54
	313	3.91	4.17	6.71
	323	3.16	3.35	5.89
	333	2.61	2.70	3.53
	343	2.19	2.21	.880
	353	1.839	1.85	.546
	363	1.575	1.573	- .128
	373	1.362	1.35	- .896
	383	1.19	1.17	- 1.66
	393	1.04	1.04	.00
	403	.92	.913	- .719
	413	.82	.822	.243
	423	.73	.750	2.70
Tetradecyl-benzene	283	10.60	10.6	.00
	293	7.68	7.89	2.74
	303	5.80	6.04	4.13
	313	4.51	4.68	3.87
	323	3.61	3.74	3.48
	333	2.95	2.98	1.17
	343	2.47	2.49	.889
	353	2.06	2.06	.00
	363	1.751	1.73	- 1.09
	373	1.507	1.49	- 1.21
	383	1.31	1.29	- 1.82

TABLE A-18 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	393	1.14	1.12	- 1.70
	403	1.01	1.01	.00
	413	.89	.889	- .068
	423	.79	.800	1.29
Pentadecyl-benzene	293	9.02	8.74	- 3.05
	303	6.72	6.67	- .689
	313	5.18	5.22	.762
	323	4.11	4.14	.833
	333	3.33	3.34	.432
	343	2.76	2.74	- .667
	353	2.29	2.28	- .258
	363	1.938	1.92	- .948
	373	1.660	1.65	- .782
	383	1.43	1.42	- .936
	393	1.25	1.23	- 1.87
	403	1.09	1.08	- 1.30
	413	.97	.975	.507
	423	.85	.859	1.09
Hexadecyl-benzene	303	7.76	7.03	- 9.40
	313	5.92	5.54	- 6.43
	323	4.65	4.41	- 5.08
	333	3.74	3.57	- 4.55
	343	3.08	2.95	- 4.36
	353	2.54	2.45	- 3.52
	363	2.14	2.07	- 3.26
	373	1.822	1.78	- 2.19
	383	1.57	1.54	- 1.60
	393	1.36	1.35	- .822
	403	1.19	1.18	- .849
	413	1.04	1.02	- 2.14
	423	.92	.951	3.39

TABLE A-19

CALCULATED AND EXPERIMENTAL VALUES OF VISCOSITIES OF n-ALCOHOLS WITH Z FUNCTION ($Z(T_{rB},C)$)

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3} Z$$

COMPOUND	TEMP. °K	VISCOSITY EXPERIMENTAL CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
Butanol	298.14	2.587	2.61	.834
	303.19	2.251	2.26	.340
	313.19	1.773	1.80	1.38
	323.16	1.424	1.45	2.13
	343.16	.9578	1.00	4.87
	353.16	.8082	.864	6.96
	363.16	.6904	.753	9.06
	373.16	.5995	.668	11.4
	383.16	.5292	.605	14.2
Pentanol	303.19	3.055	2.90	- 4.93
	313.19	2.320	2.20	- 5.35
	323.21	1.774	1.70	- 3.90
	343.12	1.086	1.08	- .490
	353.16	.8476	.883	4.17
	363.17	.6613	.737	11.5
	373.16	.4975	.566	13.8
Hexanol	298.10	4.665	4.57	- 2.13
	303.19	3.932	3.81	- 3.18
	313.31	2.941	2.81	- 4.41
	323.16	2.240	2.12	- 5.35
	343.14	1.356	1.27	- 6.42
	353.16	1.047	1.01	- 3.72
	363.16	.8162	.812	- .482
	373.21	.6264	.664	5.96
	383.16	.4753	.555	16.8
	393.21	.3361	.450	34.0
	403.18	.2264	.385	70.0
Heptanol	298.61	5.627	6.12	8.77
	303.90	4.763	5.10	7.11
	313.67	3.571	3.71	3.88
	323.21	2.764	2.77	.228
	343.16	1.661	1.59	- 4.21
	353.16	1.306	1.23	- 5.50
	363.16	1.034	.974	- 5.75

TABLE A-19 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY EXPERIMENTAL CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	373.16	.818	.778	- 4.89
	427.16	.3989	.280	-29.8
	438.31	.3460	.233	-32.6
	444.46	.3209	.208	-35.2
Octanol	298.16	7.213	8.42	16.8
	303.23	6.064	6.99	15.3
	313.21	4.488	5.01	11.7
	333.26	2.558	2.71	6.06
	343.16	2.038	2.04	.129
	353.16	1.630	1.57	- 3.92
	363.16	1.329	1.21	- 8.70
	373.16	1.104	.962	-12.9
	383.16	.9352	.775	-17.2
	403.16	.6836	.481	-29.6
	412.01	.5631	.424	-24.7
	427.16	.4564	.317	-30.6
	448.91	.3479	.216	-37.8
	458.81	.3120	.184	-41.0
Nonanol	298.16	8.948	11.0	23.1
	303.23	7.436	9.17	23.4
	313.21	5.512	6.56	19.0
	323.76	3.983	4.65	16.6
	343.16	2.444	2.61	6.98
	353.16	1.896	1.99	4.78
	363.16	1.492	1.54	2.95
	373.16	1.180	1.20	1.69
	383.16	.9387	.958	2.08
	403.16	.5738	.579	.837
Decanol	303.23	8.708	11.3	30.2
	313.21	6.616	8.06	21.8
	333.26	3.630	4.29	18.2
	353.26	2.170	2.45	13.0
	373.16	1.353	1.48	9.21
	383.16	1.077	1.17	8.60
	393.16	.8600	.931	8.23
	403.11	.6853	.750	9.50
Dodecanol	303.36	13.51	15.3	13.2
	313.86	9.197	10.8	16.9
	322.91	6.802	8.08	18.7
	333.33	4.926	5.91	20.1
	353.26	2.911	3.42	17.6

TABLE A-19 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY EXPERIMENTAL CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	363.21	2.210	2.66	20.2
	373.16	1.771	2.10	18.6
	384.23	1.408	1.64	16.2
	393.16	1.119	1.28	14.8
	403.01	.9041	1.03	14.5
	413.26	.7257	.838	15.5
	423.15	.5835	.692	18.6
	434.71	.4932	.562	14.0
Tetradecanol	313.16	12.73	6.99	-45.1
	333.16	6.407	3.98	-37.9
	343.16	4.791	3.09	-35.6
	353.19	3.679	2.44	-33.8
	363.21	2.888	1.95	-32.5
	373.16	2.339	1.59	-32.0
	383.25	1.787	1.05	-41.0
	403.36	1.170	.921	-21.3
	427.16	.7452	.640	-14.1
	459.33	.4436	.421	- 5.05
	473.11	.3803	.360	- 5.30
	495.62	.2500	.287	14.7
Hexadecanol	323.16	11.16	13.5	20.8
	333.16	8.01	9.87	23.3
	343.16	5.931	7.40	24.7
	353.16	4.533	5.65	24.7
	363.21	3.485	4.41	26.4
	373.16	2.784	3.51	26.2
	383.25	2.206	2.83	28.4
	393.16	1.842	2.34	27.2
	403.01	1.549	1.94	25.3
	413.26	1.318	1.62	22.8
	423.16	1.139	1.38	20.8
	433.66	1.021	1.20	18.0
	463.21	.7626	.837	9.81
	495.62	.6084	.617	1.44
	522.96	.5078	.508	.054

TABLE A-20

CALCULATED AND REPORTED VALUES OF VISCOSITIES OF BRANCHED ALKYL BENZENES WITH Z FUNCTION OF n-ALKYL BENZENES ($Z(T_{rB},C)$)

$$\mu = \rho^{11/3}\ \beta^3 / M^{8/3}\ N^{1/3}\ Z$$

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
o-Xylene	273	1.108	1.05	- 5.51
	283	.939	.887	- 5.50
	293	.809	.759	- 6.17
	303	.708	.656	- 7.41
	313	.625	.570	- 8.76
	323	.557	.500	-10.3
	333	.501	.441	-12.0
	343	.453	.392	-13.6
	353	.412	.350	-15.2
	363	.376	.313	-16.6
	373	.345	.282	-18.1
	383	.318	.255	-19.7
	393	.294	.232	-21.1
	403	.272	.211	-22.3
	413	.254	.193	-23.9
m-Xylene	273	.808	.962	19.1
	283	.702	.816	16.2
	293	.617	.699	13.3
	303	.549	.604	9.96
	313	.492	.526	6.82
	323	.445	.461	3.58
	333	.405	.407	.450
	343	.370	.361	- 2.35
	353	.340	.323	- 5.13
	363	.314	.289	- 7.85
	373	.290	.261	-10.1
	383	.269	.236	-12.2
	393	.250	.215	-14.2
	403	.233	.196	-16.0
	413	.218	.179	-17.8
p-Xylene	293	.644	.705	9.42
	303	.570	.609	6.82
	313	.508	.530	4.27
	323	.457	.464	1.62

TABLE A-20 (CONTINUED)

COMPOUND	TEMP. °K	VISCOSITY REPORTED CPS	VISCOSITY CALCULATED CPS	PERCENT ERROR
	333	.415	.410	- 1.27
	343	.377	.364	- 3.56
	353	.346	.324	- 6.27
	363	.318	.291	- 8.55
	373	.293	.262	-10.6
	383	.270	.237	-12.3
	393	.250	.215	-14.0
	403	.233	.196	-16.0
	413	.217	.179	-17.6
Isopropyl-benzene	273	1.076	1.11	3.01
	283	.917	.937	2.14
	293	.791	.801	1.29
	303	.693	.693	.00
	313	.612	.605	- 1.07
	323	.545	.534	- 2.04
	333	.490	.475	- 3.07
1-Methyl 4-ethyl-benzene	283	.808	1.06	31.8
	293	.705	.907	28.6
	303	.623	.781	25.4
	313	.556	.679	22.2
	323	.500	.597	19.3
	333	.454	.528	16.4
	343	.415	.472	13.6
	353	.382	.424	11.0

APPENDIX

COMPUTER PROGRAMS

COMPUTER PROGRAM NO. 1

CALCULATION OF EXPERIMENTAL DENSITY VIA HYDROSTATIC WEIGHING METHOD

Symbol	Definitions
C	C_e, cubical coefficient of expansion of Pyrex
VO	V_o or W_A'/D_o, volume of object
DW	D_W, density of balance weights
DA	D_{air}, density of air
TST	t_c, calibration temperature
V1	V_c, immersed volume at t_c
WA1	W_A', apparent weight object in air
WV1	W_A, true weight object in air
NT	Number of densities to be calculated
T2	t , centigrade temperature
WAL	W_L', apparent weight object in liquid
WL	W_L, true weight object in liquid
A	V_t, immersed volume object at t
T2A	T^{-1}, reciprocal absolute temperature
D2C	ρ , mass density of liquid

COMPUTER PROGRAM NO. 1 (Continued)

FORTRAN PROGRAM

```
C             CALCULATION OF DENSITY
              READ, C, VO, DW, DA
              READ, TST
              READ, V1
              READ, WA1
              WV1  =  WA1  +  VO * DA - WA1 * DA / DW
              PUNCH, V1
              READ, NT
              DO 4 I  =  1, NT
              READ, T2, WAL
              WL  =  WAL - (DA*WAL/DW )
              A  =  V1 * (1. + C * (T2 - TST))
              T2A = 1. / (T2 + 273.16 )
              D2C = (WV1 -WL) / A
 4            PUNCH, WL, T2, A, D2C, T2A
              STOP
              END
```

COMPUTER PROGRAM NO. 2

CALCULATION OF EXPERIMENTAL KINEMATIC VISCOSITY

Symbol	Definitions
COMP	Compound name
B	B, kinetic energy correction constant
C	C_1, viscometer constant
NT	Number of kinematic viscosities to be calculated
T	t, centigrade temperature
T1	t_i, efflux time
V	V_i, kinematic viscosity
TK	T, absolute temperature
TA	T^{-1}

FORTRAN PROGRAM

```
C       VISCOSITY CALCULATIONS
        READ, COMP
        PUNCH, COMP
        READ, B, C
        READ, NT
        DO 4 I = 1, NT
        READ, T, T1
        V = (C*T1) - B/T1
        TK = T + 273.16
        TA = 1. / TK
4       PUNCH, T, V, TA
        STOP
        END
```

COMPUTER PROGRAM NO. 3

DETERMINATION OF a_1, a_2, a_3 and a_4 CONSTANTS IN EQUATION 28 BY NON-LINEAR LEAST SQUARE METHOD

Symbol	Definitions
N	Number of data points in analysis
B1	Number of data points in analysis
XX1	t, temperature (Centagrade)
YY	ρ, mass density
XX	t^{-1}
B2	Summation of XX
X2	t^{-2}
B3	Summation t^{-2}
X3	t^{-3}
B4	Summation t^{-3}
B5	Summation ρ
X4	t^{-4}
B6	Summation t^{-4}
R	Product t^{-1} and ρ
B7	Summation product t^{-1} and ρ
X5	t^{-5}
B8	Summation t^{-5}
S	product t^{-2} and ρ
B9	Summation product t^{-2} and ρ
X6	t^{-6}
B10	Summation t^{-6}
T	Product t^{-3} and ρ

COMPUTER PROGRAM NO. 3 (Continued)

FORTRAN PROGRAM

```
              X3 = XX**3
              B4 = B4 + X3
              B5 = B5 + YY
              X4 = XX**4
              B6 = B6 + X4
              R = XX*YY
              B7 = B7 + R
              X5 = XX**5
              B8 = B8 + X5
              S = X2*YY
              B9 = B9 + S
              X6 = XX**6
              B10 = B10 + X6
              T = X3*YY
333           B11 = B11 + T
              PUNCH, B1
              PUNCH, B2, B3, B4, B5, B6
              PUNCH, B7, B8, B9, B10, B11
C         MAIN PROGRAM GAUSS-JORDAN ELIMINATION METHOD
              N = 4
              NEW = N-1
              NOW = N + 1
              A (1,1) = B1
              A (1,2) = B2
```

COMPUTER PROGRAM NO. 3 (Continued)

FORTRAN PROGRAM

```
              A (1,3) = B3
              A (1,4) = B4
              A (1,5) = B5
              A (2,1) = B2
              A (2,2) = B3
              A (2,3) = B4
              A (2,4) = B6
              A (2,5) = B7
              A (3,1) = B3
              A (3,2) = B4
              A (3,3) = B6
              A (3,4) = B8
              A (3,5) = B9
              A (4,1) = B4
              A (4,2) = B6
              A (4,3) = B8
              A (4,4) = B10
              A (4,5) = B11
              DO 300 MOM = 1,N
300           PUNCH, A(MOM,1),A(MOM,2),A(MOM,3),A(MOM,4),A(MOM,5)
              L = 0
              DO 2 K = 1, NEW
              L = L + 1
```

COMPUTER PROGRAM NO. 3 (Continued)

FORTRAN PROGRAM

```
              M = 0
              DO 2 I = L,N
              IF (A(I,L) ) 6,5,6
5             IF (N-I) 2,2,8
8             LAM = I + 1
              IF (A(LAM,L) ) 9,8,9
9             DO 7 J3 = L, NOW
              I3 = LAM
              SAM = A (L,J3)
              A (L,J3) = A (LAM,J3)
7             A (LAM, J3) = SAM
6             TEMP = A (I,L)
              M = M + 1
              DO 2 J = L, NOW
              A (I,J) = A (I,J)/TEMP
              IF (M-1) 2,2,1
1             A (I,J) = A (L,J) - A (I,J)
2             CONTINUE
              IF (A (N,N) ) 16,17,16
17            DO 18 ICE = 1,N
18            X (ICE) = 0.0
              GO TO 23
16            X (N) = A (N,N + 1)/A (N,N)
              NNN = N
```

COMPUTER PROGRAM NO. 3 (Continued)

FORTRAN PROGRAM

```
21          NN = NNN - 1
            IF (NN) 23,23,22
22          DO 20 KAM = 1, NNN
            KM = NNN - KAM
            IF (KM) 40,40,41
41          CONTINUE
            A (KM, NNN) = A (KM, NNN)*X(NNN)
            A (KM, N + 1) = A (KM, N + 1) - A (KM, NNN)
20          A (KM, NNN) = 0.0
40          CONTINUE
            X (NN) = A (NN, N+1)
            NNN = NNN - 1
            GO TO 21
23          CONTINUE

C       FINAL VALUES OF X (I) ARE NOW THE COEFFICIENTS OF
C       THE CUBIC EQUATION
C       THAT IS X (1) = A1, X (2) = A2, X (3) = A3, X (4) = A4
C       THE FINAL EQUATION IS OF THE FORM Y = A1 + A2*X + A3*
C       X**2 + A4*X**3
            DO 24 JIM = 1,N
24          PUNCH, X (JIM)
            STOP
            END
```

COMPUTER PROGRAM NO. 4

CALCULATION ABSOLUTE VISCOSITY OF LIQUID VIA EQUATION 57 AND COMPARISON WITH REPORTED VALUES

Symbol	Definitions
SUM1	Summation of error in viscosity
COMP	Compound name
TB	T_B, normal boiling point
XMW	M, molecular weight
BETA	β , empirical structural contribution factor
NT	Number of viscosities to be calculated
T	T, absolute temperature
VISE	μ_r, reported viscosity
TRB	T_{rB}, reduced temperature with respect to boiling point
AN	N, Avogadro number
YYMU	Numerator of equation 57
ZMU	Denominator of equation 57
VIS	μ, calculated viscosity
ER1	Error in calculated viscosity
RU1	Z, deviation
ABSF (ER1)	Absolute value of error in viscosity
XNT	Number of viscosities to be calculated
AVG	Average error in calculated viscosity
D	ρ , mass density

COMPUTER PROGRAM NO. 4 (Continued)

FORTRAN PROGRAM

```
C       PREDICTED VISCOSITY WITHOUT CORRECTION
1              SUM1 = 0.
               READ, COMP
               PUNCH, COMP
               READ, TB, XMW, BETA
               READ, NT
               DO 10 I = 1, NT
               READ, T, VISE, D
               TRB = T/TB
               PUNCH, T
               PUNCH, TRB
               AN = 6.023 E 23
               YYMU = D ** (11./3.) * BETA **3
               ZMU = AN ** (1./3.) * (XMW) ** (8./3.)
               VIS = YYMU * 100./ZMU
               ER1 = (VIS - VISE) * 100./VISE
               RU1 = VIS/VISE
               SUM1 = SUM1 + ABSF(ER1)
10             PUNCH, VISE, VIS, ER1, RU1, SUM1
               XNT = NT
               AVG = SUM1 / XNT
               PUNCH, AVG
               GO TO 1
               STOP
               END
```

COMPUTER PROGRAM NO. 5

DETERMINATION OF a, b, c CONSTANTS IN Z FUNCTION EQUATION 70 BY NON-LINEAR LEAST SQUARE METHOD

Symbol	Definitions
N	Number of data points in analysis
R	T_{rB}, reduced temperature with respect to boiling point
VIS	Z, deviation
RT	Natural logarithm of T_{rB}, LOGF(R), ln (T_{rB})
VISR	Natural logarithm of Z, LOGF (VIS), ln (Z)
SUMA	Summation of natural logarithm of T_{rB}
SUMB	Summation of natural logarithm of Z
A	Product of ln (T_{rB}) ln (Z)
SUMC	Summation of product ln (T_{rB}) ln (Z)
RT2	Ln^2 (T_{rB})
B	Product ln^2 (T_{rB}) ln (Z)
SUMD	Summation ln^2 (T_{rB})
SUME	Summation of product ln^2 (T_{rB}) ln (Z)
RT3	Ln^3 (T_{rB})
RT4	Ln^4 (T_{rB})
SUMG	Summation of ln^3 (T_{rB})
SUMH	Summation of ln^4 (T_{rB})
XN	Number of data points
D	Determinate
E	Determinate

COMPUTER PROGRAM NO. 5 (Continued)

Symbol	Definitions
G	Determinate
H	Determinate
C1, C2, C3	a, b, c respectively, disposable constants in equation 70

FORTRAN PROGRAM

```
C       LEAST SQ. METHOD FOR QUADRATIC-LOG-LOG
              READ, N
              SUMA = O.
              SUMB = O.
              SUMC = O.
              SUMD = O.
              SUME = O.
              SUMG = O.
              SUMH = O.
              DO 22  I = 1, N
              READ, R, VIS
              RT = LOGF (R)
              VISR = LOGF (VIS)
              SUMA = SUMA + RT
              SUMB = SUMB + VISR
              A = RT*VISR
              SUMC = SUMC + A
              RT2 = RT*RT
              B = RT2*VISR
```

COMPUTER PROGRAM NO. 5 (Continued)

FORTRAN PROGRAM

```
          SUMD = SUMD + RT2
          SUME = SUME + B
          RT3 = RT**3
          RT4 = RT**4
          SUMG = SUMG + RT3
22        SUMH = SUMH + RT4
          PUNCH, SUMA, SUMB, SUMC, SUMD, SUME, SUMG, SUMH
          XN = N
          D1 = XN*SUMD*SUMH + SUMA*SUMG*SUMD + SUMD*SUMA*SUMG
          D2 = XN*SUMG*SUMG + SUMA*SUMA*SUMH + SUMD**3
          D = D1-D2
          E1 = SUMB*SUMD*SUMH + SUMA*SUMG*SUME + SUMD*SUMC*SUMG
          E2 = SUMB*SUMG*SUMG + SUMD**2*SUME + SUMA*SUMC*SUMH
          E = E1-E2
          G1 = XN*SUMC*SUMH+SUMA*SUMD*SUME+SUMD*SUMB*SUMG
          G2 = XN*SUME*SUMG+SUMA*SUMB*SUMH+SUMD*SUMC*SUMD
          G = G1-G2
          H1 = XN*SUMD*SUME+SUMA*SUMG*SUMB+SUMD*SUMA*SUMC
          H2 = XN*SUMG*SUMC+SUMA*SUMA*SUME+SUMD*SUMD*SUMB
          H = H1-H2
          PUNCH, XN, D, E, G, H
          C1 = E/D
          C2 = G/D
          C3 = H/D
          PUNCH, C1, C2, C3
          STOP
          END
```

COMPUTER PROGRAM NO. 6

CALCULATION ABSOLUTE VISCOSITY OF LIQUID VIA EQUATION 71 WITH Z FUNCTION ($Z = f(T_{rB})$) AND COMPARISON WITH REPORTED VALUES

Symbol	Definitions
C1, C2, C3	a, b, c respectively, disposable constants in equation 70
SUM1	Summation of error in viscosity
COMP	Compound Name
TB	T_B, normal boiling point
XMW	M, molecular weight
BETA	β , empirical structural contribution factor
NT	Number of viscosities to be calculated
T	T, absolute temperature
D	ρ , mass density
VISE	μ_r, reported viscosity
TRB	T_{rB}, reduced temperature with respect to boiling point
ZLOG	Natural logarithm of Z
LOGF (TRB)	Natural logarithm of T_{rB}
EXPF (ZLOG)	Exponential function of natural logarithm of Z
AN	N, Avogadro number
YYMU	Numerator of equation 71
ZMU	Denominator of equation 71
VIS	μ , calculated viscosity
ER1	Error in calculated viscosity
RU1	Z, deviation

COMPUTER PROGRAM NO. 6 (Continued)

Symbol	Definitions
ABSF (ER1)	Absolute value of error in viscosity
XNT	Number of viscosities to be calculated
AVG	Average error in calculated viscosity

FORTRAN PROGRAM

```
C       PREDICTED VISCOSITY WITH Z CORRECTION (NOT FUNCTION
C       OF CARBON NO.)
                  READ, C1, C2, C3
1                 SUM1 = 0.
                  READ, COMP
                  PUNCH, COMP
                  READ, TB, XMW, BETA
                  READ, NT
                  DO 10 I = 1, NT
                  READ, T, D, VISE
                  TRB = T/TB
                  PUNCH, T
                  ZLOG = C1 + C2*LOGF (TRB) + C3*LOGF (TRB) *LOGF(TRB)
                  Z = EXPF (ZLOG)
                  PUNCH, TRB, Z
                  AN = 6.023E23
                  YYMU = D** (11./3.)*BETA**3
                  ZMU = AN**(1./3.)*(XMW)**(8./3.)*Z
                  VIS = YYMU*100./(ZMU)
                  ER1 = (VIS-VISE)*100./VISE
```

COMPUTER PROGRAM NO. 6 (Continued)

FORTRAN PROGRAM

```
              RU1 = VIS/VISE
              SUM1 = SUM1 + ABSF(ER1)
10            PUNCH, VISE, VIS, ER1, RU1, SUM1
              XNT = NT
              AVG = SUM1/XNT
              PUNCH, AVG
              GO TO 1
              STOP
              END
```

COMPUTER PROGRAM NO. 7

DETERMINATION OF a, b, c AS FUNCTION OF CARBON NUMBER C FOR EQUATIONS 73, 74, 75 BY LINEAR LEAST SQUARE METHOD

Symbol	Definitions
N	Number of data points
CN	C, carbon number
C	Either a, b or c respectively
SUMA	Summation of C
SUMB	Summation of either a, b, or c
A	Product of C, and either a, b, or c
SUMC	Summation of product C and either a, b, or c
CN2	C^2
SUMD	Summation of C^2
XN	Number of data points
D	Determinate
E	Determinate
G	Determinate
S	a'_1, e' or h'
T	b', f' or j'

FORTRAN PROGRAM

```
C       LEAST SQ. METHOD FOR ST. LINE
              READ, N
              SUMA = 0.
              SUMB = 0.
              SUMC = 0.
```

COMPUTER PROGRAM NO. 7 (Continued)

FORTRAN PROGRAM

```
                SUMD = 0.
                DO 22 I = 1, N
                READ, CN, C
                SUMA = SUMA + CN
                SUMB = SUMB + C
                A = CN*C
                SUMC = SUMC + A
                CN2 = CN*CN
22              SUMD = SUMD + CN2
                PUNCH, SUMA, SUMB, SUMC, SUMD
                XN = N
                D = XN*SUMD -SUMA*SUMA
                E = SUMB*SUMD -SUMA*SUMC
                G = XN*SUMC -SUMA*SUMB
                PUNCH, XN, D, E, G
                S = E/D
                T = G/D
                PUNCH, S, T
                STOP
                END
```

COMPUTER PROGRAM NO. 8

DETERMINATION OF a, b, c AS FUNCTION OF CARBON NUMBER C FOR EQUATIONS 73, 74, 75 BY NON-LINEAR LEAST SQUARE METHOD

Symbol	Definitions
N	Number of data points
RT	C, carbon number
VISR	Either a, b or c respectively
SUMA	Summation of C
SUMB	Summation of either a, b, or c
A	Product of C, and either a, b, or c
SUMC	Summation product C and either a, b, or c
RT2	C^2
B	Product C^2 and either a, b, or c
SUMD	Summation C^2
SUME	Summation of product C^2 and either a, b, or c
RT3	C^3
RT4	C^4
SUMG	Summation of C^3
SUMH	Summation of C^4
XN	Number of data points
D	Determinate
E	Determinate
G	Determinate
H	Determinate
C1	a_1', e' or h'
C2	b', f' or j'
C3	d', g' or k'

COMPUTER PROGRAM NO. 8 (Continued)

FORTRAN PROGRAM

```
C       LEAST SQ. METHOD FOR QUADRATIC REC. COORDINATES
              READ, N
              SUMA = 0.
              SUMB = 0.
              SUMC = 0.
              SUMD = 0.
              SUME = 0.
              SUMG = 0.
              SUMH = 0.
              DO 22 I = 1, N
              READ, RT, VISR
              SUMA = SUMA + RT
              SUMB = SUMB + VISR
              A = RT*VISR
              SUMC = SUMC + A
              RT2 = RT*RT
              B = RT2*VISR
              SUMD = SUMD + RT2
              SUME = SUME + B
              RT3 = RT**3
              RT4 = RT**4
              SUMG = SUMG + RT3
22            SUMH = SUMH + RT4
              PUNCH, SUMA, SUMB, SUMC, SUMD, SUME, SUMG, SUMH
```

COMPUTER PROGRAM NO. 8 (Continued)

FORTRAN PROGRAM

```
XN = N
D1 = XN*SUMD*SUMH + SUMA*SUMG*SUMD + SUMD*SUMA*SUMG
D2 = XN*SUMG*SUMG + SUMA*SUMA*SUMH + SUMD**3
D = D1 - D2
E1 = SUMB*SUMD*SUMH + SUMA*SUMG*SUME + SUMD*SUMC*SUMG
E2 = SUMB*SUMG*SUMG + SUMD**2*SUME + SUMA*SUMC*SUMH
E = E1 - E2
G1 = XN*SUMC*SUMH+SUMA*SUMD*SUME+SUMD*SUMB*SUMG
G2 = XN*SUME*SUMG+SUMA*SUMB*SUMH+SUMD*SUMC*SUMD
G = G1 - G2
H1 = XN*SUMD*SUME+SUMA*SUMG*SUMB+SUMD*SUMA*SUMC
H2 = XN*SUMG*SUMC+SUMA*SUMA*SUME+SUMD*SUMD*SUMB
H = H1 - H2
PUNCH, XN, D, E, G, H
C1 = E/D
C2 = G/D
C3 = H/D
PUNCH, C1, C2, C3
STOP
END
```

COMPUTER PROGRAM NO. 9

CALCULATION ABSOLUTE VISCOSITY OF LIQUID VIA EQUATION 71 WITH Z FUNCTION ($Z = Z(T_{rB}, C)$) AND COMPARISON WITH REPORTED VALUES

Symbol	Definitions
S, X, X2	a_1', b', d' respectively, disposable constants in equation 73
CA, CB, CC	e', f', g' respectively, disposable constants in equation 74
S2, T2, T3	h', j', k' respectively, disposable constants in equation 75
SUM1	Summation of error in viscosity
COMP	Compound name
CN	C, carbon number
TB	T_B, normal boiling point
XMW	M, molecular weight
BETA	β , empirical structural contribution factor
NT	Number of viscosities to be calculated
T	T, absolute temperature
D	ρ , mass density
VISE	μ_r, reported viscosity
TRB	T_{rB}, reduced temperature with respect to boiling point
C1, C2, C3	a, b, c respectively
ZLOG	Natural logarithm of Z
LOGF (TRB)	Natural logarithm of T_{rB}
EXPF (ZLOG)	Exponential function of natural logarithm of Z
AN	N, Avogadro number
YYMU	Numerator of equation 71

COMPUTER PROGRAM NO. 9 (Continued)

Symbol	Definitions
ZMU	Denominator of equation 71
VIS	μ, calculated viscosity
ER1	Error in calculated viscosity
RU1	Z, deviation
ABSF (ER1)	Absolute value of error in viscosity
XNT	Number of viscosities to be calculated
AVG	Average error in calculated viscosity

FORTRAN PROGRAM

```
C       PREDICTED VISCOSITY WITH Z CORRECTION, Z FUNCTION OF
C       CARBON NO.
              READ, S, X, X2
              READ, CA, CB, CC
              READ, S2, T2, T3
1             SUM1 = 0.
              READ, COMP
              PUNCH, COMP
              READ, CN
              READ, TB, XMW, BETA
              READ, NT
              DO 10 I = 1, NT
              READ, T, VISE, D
              TRB = T/TB
              C1 = S + X*CN + X2*CN*CN
              C2 = CA + CB*CN + CC*CN*CN
```

COMPUTER PROGRAM NO. 9 (Continued)

FORTRAN PROGRAM

```
               C3 = S2 + T2*CN + T3*CN*CN
               ZLOG = C1 + C2*LOGF(TRB) + C3*LOGF(TRB)*LOGF(TRB)
               Z = EXPF (ZLOG)
               PUNCH, T
               PUNCH, TRB, Z
               AN = 6.023 E23
               YYMU = D**(11./3.)*BETA**3
               ZMU = AN**(1./3.)*(XMW)**(8./3.)*Z
               VIS = YYMU*100./(ZMU)
               ER1 = (VIS - VISE)*100./VISE
               RU1 = VIS/VISE
               SUM1 = SUM1 + ABSF (ER1)
10             PUNCH, VISE, VIS, ER1, RU1, SUM1
               XNT = NT
               AVG = SUM1/XNT
               PUNCH, AVG, C1, C2, C3
               GO TO 1
               STOP
               END
```

APPENDIX

SAMPLE CALCULATIONS

Use of Equation 57 to Calculate Viscosity

Example 1: Calculate the viscosity of n-octane at 50°C (323°K) via equation 57

Density, ρ (2) = 0.6784 g/cm^3

Additive constitutive constant, β (Table 12) = 7954 (cm)$^{10/3}$ /((sec)$^{1/3}$(mole))

Molecular weight, M = 114.22

Avogadro number, N = 6.0238 x 10^{23} molecules/g mole

Substitution of these values in equation 57

$$\mu = \rho^{11/3} \beta^3 / M^{8/3} N^{1/3}$$

gives

$$\mu = (0.6784)^{11/3} (7954)^3 / (114.22)^{8/3} (6.0238 \times 10^{23})^{1/3}$$

$$\mu = 4.68 \times (10^{-3}) \text{ g/(cm) (sec)}$$

or 0.468 cps (calculated μ)

The reported viscosity, μ_r (2) is 0.3946 cps

Error in calculated viscosity

$$\text{Error} = 100 (\mu - \mu_r)/\mu_r$$

$$\text{Error} = 100 (0.468 - 0.3946)/0.3946$$

$$\text{Error} = 18.5\%$$

SAMPLE CALCULATIONS (Continued)

Use of Equation 71 to Calculate Viscosity

Example 2: Calculate the viscosity of n-octane at 50°C via equation 71

Normal boiling point, T_B = 398.7°K (2)

Coefficients for equation 70 (Table 16) $a = 0.323$, $b = 0.239$, $c = -3.56$

Reduced boiling point

$$T_{rB} = T/T_B$$

$$T_{rB} = 323/398.7 = 0.810$$

Deviation factor Z, from equation 70 (or Figure 22)

$$Z = \exp\left(a + b\,\ell n\,(T_{rB}) + c\,\ell n^2\,(T_{rB})\right)$$

$$Z = \exp\left(0.323 + 0.239\,\ell n\,(.810) - 3.56\,\ell n^2(0.810)\right)$$

$$Z = 1.12$$

Viscosity of n-octane at 50°C by equation 71

$$\mu = \rho^{11/3}\beta^3/(M^{8/3}N^{1/3}Z)$$

See Example 1

$$\mu = 4.68 \times 10^{-3}/1.12$$

$$\mu = 4.17 \times 10^{-3}\ \mathrm{g/(cm)\,(sec)}$$

or <u>0.417 cps</u> (calculated μ)

Error in calculated viscosity

$$\text{Error} = 100\,(\mu - \mu_r)/\mu_r$$

$$\text{Error} = 100\,(0.417 - 0.3946)/0.3946$$

$$\text{Error} = \underline{5.71\%}$$

SAMPLE CALCULATIONS (Continued)

Use of Parametric Equations to Calculate Viscosity

Example 3: Calculate the viscosity of n-octane at $50^{\circ}C$ via parametric equations

See Examples 1 and 2

Number of carbon atoms in n-octane, C = 8

Constants for equations 73, 74, 75 (Table 19) employed to solve for a, b, c

$$a = 0.496 - 0.0147\ (8) + 0 = 0.379$$

$$b = -0.279 + 0.0978\ (8) - 0.00498\ (8)^2 = 0.185$$

$$c = -3.15 - 0.0573\ (8) + 0 = -3.61$$

Substitution of these values in equation 70 gives

$$Z = \exp\ (0.379 + 0.185\ \ell n(0.810) - 3.61\ \ell n^2(0.810))$$

$$Z = 1.198$$

Viscosity by equation 71

$$\mu = \rho^{11/3}\beta^3 / (M^{8/3} N^{1/3} Z)$$

$$\mu = 4.68 \times 10^{-3}/1.198$$

$$\mu = 3.905 \times 10^{-3}\ g/(cm)\ (sec)$$

or 0.3905 cps (calculated μ)

Error in calculated viscosity

$$\text{Error} = 100\ (\mu - \mu_r)/\mu_r$$

$$\text{Error} = 100\ (0.3905 - 0.3946)/0.3946$$

$$\text{Error} = -1.03\%$$

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