RP244

# COMPRESSIBILITY AND THERMAL EXPANSION OF PETROLEUM OILS IN THE RANGE 0° TO 300° C.[1]

By R. S. Jessup

ABSTRACT

Measurements of compressibility and thermal expansion are reported on representative samples of petroleum oils from various sources over the pressure range 0 to 50 kg/cm² (gauge), and the temperature range 0° to 300° C.

It was found from the results obtained on these samples that the compressibility and thermal expansion of two samples of the same specific gravity, but from different sources, differed more than 30 per cent at the higher temperatures, whereas oils of the same specific gravity and also the same viscosity had the same compressibility and thermal expansion within rather narrow limits. In other words, with a knowledge of the specific gravity and viscosity of the oils, it was possible to represent all the measured volumes within less than 0.5 per cent over the entire range of temperature and pressure covered by the measurements.

CONTENTS



## I. INTRODUCTION

The extensive use of cracking processes in the petroleum industry, and the increased use of petroleum oils as heat-transfer media in various industrial processes have created a need for data on the properties of these oils at relatively high temperatures and pressures. Data on two properties, namely, compressibility and thermal expansion, are required in order to yield information on the volume which a known quantity of oil measured at atmospheric pressure and ordinary temperature will occupy at higher temperatures and pressures. Existing data on these two properties of petroleum oils were deficient either in the pressure and temperature ranges covered or in the variety of oils studied.

[1] This paper contains results obtained in an investigation of "The Thermodynamic Properties of Petroleum Hydrocarbons" listed as Project No. 38 of American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by John D. Rockefeller. This fund is being administered by the institute with the cooperation of the Central Petroleum Committee of the National Research Council.

The work described in this paper was undertaken for the purpose of supplying sufficiently comprehensive data in the range of pressure and temperature of greatest practical interest to make the data applicable in so far as possible to any petroleum oil regardless of its source or chemical composition. For this purpose data were obtained on samples of various oils from different sources.

The upper limit to which the measurements could be carried without serious loss of accuracy was 300° C. Even at this temperature cracking was evidenced by an appreciable increase in volume with time. Since the change in volume of these oils with pressure is rela- [illegible] and approximately linear at constant temperature over the pressure range ordinarily encountered in practice, the measurements were not carried above a pressure of 50 kg/cm² (710 lbs./in.²) which was considered to be a safe limit for the glass apparatus employed.

## II. MATERIAL

The samples of oil used in this investigation and the information as to their source were submitted by various oil companies through the courtesy of the American Petroleum Institute. They appear to be reasonably representative of those types of American petroleum oils, namely, gas oils and lubricating oils, which are or may be heated to high temperatures in practice. Crude oils were purposely not included among the oils here investigated because many such oils contain considerable amounts of dissolved gases, for example, methane. The effect upon compressibility and thermal expansion of known amounts of dissolved gases is being studied as a special extension of this investigation.

Three samples of gasoline and one sample of liquefied petroleum gas were included, partly to yield additional or confirmatory information on these types of petroleum products, and partly because they were convenient materials for the initial measurements, having relatively large compressibility and thermal expansion at ordinary temperatures.

## III. APPARATUS AND METHODS

### 1. DESCRIPTION OF APPARATUS

The apparatus used is shown schematically in Figure 1. The bulbs, *A* and *B*, are made of pyrex laboratory glass and were annealed at a temperature of about 520° C. for three days. The volumes of the bulbs are approximately 24 cm³ and 5.7 cm³, respectively.

The connecting capillary tubing has an internal diameter of about 1 mm. The brass unions, *b* and *d*, are soldered to the glass by a method described by McKelvy and Taylor,[2] and by Meyers.[3] The bulb, *B*, is connected to the steel valve, $V_2$, by means of the steel union, *f*, and the steel tube, *t*, the joints being made with de Khotinsky cement. Copper-constantan thermocouple junctions are cemented to the glass capillary tubing at $c_1$, $c_2$, $c_3$, etc. At points where there are sometimes large temperature gradients along the tubing, the effect of heat conduction along the thermocouple leads is minimized by winding the wires several times around the tube on each side of those junctions. A millimeter scale engraved on a glass mirror is

[2] J. Am. Chem. Soc., 42, p. 1364; 1920.

[3] J. Am. Chem. Soc., 45, p. 2135; 1923.

mounted behind the capillary U tube, *gh*. The entire apparatus is mounted on a steel frame which is supported on a special clamp stand in such a way that it can be raised or lowered, or moved about on the table. The union, *d*, is connected through the valve, $V_3$, and flexible copper tubing to a pressure gauge, and through valve, $V_4$, to a cylinder of carbon dioxide. The valve, $V_5$ can be opened to the atmosphere.

Other apparatus used which need not be described in detail include a vacuum pump capable of reducing the pressure to about 0.3 mm

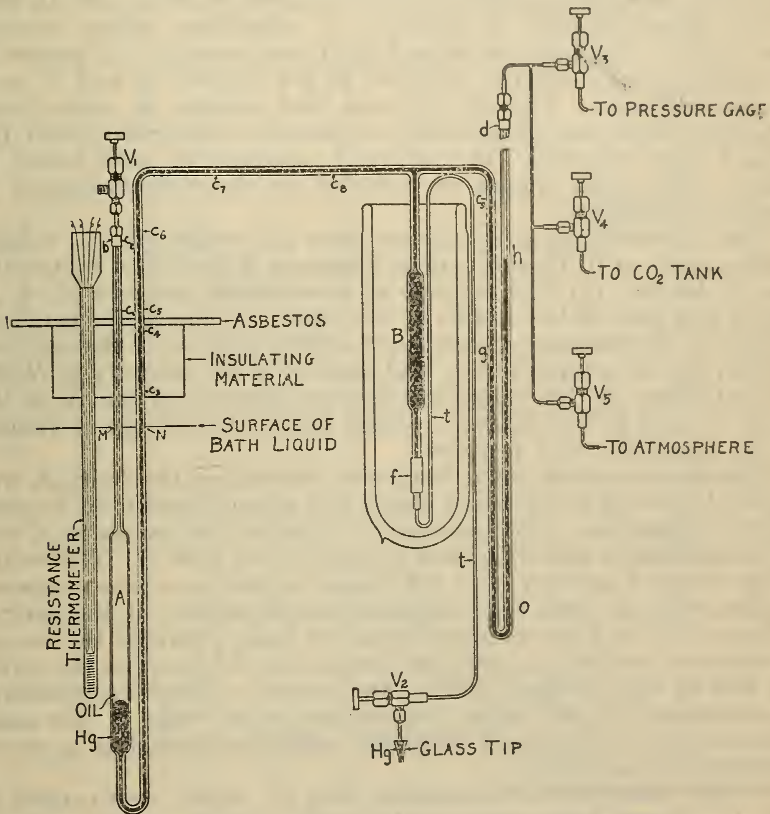


FIGURE 1.—*Schematic drawing of apparatus*

of mercury; two thermoregulated baths; a closed end mercury manometer for roughly indicating the pressure; a high precision piston pressure gauge of the dead-weight type for accurate pressure measurements; a portable potentiometer for measuring the emf of thermocouples; a Wheatstone bridge, galvanometer, and platinum resistance thermometer for temperature measurements.

## 2. METHODS OF OBSERVATION

The method of observation used in the measurements on the first four samples which were not carried above 70° C., was as follows: With valves, $V_2$, $V_3$, $V_4$, and $V_5$ (fig. 1) closed the apparatus was evacuated through $V_1$. Mercury was then admitted through $V_2$ until the bulbs, *B* and *A*, were entirely filled, and the capillary above the bulb, *A*, was filled within a few centimeters of the soldered joint, *b*. Then with the bulbs, *A* and *B*, immersed in ice baths, the oil sample was admitted through $V_1$ until the bulb, *A*, and capillary were filled with the sample to a desired point, *g*, on the U tube. The U tube from *g* to *h*, and the bulb, *B*, were left filled with mercury. The valve, $V_1$, was then closed, and with $V_5$ open to the atmosphere the positions of the menisci, *g* and *h*, were read on the scale. The valve, $V_5$, was then closed and the pressure increased to 50 kg/cm$^2$, in convenient steps (usually 10 kg/cm$^2$), by admitting carbon dioxide through $V_4$. The pressure at each step was measured by means of the piston gauge, and the positions of the menisci, *g* and *h*, were read on the scale. The pressure was then reduced to atmospheric in similar steps, the observations of pressure and positions of the menisci being repeated. It was found necessary to allow about 10 minutes after each change in pressure for the reestablishment of thermal equilibrium.

These observations give sufficient data for computing the volume of the sample at 0° C. and various pressures, if the following quantities are known: (1) The volumes at atmospheric pressure of *A*, *B*, and of that part of the sample in the valve, $V_1$, and in the capillary tubing; (2) the volume per unit length of the right arm of the capillary U tube; (3) the compressibility and amount of the mercury in *B* and in the U tube; (4) the compressibility and amount of the oil in the valve, $V_1$, and in the capillary tubing; and (5) the change in volume of the apparatus with pressure.

After the measurements at 0° C. were completed, the bulb, *A*, was removed from the ice bath and placed in a stirred liquid bath at some higher temperature. The increase in volume of the sample in *A* was accommodated by removing some of the mercury from *B*. The weight of the removed mercury, and the change in position of the meniscus, *h*, give sufficient data for computing the expansion of the sample between 0° C. and the temperature of the bath, provided the change in volume of the bulb, *A*, and the expansion of the liquid in the valve, $V_1$, and in the capillary tubing are known. The compressibility measurements at the higher temperature were made in the same way as at 0° C. The above procedure could be repeated at as many temperatures as desired.

For the measurements on samples 5 to 14, which were carried to 300° C., it was found desirable to modify the procedure outlined above as follows: The bulb, *A*, was only partially filled with the sample at 0° C. leaving sufficient mercury in *A* to take care of the expansion of the sample when heated to 300° C. The volume of the sample in *A* was determined by weighing the displaced mercury. The observations of compressibility and thermal expansion were made in the same way as before. This method has the following advantages: (1) The volume corrections for changes in temperature of the mercury in capillary tubing outside of the bath are smaller because mercury expands less than oil; and (2) the entire sample, with the exception of the small amount in the valve, $V_1$, and in the short length of capillary tube between $V_1$ and *M*, is at a uniform temperature. This method simplifies considerably the computation of the results, although it introduces two minor disadvantages: (1) A separate measurement must be made of the volume of each sample at 0° C., and (2) the height of the mercury column between $h$ and the oil-mercury meniscus in $A$ can not be observed directly. The latter is not serious, however, as the position of the oil-mercury meniscus can be computed with sufficient accuracy from the known amount of mercury in $A$.

### 3. TEMPERATURE OF EMERGENT STEM

One of the largest corrections to the expansion data is for the expansion of the oil and mercury in those parts of the capillary tubing which

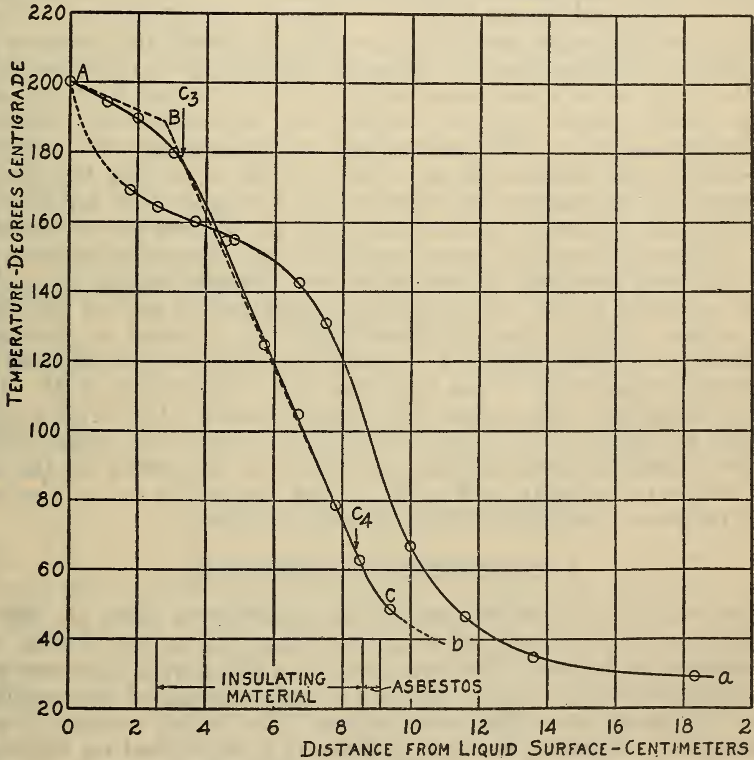


FIGURE 2.—*Temperature distribution along emergent stem*

extend out of the bath. In order to determine the shape of the temperature distribution curve along this emergent stem the following experiment was performed: A thermocouple junction was cemented to a long pyrex capillary tube, practically identical with the tubing shown in Figure 1. With the bath maintained at the constant temperature of 200° C., this tube was placed with one end in the bath and one end extending into the room. Measurements of the emf of the thermocouple were made when the junction was at various distances from the surface of the liquid. The tube was allowed to remain in each position until the reading of the thermocouple had become steady. In Figure 2 the observed temperatures are plotted against distance from the liquid surface of the bath. Curve ($a$) was obtained when the bath was covered with a sheet of asbestos about 0.5 cm thick, leaving an air space 8.6 cm deep between the cover and the surface of the bath liquid. Curve (*b*) was obtained when insulating material 6 cm in thickness was attached to the lower side of the asbestos cover, leaving an air space of only 2.6 cm. Temperature equilibrium was attained more quickly in case (*a*), but the shape of the temperature-distribution curve is such that a number of thermocouples would be required to determine it. On the other hand, curve (*b*) is much simpler and for the purpose of calculating the stem correction, can be still further simplified by replacing that part of it which represents conditions up to 9 cm from the liquid surface, by the dotted lines *A B* and *B C*. The maximum difference between the experimental curve and the dotted lines is about 5° C., while the integrated temperature difference is practically zero. Since an error of 5° C. over the entire length of the curve would cause an error of only about 0.004 per cent in the total volume of the sample, the approximation appeared sufficiently accurate. The greater ease of determining the temperature-distribution curve with the thicker bath cover was thought to outweigh the advantage of more rapid attainment of equilibrium with the thinner cover, and consequently the thicker cover was used.

In the measurements of compressibility and thermal expansion, the line *B C* was obtained by means of two thermocouples ($c_3$ and $c_4$, fig. 1) attached to one of the two stems projecting out of the bath. The points at which these thermocouples are attached are indicated by the two arrows in Figure 2. The line *A B* was obtained from the observed temperature of the bath and the temperature at *B*. It is assumed that the temperature distribution between the liquid surface and the top of the cover is the same along both of the stems which project out of the bath. This assumption is supported by the fact that the two couples ($c_1$ and $c_5$, fig. 1) just above the top of the bath cover indicated practically identical temperatures.

## 4. CALIBRATION OF APPARATUS

The volume of the right arm of the capillary U tube, *gh*, (fig. 1) from the zero of the scale up to various other points on the scale was determined as follows: The apparatus was filled with mercury with the exception of the valve, $V_1$, and a short length of the capillary below it, which were filled with water. The bulbs, *A* and *B*, were immersed in ice baths, and the position of *h* was noted on the scale. A small amount of mercury was removed through valve, $V_2$, caught in a small beaker and weighed, and the new position of the meniscus noted. This process was repeated until the meniscus had reached the zero of the scale. The temperature of the mercury was assumed to be that of a mercurial thermometer hung beside the U tube. A correction for the change in pressure due to change in the height of *h* was applied to the readings. Figure 3 shows the deviations of the observed volumes from the straight line:

$$V_R = V_{15} + 0.01533\ (R - 15) \tag{1}$$

where *R* is the height of the meniscus above the zero of the scale in centimeters. The bore of the capillary was found to be irregular below $R = 15$ and above $R = 60$, and consequently only the section between these points was used.

When the apparatus was in use the bulb $A$ was always immersed to a point, $M$, located 15.0 cm below the bottom of the glass-metal joint $b$ (fig. 1). The volume between $M$ and $N$ was determined at 0° C. as follows: The apparatus was filled with mercury to the point $M$. The capillary above this point and the valve, $V_1$, were filled with water. The bulbs, $A$ and $B$, were immersed in ice baths and the position of the meniscus $h$ noted on the scale. Mercury was then removed through the valve, $V_2$, and water admitted through $V_1$ until the mercury-water meniscus reached the point, $N$, and the position of $h$ was again noted. The mass of the mercury removed and the change in the position of $h$ give the necessary data for determining the volume of $A$ between the points $M$ and $N$. The density of mercury at 0° C. was assumed to be 13.5951 g per cm$^3$. Two determinations of the volume of $A$ gave results agreeing within 0.01 per cent of the mean value, 23.9836 cm$^3$.

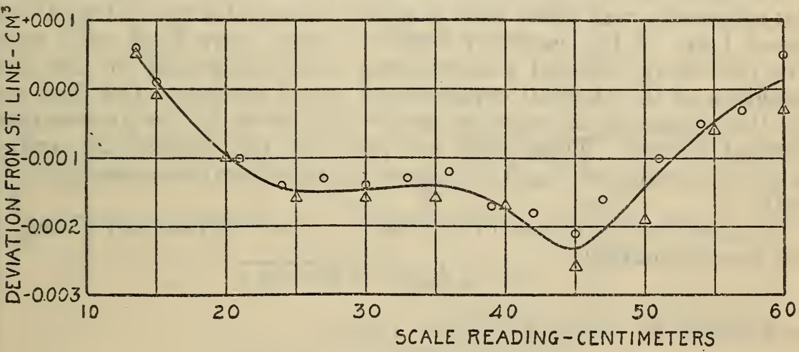


FIGURE 3.—*Calibration curve of capillary*

The volume of the connecting capillary tubing was determined in a continuation of the above-described experiment by admitting water through $V_1$ and observing the change in position of the two menisci. The volume between two positions of the water-mercury meniscus adjacent to the bulb $A$ is measured by the corresponding change in position of the meniscus $h$. The volume of the capillary above $M$ was determined in the same way. The internal volume of the valve, $V_1$, below the needle was calculated from its dimensions. The values found for these volumes were as follows:

| | cm$^3$ |
|---|---|
| Volume of glass capillary above $M$ | 0. 1271 |
| Volume of valve, $V_1$, below needle | . 1307 |
| Volume of capillary from $N$ to $O$ (zero of scale) | . 8206 |

The volume of $B$ between the T-joint above and the metal connection, $f$, was determined from the weight of mercury required to fill it at 0° C. and found to be 5.66 cm$^3$. The volume of the metal connecting tubing, $t$, between $B$ and $V_2$ was not measured since it is so small that changes in room temperature do not cause any appreciable change in the volume of the mercury contained therein.

The change in volume of the bulbs with pressure was measured as follows: The apparatus was filled with mercury with the exception of the valve $V_1$ and about 1 cm of the capillary below it, which were filled with water. The bulbs $A$ and $B$ were immersed in ice baths, and the procedure described above for the measurement of compressibility was followed. The compressibility of mercury at 0° C. was taken as $3.8 \times 10^{-6}$ per kg/cm$^2$, which is numerically equal to the slope of Bridgman's [4] volume-pressure curve at 25 kg/cm$^2$. The value found for the change in volume of the apparatus with pressure was 0.000484 cm$^3$ per kg/cm$^2$.

Values for the change in Young's modulus with temperature for various glasses are given in International Critical Tables. No figures are given for pyrex, but those given for other glasses, including fused quartz, indicate that the change is negligible over the range 0° to 300° C. The change in volume of the bulb $B$ with pressure was determined by filling it with mercury to some point in the vertical capillary above it, admitting carbon dioxide to the remainder of the apparatus and observing the change in position of the meniscus with pressure. The value found was 0.000102 cm$^3$ per kg/cm$^2$.

To determine the change in volume of bulb, $A$, with temperature, the apparatus was filled with mercury, except for the valve, $V_1$, and about 1 cm of the capillary below it which were filled with water. The procedure followed was the same as that described for the determination of the thermal expansion of an oil sample. The data used for the expansion of mercury were those given in the International Critical Tables. These data are probably not sufficiently accurate to give the value of $V_{300}/V_0$ for mercury to better than about 0.01 per cent.

The observed volumes of the bulb, $A$, are represented closely by the linear equation:

$$V_t = 23.9836 + 0.000238\, t \tag{2}$$

as is shown by the data given in Table 1.

TABLE 1.—*Comparison of observed and calculated volumes of bulb A*

| Temperature ° C. | $V$ observed | $V$ calculated | $\frac{V\text{observed} - V\text{calculated}}{V\text{ observed}} \times 10^6$ |
|---|---|---|---|
| 0 | 23.9836 | 23.9836 | 0 |
| 27.73 | 23.9903 | 23.9900 | +1 |
| 46.93 | 23.9944 | 23.9946 | −1 |
| 59.33 | 23.9971 | 23.9975 | −2 |
| 75.00 | 24.0014 | 24.0012 | +1 |
| 79.52 | 24.0018 | 24.0023 | −2 |
| 150.02 | 24.0194 | 24.0191 | +1 |
| 225.02 | 24.0362 | 24.0371 | −4 |
| 299.91 | 24.0493 | 24.0540 | −20 |

When the bulb, $A$, was removed from the bath after this calibration, it was found that the internal surface of the bulb was covered with a large number of small gas bubbles. Apparently, the low value of the observed volume at 300° C. may be attributed to the release of adsorbed gases by the walls. In subsequent experiments, the bulb was heated to 300° C. and evacuated before filling and no further evidence of gas bubbles was obtained.

Making the usual assumption that the coefficient of cubical expansion is three times the coefficient of linear expansion, the above measurements yield the value $3.31 \times 10^{-6}$ for the mean coefficient of

[4] Proc. Am. Acad. Arts and Sci., 47, p. 347, 1911.

linear expansion of pyrex glass over the interval 0° to 300° C. This value agrees well with the mean value $3.2\times10^{-6}$ for laboratory pyrex over the interval 19° to 350° C. recorded in International Critical Tables, Vol. III, p. 93, and credited to the Corning Glass Co. A somewhat larger mean value, $3.6\times10^{-6}$, for the greater interval 21° to 471° C., was obtained by Peters and Cragoe [5] on a ring section cut from a Florence flask of pyrex.

As a check on the calibration of the apparatus, a few measurements were made of the compressibility and thermal expansion of water.[6] The observed relative volumes, $V_t/V_o$, of water at atmospheric pressure are given in Table 2, together with corresponding values taken from International Critical Tables, Vol. III, p. 26.

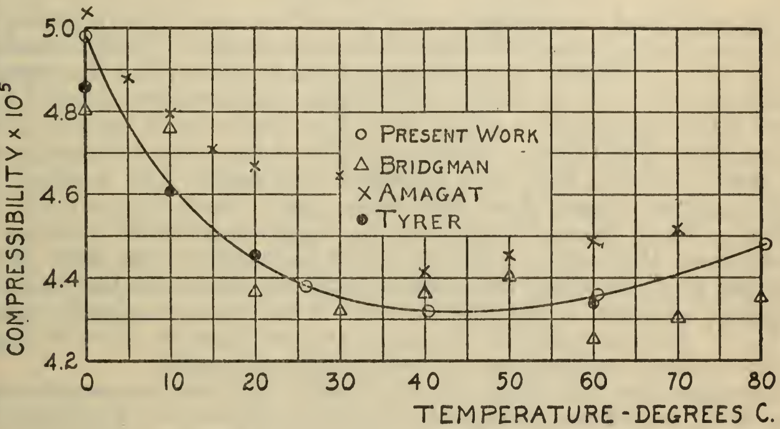


FIGURE 4.—*Compressibility of water*

TABLE 2.—*Expansion data on water compared with I. C. T. data*

| Temperature °C | Relative volumes | | Difference, observed —I. C. T. |
|---|---|---|---|
| | Observed | I. C. T. | |
| 0 | 1.00000 | 1.00000 | 0 |
| 25.98 | 1.00306 | 1.00306 | 0 |
| 40.36 | 1.00781 | 1.00783 | −2 |
| 60.49 | 1.01716 | 1.01718 | −2 |
| 80.54 | 1.02918 | 1.02921 | −3 |

If the differences shown above are due to a systematic error in the calibration of the apparatus, and if the error increases with temperature at the rate indicated by these differences, it would amount to about 0.01 per cent of the volume at 300° C.

The results of the compressibility measurements are compared in Figure 4 with values of compressibility obtained by Amagat [7] (range 1 to 50 atmospheres), Tyrer [8] (range 1 to 2 atmospheres) and values deduced from Bridgman's [9] work. Bridgman gives his results

[5] B. S. Sci. Papers, 16 (S 393) p. 449; 1929.
[6] The sample of distilled water used was boiled vigorously to remove dissolved air prior to filling the apparatus.
[7] Ann. Chim. Phys. (6), 29, p. 544; 1893.
[8] J. Chem. Soc., 10?, p. 1675; 1913.
[9] Proc. Am. Acad. of Arts and Sci., 47, p. 441; 1912.

in terms of relative volumes at pressures differing by steps of 500 kg/cm². Values of mean compressibility between 0 and 50 kg/cm² were obtained from his results by fitting the data at each temperature with an equation of the form:

$$v_0 - v_p = ap - bp^2$$

and plotting a deviation curve. From the volumes at 50 kg/cm² obtained in this way and the volumes at zero pressure the values of mean compressibility between 0 and 50 kg/cm² were computed.

## 5. COMPUTATION OF DATA

The method of computing values of $V_t/V_0$ at atmospheric pressure from the observed data is illustrated by an example in Tables 3 and 4. The method consists in computing the total volume which the sample would occupy at 0° C., and at the higher temperature (225.01° C.) if the oil in the capillary above $M$ and in the value, $V_1$, were at the temperature of the bath. Values of $V_t/V_0$ at the lower temperatures, 75° and 150° C., had been obtained previously, and a curve of $V_t/V_0$ against temperature had been drawn and extrapolated to 225° C. The values of $V_t/V_0$ and $V_{225}/V_t$ given in Table 3 were obtained from this curve. At the higher temperature the large temperature gradient along the capillary and the fact that the volume-temperature curve is not linear, make it necessary to obtain values of $V_{225}/V_t$ corresponding to the mean temperatures of short sections of the capillary and correct for each section separately.

The value given in Table 4 for the mass of mercury between $M$ and $N$ at 0° C. was obtained from the known mass of mercury required to fill this space at 0° C. and the mass displaced by introducing the oil sample. The mass displaced was determined from the weight of mercury removed through $V_2$, and the change in position of the meniscus $h$. The mass of mercury between $M$ and $N$ at 225° C. was obtained from the mass at 0° C., and the mass expelled by the expansion of the oil. The mass expelled was obtained from the weight of mercury removed through $V_2$, and the change in position of the meniscus $h$, corrected for the expansion of the mercury in the capillary. The position of $h$ in each case was corrected to atmospheric pressure by means of the compressibility data.

TABLE 3.—*Corrections for emergent stem*

| Section No. | Location of section—distance above bath liquid | Volume of section | Mean temperature with bath at— | | Data obtained from $V_t/V_0$ curve— | | Volume of oil reduced to— | |
|---|---|---|---|---|---|---|---|---|
| | | | 0° C. | 225.01° C. | $V_{225.01}/V_t$ | $V_t/V_0$ | 0° C. | 225.01° C. |
| | *cm* | *cm*³ | *° C.* | *° C.* | | | *cm*³ | *cm*³ |
| 1 | 0–2.8 | 0.0226 | | 214.4 | 1.0085 | | | 0.0228 |
| 2 | 2.8–9.0 | .0500 | | 141.5 | 1.0703 | | | .0535 |
| 3 | 9.0–15.7 | .0545 | | 44.5 | 1.1502 | | | .0627 |
| Valve | | .1307 | 27.6 | 34.0 | 1.1590 | 1.0199 | 0.1281 | .1515 |
| 1 to 3 | 0–15.7 | .1271 | 24.8 | | | 1.0179 | .1248 | |
| | | Volume of oil above $M$ (reduced to bath temperature) | | | | | .2529 | .2905 |

TABLE 4.—*Computation of $V_t/V_0$*

| Item | Bath temperature | |
|---|---|---|
| | 0° C. | 225.01° C. |
| Volume between $M$ and $N$ (equation 2) ... cm³ | 23.9836 | 24.0371 |
| Mass of mercury between $M$ and $N$ ... g | 66.9959 | 18.2746 |
| Density of mercury ... g/cm³ | 13.5951 | 13.0529 |
| Volume of mercury ... cm³ | 4.9278 | 1.4000 |
| Volume of oil below $M$ ... cm³ | 19.0558 | 22.6371 |
| Volume of oil above $M$ reduced to bath temperature (Table 3) ... cm³ | 0.2529 | 0.2905 |
| Total volume of oil sample at bath temperature ... cm³ | 19.3087 | 22.9276 |
| $V_{225.01}/V_0$ ... | ------ | 1.18742 |

The computation of compressibility is illustrated in Table 5. The mass of mercury between $M$ and $N$ at 50 kg/cm² is obtained from the mass at 0 kg/cm² (Table 4) and the observed change in position of the meniscus $h$ when the pressure is applied, corrected for the compressibility of the mercury in $B$ and in the capillaries, and for the expansion of $B$ with pressure. The value used for the compressibility of mercury at 225° was obtained from a linear extrapolation of Bridgman's values at 0° C. and 22° C. The volume of mercury in $A$ is so small at 225° C. that even a large error in the value of the compressibility of mercury would not cause an appreciable error in the compressibility of the oil. The reduction of the volume above $M$ to the bath temperature was made in a manner similar to that shown in Table 3, using a volume-temperature curve for 50 kg/cm² to obtain values of $V_{225.01}/V_t$.

TABLE 5.—*Computation of compressibility*

| | |
|---|---|
| Bath temperature ... ° C. | 225.01 |
| Volume between $M$ and $N$ at 50 kg/cm² $=24.0371+(0.000484-0.000102)\ 50$ ... cm³ | 24.0562 |
| Mass of mercury between $M$ and $N=18.2746+2.7842$ ... g | 21.0588 |
| Density of mercury $=13.0529(1+50\times5.6\times10^{-6})$ ... g/cm³ | 13.0566 |
| Volume of mercury ... cm³ | 1.6128 |
| Volume of oil below $M$ ... cm³ | 22.4434 |
| Volume of oil above $M$ reduced to bath temperature ... cm³ | 0.2890 |
| Total volume of oil at bath temperature and 50 kg/cm² ... cm³ | 22.7324 |
| Total volume of oil at bath temperature and 0 kg/cm² (Table 4) ... cm³ | 22.9276 |
| Change in volume of oil due to compression ... cm³ | 0.1952 |
| Mean compressibility $=\frac{1}{V_0}\ \frac{V_0-V_{50}}{50}=\frac{0.1952}{22.9276\times50}$ ... cm²/kg | 0.0001703 |

## IV. RESULTS

### 1. DATA OBTAINED

Measurements have been made on 14 samples. Observations on each sample were made at 5 or 6 temperatures and at from 4 to 6 pressures at each temperature. The data on two of the samples (samples 10 and 12) are shown graphically in Figures 5, 6, and 7. Figure 5 shows curves of $V_t/V_0$ at atmospheric pressure plotted against temperature. Figure 6 shows the mean compressibilities between 0 and 50 kg/cm² plotted against temperature. The compressibility decreases with pressure. Figure 7 shows the error introduced by assuming the compressibility independent of pressure and equal to the mean compressibility between 0 and 50 kg/cm².

Information regarding the sources of samples 1, 2, 3, and 4, together with A. S. T. M. distillation data, and values of specific gravity at 60°/60° F. is given in Table 6. Relative volumes and mean compressibilities between 0 and 50 kg/cm² for these samples are given in Table 7. Table 8 gives information as to sources of samples 5 to 14, inclusive, together with values of specific gravity at 60°/60° F., and viscosity at 100° F. Table 9 gives values of relative volume and mean compressibility between 0 and 50 kg/cm² for these samples. The vapor pressures of four of the oils (samples 7, 8, 9, and 10) were greater than atmospheric pressure at the higher temperatures. At 300° C., for example, it was necessary to maintain a pressure of 3 to 5.5 kg/cm² on these oils to prevent the formation of vapor. The values for the volumes of these oils at atmospheric pressure, and at temperatures above the boiling point are given in parentheses in Table 9. These values were obtained by extrapolating the pressure-volume curves to atmospheric pressure, as indicated in Figure 7.

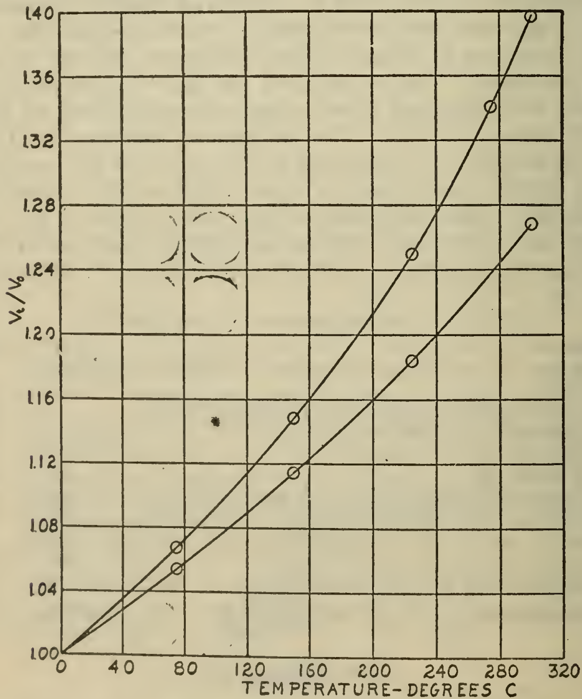


FIGURE 5.—*Expansion curves of samples 10 (upper curve) and 12 (lower curve)*

TABLE 6.—*Description of samples 1 to 4, inclusive*

| Sample No. | Material | Source | A. S. T. M. distillation data: Initial | 20 per cent | 50 per cent | 90 per cent | Maximum | Loss | Residue | Specific gravity, 60°/60° F. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ° C. | ° C. | ° C. | ° C. | ° C. | *Per cent* | *Per cent* | |
| 1 | Cracked gasoline | Los Angeles basin | 51 | 109 | 163 | 215 | 224 | 1.5 | 1.4 | 0.768 |
| 2 | Fighting aviation gas | West Virginia | 53 | 75 | 79.5 | 110 | 163 | .4 | 1.8 | .695 |
| 3 | do | Oklahoma | 58 | 68 | 72.5 | 85.5 | 106 | .5 | .5 | .697 |
| 4 | Liquefied petroleum gas. | | 14.5 per cent propane, 84.4 per cent butane, 1.1 per cent not determined | | | | | | | |

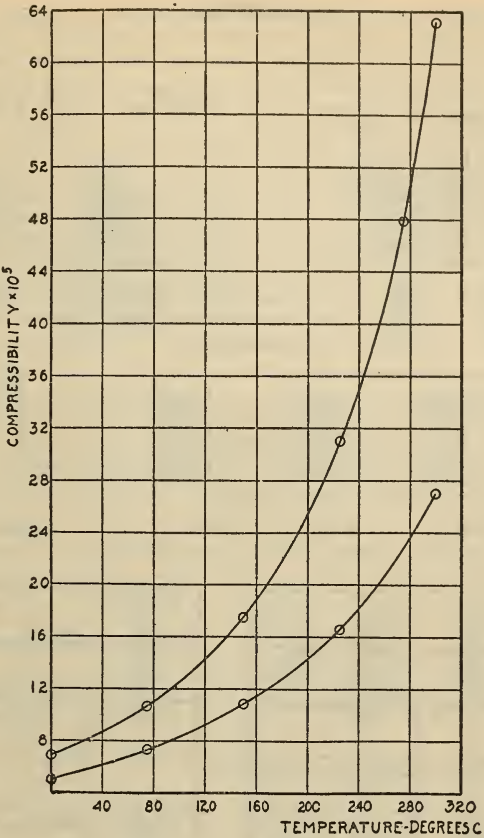


FIGURE 6.—*Mean compressibilities of samples 10 (upper curve) and 12 (lower curve)*

TABLE 7.—*Data obtained on samples 1 to 4, inclusive*

SAMPLE 1

| Pressure, kg/cm² (gauge) | Relative volumes and mean compressibilities | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0° C. | 27° C. | 28° C. | 35° C. | 36° C. | 40° C. | 50° C. | 55° C. | 65° C. | 70° C. |
| 0 | 1.00000 | 1.02865 | | 1.03754 | | | 1.05483 | | 1.07281 | |
| 10 | .99910 | 1.02752 | | 1.03632 | | | 1.05346 | | 1.07123 | |
| 20 | .99821 | 1.02642 | | 1.03512 | | | 1.05210 | | 1.06968 | |
| 30 | .99731 | 1.02530 | | 1.03394 | | | 1.05076 | | 1.06815 | |
| 40 | .99646 | 1.02421 | | 1.03277 | | | 1.04944 | | 1.06664 | |
| 50 | .99561 | 1.02314 | | 1.03161 | | | 1.04814 | | 1.06515 | |
| Mean compressibility×10⁵ | 8.78 | 10.71 | | 11.43 | | | 12.68 | | 14.28 | |

SAMPLE 2

| Pressure, kg/cm² (gauge) | 0° C. | 27° C. | 28° C. | 35° C. | 36° C. | 40° C. | 50° C. | 55° C. | 65° C. | 70° C. |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | 1.03436 | | | | 1.05227 | | 1.07424 | | 1.09764 |
| 10 | .99882 | 1.03282 | | | | 1.05049 | | 1.07215 | | 1.09516 |
| 20 | .99765 | 1.03130 | | | | 1.04875 | | 1.07008 | | 1.09273 |
| 30 | .99650 | 1.02980 | | | | 1.04702 | | 1.06807 | | 1.09036 |
| 40 | .99537 | 1.02832 | | | | 1.04535 | | 1.06610 | | 1.08806 |
| 50 | .99426 | 1.02686 | | | | 1.04372 | | 1.06417 | | 1.08583 |
| Mean compressibility×10⁵ | 11.48 | 14.50 | | | | 16.25 | | 18.75 | | 21.52 |

SAMPLE 3

| Pressure, kg/cm² (gauge) | Relative volumes and mean compressibilities | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0° C. | 27° C. | 28° C. | 35° C. | 36° C. | 40° C. | 50° C. | 55° C. | 65° C. | 70° C. |
| 0 | 1.00000 | 1.03554 | -------- | -------- | -------- | 1.05408 | -------- | 1.07686 | -------- | 1.10129 |
| 10 | .99882 | 1.03397 | -------- | -------- | -------- | 1.05226 | -------- | 1.07472 | -------- | 1.09870 |
| 20 | .99763 | 1.03241 | -------- | -------- | -------- | 1.05046 | -------- | 1.07260 | -------- | 1.09617 |
| 30 | .99646 | 1.03089 | -------- | -------- | -------- | 1.04869 | -------- | 1.07052 | -------- | 1.09370 |
| 40 | .99530 | 1.02937 | -------- | -------- | -------- | 1.04696 | -------- | 1.06850 | -------- | 1.09129 |
| 50 | .99415 | 1.02788 | -------- | -------- | -------- | 1.04526 | -------- | 1.06652 | -------- | 1.08896 |
| Mean compressibility$\times 10^5$ | 11.70 | 14.79 | -------- | -------- | -------- | 16.73 | -------- | 19.20 | -------- | 22.39 |

SAMPLE 4

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | -------- | 1.05608 | -------- | 1.07476 | -------- | -------- | -------- | -------- | -------- |
| 10 | .99839 | -------- | 1.05309 | -------- | 1.07189 | -------- | -------- | -------- | -------- | -------- |
| 20 | .99616 | -------- | 1.05018 | -------- | 1.06803 | -------- | -------- | -------- | -------- | -------- |
| 30 | .99411 | -------- | 1.04704 | -------- | 1.06442 | -------- | -------- | -------- | -------- | -------- |
| 40 | .99212 | -------- | 1.04403 | -------- | 1.06097 | -------- | -------- | -------- | -------- | -------- |
| 50 | .99017 | -------- | 1.04111 | -------- | 1.05773 | -------- | -------- | -------- | -------- | -------- |
| Mean compressibility$\times 10^5$ | 21.37 | -------- | 30.82 | -------- | 34.45 | -------- | -------- | -------- | -------- | -------- |

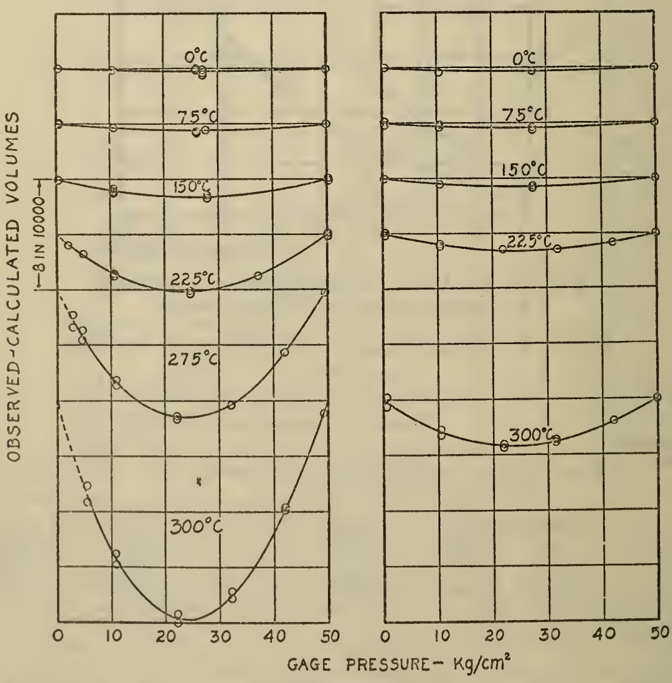


FIGURE 7.—*Error introduced by assuming the compressibilities of samples 10 (left) and 12 (right) independent of pressure and equal to the mean compressibilities between 0 and 50 kg/cm²*

TABLE 8.—*Description of samples 5 to 14, inclusive*

| Sample No. | Material | Source | Viscosity at 100° F. | | Specific gravity, 60°/60° F. | °A.P.I. |
|---|---|---|---|---|---|---|
| | | | Kinematic | Saybolt Universal | | |
| | | | *cgs units* | *Seconds* | | |
| 5 | Spindle oil | Pennsylvania | 0.317 | 147 | 0.8724 | 30.7 |
| 6 | do | do | .317 | 147 | .8724 | 30.7 |
| 7 | Gas oil | Los Angeles basin | .062 | 46 | 8739 | 30.4 |
| 8 | do | Oklahoma | .042 | 40 | .8835 | 28.7 |
| 9 | do | Mid-Continent | .056 | 44 | .8812 | 29.1 |
| 10 | do | Bradford, Pa., district | .028 | 36 | .8019 | 44.9 |
| 11 | Lubricating oil | Oklahoma (Tonkowa-Osage) | .698 | 318 | .8995 | 25.8 |
| 12 | do | Gulf Coast | .713 | 325 | .9335 | 20.1 |
| 13 | do | Pennsylvania | .658 | 300 | .8768 | 29.9 |
| 14 | do | do | .953 | 433 | .8804 | 29.2 |

TABLE 9.—*Data obtained on samples 5 to 14, inclusive*

SAMPLE 5

| Pressure, kg/cm² (gauge) | Relative volumes and mean compressibilities | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0° C. | 30° C. | 75° C. | 150° C. | 225° C. | 275° C. | 300° C. |
| 0 | 1.00000 | --------- | 1.05745 | 1.12186 | 1.1971$_1$ | --------- | 1.2893$_3$ |
| 10 | .99943 | --------- | 1.05656 | 1.12041 | 1.1946$_8$ | --------- | 1.2849$_0$ |
| 20 | .99886 | --------- | 1.05567 | 1.11901 | 1.1923$_8$ | --------- | 1.2806$_9$ |
| 30 | .99830 | --------- | 1.05480 | 1.11764 | 1.1901$_0$ | --------- | 1.2766$_5$ |
| 40 | .99775 | --------- | 1.05395 | 1.11627 | 1.1878$_5$ | --------- | 1.2728$_3$ |
| 50 | .99721 | --------- | 1.05309 | 1.11492 | 1.1856$_2$ | --------- | 1.2691$_2$ |
| Mean compressibility×10⁵ | 5.58 | --------- | 8.25 | 12.37 | 19.20 | --------- | 31.35 |

SAMPLE 6

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | --------- | 1.05750 | 1.12197 | 1.1973$_7$ | --------- | 1.2896$_2$ |
| 10 | .99942 | --------- | 1.05660 | 1.12052 | 1.1949$_4$ | --------- | 1.2852$_1$ |
| 20 | .99886 | --------- | 1.05572 | 1.11912 | 1.1926$_3$ | --------- | 1.2810$_1$ |
| 30 | .99829 | --------- | 1.05486 | 1.11775 | 1.1903$_5$ | --------- | 1.2769$_9$ |
| 40 | .99774 | --------- | 1.05400 | 1.11638 | 1.1881$_0$ | --------- | 1.2731$_8$ |
| 50 | .99719 | --------- | 1.05314 | 1.11503 | 1.1858$_8$ | --------- | 1.2694$_7$ |
| Mean compressibility×10⁵ | 5.62 | --------- | 8.25 | 12.37 | 19.19 | --------- | 31.25 |

SAMPLE 7

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | --------- | 1.06218 | 1.13360 | 1.2209$_9$ | --------- | (1.3366$_0$) |
| 10 | .99935 | --------- | 1.06116 | 1.13189 | 1.2179$_1$ | --------- | 1.3299$_8$ |
| 20 | .99873 | --------- | 1.06018 | 1.13023 | 1.2149$_3$ | --------- | 1.3239$_1$ |
| 30 | .99813 | --------- | 1.05921 | 1.12858 | 1.2120$_4$ | --------- | 1.3181$_8$ |
| 40 | .99753 | --------- | 1.05825 | 1.12698 | 1.2092$_2$ | --------- | 1.3127$_3$ |
| 50 | .99693 | --------- | 1.05728 | 1.12541 | 1.2064$_7$ | --------- | 1.3076$_5$ |
| Mean compressibility×10⁵ | 6.14 | --------- | 9.23 | 14.45 | 23.78 | --------- | 43.31 |

SAMPLE 8

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | --------- | 1.06262 | 1.13464 | 1.2229$_6$ | --------- | (1.3404$_0$) |
| 10 | .99939 | --------- | 1.06165 | 1.13301 | 1.2199$_6$ | --------- | 1.3340$_5$ |
| 20 | .99878 | --------- | 1.06070 | 1.13140 | 1.2170$_5$ | --------- | 1.3280$_7$ |
| 30 | .99818 | --------- | 1.05975 | 1.12981 | 1.2142$_2$ | --------- | 1.3223$_9$ |
| 40 | .99759 | --------- | 1.05881 | 1.12827 | 1.2114$_9$ | --------- | 1.3170$_1$ |
| 50 | .99701 | --------- | 1.05790 | 1.12674 | 1.2088$_0$ | --------- | 1.3119$_5$ |
| Mean compressibility×10⁵ | 5.98 | --------- | 8.88 | 13.92 | 23.16 | --------- | 42.45 |

TABLE 9.—*Data obtained on samples 5 to 14, inclusive*—Continued

SAMPLE 9

| Pressure, kg/cm² (gauge) | Relative volumes and mean compressibilities | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0° C. | 30° C. | 75° C. | 150° C. | 225° C. | 275° C. | 300° C. |
| 0 | 1.00000 | --------- | 1.06213 | 1.13295 | $1.2190_5$ | $(1.2902_7)$ | $(1.3323_1)$ |
| 10 | .99942 | --------- | 1.06118 | 1.13135 | $1.2161_4$ | $1.2856_3$ | $1.3262_9$ |
| 20 | .99883 | --------- | 1.06024 | 1.12976 | $1.2133_0$ | $1.2812_0$ | $1.3205_3$ |
| 30 | .99825 | --------- | 1.05930 | 1.12820 | $1.2105_4$ | $1.2769_4$ | $1.3151_8$ |
| 40 | .99766 | --------- | 1.05837 | 1.12666 | $1.2078_5$ | $1.2728_6$ | $1.3100_5$ |
| 50 | .99708 | --------- | 1.05764 | 1.12516 | $1.2052_5$ | $1.2689_7$ | $1.3051_6$ |
| Mean compressibility×10⁵ | 5.84 | --------- | 8.79 | 13.75 | 22.64 | 33.02 | 40.76 |

SAMPLE 10

| Pressure, kg/cm² (gauge) | 0° C. | 30° C. | 75° C. | 150° C. | 225° C. | 275° C. | 300° C. |
|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | --------- | 1.06788 | 1.14831 | $(1.2507_9)$ | $(1.3420_8)$ | $(1.3984_2)$ |
| 10 | .99930 | --------- | 1.06671 | 1.14622 | $1.2465_8$ | $1.3346_9$ | $1.3880_9$ |
| 20 | .99861 | --------- | 1.06555 | 1.14416 | $1.2425_4$ | $1.3278_1$ | $1.3786_0$ |
| 30 | .99793 | --------- | 1.06440 | 1.14215 | $1.2387_0$ | $1.3213_3$ | $1.3698_8$ |
| 40 | .99725 | --------- | 1.06327 | 1.14020 | $1.2350_1$ | $1.3152_5$ | $1.3618_2$ |
| 50 | .99658 | --------- | 1.06217 | 1.13828 | $1.2314_4$ | $1.3094_7$ | $1.3542_8$ |
| Mean compressibility×10⁵ | 6.84 | --------- | 10.70 | 17.47 | 30.94 | 48.59 | 63.12 |

SAMPLE 11

| Pressure, kg/cm² (gauge) | 0° C. | 30° C. | 75° C. | 150° C. | 225° C. | 275° C. | 300° C. |
|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | --------- | 1.05561 | 1.11685 | $1.1874_0$ | --------- | $1.2722_1$ |
| 10 | .99948 | --------- | 1.05480 | 1.11555 | $1.1852_9$ | --------- | $1.2685_2$ |
| 20 | .99895 | --------- | 1.05400 | 1.11428 | $1.1832_2$ | --------- | $1.2649_8$ |
| 30 | .99843 | --------- | 1.05321 | 1.11303 | $1.1812_0$ | --------- | $1.2615_6$ |
| 40 | .99792 | --------- | 1.05242 | 1.11180 | $1.1792_2$ | --------- | $1.2582_5$ |
| 50 | .99741 | --------- | 1.05164 | 1.11058 | $1.1772_9$ | --------- | $1.2550_6$ |
| Mean compressibility×10⁵ | 5.18 | --------- | 7.52 | 11.22 | 17.02 | --------- | 26.96 |

SAMPLE 12

| Pressure, kg/cm² (gauge) | 0° C. | 30° C. | 75° C. | 150° C. | 225° C. | 275° C. | 300° C. |
|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | --------- | 1.05404 | 1.11435 | $1.1844_4$ | --------- | $1.2683_1$ |
| 10 | .99949 | --------- | 1.05325 | 1.11310 | $1.1823_9$ | --------- | $1.2646_1$ |
| 20 | .99898 | --------- | 1.05247 | 1.11188 | $1.1803_8$ | --------- | $1.2611_6$ |
| 30 | .99848 | --------- | 1.05171 | 1.11067 | $1.1784_1$ | --------- | $1.2576_6$ |
| 40 | .99799 | --------- | 1.05096 | 1.10949 | $1.1764_9$ | --------- | $1.2544_0$ |
| 50 | .99751 | --------- | 1.05021 | 1.10833 | $1.1746_3$ | --------- | $1.2512_3$ |
| Mean compressibility×10⁵ | 4.98 | --------- | 7.27 | 10.79 | 16.56 | --------- | 26.93 |

SAMPLE 13

| Pressure, kg/cm² (gauge) | 0° C. | 30° C. | 75° C. | 150° C. | 225° C. | 275° C. | 300° C. |
|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | 1.02282 | 1.05719 | 1.11990 | $1.1923_4$ | --------- | $1.2797_5$ |
| 10 | .99942 | 1.02217 | 1.05632 | 1.11854 | $1.1900_7$ | --------- | $1.2757_4$ |
| 20 | .99884 | 1.02152 | 1.05548 | 1.11720 | $1.1878_7$ | --------- | $1.2719_6$ |
| 30 | .99827 | 1.02088 | 1.05463 | 1.11588 | $1.1857_2$ | --------- | $1.2683_0$ |
| 40 | .99770 | 1.02018 | 1.05381 | 1.11458 | $1.1836_4$ | --------- | $1.2647_9$ |
| 50 | .99714 | 1.01961 | 1.05299 | 1.11329 | $1.1816_0$ | --------- | $1.2614_1$ |
| Mean compressibility×10⁵ | 5.72 | 6.27 | 7.94 | 11.80 | 18.02 | --------- | 28.66 |

SAMPLE 14

| Pressure, kg/cm² (gauge) | 0° C. | 30° C. | 75° C. | 150° C. | 225° C. | 275° C. | 300° C. |
|---|---|---|---|---|---|---|---|
| 0 | 1.00000 | 1.02269 | 1.05666 | 1.11849 | $1.1895_1$ | --------- | $1.2746_0$ |
| 10 | .99942 | 1.02205 | 1.05581 | 1.11715 | $1.1873_2$ | --------- | $1.2708_3$ |
| 20 | .99885 | 1.02141 | 1.05498 | 1.11583 | $1.1851_8$ | --------- | $1.2671_9$ |
| 30 | .99828 | 1.02077 | 1.05416 | 1.11453 | $1.1831_0$ | --------- | $1.2637_0$ |
| 40 | .99773 | 1.02015 | 1.05335 | 1.11327 | $1.1810_8$ | --------- | $1.2603_0$ |
| 50 | .99717 | 1.01953 | 1.05256 | 1.11203 | $1.1790_8$ | --------- | $1.2570_5$ |
| Mean compressibility×10⁵ | 5.66 | 6.18 | 7.76 | 11.55 | 17.53 | --------- | 27.54 |

Before any measurements had been made at the higher temperatures it was expected that considerable difficulty would be experienced at those temperatures due to dissolved air coming out of solution. In order to avoid this expected difficulty an attempt was made to remove the dissolved air from sample 5 by evacuation. Some of the lighter constituents of the oil were probably removed by this process, so that the properties of the sample were changed to some extent. Sample 6 is the same as sample 5 except that no attempt had been made to remove the dissolved air. As the expected difficulty did not materialize in the case of sample 6, no effort was made to remove the dissolved air from the other samples.

The data on samples 11, 13, and 14 indicated abnormally large expansion in the range 0° to 75° C. It was also noticed that these oils became cloudy when cooled to 0° C., indicating that wax had

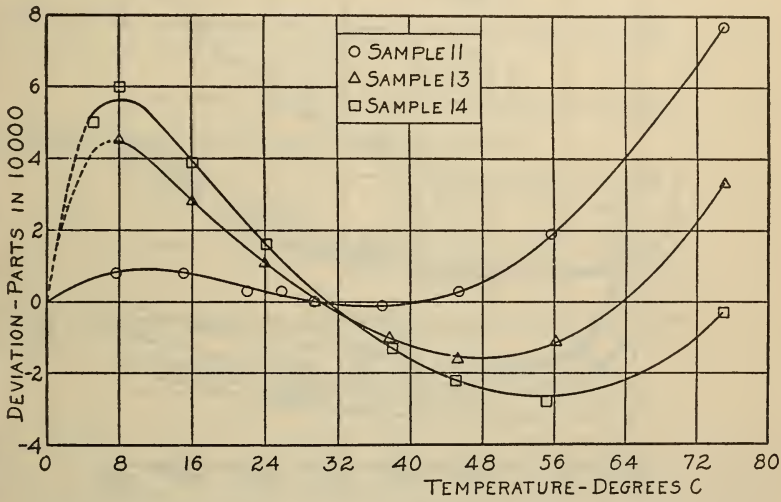


FIGURE 8.—*Deviations of expansion curves of samples 11, 13, and 14, from straight lines*

begun to freeze out at this temperature. The compressibilities of samples 13 and 14 were also abnormally large at 0° C., probably due to additional precipitation of wax at the higher pressures. The forms of the expansion curves of these three samples were investigated in the range 0° to 55° C. by means of a dilatometer which had been made for another investigation. Figure 8 shows the deviations of the observed expansion curves from straight lines through the 0° and 30° points. The volumes at 75° obtained by means of the apparatus shown in Figure 1 are included, showing that the two sets of data are in good agreement. It is seen from this figure that the expansion curves are concave downward at the lower temperatures, whereas such curves are normally concave upward.

The large expansion of these samples at the lower temperatures is also shown in Figure 9, where the ordinate is a quantity analogous to the mean coefficient of expansion. The curves for samples 11, 13, and 14 bend up more sharply at the lower temperatures than do those for the other samples.

At 300° C. a gradual increase in the volume of some of the samples was observed. This was probably due to a slight cracking of the oil. In some cases the increase in volume was measured by repeating the observation at 0° C. after completing the observations at 300° C. For sample 8 the increase in volume was only 0.002 per cent at 0° C., which is within the limits of accuracy of the measurement. For samples 12 and 13 the increase amounted to 0.014 and 0.010 per cent, respectively. Observations at 0° C. were not repeated for any of the other samples. For sample 10 the change in volume at 300° C. during the time required for the observations (about one hour) amounted to about 0.02 per cent. The change for the other samples under the same conditions amounted to about 0.005 per cent.

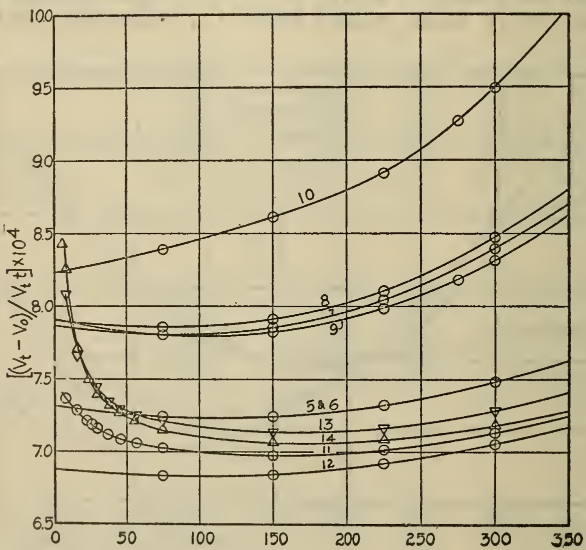


FIGURE 9.—*Plot of* $\frac{V_t - V_0}{V_t t}$ *against temperature for samples 5 to 14, inclusive*

## 2. ACCURACY OF THE DATA

As mentioned in Section III of this paper, there is an uncertainty in the data used for the expansion of mercury amounting to 0.01 per cent in the value of $V_t/V_0$ at 300° C. In addition, there is an uncertainty at 300° C. of about 0.015 per cent due to cracking of the oil. The errors involved in calibration, in applying the various corrections, and errors of observation probably amount to about 0.005 per cent at 300° C. The estimated maximum error is therefore about 0.03 per cent in the value of $V_{300}/V_0$ at atmospheric pressure. The errors in the values of $V_t/V_0$ at the lower temperatures are probably considerably less.

Bridgman's value for the compressibility of mercury ($3.8 \times 10^{-6}$), judging by the precision of his observations and the agreement with values obtained by several other observers, is probably accurate within $0.1 \times 10^{-6}$. The precision of the observations in the present work, as shown by Figure 7, indicates that the values of mean compressibility are accurate within about $0.6 \times 10^{-6}$ at the lower temperatures. At 300° C. the change in volume due to cracking introduces some uncertainty, although the method of making the observations tends to eliminate errors due to this cause.

### 3. QUANTITIES CALCULATED FROM THERMODYNAMIC RELATIONS

The data obtained are sufficient to permit the calculation of a number of quantities by means of general relations derived from the laws of thermodynamics. For example, the difference of the specific heats is given by

$$C_p - C_v = -T\frac{\left(\frac{\partial v}{\partial T}\right)_p^2}{\left(\frac{\partial v}{\partial p}\right)_T}$$

the change in $C_p$ with pressure by

$$\left(\frac{\partial C_p}{\partial p}\right)_T = -T\left(\frac{\partial^2 v}{\partial T^2}\right)_p$$

the change in internal energy with volume by

$$\left(\frac{\partial E}{\partial v}\right)_T = -T\frac{\left(\frac{\partial v}{\partial T}\right)_p}{\left(\frac{\partial v}{\partial p}\right)_T} - p$$

and the change in heat content with pressure by

$$\left(\frac{\partial h}{\partial p}\right)_T = -T\left(\frac{\partial v}{\partial T}\right)_p + v$$

In order to make use of these relations it is necessary to have the values of the partial derivatives of volume with repsect to temperature and pressure. The derivatives with respect to temperature for one sample (sample 12) were obtained by means of the following equation expressing $V_t/V_0$ as a function of temperature at atmospheric pressure:

$$V_t/V_0 = 1 + 0.69645\left(\frac{t}{1000}\right) + 0.2150\left(\frac{t}{1000}\right)^2 + 1.482\left(\frac{t}{1000}\right)^3$$

Values of $V_t/V_0$ computed from this equation are compared in Table 10 with the observed values.

TABLE 10.—*Comparison of observed and calculated values of $V_t/V_0$ at atmospheric pressure for sample 12*

| Temperature ° C. | $(V_t/V_0)$ calculated | $(V_t/V_0)$ observed | (Observed—calculated) $\times 10^5$ |
|---|---|---|---|
| 0 | 1.00000 | 1.00000 | 0 |
| 75 | 1.05407 | 1.05404 | −3 |
| 150 | 1.11431 | 1.11435 | +4 |
| 225 | 1.18447 | 1.18444 | −3 |
| 300 | 1.26830 | 1.26831 | +1 |

15377°—30——3

The partial derivatives $\left(\frac{\partial v}{\partial T}\right)_p$ and $\left(\frac{\partial^2 v}{\partial T^2}\right)_p$ were obtained by multiplying the above expression for $V_t/V_0$ by the specific volume of the oil at 0° C. (1.0607) and differentiating. The compressibilities at atmospheric pressure were obtained from the mean compressibilities by means of deviation curves similar to those of Figure 7. The compressibility at each temperature was multiplied by the specific volume of the oil at that temperature to obtain the value of the derivative $\left(\frac{\partial v}{\partial p}\right)_T$. The values of these derivatives, together with values of $C_p$, $C_p - C_v$, etc., are given in Table 11. The values of $C_p$ were obtained from an equation by Cragoe[10] for an oil of the same specific gravity as sample 12.

TABLE 11.—*Quantities derived from data on sample 12 at atmospheric pressure*

| Temperature ° C. | $\left(\frac{\partial v}{\partial T}\right)_p \times 10^4$ | $\left(\frac{\partial^2 v}{\partial T^2}\right)_p \times 10^6$ | $\left(\frac{\partial v}{\partial p}\right)_T \times 10^4$ | $C_p - C_v$ | $C_p$ |
|---|---|---|---|---|---|
| | *cm³/g °C.* | *cm³/g(°C.)²* | *cm³/g / 10⁷ dynes/cm²* | *Joules / g °C.* | *Joules / g °C.* |
| 0 | 7.39 | 0.46 | −5.61 | 0.265 | 1.75 |
| 75 | 7.99 | 1.16 | −8.64 | .257 | 2.01 |
| 150 | 9.13 | 1.87 | −13.62 | .259 | 2.27 |
| 225 | 10.80 | 2.58 | −22.42 | .259 | 2.54 |
| 300 | 13.00 | 3.29 | −40.73 | .238 | 2.80 |

| Temperature ° C. | $C_v$ | $C_p/C_v$ | $\left(\frac{\partial C_p}{\partial p}\right)_T \times 10^5$ | $\left(\frac{\partial E}{\partial v}\right)_T$ | $\left(\frac{\partial h}{\partial p}\right)_T$ |
|---|---|---|---|---|---|
| | *Joules / g °C.* | | *Joules/g / kg/cm²* | *Joules/cm³* | *Joules/g / kg/cm²* |
| 0 | 1.48 | 1.18 | −1.2 | 380 | −0.0842 |
| 75 | 1.75 | 1.15 | −4.0 | 321 | −.0823 |
| 150 | 2.01 | 1.13 | −7.8 | 283 | −.0780 |
| 225 | 2.28 | 1.11 | −12.6 | 239 | −.0704 |
| 300 | 2.56 | 1.09 | −18.4 | 182 | −.0589 |

## 4. CORRELATION OF DATA

Inspection of the data in Table 9 showed that the relation between specific gravity at 60°/60° F. and thermal expansion over a moderate temperature range (0° to 50° C.) found by Bearce and Peffer[11] did not satisfactorily represent the data over the larger temperature range (0° to 300° C.). For example, samples 9 and 14 are of approximately the same specific gravity (0.88), but the values of $V_{300}/V_0$ at atmospheric pressure for these samples are 1.33 and 1.27, respectively. The fact that the compressibilities of these samples at 300° C. are $40.8 \times 10^{-5}$ and $27.5 \times 10^{-5}$ per kg/cm², respectively, indicates that there is no close relation between compressibility and specific gravity, at least at the higher temperatures.

The data indicated, however, that both thermal expansion and compressibility were more closely related to the viscosity of the oils. When values of $V_t/V_0$ are plotted as ordinate against kinematic viscosity on a linear scale as abcissa, the lines for a given temperature

[10] Thermal Properties of Petroleum Products, Miscellaneous Publications of the Bureau of Standards No. 97; 1929.
[11] B. S. Tech. Paper No. 77.

curve upward markedly in the region of low viscosity. The curvature was much reduced when the values were plotted against a linear scale of $1/\sqrt{\log (1{,}000\ \mu/\rho)}$[12] as abcissa, where $\mu/\rho$ is kinematic viscosity at 100° F. in cgs units.

It was found that the observed values all lay on a smooth curve within about 1 per cent. The directions of the deviations indicated that the agreement would be improved by using $1/d\sqrt{\log (1{,}000\ \mu/\rho)}$ as the independent variable ($d$ is specific gravity at 60° F. referred to water at the same temperature). Figure 10 shows the curves obtained in this way for the temperatures 75°, 150°, 225°, and 300° C. The values of $V_t/V_0$ for samples 13 and 14, as plotted in Figure 10, have

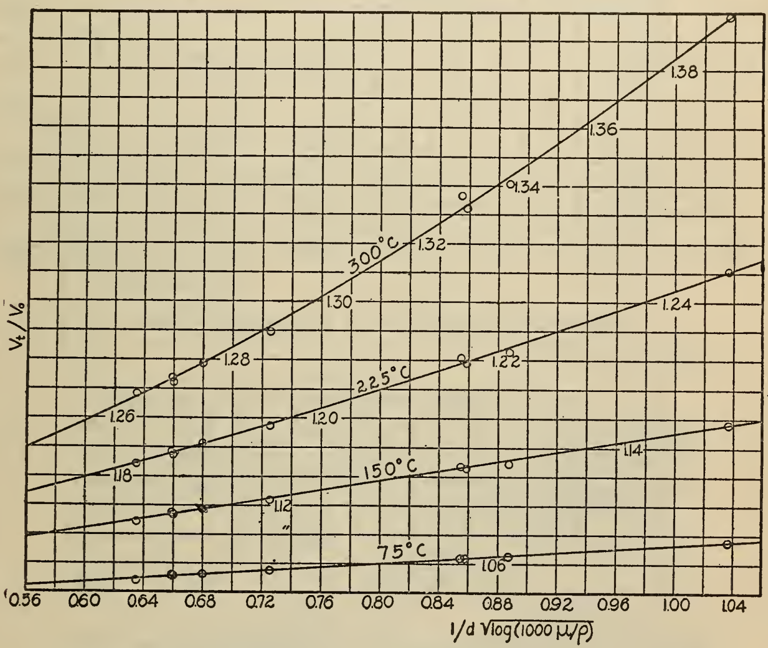


FIGURE 10.—*Correlation of expansion data*

been lowered by 0.2 per cent from the observed values in order to eliminate the effect of the abnormally large expansion in the vicinity of 0° C. As might be expected, the deviations of the observed points from the curves are larger at the higher temperatures. The maximum deviation is 0.4 per cent of the value of $V_t/V_0$ at 300° C.

Figure 11 shows curves of mean compressibility at the various temperatures plotted against the same independent variable. The maximum deviation of an observed point from the curve to which it belongs is $2 \times 10^{-5}$ per kg/cm², corresponding to a difference of 0.1 per cent in the volume at 50 kg/cm².

Data obtained from the curves of Figures 10 and 11 are shown in Figures 12 and 13, respectively, plotted against $1/\sqrt{\log (1{,}000\ \mu/\rho)}$. The curves in these figures are curves of constant specific gravity and temperature.

[12] The use of this quantity as the independent variable was suggested by C. S. Cragoe, of this bureau.

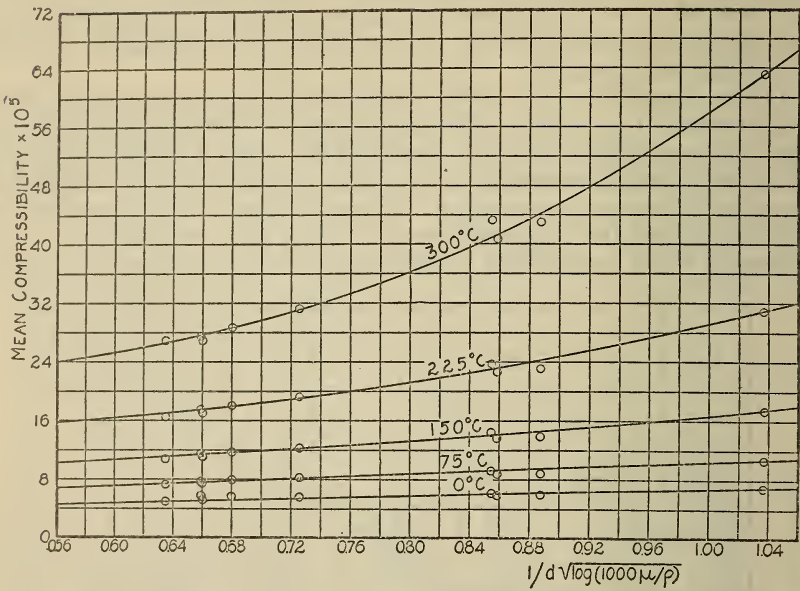


FIGURE 11.—*Correlation of compressibility data*

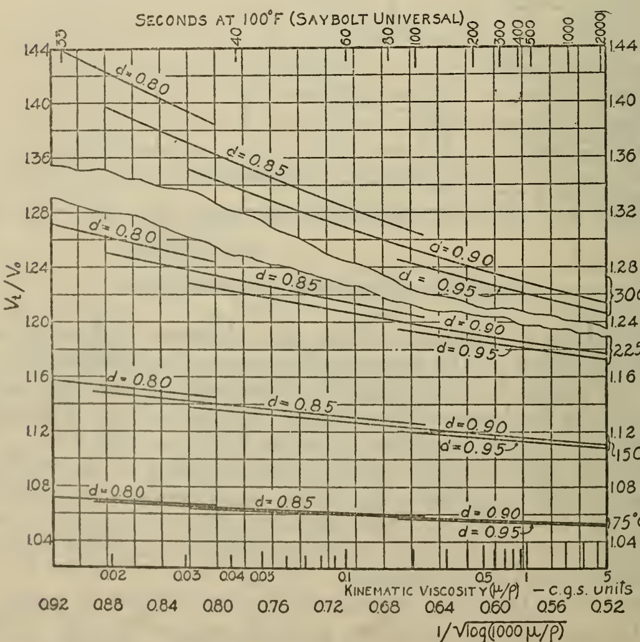


FIGURE 12.—*Curves showing relation between expansion and kinematic viscosity for oils of various specific gravities*

Tables of the relative volumes of oils at various temperatures and at two pressures are given in the Appendix to this paper. These tables were obtained from the data of Figures 12 and 13 by plotting values of volume against temperature, and drawing curves through the points. Two curves were drawn for each oil, one for atmospheric pressure and one for 50 kg/cm². The curves were drawn by means of a spline and were extrapolated to 400° C. Values of volumes at temperatures above 300° C. are given in parentheses in the tables, in order to emphasize that these values represent extrapolation beyond the range covered by the experiments.

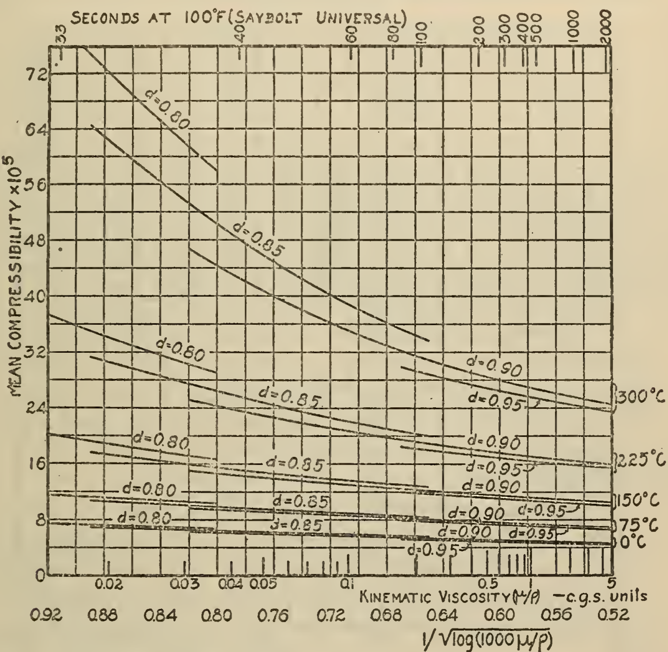


Figure 13.—*Curves showing relation between compressibility and kinematic viscosity for oils of various specific gravities*

As mentioned in Section IV, the vapor pressures of some of the lighter oils are higher than atmospheric pressure at the higher temperatures. The values of relative volumes at atmospheric pressure given in the Appendix may represent fictitious values at the higher temperatures if the vapor pressure is greater than atmospheric pressure. They are, however, the values which would be obtained by extrapolating the pressure-volume curves to atmospheric pressure, and are given for convenience in interpolating.

## V. COMPARISON WITH PREVIOUS WORK

Measurements of thermal expansion of oils from various sources have been made by Bearce and Peffer.[13] Measurements of thermal expansion of a number of California oils were made by Zeitfuchs.[14]

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[13] See footnote 11, p. 1004.
[14] J. Ind. and Eng. Chem., 17, p. 1280; 1925.

Fortsch and Wilson [15] give expansion data on a number of oils, but give no information as to methods of measurement.

Direct comparison of the present measurements with those of Bearce and Peffer and those of Zeitfuchs is not possible, as these observers do not give the viscosities of their samples. It can be shown, however, that their measurements are at least not inconsistent with those described in this paper. The results of Bearce and Peffer have been embodied in Bureau of Standards Circular No. 154. Expansion data from this circular are compared in Table 12 with similar data taken from the tables in the Appendix to this paper. It is seen that for an oil of a given specific gravity the values

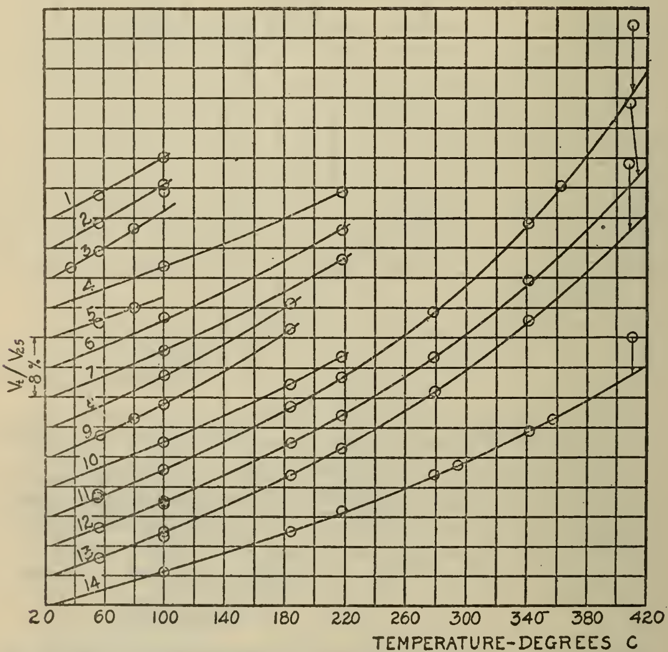


Figure 14.—*Comparison of data of present work with those of Zeitfuchs*

of $V_t/V_{60}$ from Circular No. 154 usually lie between the highest and lowest values from the present work.

In Figure 14 the results of Zeitfuchs, represented by circles, are compared with data from the present work, represented by the curves. Each curve is for an oil of the same specific gravity as the corresponding oil reported by Zeitfuchs and of a viscosity so chosen as to make the agreement with his data as good as possible. The high values obtained by Zeitfuchs at 410° C. are probably due to cracking of the oil and the consequent formation of gas bubbles. Table 13 gives Zeitfuchs' values for the specific gravities of the various oils together with values of kinematic viscosity inferred from the expansion data. These values of kinematic viscosity, excepting those for the two samples of mineral seal distillate, are in fair agreement

[15] J. Ind. and Eng. Chem., 16, p. 789; 1924.

with a curve of viscosity versus density for California oils based on the work of Lane and Dean.[16]

TABLE 12.—*Values of $V_t/V_{60}$ from B. S. Circular No. 154 compared with present work*

| Temperature ° F. | Specific gravity, 60°/60° F. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.80 | | | 0.85 | | | 0.90 | | | 0.95 | | | 1.00 | | |
| | Kinematic viscosity at 100° F. (cgs units) | | | | | | | | | | | | | | |
| | C. 154 | 0.016 | 0.028 | C. 154 | 0.028 | 0.200 | C. 154 | 0.049 | 5.000 | C. 154 | 0.200 | 5.000 | C. 154 | [1] 0.042 | [1] 1.100 |
| | | Present work | | | Present work | | | Present work | | | Present work | | | Present work | |
| 20 | 0.980 | 0.981 | 0.981 | 0.982 | 0.981 | 0.983 | 0.984 | 0.983 | 0.985 | 0.985 | 0.984 | 0.985 | 0.985 | 0.985 | 0.985 |
| 40 | .990 | .990 | .990 | .991 | .991 | .991 | .992 | .991 | .992 | .992 | .992 | .993 | .993 | .993 | .993 |
| 60 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 80 | 1.010 | 1.010 | 1.010 | 1.009 | 1.009 | 1.009 | 1.008 | 1.009 | 1.008 | 1.008 | 1.008 | 1.008 | 1.007 | 1.008 | 1.007 |
| 100 | 1.021 | 1.021 | 1.020 | 1.018 | 1.019 | 1.017 | 1.017 | 1.018 | 1.016 | 1.015 | 1.016 | 1.015 | 1.015 | 1.016 | 1.013 |
| 120 | 1.031 | 1.031 | 1.030 | 1.027 | 1.029 | 1.026 | 1.025 | 1.027 | 1.023 | 1.023 | 1.025 | 1.023 | 1.022 | 1.024 | 1.020 |
| 140 | 1.042 | 1.042 | 1.040 | 1.037 | 1.039 | 1.035 | 1.033 | 1.036 | 1.031 | 1.031 | 1.033 | 1.030 | 1.029 | 1.031 | 1.027 |
| 160 | ------ | ------ | ------ | 1.046 | 1.048 | 1.044 | 1.042 | 1.045 | 1.039 | 1.039 | 1.042 | 1.038 | 1.037 | 1.040 | 1.034 |
| 180 | ------ | ------ | ------ | 1.056 | 1.059 | 1.053 | 1.051 | 1.055 | 1.047 | 1.047 | 1.050 | 1.046 | 1.044 | 1.048 | 1.041 |

[1] Kinematic viscosity at 210° F.

TABLE 13.—*Description of samples used by Zeitfuchs*

| Curve | Material | Specific gravity 60°/60° F. (Zeitfuchs) | $\mu/\rho$ at 100° F. from expansion data |
|---|---|---|---|
| 1 | Engine distillate | 0.7991 | 0.007 |
| 2 | Crude naphtha | .7886 | .006 |
| 3 | Gasoline | .766 | (1) |
| 4 | 18° tar | .9485 | 1.0 |
| 5 | Lubricating oil | .9321 | 1.8 |
| 6 | Mineral seal distillate | .8564 | .086 |
| 7 | do | .8636 | .085 |
| 8 | Water white distillate | .8493 | .022 |
| 9 | Kerosene | .8242<br>.8142 | .020 |
| 10 | Light lubricating distillate | .9021 | .12 |
| 11 | Gas oil | .8885<br>.8870 | .05 |
| 12 | Light lubricating distillate | .9005 | .10 |
| 13 | do | .9058 | .144 |
| 14 | Asphalt | 1.017 | 10,000.0 |

[1] The comparison curve for this material is the expansion curve of sample 1, a cracked gasoline ($d$=0.768) from California crude.

The results of Fortsch and Wilson are compared with data from the present work in Figure 15. These observers give both the specific gravities and the viscosities of their samples, which are described in Table 14. Each comparison curve in Figure 15 is for an oil of the same viscosity and specific gravity as the corresponding sample of Fortsch and Wilson. For some of the oils the agreement is very good, while for others it is poor. The difference between the observed

[16] J. Ind. and Eng. Chem., 16, p. 905; 1924.

points and the curves amounts in some cases to as much as 2 per cent of the value of $V_t/V_{60}$. As no experimental details are given it is not possible to say whether the differences are due to experimental error or to the fact that the method of correlation used in this paper may not be applicable to all classes of oils.

Measurements of the compressibilities at 40° C. of water and four mineral oils have been made by Hyde[17]. The pressure range covered

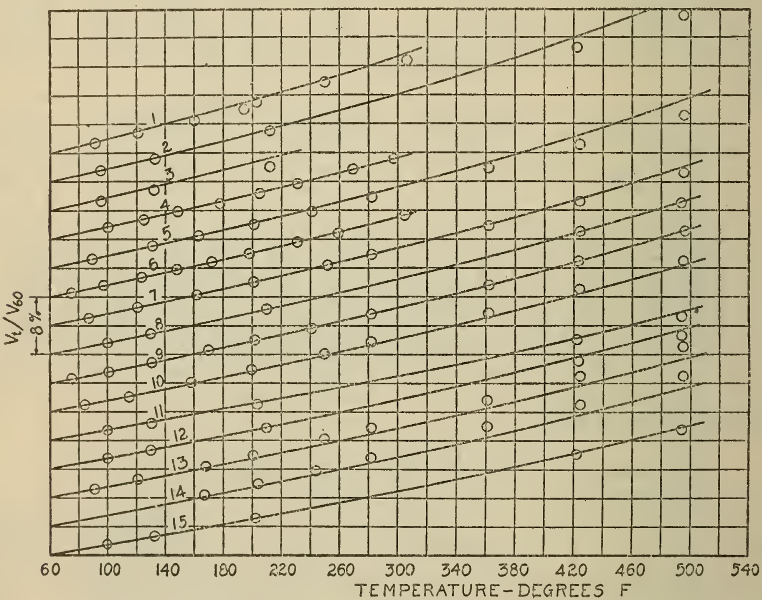


FIGURE 15.—*Comparison of data of present work with those of Fortsch and Wilson*

was from 0 to about 1,500 kg/cm². Values of compressibility between 0 and 50 kg/cm² were obtained from his data by means of values of mean compressibility, and deviation curves similar to those of Figure 7. These values are compared in Table 15 with values deduced from the correlation given in this paper. It is seen that Hyde's values for the oils are all lower than those deduced from the present work, although his value for water is slightly higher. The maximum difference is $1.0 \times 10^{-5}$ per kg/cm², corresponding to 0.05 per cent of the volume of the oil at 50 kg/cm².

[17] Report of the Lubricants and Lubrication Inquiry Committee, Dept. of Sci. and In. Research of Gt. Britian (1920). See also Proc. Roy. Soc., A 97, p. 240; 190.2

TABLE 14.—*Description of samples used by Fortsch and Wilson*

| Curve | Material | Specific gravity, 60°/60° F. | $\mu/\rho$ at 100° F. |
|---|---|---|---|
| | | | *cgs units* |
| 1 | Kerosene | 0.8234 | 0.0184 |
| 2 | Mineral seal | .848 | .056 |
| 3 | Mid-Continent crude | .849 | .059 |
| 4 | Pressed distillate | .876 | .091 |
| 5 | Light paraffin oil | .8837 | .155 |
| 6 | White oil | .8604 | .234 |
| 7 | Light paraffin oil | .892 | .301 |
| 8 | Distillate from Louisana heavy crude | .918 | .363 |
| 9 | Light motor oil | .8985 | .481 |
| 10 | Red oil | .909 | 1.067 |
| 11 | Road oil | 1.050 | 3.88 |
| 12 | North Louisiana heavy crude | .943 | 2.58 |
| 13 | Heavy motor oil | .914 | .255 (at 210° F.) |
| 14 | Cylinder stock | .916 | .338 (at 210° F.) |
| 15 | 14.5 gravity mid-Continent residuum | .970 | 59.0 |

TABLE 15.—*Comparison of Hyde's values of compressibility at 40° C. with values deduced from the present work*

| Material | Specific gravity, 60°/60° F. | ($\mu/\rho$) at 100° F. | Compressibility × $10^5$ | |
|---|---|---|---|---|
| | | | Hyde | Present work |
| | | *cgs units* | | |
| FFF Cylinder | 0.893 | 4.2 | 5.0 | 5.9 |
| Mobiloil A | .910 | .60 | 5.2 | 6.2 |
| Mobiloil BB | .914 | 1.8 | 5.2 | 5.9 |
| Bayonne | .907 | .60 | 5.2 | 6.2 |
| Victory red | .944 | 2.2 | 5.0 | 5.6 |
| Water | | | 4.5 | 4.2 |

## VI. CONCLUSION

It has been shown that the data on thermal expansion and compressibility of four gas oils and six lubricating oils can be correlated with specific gravity and viscosity. These oils were obtained from crudes from a number of different sources, and appear to be fairly representative of these two classes of oils. It seems reasonably safe to conclude that the correlation is applicable to all mineral oils of these classes; that is, to oils whose constituents have a relatively narrow range of volatilities. As no data were obtained on crudes or other oils whose constituents have a wide range of volatilities, it is not possible to say whether or not the correlation is applicable to such oils.

In conclusion, the author acknowledges with thanks the advice and assistance of C. S. Cragoe and H. C. Dickinson, under whose supervision this work was done.

## VII. APPENDIX. TABLES OF RELATIVE VOLUMES OF OILS

I. *Centigrade table for oils of moderate viscosity*

| Temperature ° C. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.020 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 34 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.80 | | 0.85 | | 0.90 | |
| | °A. P. I. | | | | | |
| | 45.4 | | 35.0 | | 25.7 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.996 | 1.000 | 0.997 | 1.000 | 0.997 |
| 10 | 1.009 | 1.005 | 1.009 | 1.005 | 1.008 | 1.005 |
| 20 | 1.018 | 1.014 | 1.017 | 1.014 | 1.017 | 1.013 |
| 30 | 1.027 | 1.023 | 1.026 | 1.022 | 1.025 | 1.021 |
| 40 | 1.036 | 1.032 | 1.035 | 1.031 | 1.034 | 1.030 |
| 50 | 1.045 | 1.041 | 1.044 | 1.040 | 1.043 | 1.038 |
| 60 | 1.055 | 1.050 | 1.054 | 1.049 | 1.052 | 1.047 |
| 70 | 1.064 | 1.059 | 1.063 | 1.058 | 1.061 | 1.056 |
| 80 | 1.075 | 1.068 | 1.073 | 1.067 | 1.070 | 1.065 |
| 90 | 1.085 | 1.078 | 1.083 | 1.076 | 1.080 | 1.074 |
| 100 | 1.096 | 1.089 | 1.093 | 1.086 | 1.090 | 1.084 |
| 120 | 1.118 | 1.109 | 1.114 | 1.106 | 1.110 | 1.103 |
| 140 | 1.141 | 1.131 | 1.136 | 1.127 | 1.132 | 1.123 |
| 160 | 1.166 | 1.154 | 1.160 | 1.149 | 1.154 | 1.144 |
| 180 | 1.193 | 1.179 | 1.185 | 1.172 | 1.178 | 1.167 |
| 200 | 1.222 | 1.205 | 1.213 | 1.197 | 1.204 | 1.191 |
| 220 | 1.253 | 1.233 | 1.242 | 1.223 | 1.232 | 1.216 |
| 240 | 1.288 | 1.263 | 1.274 | 1.252 | 1.262 | 1.243 |
| 260 | 1.327 | 1.296 | 1.310 | 1.282 | 1.296 | 1.272 |
| 280 | 1.371 | 1.332 | 1.350 | 1.316 | 1.333 | 1.303 |
| 300 | 1.422 | 1.370 | 1.396 | 1.352 | 1.375 | 1.337 |
| 320 | (1.48) | (1.41) | (1.45) | (1.39) | (1.42) | (1.37) |
| 340 | (1.54) | (1.46) | (1.50) | (1.43) | (1.47) | (1.41) |
| 360 | (1.6) | (1.51) | (1.57) | (1.48) | (1.53) | (1.46) |
| 380 | (1.7) | (1.57) | (1.64) | (1.53) | (1.60) | (1.53) |
| 400 | ---------- | (1.63) | (1.71) | (1.58) | (1.67) | (1.55) |

I. *Centigrade table for oils of moderate viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 100° F., cgs units: 0.028; Saybolt universal viscosity at 100° F.: 36 seconds | | | | | |
|---|---|---|---|---|---|---|
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.80 | | 0.85 | | 0.90 | |
| | °A. P. I. | | | | | |
| | 45.4 | | 35.0 | | 25.7 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.997 | 1.000 | 0.997 | 1.000 | 0.997 |
| 10 | 1.008 | 1.005 | 1.008 | 1.004 | 1.008 | 1.005 |
| 20 | 1.017 | 1.013 | 1.017 | 1.013 | 1.016 | 1.013 |
| 30 | 1.026 | 1.022 | 1.025 | 1.021 | 1.025 | 1.021 |
| 40 | 1.035 | 1.031 | 1.034 | 1.030 | 1.033 | 1.029 |
| 50 | 1.045 | 1.039 | 1.043 | 1.038 | 1.042 | 1.037 |
| 60 | 1.054 | 1.048 | 1.052 | 1.047 | 1.051 | 1.046 |
| 70 | 1.063 | 1.057 | 1.061 | 1.056 | 1.060 | 1.054 |
| 80 | 1.073 | 1.066 | 1.070 | 1.065 | 1.069 | 1.063 |
| 90 | 1.083 | 1.076 | 1.080 | 1.074 | 1.078 | 1.072 |
| 100 | 1.093 | 1.086 | 1.090 | 1.084 | 1.088 | 1.082 |
| 120 | 1.114 | 1.106 | 1.110 | 1.103 | 1.107 | 1.100 |
| 140 | 1.137 | 1.127 | 1.132 | 1.123 | 1.128 | 1.120 |
| 160 | 1.161 | 1.150 | 1.155 | 1.145 | 1.150 | 1.141 |
| 180 | 1.186 | 1.173 | 1.179 | 1.167 | 1.173 | 1.162 |
| 200 | 1.214 | 1.198 | 1.205 | 1.191 | 1.197 | 1.185 |
| 220 | 1.244 | 1.225 | 1.233 | 1.216 | 1.224 | 1.209 |
| 240 | 1.276 | 1.253 | 1.263 | 1.243 | 1.252 | 1.234 |
| 260 | 1.313 | 1.284 | 1.297 | 1.272 | 1.283 | 1.262 |
| 280 | 1.354 | 1.318 | 1.334 | 1.303 | 1.318 | 1.291 |
| 300 | 1.399 | 1.355 | 1.376 | 1.338 | 1.356 | 1.323 |
| 320 | (1.45) | (1.39) | (1.42) | (1.37) | (1.40) | (1.36) |
| 340 | (1.51) | (1.44) | (1.47) | (1.41) | (1.45) | (1.40) |
| 360 | (1.58) | (1.49) | (1.54) | (1.46) | (1.50) | (1.44) |
| 380 | (1.66) | (1.54) | (1.60) | (1.50) | (1.57) | (1.48) |
| 400 | (1.74) | (1.60) | (1.68) | (1.56) | (1.64) | (1.52) |

I. *Centigrade table for oils of moderate viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.050 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 42 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.80 | | 0.85 | | 0.90 | |
| | °A. P. I. | | | | | |
| | 45.4 | | 35.0 | | 25.7 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.997 | 1.000 | 0.997 | 1.000 | 0.997 |
| 10 | 1.008 | 1.005 | 1.008 | 1.005 | 1.008 | 1.005 |
| 20 | 1.017 | 1.013 | 1.016 | 1.013 | 1.016 | 1.012 |
| 30 | 1.025 | 1.021 | 1.024 | 1.021 | 1.024 | 1.020 |
| 40 | 1.034 | 1.030 | 1.033 | 1.029 | 1.032 | 1.028 |
| 50 | 1.043 | 1.038 | 1.041 | 1.037 | 1.040 | 1.036 |
| 60 | 1.052 | 1.047 | 1.050 | 1.046 | 1.049 | 1.044 |
| 70 | 1.061 | 1.055 | 1.059 | 1.054 | 1.057 | 1.053 |
| 80 | 1.070 | 1.064 | 1.068 | 1.063 | 1.066 | 1.061 |
| 90 | 1.080 | 1.074 | 1.077 | 1.072 | 1.075 | 1.070 |
| 100 | 1.089 | 1.083 | 1.087 | 1.081 | 1.084 | 1.078 |
| 120 | 1.110 | 1.102 | 1.106 | 1.099 | 1.103 | 1.096 |
| 140 | 1.131 | 1.123 | 1.127 | 1.119 | 1.123 | 1.115 |
| 160 | 1.153 | 1.143 | 1.148 | 1.139 | 1.144 | 1.135 |
| 180 | 1.177 | 1.165 | 1.171 | 1.160 | 1.165 | 1.155 |
| 200 | 1.202 | 1.189 | 1.194 | 1.182 | 1.188 | 1.176 |
| 220 | 1.230 | 1.214 | 1.220 | 1.206 | 1.212 | 1.199 |
| 240 | 1.260 | 1.240 | 1.248 | 1.231 | 1.238 | 1.222 |
| 260 | 1.293 | 1.269 | 1.278 | 1.258 | 1.266 | 1.248 |
| 280 | 1.329 | 1.300 | 1.311 | 1.287 | 1.297 | 1.275 |
| 300 | 1.369 | 1.333 | 1.349 | 1.318 | 1.331 | 1.304 |
| 320 | (1.42) | (1.37) | (1.39) | (1.35) | (1.37) | (1.34) |
| 340 | (1.47) | (1.41) | (1.44) | (1.39) | (1.41) | (1.37) |
| 360 | (1.54) | (1.46) | (1.49) | (1.43) | (1.45) | (1.41) |
| 380 | (1.62) | (1.53) | (1.56) | (1.47) | (1.50) | (1.44) |
| 400 | (1.71) | (1.56) | (1.63) | (1.51) | (1.56) | (1.48) |

I. *Centigrade table for oils of moderate viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.100 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 60 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.85 | | 0.90 | | 0.95 | |
| | ° A. P. I. | | | | | |
| | 35.0 | | 25.7 | | 17.5 | |
| | Pressure, kg/cm ² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.997 | 1.000 | 0.997 | 1.000 | 0.997 |
| 10 | 1.008 | 1.005 | 1.008 | 1.005 | 1.007 | 1.004 |
| 20 | 1.016 | 1.012 | 1.015 | 1.012 | 1.015 | 1.012 |
| 30 | 1.024 | 1.020 | 1.023 | 1.020 | 1.023 | 1.019 |
| 40 | 1.032 | 1.028 | 1.031 | 1.027 | 1.031 | 1.027 |
| 50 | 1.040 | 1.036 | 1.039 | 1.035 | 1.038 | 1.034 |
| 60 | 1.048 | 1.044 | 1.047 | 1.043 | 1.046 | 1.042 |
| 70 | 1.057 | 1.052 | 1.055 | 1.051 | 1.054 | 1.050 |
| 80 | 1.066 | 1.060 | 1.064 | 1.059 | 1.062 | 1.058 |
| 90 | 1.074 | 1.069 | 1.072 | 1.067 | 1.071 | 1.066 |
| 100 | 1.083 | 1.078 | 1.081 | 1.076 | 1.079 | 1.074 |
| 120 | 1.102 | 1.096 | 1.099 | 1.093 | 1.097 | 1.091 |
| 140 | 1.121 | 1.114 | 1.118 | 1.111 | 1.115 | 1.108 |
| 160 | 1.142 | 1.133 | 1.137 | 1.129 | 1.134 | 1.126 |
| 180 | 1.163 | 1.153 | 1.158 | 1.149 | 1.153 | 1.145 |
| 200 | 1.185 | 1.174 | 1.179 | 1.169 | 1.174 | 1.164 |
| 220 | 1.209 | 1.196 | 1.202 | 1.190 | 1.195 | 1.184 |
| 240 | 1.234 | 1.219 | 1.226 | 1.212 | 1.218 | 1.205 |
| 260 | 1.262 | 1.244 | 1.252 | 1.236 | 1.243 | 1.227 |
| 280 | 1.292 | 1.271 | 1.280 | 1.261 | 1.269 | 1.251 |
| 300 | 1.325 | 1.299 | 1.309 | 1.287 | 1.297 | 1.276 |
| 320 | (1.36) | (1.33) | (1.34) | (1.31) | (1.33) | (1.30) |
| 340 | (1.40) | (1.36) | (1.38) | (1.34) | (1.36) | (1.33) |
| 360 | (1.44) | (1.40) | (1.41) | (1.37) | (1.39) | (1.36) |
| 380 | (1.49) | (1.43) | (1.45) | (1.41) | (1.43) | (1.39) |
| 400 | (1.54) | (1.47) | (1.49) | (1.44) | (1.47) | (1.43) |

I. *Centigrade table for oils of moderate viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.200 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 98 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.85 | | 0.90 | | 0.95 | |
| | °A. P. I. | | | | | |
| | 35.0 | | 25.7 | | 17.5 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.997 | 1.000 | 0.997 | 1.000 | 0.997 |
| 10 | 1.007 | 1.005 | 1.007 | 1.005 | 1.007 | 1.005 |
| 20 | 1.015 | 1.012 | 1.015 | 1.012 | 1.015 | 1.012 |
| 30 | 1.023 | 1.020 | 1.022 | 1.019 | 1.022 | 1.019 |
| 40 | 1.031 | 1.027 | 1.030 | 1.027 | 1.029 | 1.026 |
| 50 | 1.039 | 1.035 | 1.038 | 1.034 | 1.037 | 1.034 |
| 60 | 1.047 | 1.043 | 1.046 | 1.042 | 1.045 | 1.041 |
| 70 | 1.055 | 1.051 | 1.054 | 1.050 | 1.053 | 1.049 |
| 80 | 1.063 | 1.059 | 1.062 | 1.057 | 1.060 | 1.056 |
| 90 | 1.072 | 1.067 | 1.070 | 1.065 | 1.069 | 1.064 |
| 100 | 1.081 | 1.075 | 1.078 | 1.073 | 1.077 | 1.072 |
| 120 | 1.098 | 1.093 | 1.095 | 1.090 | 1.094 | 1.088 |
| 140 | 1.117 | 1.110 | 1.113 | 1.107 | 1.111 | 1.105 |
| 160 | 1.136 | 1.129 | 1.131 | 1.125 | 1.129 | 1.122 |
| 180 | 1.156 | 1.148 | 1.151 | 1.143 | 1.148 | 1.140 |
| 200 | 1.177 | 1.167 | 1.171 | 1.162 | 1.167 | 1.158 |
| 220 | 1.200 | 1.188 | 1.193 | 1.183 | 1.188 | 1.177 |
| 240 | 1.224 | 1.210 | 1.216 | 1.203 | 1.209 | 1.197 |
| 260 | 1.249 | 1.233 | 1.240 | 1.225 | 1.232 | 1.219 |
| 280 | 1.277 | 1.258 | 1.266 | 1.249 | 1.257 | 1.240 |
| 300 | 1.306 | 1.284 | 1.293 | 1.273 | 1.282 | 1.264 |
| 320 | (1.34) | (1.31) | (1.32) | (1.30) | (1.31) | (1.29) |
| 340 | (1.37) | (1.34) | (1.35) | (1.33) | (1.34) | (1.31) |
| 360 | (1.41) | (1.37) | (1.39) | (1.36) | (1.37) | (1.34) |
| 380 | (1.45) | (1.41) | (1.42) | (1.39) | (1.40) | (1.37) |
| 400 | (1.49) | (1.44) | (1.46) | (1.42) | (1.44) | (1.40) |

I. *Centigrade table for oils of moderate viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.500 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 229 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.85 | | 0.90 | | 0.95 | |
| | °A. P. I. | | | | | |
| | 35.0 | | 25.7 | | 17.5 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.997 | 1.000 | 0.997 | 1.000 | 0.998 |
| 10 | 1.007 | 1.005 | 1.007 | 1.004 | 1.007 | 1.005 |
| 20 | 1.015 | 1.012 | 1.014 | 1.012 | 1.014 | 1.012 |
| 30 | 1.022 | 1.019 | 1.022 | 1.019 | 1.021 | 1.019 |
| 40 | 1.030 | 1.027 | 1.029 | 1.026 | 1.029 | 1.026 |
| 50 | 1.038 | 1.034 | 1.037 | 1.033 | 1.036 | 1.033 |
| 60 | 1.046 | 1.042 | 1.044 | 1.040 | 1.043 | 1.040 |
| 70 | 1.053 | 1.049 | 1.052 | 1.048 | 1.051 | 1.047 |
| 80 | 1.061 | 1.057 | 1.060 | 1.055 | 1.058 | 1.055 |
| 90 | 1.070 | 1.065 | 1.068 | 1.063 | 1.066 | 1.062 |
| 100 | 1.078 | 1.073 | 1.076 | 1.071 | 1.074 | 1.070 |
| 120 | 1.095 | 1.089 | 1.092 | 1.087 | 1.090 | 1.085 |
| 140 | 1.113 | 1.106 | 1.110 | 1.103 | 1.107 | 1.101 |
| 160 | 1.131 | 1.124 | 1.127 | 1.120 | 1.124 | 1.118 |
| 180 | 1.150 | 1.142 | 1.146 | 1.138 | 1.142 | 1.135 |
| 200 | 1.170 | 1.161 | 1.165 | 1.156 | 1.161 | 1.152 |
| 220 | 1.191 | 1.180 | 1.185 | 1.175 | 1.181 | 1.171 |
| 240 | 1.213 | 1.201 | 1.206 | 1.195 | 1.201 | 1.190 |
| 260 | 1.237 | 1.223 | 1.229 | 1.215 | 1.222 | 1.209 |
| 280 | 1.262 | 1.245 | 1.252 | 1.237 | 1.245 | 1.230 |
| 300 | 1.289 | 1.269 | 1.278 | 1.260 | 1.269 | 1.252 |
| 320 | (1.32) | (1.29) | (1.30) | (1.28) | (1.29) | (1.27) |
| 340 | (1.35) | (1.32) | (1.33) | (1.31) | (1.32) | (1.30) |
| 360 | (1.38) | (1.35) | (1.36) | (1.33) | (1.34) | (1.32) |
| 380 | (1.41) | (1.38) | (1.39) | (1.36) | (1.37) | (1.34) |
| 400 | (1.45) | (1 41) | (1.43) | (1.38) | (1.40) | (1.37) |

I. *Centigrade table for oils of moderate viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 1.000 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 445 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.85 | | 0.90 | | 0.95 | |
| | ° A. P. I. | | | | | |
| | 35.0 | | 25.7 | | 17.5 | |
| | Pressure, kg/cm [2] | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.997 | 1.000 | 0.998 | 1.000 | 0.998 |
| 10 | 1.007 | 1.005 | 1.007 | 1.004 | 1.007 | 1.004 |
| 20 | 1.015 | 1.012 | 1.014 | 1.011 | 1.014 | 1.011 |
| 30 | 1.022 | 1.019 | 1.021 | 1.018 | 1.021 | 1.018 |
| 40 | 1.029 | 1.026 | 1.029 | 1.025 | 1.028 | 1.025 |
| 50 | 1.037 | 1.034 | 1.036 | 1.033 | 1.035 | 1.032 |
| 60 | 1.045 | 1.041 | 1.044 | 1.040 | 1.043 | 1.039 |
| 70 | 1.052 | 1.048 | 1.051 | 1.047 | 1.050 | 1.046 |
| 80 | 1.060 | 1.056 | 1.059 | 1.055 | 1.058 | 1.054 |
| 90 | 1.068 | 1.064 | 1.066 | 1.062 | 1.065 | 1.061 |
| 100 | 1.076 | 1.071 | 1.074 | 1.070 | 1.073 | 1.068 |
| 120 | 1.093 | 1.087 | 1.090 | 1.085 | 1.088 | 1.083 |
| 140 | 1.110 | 1.104 | 1.107 | 1.101 | 1.104 | 1.099 |
| 160 | 1.128 | 1.121 | 1.124 | 1.118 | 1.121 | 1.115 |
| 180 | 1.146 | 1.138 | 1.142 | 1.135 | 1.139 | 1.131 |
| 200 | 1.165 | 1.157 | 1.161 | 1.152 | 1.157 | 1.149 |
| 220 | 1.186 | 1.176 | 1.180 | 1.171 | 1.176 | 1.166 |
| 240 | 1.207 | 1.195 | 1.201 | 1.190 | 1.195 | 1.185 |
| 260 | 1.230 | 1.216 | 1.222 | 1.210 | 1.216 | 1.204 |
| 280 | 1.254 | 1.238 | 1.245 | 1.230 | 1.238 | 1.226 |
| 300 | 1.279 | 1.260 | 1.269 | 1.252 | 1.261 | 1.244 |
| 320 | (1.30) | (1.28) | (1.29) | (1.27) | (1.28) | (1.27) |
| 340 | (1.33) | (1.31) | (1.32) | (1.30) | (1.31) | (1.29) |
| 360 | (1.37) | (1.33) | (1.35) | (1.32) | (1.33) | (1.31) |
| 380 | (1.40) | (1.36) | (1.38) | (1.34) | (1.36) | (1.33) |
| 400 | (1.43) | (1.39) | (1.41) | (1.37) | (1.39) | (1.36) |

I. *Centigrade table for oils of moderate viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 2.000 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 910 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.85 | | 0.90 | | 0.95 | |
| | °A. P. I. | | | | | |
| | 35.0 | | 25.7 | | 17.5 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.998 | 1.000 | 0.998 | 1.000 | 0.998 |
| 10 | 1.007 | 1.004 | 1.007 | 1.005 | 1.007 | 1.004 |
| 20 | 1.014 | 1.011 | 1.014 | 1.011 | 1.014 | 1.011 |
| 30 | 1.021 | 1.018 | 1.021 | 1.018 | 1.021 | 1.018 |
| 40 | 1.029 | 1.026 | 1.028 | 1.025 | 1.028 | 1.025 |
| 50 | 1.036 | 1.033 | 1.036 | 1.033 | 1.035 | 1.032 |
| 60 | 1.044 | 1.040 | 1.043 | 1.040 | 1.042 | 1.039 |
| 70 | 1.051 | 1.047 | 1.051 | 1.047 | 1.049 | 1.046 |
| 80 | 1.059 | 1.055 | 1.058 | 1.054 | 1.056 | 1.053 |
| 90 | 1.067 | 1.062 | 1.066 | 1.061 | 1.064 | 1.060 |
| 100 | 1.075 | 1.070 | 1.073 | 1.069 | 1.071 | 1.067 |
| 120 | 1.091 | 1.085 | 1.089 | 1.084 | 1.087 | 1.082 |
| 140 | 1.108 | 1.102 | 1.105 | 1.099 | 1.102 | 1.097 |
| 160 | 1.125 | 1.118 | 1.122 | 1.115 | 1.119 | 1.112 |
| 180 | 1.143 | 1.135 | 1.139 | 1.132 | 1.136 | 1.129 |
| 200 | 1.162 | 1.153 | 1.157 | 1.149 | 1.153 | 1.145 |
| 220 | 1.181 | 1.171 | 1.176 | 1.167 | 1.172 | 1.163 |
| 240 | 1.202 | 1.190 | 1.196 | 1.185 | 1.191 | 1.180 |
| 260 | 1.223 | 1.210 | 1.217 | 1.205 | 1.211 | 1.199 |
| 280 | 1.246 | 1.231 | 1.239 | 1.225 | 1.232 | 1.218 |
| 300 | 1.270 | 1.253 | 1.261 | 1.245 | 1.254 | 1.239 |
| 320 | (1.30) | (1.28) | (1.29) | (1.27) | (1.28) | (1.26) |
| 340 | (1.32) | (1.30) | (1.31) | (1.29) | (1.30) | (1.28) |
| 360 | (1.35) | (1.32) | (1.34) | (1.31) | (1.32) | (1.30) |
| 380 | (1.38) | (1.35) | (1.36) | (1.34) | (1.35) | (1.32) |
| 400 | (1.41) | (1.37) | (1.39) | (1.36) | (1.37) | (1.35) |

15377°—30——4

I. *Centigrade table for oils of moderate viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 100° F., cgs units: 5.000; Saybolt universal viscosity at 100° F.: 2,270 seconds; Specific gravity, 60°/60° F.: 0.85; °A. P. I.: 35.0 | | 0.90; 25.7 | | 0.95; 17.5 | |
|---|---|---|---|---|---|---|
| | Pressure, kg/cm ²: 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.998 | 1.000 | 0.998 | 1.000 | 0.998 |
| 10 | 1.007 | 1.004 | 1.007 | 1.004 | 1.007 | 1.004 |
| 20 | 1.014 | 1.011 | 1.014 | 1.011 | 1.013 | 1.011 |
| 30 | 1.021 | 1.018 | 1.021 | 1.018 | 1.020 | 1.018 |
| 40 | 1.028 | 1.025 | 1.028 | 1.025 | 1.027 | 1.024 |
| 50 | 1.035 | 1.032 | 1.035 | 1.032 | 1.034 | 1.031 |
| 60 | 1.043 | 1.039 | 1.042 | 1.039 | 1.041 | 1.038 |
| 70 | 1.050 | 1.046 | 1.049 | 1.046 | 1.048 | 1.045 |
| 80 | 1.058 | 1.054 | 1.056 | 1.053 | 1.055 | 1.051 |
| 90 | 1.065 | 1.061 | 1.064 | 1.060 | 1.062 | 1.058 |
| 100 | 1.073 | 1.068 | 1.071 | 1.067 | 1.069 | 1.065 |
| 120 | 1.089 | 1.084 | 1.086 | 1.082 | 1.084 | 1.080 |
| 140 | 1.105 | 1.099 | 1.102 | 1.097 | 1.099 | 1.094 |
| 160 | 1.122 | 1.115 | 1.119 | 1.112 | 1.115 | 1.109 |
| 180 | 1.139 | 1.132 | 1.136 | 1.128 | 1.131 | 1.125 |
| 200 | 1.157 | 1.149 | 1.153 | 1.145 | 1.148 | 1.141 |
| 220 | 1.176 | 1.167 | 1.172 | 1.163 | 1.166 | 1.158 |
| 240 | 1.196 | 1.185 | 1.191 | 1.181 | 1.184 | 1.175 |
| 260 | 1.217 | 1.204 | 1.211 | 1.199 | 1.203 | 1.192 |
| 280 | 1.239 | 1.224 | 1.232 | 1.218 | 1.223 | 1.210 |
| 300 | 1.261 | 1.245 | 1.254 | 1.238 | 1.244 | 1.229 |
| 320 | (1.29) | (1.27) | (1.28) | (1.26) | (1.26) | (1.25) |
| 340 | (1.31) | (1.29) | (1.30) | (1.28) | (1.29) | (1.27) |
| 360 | (1.34) | (1.31) | (1.32) | (1.30) | (1.31) | (1.29) |
| 380 | (1.36) | (1.33) | (1.35) | (1.32) | (1.33) | (1.31) |
| 400 | (1.39) | (1.36) | (1.38) | (1.35) | (1.36) | (1.33) |

II. *Centigrade table for oils of high viscosity*

| Temperature ° C. | Kinematic viscosity at 210° F., cgs units: 0.042; Saybolt universal viscosity at 210° F.: 40 seconds; Specific gravity, 60°/60° F.: 0.90; °A. P. I.: 25.7; Pressure, kg/cm²: 0 | 50 | 0.95; 17.5; 0 | 50 | 1.00; 10.0; 0 | 50 |
|---|---|---|---|---|---|---|
| 0 | 1.000 | 0.997 | 1.000 | 0.998 | 1.000 | 0.998 |
| 10 | 1.007 | 1.004 | 1.007 | 1.004 | 1.007 | 1.004 |
| 20 | 1.014 | 1.011 | 1.014 | 1.011 | 1.014 | 1.011 |
| 30 | 1.022 | 1.019 | 1.022 | 1.019 | 1.021 | 1.018 |
| 40 | 1.029 | 1.026 | 1.029 | 1.026 | 1.028 | 1.025 |
| 50 | 1.037 | 1.034 | 1.036 | 1.033 | 1.035 | 1.033 |
| 60 | 1.045 | 1.041 | 1.044 | 1.040 | 1.042 | 1.039 |
| 70 | 1.053 | 1.049 | 1.051 | 1.047 | 1.050 | 1.046 |
| 80 | 1.061 | 1.056 | 1.059 | 1.055 | 1.057 | 1.053 |
| 90 | 1.069 | 1.064 | 1.067 | 1.062 | 1.065 | 1.060 |
| 100 | 1.077 | 1.072 | 1.075 | 1.070 | 1.072 | 1.068 |
| 120 | 1.094 | 1.089 | 1.091 | 1.086 | 1.088 | 1.083 |
| 140 | 1.112 | 1.105 | 1.108 | 1.102 | 1.104 | 1.098 |
| 160 | 1.130 | 1.123 | 1.125 | 1.118 | 1.121 | 1.115 |
| 180 | 1.149 | 1.140 | 1.143 | 1.135 | 1.138 | 1.131 |
| 200 | 1.168 | 1.159 | 1.162 | 1.153 | 1.156 | 1.148 |
| 220 | 1.189 | 1.179 | 1.182 | 1.171 | 1.175 | 1.166 |
| 240 | 1.211 | 1.199 | 1.202 | 1.190 | 1.195 | 1.184 |
| 260 | 1.234 | 1.220 | 1.224 | 1.210 | 1.216 | 1.204 |
| 280 | 1.259 | 1.243 | 1.247 | 1.231 | 1.237 | 1.223 |
| 300 | 1.286 | 1.266 | 1.271 | 1.254 | 1.260 | 1.244 |
| 320 | (1.31) | (1.29) | (1.30) | (1.28) | (1.28) | (1.27) |
| 340 | (1.34) | (1.32) | (1.32) | (1.30) | (1.31) | (1.29) |
| 360 | (1.38) | (1.34) | (1.35) | (1.33) | (1.33) | (1.31) |
| 380 | (1.41) | (1.37) | (1.38) | (1.35) | (1.36) | (1.33) |
| 400 | (1.45) | (1.40) | (1.41) | (1.38) | (1.39) | (1.36) |

II. *Centigrade table for oils of high viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 210° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.100 | | | | | |
| | Saybolt universal viscosity at 210° F. | | | | | |
| | 60 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.90 | | 0.95 | | 1.00 | |
| | ° A. P. I. | | | | | |
| | 25.7 | | 17.5 | | 10.0 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.998 | 1.000 | 0.998 | 1.000 | 0.998 |
| 10 | 1.007 | 1.004 | 1.007 | 1.004 | 1.007 | 1.004 |
| 20 | 1.014 | 1.011 | 1.014 | 1.011 | 1.014 | 1.011 |
| 30 | 1.021 | 1.018 | 1.021 | 1.018 | 1.020 | 1.017 |
| 40 | 1.029 | 1.025 | 1.028 | 1.025 | 1.027 | 1.024 |
| 50 | 1.036 | 1.032 | 1.035 | 1.032 | 1.034 | 1.031 |
| 60 | 1.043 | 1.039 | 1.042 | 1.038 | 1.041 | 1.037 |
| 70 | 1.051 | 1.047 | 1.049 | 1.046 | 1.048 | 1.044 |
| 80 | 1.058 | 1.054 | 1.057 | 1.053 | 1.055 | 1.051 |
| 90 | 1.066 | 1.062 | 1.064 | 1.060 | 1.063 | 1.059 |
| 100 | 1.074 | 1.070 | 1.071 | 1.067 | 1.070 | 1.066 |
| 120 | 1.090 | 1.085 | 1.087 | 1.082 | 1.085 | 1.080 |
| 140 | 1.107 | 1.101 | 1.103 | 1.098 | 1.100 | 1.095 |
| 160 | 1.124 | 1.118 | 1.119 | 1.113 | 1.116 | 1.110 |
| 180 | 1.142 | 1.135 | 1.136 | 1.130 | 1.132 | 1.126 |
| 200 | 1.161 | 1.152 | 1.154 | 1.147 | 1.149 | 1.142 |
| 220 | 1.180 | 1.171 | 1.173 | 1.164 | 1.167 | 1.159 |
| 240 | 1.201 | 1.190 | 1.192 | 1.182 | 1.186 | 1.176 |
| 260 | 1.222 | 1.210 | 1.213 | 1.201 | 1.205 | 1.194 |
| 280 | 1.245 | 1.230 | 1.234 | 1.221 | 1.225 | 1.213 |
| 300 | 1.269 | 1.252 | 1.256 | 1.241 | 1.247 | 1.232 |
| 320 | (1.29) | (1.27) | (1.28) | (1.26) | (1.27) | (1.25) |
| 340 | (1.32) | (1.30) | (1.30) | (1.28) | (1.29) | (1.27) |
| 360 | (1.35) | (1.32) | (1.33) | (1.31) | (1.32) | (1.29) |
| 380 | (1.38) | (1.35) | (1.35) | (1.33) | (1.34) | (1.32) |
| 400 | (1.41) | (1.37) | (1.38) | (1.35) | (1.37) | (1.34) |

II. *Centigrade table for oils of high viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 210° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.200 | | | | | |
| | Saybolt universal viscosity at 210° F. | | | | | |
| | 100 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.90 | | 0.95 | | 1.00 | |
| | ° A. P. I. | | | | | |
| | 25.7 | | 17.5 | | 10.0 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.998 | 1.000 | 0.998 | 1.000 | 0.998 |
| 10 | 1.007 | 1.004 | 1.006 | 1.004 | 1.006 | 1.004 |
| 20 | 1.014 | 1.011 | 1.013 | 1.011 | 1.013 | 1.011 |
| 30 | 1.021 | 1.018 | 1.020 | 1.017 | 1.020 | 1.017 |
| 40 | 1.028 | 1.024 | 1.027 | 1.024 | 1.026 | 1.023 |
| 50 | 1.035 | 1.031 | 1.034 | 1.031 | 1.033 | 1.030 |
| 60 | 1.042 | 1.038 | 1.041 | 1.038 | 1.040 | 1.037 |
| 70 | 1.049 | 1.045 | 1.048 | 1.045 | 1.046 | 1.043 |
| 80 | 1.057 | 1.052 | 1.055 | 1.051 | 1.053 | 1.050 |
| 90 | 1.064 | 1.060 | 1.062 | 1.058 | 1.060 | 1.057 |
| 100 | 1.072 | 1.067 | 1.069 | 1.065 | 1.067 | 1.064 |
| 120 | 1.087 | 1.082 | 1.084 | 1.080 | 1.082 | 1.078 |
| 140 | 1.104 | 1.098 | 1.100 | 1.094 | 1.096 | 1.092 |
| 160 | 1.120 | 1.113 | 1.115 | 1.109 | 1.112 | 1.107 |
| 180 | 1.137 | 1.130 | 1.132 | 1.125 | 1.128 | 1.122 |
| 200 | 1.155 | 1.147 | 1.149 | 1.141 | 1.144 | 1.137 |
| 220 | 1.173 | 1.164 | 1.167 | 1.158 | 1.161 | 1.153 |
| 240 | 1.193 | 1.183 | 1.185 | 1.175 | 1.179 | 1.170 |
| 260 | 1.213 | 1.201 | 1.204 | 1.193 | 1.198 | 1.187 |
| 280 | 1.235 | 1.221 | 1.224 | 1.212 | 1.217 | 1.205 |
| 300 | 1.258 | 1.241 | 1.245 | 1.230 | 1.237 | 1.223 |
| 320 | (1.28) | (1.26) | (1.27) | (1.25) | (1.26) | (1.24) |
| 340 | (1.31) | (1.28) | (1.29) | (1.27) | (1.28) | (1.26) |
| 360 | (1.33) | (1.31) | (1.31) | (1.29) | (1.30) | (1.28) |
| 380 | (1.36) | (1.33) | (1.33) | (1.31) | (1.32) | (1.30) |
| 400 | (1.39) | (1.35) | (1.36) | (1.33) | (1.35) | (1.32) |

II. *Centigrade table for oils of high viscosity*—Continued

| Temperature °C. | Kinematic viscosity 210° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.440 | | | | | |
| | Saybolt universal viscosity at 210° F. | | | | | |
| | 200 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.90 | | 0.95 | | 1.00 | |
| | °A. P. I. | | | | | |
| | 25.7 | | 17.5 | | 10.0 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.998 | 1.000 | 0.998 | 1.000 | 0.998 |
| 10 | 1.006 | 1.004 | 1.006 | 1.004 | 1.006 | 1.004 |
| 20 | 1.013 | 1.011 | 1.013 | 1.010 | 1.012 | 1.010 |
| 30 | 1.020 | 1.017 | 1.020 | 1.017 | 1.119 | 1.017 |
| 40 | 1.027 | 1.024 | 1.026 | 1.023 | 1.025 | 1.023 |
| 50 | 1.034 | 1.031 | 1.033 | 1.030 | 1.032 | 1.029 |
| 60 | 1.041 | 1.038 | 1.040 | 1.037 | 1.039 | 1.036 |
| 70 | 1.048 | 1.045 | 1.046 | 1.043 | 1.045 | 1.042 |
| 80 | 1.055 | 1.052 | 1.053 | 1.050 | 1.052 | 1.049 |
| 90 | 1.063 | 1.059 | 1.060 | 1.057 | 1.059 | 1.056 |
| 100 | 1.070 | 1.066 | 1.068 | 1.064 | 1.066 | 1.063 |
| 120 | 1.085 | 1.081 | 1.082 | 1.078 | 1.080 | 1.076 |
| 140 | 1.101 | 1.096 | 1.097 | 1.092 | 1.094 | 1.090 |
| 160 | 1.117 | 1.111 | 1.112 | 1.107 | 1.109 | 1.104 |
| 180 | 1.133 | 1.127 | 1.128 | 1.122 | 1.124 | 1.119 |
| 200 | 1.151 | 1.143 | 1.145 | 1.138 | 1.140 | 1.134 |
| 220 | 1.169 | 1.160 | 1.162 | 1.154 | 1.157 | 1.149 |
| 240 | 1.187 | 1.177 | 1.180 | 1.170 | 1.174 | 1.164 |
| 260 | 1.207 | 1.195 | 1.198 | 1.188 | 1.191 | 1.181 |
| 280 | 1.227 | 1.214 | 1.217 | 1.205 | 1.209 | 1.197 |
| 300 | 1.248 | 1.234 | 1.237 | 1.223 | 1.228 | 1.214 |
| 320 | (1.27) | (1.25) | (1.26) | (1.24) | (1.25) | (1.23) |
| 340 | (1.29) | (1.27) | (1.28) | (1.26) | (1.27) | (1.25) |
| 360 | (1.32) | (1.30) | (1.30) | (1.28) | (1.29) | (1.27) |
| 380 | (1.34) | (1.32) | (1.32) | (1.30) | (1.31) | (1.29) |
| 400 | (1.36) | (1.34) | (1.34) | (1.32) | (1.33) | (1.31) |

II. *Centigrade table for oils of high viscosity*—Continued

| Temperature ° C. | Kinematic viscosity at 210° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 1.100 | | | | | |
| | Saybolt universal viscosity at 210° F. | | | | | |
| | 500 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.90 | | 0.95 | | 1.00 | |
| | ° A. P. I. | | | | | |
| | 25.7 | | 17.5 | | 10.0 | |
| | Pressure, kg/cm² | | | | | |
| | 0 | 50 | 0 | 50 | 0 | 50 |
| 0 | 1.000 | 0.998 | 1.000 | 0.998 | 1.000 | 0.998 |
| 10 | 1.006 | 1.004 | 1.006 | 1.004 | 1.006 | 1.004 |
| 20 | 1.013 | 1.010 | 1.012 | 1.010 | 1.012 | 1.010 |
| 30 | 1.020 | 1.017 | 1.019 | 1.017 | 1.018 | 1.016 |
| 40 | 1.026 | 1.023 | 1.025 | 1.023 | 1.025 | 1.022 |
| 50 | 1.033 | 1.030 | 1.032 | 1.029 | 1.031 | 1.028 |
| 60 | 1.040 | 1.037 | 1.038 | 1.036 | 1.037 | 1.034 |
| 70 | 1.047 | 1.044 | 1.045 | 1.042 | 1.043 | 1.040 |
| 80 | 1.054 | 1.050 | 1.052 | 1.049 | 1.050 | 1.047 |
| 90 | 1.061 | 1.057 | 1.058 | 1.055 | 1.056 | 1.053 |
| 100 | 1.068 | 1.065 | 1.065 | 1.062 | 1.063 | 1.060 |
| 120 | 1.083 | 1.079 | 1.080 | 1.075 | 1.076 | 1.072 |
| 140 | 1.098 | 1.093 | 1.094 | 1.089 | 1.089 | 1.086 |
| 160 | 1.113 | 1.108 | 1.109 | 1.103 | 1.104 | 1.099 |
| 180 | 1.129 | 1.123 | 1.125 | 1.118 | 1.118 | 1.113 |
| 200 | 1.146 | 1.139 | 1.140 | 1.133 | 1.134 | 1.128 |
| 220 | 1.163 | 1.155 | 1.157 | 1.149 | 1.150 | 1.142 |
| 240 | 1.182 | 1.172 | 1.174 | 1.165 | 1.166 | 1.157 |
| 260 | 1.201 | 1.189 | 1.192 | 1.181 | 1.183 | 1.173 |
| 280 | 1.220 | 1.207 | 1.210 | 1.198 | 1.200 | 1.188 |
| 300 | 1.241 | 1.225 | 1.229 | 1.216 | 1.218 | 1.205 |
| 320 | (1.26) | (1.24) | (1.25) | (1.23) | (1.24) | (1.22) |
| 340 | (1.28) | (1.26) | (1.27) | (1.25) | (1.26) | (1.24) |
| 360 | (1.31) | (1.28) | (1.28) | (1.26) | (1.28) | (1.26) |
| 380 | (1.33) | (1.31) | (1.31) | (1.29) | (1.30) | (1.27) |
| 400 | (1.35) | (1.33) | (1.33) | (1.31) | (1.32) | (1.29) |

III. *Fahrenheit table for oils of moderate viscosity*

| Temperature ° F. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.020 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 34 seconds | | | | | |
| | Specific gravity 60°/60°F. | | | | | |
| | 0.80 | | 0.85 | | 0.90 | |
| | °A. P. I. | | | | | |
| | 45.4 | | 35.0 | | 25.7 | |
| | Pressure, lbs./in.² | | | | | |
| | 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0. 981 | 0. 978 | 0. 981 | 0. 978 | 0. 982 | 0. 978 |
| 40 | . 990 | . 987 | . 990 | . 987 | . 991 | . 987 |
| 60 | 1. 000 | . 996 | 1. 000 | . 996 | 1. 000 | . 996 |
| 80 | 1. 010 | 1. 006 | 1. 010 | 1. 006 | 1. 009 | 1. 005 |
| 100 | 1. 020 | 1. 016 | 1. 019 | 1. 015 | 1. 019 | 1. 015 |
| 120 | 1. 030 | 1. 026 | 1. 029 | 1. 025 | 1. 028 | 1. 024 |
| 140 | 1. 041 | 1. 036 | 1. 040 | 1. 035 | 1. 038 | 1. 034 |
| 160 | 1. 052 | 1. 046 | 1. 050 | 1. 045 | 1. 048 | 1. 044 |
| 180 | 1. 063 | 1. 056 | 1. 061 | 1. 055 | 1. 059 | 1. 053 |
| 200 | 1. 074 | 1. 067 | 1. 072 | 1. 065 | 1. 069 | 1. 063 |
| 220 | 1. 086 | 1. 079 | 1. 083 | 1. 076 | 1. 080 | 1. 074 |
| 240 | 1. 098 | 1. 090 | 1. 095 | 1. 087 | 1. 091 | 1. 084 |
| 260 | 1. 110 | 1. 101 | 1. 106 | 1. 098 | 1. 103 | 1. 095 |
| 280 | 1. 123 | 1. 113 | 1. 119 | 1. 109 | 1. 115 | 1. 106 |
| 300 | 1. 136 | 1. 126 | 1. 131 | 1. 121 | 1. 126 | 1. 118 |
| 350 | 1. 172 | 1. 159 | 1. 165 | 1. 153 | 1. 159 | 1. 148 |
| 400 | 1. 212 | 1. 195 | 1. 203 | 1. 187 | 1. 195 | 1. 181 |
| 450 | 1. 257 | 1. 235 | 1. 245 | 1. 225 | 1. 234 | 1. 216 |
| 500 | 1. 310 | 1, 279 | 1. 293 | 1, 266 | 1. 279 | 1. 256 |
| 550 | 1. 371 | 1, 328 | 1. 349 | 1. 313 | 1. 331 | 1. 299 |
| 600 | (1. 45) | (1. 39) | (1. 42) | (1. 37) | (1. 39) | (1. 35) |
| 650 | (1. 53) | (1. 45) | (1. 49) | (1. 42) | (1. 46) | (1. 40) |
| 700 | (1. 64) | (1. 53) | (1. 58) | (1. 49) | (1. 55) | (1. 47) |
| 750 | ---------- | (1. 61) | (1. 70) | (1. 56) | (1. 65) | (1. 54) |
| 800 | ---------- | (1. 7) | (1. 83) | (1. 65) | (1. 76) | (1. 61) |

III. *Fahrenheit table for oils of moderate viscosity*—Continued

| Temperature °F. | Kinematic viscosity at 100° F., cgs units 0.028; Saybolt universal viscosity at 100° F 36 seconds; Specific gravity, 60°/60° F. 0.80; °A. P. I. 45.4; Pressure, lbs./in.² 0 | 700 | 0.85; 35.0; 0 | 700 | 0.90; 25.7; 0 | 700 |
|---|---|---|---|---|---|---|
| 20 | 0. 981 | 0. 977 | 0. 981 | 0. 978 | 0. 982 | 0. 979 |
| 40 | . 990 | . 987 | . 991 | . 987 | . 991 | . 988 |
| 60 | 1. 000 | . 996 | 1. 000 | . 996 | 1. 000 | . 996 |
| 80 | 1. 010 | 1. 005 | 1. 009 | 1. 005 | 1. 009 | 1. 005 |
| 100 | 1. 020 | 1. 015 | 1. 019 | 1. 015 | 1. 018 | 1. 014 |
| 120 | 1. 030 | 1. 025 | 1. 029 | 1. 024 | 1. 028 | 1. 023 |
| 140 | 1. 040 | 1. 034 | 1. 039 | 1. 034 | 1. 037 | 1. 033 |
| 160 | 1. 050 | 1. 044 | 1. 048 | 1. 044 | 1. 047 | 1. 042 |
| 180 | 1. 061 | 1. 055 | 1. 059 | 1. 053 | 1. 057 | 1. 052 |
| 200 | 1. 072 | 1. 065 | 1. 069 | 1. 064 | 1. 067 | 1. 062 |
| 220 | 1. 083 | 1. 076 | 1. 081 | 1. 074 | 1. 078 | 1. 072 |
| 240 | 1. 095 | 1. 087 | 1. 092 | 1. 085 | 1. 089 | 1. 082 |
| 260 | 1. 107 | 1. 098 | 1. 103 | 1. 096 | 1. 100 | 1. 093 |
| 280 | 1. 119 | 1. 110 | 1. 115 | 1. 107 | 1. 111 | 1. 104 |
| 300 | 1. 132 | 1. 122 | 1. 127 | 1. 118 | 1. 123 | 1. 115 |
| 350 | 1. 166 | 1. 154 | 1. 160 | 1. 148 | 1. 154 | 1. 144 |
| 400 | 1. 204 | 1. 188 | 1. 195 | 1. 181 | 1. 188 | 1. 175 |
| 450 | 1. 246 | 1. 226 | 1. 235 | 1. 217 | 1. 225 | 1. 209 |
| 500 | 1. 296 | 1. 268 | 1. 280 | 1. 256 | 1. 267 | 1. 246 |
| 550 | 1. 354 | 1. 316 | 1. 332 | 1. 300 | 1. 315 | 1. 287 |
| 600 | (1. 42) | (1. 37) | (1. 39) | (1. 35) | (1. 37) | (1. 33) |
| 650 | (1. 50) | (1. 43) | (1. 47) | (1. 41) | (1. 44) | (1. 38) |
| 700 | (1. 60) | (1. 50) | (1. 55) | (1. 46) | (1. 52) | (1. 44) |
| 750 | (1 71) | (1. 58) | (1. 65) | (1. 54) | (1. 61) | (1. 50) |
| 800 | (1. 84) | (1. 66) | (1. 76) | (1. 62) | (1. 72) | (1. 57) |

III. *Fahrenheit table for oils of moderate viscosity*—Continued

| Temperature °F. | Kinematic viscosity at 100° F., cgs units: 0.050; Saybolt Universal viscosity at 100° F.: 42 seconds | | | | | |
|---|---|---|---|---|---|---|
| | Specific gravity, 60°/60° F.: 0.80 | | 0.85 | | 0.90 | |
| | °A. P. I.: 45.4 | | 35.0 | | 25.7 | |
| | Pressure, lbs./in.² 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0.982 | 0.979 | 0.982 | 0.979 | 0.983 | 0.980 |
| 40 | .991 | .988 | .991 | .988 | .991 | .988 |
| 60 | 1.000 | .997 | 1.000 | .996 | 1.000 | .996 |
| 80 | 1.009 | 1.005 | 1.009 | 1.005 | 1.009 | 1.005 |
| 100 | 1.019 | 1.014 | 1.018 | 1.014 | 1.018 | 1.014 |
| 120 | 1.028 | 1.024 | 1.028 | 1.023 | 1.027 | 1.023 |
| 140 | 1.038 | 1.033 | 1.037 | 1.033 | 1.036 | 1.032 |
| 160 | 1 048 | 1.043 | 1.047 | 1.042 | 1.045 | 1.041 |
| 180 | 1.059 | 1.053 | 1.057 | 1.052 | 1.055 | 1.050 |
| 200 | 1.069 | 1.063 | 1.067 | 1.061 | 1.065 | 1.059 |
| 220 | 1.080 | 1.074 | 1.077 | 1.071 | 1.075 | 1.069 |
| 240 | 1.091 | 1.084 | 1.088 | 1.081 | 1.085 | 1.079 |
| 260 | 1.103 | 1.095 | 1.099 | 1.092 | 1.096 | 1.089 |
| 280 | 1.114 | 1.106 | 1.110 | 1.103 | 1.107 | 1.099 |
| 300 | 1.126 | 1.117 | 1.122 | 1.113 | 1.118 | 1.110 |
| 350 | 1.157 | 1.147 | 1.152 | 1.142 | 1.147 | 1.137 |
| 400 | 1.193 | 1.179 | 1.185 | 1.173 | 1.178 | 1.167 |
| 450 | 1.232 | 1.214 | 1.222 | 1.206 | 1.213 | 1.199 |
| 500 | 1.276 | 1.253 | 1.262 | 1.242 | 1.251 | 1.233 |
| 550 | 1.327 | 1.296 | 1.309 | 1.283 | 1.294 | 1.270 |
| 600 | (1.39) | (1.34) | (1.36) | (1.33) | (1.34) | (1.31) |
| 650 | (1.46) | (1.40) | (1.43) | (1.38) | (1.40) | (1.36) |
| 700 | (1.56) | (1.47) | (1.51) | (1.43) | (1.47) | (1.41) |
| 750 | (1.69) | (1.54) | (1.60) | (1.49) | (1.56) | (1.46) |
| 800 | (1.82) | (1.63) | (1.70) | (1.56) | (1.66) | (1.53) |

III. *Fahrenheit table for oils of moderate viscosity*—Continued

| Temperature ° F. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.100 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 60 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.85 | | 0.90 | | 0.95 | |
| | °A. P. I. | | | | | |
| | 35.0 | | 25.7 | | 17.5 | |
| | Pressure, lbs./in.² | | | | | |
| | 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0.982 | 0.980 | 0.983 | 0.980 | 0.983 | 0.981 |
| 40 | .991 | .988 | .992 | .989 | .992 | .989 |
| 60 | 1.000 | .997 | 1.000 | .997 | 1.000 | .997 |
| 80 | 1.009 | 1.005 | 1.009 | 1.005 | 1.008 | 1.005 |
| 100 | 1.018 | 1.014 | 1.017 | 1.014 | 1.017 | 1.013 |
| 120 | 1.027 | 1.022 | 1.026 | 1.022 | 1.025 | 1.022 |
| 140 | 1.036 | 1.031 | 1.035 | 1.031 | 1.034 | 1.031 |
| 160 | 1.045 | 1.040 | 1.044 | 1.040 | 1.043 | 1.039 |
| 180 | 1.055 | 1.049 | 1.053 | 1.049 | 1.052 | 1.048 |
| 200 | 1.064 | 1.059 | 1.062 | 1.058 | 1.061 | 1.056 |
| 220 | 1.074 | 1.069 | 1.072 | 1.067 | 1.071 | 1.066 |
| 240 | 1.084 | 1.078 | 1.082 | 1.076 | 1.080 | 1.075 |
| 260 | 1.095 | 1.088 | 1.092 | 1.086 | 1.090 | 1.084 |
| 280 | 1.105 | 1.098 | 1.102 | 1.096 | 1.100 | 1.094 |
| 300 | 1.116 | 1.109 | 1.113 | 1.106 | 1.110 | 1.103 |
| 350 | 1.145 | 1.136 | 1.141 | 1.132 | 1.137 | 1.128 |
| 400 | 1.176 | 1.164 | 1.170 | 1.160 | 1.165 | 1.155 |
| 450 | 1.209 | 1.195 | 1.202 | 1.189 | 1.195 | 1.183 |
| 500 | 1.247 | 1.229 | 1.237 | 1.221 | 1.228 | 1.213 |
| 550 | 1.288 | 1.265 | 1.275 | 1.255 | 1.265 | 1.246 |
| 600 | (1.34) | (1.31) | (1.32) | (1.29) | (1.30) | (1.28) |
| 650 | (1.39) | (1.35) | (1.37) | (1.33) | (1.35) | (1.32) |
| 700 | (1.45) | (1.40) | (1.42) | (1.38) | (1.40) | (1.36) |
| 750 | (1.52) | (1.45) | (1.47) | (1.42) | (1.45) | (1.41) |
| 800 | (1.60) | (1.51) | (1.54) | (1.48) | (1.51) | (1.46) |

III. *Fahrenheit table for oils of moderate viscosity*—Continued

| Temperature ° F. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0. 200 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 98 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0. 85 | | 0. 90 | | 0. 95 | |
| | °A. P. I. | | | | | |
| | 35. 0 | | 25. 7 | | 17. 5 | |
| | Pressure, lbs./in.² | | | | | |
| | 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0. 983 | 0. 981 | 0. 983 | 0. 981 | 0. 984 | 0. 981 |
| 40 | . 991 | . 989 | . 992 | . 989 | . 992 | . 989 |
| 60 | 1. 000 | . 997 | 1. 000 | . 997 | 1. 000 | . 997 |
| 80 | 1. 009 | 1. 006 | 1. 008 | 1. 005 | 1. 008 | 1. 005 |
| 100 | 1. 017 | 1. 014 | 1. 017 | 1. 014 | 1. 016 | 1. 013 |
| 120 | 1. 026 | 1. 022 | 1. 025 | 1. 022 | 1. 025 | 1. 021 |
| 140 | 1. 035 | 1. 031 | 1. 034 | 1. 030 | 1. 033 | 1. 029 |
| 160 | 1. 044 | 1. 040 | 1. 043 | 1. 038 | 1. 042 | 1. 038 |
| 180 | 1. 053 | 1. 049 | 1. 052 | 1. 047 | 1. 050 | 1. 046 |
| 200 | 1. 063 | 1. 058 | 1. 061 | 1. 056 | 1. 059 | 1. 055 |
| 220 | 1. 072 | 1. 067 | 1. 070 | 1. 065 | 1. 068 | 1. 063 |
| 240 | 1. 082 | 1. 076 | 1. 079 | 1. 074 | 1. 078 | 1. 072 |
| 260 | 1. 092 | 1. 086 | 1. 088 | 1. 083 | 1. 087 | 1. 081 |
| 280 | 1. 102 | 1. 096 | 1. 098 | 1. 093 | 1. 096 | 1. 090 |
| 300 | 1. 112 | 1. 105 | 1. 108 | 1. 102 | 1. 106 | 1. 099 |
| 350 | 1. 140 | 1. 132 | 1. 135 | 1. 127 | 1. 131 | 1. 124 |
| 400 | 1. 168 | 1. 158 | 1. 163 | 1. 153 | 1. 158 | 1. 149 |
| 450 | 1. 200 | 1. 188 | 1. 193 | 1. 181 | 1. 187 | 1. 176 |
| 500 | 1. 235 | 1. 219 | 1. 226 | 1. 211 | 1. 218 | 1. 205 |
| 550 | 1. 273 | 1. 253 | 1. 262 | 1. 244 | 1. 252 | 1. 235 |
| 600 | (1. 32) | (1. 29) | (1. 30) | (1. 28) | (1. 29) | (1. 27) |
| 650 | (1. 36) | (1. 33) | (1. 34) | (1. 32) | (1. 33) | (1. 30) |
| 700 | (1. 41) | (1. 38) | (1. 39) | (1. 36) | (1. 37) | (1. 34) |
| 750 | (1. 47) | (1. 42) | (1. 44) | (1. 40) | (1. 42) | (1. 38) |
| 800 | (1. 53) | (1. 48) | (1. 50) | (1. 45) | (1. 47) | (1. 42) |

III. *Fahrenheit table for oils of moderate viscosity*—Continued

| Temperature °F. | Kinematic viscosity at 100° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.500 | | | | | |
| | Saybolt universal viscosity at 100° F. | | | | | |
| | 229 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.85 | | 0.90 | | 0.95 | |
| | °A. P. I. | | | | | |
| | 35.0 | | 25.7 | | 17.5 | |
| | Pressure, lbs./in.$^2$ | | | | | |
| | 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0.984 | 0.981 | 0.984 | 0.982 | 0.985 | 0.982 |
| 40 | .992 | .989 | .992 | .990 | .992 | .990 |
| 60 | 1.000 | .997 | 1.000 | .997 | 1.000 | .997 |
| 80 | 1.008 | 1.005 | 1.008 | 1.005 | 1.008 | 1.005 |
| 100 | 1.017 | 1.013 | 1.016 | 1.013 | 1.016 | 1.013 |
| 120 | 1.025 | 1.021 | 1.024 | 1.021 | 1.024 | 1.021 |
| 140 | 1.034 | 1.030 | 1.033 | 1.029 | 1.032 | 1.029 |
| 160 | 1.042 | 1.038 | 1.041 | 1.037 | 1.040 | 1.037 |
| 180 | 1.051 | 1.047 | 1.050 | 1.045 | 1.049 | 1.045 |
| 200 | 1.060 | 1.055 | 1.059 | 1.054 | 1.057 | 1.053 |
| 220 | 1.069 | 1.064 | 1.068 | 1.063 | 1.066 | 1.062 |
| 240 | 1.079 | 1.073 | 1.077 | 1.071 | 1.074 | 1.070 |
| 260 | 1.088 | 1.082 | 1.086 | 1.080 | 1.084 | 1.079 |
| 280 | 1.098 | 1.092 | 1.096 | 1.089 | 1.093 | 1.087 |
| 300 | 1.108 | 1.101 | 1.105 | 1.099 | 1.102 | 1.096 |
| 350 | 1.134 | 1.126 | 1.130 | 1.122 | 1.127 | 1.119 |
| 400 | 1.161 | 1.152 | 1.156 | 1.147 | 1.153 | 1.144 |
| 450 | 1.191 | 1.179 | 1.185 | 1.174 | 1.180 | 1.170 |
| 500 | 1.223 | 1.209 | 1.215 | 1.202 | 1.209 | 1.196 |
| 550 | 1.257 | 1.240 | 1.248 | 1.232 | 1.240 | 1.225 |
| 600 | (1.30) | (1.27) | (1.28) | (1.26) | (1.27) | (1.25) |
| 650 | (1.34) | (1.31) | (1.32) | (1.30) | (1.31) | (1.29) |
| 700 | (1.38) | (1.35) | (1.37) | (1.33) | (1.35) | (1.32) |
| 750 | (1.43) | (1.39) | (1.41) | (1.37) | (1.38) | (1.35) |
| 800 | (1.48) | (1.43) | (1.46) | (1.41) | (1.43) | (1.39) |

III. *Fahrenheit table for oils of moderate viscosity*—Continued

| Temperature ° F. | Kinematic viscosity at 100° F., cgs units: 1.000; Saybolt universal viscosity at 100° F.: 445 seconds; Specific gravity, 60°/60° F.: 0.85; ° A. P. I.: 35.0; Pressure, lbs./in.²: 0 | 0.85; 35.0; 700 | 0.90; 25.7; 0 | 0.90; 25.7; 700 | 0.95; 17.5; 0 | 0.95; 17.5; 700 |
|---|---|---|---|---|---|---|
| 20 | 0.984 | 0.982 | 0.984 | 0.982 | 0.985 | 0.983 |
| 40 | .992 | .990 | .992 | .990 | .992 | .990 |
| 60 | 1.000 | .998 | 1.000 | .997 | 1.000 | .998 |
| 80 | 1.008 | 1.005 | 1.008 | 1.005 | 1.008 | 1.005 |
| 100 | 1.016 | 1.013 | 1.016 | 1.013 | 1.016 | 1.013 |
| 120 | 1.025 | 1.021 | 1.024 | 1.021 | 1.024 | 1.021 |
| 140 | 1.033 | 1.030 | 1.032 | 1.029 | 1.032 | 1.029 |
| 160 | 1.042 | 1.038 | 1.041 | 1.037 | 1.040 | 1.037 |
| 180 | 1.050 | 1.046 | 1.049 | 1.045 | 1.048 | 1.044 |
| 200 | 1.059 | 1.054 | 1.057 | 1.053 | 1.057 | 1.052 |
| 220 | 1.068 | 1.063 | 1.066 | 1.061 | 1.065 | 1.060 |
| 240 | 1.077 | 1.072 | 1.075 | 1.070 | 1.074 | 1.069 |
| 260 | 1.086 | 1.081 | 1.084 | 1.079 | 1.082 | 1.077 |
| 280 | 1.095 | 1.090 | 1.093 | 1.087 | 1.091 | 1.086 |
| 300 | 1.105 | 1.099 | 1.102 | 1.096 | 1.100 | 1.094 |
| 350 | 1.130 | 1.123 | 1.127 | 1.120 | 1.124 | 1.117 |
| 400 | 1.157 | 1.148 | 1.152 | 1.144 | 1.149 | 1.141 |
| 450 | 1.186 | 1.175 | 1.180 | 1.170 | 1.176 | 1.166 |
| 500 | 1.216 | 1.203 | 1.209 | 1.197 | 1.203 | 1.191 |
| 550 | 1.249 | 1.232 | 1.240 | 1.225 | 1.233 | 1.219 |
| 600 | (1.28) | (1.26) | (1.27) | (1.26) | (1.27) | (1.25) |
| 650 | (1.32) | (1.30) | (1.31) | (1.29) | (1.30) | (1.28) |
| 700 | (1.36) | (1.33) | (1.35) | (1.32) | (1.33) | (1.31) |
| 750 | (1.41) | (1.37) | (1.39) | (1.36) | (1.37) | (1.34) |
| 800 | (1.45) | (1.41) | (1.43) | (1.39) | (1.42) | (1.38) |

III. *Fahrenheit table for oils of moderate viscosity*—Continued

| Temperature ° F. | Kinematic vicosity at 100° F., cgs units: 2.000; Saybolt universal viscosity at 100° F.: 910 seconds; Specific gravity, 60°/60° F.: 0.85; ° A. P. I.: 35.0 | | 0.90; 25.9 | | 0.95; 17.5 | |
|---|---|---|---|---|---|---|
| | Pressure, lbs./in.² | | | | | |
| | 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0.984 | 0.982 | 0.984 | 0.982 | 0.985 | 0.983 |
| 40 | .992 | .990 | .992 | .990 | .992 | .990 |
| 60 | 1.000 | .997 | 1.000 | .997 | 1.000 | .998 |
| 80 | 1.008 | 1.005 | 1.008 | 1.005 | 1.008 | 1.005 |
| 100 | 1.016 | 1.013 | 1.016 | 1.013 | 1.016 | 1.012 |
| 120 | 1.024 | 1.021 | 1.024 | 1.021 | 1.023 | 1.020 |
| 140 | 1.032 | 1.029 | 1.032 | 1.029 | 1.031 | 1.028 |
| 160 | 1.041 | 1.037 | 1.040 | 1.036 | 1.039 | 1.036 |
| 180 | 1.049 | 1.045 | 1.048 | 1.044 | 1.047 | 1.043 |
| 200 | 1.058 | 1.053 | 1.056 | 1.052 | 1.055 | 1.051 |
| 220 | 1.066 | 1.062 | 1.065 | 1.061 | 1.063 | 1.059 |
| 240 | 1.075 | 1.070 | 1.074 | 1.069 | 1.072 | 1.067 |
| 260 | 1.084 | 1.079 | 1.083 | 1.077 | 1.080 | 1.075 |
| 280 | 1.093 | 1.088 | 1.091 | 1.086 | 1.089 | 1.084 |
| 300 | 1.103 | 1.097 | 1.100 | 1.095 | 1.098 | 1.092 |
| 350 | 1.127 | 1.120 | 1.124 | 1.117 | 1.121 | 1.114 |
| 400 | 1.153 | 1.145 | 1.149 | 1.141 | 1.145 | 1.137 |
| 450 | 1.181 | 1.170 | 1.176 | 1.166 | 1.171 | 1.161 |
| 500 | 1.210 | 1.197 | 1.204 | 1.192 | 1.198 | 1.186 |
| 550 | 1.242 | 1.226 | 1.234 | 1.219 | 1.227 | 1.213 |
| 600 | (1.28) | (1.26) | (1.27) | (1.25) | (1.26) | (1.24) |
| 650 | (1.31) | (1.29) | (1.30) | (1.28) | (1.29) | (1.27) |
| 700 | (1.35) | (1.32) | (1.34) | (1.31) | (1.32) | (1.30) |
| 750 | (1.39) | (1.36) | (1.38) | (1.34) | (1.36) | (1.33) |
| 800 | (1.43) | (1.39) | (1.42) | (1.38) | (1.40) | (1.37) |

III. *Fahrenheit table for oils of moderate viscosity*—Continued

| Temperature ° F. | Kinematic viscosity at 100° F., cgs units: 5.000; Saybolt universal viscosity at 100° F.: 2270 seconds; Specific gravity, 60°/60° F.: 0.85; ° A. P. I.: 35.0; Pressure, lbs./in.²: 0 | 700 | 0.90; 25.7; 0 | 700 | 0.95; 17.5; 0 | 700 |
|---|---|---|---|---|---|---|
| 20 | 0. 985 | 0. 983 | 0. 985 | 0. 983 | 0. 985 | 0. 983 |
| 40 | . 992 | . 990 | . 992 | . 990 | . 993 | . 990 |
| 60 | 1. 000 | . 997 | 1. 000 | . 998 | 1. 000 | . 998 |
| 80 | 1. 008 | 1. 005 | 1. 008 | 1. 005 | 1. 008 | 1. 005 |
| 100 | 1. 016 | 1. 013 | 1. 016 | 1. 013 | 1. 015 | 1. 012 |
| 120 | 1. 024 | 1. 020 | 1. 023 | 1. 020 | 1. 023 | 1. 020 |
| 140 | 1. 032 | 1. 028 | 1. 031 | 1. 028 | 1. 030 | 1. 027 |
| 160 | 1. 040 | 1. 036 | 1. 039 | 1. 036 | 1. 038 | 1. 035 |
| 180 | 1. 048 | 1. 044 | 1. 047 | 1. 044 | 1. 046 | 1. 042 |
| 200 | 1. 056 | 1. 052 | 1. 055 | 1. 051 | 1. 054 | 1. 050 |
| 220 | 1. 065 | 1. 061 | 1. 064 | 1. 059 | 1. 062 | 1. 058 |
| 240 | 1. 074 | 1. 069 | 1. 072 | 1. 067 | 1. 070 | 1. 066 |
| 260 | 1. 082 | 1. 077 | 1. 080 | 1. 075 | 1. 078 | 1. 074 |
| 280 | 1. 091 | 1. 085 | 1. 089 | 1. 084 | 1. 087 | 1. 082 |
| 300 | 1. 100 | 1. 094 | 1. 098 | 1. 092 | 1. 096 | 1. 090 |
| 350 | 1. 124 | 1. 117 | 1. 121 | 1. 114 | 1. 118 | 1. 112 |
| 400 | 1. 149 | 1. 141 | 1. 146 | 1. 137 | 1. 141 | 1. 134 |
| 450 | 1. 176 | 1. 166 | 1. 171 | 1. 162 | 1. 166 | 1. 157 |
| 500 | 1. 204 | 1. 192 | 1. 198 | 1. 187 | 1. 193 | 1. 182 |
| 550 | 1. 234 | 1. 219 | 1. 227 | 1. 213 | 1. 220 | 1. 207 |
| 600 | (1. 27) | (1. 25) | (1. 26) | (1. 24) | (1. 25) | (1. 23) |
| 650 | (1. 30) | (1. 28) | (1. 29) | (1. 27) | (1. 28) | (1. 26) |
| 700 | (1. 34) | (1. 31) | (1. 33) | (1. 30) | (1. 31) | (1. 29) |
| 750 | (1. 38) | (1. 34) | (1. 36) | (1. 33) | (1. 35) | (1. 32) |
| 800 | (1. 42) | (1. 38) | (1. 40) | (1. 37) | (1. 38) | (1. 35) |

IV. *Fahrenheit table for oils of high viscosity*

| Temperature ° F. | Kinematic viscosity at 210° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.042 | | | | | |
| | Saybolt universal viscosity at 210° F. | | | | | |
| | 40 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.90 | | 0.95 | | 1.00 | |
| | ° A. P. I. | | | | | |
| | 25.7 | | 17.5 | | 10.0 | |
| | Pressure, lbs./in.$^2$ | | | | | |
| | 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0.984 | 0.982 | 0.985 | 0.982 | 0.985 | 0.983 |
| 40 | .992 | .990 | .992 | .990 | .993 | .990 |
| 60 | 1.000 | .997 | 1.000 | .997 | 1.000 | .997 |
| 80 | 1.008 | 1.005 | 1.008 | 1.005 | 1.008 | 1.005 |
| 100 | 1.017 | 1.013 | 1.016 | 1.013 | 1.016 | 1.013 |
| 120 | 1.025 | 1.021 | 1.024 | 1.021 | 1.024 | 1.020 |
| 140 | 1.033 | 1.030 | 1.032 | 1.029 | 1.031 | 1.028 |
| 160 | 1.042 | 1.038 | 1.041 | 1.037 | 1.040 | 1.036 |
| 180 | 1.051 | 1.047 | 1.049 | 1.045 | 1.048 | 1.044 |
| 200 | 1.060 | 1.055 | 1.058 | 1.053 | 1.056 | 1.052 |
| 220 | 1.069 | 1.064 | 1.067 | 1.062 | 1.065 | 1.060 |
| 240 | 1.079 | 1.073 | 1.076 | 1.070 | 1.073 | 1.068 |
| 260 | 1.088 | 1.082 | 1.085 | 1.079 | 1.082 | 1.077 |
| 280 | 1.098 | 1.091 | 1.094 | 1.088 | 1.091 | 1.085 |
| 300 | 1.107 | 1.101 | 1.103 | 1.097 | 1.100 | 1.094 |
| 350 | 1.133 | 1.125 | 1.128 | 1.120 | 1.123 | 1.117 |
| 400 | 1.160 | 1.151 | 1.154 | 1.144 | 1.149 | 1.140 |
| 450 | 1.189 | 1.178 | 1.181 | 1.170 | 1.175 | 1.165 |
| 500 | 1.221 | 1.207 | 1.211 | 1.197 | 1.203 | 1.191 |
| 550 | 1.255 | 1.238 | 1.242 | 1.226 | 1.233 | 1.219 |
| 600 | (1.29) | (1.27) | (1.28) | (1.26) | (1.27) | (1.25) |
| 650 | (1.33) | (1.31) | (1.31) | (1.29) | (1.30) | (1.28) |
| 700 | (1.38) | (1.35) | (1.35) | (1.33) | (1.34) | (1.31) |
| 750 | (1.43) | (1.39) | (1.39) | (1.36) | (1.37) | (1.34) |
| 800 | (1.49) | (1.43) | (1.44) | (1.40) | (1.41) | (1.38) |

15377°—30——5

IV. *Fahrenheit table for oils of high viscosity*—Continued

| Temperature ° F. | Kinematic viscosity at 210° F., cgs units: 0.100; Saybolt universal viscosity at 210° F.: 60 seconds | | | | | |
|---|---|---|---|---|---|---|
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.90 | | 0.95 | | 1.00 | |
| | ° A. P. I. | | | | | |
| | 25.7 | | 17.5 | | 10.0 | |
| | Pressure, lbs./in.² | | | | | |
| | 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0.984 | 0.982 | 0.985 | 0.983 | 0.986 | 0.983 |
| 40 | .992 | .990 | .993 | .990 | .993 | .990 |
| 60 | 1.000 | .997 | 1.000 | .997 | 1.000 | .997 |
| 80 | 1.008 | 1.005 | 1.008 | 1.005 | 1.007 | 1.004 |
| 100 | 1.016 | 1.013 | 1.015 | 1.012 | 1.015 | 1.012 |
| 120 | 1.024 | 1.020 | 1.023 | 1.020 | 1.023 | 1.019 |
| 140 | 1.032 | 1.028 | 1.031 | 1.028 | 1.030 | 1.027 |
| 160 | 1.040 | 1.036 | 1.039 | 1.036 | 1.038 | 1.034 |
| 180 | 1.048 | 1.045 | 1.047 | 1.043 | 1.046 | 1.042 |
| 200 | 1.057 | 1.053 | 1.055 | 1.051 | 1.054 | 1.050 |
| 220 | 1.066 | 1.061 | 1.064 | 1.059 | 1.062 | 1.058 |
| 240 | 1.075 | 1.070 | 1.072 | 1.068 | 1.070 | 1.066 |
| 260 | 1.084 | 1.078 | 1.081 | 1.076 | 1.078 | 1.074 |
| 280 | 1.093 | 1.087 | 1.089 | 1.084 | 1.087 | 1.082 |
| 300 | 1.102 | 1.096 | 1.098 | 1.093 | 1.095 | 1.090 |
| 350 | 1.127 | 1.120 | 1.121 | 1.115 | 1.118 | 1.111 |
| 400 | 1.153 | 1.144 | 1.146 | 1.138 | 1.141 | 1.134 |
| 450 | 1.180 | 1.169 | 1.172 | 1.163 | 1.166 | 1.157 |
| 500 | 1.209 | 1.197 | 1.200 | 1.189 | 1.193 | 1.182 |
| 550 | 1.240 | 1.225 | 1.229 | 1.216 | 1.221 | 1.208 |
| 600 | (1.27) | (1.26) | (1.26) | (1.24) | (1.25) | (1.24) |
| 650 | (1.31) | (1.29) | (1.29) | (1.27) | (1.28) | (1.26) |
| 700 | (1.35) | (1.32) | (1.33) | (1.31) | (1.32) | (1.29) |
| 750 | (1.39) | (1.36) | (1.37) | (1.34) | (1.35) | (1.32) |
| 800 | (1.44) | (1.40) | (1.40) | (1.37) | (1.39) | (1.36) |

IV. *Fahrenheit table for oils of high viscosity*—Continued

| Temperature ° F. | Kinematic viscosity at 210° F., cgs uuits 0.200; Saybolt Universal viscosity at 210° F. 100 seconds; Specific gravity, 60°/60°F. 0.90; ° A. P. I. 25.7; Pressure, lbs./in.² 0 | 700 | 0.95; 17.5; 0 | 700 | 1.00; 10.0; 0 | 700 |
|---|---|---|---|---|---|---|
| 20 | 0. 985 | 0. 983 | 0. 986 | 0. 983 | 0. 986 | 0. 984 |
| 40 | . 993 | . 990 | . 993 | . 990 | . 993 | . 990 |
| 60 | 1. 000 | . 997 | 1. 000 | . 998 | 1. 000 | . 998 |
| 80 | 1. 008 | 1. 005 | 1. 007 | 1. 005 | 1. 007 | 1. 005 |
| 100 | 1. 016 | 1. 012 | 1. 015 | 1. 012 | 1. 014 | 1. 012 |
| 120 | 1. 023 | 1. 020 | 1. 022 | 1. 019 | 1. 022 | 1. 019 |
| 140 | 1. 031 | 1. 028 | 1. 030 | 1. 027 | 1. 029 | 1. 026 |
| 160 | 1. 039 | 1. 036 | 1. 038 | 1. 035 | 1. 037 | 1. 034 |
| 180 | 1. 047 | 1. 043 | 1. 046 | 1. 042 | 1. 044 | 1. 041 |
| 200 | 1. 056 | 1. 051 | 1. 053 | 1. 050 | 1. 052 | 1. 049 |
| 220 | 1. 064 | 1. 059 | 1. 062 | 1. 058 | 1. 060 | 1. 056 |
| 240 | 1. 073 | 1. 068 | 1. 070 | 1. 065 | 1. 068 | 1. 064 |
| 260 | 1. 082 | 1. 076 | 1. 078 | 1. 073 | 1. 076 | 1. 071 |
| 280 | 1. 090 | 1. 084 | 1. 087 | 1. 081 | 1. 084 | 1. 079 |
| 300 | 1. 099 | 1. 093 | 1. 095 | 1. 089 | 1. 092 | 1. 087 |
| 350 | 1. 122 | 1. 115 | 1. 118 | 1. 111 | 1. 114 | 1. 108 |
| 400 | 1. 147 | 1. 139 | 1. 141 | 1. 133 | 1. 137 | 1. 130 |
| 450 | 1. 173 | 1. 163 | 1. 166 | 1. 157 | 1. 161 | 1. 152 |
| 500 | 1. 201 | 1. 189 | 1. 192 | 1. 181 | 1. 186 | 1. 175 |
| 550 | 1. 231 | 1. 216 | 1. 219 | 1. 206 | 1. 212 | 1. 200 |
| 600 | (1. 26) | (1. 24) | (1. 25) | (1. 23) | (1. 24) | (1. 22) |
| 650 | (1. 30) | (1. 27) | (1. 28) | (1. 26) | (1. 27) | (1. 25) |
| 700 | (1. 34) | (1. 31) | (1. 31) | (1. 29) | (1. 30) | (1. 28) |
| 750 | (1. 38) | (1. 34) | (1. 34) | (1. 32) | (1. 33) | (1. 31) |
| 800 | (1. 42) | (1. 37) | (1. 37) | (1. 35) | (1. 36) | (1. 34) |

IV. *Fahrenheit table for oils of high viscosity*—Continued

| Temperature ° F. | Kinematic viscosity at 210° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 0.440 | | | | | |
| | Saybolt Universal viscosity at 210° F. | | | | | |
| | 200 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.90 | | 0.95 | | 1.00 | |
| | ° A. P. I. | | | | | |
| | 25.7 | | 17.5 | | 10.0 | |
| | Pressure, lbs./in.[2] | | | | | |
| | 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0.986 | 0.983 | 0.986 | 0.984 | 0.986 | 0.984 |
| 40 | .993 | .990 | .993 | .991 | .993 | .991 |
| 60 | 1.000 | .998 | 1.000 | .998 | 1.000 | .998 |
| 80 | 1.008 | 1.005 | 1.007 | 1.005 | 1.007 | 1.005 |
| 100 | 1.015 | 1.012 | 1.015 | 1.012 | 1.014 | 1.012 |
| 120 | 1.023 | 1.020 | 1.022 | 1.019 | 1.021 | 1.019 |
| 140 | 1.030 | 1.028 | 1.029 | 1.026 | 1.029 | 1.026 |
| 160 | 1.039 | 1.035 | 1.037 | 1.034 | 1.036 | 1.033 |
| 180 | 1.047 | 1.043 | 1.045 | 1.041 | 1.044 | 1.041 |
| 200 | 1.055 | 1.051 | 1.052 | 1.049 | 1.051 | 1.048 |
| 220 | 1.063 | 1.059 | 1.060 | 1.056 | 1.059 | 1.055 |
| 240 | 1.071 | 1.067 | 1.068 | 1.064 | 1.066 | 1.063 |
| 260 | 1.079 | 1.075 | 1.076 | 1.072 | 1.074 | 1.070 |
| 280 | 1.088 | 1.083 | 1.084 | 1.080 | 1.082 | 1.078 |
| 300 | 1.097 | 1.091 | 1.093 | 1.088 | 1.090 | 1.086 |
| 350 | 1.119 | 1.113 | 1.114 | 1.109 | 1.111 | 1.105 |
| 400 | 1.143 | 1.135 | 1.137 | 1.130 | 1.133 | 1.126 |
| 450 | 1.168 | 1.159 | 1.161 | 1.152 | 1.156 | 1.147 |
| 500 | 1.195 | 1.183 | 1.186 | 1.176 | 1.180 | 1.169 |
| 550 | 1.223 | 1.209 | 1.213 | 1.200 | 1.205 | 1.192 |
| 600 | (1.25) | (1.24) | (1.24) | (1.23) | (1.23) | (1.22) |
| 650 | (1.28) | (1.27) | (1.27) | (1.25) | (1.26) | (1.24) |
| 700 | (1.32) | (1.30) | (1.30) | (1.28) | (1.29) | (1.27) |
| 750 | (1.35) | (1.33) | (1.33) | (1.31) | (1.32) | (1.29) |
| 800 | (1.38) | (1.36) | (1.36) | (1.34) | (1.35) | (1.32) |

IV. *Fahrenheit table for oils of high viscosity*—Continued

| Temperature ° F. | Kinematic viscosity at 210° F., cgs units | | | | | |
|---|---|---|---|---|---|---|
| | 1.100 | | | | | |
| | Saybolt universal viscosity at 210° F. | | | | | |
| | 500 seconds | | | | | |
| | Specific gravity, 60°/60° F. | | | | | |
| | 0.90 | | 0.95 | | 1.00 | |
| | ° A. P. I. | | | | | |
| | 25.7 | | 17.5 | | 10.0 | |
| | Pressure, lbs/in.² | | | | | |
| | 0 | 700 | 0 | 700 | 0 | 700 |
| 20 | 0.986 | 0.983 | 0.986 | 0.985 | 0.987 | 0.985 |
| 40 | .993 | .990 | .993 | .991 | .993 | .991 |
| 60 | 1.000 | .998 | 1.000 | .998 | 1.000 | .998 |
| 80 | 1.007 | 1.005 | 1.007 | 1.005 | 1.007 | 1.004 |
| 100 | 1.015 | 1.012 | 1.014 | 1.012 | 1.013 | 1.011 |
| 120 | 1.022 | 1.019 | 1.021 | 1.019 | 1.020 | 1.018 |
| 140 | 1.030 | 1.027 | 1.028 | 1.026 | 1.027 | 1.025 |
| 160 | 1.037 | 1.034 | 1.036 | 1.033 | 1.034 | 1.032 |
| 180 | 1.045 | 1.042 | 1.043 | 1.040 | 1.041 | 1.038 |
| 200 | 1.053 | 1.049 | 1.051 | 1.047 | 1.048 | 1.045 |
| 220 | 1.061 | 1.057 | 1.059 | 1.055 | 1.056 | 1.053 |
| 240 | 1.069 | 1.065 | 1.066 | 1.062 | 1.063 | 1.060 |
| 260 | 1.077 | 1.073 | 1.074 | 1.070 | 1.070 | 1.067 |
| 280 | 1.085 | 1.081 | 1.082 | 1.077 | 1.078 | 1.074 |
| 300 | 1.094 | 1.089 | 1.090 | 1.085 | 1.086 | 1.082 |
| 350 | 1.116 | 1.109 | 1.111 | 1.105 | 1.106 | 1.100 |
| 400 | 1.139 | 1.131 | 1.133 | 1.126 | 1.127 | 1.120 |
| 450 | 1.163 | 1.154 | 1.156 | 1.147 | 1.149 | 1.140 |
| 500 | 1.189 | 1.177 | 1.180 | 1.170 | 1.172 | 1.161 |
| 550 | 1.216 | 1.202 | 1.206 | 1.194 | 1.196 | 1.183 |
| 600 | (1.24) | (1.23) | (1.23) | (1.22) | (1.22) | (1.21) |
| 650 | (1.27) | (1.25) | (1.26) | (1.24) | (1.25) | (1.23) |
| 700 | (1.31) | (1.28) | (1.29) | (1.27) | (1.28) | (1.25) |
| 750 | (1.34) | (1.31) | (1.32) | (1.30) | (1.30) | (1.28) |
| 800 | (1.37) | (1.34) | (1.35) | (1.33) | (1.33) | (1.30) |

WASHINGTON, July 19, 1930.