Int. J. Heat Mass Transfer. Vol. 25, No. 8, pp. 1093–1101, 1982
Printed in Great Britain

0017–9310/82/081093–09 $03.00/0
Pergamon Press Ltd.

THE THERMAL CONDUCTIVITY OF SOME ORGANIC LIQUIDS BETWEEN 30 AND 190°C

H. Poltz and R. Jugel
Physikalisch-Technische Bundesanstalt, Bundesallee 100,
D-3300 Braunschweig, F.R.G.

(*Received* 22 *December* 1980 *and in revised form* 15 *June* 1981)

Abstract—The thermal conductivity of three dialkylphthalates, of silicone oil and of liquid paraffin was measured with a new guarded hot plate apparatus between 30 and 190°C at several thicknesses of the liquid layer. The effective thermal conductivity of the dialkylphthalates increases by about 3% when the thickness of the liquid layer is increased from 0.5 to 2 mm. Silicone oil shows an enlargement which is only slightly greater, but the thermal conductivity of liquid paraffin is increased by about 10%. Dialkylphthalates and silicone oils therefore seem to be more suitable than hydrocarbons as reference liquids for thermal conductivity measurements at elevated temperatures.

NOMENCLATURE

A,	area of the sample [m^2];
a, b, c,	coefficients of least square parabolas representing the measured values;
B, B',	heat flow rates divided by temperature difference between the main heater and the cooling plate [$W K^{-1}$];
d,	thickness of the sample [m];
P,	heat output within the main heater [W];
V,	heat loss divided by temperature difference [$W K^{-1}$].

Greek symbols

$\Delta\vartheta, \Delta'\vartheta, \Delta''\vartheta$,	temperature differences [K];
δ, δ',	temperature differences which exist during the determination of the influence of the thermocouple deviations [K];
ε,	difference between correct and approximate value of heat flow rate divided by temperature difference between the main heater and the cooling plate [$W K^{-1}$];
ϑ,	temperature [°C];
λ, λ',	thermal conductivity [$W K^{-1} m^{-1}$];
μ,	apparent heat flow arising from thermocouple deviations [W];
Φ,	heat flow rates [W].

Subscripts

heat flow rates or temperature differences between main heater and;

0,	cooling plate;
1,	upper guard heater;
2,	annular guard heater.

INTRODUCTION

For purposes of testing and calibrating in the field of thermal conductivity measurements of liquids, a sufficient number of reliably measured values of suitable materials are needed. For these purposes thermal conductivity data of some hydrocarbons have been proposed [1]. However, it was shown [2] that these types of organic compounds, particularly at elevated temperatures, were not qualified as reference materials because of their low infra-red absorption. Schoedel and Grigull [3] have shown that due to the inner radiation, the effective thermal conductivity of carbon tetrachloride even at room temperature may rise to more than twice the initial amount when the thickness of the liquid sample is sufficiently increased.

To avoid such difficulties, it was proposed to use thermal conductivity data of compounds with strong infra-red absorption as reference values, for these values depend only insignificantly on the experimental arrangements, as shown by measurements of aliphatic alcohols [4]. Dialkylphthalates seemed to be more suitable as reference materials than alcohols which are rather hygroscopic and have low boiling points. This was confirmed by measurements between 10 and 85°C [5]. For investigating the thermal conductivity of dialkylphthalates and other substances within a wider range of temperatures, a new guarded hot plate apparatus was built and used for measurements between 30 and 190°C.

EXPERIMENTAL

Apparatus

Figure 1 gives a general view of the new apparatus. The liquid sample A is situated between the cooling plate D and the heater plate (main heater) B. E is an annular guard heater, O.D. 180 mm. B is 101 mm dia. The thickness of A is fixed by three glass spacers C. A guard heater plate F covers B and E. B, D, E and F are made of pure copper. The surfaces in contact with the sample A are coated with a 50 μm thick layer of nickel. The surfaces are precisely levelled and highly polished. Frequent controls and repeated finishing ensured that the deviation from an exactly plane surface was always smaller than 1 μm. The cooling plate D can be kept at a constant temperature by a liquid from a thermostat circulating in the space H below D. The three heaters

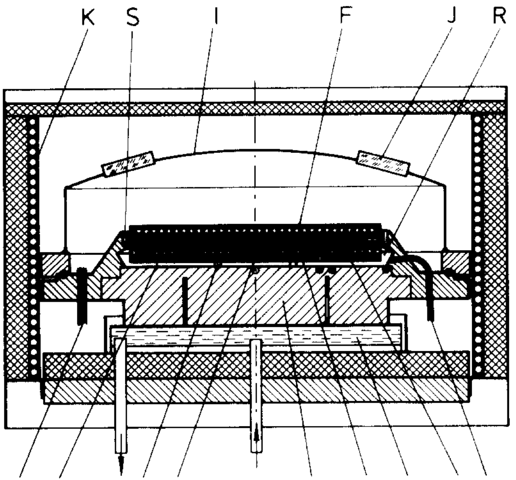

FIG. 1. Guarded hot plate apparatus.

B, E and F are heated by DC. The cap I is situated above the plate arrangement to allow the evacuation of the space below through the pipe M. The tube L serves for filling the apparatus with the sample. The filling can be controlled by looking through the glass windows J and observing the rising of the liquid in a circular groove S at the outer edge of the annular guard heater. The measurement arrangement is enclosed by a protecting cap K which can be heated by AC. To maintain a suitable constant temperature within the apparatus, the power is regulated by an automatic controller. The temperature measurements are performed by ten thermocouples G which are plotted by small circles in Fig. 1.

In Fig. 2, the junction point N between the main heater B and the guard heater E is shown on a larger scale. The distance between these two heaters must be small in the region adjacent to the liquid sample in order to define the precise diameter of that part of the liquid layer whose dimensions are to be used for calculating the thermal conductivity values. The gap N between B and E is 1 mm high and has a clearance of 0.2 mm. It is closed by a sort of silicone rubber of small thermal conductivity which has been determined by measurement. The annular air gap O between the two heaters above the region N is 1 mm thick. The resistance wires P used for all heaters are made of Thermocoax from Philips. The main heater B and the lateral guard heater E are joined by three connection pieces Q. They are made of Remanit (stainless steel) and shown on a larger scale in Fig. 3. The thermocouples used for all temperature measurements are made of copper and constantan wires with a diameter of 0.2 mm.

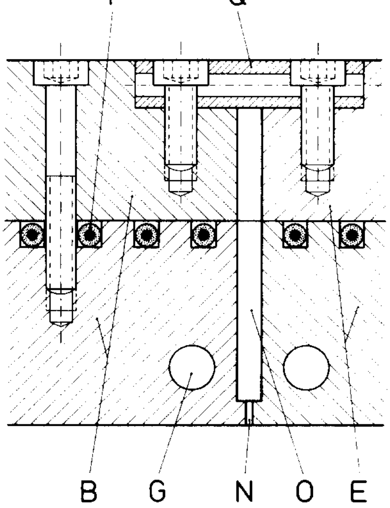

FIG. 2. Junction between main heater and annular guard heater.

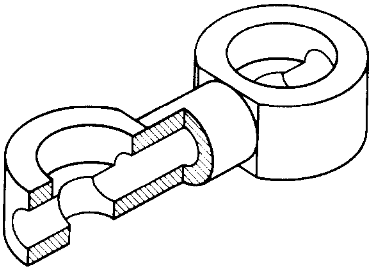

FIG. 3. Pieces of stainless steel connecting the main heater and the annular guard heater.

Calibration of the thermocouples

The thermocouples were gauged in a bath at the temperatures 30, 60, 90, 120, 150, 180 and 210°C using a calibrated platinum resistance thermometer. For each temperature the mean value of the thermopower of each thermocouple was calculated. The interpolated mean values were represented in a table as a function of the temperature.

For the careful determination of the differences between the temperature of the main heater B and the temperatures of the cooling plate D and the guard heaters E and F, it is also necessary to precisely determine the small differences of the thermovoltages of the particular thermocouples. These differences must be used for the corrections when calculating the value of the thermal conductivity. The differences not only originate from potential jumps which are not quite equal on the soldering spots of the particular couples, but also result from inequalities of the wire material. The small additional voltages which are caused by these inequalities mainly arise in sections where larger temperature gradients exist. For keeping these corrections constant as far as possible, the thermocouples were immovably fixed at the entrance of the apparatus. Consequently, the largest temperature slopes always occurred at the same wire sections.

In order to determine the deviations between the particular thermocouples, the heater combination B–E–F (Fig. 1) was replaced by a copper block 40 mm high and 150 mm dia which had ten borings for the thermocouples. The borings were of different lengths, each length being equal to the boring for the particular thermocouples in the heaters and the cooling plate. The borings in the copper block were so made that the ends of the thermocouples were all situated within an area of 1 cm^2 after their insertion.

The measurement of the voltage differences between the particular thermocouples was performed in the apparatus at the same temperatures used for the determination of the mean values. It was found that the resulting voltage deviations increased linearly with the temperature. The maximum deviations were $+0.004$ to -0.003 K at 30°C, and $+0.020$ to -0.040 K at 210°C.

Determination of the power losses

During the measurements a vertical heat flow exists between the main heater and the upper guard heater, and a horizontal flow between the main heater and the annular guard heater. Both heat flows are proportional to the corresponding temperature differences. The vertical heat flow $\Phi_1 = V_1\Delta_1\vartheta$ was calculated from the temperature difference $\Delta_1\vartheta$ between the surfaces of the main heater and the upper guard heater, their area, a distance of 2 mm being between them, and the thermal conductivity of air. The horizontal heat flow $\Phi_2 = V_2\Delta_2\vartheta$ between the main heater and the annular guard heater arising from the temperature difference $\Delta_2\vartheta$ cannot be calculated exactly, for Φ_2 is composed of flows going through three materials with different dimensions and thermal conductivities (silicone rubber, air gap, stainless steel clamps). V_2 must therefore be measured. During this measurement no liquid sample was in the apparatus.

The temperature of the upper guard heater was regulated as precisely as possible to such a value that there was no heat exchange between it and the main heater ($\Delta_1\vartheta \approx 0$). The main heater was supplied with just so much power P that a temperature difference $\Delta_0\vartheta$ of about 5 K resulted between the heater and the cooling plate, as this difference was used during the measurements on liquids.

Two measurements were carried out. First, the annular guard heater was supplied with power which, in the stationary state, created within it a temperature which was higher by an amount of $\Delta'_2\vartheta$ of about 0.3 K than the temperature in the main heater. In this case, a temperature difference $\Delta'_0\vartheta$ may result between the main heater and the cooling plate. In a second experiment, the power in the guard heater was reduced just sufficiently to obtain a temperature which was lower by an amount of $\Delta''_2\vartheta$ of about 0.3 K than that in the main heater. Then there may be the temperature difference $\Delta''_0\vartheta$ between the main heater and the cooling plate. If Φ_0 is the heat flux between the main heater and the cooling plate, and if λ, A and d are the thermal conductivity, the area and the thickness of the sample, the following two equations are valid for $\Delta_1\vartheta = 0$:

$$\Phi'_0 = \frac{\lambda A}{d}\Delta'_0\vartheta = P + V_2\Delta'_2\vartheta,$$

$$\Phi''_0 = \frac{\lambda A}{d}\Delta''_0\vartheta = P - V_2\Delta''_2\vartheta.$$

Then

$$V_2 = \frac{P(\Delta'_0\vartheta - \Delta''_0\vartheta)}{\Delta'_0\vartheta\Delta''_2\vartheta + \Delta''_0\vartheta\Delta'_2\vartheta}.$$

From these measurements a value of $V_2 = 0.834$ W K^{-1} resulted at 50°C, and 0.848 W K^{-1} at 150°C. As V_2 depends only insignificantly on the temperature, a value of $V_2 = 0.84$ W K^{-1} was always used.

When performing the thermal conductivity measurements on liquids all heaters were controlled so that $\Delta_1\vartheta$ and $\Delta_2\vartheta$ were less than 0.01 K. Then, the portion of the heat flowing in a horizontal direction was not more than 0.68%, and the heat transfer between the main heater and the upper guard heater did not exceed 0.12% of the heat transfer from the main heater to the cooling plate (at 190°C and a distance of 4 mm between the cooling and the heater plate). As, in general, the largest thickness of the liquid layer was 2 mm, the corresponding values did not exceed 0.34% and 0.06%.

Materials used for the measurements

We obtained, free of charge, several dialkylphthalates from the Badische Anilin- und Soda-Fabrik AG, Ludwigshafen/Rhein. The substances were commercial products selected from charges of very high purity. Before being used for the measurements the liquids were distilled in a vacuum fractionating column. The purity of the materials thus treated was tested by chromatographic analysis and was better than 99.9%. Moreover, comparison measurements of thermal conductivity were made on the uncleaned commercial products which had only been dried using a 4Å (0.4 nm) molecular sieve. All liquids used were stored in contact with this agent in order to remove water which may have been absorbed from the atmosphere. The liquid paraffin and the silicone oil (polydimethylsiloxane, viscosity 12 500 mm^2 s^{-1} at 20°C) used for the measurements were taken from the stock of the Physikalisch-Technische Bundesanstalt.

Performance of the measurements

Before being filled with liquid, the apparatus was evacuated and heated up to 150°C for some time. Next, the evacuated apparatus was filled with the sample and dry air was admitted to the space in the apparatus.

The difference between the measured and the correct value of each thermocouple shows temporary fluctuations. Frequent controls are therefore necessary. In order to avoid the tedious control procedure as described for the calibration procedure, a simpler method for eliminating the error resulting from these differences was used.

After putting the liquid into the apparatus and before beginning the thermal conductivity measurements, two experiments were made at 30 and 180°C. Meanwhile, no power was fed to the main heater. The other parts of the device whose temperatures could be regulated were so adjusted that the measured temperature differences δ'_0, δ'_1 and δ'_2 between the main heater and the cooling plate, the upper guard heater and the annular guard heater were, in the stationary state, as small as possible. These differences may have, e.g., the positive sign when the heat flows away from the main heater.

If $B' = \lambda' A/d$ is a value calculated from the approximate thermal conductivity λ' of the sample, we have the following equation for the thermal flux:

$$B'\delta'_0 + V_1\delta'_1 + V_2\delta'_2 = \mu.$$

This equation represents a law of conservation and μ would be zero if all values of the quantities on the LHS were correct. If V_1 and V_2 are determined as described previously, the value of μ depends on the errors made at the measurement of the temperature differences. Generally, due to these errors, $\mu \neq 0$ results. Our measurements showed that μ is linearly dependent on the temperature. Its determination at two temperatures is therefore sufficient.

If we write $B' = B + \varepsilon$, where $B = \lambda A/d$, with the correct value λ of the thermal conductivity, and ε being small compared with B, then we have

$$B\delta'_0 + \varepsilon\delta'_0 + V_1\delta'_1 + V_2\delta'_2 = \mu.$$

In this equation ε, too, is small compared with V_1 and V_2. We can therefore write

$$B\delta'_0 + V_1\delta'_1 + V_2\delta'_2 \approx \mu.$$

When measuring the thermal conductivity of the sample, the main heater may receive the power P, and temperature differences $\Delta_0\vartheta$, δ_1 and δ_2 may be measured between the main heater and the cooling plate, the upper guard heater and the annular guard heater. The following equation is then valid:

$$B\Delta_0\vartheta - P + V_1\delta_1 + V_2\delta_2 = \mu$$

or

$$\lambda = \frac{d}{A\Delta_0\vartheta}(P - V_1\delta_1 - V_2\delta_2 + \mu).$$

This equation shows that the correct values of λ can be calculated within the whole temperature range using the measured values of the temperatures if μ has been determined beforehand at two suitable temperatures.

For testing the accuracy of the results obtained by this procedure, two series of measurements of the thermal conductivity were made on samples of silicone oil with a layer thickness of 1 mm, in the range 30–190°C. The deviations of the thermocouples were taken into account in the first series by using the method just described and in the second by directly measuring the deviations as during calibration. If the results thus obtained are represented by least squares parabolas

$$\lambda = \mathrm{a} + \mathrm{b}\vartheta + \mathrm{c}\vartheta^2$$

the mean deviation of the two curves is 0.1% and the maximum deviation 0.14%.

The spacers fixing the distance between the surfaces of the main heater and the cooling plate consisted of Jenaer Geraeteglas 20. The thermal conductivity of this glass had been previously measured. The heat flow through the spacers was calculated and subtracted from the heat flowing from the main heater to the cooling plate. The differences between the temperatures at the loci of the thermocouples and those at the corresponding surfaces were calculated from the value of the thermal conductivity of copper and subtracted from the measured values of the temperature differences.

The measurements on one sample were started at the lowest temperature and, in general, were continued from point to point by raising the temperature by the same value. After measuring at the highest temperature, there was another measurement made at the lowest in order to control the constancy of all conditions of the measurements. It was found that measurements on the dialkylphthalates were not possible at temperatures above 190°C as at higher temperatures, the materials undergo a thermal decomposition perceptibly altering the value of the thermal conductivity owing to the length of time necessary for performing the measurements. It seems possible that the decomposition of diisobutylphthalate begins at 190°C.

RESULTS

Measurements were made on three dialkylphthalates, on silicone oil (polydimethylsiloxane, kinematic viscosity 12 500 mm^2 s^{-1}), and on liquid paraffin at different thicknesses of the liquid samples. The measured values of the effective thermal conductivity are listed in Table 1 and represented by the curves in Figs. 4 and 5. The curves show that the thermal conductivity is not exactly a linear function of temperature. Least squares parabolas $\lambda = \mathrm{a} + \mathrm{b}\vartheta + \mathrm{c}\vartheta^2$ were therefore calculated, representing the results for each liquid disk thickness. The coefficients of these parabolas are given in Table 2.

From Fig. 4 in particular, one may suppose a logarithmic dependence of the effective thermal conductivity on the thickness of the liquid layer. But as it is well known that this dependence is a complicated function of the infra-red absorption by the individual substance, this result seems rather coincidental. It is estimated that the reliability and accuracy of the measured values of the effective thermal conductivity are about ±0.5%.

The measured values of the thermal conductivity of the three dialkylphthalates increase by only about 3%

Table 1. Measured values of the effective thermal conductivity (W m^{-1} K^{-1})

Thickness of the liquid layer (mm)	Temperatures (°C) 30	40	45	60	70	80	90	100	110	140	150	190
Dimethylphthalate, pure												
0.484		0.1449					0.1391			0.1312		0.1225
1.001	0.1468			0.1439		0.1415	0.1403	0.1388	0.1375	0.1328		0.1246
2.002	0.1474						0.1411			0.1338		0.1265
Dimethylphthalate, commercial product												
1.001	0.1472			0.1441			0.1405		0.1376	0.1331		0.1250
Di-*n*-butylphthalate, pure												
0.271			0.1323		0.1293				0.1237		0.1175	0.1111
0.484		0.1334			0.1299				0.1246		0.1186	0.1124
1.001	0.1352				0.1307				0.1256		0.1202	0.1144
2.002	0.1356				0.1313				0.1264		0.1215	0.1160
3.992	0.1363				0.1320				0.1278		0.1226	0.1176
Di-*n*-butylphthalate, commercial product												
1.001	0.1351				0.1307				0.1256		0.1202	
Diisobutylphthalate, pure												
0.484		0.1230			0.1200				0.1153		0.1099	0.1043
1.001	0.1248				0.1209				0.1164		0.1116	
2.002	0.1255				0.1216				0.1176		0.1131	
Diisobutylphthalate, commercial product												
1.001	0.1248				0.1210				0.1165		0.1115	
Silicone oil (polydimethylsiloxane, visc. 12500 mm^2 s^{-1} at 20°C)												
0.484		0.1594			0.1547				0.1477		0.1404	0.1331
1.001	0.1615				0.1555				0.1488		0.1420	0.1353
2.002	0.1621				0.1562				0.1502		0.1438	0.1384
Liquid paraffin												
0.484		0.1184			0.1159				0.1125		0.1087	
1.001	0.1212				0.1182				0.1154		0.1124	
2.002	0.1236				0.1219				0.1202		0.1187	

at 200°C when the thickness of the sample is increased from 0.5 to 2 mm. In order to compare this property with that of hydrocarbons which have a much smaller infra-red absorption, liquid paraffin was measured under the same conditions. The corresponding increase is about 12%. This confirms that the dialkylphthalates measured previously [5] between 10 and 85°C and recommended as reference liquids for thermal conductivity measurements are more appropriate than hydrocarbons. Their effective thermal conductivity depends only a little more on the thickness of the sample than does that of aliphatic alcohols [4]. From Fig. 5 it can be supposed that silicone oils may also be suitable for testing purposes if it is possible to supply interested laboratories with well-specified substances.

It was interesting to compare the thermal conductivity values measured with the new apparatus with those obtained from the guarded hot plate apparatus formerly used [6]. The comparison was carried out by using silicone oil. The thickness of the liquid layer was 1 mm. The experimental results are shown in Fig. 6. From this it can be seen that the values measured with the new apparatus are lower by about 0.3%. There is almost the same difference between the new values of the two dibutylphthalates and the values formerly measured [5]. However, the new values of the thermal conductivity of dimethylphthalate are lower by about 0.8% than the former ones. In order to explain this discrepancy, the reaction of the substance with water vapour was tested. A layer of dimethylphthalate 3 or 4 mm thick was brought into contact with an atmosphere with a moisture content of 50%. The mass percentage of water in the substance was measured as a function of time by chromatographic analysis. The results are represented in Fig. 7. After 1 h, the substance had already absorbed 0.7% water and the hygroscopicity diminished with rising water content.

In order to investigate more exactly the influence of the hygroscopicity of dimethylphthalate on its effective thermal conductivity, measurements were made on a 1 mm thick layer of the substance. During this experiment the annular free surface of the liquid (density 1190 kg m^{-3} at 20°C) at R (Fig. 1) was covered with a layer of water. Water could therefore diffuse from this into the dimethylphthalate. The measurements were made at 30 and 60°C. The results are shown in Fig. 8. At the end of the test the thermal conductivity of the sample was increased by about 2.8%, and the mass percentage of water was 1.4%. But it is supposed that these results are not appropriate for deducing a mixing

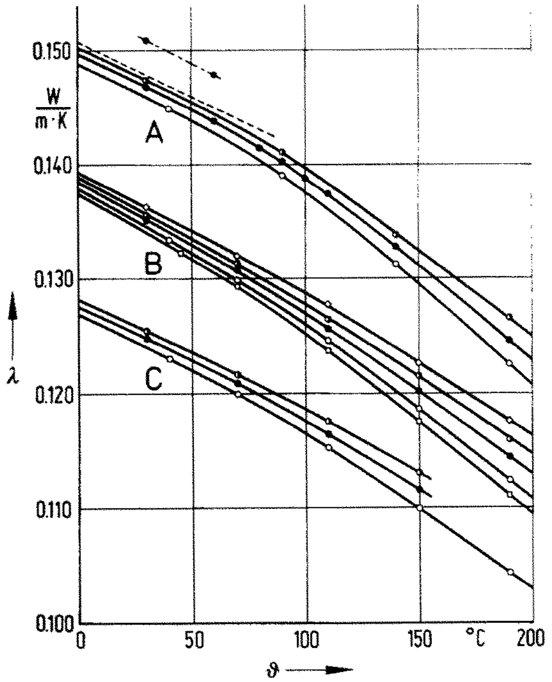

Fig. 4. Thermal conductivity of dimethylphthalate A, di-*n*-butylphthalate B and diisobutylphthalate C. Sample thickness: —□— 0.27 mm, —○— 0.48 mm, —●— 1.0 mm, —◐— 2.0 mm, —◇— 4.0 mm. Dimethylphthalate, sample thickness 1 mm: – –●– – 1.4% water content; - - - - former measurements, water content unknown.

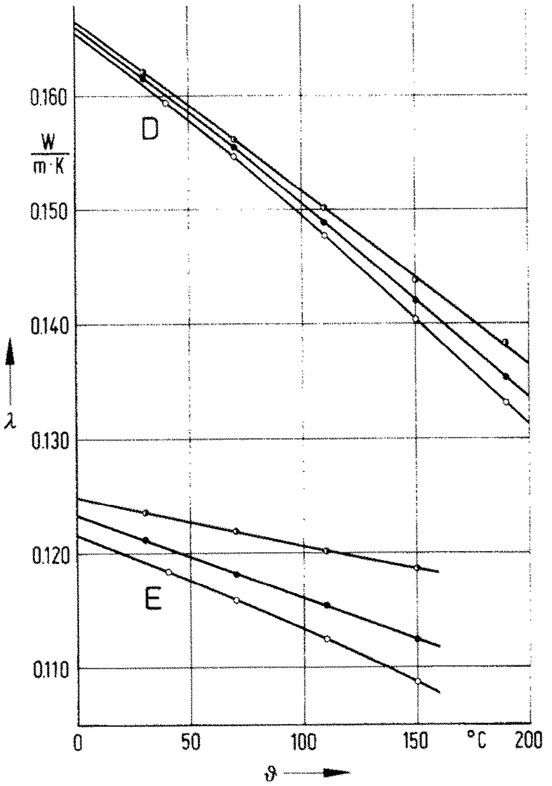

Fig. 5. Thermal conductivity of silicone oil D and paraffin oil E. Sample thicknesses as in Fig. 4.

Table 2. Representation of the measured values by least squares parabolas $\lambda = a + b\vartheta + c\vartheta^2$

Thickness of the liquid layer (mm)	Coefficients of the equation $\lambda = a + b\vartheta + c\vartheta^2$ (λ in W m^{-1} K^{-1}, ϑ in °C) a	b × 10^3	c × 10^6	Temperature range (°C)
Dimethylphthalate				
0.484	0.1488	−0.0847	−0.284	40–190
1.001	0.1496	−0.0801	−0.273	30–190
2.002	0.1503	−0.0874	−0.202	30–190
Di-*n*-butylphthalate				
0.271	0.1375	−0.1067	−0.172	45–190
0.484	0.1378	−0.1028	−0.164	40–190
1.001	0.1384	−0.1015	−0.130	30–190
2.002	0.1386	−0.0968	−0.118	30–190
3.992	0.1392	−0.0943	−0.104	30–190
Diisobutylphthalate				
0.484	0.1268	−0.0869	−0.166	40–190
1.001	0.1275	−0.0838	−0.147	30–150
2.002	0.1281	−0.0835	−0.109	30–150
Silicone oil (polydimethylsiloxane)				
0.484	0.1658	−0.1538	−0.098	40–190
1.001	0.1662	−0.1501	−0.066	30–190
2.002	0.1669	−0.1560	+0.028	30–190
Liquid paraffin				
0.484	0.1215	−0.0741	−0.074	40–150
1.001	0.1234	−0.0739	+0.008	30–150
2.002	0.1249	−0.0446	+0.020	30–150

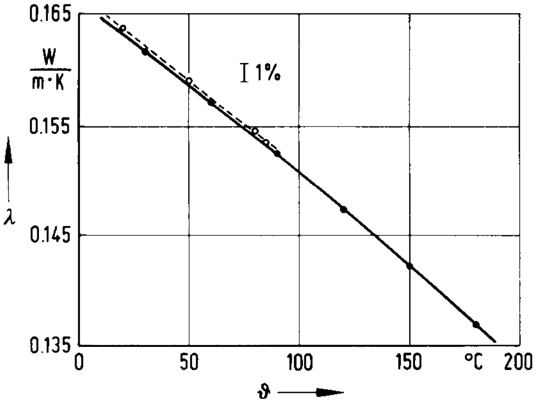

FIG. 6. Thermal conductivity of silicone oil, sample thickness 1 mm. Comparison of measurements with the former (--○--) and the new (—●—) apparatus.

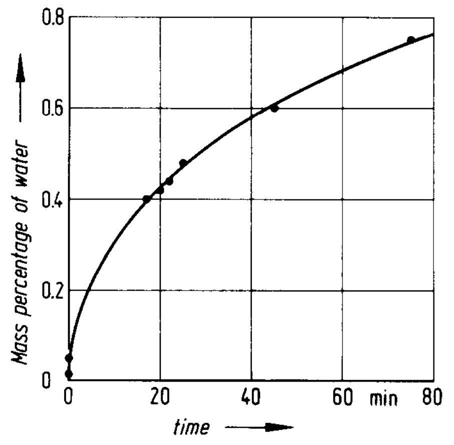

FIG. 7. Water absorption of a layer of dimethylphthalate in contact with air of a relative humidity of 50%.

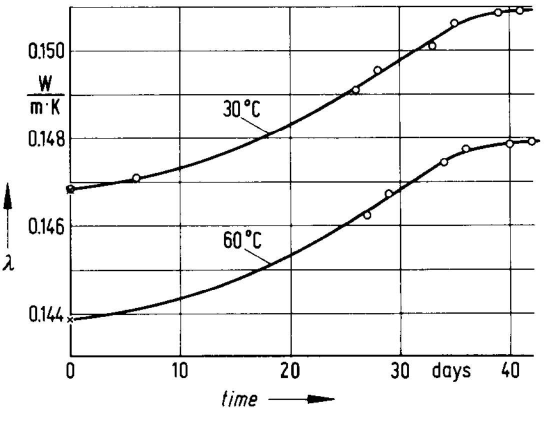

FIG. 8. Increase of the thermal conductivity of a layer of dimethylphthalate of 1 mm thickness at 30 and 60°C resulting from water absorption. × dried with molecular sieve 4Å (0.4 nm), ○ covered with a layer of water (at R, Fig. 1).

Table 3.

Temperature (°C)	Thermal conductivity of liquid paraffin ($W m^{-1} K^{-1}$) at a temperature difference of 2.5 K	5.0 K	10.0 K
40	0.1205	0.1205	0.1204
110	0.1157	0.1156	0.1156

rule, as there may be electrolytic dissociation of the ester.

The measurements on all liquids which were stored in contact with a 4Å molecular sieve (0.4 nm) did not show any influence of water contamination. As all organic liquids, even the hydrocarbons in traces, can absorb more or less water, it may be useful always to consider this question when carrying out precise measurements of thermal conductivity.

Besides the values of the purified dialkylphthalates, the values of the dried commercial products are also listed in Table 1. No appreciable difference can be seen between the values of the thermal conductivity of pure and commercial materials.

In general, a temperature difference of 5 K between the main heater and the cooling plate was used when performing the measurements. In order to investigate whether the value of this difference could influence the values of thermal conductivity, measurements were made on a sample of liquid paraffin with a layer thickness of 1 mm at 40 and 110°C, using temperature differences of 2.5, 5.0 and 10.0 K. These measurements yielded the results shown in Table 3 and show that the temperature gradient does not influence the value of the thermal conductivity.

Table 4 represents a comparison of thermal conductivity data for the three dialkylphthalates measured by several authors [5, 7–11]. These data were calculated from formulas obtained by fitting the values measured at different temperatures. Some values were obtained by using the tables of Jamieson, Irving and Tudhope [12]. As it was shown that the thermal conductivity depends somewhat on the thickness of the liquid layer, we calculated our own values in the table for thicknesses of 0.5, 1.0 and 2.0 mm.

Acknowledgements—The authors are very indebted to Professor Dr. Pommer, Badische Anilin- und Soda-Fabrik AG, Ludwigshafen/Rhein, for providing them with special charges of dialkylphthalates of high purity, produced by BASF. We are also grateful to Professor Dr. H. H. Kirchner and Dr. W. Richter, Physikalisch-Technische Bundesanstalt, for performing the vacuum fractionating of the dialkylphthalates and for testing their purity and water content by chromatographic methods. Finally, our thanks are due to Dr. K.-H. Bode, PTB, and Dr. A. E. Heacox, Washington State University who read the manuscript and made helpful suggestions.

Table 4. Comparison of thermal conductivity data of dialkylphthalates

Substance	Reference	Thermal conductivity ($W\,m^{-1}\,K^{-1}$) at				Thickness of the liquid layer (mm)
		40°C	80°C	120°C	160°C	
Dimethylphthalate	[7]	0.1470	0.1427			
	[8]	0.144	0.139	0.135	0.130	
	[9]	0.147				
	[5]	0.1465	0.1425			0.5
		0.1470	0.1431			1.0
		0.1474	0.1436			2.0
	This work	0.1450	0.1403	0.1346	0.1281	0.5
		0.1459	0.1414	0.1360	0.1298	1.0
		0.1465	0.1420	0.1369	0.1312	2.0
Di-*n*-butylphthalate	[8]	0.132	0.129	0.125		
	[10]	0.1328	0.1265			
	[11]	0.1336	0.1254			
	[5]	0.1337	0.1292			0.5
		0.1345	0.1299			1.0
		0.1351	0.1308			2.0
	This work	0.1335	0.1286	0.1232	0.1172	0.5
		0.1341	0.1294	0.1243	0.1188	1.0
		0.1346	0.1301	0.1253	0.1201	2.0
Diisobutylphthalate	[5]	0.1234	0.1193			0.5
		0.1244	0.1204			1.0
		0.1248	0.1210			2.0
	This work	0.1231	0.1188	0.1140	0.1087	0.5
		0.1239	0.1198	0.1153	0.1103	1.0
		0.1246	0.1207	0.1165	0.1119	2.0

REFERENCES

1. R. W. Powell, C. Y. Ho and P. E. Liley, Thermal conductivity of selected materials, NSRDS, NBS 8, Washington DC (1966).
2. H. Poltz, Die Wärmeleitfähigkeit von Flüssigkeiten III: Abhängigkeit der Wärmeleitfähigkeit von der Schichtdicke bei organischen Flüssigkeiten, *Int. J. Heat Mass Transfer* **8**, 609–620 (1965).
3. G. Schödel and U. Grigull, Kombinierte Wärmeleitung und Wärmestrahlung in Flüssigkeiten, *Proc. 4th Int. Heat Transfer Conf. Paris* (1970) Vol. III, Session R2; G. Schödel, Kombinierte Wärmeleitung und Wärmestrahlung in konvektionsfreien Flüssigkeitsschichten, Dissertation, Technische Hochschule München (1969).
4. H. Poltz and R. Jugel, Die Wärmeleitfähigkeit von Alkoholen, *Wärme- u. Stoffübertragung* **1**, 197–201 (1968).
5. H. Poltz, The thermal conductivity of dialkylphthalates, *Wärme- u. Stoffübertragung* **3**, 247–250 (1970).
6. W. Fritz. and H. Poltz, Absolutbestimmung der Wärmeleitfähigkeit von Flüssigkeiten I: Kritische Versuche an einer neuen Plattenapparatur, *Int. J. Heat Mass Transfer* **5**, 307–316 (1962).
7. N. Mani and J. E. S. Venart, Thermal conductivity of some organic cooled reactor coolants to 400°C, *Proc. 12th Conf. Thermal Conductivity*, Birmingham, Alabama, pp. 166–171 (1972).
8. D. T. Jamieson, J. B. Irving and J. S. Tudhope, unpublished results (1972).
9. Y. N. Suloev and A. G. Belkin, The measurement of heat conductivity of fluids and changes in the coefficient of heat conductivity of polymerising mixtures (in Russian), *Trudy po-Khim. i Khim. Tekhnol.* **3**, 175–188 (1960).
10. P. S. Pagerey, C. R. St. Clair and W. L. Sibbit, Thermal conductivity of organic liquids, *Trans. Amer. Soc. Mech. Engrs* **78**, 1169–1173 (1956).
11. O. B. Cecil and R. H. Munch, Thermal conductivity of organic liquids, *Ind. Engng Chem.* **48**, 437–440 (1956).
12. D. T. Jamieson, J. B. Irving and J. S. Tudhope, *Liquid Thermal Conductivity, a data survey to* 1973. National Engineering Laboratory, HMSO, Edinburgh (1975).

LA CONDUCTIBILITE THERMIQUE DE QUELQUES LIQUIDES ORGANIQUES ENTRE 30 ET 190°C

Résumé—La conductibilité thermique de trois dialkylphthalates, de l'huile de silicone et de l'huile de paraffine a été mesurée à l'aide d'un nouvel appareil à plaques parallèles muni d'un anneau de garde, entre 30 et 190°C, à des épaisseurs différentes de la couche du liquide. La conductibilité thermique effective des dialkylphthalates accroît d'environ 3% quand l'epasseur de la couche du liquide est augmentée de 0,5 à 2,0 mm. L'augmentation n'est pas beaucoup plus grande pour l'huile de silicone tandis que la conductibilité thermique de l'huilse de paraffine accroît d'environ 10%. Par conséquent, les dialkylphthalates et l'huile de silicone semblent être plus appropriés à être utilisés comme liquides de référence dans les mesurages de la conductibilité thermique à température élevées que les hydrocarbures.

DIE WÄRMELEITFÄHIGKEIT EINIGER ORGANISCHER FLÜSSIGKEITEN ZWISCHEN 30°C UND 190°C

Zussamenfassung—Die Wärmeleitfähigkeit von drei Dialkylphthalaten, von Siliconöl und Paraffinöl wurde mit einer neuen Parallel-platten-Apparatur mit Schutzring zwischen 30 und 190°C bei verschiedenen Dicken der Flüssigkeitsschicht gemessen. Die effektive Wärmeleitfähigkeit der Dialkylphthalate steigt um etwa 3% an, wenn die Schichtdicke der Flüssigkeit von 0,5 auf 2,0 mm erhöht wird. Bei Siliconöl ist der Anstieg nicht wesentlich größer, während die Wärmeleitfähigkeit von Paraffinöl um etwa 10% ansteigt. Dialkylphthalate und Siliconöle scheinen daher als Referenzflüssigkeiten für Wärmeleitfähigkeitsmessungen bei höheren Temperaturen besser geeignet zu sein als Kohlenwasserstoffe.

ТЕПЛОПРОВОДНОСТЬ НЕКОТОРЫХ ОРГАНИЧЕСКИХ ЖИДКОСТЕЙ ОТ 30°C ДО 190°C

Аннотация — Теплопроводность трех диалкилфталатов, силиконового масла и парафинового масла была измерена с помощью новой аппаратуры с параллельными плитами с защитным кольцом при различных толщинах слоя жидкости в интервале температур от 30°C до 190°C. Эффективная теплопроводность диалкилфталатов возрастает на 3 процента при увеличении толщины слоя жидкости с 0,5 жо 2,0 мм. Для силиконового масла это увеличение теплопроводности также не значительно бо́льше, в то время, как теплопроводность парафинового масла увелеичивается на около 10 процентов. Поэтому нам кажется, что диалкилфталаты и силиконовое масло более пригодны для применения в качестве эталонных жидкостей при измерении теплопроводности в интервале высоких температур, чем углеводороды.