CONCERNING THE EFFECT OF RADIATION ON THE THERMAL CONDUCTIVITY OF LIQUIDS IN PLANE LAYERS

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In [1-4] the authors have published the results of an experimental study concerning the radiative—conductive heat transmission through plane layers of water and eleven different organic liquids (saturated hydrocarbons, toluene, benzene, and alcohols). That study had two basic objectives.

The first purpose was to estimate the radiative component of the thermal conductivity of these liquids. This problem was solved by measuring the thermal conductivity of specimens of various thicknesses (1.2 to 6.0 mm) according to the method of a plane layer.

These measurements, performed on several liquids translucent to infrared radiation (toluene, benzene, and saturated hydrocarbons), have revealed that the thermal conductivity is a monotonic function of the specimen thickness, making it feasible to estimate the magnitude of the radiative component of the effective thermal conductivity. For semitranslucent liquids under our test conditions, the radiative component was 3.7–7.6% of the total at 293°K. For water and alcohols, which strongly absorb infrared radiation, this component of thermal conductivity was negligibly small.

Our results for layers 5 mm in thickness agree closely with the data obtained by G. Schodel and U. Grigull [5]. Measurements on thinner layers were not made by those authors.

The second purpose of our study was to determine the temperature field of a liquid layer. This was done by the interferometer method. It was thus possible to simultaneously ensure convectionless conditions, to observe the temperature distribution, and to determine the temperature difference between the boundaries of a liquid layer:

$$\Delta T = \frac{m\Lambda}{l\dfrac{dn}{dT}}. \tag{1}$$

The interferograms were plotted on a model IAB-451 instrument which had been modified into a diffraction interferometer with a model LG-75 optical quantum generator as the light source.

The optical system of this IAB-451 instrument records beam deflections not larger than ±12'. The given liquids, however, are known to be optically very nonhomogeneous and, therefore, the beam deflection exceeded this limit in most of our tests.

In view of this, producing an interference pattern required the use of optical wedges for partially compensating the beam deflection. Under such conditions the interference pattern represented a superposition of two interference fields: one due to the nonlinear temperature distribution in the semitranslucent liquid, the other due to the linear field of the optical wedge.

For the calculation of ΔT according to Eq. (1), the total number of interference fringes was found as the sum of the fringes on the interferogram and the fringes compensated by the optical wedge.

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TABLE 1. Temperature Distribution in Liquid Layers 5 mm Thick

Substance	ΔT, °C	$\theta = T_y - T_1$						
		y						
		0,1	0,2	0,4	0,6	0,8	0,9	1,0
Toluene	2,80	0,30	0,61	1,18	1,72	2,25	2,50	2,80
	4,70	0,55	1,03	1,96	2,88	3,73	4,16	4,70
Hexane	2,84	0,32	0,65	1,21	1,74	2,26	2,52	2,84
	4,50	0,54	1,04	1,90	2,70	3,52	3,95	4,50
Octane	3,24	0,39	0,75	1,40	2,02	2,58	2,9	3,24
	5,10	0,57	1,12	2,10	3,08	4,02	4,55	5,10

In plotting the temperature distribution in a layer of a semitranslucent medium, however, we incurred some error. Namely, we regarded the optical wedge as merely compensating a part of the interference fringes without affecting their distribution. Actually, however, the distribution of interference fringes must be determined as the sum of the interference fields of the tested specimen wedge and of the optical wedge. In such a plot, the qualitative pattern of the temperature distribution in toluene, hexane, and octane layers shown in [1-4] would not change. The temperature distribution curves, on the other hand, deviate from a straight line much less. Adjusted data pertaining to temperature fields in toluene, hexane, and octane layers are given in Table 1. From these data one can easily plot the temperature distribution in layers of the respective liquids.

NOTATION

ΔT	is the temperature difference between the layer boundaries;
T_1	is the temperature of the cold plate;
T_y	is the temperature at any point;
H	is the thickness of a liquid layer;
$y = X/H$	is the dimensionless length coordinate;
l	is the length of beam path through a liquid layer;
Λ	is the wavelength of the light;
dn/dT	is the temperature coefficient of the refractive index;
m	is the number of interference fringes.

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