THERMAL CONDUCTIVITY OF COMMERCIALLY PURE DOMESTIC COPPER AT ROOM, LIQUID NITROGEN AND LIQUID HELIUM TEMPERATURE RANGE*

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The thermal conductivity of three types of unannealed and annealed samples of commercially pure domestic copper was measured in the range of room, liquid nitrogen and liquid helium temperatures.

The obtained results of measurements are arranged in tables and plotted in graphical form in order to compare them with the most representative data to be found in the scientific literature.

As copper is used in the construction of cryotechnical equipment and low-temperature experimental arrangements, there arose the need for measuring the thermal conductivity of domestic copper employed in such devices. Three types of annealed and unannealed copper were examined. The copper was annealed by heating samples for two hours in air at a temperature of about 523 K. The grades of the examined copper, according to the Polish standard PN-66/H-82120, are as follows:

M-1E — 99.9% pure electrolytic copper,
M-2G — 99.7% pure set copper,
M-3G — 99.5% pure set copper.

The purity of the copper was determined by spectral analysis. The results obtained from this analysis did not diverge much from the data specified in the technical standards. There were differences in the amount of nickel in the M-2G and M-3G samples, which proved to contain two orders of magnitude less of this element than stated in the technical standard.

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Also, the content of zinc (in per cents by weight), which had not been specified in the standard for the M-2G and M-3G samples, was found by chemical analysis to be:

0.12% Zn in M-2G (unannealed),
0.075% Zn in M-2G (annealed),
0.069% Zn in M-3G (unannealed),
none detected in M-3G (annealed).

The examined copper samples had the shape of tubes of outer radius about 9.8 mm and inner radius about 7.5 mm. The samples were about 10 cm long. The way in which the samples were mounted in the vacuum vessel and the technique of measuring the thermal conductivity were typical an just like for stationary measurements by the potentiometric method for the axial flow of heat.

This classical method of measurement [1–4] was realized as follows. The examined sample was anchored thermally at one end to the cold block constituting an integral part of the vacuum measuring chamber, inside which the sample is placed. At the other end of the sample an electric resistance heater was wound, it being the source, of a precisely determined power, of the heat flowing through the examined sample. Along the sample two thermometers were placed, spaced about 4 cm apart, for determining the temperature difference and, hence, the mean temperature gradient. When the assembly is without fault, it is indispensible for the total thermal resistance of electric leads to the heater and thermometers to

TABLE I

	Unannealed copper		Annealed copper	
	T [K]	K [W/cm K]	T [K]	K [W/cm K]
M–3G	3.9– 4.1	0.13	3.9– 4.1	0.15
	72 – 75	0.44	72 – 75	0.66
	290 –295	0.25	290 –295	0.29
M–2G	3.9– 4.1	0.16	3.9– 4.1	0.21
	72 – 75	0.54	72– 75	0.80
	290 –295	0.38	290 –295	0.53
M–1E	3.9– 4.1	0.22	3.9– 4.1	0.27
	72 – 75	0.67	72 – 75	1.37
	290 –295	0.47	290 –295	0.55

be about two orders higher than the thermal resistance of the examined sample. The fulfilment of this condition of sample assembly for thermal conductivity measurements enables the assumption to be made that the heat flux flowing along the sample in the direction from the heater to the cold block does not become dissipated laterally.

The flow of heat along a sample whose length is at least an order of magnitude larger than its transverse dimensions is considered to be a case of axial flow of heat.

The results of measurements of the thermal conductivity of the six examined samples of copper at helium, nitrogen and room temperatures are gathered in Table I and plotted in $K(T)$ curve form. In Fig. 1 these values are compared with the most representative results of measurements to be found in the scientific literature.

This comparison shows that the character of the temperature-dependence of thermal conductivity for the samples we studied is in qualitative accord with literature data. The

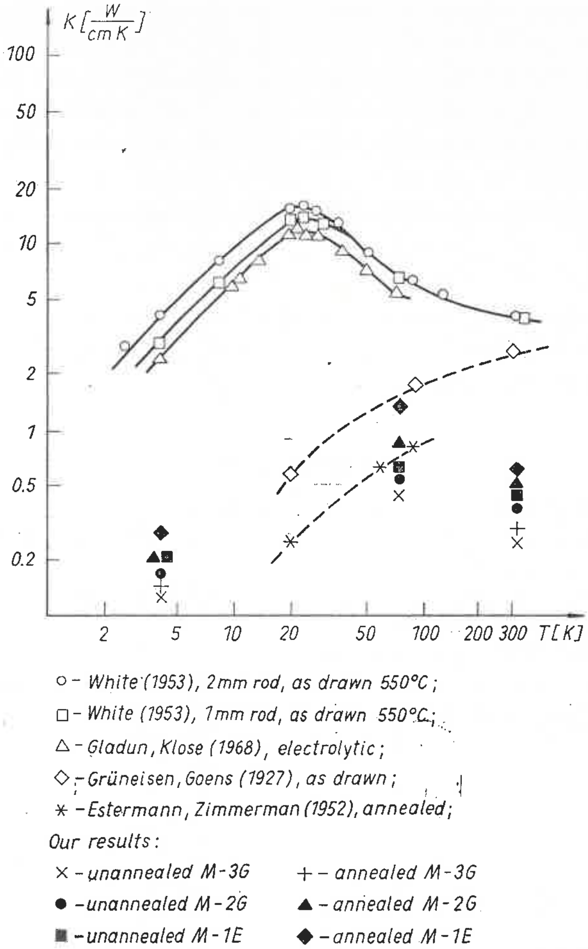

Fig. 1. Comparison of the thermal conductivity of six samples of annealed and unannealed domestic copper of technical purity with data found in the scientific literature

thermal conductivity values obtained here proved to be approximately an order of magnitude lower than the conductivity of samples of copper of 99.999% purity examined in study [5] and of 99.9% purity examined in study [6]. The thermal conductivity of the samples studied now, however, is found to be comparable at nitrogen temperatures with conductivity values measured in study [7] for a sample of 99% purity and in study [8] for a sample of

95.52% purity, although the character of the temperature dependences is different. The samples examined in studies [7] and [8] seem to show up a maximum of thermal conductivity in the range of room temperature or above, whereas our results rather point to the appearance of a maximum of thermal conductivity in the hydrogen temperature range.

The supposition that there is a maximum of thermal conductivity in the region between the temperature of liquid nitrogen and that of liquid helium stems from the distribution of thermal conductivity values measured by us and shown in Fig. 1. The thermal conductivity of the examined copper samples is higher at liquid nitrogen temperature than at room temperature; we thus have to do here with the high-temperature branch of the $K(T)$ curve. On the other hand, the thermal conductivity measured by us at helium temperature is distinctly lower than the previous values (at room and nitrogen temperatures), what would indicate that the helium temperatures correspond to the low-temperature branch of the $K(T)$ curve. Between the high-temperature and low-temperature branches of the temperature-dependence of thermal conductivity $K(T)$ there is a maximum in the $K(T)$ curve which for metals appears in the region of hydrogen temperatures, as is seen from literature data presented in Fig. 1.

Our measurements clearly show that annealed copper has higher thermal conductivity than unannealed copper. This is understandable, for annealing of copper improves the homogeneity of the physical structure of the samples.

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