Thermal conductivity measuring apparatus

04518.01

Operating Instructions

Fig. 1: Thermal conductivity measuring apparatus

1 PURPOSE AND DESCRIPTION

This apparatus serves to measure the thermal conductivity of copper and aluminium. It consists of two calorimeter vessels which act as thermal storage tanks when one is filled with iced water (the lower one in Fig. 2) and the other with boiling water (upper one). The upper calorimeter vessel has a heat conductivity connection in its base, i.e. a cylindrical hole in which the heat conductivity rod which is to be examined can be fitted.

The heat conductivity rods are made of solid copper or aluminium. They are coated with a transparent plastic material to reduce lateral loss of heat, except for about 2 cm at one of their ends. This is uncoated so that it can be fitted into the heat conductivity connection. There are 10 equidistant recesses along the length of each rod for the measurement of the temperature gradient.

The heat conductivity rods are also suitable for the determination of the electrical conductivity and so for the confirmation of the Wiedemann-Franz Law (proportionality between the thermal conductivity and the electrical conductivity of a metal). The rods have 4 mm drill-holes in each ends for the electrical connection (flow of current). Two further 4 mm drill-holes in the side of the rod allow the voltage drop along the rod to be measured.

2 HANDLING

2.1 Thermal conductivity

For the determination of the thermal conductivity, set up the apparatus as listed in the „List of Equipment“ as shown in Fig. 2. Observe the following points when doing this:

— Use heat conductivity paste to ensure good thermal contact between the upper calorimeter vessel and the frontal area of the heat conductivity rod.

— Always put iced water in the lower calorimeter vessel, while you are bringing the water in the upper calorimeter vessel to boiling with the immersion heater. (In the literature reference 01141.51 cited in section 5, a set-up with a burner is described in which the lower vessel must be heated. The hot steam which rises up along the heat conductivity rod impairs the results.)

— Ensure that the iced water in the lower vessel is continually stirred (magnetic stirrer).

Fig. 2: Complete experimental set-up for the determination of the thermal conductivity of Cu and Al

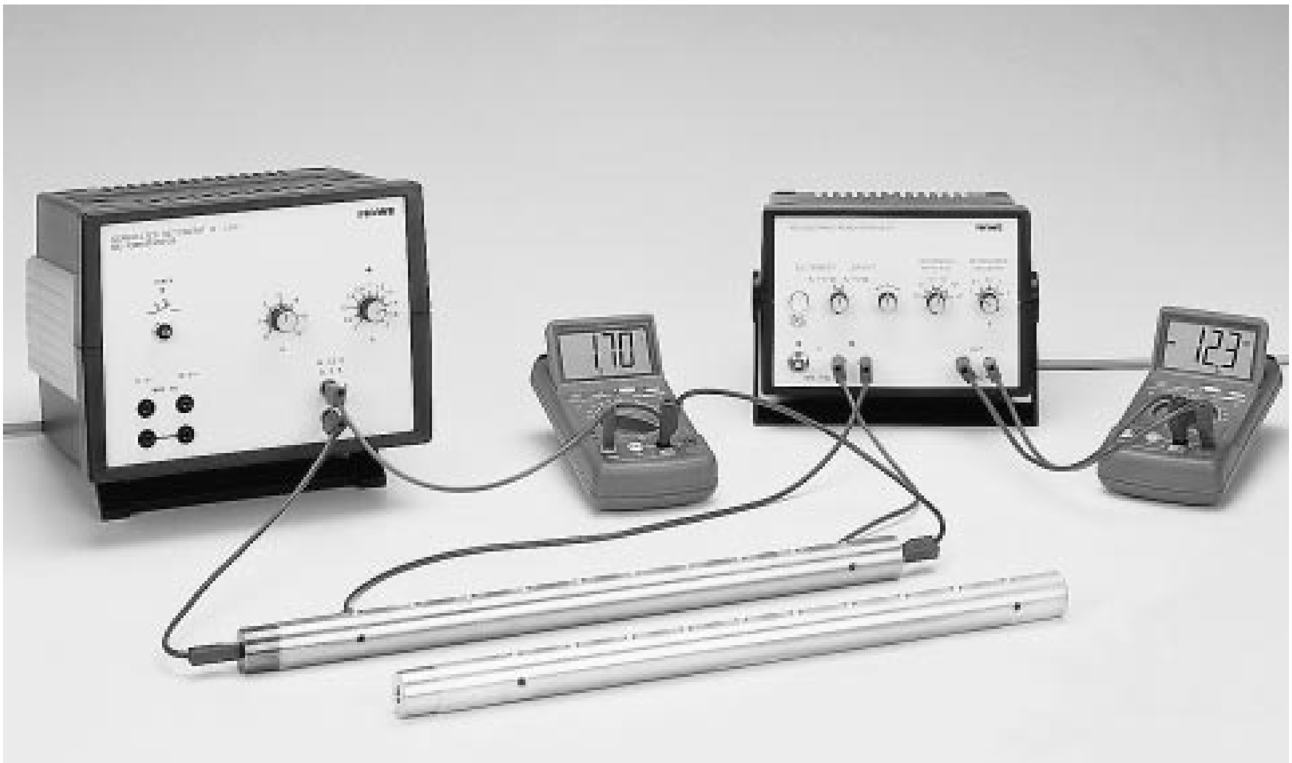

Fig. 3: Experimental set-up for the determination of the electrical conductivity of Cu and Al

— Wait about 5 minutes after the water starts to boil, then measure the temperatures T_1 to T_{10} at the 10 measuring recesses along the rod. Plot the measured values against the number of the measurement position. The measured values should lie nearly on a straight line. If this is not the case, stationary conditions had not been attained and the measurement must be repeated.
— Measure the distance *l* between the two outermost measurement positions.
— Take the pieces of ice out of the lower calorimeter vessel. Now, while stirring continuously, measure the rise in temperature ΔT in the lower vessel over an exactly determined time interval Δt (e.g. 3 minutes).
— Stop the experiment by switching off the immersion heater.
— Determine the mass *m* of the water in the lower vessel.

Use heat conductivity paste to ensure good thermal contact between the measuring sensor and the metal rod in all temperature measurements. Thermoelements with matching display units can also be used for the measurement of temperature, or, with a somewhat lower measurement accuracy, thermometers.

2.2 Electrical conductivity

An experimental set-up which is suitable for the determination of the electrical conductivity of the two rods is shown in Fig. 3. Pass as large a current as possible *I* through the rod and measure the voltage drop between the two 4 mm side drill-holes which are separated by the distance *l*. Note: at 10 A the voltage drop which is to be expected in the copper rod is of the order of 100 μV; a suitable amplifier is therefore required for the measurement of voltage.

3 EVALUATION

— Calculate the temperature gradient from the measured values

$$grad(T) = \frac{T_{10} - T_1}{l}$$

— Calculate the flow of energy which flows through the cross-section *A* of the rod from the rise in temperature ΔT measured in the lower calorimeter vessel in the time interval ΔT.

$$\frac{\Delta Q}{\Delta t} = \frac{(c \cdot m + C) \cdot \Delta T}{\Delta t}$$

Where c is the specific heat capacity of water (c = 4.19J/(g·K)) and m the mass of the water. C is the heat capacity of the calorimeter, which can be separately determined, or be neglected when the demands on the accuracy are low.

— Calculate the thermal conductivity λ from

$$\lambda = \frac{\frac{\Delta Q}{\Delta t}}{A \cdot grad(T)}$$

Calculate the electrical conductivity γ from the measured values *U*, *I* and *l* using the formula

$$\gamma = \frac{l}{A} \cdot \frac{I}{U}$$

4 LIST OF EQUIPMENT

The thermal conductivity measuring apparatus 04518.01 consists of the following parts:

Calorimeter vessel, 500 ml		04401.10
Calorimeter vessel with heat conductivity connection		04518.10
Heat conductivity rod, Cu		04518.11
Heat conductivity rod, Al		04518.12

The following parts are additionally required for a set-up as in Fig. 2:

Tripod base -PASS-		02002.55
Bench clamp -PASS-		02010.00
Support rod -PASS-, square, l = 630 mm		02027.55
Support rod -PASS-, square, l = 1000 mm		02028.55
Universal clamp	(4x)	37715.00
Right angle clamp -PASS-	(6x)	02040.55
Supporting block, 105x105x57 mm		02073.00
Glass beaker, short, 400 ml		36014.00
Heat conductivity paste, 50 g		03747.00
Gauze bag		04408.00
Immersion heater, 300 W, 220-250 VDC/AC		05947.93
Temperature measuring device, 4-2, demo		13617.93
Temperature probe, immersion type		11759.01
Surface temperature probe PT 100	(2x)	11759.02
Magnetic stirrer, mini, controllable		35712.93
Stop clock		03077.00

The following parts are additionally required for the electrical measurement as in Fig. 3, with the exception of the heat conductivity rod from 04518.01:

Multitap transformer, 14 VAC/12 VDC, 5 A		13533.93
Rheostat, 10 Ohm, 5.7 A		06110.02
Digital multimeter	(2x)	07134.00
Universal measuring amplifier		13626.93
Connecting cord, 500 mm, red	(4x)	07361.01
Connecting cord, 500 mm, blue	(4x)	07361.04

5 LITERATURE

Physik in Demonstrationsversuchen, Ausgabe A/B, Wärme 01141.51
Handbook University Laboratory Experiments in Physics 16502.12