A SIMPLE APPARATUS FOR THE DETERMINATION OF THE THERMAL CONDUCTIVITY OF CRYSTALS

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ABSTRACT

A simple apparatus has been constructed to measure the thermal conductivity of crystals at room temperatures. The accuracy claimed is 3% and the apparatus has been successfully used over a range of conductivity values from 4×10^{-4} to 4×10^{-2} cals./cm. deg. sec. The measurements on a few crystals are reported.

1. INTRODUCTION

Thermal conductivity is one of the important thermal properties of crystals; yet it is the only thermal property which has received little attention. Reliable values of conductivity are at present available only for a few crystals.

Most of the present-day work is centred around a study of temperature variation of the thermal conductivity of relatively simple crystals at low temperatures. Here the emphasis is not on the true value of conductivity but on the nature of its variation. The reason is not far to seek. The theories of thermal conductivity [Peierls (1929); Pomeranchuk (1941, 1942); Klemens (1951), (1952)] do not enable us to calculate the absolute value of the conductivity; they indicate in a very general way the nature of its variation with temperature. This variation in conductivity is mainly conditioned by the following factors:—

1. The 'Umklapp' process; (2) Boundary scattering; (3) Scattering of the phonons at lattice defects; (4) mosaic scattering; and (5) the magnetic nature of the crystal. These different factors are of importance in different temperature ranges: for example, the 'U' process is the only effective one at high temperatures; near the absolute zero boundary scattering of the phonons is excessively predominant and gives rise to a conductivity depending on the dimensions of the specimen (Casimir, 1938). The interplay of these factors gives rise to curious behaviour in the temperature variation of thermal conductivity. The most notable and universal phenomenon is the existence of a maximum in the thermal conductivity curve for all crystals at liquid helium temperatures [De Haas, 1935, 1936; De Haas and Biermasz, 1937, 1938; Berman, 1951; Berman, Simon and Wilks (1951)]. The effect of the various factors mentioned above on the conductivity of crystals is being actively studied by Berman (1951, 1952).

The only reliable work on the absolute value of thermal conductivity was carried out by Eucken in 1911. He was able to examine some of the common crystals which could be grown to large sizes. Later Eucken and Kuhn (1928) determined the conductivities of a number of pressed powder specimens of various substances. These results are not claimed to be as accurate as those of the previous work and anomalous results have been obtained due to recrystallisation of the specimens. Apart from these, no further work on the absolute thermal conductivity of crystals has been done so far.

Any determination of the absolute conductivity is beset with two serious difficulties:—

1. The temperature drop at the layers of contact between the crystal and the hot and cold plates causes a large error in the determination of the conductivity. This error is difficult to determine and uncertain to allow for. This defect is greatly reduced by using thick crystals. The crystals employed by Eucken were about 2 cm. cubes. Such large crystals are by no means easy or possible to secure in many cases and this is the chief difficulty in thermal conductivity work. The thermal contact is considerably improved by using a liquid for the intermediate layer. Tin amalgam and mercury were successfully used in the later work of Eucken (1911). By using such layers the size of the crystal could be enormously reduced. In their work on the conductivity of Bismuth, Roberts and Kaye (1923) used paraffin oil for securing good thermal contact; and they devised a method for correcting for the temperature drop through this layer. Paraffin is less conducting than mercury and so is less satisfactory as an intermediate layer.

2. There is a certain amount of heat lost from the hot plate to the surroundings. This can be completely prevented by employing a guard ring. The heat loss can be minimised by properly lagging the hot plate and any residual heat loss can be allowed for. The latter alternative has been employed by Eucken and Roberts and Kaye.

Determinations of the relative values of conductivity are much simpler because many of these defects get compensated automatically. Relative determinations of conductivity have been carried out by Giacomini (1918) and Ballard, Macarthy and Davies (1950), and Macarthy and Ballard (1951).

Eucken's measurements involved considerable labour and that is probably the reason why his apparatus was not used further.

If the measurements are to be extended to as large a number of crystals as possible, the apparatus has to satisfy the following conditions:—

(1) The apparatus must be simple in construction and easy to use without considerable decrease in the accuracy.

(2) It must be possible to use crystals a few mm. in thickness and 1 to 2 sq. cm. in area.

(3) It must be capable of being used over a wide range of conductivity values without much sacrifice in the accuracy and

(4) The corrections for the above-mentioned errors must be easy to work out and apply.

Such an apparatus has been constructed by the author and measurements of conductivity of several crystals at room temperatures are reported. The apparatus follows closely that of Kaye and Roberts in design.

2. DESCRIPTION OF THE APPARATUS AND METHOD OF MEASUREMENT

The plate method for measuring the conductivity is employed.

The apparatus used is shown in section in Fig. 1.

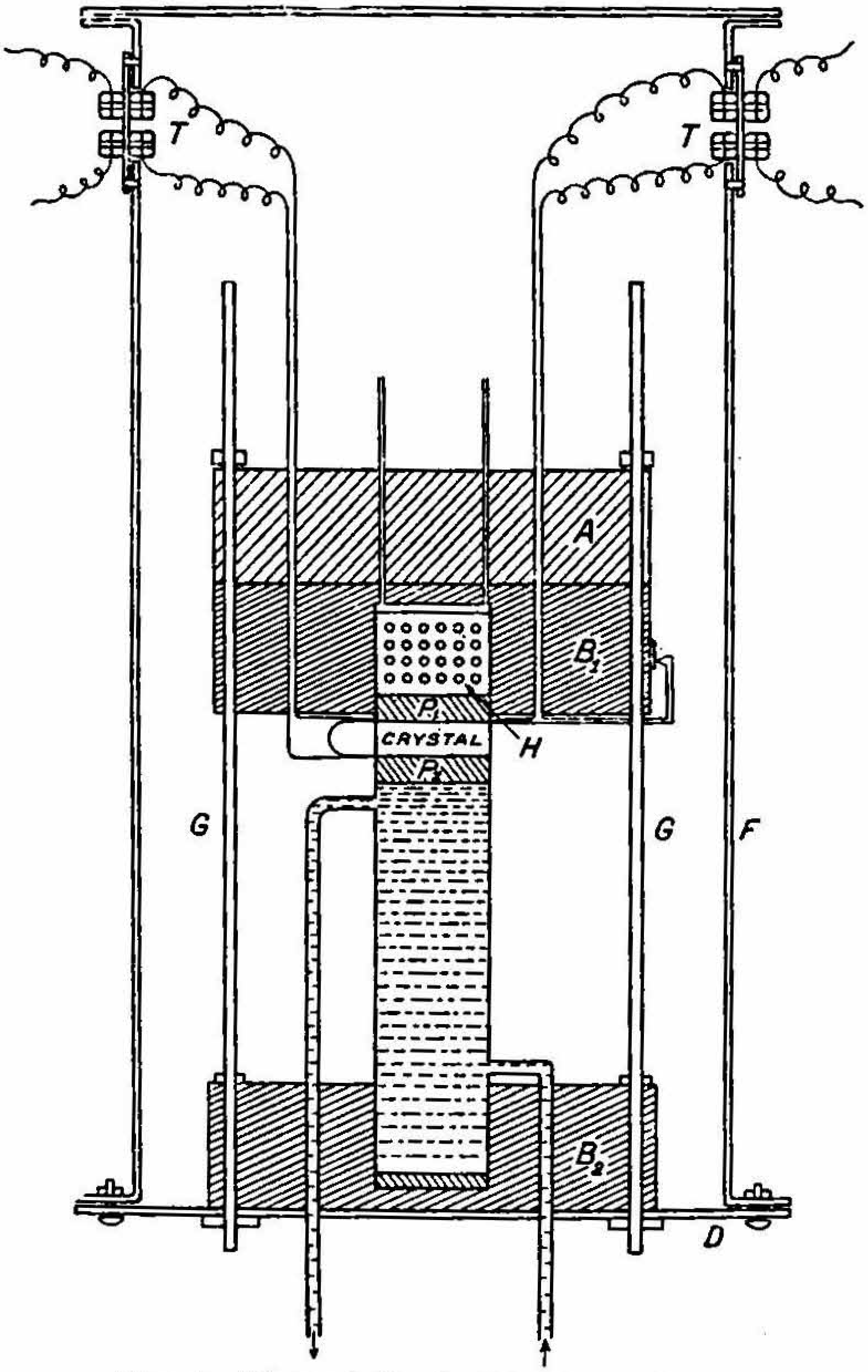

FIG. 1. Thermal Conductivity Apparatus.

(i) *Hot Plate P_1.*—The Hot Plate H is in the form of a copper cup 2 cm. diameter and 1·5 cm. internal depth. The bottom wall of the cup is about 0·5 cm. in thickness to allow for the temperature to attain uniformity over the surface. A heater of Eureka wire of S.W.G. 32 was wound over mica strips and placed in the cup insulated from its walls by mica pieces. The heater was of resistance 16 ohms. To each end of the heater wire, two copper wires were soldered to serve as the current and potential leads. The top of the heater was closed by an ebonite piece and the four copper leads issued through holes in it. The copper cup fitted into a hole made in a balsa wood piece B_1 of 8 cm. diameter and 2 cm. thickness so that the bottom face of the cup was almost flush with the bottom face of the balsa wood. Two small holes were bored in the hot plate P_1 to receive the junctions of thermocouples. These holes were situated within 1 mm. distance from the bottom of P_1. The bottom face is made plane.

(ii) *Cold Plate.*—The cold plate P_2 was of copper of the same diameter as the hot plate and of thickness 0·5 cm. It was provided with a small hole near the top to receive a thermojunction. It covered a cylinder of copper 8 cm. long through which water could be circulated. This copper cylinder fitted into a recess made in a balsa wood piece B_2 of 8 cm. diameter and 2 cm. thickness. This balsa wood piece was attached to the base plate D of copper by two screws. Holes were made in B_2 and D for the inlet and exit tubes to the cylinder. This kept the cylinder in position.

Two rods G G of brass carrying screw threads passed through the base plate D and the balsa wood piece B_2. They were held upright by the nuts on B_2 and D.

The balsa wood B_1 carrying the hot plate slided over these two rods so that, without the crystal, the hot and cold plates were brought into perfect juxtaposition.

The teak wood block A added strength to the upper balsa wood piece.

The two plates were amalgamated. The crystal was placed between the two plates and the contacts were flooded with mercury. The crystal was pressed between the plates by tightening the nuts on G G. By this means very good thermal contact was secured.

The copper cover F was 4" in diameter and carried silvered copper terminals at the top. The heater and thermocouple leads were fixed to these terminals.

(iii) *Potentiometer Installation.*—The potentiometer used to measure the various potential differences and thermo E.M.F.'s was a precision vernier potentiometer supplied by the W.G. Pye & Company. The potentiometer has two ranges: in one range, it reads in steps of 10 μv upto a maximum of 1·8 volts; in the other it reads in steps of 1 μv upto a maximum of 0·18 volt. In the former range the accuracy is stated to be ± 0·002% or ± 10 μv whichever is larger. In the latter it is ± 0·004% or ± 1 μv whichever is larger.

Since the temperature drop across the crystal was about $100\,\mu v$ greater accuracy could be attained by measuring it on a calibrated galvanometer. The galvanometer used had a resistance of $299\,\Omega$ in its circuit and after calibration it could measure applied E.M.F.'s to an accuracy of $\pm 0 \cdot 3\,\mu v$.

The potentiometer assembly was carefully shielded by the method given by White (1914). The whole assembly was mounted on tables, lined with aluminium sheets but insulated from them. These metal sheets were connected to one another and finally to earth.

Parasitic E.M.F.'s were avoided by using copper knife switches and copper wires for connection. The galvanometer deflection was reversed to correct for any shift in zero.

(iv) *Construction of Thermocouples.*—Enamelled constantan (S.W.G. 30) and enamelled copper (S.W.G. 26) were used for constructing the thermocouples. The constantan wire was tested for any inhomogeneities by one of the methods prescribed by White (1914).

A large couple of the same material was used for calibration. The calibration was done with a normal Beckman thermometer graduated to 0·01 of a degree Centigrade. Both were enclosed in a well stirred water-bath which was gradually heated and the thermo-EMF rise for a known rise in temperature of the bath was found.

Two thermocouples are employed in the apparatus:—

(1) *To measure the temperature drop across the crystal.*—The two junctions of this couple are soldered by Wood's metal into the two holes—one—in the hot plate and the other in the cold plate.

(2) *To measure the excess temperature of hot plate over the surroundings.*—One junction of this thermocouple is soldered with Wood's metal into a hole in the hot plate. The other is soldered on to a brass stud which fits into a recess at the exterior surface of the balsa wood piece B_1. The temperature of the stud is almost the temperature of the surroundings.

(v) *Preparation of Specimens.*—The specimen used in conductivity measurement is cut from a clear portion of a big crystal. The piece that is cut is ground down to form a rectangular plate of the largest area possible that can fit in between the circular plates P_1 and P_2. The crystal is made plane so that its thickness is the same over the entire surface. The grinding is finished with 2 F carborundum powder. Polishing of the crystal is found to be unnecessary. In every case the thickness of the crystal has got to be adjusted so that the heat loss to the surroundings may be kept small. This means that in crystals of poor conductivity, the plates used were as thin as could be permitted by the mechanical strength of the piece.

(vi) *Measurement of Conductivity.*—A measurement of conductivity requires he measurement of (1) the current through the heater; (2) the potential difference across the heater; (3) the excess temperature of the hot plate over the surroundings; and (4) the temperature drop across the crystal. The first two yield the heat supplied to the crystal; the third gives the heat lost to the surroundings. The heat traversing the crystal is the difference between the heat supplied and the heat lost to the surroundings. The current, potential difference and the excess temperature of the hot plate are measured on the potentiometer. The temperature drop across the crystal is measured by the direct deflection of the galvanometer for greater accuracy.

(*a*) *Measurement of heat supplied*

(1) *Measurement of current through the heater.*—The current for the heater is supplied by 6 accumulators of 2 volts each connected in series. A standard resistance of $0 \cdot 1\ \Omega$ of constantan supplied by Pye and Company is connected in series with the heater and a rheostat. The potential difference across this resistance is measured on the potentiometer. This potential difference gives 1/10th the current passing through the heater.

(2) *Measurement of the potential difference across the heater.*—Two resistances R_1 and R_2 are connected across the heater. Resistance R_1 is of constantan and of value 9000 ohms. Resistance R_2 is of manganin and of value $1000\ \Omega$. These resistance boxes were supplied by Pye and Company and are accurate to $0 \cdot 02\%$. The potential difference across R_2 measured on the potentiometer yields 1/10th the potential difference across the heater.

(*b*) *Measurement of heat lost to the surroundings*

To determine the amount of heat lost from the hot plate to the surroundings we must know:—

(1) The excess of temperature of hot plate over the surrounding temperature and

(2) The heat, in calories, lost per second per degree excess of temperature of hot plate.

The excess temperature is measured directly on the potentiometer in the $0 \cdot 1$ range.

To determine the heat loss per degree excess temperature, the following procedure is adopted.

A circular piece of ebonite of the same diameter as the hot and cold plates and of large thickness is placed between the two plates. Ebonite being a very poor conductor, most of the heat is lost to the surroundings and only a small portion flows through it. If we know the conductivity of the piece we employ, we can calculate the heat transmitted through it and hence the heat lost to the surroundings for a known mean excess of temperature of the hot plate. But the conductivity of ebonite has to be known accurately and Kaye and Roberts determined this employing a separate guard ring method. Here such a separate measurement was not carried out; but by a slightly different procedure the heat loss per degree excess of temperature of the hot plate and the conductivity of the ebonite piece used can be determined simultaneously.

Two pieces of ebonite were cut from the same rod. One was 1·06 cm. thick so that the major portion of the heat was lost to the surroundings; and the other was 0·150 cm. thick so that the major portion of the heat was transmitted through the piece. The two pieces were enclosed between the plates separately and the heat supplied to the hot plate, the excess of temperature of hot plate over that of the surroundings, and the temperature drop across the specimen were noted. A certain value for the conductivity ' K ' of the ebonite piece was assumed, and it was used with the readings on the thicker specimen to calculate the heat lost from the hot plate for 1 μv excess of temperature. This quantity was designated ' λ '. This value was purely provisional and might be in error by a large percentage if the assumed value of conductivity K of the ebonite piece was not correct. This value of ' λ ' was substituted in the readings for the thin piece, and the value of the conductivity ' K ' calculated. A large error in ' λ ' was much reduced and appeared as a much smaller error in the value of K because the heat lost in this case was only a small fraction of the heat supplied. This value of K was closer to the true value of the conductivity of the ebonite piece than the value used previously for the thick piece. This value of ' K ' was substituted in the readings for the thick piece and a new value of ' λ ' was deduced. This value of ' λ ' was much closer to the actual value of heat loss per 1 μv excess temperature than the previous one. This was used to calculate ' K ' in the second case. This process was repeated 3 or 4 times till the values of 'λ ' and ' K ' did not show much difference for subsequent reckonings. The convergence was very large and the method of successive approximation worked very well. The method can be grasped better by a study of Table I given below.

(c) *Measurement of temperature drop across the specimen*

The temperature drop across the specimen was determined by noting the deflection of the galvanometer to the right and to the left when the corresponding thermo E.M.F. was applied to it. From the calibration of the galvanometer the value of the temperature drop in μv could be deduced.

(vii) *Correction for air gap area.*—The hot and cold plates were made circular to simplify machining operations. It is much simpler to make the crystals rectangular or square in section than circular. Also in many cases crystals of large area cannot be obtained. In order to extend the apparatus to measurements on as many crystals as possible, it must be feasible to employ crystals of any area of section not exceeding a definite maximum, and to work out the correction for the heat transfer through the area left uncovered by the crystal. Since the hot and cold plates are made of copper, the temperature can be assumed to be uniform over the entire surface of the plates P_1 and P_2. Then, if K_1 and A_1 are the conductivity and area of air gap, K_2 and A_2 those of the crystal

TABLE I

Heat Loss from the Hot Plate

Ebonite:—Thickness: 1·06 cm. Diam: 1·91 cm.

Heat supplied in cals./sec.	Temp. drop across specimen in μv	Trial No.	Assumed value of $K \times 10^4$	Heat transmitted through specimen in cals./sec.	Heat lost from hot plate in cals./sec.	Mean excess of hot plate temp. over surroundings in μv	Heat lost / Mean excess of temp. $\lambda \times 10^4$	Average value of $\lambda \times 10^4$
0·02612	156	I	4·0	0·00438	0·02174	136	1·599	Trial I 1·573
		II	7·33	0·00803	0·01809		1·330	
		III	7·83	0·00858	0·01754		1·290	
		IV	7·90	0·00866	0·01746		1·283	
0·03701	219	I	4·0	0·00615	0·03086	193	1·599	Trial II 1·304
		II	7·33	0·01127	0·02574		1·334	
		III	7·83	0·01203	0·02498		1·294	
		IV	7·90	0·01214	0·02487		1·288	
0·05985	368	I	4·0	0·01033	0·04952	320	1·547	Trial III 1·264
		II	7·33	0·01892	0·04093		1·279	
		III	7·83	0·02021	0·03964		1·239	
		IV	7·90	0·02040	0·03945		1·233	
0·04595	286	I	4·0	0·00803	0·03792	245	1·547	Trial IV 1·258
		II	7·33	0·01471	0·03124		1·276	
		III	7·83	0·01571	0·03024		1·234	
		IV	7·90	0·01586	0·03009		1·228	
0·08028	486	I	4·0	0·01365	0·06663	424	1·571	
		II	7·33	0·02501	0·05527		1·303	
		III	7·83	0·02672	0·05356		1·263	
		IV	7·90	0·02698	0·05330		1·257	

Heat loss/1 μv: Excess of temperature of hot plate $= \lambda = 1 \cdot 258 \times 10^{-4}$ cals./sec.

TABLE I—(*Contd.*)

Ebonite :— Thickness : 0·150 cm. Diam. : 1·91 cm.

Heat supplied in cals./sec.	Trial No.	Assumed value of $\lambda \times 10^4$	Mean excess of hot plate temp. in μv	Heat loss from hot plate in cals./sec.	Heat transmitted through specimen in cals,/sec.	Temp. drop in μv	$\frac{\text{Heat transmitted}}{\text{Temp. drop}} \times 10^4$	Average value of $K \times 10^4$
0·1185	I	1·573	220	0·03460	0·0839	232	3·616	Trial I
	II	1·304		0·02868	0·0898		3·871	7·33
	III	1·264		0·02781	0·0907		3·909	
	IV	1·258		0·02768	0·0908		3·913	
0·08021	I	1·573	147	0·02312	0·05709	158	3·613	Trial II
	II	1·304		0·01916	0·06105		3·864	
	III	1·264		0·01857	0·06164		3·901	7·83
	IV	1·258		0·01847	0·06174		3·907	
0·09391	I	1·573	167	0·02626	0·06765	187	3·617	Trial III
	II	1·304		0·02177	0·07214		3·858	7·90
	III	1·264		0·02111	0·07280		3·893	
	IV	1·258		0·02101	0·07290		3·898	
0·04814	I	1·573	83	0·01305	0·03509	95	3·694	Trial IV
	II	1·304		0·01081	0·03733		3·929	7·91
	III	1·264		0·01048	0·03766		3·965	
	IV	1·258		0·01042	0·03772		3·970	

Conductivity of the ebonite piece used $K = 7 \cdot 9 \times 10^{-4}$ cals./cm. deg. sec.

$A_1 + A_2 = A$ = Area of the hot or cold plate; and the heat transmitted

$$H = K_1 A_1 \frac{\theta}{t} + K_2 A_2 \frac{\theta}{t}$$

where θ = temperature drop across the crystal and t = thickness of the crystal.

The apparent conductivity of the crystal, defined by $K A_2 \theta/t = H$, is larger than the actual conductivity K_2 and is given by

$$K = K_1 \frac{A_1}{A_2} + K_2.$$

The correction factor $K_1 A_1/A_2$ has to be subtracted from K to get the actual conductivity K_2. To determine K_1, we employ circular pieces of polystyrene varying in diameter from 1·930 cm. to 1·296 cm. Polystyrene is employed because here the effect of air gap will be most marked on account of the small conductivity of polystyrene. The values of the apparent conductivity 'K' of the specimens are plotted against the ratio of air gap area to crystal area $\frac{A_1}{A_2} = \frac{A - A_2}{A_2}$. A straight line is drawn passing evenly through the points. The slope of the line gives K_1. This correction was never more than 10% for crystals of lowest conductivity employed and was insignificant for crystals of high conductivity. Table II gives the apparent conductivity K of polystyrene pieces having different ratios of A_1/A_2. Figure 2 gives the graph drawn between K and A_1/A_2. Such a correction is most

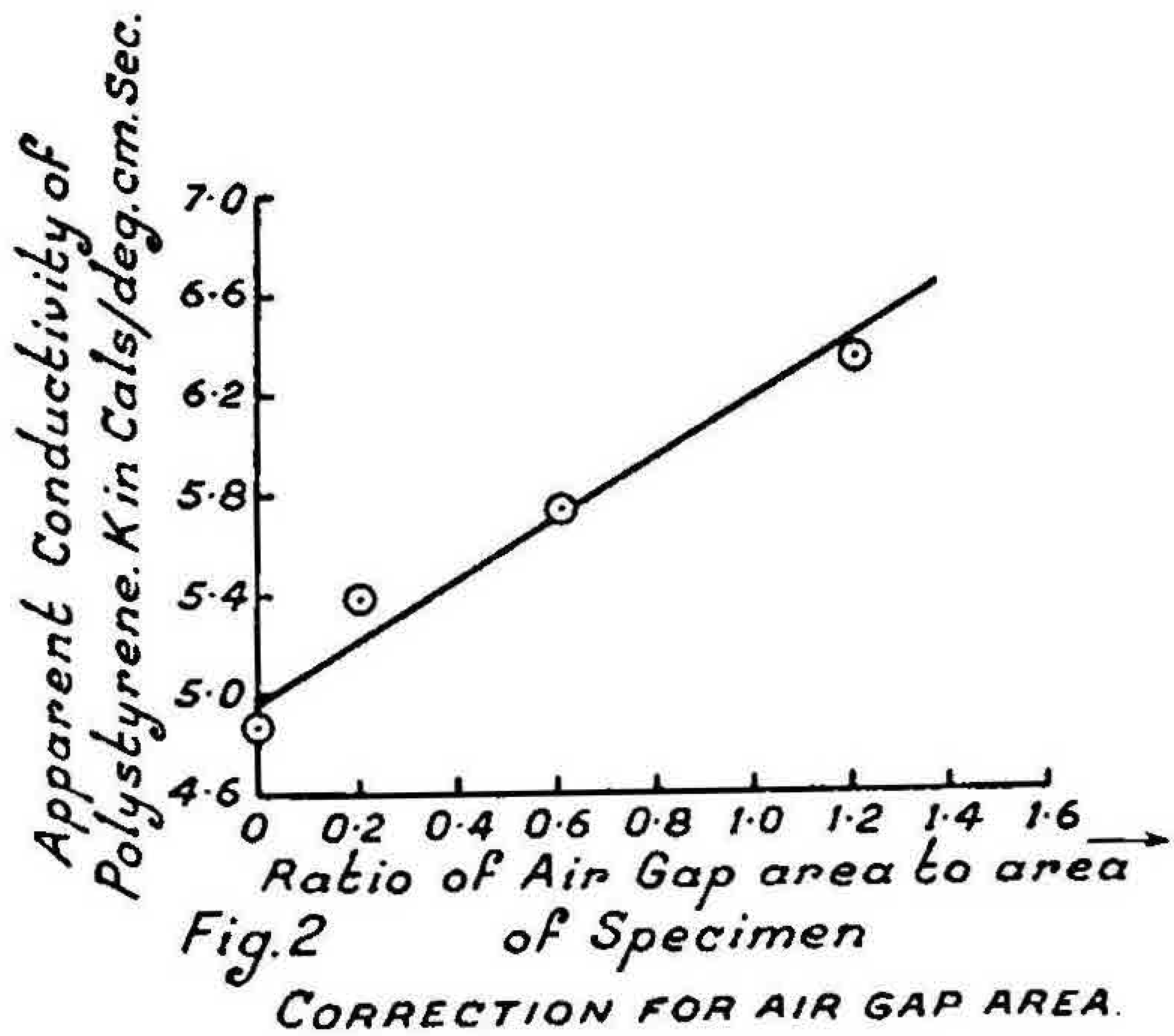

FIG. 2. Correction for Air Gap Area.

useful because it enables crystals of any area to be used for conductivity measurement and yields results correct to 2 to 3%.

TABLE II

Apparent Conductivities K of Polystyrene Pieces having Different Diameters

Specimen No.	A_1/A_2	K in cals./deg. cm. sec.
1	0	$4{\cdot}89\times10^{-4}$
2	0	$4{\cdot}86\times10^{-4}$
3	0·226	$5{\cdot}38\times10^{-4}$
4	0·609	$5{\cdot}74\times10^{-4}$
5	1·204	$6{\cdot}36\times10^{-4}$

The value of K_1 obtained from graph $= 1{\cdot}4 \times 10^{-4}$ cals./deg. cm. sec.

The thermal contact was very good and no correction was thought necessary for it. A comparison of Eucken's measurements and the present values for crystals of large conductivity as quartz and rock salt provides justification for this assumption—especially when it is remembered that the crystals used by Eucken were about five times thicker than those employed by the author. Any small correction is within the limits of experimental error.

3. RESULTS AND DISCUSSION

In the following are set forth some of the measurements of the conductivities of rock salt and sodium chlorate to indicate the degree of internal consistency and reproducibility.

The thermo electric power of the thermocouple at 27° C. $= 38{\cdot}5\,\mu v/{}^\circ$ C.

The sensitivity of the Galvanometer:—

$$E_{\mu v} = 0{\cdot}4552\,\theta_{\text{in mms}} - 8{\cdot}22\times10^{-6}\,\theta^2$$

The heat loss/1 μv excess temperature of hot plate, $\lambda = 1{\cdot}258\times10^{-4}$ cals./sec.

From these tables we see that the values are very well reproducible and the results for the different specimens do not deviate by more than 3%. This accuracy is available for measurements with specimens having a conductivity of 4×10^{-4} to 4×10^{-2} cals./deg. cm. sec. In Table V are summarised the values of conductivity for different substances determined thus.

TABLE III

Specimen Table detailing the Measurement of Thermal Conductivity

Rock Salt Thickness 0·557 cm. Area: 1·41 × 1·37sq.cm.

Current in amps.	Potential difference in volts	Heat supplied in cals./sec.	Mean excess of hot plate temp. μv	Heat loss from hot plate in cals./sec.	Heat transmitted through crystal cals./sec.	Deflection of Galvanometer in mm.			Temp. drop in μv in across the crystal	Heat transmitted / temp. drop × 10³
						Left	Right	⊖		
0·1524	2·432	0·0886	45	0·0057	0·0829	64·8	68·6	133·4	60·6	1·368
0·1751	2·795	0·1169	71	0·0089	0·1080	84·0	89·7	173·7	78·8	1·371
0·1916	3·058	0·1400	90	0·0113	0·1287	100·0	106·1	206·1	93·5	1·378
0·2286	3·648	0·1993	136	0·0171	0·1822	142·4	151·1	293·5	132·9	1·371
0·2049	3·270	0·1601	120	0·0151	0·1450	113·5	117·5	231·0	104·8	1·384
									Mean	1·374

Apparent Conductivity $K' = \frac{1{\cdot}374 \times 10^{-3} \times 38{\cdot}5 \times 0{\cdot}557}{1{\cdot}37 \times 1{\cdot}41} = 1{\cdot}526 \times 10^{-2}$

Correction for air gap area: $-\frac{(2{\cdot}907 - 1{\cdot}932)}{1{\cdot}932} \times 1{\cdot}4 \times 10^{-4} = -7 \times 10^{-5}$

Corrected value of K: $(1{\cdot}526 - 0{\cdot}007) = 1{\cdot}519 \approx 1{\cdot}52 \times 10^{-2}$ cals./deg. cm. sec.

Mean temp.: 26 °C.

TABLE IV

Thermal Conductivity Values of Rock Salt and Sodium Chlorate Specimens Determined at Different Periods

Rock Salt				Sodium Chlorate			
Thickness in cm.	Area in sq. cm.	K cals./deg. cm. sec.	Date	Thickness in cm.	Area in sq. cm.	K cals./deg. cm. sec.	Date
0·557	1·932	$1\cdot52\times10^{-2}$	Jan. 1954	0·185	1·809	$2\cdot53\times10^{-3}$	Jan. 1954
0·557	1·932	$1\cdot50\times10^{-2}$	Decr. 1954	0·185	1·809	$2\cdot51\times10^{-3}$	March 1954
0·340	1·944	$1\cdot48\times10^{-2}$	Jan. 1954	0·207	2·568	$2\cdot50\times10^{-3}$	Jan. 1954
0·340	1·944	$1\cdot49\times10^{-2}$	Decr. 1954	0·207	2·568	$2\cdot54\times10^{-3}$	March 1954

TABLE V

Thermal Conductivity Values of a Few Crystals

Substance	Value of K at 26° C. (author)	Value of K in Literature	Temp. in °C.	Author	Year
Rock Salt ..	$1\cdot51\times10^{-2}$	$1\cdot50\times10^{-2}$	30°	Eucken (±1%)	1911
Pot. Chloride ..	$1\cdot59\times10^{-2}$	$1\cdot67\times10^{-2}$	0°	,,	1911
		$1\cdot56\times10^{-2}$	42°	Ballard *et al.*	1950
Quartz $K_{\parallel}$ ..	$2\cdot91\times10^{-2}$	$2\cdot94\times10^{-2}$	30° C.	Eucken	1911
Quartz $K_{\perp}$ ..	$1\cdot58\times10^{-2}$	$1\cdot565\times10^{-2}$	30° C.	,,	1911
Sodium Chlorate ..	$2\cdot52\times10^{-3}$	$2\cdot665\times10^{-3}$	0° C.	,,	1911
Fused Quartz (Optical Quality) ..	$3\cdot63\times10^{-3}$	$3\cdot61\times10^{-3}$	26°C.	Int. Crit. Tables	
Lithium Fluoride (Harshaw Chemicals)	3.40×10^{-2}				
Pot. Bromide* ..	$6\cdot98\times10^{-3}$				
Pot. Iodide* ..	$5\cdot00\times10^{-3}$				
Ammonium Chloride	$3\cdot16\times10^{-3}$				
Ammonia Alum ..	$1\cdot28\times10^{-3}$				
Pot. Alum ..	$1\cdot41\times10^{-3}$				
Barytes					
$K^{\parallel}$ to '*a*' axis ..	$3\cdot93\times10^{-3}$				
$K^{\parallel}$ to '*b*' axis ..	$3\cdot78\times10^{-3}$				
$K^{\parallel}$ to '*c*' axis ..	$3\cdot53\times10^{-3}$				
Rochelle Salt					
$K^{\parallel}$ to '*a*' axis ..	$1\cdot10\times10^{-3}$				
$K^{\parallel}$ to '*b*' axis ..	$1\cdot46\times10^{-3}$				
$K^{\parallel}$ to '*c*' axis ..	$1\cdot34\times10^{-3}$				
Polystyrene ..	$4\cdot88\times10^{-4}$				

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* These specimens were grown from melt in the Laboratory by Dr. Vedam to whom the author's thanks are due.

A study of the table reveals that the thermal conductivity values determined by this method agree well with the values found in literature. Eucken's measurements are the most accurate available. The values given by Combes, Ballard and Macarthy are less reliable.

In lithium fluoride Combes, Ballard and Macarthy (1951) have found large variations in mechanical and thermal properties. The specimen of lithium fluoride was obtained from Harshaw Chemicals in 1954 and the larger values here compared to those reported by Combes *et al.* is probably due to the fluctuation in the properties of the crystal.

The value for Pot. Bromide is considerably smaller than the value found by Ballard *et al.* The determinations were made on 3 different samples—one obtained from Harshaw Chemicals—one grown from the melt in our laboratory after 2 recrystallisations and the other after 6 recrystallisations. The values for all the 3 crystals agreed very well. The discrepancy between our results and those of the above-mentioned authors remains unexplained.

The values for ammonium and potassium alums are very close to the value for potassium chromium alum measured by Eucken. Thus in these alums replacement of one metallic ion by another affects the conductivity very little. The greatly reduced value of the conductivity of ammonium chloride compared to that of the other alkali halides clearly indicates the decisive influence of the size of ammonium group. This behaviour is parallel to that in sodium chlorate.

For the orthorhombic crystals, the cuts were made to within a degree using a polarising microscope to locate the axes of cut by the interference figures.

The small value of the conductivity of barytes is to be expected because of its low value of hardness. The ratio of conductivity A: B: C: : 1·11: 1·07: 1. The value reported in International Critical Tables is 1·13: 1·05: 1.

The conductivity of rochelle salt was measured near its upper curie point. The individual values for different specimens showed variations up to 5% but not more. Rochelle Salt has a large anisotropy of thermal conductivity compared to barytes.

More determinations of the conductivity will be reported in due course.

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REFERENCES

1.	Ballard, Macarthy and Davies	*Rev. Sci. Instr.*, 1950, **21**, 905.
2.	Berman ..	*Proc. Roy. Soc.*, 1951, **208 A**, 90.
	———— ..	*Proc. Phys. Soc.*, 1952, **65 A**, 1029.
3.	———, Simon and Wilks	*Nature*, 1951, **168**, 277.
4.	Casimir ..	*Physica*, 1938, **5**, 495.

5. Combes, Ballard and Macarthy *J.O.S.A.*, 1951, **41**, 772.

6. De Haas .. *Physica*, 1935, **2**, 673.

7. ——— and Biermasz .. *Ibid.*, 1937, **4**, 752.

——————— .. *Ibid.*, 1938, **5**, 47.

8. Eucken .. *Ann. der Physik.*, 1911, **34**, 185; *Ber. d. Deut. Phys. Ges.*, 1911, **9**, 829.

9. ——— and Kuhn .. *Zeit. f. Phys. Chim.*, 1928, **134**, 193.

10. Giocomini .. *Ber. d. Deu. Phys. Ges.*, 1918, **120**, 94.

11. Kaye and Roberts .. *Proc. Roy. Soc.*, 1923, **104 A**, 98.

12. Klemens .. *Ibid.*, 1951, **208 A**, 108.

——————— .. *Phys. Rev.*, 1952, **86**, 1055.

13. Macarthy and Ballard .. *J.O.S.A.*, 1951, **41**, 1062.

14. Peierls .. *Ann. d. Physik.*, 1929, **3**, 1055.

15. Pomeranchuk .. *Phys. Rev.*, 1941, **60**, 820.

16. ——————— .. *J. Phys. U.S.S.R.*, 1941, **4**, 259.

17. ——————— .. *Ibid.*, 1941, **4**, 357.

18. ——————— .. *Ibid.*, 1942, **6**, 237.

19. White, W. P. .. *J.A.C.S.*, 1914, **36**, 1856.