Reprinted from The Review of Scientific Instruments, Vol. 31, No. 4, 462–464, April, 1960
Printed in U. S. A.

Apparatus for Accurate Measurement of Thermoelectric Power

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(Received November 25, 1959; and in final form, January 29, 1960)

ORDINARILY, the Seebeck coefficient is measured by placing a specimen between copper blocks at different temperatures and measuring the potential difference developed across it. This method is geometrically well suited for disks, as the flat faces make good contact with the copper blocks, though oxide films can sometimes vitiate this contact and lead to substantial errors. It can give misleading results, however, when applied to cylindrical samples, as in Fig. 1, particularly if these are inhomogeneous towards the surface (as would be the case after a relatively volatile component of an alloy has evaporated away while at elevated temperatures).

In measuring the thermoelectric power of a cylindrical sample as shown in Fig. 1, most of the temperature drop will be concentrated at the regions of high thermal resistance, namely at the points of contact of the cylinder with the copper blocks, where the conducting cross section normal to the heat flow is narrowest. The Seebeck coefficient measured in this way will therefore be more representative of the surface material than of the bulk.

A further source of error inherent in this method, which affects completely homogeneous specimens as well, is the contact thermal resistance which renders the actual temperature difference across the specimen lower than that measured between the copper blocks. This leads to measured values of thermoelectric power lower than the true values. For some materials the thermal contact is so poor that, unless considerable pressure is applied through the contacts, the measured thermoelectric power can be off by as much as 50%.

The apparatus described here overcomes the foregoing difficulties by providing a longitudinal temperature gradient along a short length of any part of the specimen and maintaining substantially isothermal conditions over the remaining portions of the specimen. A very good thermal

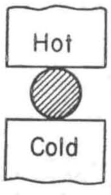

Fig. 1. Cylindrical specimen between planar contacts.

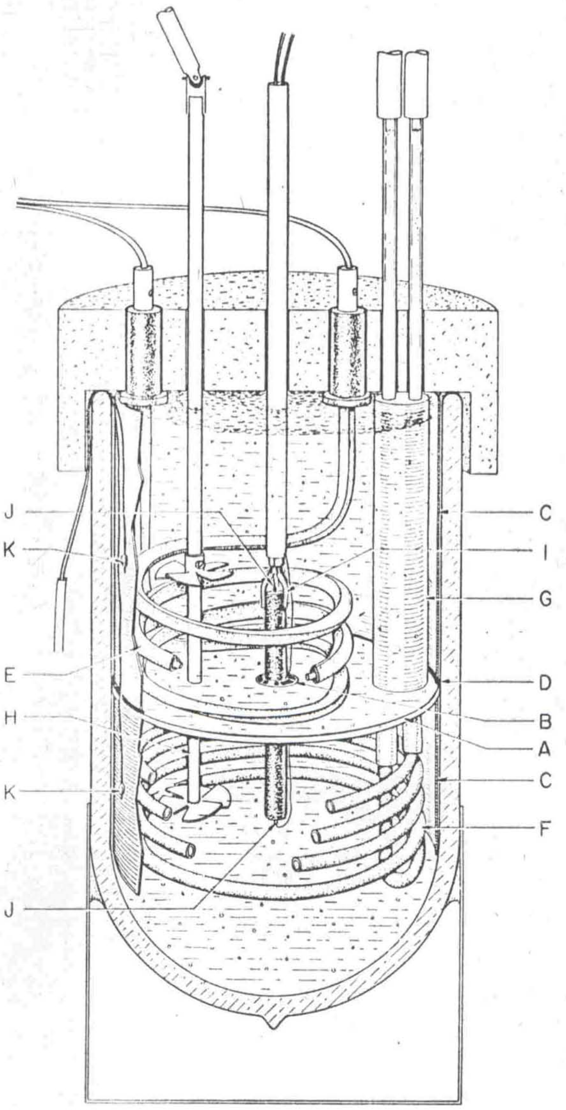

Fig. 2. Cut-away diagram of apparatus.

contact is made to the specimen in the hot and cold regions by circulating water. Basically, the apparatus consists of a 4-liter Dewar (approximately 6 in. i.d.) divided into two isothermal chambers by a horizontal insulating disk (A in Fig. 2). This disk is fitted with a grommet[1] B in its center to permit reasonably watertight passage of the specimen. The thermoelectric power measured is that corresponding to the portion of the specimen inside the grommet.

In order to maintain more nearly isothermal conditions, both the upper and lower chambers are surrounded by copper cylinders C ($\frac{1}{32}$ in. wall thickness). The lower cylinder rests against the narrowing bottom portion of the Dewar and supports the insulating disk. Two impellers on a common shaft circulate the water against convection, forcing water upwards in the lower (cold) chamber and downwards in the upper (hot) chamber.

The insulating disk cannot be tight fitting and so an O-ring D, cut to match the circumference of the inner wall of the Dewar, rests atop the outer edge of the disk and supports the upper copper cylinder, sealing the upper and lower chambers fairly well from one another. (A poor seal between the chambers would drastically reduce their temperature difference because of intermixing of the hot and cold waters.) A 300-w immersion heater bent into a coil E heats the upper chamber, while the lower chamber is cooled by tap water flowing through a coil of copper tubing F. The cooling water passes through the upper chamber in glass tubes surrounded by a 1-in. watertight copper tube G to minimize heat exchange. These tubes fit rather snugly through the insulating disk and connect to the copper tubing through short lengths of rubber hose.

The Plexiglas resin stirrer shaft H has a bearing surface in the Micarta disk. This is reasonably watertight and has very little friction.

The specimen is held in a collet-like grip I on the end of a thin-walled stainless steel tube which passes down the axis of the apparatus through a hole in the center of the styrofoam cover. Small holes machined in the ends of the specimen accept tiny phosphor-bronze plugs to which copper-Constantan thermocouples J have been soldered.

In practice, the lower chamber is operated at tap water temperature (which ranges from 6°C in winter to 23°C in summer), while the upper chamber is heated to maintain its temperature about 15°C higher.[2] This temperature difference is maintained constant to within a few tenths of a degree, provided the flow of cooling water is relatively constant.

In order to check on the temperature uniformity in each chamber, thermocouples K are also attached to the copper cylinders. We have found that the temperatures at the copper can and at the upper end of the specimen are usually within 0.1°C of one another, while the readings in the lower chamber usually agree within $\frac{1}{4}$°C. Thus, the apparatus yields values of the bulk longitudinal thermoelectric power probably accurate to better than 3%.

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[1] Grommet No. 2186 supplied by Herman H. Smith, Inc., Brooklyn, New York, has a thin membrane over one end of the hole which can be custom cut to fit samples of square or irregular cross section.

[2] A temperature difference of ~15°C is obtained by operating the heater at 50 v (~60 w).