

provided we have made the measurements so quickly that  $V_R$  and  $V_S$  have not changed.

Table 2-1 defines three thermomagnetic effects;  $\Delta T$  and  $V$  refer to the amount that the temperature of the potential at point A in Fig. 1-1 is greater than that at point B. The Ettingshausen effect is the transverse temperature gradient which occurs when we have a longitudinal current and a transverse magnetic field; it is the thermal analogy of the Hall effect. The Nernst effect is the transverse voltage produced when there is a temperature gradient along the sample and a magnetic field perpendicular to it. The Righi-Leduc effect is the transverse thermal gradient caused by the same conditions. The effects are evaluated for the values of field, current, and dimensions corresponding to our experiment. The value of  $dT/dx$  used,  $1^\circ \text{C}/\text{cm}$ , is almost certainly too high, as the mass of the bomb surrounding the sample acts as a constant temperature bath. As the Ettingshausen and Righi-Leduc coefficients are not known for the alkalis, we estimate the effect by using the value for copper [5]. These coefficients are probably smaller in the alkalis, where the Fermi surface is more nearly spherical than in copper. The thermoelectric power of a potassium-steel thermocouple is 22 microvolts/ $^\circ \text{C}$ . [6]; hence the voltage due to a Righi-Leduc temperature of  $1.4 \times 10^{-3} \text{ }^\circ \text{C}$  is .03 microvolt. For a more reasonable value of  $dT/dx$  we can ignore the thermomagnetic effects.

The Nernst and Righi-Leduc effects are usually eliminated by reversing the sample current and making a measurement before the temperature gradient can reverse sign. This requires a reversing switch in the input to the potentiometer as  $V_R$ , the dominant term in  $V$ , changes sign. Since such a reversing switch could introduce thermoelectric voltages, we decided to do the measurement without current reversal.

Throughout the measurements we tried to maintain a precision of 1 percent on an individual voltage measurement. This figure was dictated to a large degree by the potentiometer, which was specified free of thermal voltages greater than .01 microvolt. Since two readings were needed for each value of  $2 V_H$  obtained, this voltage was obtained within .02 microvolt, or to a precision of about 1 percent for typical values of  $2 V_H$ .

We can estimate the effect of the various parts of the system on the precision of the measurement. The potentiometer, as mentioned above, may contribute thermal voltages of .01 microvolt. Most of these probably stay constant over short periods of time, with the exception of the emf. . . due to the reversing switch, which may change each time the key is pressed.

The magnet current can be set to 1/3 percent. A regulated power supply was not used, as frequent checking of the magnet current minimized the effect of current drifts and allowed us to achieve the desired precision.

Successive readings of  $V_H + IR$  at constant pressure varied by amounts ranging from 1 part in 500 to 1 part in 5000. Since the IR drop is of the order of 50 microvolts, this corresponds to changes of several hundredths of a microvolt. This change is too large to be due to magnetic field variations and is due either to sample current fluctuations or to thermal voltages caused by variations of sample temperature. We did not isolate the cause of these changes but minimized their effect by taking pairs of voltage readings rapidly. These drifts were the most important limitation on the precision of the individual Hall voltage measurements.

Slow, visible, oxidation of the sample sometimes occurred. Such oxidation would decrease the thickness of the sample and cause the atmospheric pressure Hall voltage to increase with time, as was observed. Such oxidation during a run can cause hysteresis in the  $V_H$  vs. pressure curves, reducing their precision. We found we could obtain some runs with a hysteresis of less than 1 percent.

On successive runs of the same sample the normalized Hall voltages at fixed pressure generally differed by less than 2 percent. In most cases, with the exception of potassium, the reproducibility from sample to sample was about the same as from run to run; specific comments on each metal are included in Sec. III. Since a good run with 1 percent precision on individual values of  $V_H$  defined a curve to better than 1 percent, the ultimate limit on the precision of the measurements came from the presence of some hysteresis in most runs and from the variation between samples mentioned above.