

shown that this technique of applying pressure by means of solid helium does in fact produce a very close approximation to hydrostatic pressure (9).

Our measurements so far have been confined to the monovalent metals—in particular to copper and the alkali metals, except cesium (9, 13). Alkali-metal specimens used in the measurements of resistance at low temperatures have usually been enclosed in glass capillaries because the metals are chemically very reactive and mechanically very soft. For the measurement of pressure effects such specimens are not satisfactory, and we have used extruded bare wires mounted loosely on insulated formers; a photograph of such a speci-

men is shown in Fig. 4. The photograph shows the specimen mounted in position and ready to be enclosed by the high-pressure bomb, which is made of beryllium copper; the high-pressure seal is made by means of a steel lens ring.

#### Expectations and Findings

As already mentioned, we expect a linear relation between the logarithmic volume coefficient of ideal resistivity and the logarithmic temperature coefficient of ideal resistivity. Figure 5 shows that such a linear relationship does in fact exist (9, 13) for those

metals (lithium, sodium, potassium, and copper) for which the necessary data are available. In these graphs I am referring to the high-temperature modifications of sodium and lithium—it is to say, the body-centered cubic phases. At low temperatures both the metals partially transform to a close-packed phase; in lithium this transformation affects the pressure coefficient of resistivity so greatly that reliable results have been obtained below about 75°K on this metal.

From the curves in Fig. 5 we can deduce for each metal the two quantities  $d \ln \theta_R / d \ln V$  and  $d \ln K / d \ln V$ . These values are given in Table I. For comparison, the Grüneisen parameter  $\gamma$  [or  $-d \ln \theta_D / d \ln V$  (14)], which as I showed earlier, can be evaluated from readily available thermodynamic data, is also included; it is evident that the change of  $\theta_R$  with volume is quite similar to that of  $\theta_D$ , as one might expect. Although accurate pressure measurements over a sufficiently wide temperature range have so far been made on only the four metals mentioned, the quantity  $d \ln K / d \ln V$  which can be derived from high-temperature measurements only, by assuming that  $-d \ln \theta_R / d \ln V$  equals (the Grüneisen parameter), has been derived for all the monovalent metals. The results are presented in Table I (columns 2, 3, and 4); the data for cesium are rather uncertain.

In order to understand why some of these values of  $d \ln K / d \ln V$  are positive and why some are negative, it is necessary to digress and to explain something more of the behavior of the conduction electrons (5). Although I often gives a good approximation to imagine the conduction electrons moving through the ionic lattice as though they were free electrons (apart from the scattering processes which I have mentioned), it is in general necessary to take account of the fact that their motion is in fact modified by the periodic potential inside the solid crystal. This can often be done by assigning an "effective" mass to the electron which differs from its true mass but takes account of interaction with the lattice potential. Another important feature of the electron motion arises from the fact that electrons obey the Pauli exclusion principle. At the absolute zero of temperature the electrons take up a configuration of minimum energy which, classically, would be one of zero kinetic energy—that is, with all the electrons at rest. Because of

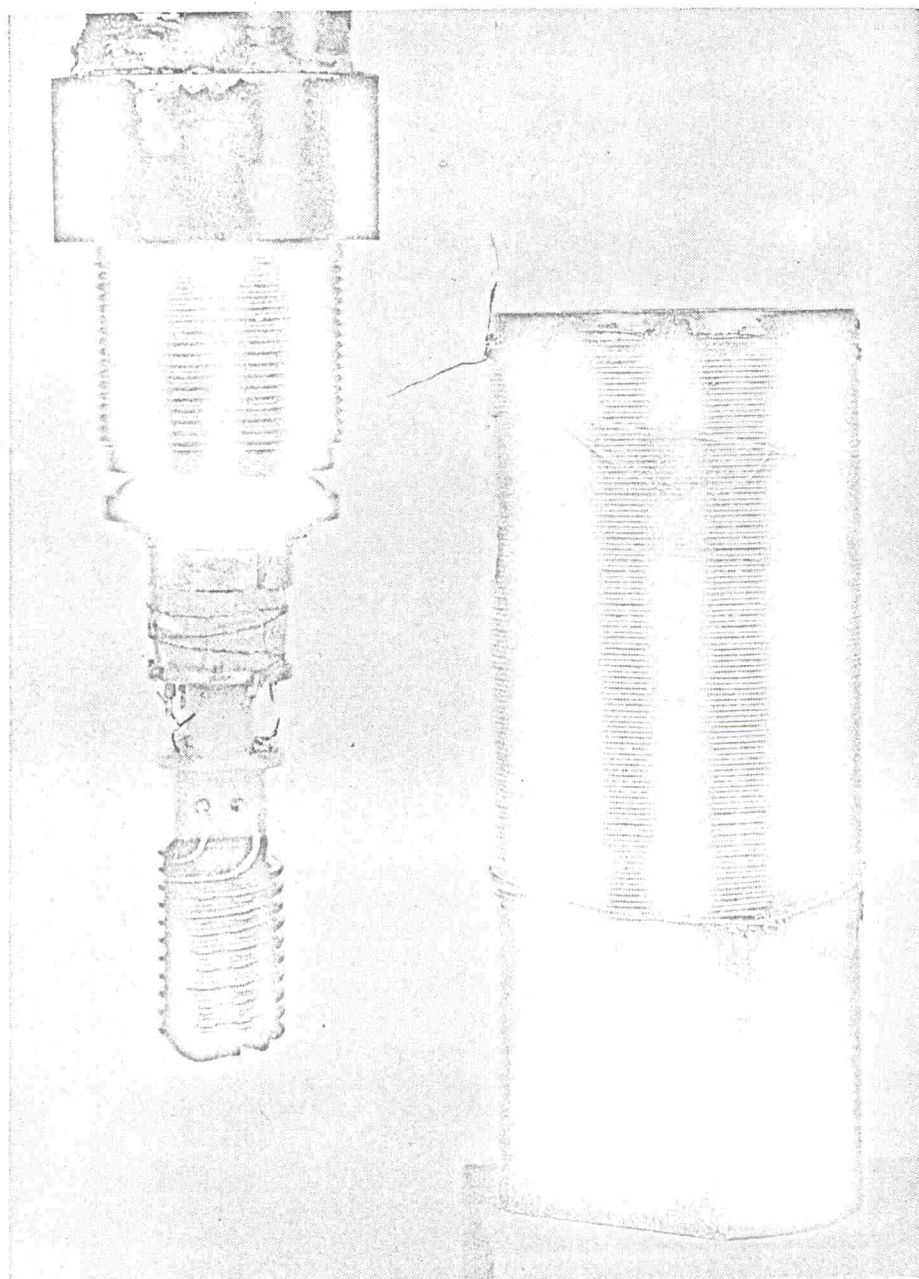


Fig. 4. A photograph of a typical alkali metal specimen wound on an insulated former. At right is the beryllium-copper bomb which encloses the specimen.