The centrifugal furnace consists of a steel cylinder approximately 12 centimeters in diameter, surrounded by a water jacket. The unit is rotated in a ball-bearing mount by a 1-horsepower variable-drive unit. The range of rotation for this unit is from 500 to 1500 rotations per minute. The interior of the steel pipe can be filled with any desired insulating material, such as aluminum oxide bubbles or Thermax carbon. The reaction section of the furnace consists of a number of coaxial tubes of any oxide or other refractory material, depending upon the substance to be contained.

The power consumed in operating a furnace of this type varies from 8 to 15 kilowatts at 25 to 30 volts, and from 350 to 500 amperes. The flow of helium is from 15 to 30 liters per minute, at normal temperature and pressure. The average temperature of the plasma is 10,000° to 17,500°K.

In the example shown in Fig. 6, aluminum was boiled in liquid aluminum oxide. An aluminum oxide tube was first melted by being heated for about 5 minutes in the plasma jet. The liquid aluminum oxide could be readily observed through the exit port. A solid rod of aluminum of known weight was then introduced through the exit port, at a slight angle; it melted in a few seconds and floated on the liquid aluminum oxide container and came to a boil in about 3 minutes. It distilled through the exit port and burned in the air with the usual brilliant flame.

Subsequent examination revealed that the innermost aluminum oxide tube had melted over a length of about 10 centimeters and that the remaining aluminum metal formed a sharp cylindrical band, about 3 centimeters wide and 3 millimeters thick, on the aluminum oxide. The two phases were perfectly defined and separate, as shown in Fig. 7. We have melted a thorium dioxide tube in the plasma jet, also.

The range of use of liquid oxide container's should be, on the average, for Al_2O_3, 2288° (melting point) to about 3800°K; for ZrO_2, 3000° (melting point) to about 4600°K; and for ThO_2 3300° (melting point) to about 4700°K.

The ratio of the vapor pressure of the container material to the total pressure can be adjusted, if desired, by operating the plasma jet and furnace at a higher total pressure. Thus, a way is now open to extend inorganic chemical research, particularly on chemical reactions in liquid phase (for example, between the container and any added substance lighter than the container), to a much higher temperature range.

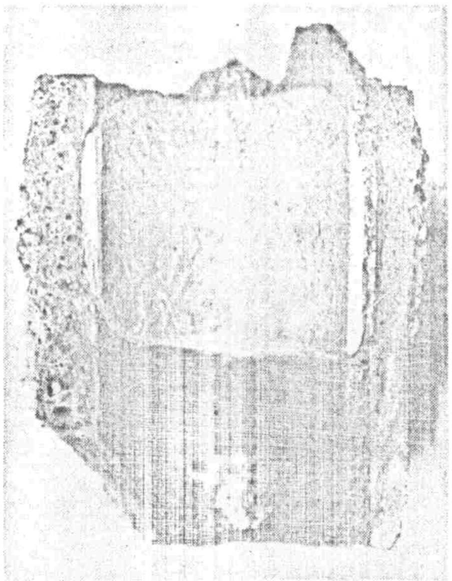

Fig. 7. After solidification, aluminum is clearly defined inside the aluminum oxide tube. The light gray area is aluminum.

The method just described is not well suited for making physical measurements (such as measurements of density and electrical resistivity) because of imperfect geometry. These measurements may be made by means of centrifugal furnaces heated by ohmic resistance, as illustrated in Fig. 8. That liquid metals may be used in this way as conductors was not realized in the past, due to the fact that the magnetic field created by the large electric current that is needed constricts and finally "pinches off" the liquid metal, thus breaking the circuit.

The phenomenon of the "pinch" was first discussed in Philadelphia by Carl Hering at the 3 May 1907 meeting of the American Electrochemical Society (*29*) and was further described by him in subsequent publications (*30*). The phenomenon was investigated quantitatively by Edwin F. Northrup (*31*), who established the relationship between the pressure P of the pinch (in dynes per square centimeter), the current strength I (in absolute centimeter-gram-second units), and the cross-sectional area of the liquid metal, A (in square centimeters). The relationship is $P = I^2/A$. If the current is measured in amperes, $P = \text{amp}^2/100\,A$.

Two methods have been found to counteract the pinch: (i) arranging the geometry of the current path to take advantage of the hydrostatic pressure of the liquid metal, and (ii) using a centrifugal force greater than the pinch pressure, as illustrated in Fig. 8. The liquid metal can be heated in a solid tube or in a "liquid pipe" of significantly greater electrical resistance than the metal.

It has been found possible to overcome the pinch effect and to use ohmic-resistance heating to boil bismuth, lead, tin, and other metals at or slightly above atmospheric pressure. We can now reflux bismuth or lead at about 2000°K for long periods. It is also possible, therefore, to construct thermostats by means of boiling liquid metals.

Physical Properties of Liquid Metals

Liquid metals are monatomic substances, and thus the relationships between their physical properties and temperature are simpler to comprehend than the corresponding relationships that exist for molecular liquids. For example, electrical conductivities may be extrapolated to higher temperatures, and from them thermal conductivities

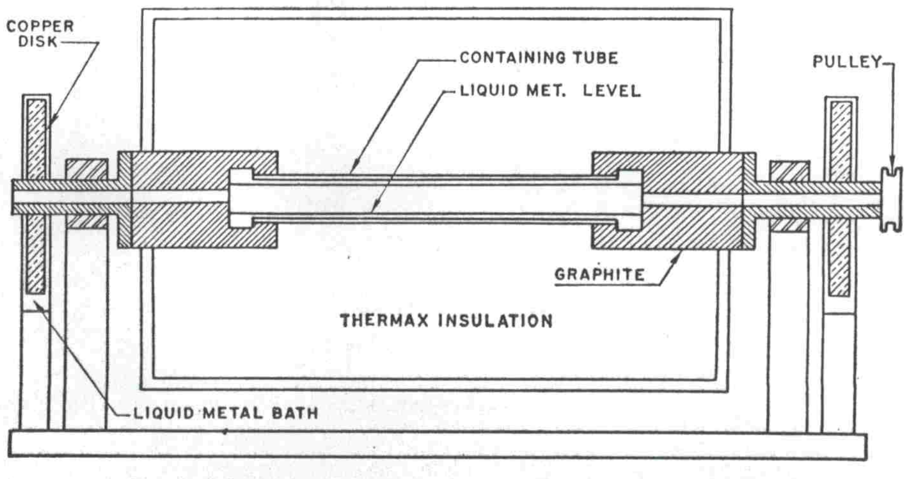

Fig. 8. Schematic diagram of the centrifugal electrical furnace.