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The method used in estimating the errors is given in reference (7).

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Discussion

H. M. BLACK.[5] The writer maintained contact with this project on thermal conductivity of molten lithium from the earliest stages until the container failed. In his opinion, the results are reliable within the limits of accuracy expressed in the paper.

The project was somewhat hurried in order to secure results as early as possible. Facilities for fabrication of equipment were limited. Consequently, parts of the apparatus were not as well constructed as ultimately might be done. Better methods of installing the thermocouples should be used.

A redesign of the apparatus should provide a method of preventing heat flow in any direction except through the sample. The calcined Sil-O-Cel which was used as insulation should be graded into uniform sizes, or a more uniform material obtained.

J. F. DOWNIE SMITH.[6] The authors of this paper have left out a discussion of many of the difficulties involved in the determination of thermal conductivity of liquid lithium. The most surprising difficulties were encountered. Perhaps the two most important were the difficulty of keeping lithium from contaminating the thermocouples, and the difficulty in preventing corrosion of metals by the liquid lithium.

A study of the literature had indicated that Armco metal might be satisfactory, particularly if it did not have residual stresses. The forging from which the cylinder was made was annealed and shot-blasted before shipment to the college. After machining no additional heat-treatment was performed. Yet a comparatively few days of operation caused complete corrosion through the cylinder. This, of course, caused contamination of the lithium and spoiled the accuracy of the results. The investigators had hoped to carry the determinations of thermal conductivities of liquid lithium and some other liquid metals to temperatures approaching the boiling point. However, within the time which was allowed for the experiment, this was not feasible.

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The equipment would have to be rebuilt to take the somewhat higher temperatures than were measured, and there is still the difficulty of finding a metal completely resistant to lithium. The investigators also had hoped to tackle sodium and some of the other metals which are considered for certain heat-transfer apparatus today. Perhaps at some time in the future this work may be continued.

It may be mentioned that the authors carried through this particular experiment overcoming difficulties not ordinarily encountered in experimental work, and they are to be commended for their efforts.

While there is no absolute check of the thermal-conductivity data from other sources, and there is no good check on the heat balance obtained with this one apparatus, the data obtained should be of some help to those engineers and scientists interested in developing equipment utilizing liquid lithium at temperatures within the range of those measured. More accurate data at higher temperatures would involve a very considerable amount of work.

VICTOR PASCHKIS.[7] With interest in heat-flow computation increasing, the lack of adequate data on thermal conductivity becomes apparent; all research in this field is therefore most welcome, if it leads to reliable data. The authors are to be commended for the inclusion of the "Discussion of Errors," but the writer feels that, in order to accept the conclusion that results are good to ± 10 per cent, this section should be still greatly expanded. In Table 1, experimentally obtained conductivity values of Armco iron are compared with data from literature. The per cent deviation is almost as large as the expected error and is not much different for low and for high temperatures, while the authors claim that errors decrease sharply with the temperature range.

A few comments should be made regarding specific errors:

1 The fundamental question seems not to be discussed in the section on errors: Is Equation [1] correct? "Proper radial guarding" at best can prevent heat flow from the container to the outside. This does not preclude radial flow between molten metal and container wall, unless there is zero contact resistance between the following:

(*a*) Molten metal and the sample container.
(*b*) The sample container and the heat sink.
(*c*) The heat sink and the ambient (on the plane surface of the former).

This can be ascertained by drawing temperature gradients for sample, container, and molten metal. At equal distance from the heat source two different temperatures would prevail at immediately adjacent points, resulting in radial flow. (A similar case was treated by the writer.[8])

The influence of these contact resistances, which obviously are not zero, becomes more significant because radial guarding is, necessarily, not ideal.

2 Therefore (calculated) radial heat flow of 0.4 to 0.9 per cent is in itself no proof that the error in conductivity is less than 1 per cent.

3 In the last paragraph of the section on "Procedure," it is said that "A negligible change in reading . . . was considered steady state. . . ." Unless the changes are in opposite directions, so that the readings lie on both sides of a mean value, the assumption would be wrong.

[7] Technical Director, Heat and Mass Flow Analyzer Laboratory, Columbia University, New York, N. Y. Mem. ASME.

[8] "Influence of Through-Metal on the Heat Loss From Insulated Walls," by V. Paschkis and M. P. Heisler, Trans. ASME, vol. 66, 1944, pp. 653–663.

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4 Temperatures, measured in the sample container, are not necessarily the same as those in the molten metal, if the contact resistances are not negligible.[8]

5 No estimate is shown for the error due to a possible thermal resistance between the container and the couple.

SAMUEL UNTERMYER.[9] The results obtained by the authors seem reliable since they are consistent with other sources of information. It has been thought that errors due to radial heat flow may be larger than ordinarily calculated, since variations in radial temperatures may cause convection currents within the liquid sample.

The authors are to be commended for their success in minimizing this source of error.

AUTHORS' CLOSURE

One of the major difficulties encountered in this work was finding a suitable means of thermocouple installation. As measurements had been originally planned up to 1000 C, no solder was found which would have the desirable properties at this high temperature. At lower temperatures a solder connection would be advantageous from the point of view of good-thermocouple to tube-wall contact. However, an erroneous calculation for heat flow down the tube wall might be obtained in using solder connections. No attempt was made to electric-arc-weld the couple onto the wall due to the thinness of the wall itself.

[9] Laboratory Director's Office, Argonne National Laboratory, Lemont, Ill. Mem. ASME.

During the experimental work, there was no evidence of the thermocouples' being attacked by lithium vapors, as complete failure of the couples would probably have occurred. No such failure was detected in the potentiometer readings. Also, the vapor pressure of lithium over the experimental temperature range is extremely low, thus minimizing the possibility of escaping lithium vapor from the sample container.

In the section, Discussion of Errors, no mention is made that the "errors decrease sharply with the temperature range" as pointed out by Mr. Paschkis. It was merely stated that the measured temperature gradients in the lower-temperature runs were smaller than the measured gradients in the higher-temperature runs due to the decreased thermal conductivity at the higher temperatures. Hence a greater error in the measured temperature gradient is to be expected at the lower temperatures. However, errors due to heat exchange, accuracy of thermocouple calibration, and dimension measurement are correspondingly smaller at the low temperatures. This led the authors to assume that perhaps errors over the whole temperature range of measurements are essentially the same. This assumption is substantiated by the calculated per cent deviation in the calibration results.

Mr. Paschkis' remarks on errors due to contact resistances are very well taken. The authors feel, however, that determining contact resistances in a molten-metal system involves greater experimental difficulties than in a solid-metal system. Future work involving measurement of contact resistances between a molten metal and a solid metal would be of invaluable aid in increasing the accuracy of conductivity data.

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