COMMENTS AND ADDENDA

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New Investigation of the Thermal-Conductivity Length Dependence in Helium II†

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The thermal-conductivity length dependence of helium II in small channels previously reported was found to arise from defects in our channel material. New thermal-conductivity measurements using more nearly perfect capillary channels do not show a length effect.

Previous reports in the literature[1,2] have indicated that the experimentally determined thermal conductivity of liquid helium II contained in small channels is dependent upon the length of the channels. These results are in disagreement with the London-Zilsel theory of heat transfer in helium II.[3] After publication of our earlier paper,[2] it was frequently suggested that the cause of our positive length-effect results might possibly be defects in our channels. These defects might not have been observed in the manufacturer's survey, nor in our check of his observations, because of the limited depth of field of the optical microscopes used in looking at the ends of the channel bundles. This suggestion led us to a destructive-testing survey of our channel materials and defects were indeed found. With new channel materials, results have now been obtained which show no dependence of the thermal conductivity of helium II on the length of the channels.

Our new channels[4] were fabricated by a method similar to that employed to make the channels used in our earlier measurements.[2] The basic channel bundle comprises a number of parallel glass capillaries (circular cross section) embedded in a glass matrix. Three different channel sizes were used in these new experiments: 8.7, 5.0, and 3.7 μ diam. (optically measured). There were 469 parallel channels in the 8.7-μ bundles, while the 5.0-μ and the 3.7-μ bundles had 1801 parallel channels apiece. For the length-effect investigations, measurements were made separately with each size (diameter) channel bundle; and for each size bundle, separate measurements of thermal conductivity versus temperature between 1.5 and 2.1 °K were made, using bundles of different lengths. The lengths of the capillary bundles used ranged from 1.9 to 10 cm.

It was possible in our new measurements to utilize a single bundle as the heat-carrying element between the hot and cold reservoirs of our heat-flow apparatus. This had the advantage in these length-effect investigations that sublengths of the same long bundle used in a set of measurements to determine thermal conductivity versus temperature could be used for subsequent shorter-length measurements. This technique allowed us further to check for nonuniformity and defects in the channels during the subdividing process. The utilization of a single-bundle element was not employed in our original investigation[2]; there, the multibundle heat-flow elements of different lengths were each made from virgin stock material.

A linear relationship between the heat current density through the channels and the temperature gradient along the channels (temperature gradients were always less than 3×10^{-3} °K/cm) could be discerned in all of our new data. Thermal-conductivity values were obtained from the slopes of straight-line plots of this data. While the actual experimental values of the thermal-conductivity coefficient, using the optically measured channel diameters, are not crucial to a discussion of the length effect, it may be noted that the experimental values are in good agreement with the London-Zilsel theory.[3] A more complete comparison of our experimental results with that theory is planned for future publication. Although negative results are usually anticlimactic, even when they are meaningful, the important fact to be stressed here is that the thermal conductivity of helium II contained in small channels does not depend upon the length of the channels.

The defects in our original channels have been discussed in detail elsewhere.[5] It may be worthwhile, however, to give a short description of these defects here. The defect channels were found to be of an order of magnitude, or more, larger in diameter than the desired channels. Like the desired channels, they were circular in cross section. They were probably caused by breaks in the hollow glass fibers during the process of pulling down the embedded fiber bundles to reduce their size. No interconnection between any of the channels was found. In no case was the total defect cross-sectional area more than 5% of the total desired cross-sectional area. The defect channels were more important in the heat-flow process than this comparison would indicate, however, because of the dependence of the thermal-conductivity coefficient on the square of the channel diameter. A simple argument based on the defect-channel analysis[5] indicates that the entire length-effect results of our earlier publication[2] can be explained on the basis of the defect channels.

The defect structure of our original channels represents a relatively simple array when compared with the porous-plug channel array of a column of packed jeweler's rouge. Yet our earlier use of relative gas-flow measurements to normalize our results[2] was unsuccessful in eliminating the positive length-effect results. It is now evident that those positive results were due to defect channels. This fact suggests that our original skepticism[6] of Forstat's positive length-effect results,[1] obtained using columns of packed jeweler's rouge, was valid and that great care should be taken in attempting to use simple models to analyze the flow of fluids through porous media.

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†Work based in part on Ph. D. thesis of E. C. Alcaraz submitted at Wayne State University.

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[1]H. Forstat, Phys. Rev. 111, 1450 (1958).

[2]H. H. Madden. H. V. Bohm, M. D. Cowan, and E. C. Alcaraz, Phys. Rev. 139, A1783 (1965).

[3]F. London and P. R. Zilsel, Phys. Rev. 74, 1148 (1948).

[4]Our new channels were obtained from the Bendix Research Laboratories of Southfield, Mich.

[5]E. C. Alcaraz, thesis, Wayne State University, 1968 (unpublished).

[6]See Sec. V of Ref. 2.