The values between horizontal lines in the tables are consecutive values.

$\mu_D/\mu_H = 0.30701337 \pm 0.00000050$ is in extremely good agreement with 0.3070126 ± 0.0000020 given by Bloch, Levinthal, and Packard.[1] The value with paraffin oil is a little higher than the water value.

There is a small decrease in the new paraffin value compared to our previous one,[2] which is mainly due to a more accurate way of determining the field difference between the two positions in the field.

The difference between the water and the paraffin value is being investigated further.

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[1] Bloch, Levinthal, and Packard, Phys. Rev. **72**, 1125 (1947).
[2] K. Siegbahn, and G. Lindström, Nature **163**, 211 (1949).

Observation of Second Sound Radiation Pressure by the Thermal Pitot Tube*

JOHN R. PELLAM
Cryogenics Laboratory, National Bureau of Standards, Washington, D. C.
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THE writer has previously discussed the radiation pressure $P_{\rm rad}$ which should exist for second sound and has expressed[1] this quantity in terms of the square of the temperature fluctuation[1a], τ, in the wave from the ambient absolute temperature T (deg. Kelvin),

$$P_{\rm rad} = \tfrac{1}{2}\rho c_v \tau^2/T. \qquad (1)$$

Entering also in (1) were the density and specific heat of liquid helium ρ(g/cc) and c_v(cal./g.-deg.). This radiation pressure has now been observed directly.

Although proof will be left to a later publication, a completely equivalent formulation of (1) results from the additional fourth term of the generalized Bernoulli equation for pressure, previously employed[2] for analyzing the thermal Rayleigh disk. This form is more realistically suited to the present experiment, as it relates hydrostatic pressure differences directly to heat flow density $\dot{H}$(cal /sec.-cm^2) in terms of the properties of the liquid. Thus

$$\tfrac{1}{2}\rho V^2 + \rho gh + p + \tfrac{1}{2}\rho(\rho_n/\rho_s)(\dot{H}/\rho ST)^2 = \text{constant}. \qquad (2)$$

The gross properties of He II appearing in the additional fourth term are the density ρ and the entropy S (cal./cc-deg.); the constituent quantities ρ_n and ρ_s(g/cc) are the density of normal fluid and superfluid, respectively. Employing known thermodynamic expressions for second sound velocity v_2(cm/sec.), an alternative and perhaps more convenient form of (2) may be written

$$\tfrac{1}{2}\rho V^2 + \rho gh + p + \tfrac{1}{2}(1/\rho c_v T)(\dot{H}/v_2)^2 = \text{constant}. \qquad (3)$$

Whereas the thermal Rayleigh disk experiment provides an insight to the hydrodynamics of internal counterflow about an obstacle, this present investigation provides an insight to the one-dimensional aspect of heat flow in liquid He II. Observations of hydrostatic pressure differences between portions of a second sound standing wave system provide a direct measure of the associated radiation pressure.

The simplicity of the apparatus employed is indicated by the diagram of Fig. 1. Second sound generated within the horizontally oriented chamber A by means of the plane electrical heating surface B is tuned to half-wave resonance by varying the driving frequency. The heat flow distribution thus set up (represented by the dotted line of Fig. 1) is maximum at the center, diminishing systematically to zero at either extremity. The junction of the vertical tube C is located at the midpoint of chamber A and therefore at the position of maximum horizontal heat flow density. Tube E, on the other hand, joins A near the end boundary where a heat flow node exists.

On the basis of the mass transport concept of heat flow in liquid He II, the associated internal particle convection is likewise a maximum at the midpoint of A. According to Eqs. (2) and (3) then, this internal streaming of particles horizontally past the orifice of C results in a smaller hydrostatic pressure than at E where no streaming exists, in a manner exactly analogous to the classical operation of the Bernoulli principle. In this situation however, the effect is due to differences in internal mass flow rather than to differences in net mass flow. At resonance the difference is presumably fixed by the value of the heat flow term in Eqs. (2) and (3) (not the classical first term which remains zero throughout).

The arrangement of the tubes constitutes essentially a liquid helium differential manometer system. Actually, a vent D is provided at the midpoint of A (for escape of heat) so that the level within tube C does not change. Thus *at resonance the height of the helium column in E is observed to rise very slightly* (a fraction of a millimeter) above that within C.

In view of the present generalized form of the Bernoulli relationship, it would appear that for the majority of classical hydrodynamical devices (and experiments) there exists the thermal counterpart in liquid He II. Thus the device described herein might be regarded as a form of *thermal pitot tube*. The geometry is modified, but the basic principle of comparing the hydrostatic pressure at a point of no (internal) flow with that in a region of (internal) flow is identical.

So far the observations have been primarily qualitative, but the general results conform to the expected behavior. The response is in the correct sense (i.e., the level in E rises) and second sound velocities deduced from the associated resonance frequencies have proper values. Actual comparison of observed pressure differentials with the heat flow term in Eqs. (2) and (3) awaits more detailed and precise observations. A later paper giving a full description of the experiment will include a complete derivation and discussion of these equations.

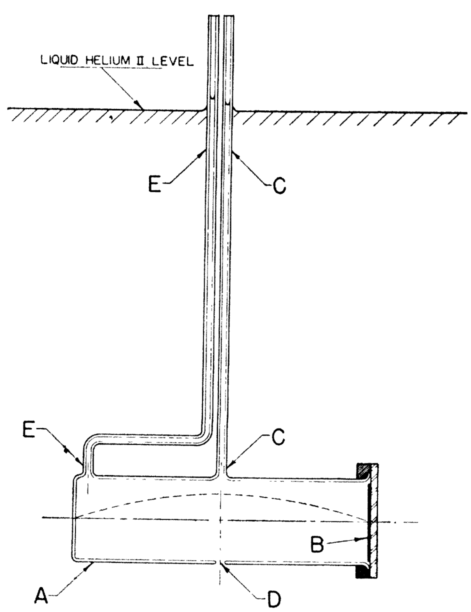

FIG. 1. Diagram of thermal pitot tube. Dotted line within horizontal cavity A represents distribution of heat flow density (and internal particle convection) for condition of resonance. The resulting forced difference in the levels within the vertical tubes (as well as the net elevation due to capillarity) is exaggerated here.

* Supported by the ONR.
[1] J. R. Pellam, Phys. Rev. **76**, 872 (1949).
[1a] The factor $\frac{1}{2}$ appears in (1) because $P_{\rm rad}$ now includes incident plus reflected waves, making τ the *net* temperature fluctuation at a boundary.
[2] J. R. Pellam and P. M. Morse, Phys. Rev. **78**, 474 (1950).