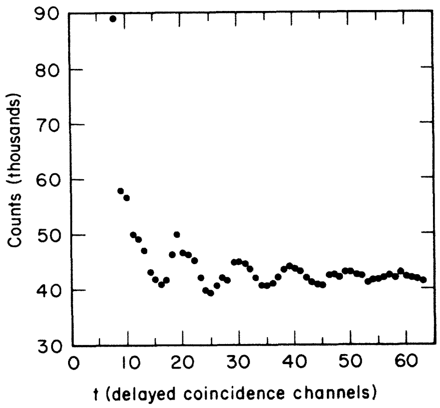

FIG. 2. Quantum beats at 0.88 G.

rate of 10 kc/sec. The count rate was very low, so that the probability of two photons arriving during the duty cycle of the time-to-height converter was negligible. The schematic of the apparatus is shown in Fig. 1.

Figure 2 shows the effect of quantum beats at 0.88 G. The data-accumulation time, because of the low count rate, was 10 h. The period of oscillation corresponded to 270 nsec, resulting in $g_J = 1.5$. The lifetime measured from the exponential decay is 2.2×10^{-6} sec. Similar results were also observed in the $4\,^3P_1$ state of Zn for the transition between $4\,^3P_1$ and $4\,^1S_0$ at 3076 Å, but with a much weaker signal owing to the lower vapor pressure of Zn. It seems that some interesting application of this type of detection method may be realized in the near future.

We wish to acknowledge the aid of Ron Keller of Huggins Laboratory, Inc., who supplied the parts of the traveling-wave tube and advised us on construction of the electron gun. William Berlund of the Lawrence Radiation Laboratory glass shop constructed the electron gun.

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MOTION OF SUSPENDED PARTICLES IN TURBULENT SUPERFLOW OF LIQUID HELIUM II

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We report here some observations on the motion of suspended particles in pure superflow. Solid hydrogen is less dense than liquid helium, whereas solid deuterium is more dense. By mixing hydrogen and deuterium gases together at room temperature in the correct proportions, solid particles with a density very close to that of liquid helium may be obtained.[1]

The superfluid wind tunnel is very similar to the one used by Koehler and Pellam.[2] The essential features are shown schematically in Fig. 1. Except for the superleaks F_1 and F_2 and the Kovar seals K_1 and K_2, the apparatus is constructed entirely of glass. A cloud of H_2-D_2 particles is introduced into the main experimental region S by allowing a predetermined quantity of hydrogen and deuterium mixture to enter the tube G. The heater H' allows some control of the particle size. A horizontal flow of pure superfluid is achieved using the heater H and the superleaks, which are constructed of tightly packed cerium-oxide powder. This double superleak configuration prevents the back flow of normal fluid through S by providing a thermal ground through the metal sections. Superfluid velocities are determined by measuring the rate of filling of a 2-cc beaker B. Small corrections to this velocity are made to allow for evaporation and film flow. A fountain pump P enables the beaker to be emptied

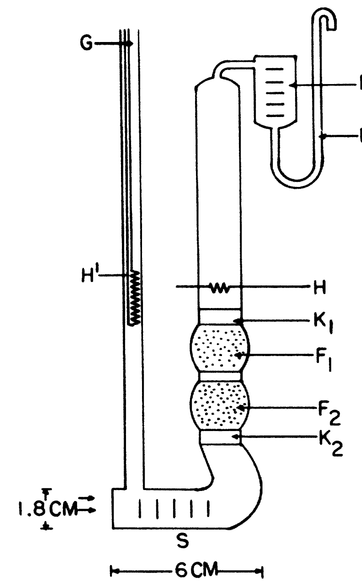

FIG. 1. The superfluid wind tunnel. (S), experimental region; (H) and (H'), heaters; (F_1) and (F_2), powder-packed superleaks; (K_1 and K_2) Kovar seals; (B), small beaker; and (P), a fountain pump.

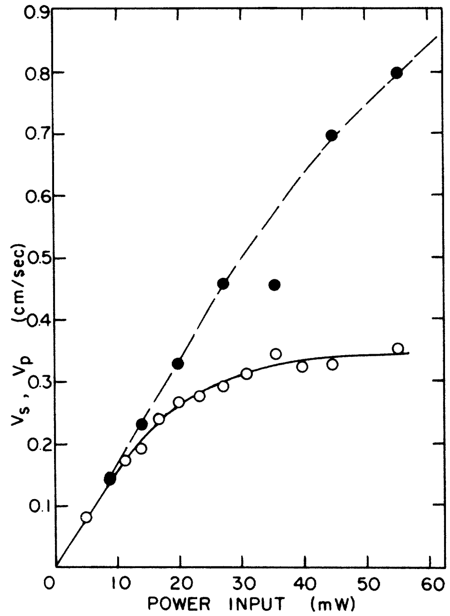

FIG. 2. A typical plot for average superfluid velocity (○) and particle velocity (●) versus power input.

after each filling.

All the measurements have been taken at 1.4°K. Because of the difficulty of measuring two time intervals simultaneously, a calibration curve of the average superfluid velocity against power input to the heater H was first obtained. Below a certain power input the velocity is linearly proportional to power; at higher powers the curve flattens off somewhat. This behavior is shown in Fig. 2. The departure from linearity, at approximately 20 mW or 0.25 cm/sec, is interpreted as the breakdown of pure potential flow, and we have, as will be seen later, reasons to believe that the breakdown occurs in the tube S.

After the introduction of a cloud of particles, conditions were allowed to return to equilibrium before the superfluid was set in motion. The particle velocity measurements were made by direct sighting, observations being restricted to particles moving in the central region of S and to particles of a similar size. This size was estimated to be a few hundred microns. Between 10 and 20 observations were taken of the particle velocity at each power. The particles had moved about 2 cm before their motion was timed.

The dependence of the particle velocity on heater power may be conveniently divided into three regions. At the smallest powers, i.e., below about 8 mW, no observable motion of the particles could be detected. Between 8 and 20 mW the particle velocities observed at each power showed relatively small scatter, and their averages were closely equal to the corresponding superfluid velocity. Above 20 mW a large spread in particle velocities is obtained at each power, the average of these values being greater than the corresponding superfluid velocity. The dashed curve in Fig. 2 shows the locus of the average particle velocity.

These observations strongly suggest that the superfluid flow in the tube S is purely potential below 0.25 cm/sec but turbulent above this velocity. In each of the two previous investigations[2,3] of pure superfluid flow in wide tubes, pure potential flow has been observed to persist to velocities greater than 0.25 cm/sec. In pure potential flow of a superfluid the velocity profile would be planar and the particles, if they move with their local superfluid velocity, would show little velocity variation. However, in the turbulent flow the velocity profile is unlikely to be planar. Probably the velocity near the tube's axis is larger than that near the walls. In addition, random velocity fluctuations due to the vortex lines will be superimposed on the average profile. Thus, any radial variation in superfluid velocity and its turbulent nature would account for the large scatter in particle velocities and also for the fact that the average particle velocity is greater than the average superfluid velocity.

It is difficult to imagine how vortex lines could become attached to a particle; therefore, we suggest the following mechanism by which a particle may be accelerated to the local superfluid velocity. In classical hydrodynamics,[4] as the velocity of flow of a liquid around an obstacle is increased, vortices first appear in the wake of the obstacle (eddy shedding), and later, at a much higher Reynolds number, the main flow becomes turbulent. Although the shedding of vortices in the wake of the obstacle is associated with separation of the boundary layer (the formation of which is assumed to require viscosity), a similar process could conceivably occur in superfluid flow. When separation occurs, the pressure distribution in the wake deviates considerably from that in frictionless fluid flow and results in a dragging force.[5] A calculation of the acceleration of a particle would be complex and still further complicated by the normal fluid viscosity. However, if the viscous damping is small compared to the accelerating force, it is reasonable to expect the particle velocity to be only slightly smaller than the local superfluid velocity.

We can now picture the observed particle behavior as follows. Below 8 mW, no eddy shedding occurs and a very small or zero dragging force exists. Above 8 mW, vortices are formed in the wake of a particle and a large dragging force is produced, accelerating the particles to the superfluid velocity. Thus between 8 and 20 mW, the potential flow region, the observed particle velocities are all close to the superfluid velocity. Above 20 mW, in the turbulent regime, the particle and superfluid velocities both show large scatter, and since observations are confined to the center of the tube where the superfluid velocity is greatest, the average particle velocity is greater than the corresponding average superfluid velocity.

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