inner level moving towards the outer level at a rate in excess of 1 cm per sec. In Fig. 1 the rate of flow is plotted against the temperature for four of the tubes used. The onset temperature at which superfluidity commences is seen to be well defined except for a very small foot corresponding perhaps to slight variations in pore diameter. The onset temperature is also seen to be well below the λ point of the bulk liquid and to decrease with decreasing pore diameter. This last point was well illustrated by two runs, using the same tube, but separated by a time interval of 4 months. During this time the glass adsorbed a small amount of matter from the atmosphere so that the average pore diameter decreased and the onset temperature fell from 1.73°K to 1.65°K.

TABLE I. Onset temperatures, corresponding film thicknesses, and average pore diameters.

Tube No.	Onset temperature °K	Corresponding film thickness 10^{-8} cm	Average pore diameter 10^{-8} cm
1	1.78	23	57
2	1.64	16	50
3	1.68	17	57
4	1.36	8	42

Experiments on the flow of unsaturated helium films[2,3] have already demonstrated that the onset temperature decreases as the film thickness decreases. Our results confirm this and show that the effect is a feature of flow through vary narrow channels and not a consequence of some peculiarity of helium films. The relationship between onset temperature and film thickness has been established,[4] and so for each onset temperature in our experiments there is a corresponding film thickness, as shown in Table I. The average pore diameter, as determined from absorption measurements,[5] is also shown and is seen to be much larger than the corresponding film thickness. However, electron micrographs reveal that the porous Vycor glass has a sponge-like structure and that the diameter along any channel available for flow varies by a factor of at least 2. The onset temperature is obviously determined by the narrowest point in the channel. Also, if the forces due to the wall render part of the film immobile,[4,6] this effect is likely to be greater in a channel with two walls.

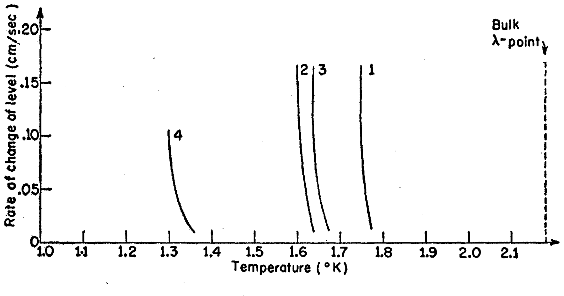

FIG. 1. The rate of flow of liquid helium through porous Vycor glass.

The rate of flow through the pores varied nonlinearly with the pressure head, but we have not yet made a careful evaluation of the importance of thermal effects. Porous Vycor obviously provides a very convenient means of studying superfluid flow through extremely narrow channels and we hope to make a detailed investigation of all aspects of this flow.

We should like to express our gratitude to Dr. Martin E. Nordberg of Corning Glass Works for providing the Vycor samples and much useful information about them.

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High-Velocity Particle Ranges in Emulsion*

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AN experimental program to determine the range-momentum relation for emulsion at high-particle velocities has been undertaken because of the current and continuing need for such information. Ranges of five groups of mesons in Ilford G-5 emulsion have now been determined. The independent parameter was the particle momentum which was measured to better than one part in 1000 by bending the particles through an angle of ~180° in the magnetic field of the 184-in. cyclotron and computing the momentum of individual orbits by the method of Barkas, Birnbaum, and Smith.[1]

The emulsion as received from the manufacturer was stored in a closed container for several weeks to attain uniform equilibrium[2] with a definite content of water. The specific gravities of 17 samples (1–2 g) of the emulsion were then determined by weighing in air, in CCl_4, and again in air. By Archimedes' principle we obtained a specific gravity of 3.8225, and the standard deviation was 0.0062. The deviations are real and must correspond to fluctuations in the local density of the emulsion in excess of the expected statistical variance.[3]

For the measurements we exposed four emulsion stacks. They were located at various radial distances from a small polyethylene target bombarded by the internal proton beam of the cyclotron. Location of a considerable amount of heavy-element shielding as indicated by previous experience[1] proved effective in

Table I. Measured momenta and ranges.

Particle	μ^+	π^+	π^+	π^+	π^+
Measured momentum (Mev/c)	29.80	95.94	129.2	172.0	199.9
Measured particle mean range (cm)	0.06013±0.00025	1.5235±0.0088	3.655±0.018	7.759±0.048	11.008±0.059
Mean range (cm) adjusted to standard density	0.06022±0.00025	1.526±0.009	3.661±0.018	7.771±0.048	11.025±0.059
Equivalent proton energy (Mev)	36.55	200	340	550	700
Equivalent proton range (cm)	0.5344±0.0022	10.25±0.06	24.59±0.12	52.20±0.32	74.06±0.40
Percent straggling (100σ)	4.1±0.4	3.9±0.4	2.7±0.4	2.8±0.5	2.5±0.4
Theoretical straggling[a]	4.1	3.0	2.8	2.6	2.6

[a] See reference 5.

eliminating confusable tracks. The data were entirely free of background, and the range straggling[3] was as expected on the assumption that each orbit originated in the target, allowance being made for the target dimensions. Measurements of the magnetic field in vacuum were made to a few parts in 10 000, and the distances from the target to fiducial points in the emulsion were determined with similar accuracy. The position and angle of entry of each track into the emulsion were recorded.

The rectified ranges were measured by breaking up each track into many straight segments. By determining the emulsion thickness before and after processing, the shrinkage factor was obtained. Before exposure each stack of pellicles was clamped firmly between Bakelite boards. The edges were then machined flat in a milling machine. It was found, on releasing the clamping pressure after exposure, that the area of each sheet decreased. Range corrections for this deformation varying from two to five tenths of a percent were required. The magnitude of this type of deformation is of sufficient importance so that cognizance should be taken of it in other experiments.

For the analysis of the results we introduced as a "standard range curve" that of Barkas and Young.[4] Taking the ratio[1] of positive pion mass to proton mass to be 0.14887, a range-momentum relation is predicted for pions. If the measured range of a pion of momentum p is R and the standard range is R_0, then the quantity $u=(R-R_0)/R_0$ is expected to have approximately a Gaussian distribution when the values of R_0 are limited to a small interval. The mean value of u measures the deviation of the experimental result from the standard curve, and $\sigma^2=\langle u^2\rangle-\langle u\rangle^2$ measures the range variance. The quantities $\langle u\rangle$ and σ are slowly-varying functions of the velocity. In Table I the ranges at particular values of the velocity are derived from the standard curve and the local values of $\langle u\rangle$. Since the standard range is calculated for emulsion of specific gravity 3.815, a slight correction is necessary for the difference in emulsion densities. Table I includes a point derived from the ranges of 100 muons produced by the decay of pions in the emulsion.

Many range measurements for particles of low velocity are to be found in the literature, but in almost no case has the emulsion density been measured or was it known to be independent of depth below the emulsion surface.[2] As part of this investigation we have obtained a considerable amount of range data at low-particle velocities while attempting to keep the emulsion density uniform and known, but, because of the added complexity and the difficulty of these measurements, a complete report will be deferred until further checks are made. It can be stated, nevertheless, that existing range curves for slow particles are incorrect by several percent if applied to emulsion having the density usual in stacks.

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Temperature-Dependent Factor in Carrier Lifetime

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It has been suggested that electrons and holes can become trapped near edge-type dislocations because of local deformation of the valence and conduction bands.[1] It has also been suggested that electron-hole recombination occurs largely at edge-type dislocations[2] on the basis of comparison between measured lifetimes and measured x-ray scattering method of counting dislocation density. This plainly suggests that electron-hole recombination occurs largely at dislocation edges because that is where the electrons have been partially localized by trapping, whatever the recombination mechanism may be.

We wish to suggest that the rapid recombination believed to occur at dislocations occurs because of relaxation of momentum selection rules. We also wish to point out that the observed lifetime, when recombination does take place predominantly at dislocations,