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DESTRUCTION OF SUPERCONDUCTIVITY BY A CURRENT

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IT was shown by Shubnikov and Alekseevskiĭ[1] as early as 1936 that when the superconductivity of a cylindrical specimen is destroyed by a current, there is a sharp jump in resistance to a value which is less than that in the normal state, and then the resistivity gradually returns to its normal value. This phenomenon was examined theoretically by London[2] and by Landau.[3] It was shown that the resistance jump must be $0.5\,R_n$ (R_n being the resistance in the normal state).

In the first experiments[1,4] the jump was greater than the theoretical value and reached $0.7 - 0.8\,R_n$, and Scott[5] suggested a dependence of R_c/R_n (R_c is the resistance of the specimen for the critical current) on the specimen diameter, due to the surface energy. It therefore seemed interesting to carry out measurements on specimens of different diameters. In addition, by using specimens of different purity, it would be possible to test Kuper's[6] view on the connection between the magnitude of the resistance jump and the ratio of specimen diameter to the mean free path.

Specimen No.	Diameter, cm	Length, cm	$10^3\rho_n$, Ω·cm at 3.8° K	$10^4 R_{3.8°}/R_{300°}$
1	0.050	6.3	1.37	0.80
2	0.032	3.7	1.70	0.96
3	0.0181	0.81	1.97	1.28
4	0.0083	0.50	2.30	1.51
5	0.0041	0.90	2.65	2.0
6	0.034	1.65	18	15
7	0.0181	0.82	20	17
8	0.0083	0.43	20	17
9	0.0041	0.78	20	17

We made two series of specimens from two tin samples of different purity. The specimens were prepared from wires obtained by extruding the metal through fine holes. The specimen characteristics are shown in the table. They were mounted on a frame and placed horizontally in a Dewar vessel to avoid a temperature gradient along the specimen. The earth's magnetic field was compensated to an accuracy of 3%. From the measurements, curves were obtained of the dependence of R_c/R_n on the temperature of the helium bath for various specimens (Fig. 1). In the value of R_n account was taken of the effect of the magnetic field of the current. When the values of R_c/R_n at temperatures above and below the λ-point are compared, it can be seen that the heating of the specimen above the temperature of the helium bath has a considerable effect. The dependence of R_c/R_n on the heat flow from the specimen per unit area, q, is shown in Fig. 2. (The points on the curves for each temperature correspond to the specimens 1, 2, 3, 4, 5, 6, 7, 8 and 9 of the table.) The shapes of the curves suggest that R_c/R_n depends primarily on q. It is probable that the dependence, found by Scott, on the diameter of the specimen is mainly determined by the dependence of q on d, since $q \sim H_c^2\rho_n/d$ (ρ_n is the specific resistivity of the specimen).

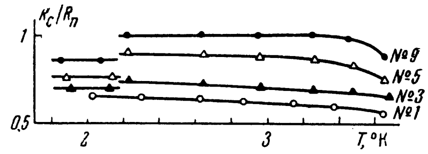

FIG. 1

If the variation of R_c/R_n with q is extrapolated to $q = 0$, the limiting value depends on temperature (increasing with falling temperature) and is about 0.5 only near T_c. It is not impossible that the reason for this is the surface forces between the superconducting and normal phases, which increase with decreasing temperature.

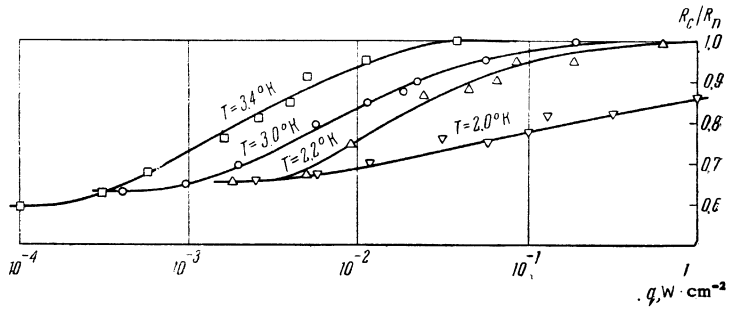

FIG. 2

The data presented thus indicates that it is only possible to elucidate the influence of surface forces (Scott) and mean free path (Kuper) if overheating of the specimen is avoided.

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DAMPING OF THE OSCILLATIONS OF A CYLINDER IN ROTATING HELIUM II

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We have previously shown[1] that the interaction of a disk oscillating in rotating helium II with the Onsager-Feynman vortex lines leads to a specific dependence of the damping upon the rotational velocity, with a characteristic maximum[2,3] which is not to be explained by consideration of the influence on the disk of the normal component of the helium II alone (even when the mutual friction between the normal and superfluid liquids is taken into account). A decisive role in the explanation of the formulas derived in reference 1 is played by the circumstance that the vortex lines, being perpendicular to the plane surface of the disk, lie with one end upon this surface. Distorted by the perpendicular displacement of the surface, they act upon it with a force which depends upon their tension. The relation between the tension of a vortex line and its circulation, moreover, determines the effective viscosity of the superfluid component (the quantity η_s in reference 1).

From what has been said, it is clear that if the disk be replaced by a cylinder whose surface is parallel to the axes of the vortex lines, then the possibility of direct interaction of the oscillating body with the vortices which form when a superfluid liquid is rotated is completely excluded. The presence of the vortices manifests itself solely in mutual friction effects.

Solving the system of hydrodynamic equations for rotating helium II,[4,1] for boundary conditions corresponding to small oscillations of an infinite cylinder rotating together with an unbounded liquid about their common axis,* one can readily verify that the force acting upon the surface of the cylinder is wholly determined by the momentum flow of the normal component.

The sum of the moments of the forces acting upon unit length of the outer and inner surfaces of a thin-walled cylinder of radius R turns out to be

$$M = -2\pi i R^3 \eta_n \Omega \varphi_0 k \left[H_2^{(1)}(kR) / H_1^{(1)}(kR) - J_2(kR) / J_1(kR) \right] e^{i\Omega t}. \quad (1)$$

Here, η_n is the viscosity of the normal component, Ω and φ_0 are the frequency and amplitude of the oscillations of the cylinder, J_p is a Bessel function, $H_p^{(1)}$ is a Hankel function, and k is the complex wave number, determined by the equation

$$k^2 = -\frac{i\Omega}{\nu_n}\left[1 + i\frac{2\omega_0}{\Omega}\beta_s\left(1 - i\frac{2\omega_0}{\Omega}\frac{\beta_n}{1 + 2i\omega_0\beta_n/\Omega}\right)\right], \quad (2)$$