CONCERNING THE "HARDNESS" OF CRYSTALLINE HELIUM

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Observations were made of the penetration of a glass indentor into the surface of crystalline helium.

Simultaneously with the attempts to observe vacancions, several experiments were performed on the mechanical properties of He^4 crystals. The idea of these experiments consists of measuring the "hardness" of the crystal on the boundary with the liquid[2]. To this end, the instrument shown in Fig. 1 was constructed. In the first variant of the instrument, the indentor was a 0.6-mm diam. glass rod with its end rounded by melting (see Fig. 2), mounted on the axis of a glass prism (piston) of triangular cross section. A magnetic yoke was placed on the other end of the prism. In the second variant of the instrument, the shape of the indentor was strictly cylindrical with diameter 0.61 mm.

The indentor was moved with the aid of a superconducting coil. At small displacements of the yoke, the pulling force in the described geometry was 670 dyn/A. To eliminate dry friction between the piston and the container walls, an electric toothbrush was connected to the cryostat.

The experiment consisted of visually observing with an MBS-2 microscope the penetration of the end of the indentor into the flat surface of the helium crystal. Unfortunately, these observations had to be made through six glass walls (two walls of the nitrogen Dewar, two walls of the helium Dewar, one wall of the vacuum jacket, and one wall of the container with the crystal).

In the experiments with the rounded indentor, our observations reduce in general outline to the following. After growing the crystal ($T \sim 1.93 - 2.18°K$,

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[2] Keesom [2] notes that in his attempts to observe solid helium he "forged" it with a hammer actuated by an electromagnet.

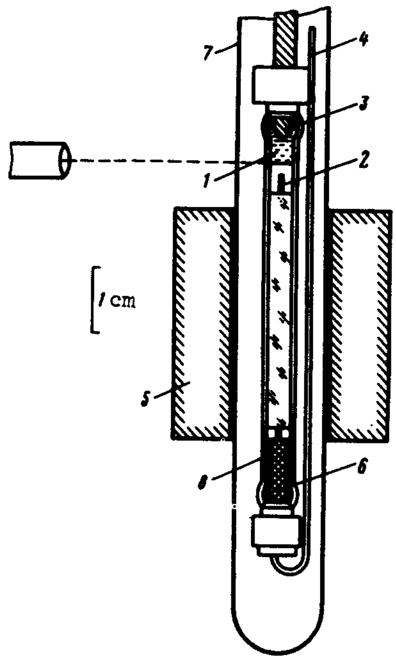

Fig. 1

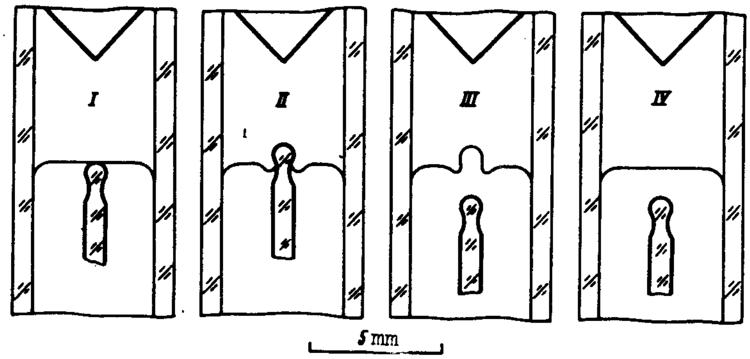

Fig. 2

Fig. 1. 1 - Helium crystal, 2 - indentor, 3 - cold finger, 4 - helium supply tube, 5 - superconducting coil, 6 - magnetic yoke, 7 - vacuum jacket, 8 - ampule.

Fig. 2. Successive stages of indentor action.

$p \sim 35 - 40$ atm) and establishing equilibrium, the speed of the crystal-liquid boundary did not exceed 1 μ/sec (see Fig. 2-I). The penetration of the indentor into the crystal occurred at a speed ~100 μ/sec and led to the formation of a deep crater with edges surrounded by the "extruded" matter, the volume of which was comparable with the volume occupied by the penetrating end of the indentor (Fig. 2-II). When the current was turned on, the indentor dropped and the deep indentation produced by it was unexpectedly "healed" within several seconds, i.e., at a rate of about one hundred μ/sec (Fig. 2-III).

After equalization of the crystal surface, its surface again continued to move at a speed not exceeding 1 μ/sec (Fig. 2-IV). The results obtained in the instrument with the cylindrical indentor, the displacement of which was measured with a KM-5 cathetometer, are shown in Fig. 3.

No penetration of the indentor took place up to a current of 0.5 A (effective force ~330 dyn). With further increase of the active force the indentor began to penetrate into the crystal at a practically constant speed ~3 μ/sec.

We consider the most interesting of the qualitative observations made by us to be the formation and "healing" of the indentation on the boundary of the liquid and the crystal, which can hardly be attributed to some temperature effects.

We now have at our disposal a metallic cryostat with plane-parallel 10 × 50 mm windows of chemical glass, sealed with a lap joint into

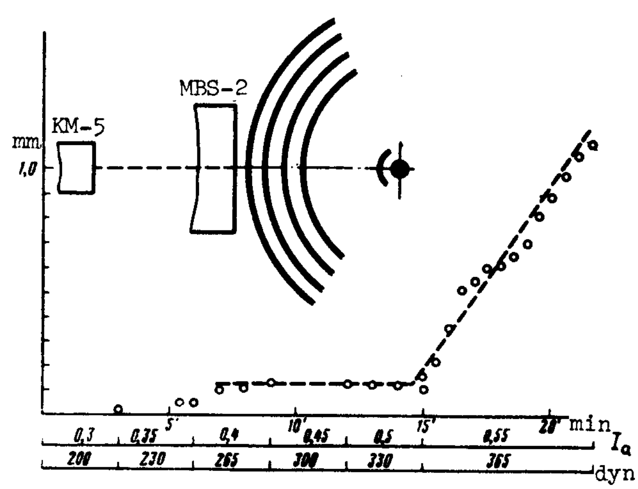

Fig. 3. Displacement of indentor vs. the time, the coil current, and the acting force.

ferrochrome frames which are then brazed with Wood's alloy to a stainless-steel helium vessel. Such windows can withstand repeated thermal shocks from 300 to 80°K without disturbing the vacuum. Thus, the six glass walls that distort the object greatly are replaced by only two, the wall of the vacuum jacket and of the container with the crystal.

The new apparatus will greatly facilitate the investigation of the mechanical properties of crystalline helium.

[1] A. Andreev, K. Keshishev, L. Mezhov-Deglin, and A. Shal'nikov, ZhETF Pis. Red. 9, 507 (1969) [JETP Lett. 9, 306 (1969)].
[2] W.H. Keesom, Comm. Phys. Lab. Leiden, No. 184 "b", Vol. 17 (1926).