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STRESS HEATING OF A THERMALLY INSULATED SUPERCONDUCTOR*

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Introduction

It has been observed[1] in Energy Doubler magnets that the heat loss per cycle for a given ramp rate shows an anomalous increase at fields above 30kG. In an attempt to identify the cause of this increase with heat generated by mechanical deformation, a series of tests was started. Here is reported a test on the heat of deformation generated by stretching a single NbTi multifilamentary strand. This test shows that this heat can be easily measured using calorimetric techniques.

Multifilamentary res of NbTi in Cu matrix present the interesting effect of heating when stretched and heating again when released, provided the stretching is done beyond the elastic limit of the copper and below the elastic limit of NbTi. The heating on releasing is due to the compression of the copper beyond its elastic limit by the elastically stretched NbTi filaments when unstretching. This phenomenon is known as the Bauschinger Effect.[2]

Experiment

The equipment used for this test was the cryostat designed for measuring the thermalconductance of roller suspensions. The main feature of this cryostat is a vacuum can immersed in liquid helium in which we can apply forces up to 700 lb by means of a hydraulic cylinder extension.

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Three runs were involved in this test. In the first one we measured the residual resistivity ratio of the sample wire, its dependence on cold working by stretching at the test temperatures and, finally, its yield point. For the second run the wire had improved attachment joints and was instrumented with a heater, a thermometer and a thermal contact to a 4.2K reservoir. This thermal contact was necessary for cooling the wire back after a heating operation (change of stress or electrical heating). However, the time constant for the cooling was much longer than the heating time and the wire can be considered thermally isolated during the heating operations. The measurements were made in this second run. Two balancing wires were stretched or released simultaneously in a configuration shown schematically in Fig. 1. The third run was a check run using a copper wire instead of the multifilamentary wire. Its purpose was to verify the appropriateness of the technique and apparatus used. It did actually show that the observed heating on release of tension did not occur for copper. Actually, under higher tension conditions some small heating was observed which could be attributed to friction in the apparatus or deformation on the fiberglass epoxy material (G-10) that supported the wires.

The wire used was one strand of two previously formed 23 strand cable. As such its initial shape was not exactly straight and its cross section not uniform along its length. A rough photomicrograph of the wire and a description of it is presented in Fig. 2 for identification purposes.

Measurements

In order to get more than just qualitative data: 1) the installation of the thermometer and heater was according to the techniques used in thermalconductivity work; 2) direct calibration of the thermometer in terms of energy deposited in the wire-heater-thermometer system was carried out between measurements.

ıe thermometer used, an 1/8W, 100Ω, Allen Bradley carbon resistor, previously calibrated[3], was wrapped to the wire with copper wire and GE7031 varnish. Its leads of #40 enamel insulated copper-phosphorus alloy wire were also well heat sinked to the wire and away from the heater wire. The heater, made up also of the same copper-phosphorus wire for low heat capacity, was wound around the wire aiming for a uniform coverage but away from the thermometer and the thermal contact to the 4.2K reservoir.

The direct calibration was made by discharging the energy of a capacitor ($1/2CV^2$) through the heater and associating the corresponding excursion of the thermometer with this energy properly corrected for the heater lead resistance.

Figure 3 is a typical chart recording of thermometer excursions due to application and release of a 39.7Kgf load and capacitor discharges (zaps). The load was applied by pumping on a hydraulic cylinder the oil pressure of which was previously correlated with the readings of a dynamometer in the sample chamber. The major difficulty in these measurements was the correct application and evaluation of the load due to some relaxation in the oil pressure and friction in the cylinder. From the preliminary data obtained we can, however, associate an energy release of 20mJ with the loading or unloading of 40Kgf to our wire. In order to complete this demonstration a stress vs strain curve for this wire was obtained at room temperature using an Instrom machine. Here the cycling of the force generates hysteresis loops due to the Baushinger Effect in copper.[2] The heat generated in this process is given by the area of the loop. Figure 4 presents the raw data and its insert the corresponding heat generated.

Although the loads used at low temperature were excessive for engineering designs it remains clearly demonstrated that this heating effect is quite visible and that the technique used could be the basis for much more accurate measurements.

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References

1. R.Yamada, H.Ishimoto and R.E.Pighetti; AC Loss Test of D10-3 Magnet, Fermilab Technical Memo TM-638 (December 1975).

2. J.R.Heim,; Superconducting Coil Training and Instabilities Due to Bauschinger Effect, Fermilab Technical Memo TM-334 (June 1974).

3. M.Kuchnir and J.L.Tague; Carbon Resistance Thermometers, Fermilab Technical Memo TM-647 (March 1976).

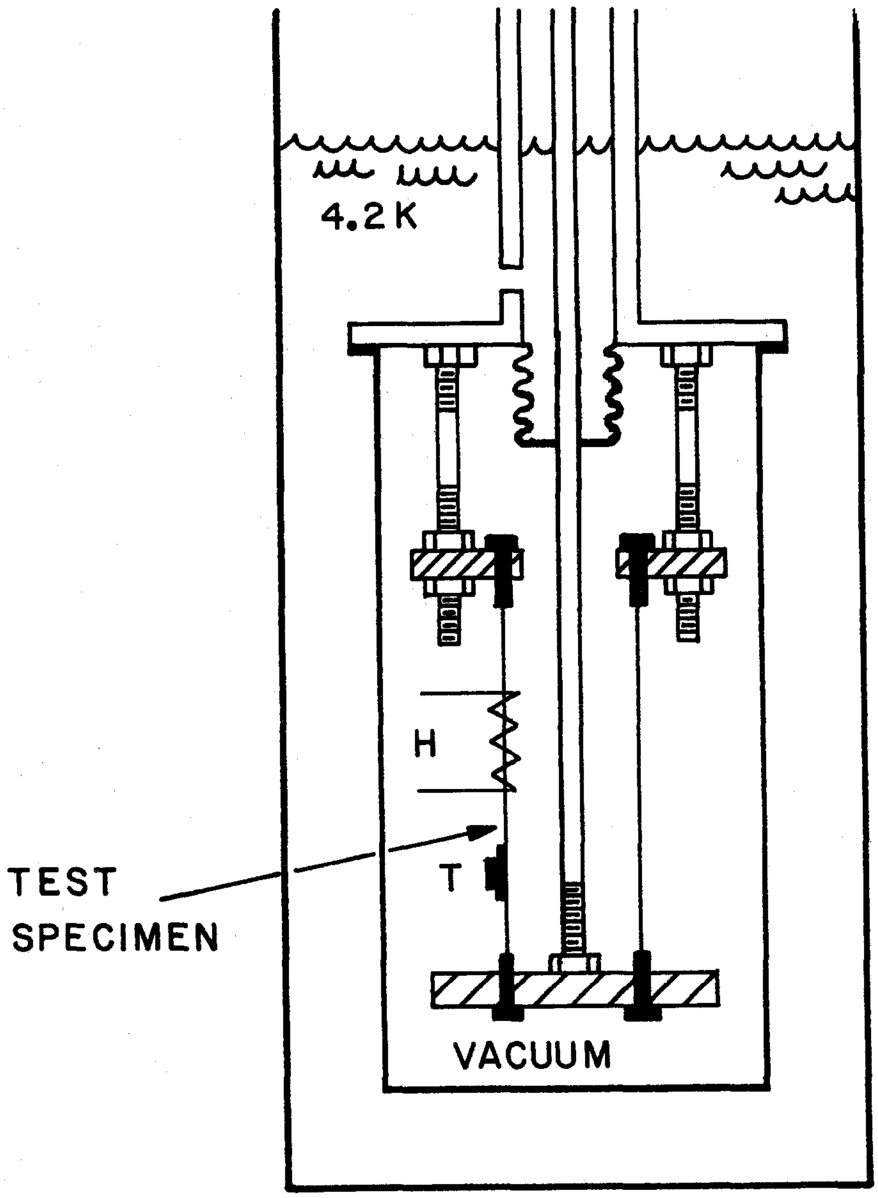

FIGURE 1. SCHEMATIC OF THE TEST SET-UP

SHOWING THE HEATER, H, AND THERMOMETER,

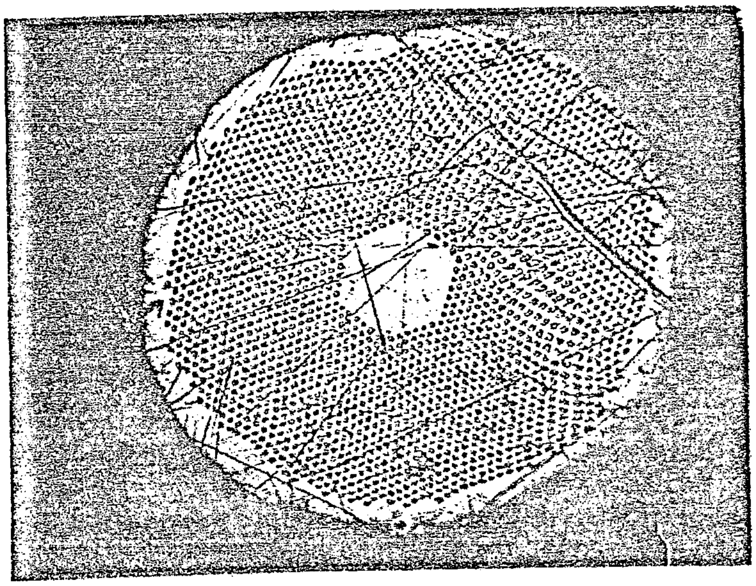

FIGURE 2. PHOTOMICROGRAPH OF THE MULTIFILAMENTARY WIRE USED. THE LINES ARE SCRATCHES AND SHOULD BE DISREGARDED. THE DOTS ARE 8μ DIAMETER NbTi FILAMENTS. MORE THAN 2000 OF THEM ARE IMBEDDED IN THE COPPER MATRIX (WHITE BACKGROUND) OF .027 INCH DIAMETER PROVIDING A Cu TO SUPERCONDUCTOR RATIO OF 1.8 TO 1. THE RESIDUAL RESISTIVITY RATIO IS ∿50.

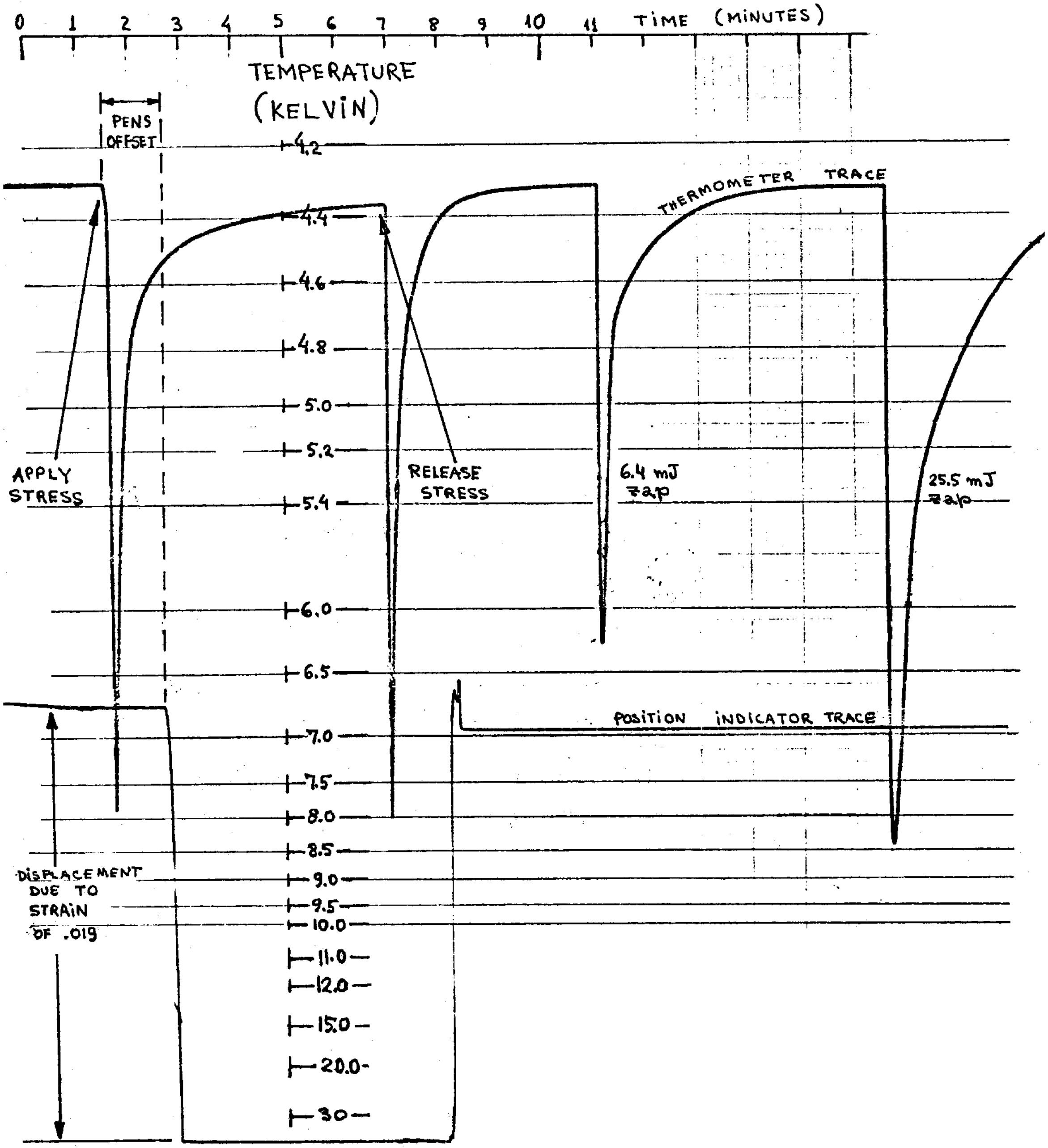

FIGURE 3. CHART RECORDER TRACES OF THE THERMOMETER (UPPER TRACE) SHOWING AN APPLICATION AND RELEASE OF 153×10^3 PSI STRESS FOLLOWED BY TWO CAPACITOR DISCHARGES. THE LOWER TRACE IS DISPLACED TO THE RIGHT AND RECORDS THE POSITION OF THE STRESS APPLYING MEMBER.

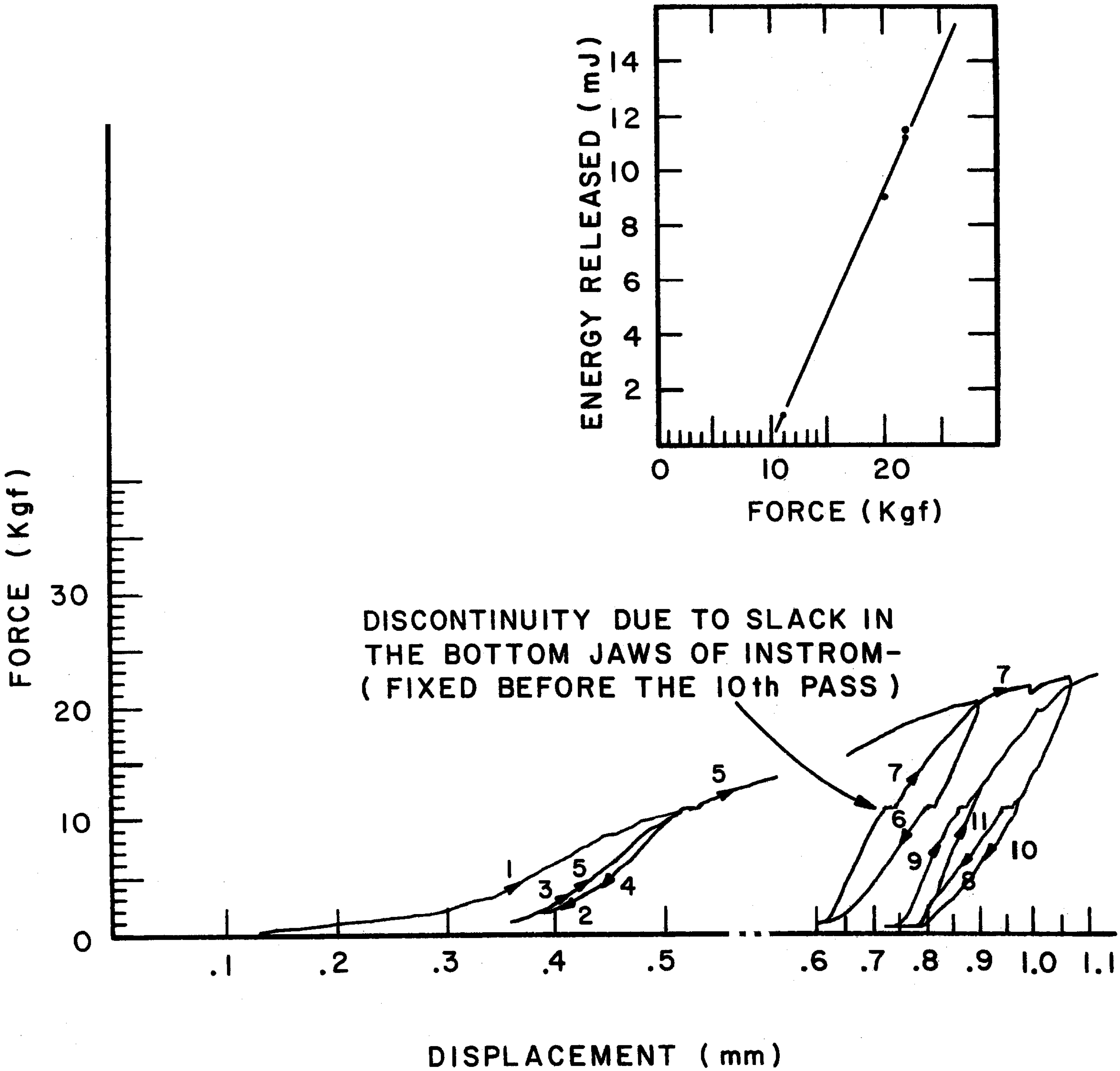

FIGURE 4 ROOM TEMPERATURE INSTROM TEST ON MULTIFILAMENTARY NbTi-Cu WIRE