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Recent reports by Berlincourt, Hake, and Leslie[1] and by Kunzler[2] of the high superconducting current density at high magnetic fields exhibited by the Nb-Zr alloy system have stimulated great interest. This Letter is a report of measurements made on Nb-25 a/o Zr alloy wire in the 12-cm i.d. air-core solenoid[3] of the Low-Temperature Laboratory of the University of California.

The data reveal that as transverse fields reach or exceed 70 kilogauss at 4.2°K the superconducting current density diminishes rapidly from a value of 5×10^4 amp/cm^2, and suggest that the high-field properties of this material are very sensitive to its thermal history. In addition we have observed the appearance of anomolous nonresistive voltages at current values within the pretransition range.

Five samples were taken over a 152-cm length of 0.052-cm diam Nb-25 a/o Zr alloy wire which had been cold-reduced $\geq$ 99%. The samples, 6 cm long, were "tinned" in an argon-shielded bath of a Cu-(25 wt %) Ag-(50 wt %) xSn-(tr) Ti alloy (Sample 3 @ 660°C, 1 and 2 @ 530°C) or ultrasonically in a Bi-(50 wt %) Zn alloy (Sample 4 @ 450°C, 5 @ 360°C). "Tinning" times were on the order of 15 sec. The samples were soft-soldered to grooved copper blocks with a contact length of 1.6 cm. Potential leads having a centered 2-cm spacing were attached with soft solder. The contact blocks were rigidly supported by a grooved micarta pad which also mechanically supported the sample along its entire length. It was electrically shunted by .0025 ohm of

of constantan to prevent its damage at high currents. The sample assembly was centered with brass guides in a glass Dewar. A steady dc current supplied by a storage battery was fed to the sample by a twisted pair of B.S.W.G. No. 10 heavy-formvar-insulated copper leads soft-soldered to the contact blocks.

The measurement was made by starting the run with the magnetic field at its peak value after having cooled the sample to the appropriate temperature. Then the measuring current was increased until a resistive voltage appeared across the sample. The current was quickly reduced to zero and the measurement was repeated several times; then the next lower field value was set. The sample potential was amplified by a Beckman Model 14 amplifier and recorded on the y axis of a Moseley Model 3S x-y plotter. The x axis of the plotter was connected to a 200-amp 50-mv Weston shunt; thus a plot of E as a function of I for the sample was obtained. The system noise level varied in the range 0.2 to 4μv, depending on the particular sample assembly used.

The results of the measurements are given in Fig. 1. A reduction in the sample temperature of approximately $2^{\circ}K$ shifts the critical field about 12 kilogauss higher. The $2.15^{\circ}K$ point for Sample 5 corresponds to a current density of 5×10^{4} amp/cm^{2}. This is a greater by factor of five than that previously reported[2] for a sample of Nb-33 a/o Zr ribbon at $1.5^{\circ}K$. The current density value of 10^{5} amp/cm^{2} for Sample 3 at $4.2^{\circ}K$ implies the effect of the increased cold-working of this material. A comparison of the high-field results for the five samples suggests that this material is affected by its thermal history, as the field data have an approximate inverse ordering correspondence to the "tinning" temperature.

A perplexing feature of our observations was that pretransition behavior was complicated by the appearance of anomolous nonresistive potentials. These

are related to the time rate of change of current through the sample, and were particularily evident in Samples 3, 4 and 5. In addition to the typical features shown in Fig. 2, these voltages have the following properties:
(a) with dT/dt positive the sign of the nonresistive voltage is either the same as that of the resistive transition voltage (Samples 3, 4) or has an opposite sign (Sample 5); (b) the polarity of the nonresistive voltage reverses in all cases as dI/dt reverses sign; (c) the area under the curve of the anomolous disturbance goes to zero as $dI/dt \rightarrow 0$; (d) the value of the measuring current at which the maximum voltage appears is shifted downward as the current is swept down through the range of appearance (see Fig. 2a), and (e) at a given value of field the anomolous voltages are highly reproducible with respect to the region of current over which they occur but not necessarily so in amplitude or shape.

By installing a pickup loop coaxial with the main field and having an area-turns product 10^3 times that of the loop defined by the potential leads, we were able to observe that these voltages were not caused by translation of the sample or lead assembly: this result is confirmed by (a) above. Furthermore, we have not observed[4] this effect in measurements made on Nb_3Sn wires[5] in the sample assemblies described above.

This interesting phenomenon,[6] the possible effects of heat treatment on Nb-Zr alloys, and the application of these materials to the production of high magnetic fields are being studied further at this Laboratory.

We wish to thank J. Donald Gow and, in particular, H. Paul Hernandez for their long interest and encouragement in this work. We also wish to commend Ken Solomon for his excellent electronics work, Donald N. Lyon for his cooperation in the use of the Low-Temperature Laboratory and, for their help with the measurements, Ted Baker and Richard Wolgast. We further wish to express our gratitude to Dr. James Wong of the Wah Chang Corporation for providing the wire for measurement.

References

*Work performed under the auspices of the U. S. Atomic Energy Commission.

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4. Paul R. Aron and Harley C. Hitchcock, (Lawrence Radiation Laboratory), unpublished data.
5. J. E. Kunzler, E. Beuhler, F. S. L. Hsu, and J. H. Wernick, Phys. Rev. Letters 6, 89 (1961).
6. Vince J. Arp (National Bureau of Standards Cryogenic Engineering Laboratory), reports observing similar effects in Nb–25 a/o Zr alloy (private communication).

Figure Captions

Fig. 1. Critical Current vs Applied Magnetic Field for Nb–25 a/o Zr wire 0.052-cm diam, $H \perp I$.

⊙	Sample 1	4.2°K
△	Sample 2	4.2°K
⊡	Sample 3	4.2°K
⊠	Sample 3	2.05±.05°K
◇	Sample 4	4.2°K
◇	Sample 4	2.15±.01°K
×	Sample 5	4.2°K

Fig. 2. Sample voltage as a function of current for Sample 3. Transverse H applied = 50 kilogauss; T = 4.2°K.

a. current raised and lowered at constant $\frac{dI}{dt}$ (~5 amp/sec)

b. typical

c. $\frac{dI}{dt} = 0$ at these points

d. resistive superconducting to normal transition

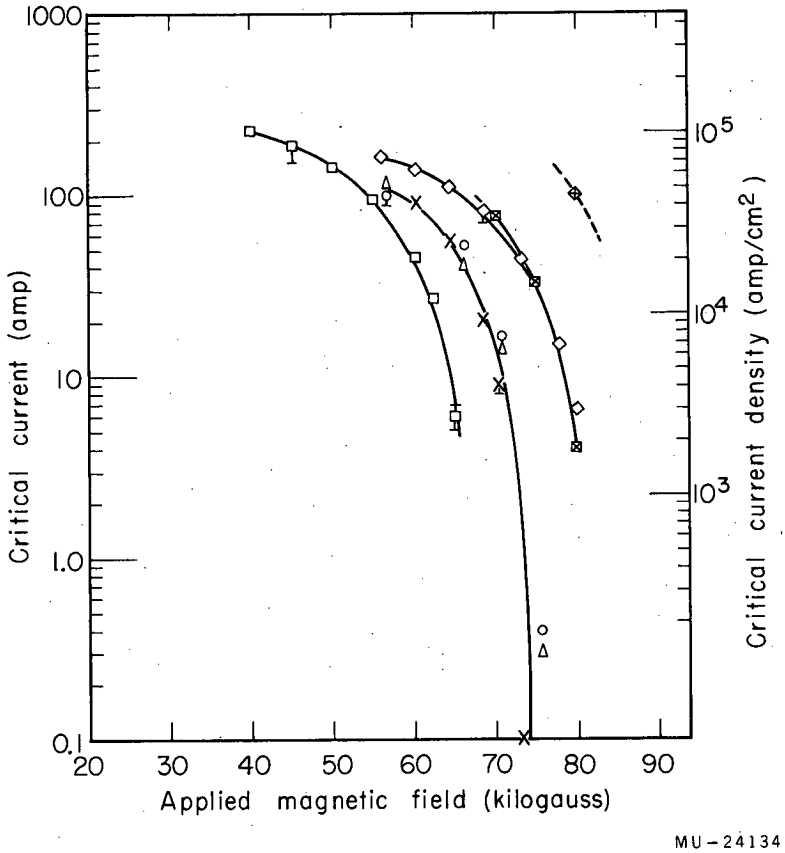
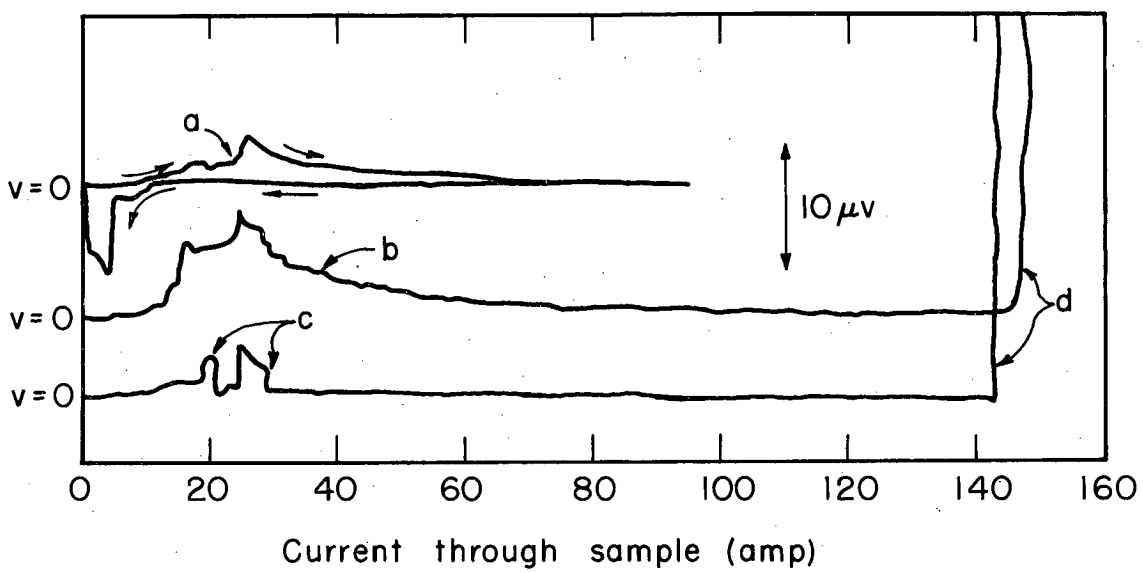

1000
100
10
1.0
0.1
Critical current (amp)
10^5
10^4
10^3
Critical current density (amp/cm^2)
20
30
40
50
60
70
80
90
Applied magnetic field (kilogauss)
MU-24134

Fig. 1



MU-24135

Fig. 2

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