THIRD QUARTERLY PROGRESS REPORT

INVESTIGATION OF CURRENT DEGRADATION PHENOMENON IN SUPERCONDUCTING SOLENOIDS

JANUARY 15, 1965 TO APRIL 15, 1965

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SUPERCURRENT STABILITY TESTS

A. DESCRIPTION

Supercurrent stability of the heat-treated Ti - 22 at. % Nb wire samples has been investigated. This measurement consists of testing a short wire sample, carrying a dc current, for super-to-normal transitions in a time varying magnetic field. Unstable samples go normal at field-current values below the standard short sample curve.* For these unstable superconductors, a region of instability can be found. For a typical Nb-Zr wire, this region is bounded in field between approximately 5 and 30 kgauss and in current density between a minimum of ~4×10^4 A/cm^2 and the standard J versus H curve. Generally, for a particular material the size of this region is dependent upon the rate of charge of field, with the degree of instability increasing with increasing dH/dt. Also, and most important for our work, the size of the unstable region is material dependent.†

For the following experiments, the magnetic field was supplied by a 45 kgauss superconducting solenoid rated at 5 kgauss/A. The solenoid was powered by a transistorized dc power supply which was electrically programmed to generate linear magnetic field ramps. The magnetic field could be increased or decreased at rates between 5 and 2000 gauss/sec.

The samples consisted of 0.010-in.-diameter wires which were mounted in hairpin fashion, potted in Stycast 2850 FT epoxy, and inserted in the bore of the solenoid. Sample current was supplied by a 12-volt battery bank and controlled with two large carbon pile resistors. The experimental circuitry is shown in Figure 1.

The experimental sequence is as follows. After a sample current is established in zero field, the field ramp is initiated at a preset value of dH/dt. At some current-field value, the sample will be normal (resistive) and a voltage will appear across the sample. When this happens, the sample current is turned

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*The standard short sample currents are measured by holding field constant and increasing sample current until the wire goes normal. This procedure defines a unique J versus H curve.

†For additional discussion of this phenomenon, see "Summary Report - Investigations of Current Degradation in Superconducting Solenoids, June 1963 - May 1964," pp 10-12

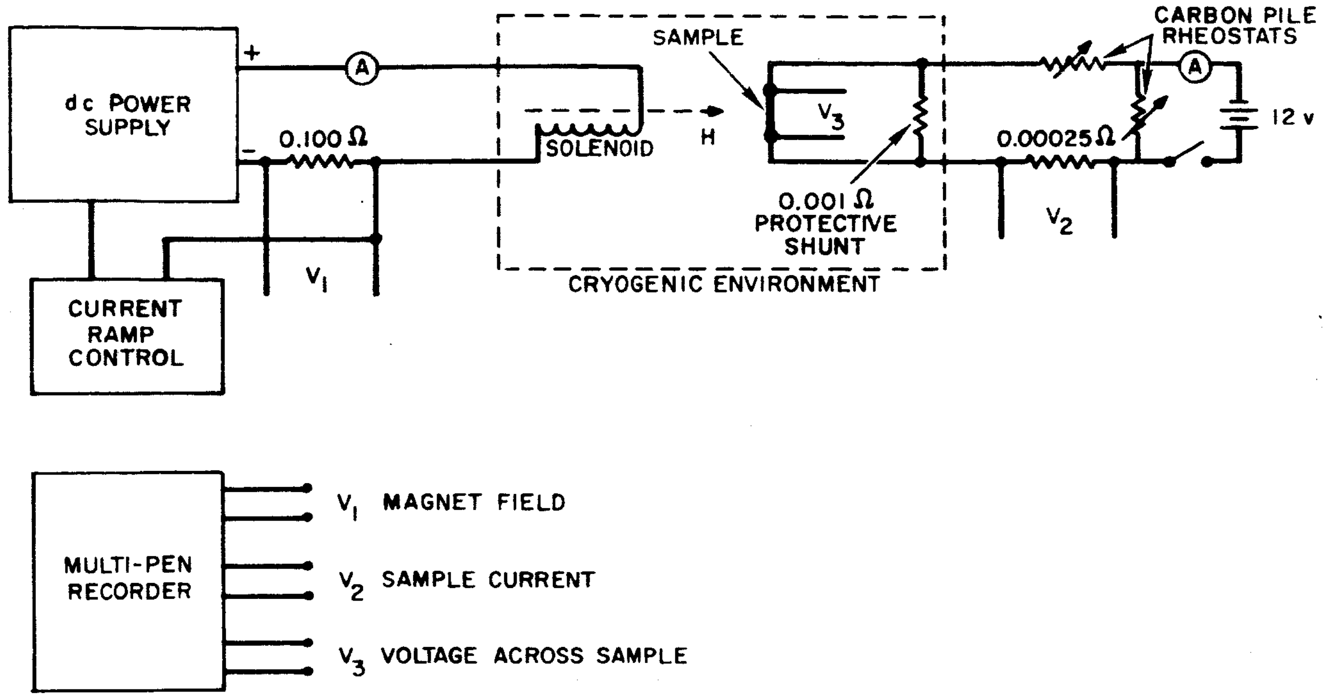

Figure 1. Experimental Circuitry

off, and the field is held constant. If this SN transition occurs below the value expected from the standard J versus H curve, the sample current is again turned on, and the field sweep resumed, beginning at the field value of the preceding SN transition. This sequence is repeated until the standard J versus H curve is reached. The process is then reversed with dH/dt negative. Subsequently, different rates of dH/dt are used.

B. RESULTS

None of the Ti - 22 at. % Nb samples tested exhibited any supercurrent instabilities for values of dH/dt up to the maximum rate of 2000 gauss/sec provided that the field remained in the positive sense. Thus, the wires would not go normal until the standard J versus H curve was reached. However, SN transitions occurred in three samples (the starting material and samples 2 and 7) as the sense of the field became negative provided that dH/dt >1000 gauss/sec. If dH/dt was then made positive, a second SN transition was found to occur, not as H again became positive, but as H increased to ~+5 kgauss. There does not appear to be a correlation between the samples which showed the field reversal instability and the annealing times and temperatures. Because of the seemingly random occurrence of these instabilities, we do not believe that the cause is basic to the superconductor but might be externally induced by movement of the sample as the field changes sense.

Samples 6 and 12 (annealed at 600°C) and samples 1, 11, and 23 (annealed at 650°C) were not tested because their current densities were too low to have instabilities; i. e., $<3 \times 10^4$ A/cm^2 for H $\leq$ 5 kgauss. Since tested samples with similar heat treatments show absolutely no instabilities, it is unnecessary to test the samples marked "nt" (no test) in Table 1.

Test results are summarized in Table 1. The J versus H curves were published in the preceding quarterly report and are not repeated here.

C. CONCLUSION

Results of these measurements show that the Ti - 22 at. % Nb alloy is a stable superconductor, regardless of the heat treatment, for all values of critical current densities and for the maximum field conditions employed, ±2000 gauss/sec up to 35 kgauss. This high degree of stability, plus the high current densities and upper critical fields, make this alloy a potentially excellent material for use in high field superconducting solenoids. Evidently these superior properties result because the flux pinning sites are weak and thus allow flux to flow through the superconductor without catastrophic SN transitions. On the other hand, there must be many weak pinning sites to support the large current densities.

TABLE 1

SUPERCURRENT STABILITY OF HEAT-TREATED 0.010-in. -DIAMETER Ti - 22 at. % Nb WIRE SAMPLES

Sample	Heat Treatment Temperature (°C)	Heat Treatment Time (min)	Stability X Stable Y Unstable to Field Reversal
800°C*	None*		
2	200	10	Y
10		3,000	X
25		36,000	nt**
18	250	10	nt
4		1,000	X
3		3,000	nt
24	300	300	nt
13		3,000	X
15		3,000	nt
17	350	100	X
22		300	X
14		1,000	X
26	400	30	X
19		100	X
29		300	nt
27	450	10	X
21		30	nt
28		100	X
30	500	30	nt
7		100	Y
9		300	X
20	550	30	X
16		1,000	nt
8		3,000	X
5	600	10	X
6		300	nt
12		1,000	nt
23	650	3	nt †
11		30	nt
1		3,000	nt

*Starting material

†J *versus* H curve too low to have instabilities, which occur for values of J and H above 3×10^4 A/cm^2 and 5 kgauss respectively.

**No test