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SOME AC LOSS DETERMINATIONS BY AN ELECTRICAL MULTIPLIER METHOD*

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At the Lawrence Radiation Laboratory in Berkeley we have been measuring cyclic losses in various superconducting magnets with an electrical multiplier method, currently employing Hall effect multipliers. In the range of 1-5 W power dissipation, the evolved helium gas has been monitored to provide a check on the electrical method. The method and test results on several solenoids were presented by Voelker at this Summer Study[1] and pertinent details will be found in his report.

The particular magnet of interest for this talk is a solenoid 4.5 in. long, with a 1.5 in. bore and a 4.5 in. o.d., wound with single core NbTi Supercon wire. The wire core size is 15 mils and the conductor is 30 mils over-all, giving a copper-to-superconductor ratio of 3:1. The wire is insulated by forming a copper oxide coating and fiberglass cloth is used for interlayer insulation. The coil, operated at short sample characteristics, was definitely understabilized. The field was 67 kG on the axis and a few percent higher at the conductor. The average current density is $\overline{J} = 18\ 000\ A/cm^2$ and the gross filling factor is $\lambda = 0.18$. Therefore, it seems quite reasonable that if one can increase the amount of superconductor per unit volume, $\lambda = 0.5$ has been mentioned, $\overline{J} = 50\ 000\ A/cm^2$ seems achievable. Other coils with less copper and NbTi cores have yielded $\overline{J} > 30\ 000\ A/cm^2$ and a single layer solenoid for which the field was only about 6 kG gave $\overline{J} \cong 85\ 000\ A/cm^2$.

Figure 1 shows the loss/cycle vs frequency for this coil at $I_{max} = 10$ A and 15 A. The loss at low frequency is about what one would expect for loss in the 15 mil diameter superconductor. The dependence of loss on frequency has been something of a mystery to us. Eddy current losses in the copper would give the same frequency dependence but are some 50 times smaller than the measured frequency-dependent term We were unable to find any low resistance shorts, which would yield the same type of data. Smith and Sampson have both pointed out that a number of high resistance shorts could give the same type of results and that our insulating technique might be subject to this condition.

An identical magnet using a multicore conductor made by Airco was tested to give a measure of the effect of core filament size. There were 131 approximately 1.3 mil cores uniformly distributed in the copper matrix. These measurements were made last week before I heard Peter Smith talk, and so perhaps I may be forgiven for thinking, at that time, that his theories on multicore conductor behavior might not be correct. The direct comparison of the Airco and Supercon magnets might then yield the following possible results:

1) If Smith were wrong and the loss simply depended on filament size, $L_{Airco}/L_{Supercon} \approx 1/10$.
2) If the normal material tied the superconductor together so that it acted as one core, $L_A/L_S \approx 1$.
3) If Smith were correct, $L_A/L_S \approx 2$.

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

1. F. Voelker, these Proceedings, p.

Examination of Fig. 1 shows less frequency dependence in the Airco magnet case than in the Supercon magnet case. If one makes the assumption that in both cases the frequency dependence is due to high resistance shorts, then the relevant loss data is found at the low frequency end of the curves. Then the Airco magnet losses are approximately twice those of the Supercon magnet. For single cycle measurements up to I_{max} = 100 A (some 57 kG) this same factor of two persists. Therefore, alternative 3) above is the proper one and Smith's suggested solutions to the ac loss problem are the most reasonable to pursue at this time.

A most striking advantage of the Airco magnet as compared with the Supercon magnet was the absence of flux jumps in the small filament Airco case. In both magnets $\dot{B}$ coils were used to monitor field changes and flux jumps could easily be observed in the Supercon material when the field was changed at a rate greater than a few kilogauss per second. This is a relatively fast charge rate and this magnet is considered reliable, stable, only slightly charge rate sensitive, and generally quite satisfactory. In the Airco case we could not induce measurable flux jumps at even greater rates of field change and so the material seems to be intrinsically stable, as Smith also predicts.

We have also tested an Nb_3Sn ribbon pancake wound with RCA 600 tape. We used a fiberglass tape for insulation and achieved I_c = 1284 A, or 48 000 A/cm^2 at 52 kG, which is on the short sample curve. The pulse loss data are shown in Fig. 2. The low frequency data are incorrect due to power supply ripple and the curve is dotted in this region. We get agreement with Sampson in the low, 300 A range. Our magnet went normal in the 0.5-1.5 W range while he was able to dissipate 5.5 W. Our Q's at high current were quite low as compared with Sampson's. The most probable reason for the difference is our having high resistance shorts in our pancake.

CONCLUSIONS

1) High average current density in NbTi systems, above 50 000 A/cm^2, seem readily achievable if the fraction of stabilizing material can be reduced.

2) Losses small enough to make pulsed accelerators attractive have not yet been demonstrated but might well be within a year if experimental programs under way continue to confirm Smith's theory.

3) Multicore conductor with large (15 mil) cores is degraded when wound into magnets, not because of heat added through cyclic loss (which we measured) but because of flux jumps.

Figure Captions

Fig. 1. Loss/cycle V_S frequency for 2 solenoids.

Fig. 3. Loss/cycle V_S frequency in an Nb, SN Ribbon Pancake.

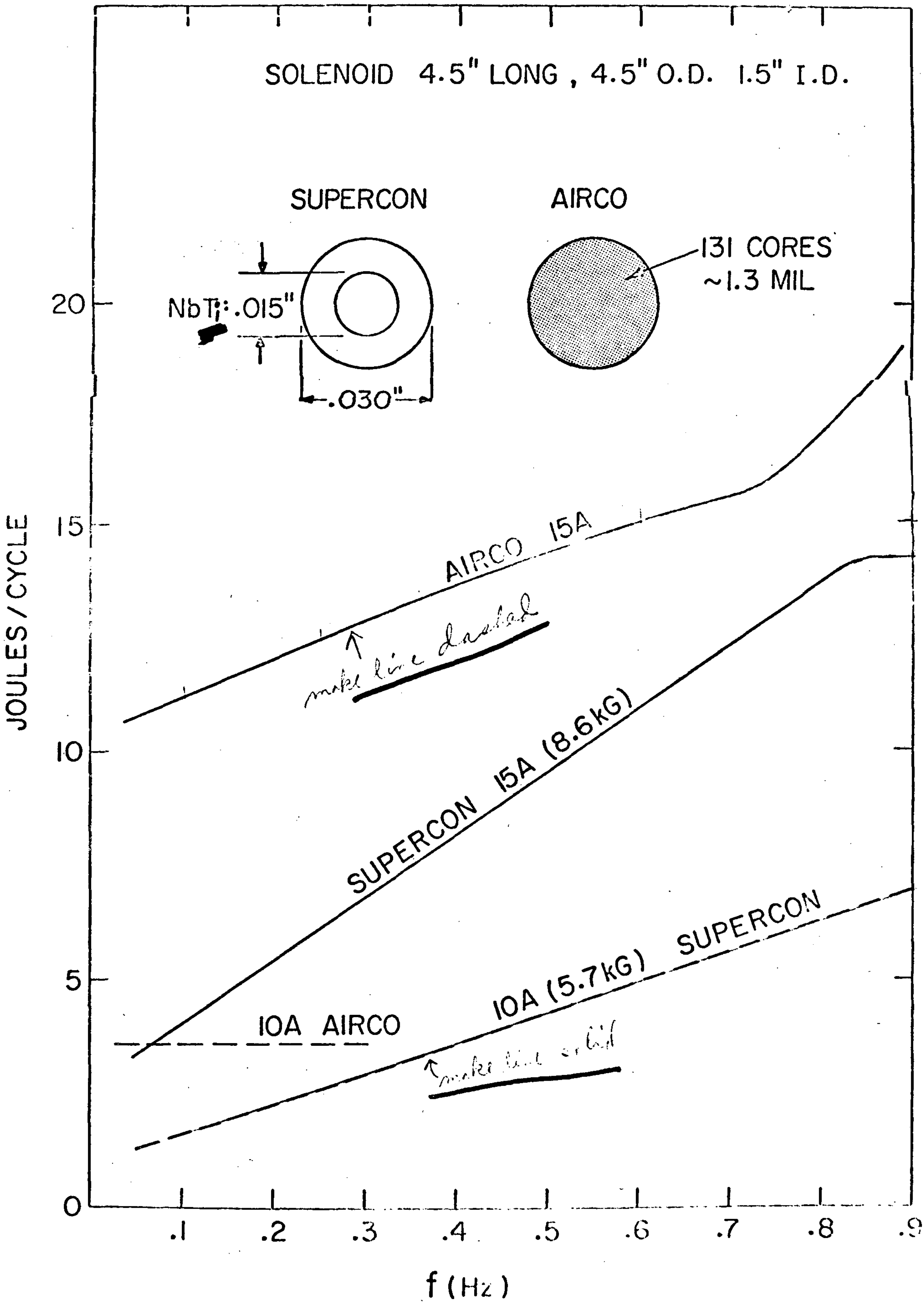
SOLENOID 4.5" LONG, 4.5" O.D. 1.5" I.D.
SUPERCON
AIRCO
NbTi .015"
.030"
131 CORES
~1.3 MIL
JOULES / CYCLE
AIRCO 15A
make line dashed
SUPERCON 15A (8.6kG)
10A AIRCO
10A (5.7kG) SUPERCON
make line solid
0
5
10
15
20
.1
.2
.3
.4
.5
.6
.7
.8
.9
f (Hz)

Fig. 1

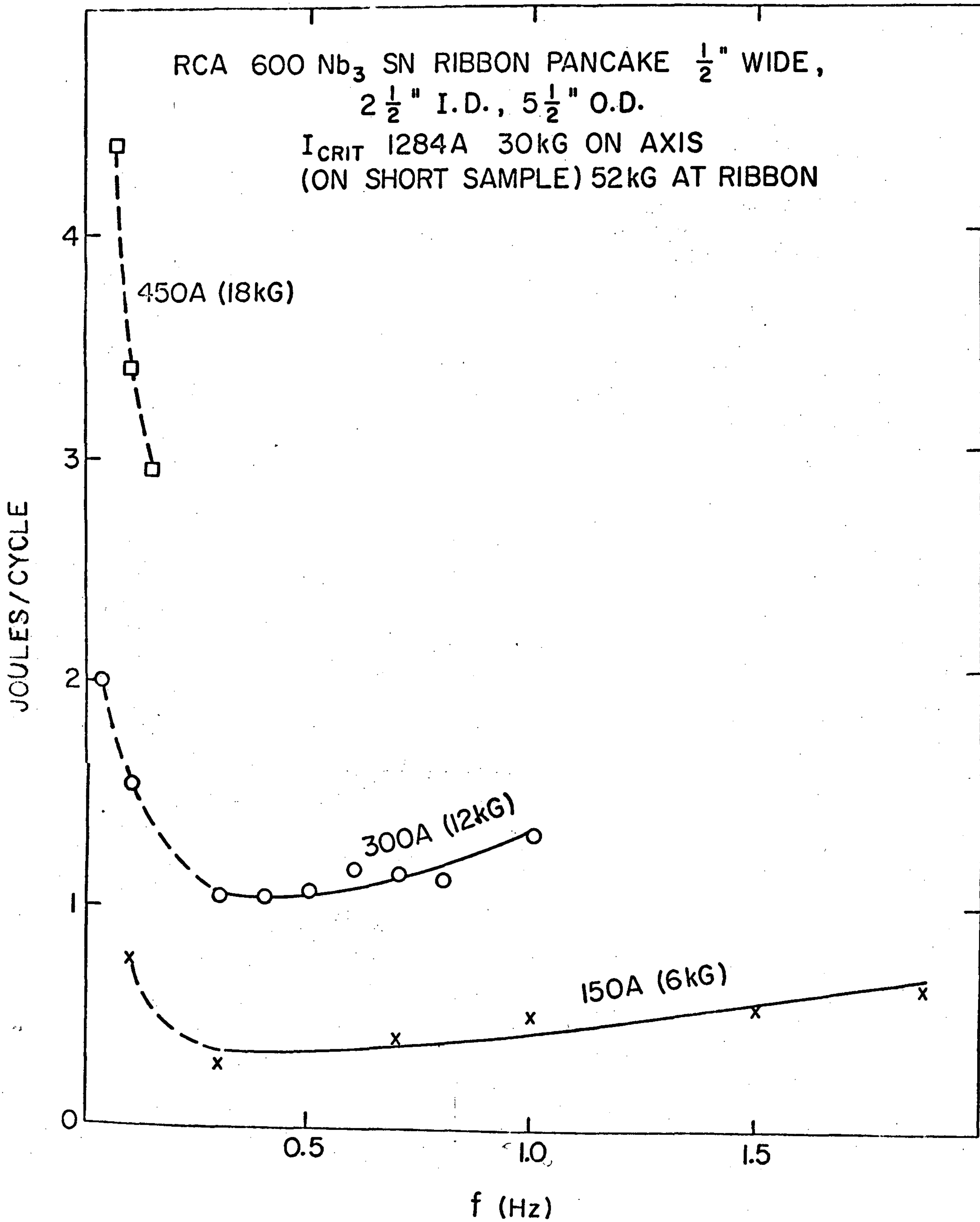
RCA 600 Nb_3 SN RIBBON PANCAKE $\frac{1}{2}$" WIDE,
$2\frac{1}{2}$" I.D., $5\frac{1}{2}$" O.D.
I_{CRIT} 1284A 30kG ON AXIS
(ON SHORT SAMPLE) 52kG AT RIBBON
450A (18kG)
300A (12kG)
150A (6kG)
JOULES/CYCLE
0
1
2
3
4
0.5
1.0
1.5
f (Hz)

Fig. 2

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