

# Lawrence Berkeley National Laboratory

## Recent Work

### Title

SOME AC LOSS DETERMINATIONS BY AN ELECTRICAL MULTIPLIER METHOD

### Permalink

<https://escholarship.org/uc/item/82s8x4rc>

### Author

Gilbert, W.S.

### Publication Date

1968-07-01

UCRL-18755

*ey. 2*

RECEIVED  
LAWRENCE  
RADIATION LABORATORY

MAR 3 1969

LIBRARY AND  
DOCUMENTS SECTION

SOME AC LOSS DETERMINATIONS BY AN  
ELECTRICAL MULTIPLIER METHOD

W. S. Gilbert

July 1968

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy  
which may be borrowed for two weeks.  
For a personal retention copy, call  
Tech. Info. Division, Ext. 5545*

LAWRENCE RADIATION LABORATORY  
UNIVERSITY of CALIFORNIA BERKELEY

UCRL-18755

## **DISCLAIMER**

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Proc. of the Summer Study on  
Superconducting Devices and Accelerators,  
Brookhaven National Laboratory, June 10-  
July 19, 1968

UCRL-18755

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory  
Berkeley, California

AEC Contract No. W-7405-eng-48

SOME AC LOSS DETERMINATIONS  
BY AN ELECTRICAL MULTIPLIER METHOD

W. S. Gilbert

July 1968

SOME AC LOSS DETERMINATIONS BY AN ELECTRICAL MULTIPLIER METHOD\*

W.S. Gilbert  
Lawrence Radiation Laboratory  
Berkeley, California

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<sup>1</sup> 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  $\bar{J} = 18\,000\text{ A/cm}^2$  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,  $\bar{J} = 50\,000\text{ A/cm}^2$  seems achievable. Other coils with less copper and NbTi cores have yielded  $\bar{J} > 30\,000\text{ A/cm}^2$  and a single layer solenoid for which the field was only about 6 kG gave  $\bar{J} \approx 85\,000\text{ A/cm}^2$ .

Figure 1 shows the loss/cycle vs frequency for this coil at  $I_{\max} = 10\text{ A}$  and  $15\text{ A}$ . 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,  $L_{\text{Airco}}/L_{\text{Supercon}} \approx 1/10$ .
- 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,  $L_A/L_S \approx 2$ .

---

\* 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<sup>2</sup> 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<sup>2</sup>, 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.

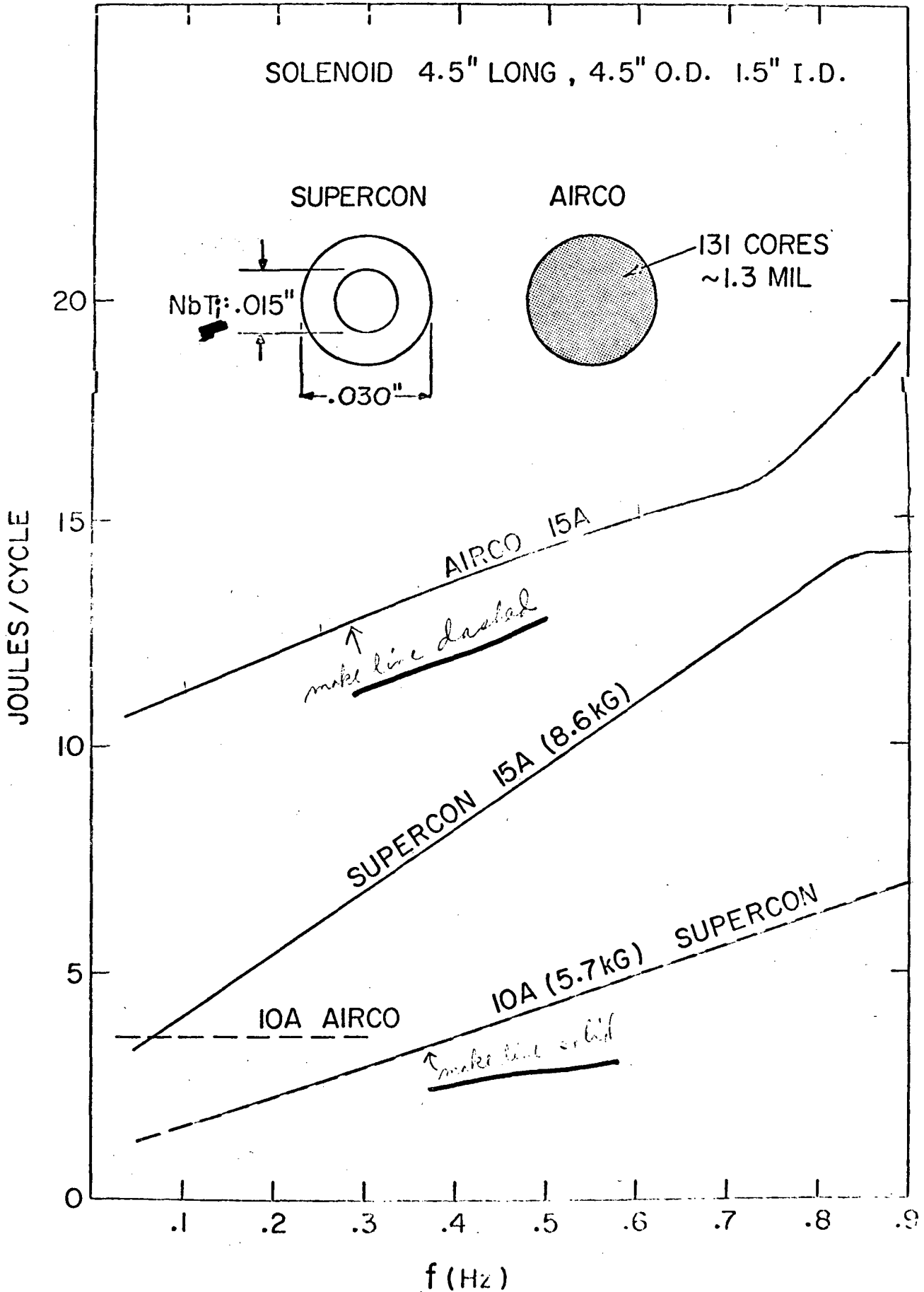


Fig. 1



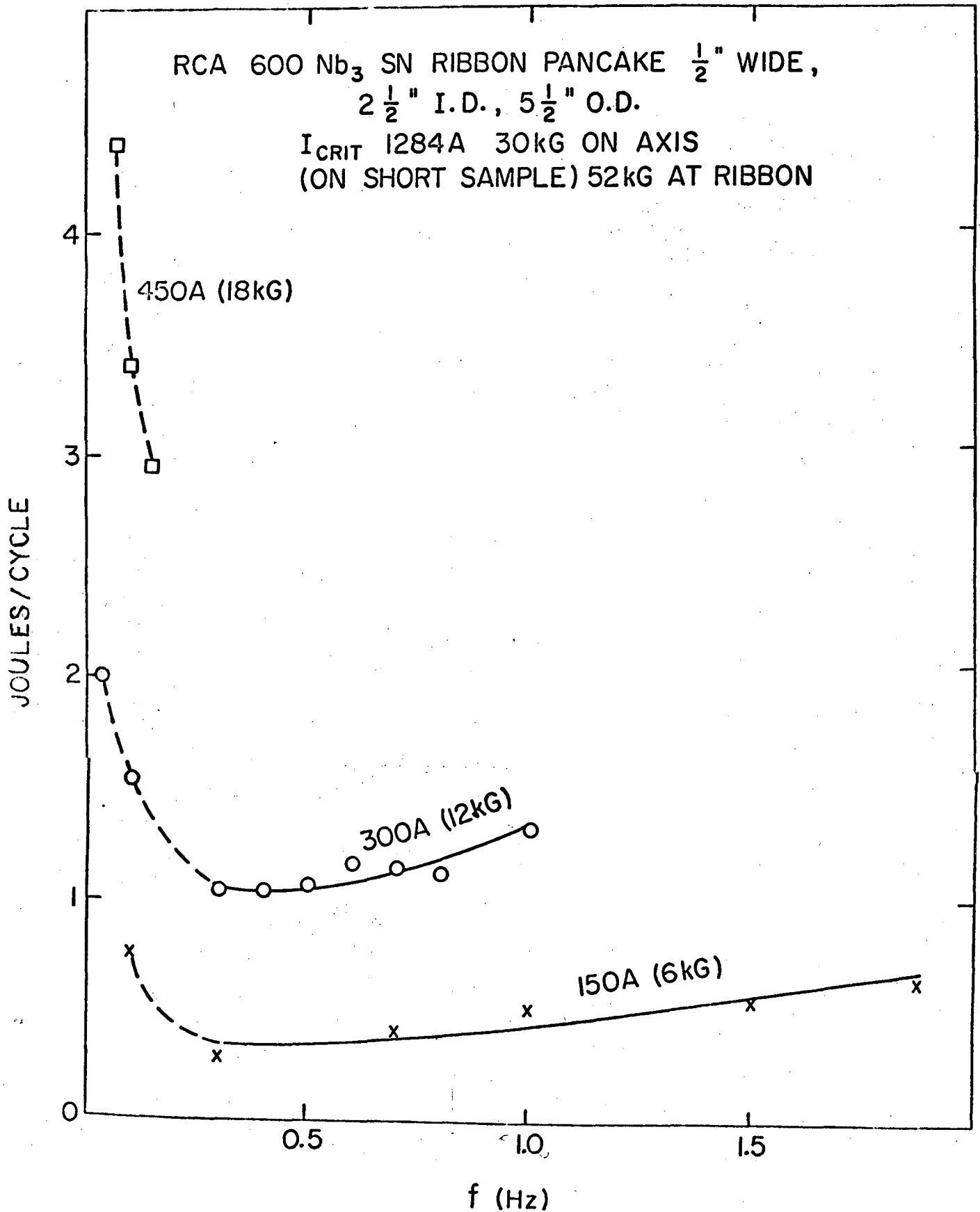


Fig. 2

LEGAL NOTICE

*This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:*

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or*
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.*

*As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.*

TECHNICAL INFORMATION DIVISION  
LAWRENCE RADIATION LABORATORY  
UNIVERSITY OF CALIFORNIA  
BERKELEY, CALIFORNIA 94720