



BNL-104624-2014-TECH

AGS/AD/Tech Note No. 197;BNL-104624-2014-IR

## PRE-CONVERSION CAVITY FERRITE MEASUREMENTS

M. Plotkin

March 1984

Collider Accelerator Department  
**Brookhaven National Laboratory**

**U.S. Department of Energy**

USDOE Office of Science (SC)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No.DE-AC02-76CH00016 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

## **DISCLAIMER**

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use 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 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 its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Accelerator Department  
BROOKHAVEN NATIONAL LABORATORY  
Associated Universities, Inc.  
Upton, New York 11973

AGS Division Technical Note

No. 197

PRE-CONVERSION CAVITY FERRITE MEASUREMENTS

M. Plotkin

March 14, 1984

Note: In a number of Tech Notes and other papers the pre-conversion AGS rf cavity ferrite has been called Ferroxcube 4L. This has been an error. The ferrite is correctly Ferroxcube 4H.

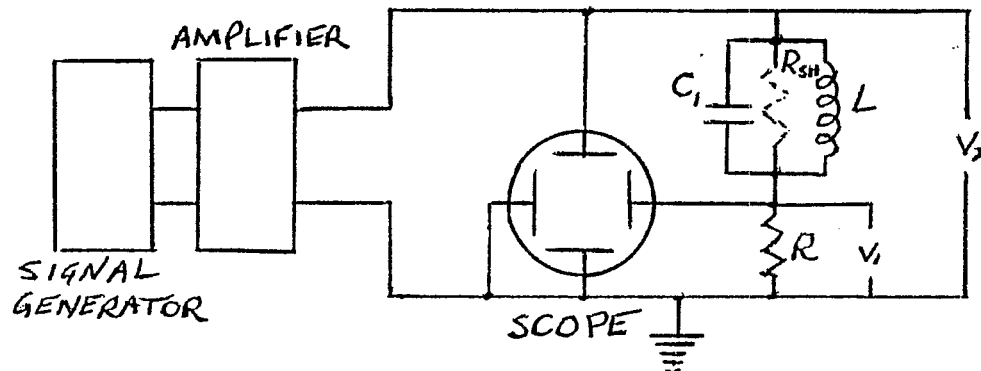
The first phase of the heavy ion acceleration in the AGS requires rf acceleration with 17 kV rf peak voltage and a frequency range from 0.5 to 2.0 MHz. The ferrite in the AGS pre-conversion cavities is a Philips 4H which was designed for 8 kV (cw) peak per cavity, and a frequency range of 1.35 to 4.46 MHz. Acceptance testing of the ferrite was based upon 1.5 MHz (unbiased) at 135 gauss peak flux density. This flux density corresponds to 8.0 kV peak per cavity at 1.5 MHz.

Tuning, with a fixed total capacitance, was accomplished by dc biasing the cavity to vary the inductance over a range of 11:1,  $(f_2/f_1)^2$ . The use for heavy ions involves a different frequency range, higher voltage and a 16:1 inductance range. Using known extrapolation relationships it was estimated that, at 0.5 MHz and 8.5 KV pk, the losses in the ferrite would be about 500 mw/cc which is twice that in the original design. The duty factor, however, is much lower in the heavy ion case so the average dissipation in the ferrite is low enough for the existing water cooling to be effective. The amplifier,

must, in all cases, supply the actual power in the ferrite during the "on" time.

To measure the actual behavior of the ferrite at the new frequency and flux density, small ring samples were cut from pieces of the Philips 4L material. The rings were about 3.5 cm OD, 2.5 cm ID and .8 cm high. Each pair of rings was made from a 2.1 cm high ring sliced into two and then ground to the same height. The rings were wound with a figure "8" rf winding and then were placed in a brass shield can. A dc bias winding of 75 turns was wound over the shield. In operation, shorting the dc winding had no effect on the rf measurements, indicating complete dc/rf isolation.

The test set-up initially was as follows:



L - ferrite core inductance

C<sub>1</sub> - tuning capacitance

R<sub>sh</sub> - ferrite loss resistance

R - small (50-100Ω) non-inductive resistor

It can be readily shown that:

$$R_{sh} = \frac{R(V_2 - V_1)}{V_1}, \quad P_{diss} = \frac{(V_2 - V_1)V_1}{R}$$

$$B_{pk} = \frac{k(V_2 - V_1)}{nAf}, \quad \begin{array}{l} n = \text{number of rf turns} \\ A = \text{area of two ferrite rings} \\ f = \text{frequency} \\ k = 22.49 \text{ for } A\text{-cm}^2, f\text{-MHz} \end{array}$$

In operation, the tuning capacitance is adjusted for a straight line Lissajous pattern, indicating a pure resistive tuned circuit. Since the power dissipation, w/cc, is readily calculated knowing the core volume, the curve of w/cc vs B is easy to obtain. There are two problems with this set-up. The set-up accentuates harmonics in  $V_1$  resulting in higher than actual readings at high flux densities. The harmonics are generated at higher voltages in the rf power amplifier being used. The other problem is finding low reactance resistors and possible heating in the resistor during operation at high flux densities. The first effect, higher harmonics, causes the P vs B curve to deviate from a straight line on a log-log plot.

If the resistor is replaced by a capacitor with  $1/\omega C < 0.1 R_{sh}$ , then resonance is indicated by a circular pattern on the oscilloscope, harmonics are reduced somewhat since  $1/\omega C$  decreases with frequency, there is no heating problem and the voltage across the resonant circuit is within one percent of the applied voltage. The equations for the ferrite properties reduce to:

$$P_{diss} = V_1 V_2 \omega C_2, \quad R_{sh} = \frac{V_2}{V_1 \omega C_2}$$

$$B_{pk} = \frac{k V_2}{naf}$$

At 0.5 MHz the resonant circuit was tuned with  $C_1$  at each flux density. The ferrite permeability varies with the flux density, increasing as the flux increases. With dc bias, above 0.5 MHz, the tuning was accomplished by varying the dc bias with the capacitance,  $C_1$ , left at the value for the high flux density point (0.5 MHz) since this represents the actual operating point.

Many measurements were made on two pairs of rings, one with 8 rf turns, the other with 12 rf turns. With 12 rf turns, the power amplifier harmonics to achieve the maximum flux density were quite severe. Except with no bias, the readings were dependent on the magnetic history of the rings. In some cases the rings were biased to saturation and then demagnetized by reversing the bias as it was reduced to zero. In most cases, the rings were biased, unidirectionally, for ten cycles to just beyond the operating range. During some runs the 10 cycles were applied at each frequency change.

Figure 1 represents the results of about 8-10 runs under the different conditions mentioned above. Most of the readings cluster about a loss dropping from  $\sqrt{620}$  mw/cc at 0.5 MHz to  $\sqrt{430}$  mw/cc at 2.0 MHz. Six hundred twenty mw/cc corresponds to a total power level of about 68 kW, dropping to  $\sqrt{47}$  kW at 2.0 MHz. Figure 1 includes results from tests with the resistor as well as with the capacitor. Figure 2 is representative of a run using the capacitor, C<sub>2</sub>.

To bias the core to 2.0 MHz required a current of about 1.5 amperes in 75 turns, 112.5 AT. The average path length in the ferrite with OD-3.55 cm and ID-2.55 cm is 9.58 cm. Thus, 11.74 AT/cm are required. The average path length in the large rings, OD-35 cm and ID-20 cm, is 86.4 cm. The required bias current is about 1014 amperes. The core was very easily biased to 2.2 MHz (about 2 amperes dc), and to 2.5 MHz (about 3 amperes dc). The corresponding currents in the large rings would be 1352 amperes and 2029 amperes. The rf losses at 2.5 MHz are at about the same level as at 2.0 MHz. In one run the circuit was turned to 3.15 MHz at a bias current of about 5 amperes (3382 amps in the large rings). The rf losses were, by extrapolation, about 600 mw/cc.

The measurements must be corroborated on the full cavity. The dc bias can be checked roughly using a supply borrowed from EP&S or CBA and measuring low rf level inductance. The actual bias currents will be less than the values measured in this fashion since the permeability increases with flux density and, the higher the initial  $\mu$ , the easier it is to effect a given  $\mu$  change. The rf measurements can be made, initially, with the Gates amplifier. Since the curves are straight lines on a log-log plot we can measure up to perhaps half power and extrapolate to check agreement with the small sample measurements.

A third pair of small rings is now prepared with a smaller cross sectional area. These cores can be run to the operating rf flux density at lower voltage output from the amplifier. This should reduce the harmonics in the  $V_2$  reading so no anomalous errors will be introduced in the power loss calculation.

WPC

Distribution: A.D. S&P

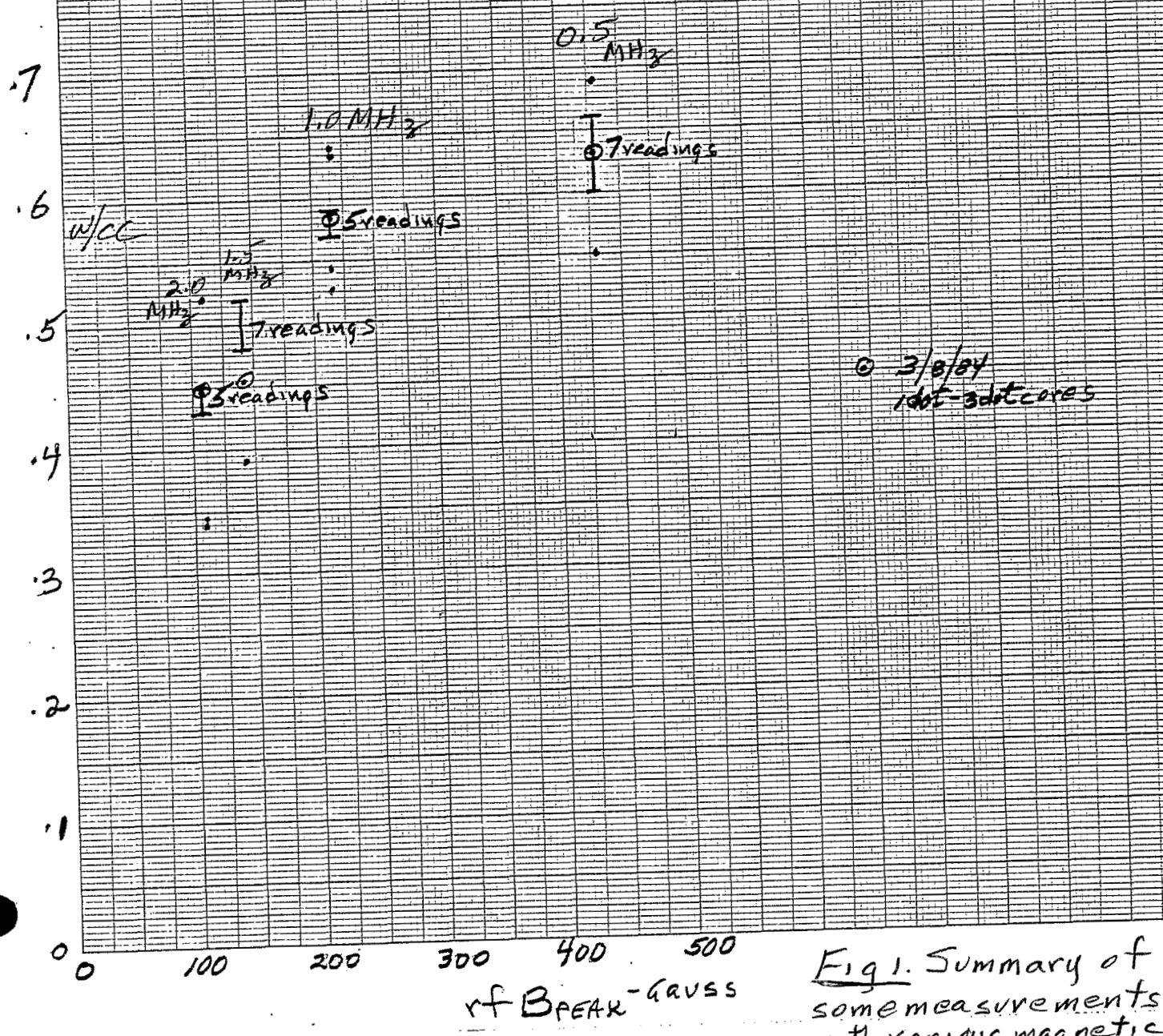


Fig 1. Summary of some measurements with various magnetic materials



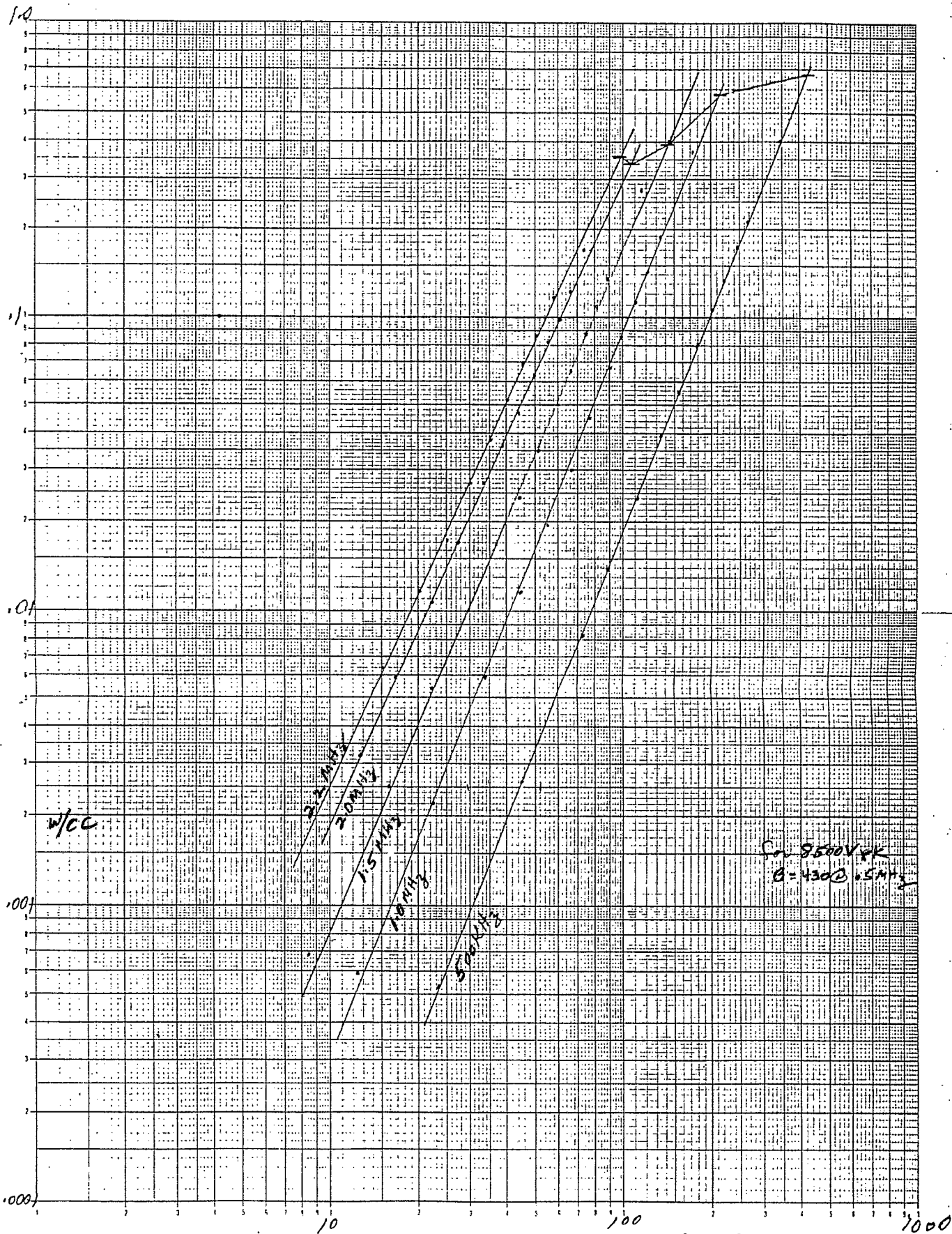


Fig2. Ferroxcube 4H  
dc bias tuned to 2.2 MHz.

$B_{mf}\text{-Peak}$