Fermi National Accelerator Laboratory

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Design Note of an Air-Cooled 2 ft. x 2 ft. x 10.5 ft. Long Muon Spoiler

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DESIGN NOTE OF AN AIR-COOLED 2 FT X 2 FT X 10.5 FT LONG MUON SPOILER

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1. SUMMARY

This note describes the construction of a muon spoiler (magnetized steel assembly) with a cross section of 2 ft. by 2 ft. and a length of 10.5 ft.

Two such spoilers are operated in series at an average field of about 15 kGauss, from one 100 ADC, 40 V power supply. The purpose of the spoilers is to prevent muons from easily escaping beyond the muon laboratory experimental area by bending them down so that they have to pass through more earth. The spoilers reduce the muon dose rate beyond the experimental area by about a factor of 15 to 20.

These types of spoilers are not precision devices. They were inexpensive to build from scrap materials using rough flame cutting methods. It took about 14 days to fabricate them.

2. ESTIMATE OF THE REQUIRED EXCITATION FOR 15 KG IN THE STEEL

A large number of steel plates, sufficient to construct 2 spoilers, were found in surplus. Each plate measured 2 ft. by 2 ft. and was 0.5 inch thick. They could be stacked in a row, like a sliced loaf of bread, with a round hole cut in the center for the excitation winding. The magnetic properties of such unknown steel are always a question. Looking at Fig. 1 we can estimate that an excitation of about 25 to 50 Oersteds would probably yield the required average 15 kGauss field. The higher excitation is probably the most likely to be required. The average iron length

through which 15 kG has to be established is about 4 ft. Fifty Oersteds (1 Oersted = 80 AT/m) over 4 ft. amounts to $50x80x4x12x2.54x10^{-2}$=4877 Ampere Turns (AT). Thus it might require 25 to 50 turns at 100A, depending on the quality of the steel, to establish a 15 kGauss average field. Twenty-five turns for an air-cooled coil are reasonable, but 50 turns require too large a hole for the excitation winding in the center of the steel. The magnetic behavior of one 0.5 inch thick plate was measured so that a better excitation estimate could be made. The results are shown in Fig. 2. It turns out that, for the sample plate, 3000 AT yield about 18 kGauss. The curves in Fig. 2 are plotted from the measured flux changes at windings 1, 2 and 3, resulting from changes in the excitation current. This integration method is described in greater detail in reference 1.

It was decided to use 3000 AT, or 30 turns at 100A for the excitation winding. With this amount of excitation we might reasonably expect an average field of 15 kGauss or better. One completed spoiler assembly was later on measured and the results are shown in Fig. 3. The average field at 3000 AT is slightly higher than 15 kGauss, but lower than we might have expected from Fig. 2. Did we select a very good sample plate?

3. MECHANICAL CONSTRUCTION

The excitation winding is made from 30 turns of AWG #1, 600V copper, XHHW, 90°C electrical cable with an O.D. ~0.45 inch. The listed IPCEA ampacity for such a cable is 156 Amp. based on 3 wires in a conduit at 40°C ambient. The NEC allows 60% of 156 Amp or 93.6 Amp to be

used for 30 wires in a pipe. The stacked steel plates are not perfectly flat and some cooling air will leak through. It is reasonable to estimate that the coil can handle 100 ADC without exceeding 90°C copper temperature. A 90°C klixon has been embedded in the coil for an overtemperature interlock. The cable was hand-threaded through the center hole, using a few splices until the 30 turns were installed. The excitation windings are located around the bottom half of the spoiler steel for the best field distribution in that area.

Each 2 ft. x 2 ft. x 0.5 inch thick steel plate had a 3-1/2 inch diameter flame cut center hole made into it. The rough edges were somewhat ground off, after which the plates were placed on a steel base, using one corner as a stop. After 240 plates had been placed they were welded to the base, and formed the steel assembly of one spoiler, having a total length of about 10.5 ft.

The center holes in the plates do not line up and we expected a clear bore of about 3-3/8 inch diameter. The percent fill with 30 cables of 0.45 inch diameter is thus:

$$\frac{30 \times \frac{\pi}{4} \times 0.45^2}{\frac{\pi}{4} \times 3.375^2} \times 100 = 53\%$$

The NEC recommends 40% fill. We have used these fill numbers only for estimating guidelines. We did not have any problem inserting the 30 turns of the excitation winding.

ATV

J.P.

REFERENCE 1 - TM 1432/9204.000

11/25/86 - A. Visser

Meson West Beamline Spoiler Magnets Electrical Design and Test Report

USS HOT ROLLED LOW CARBON STEEL PLATES
C1030 — OVER .250 INCHES
DC MAGNETIZATION

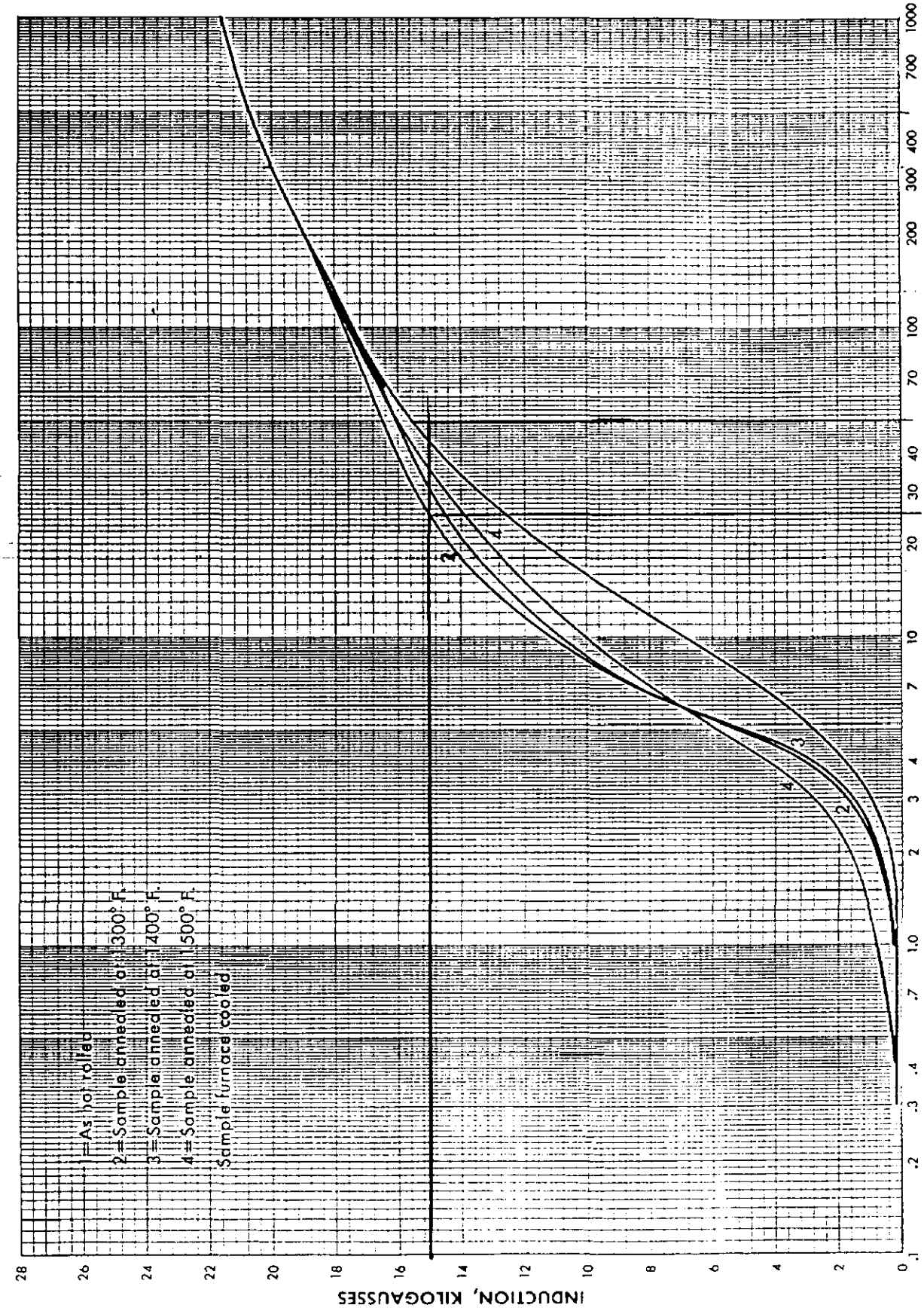

FIG. 1

Test Conditions: Lengthwise samples tested in Fahy Permeameter.

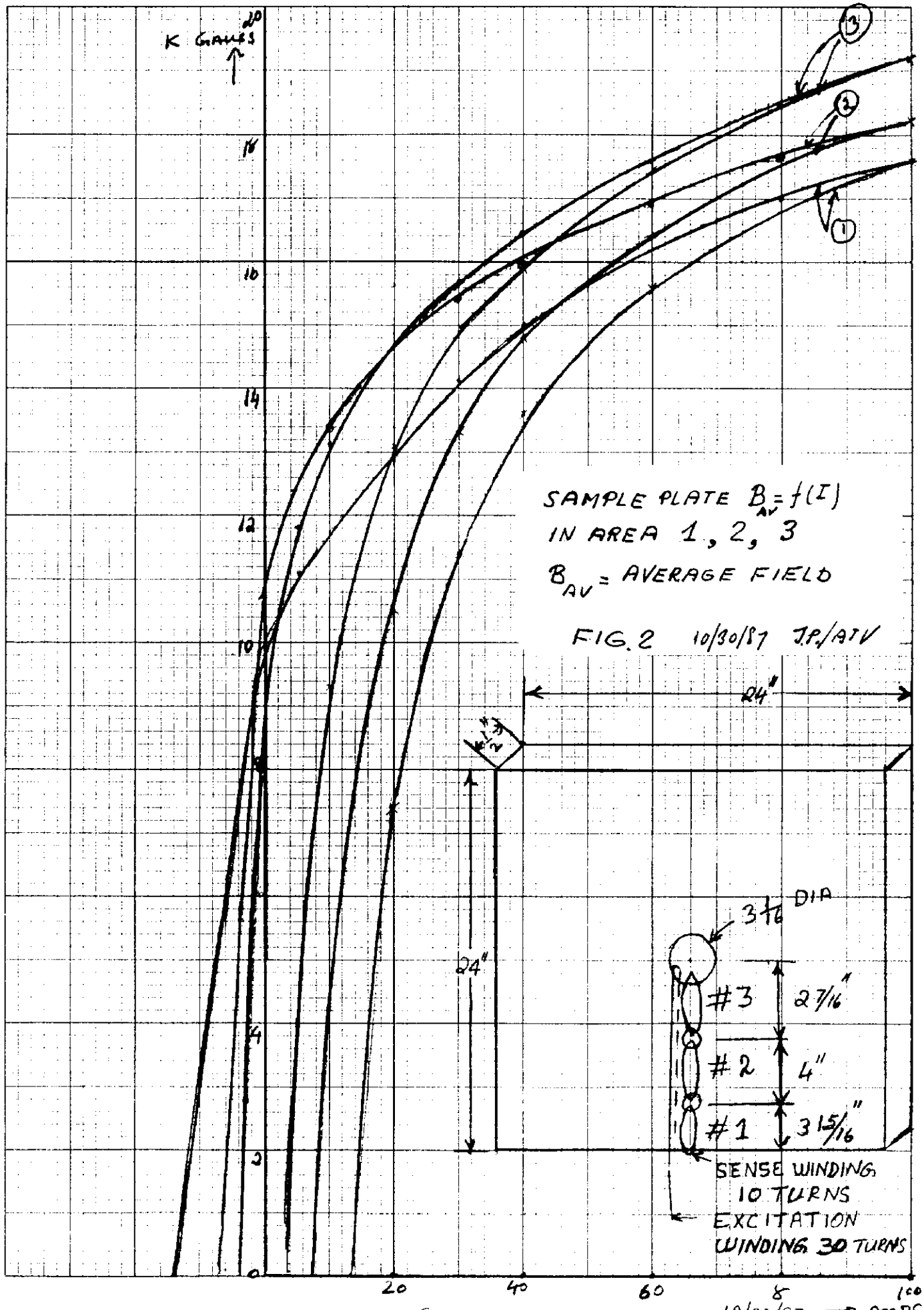

FIG. 2

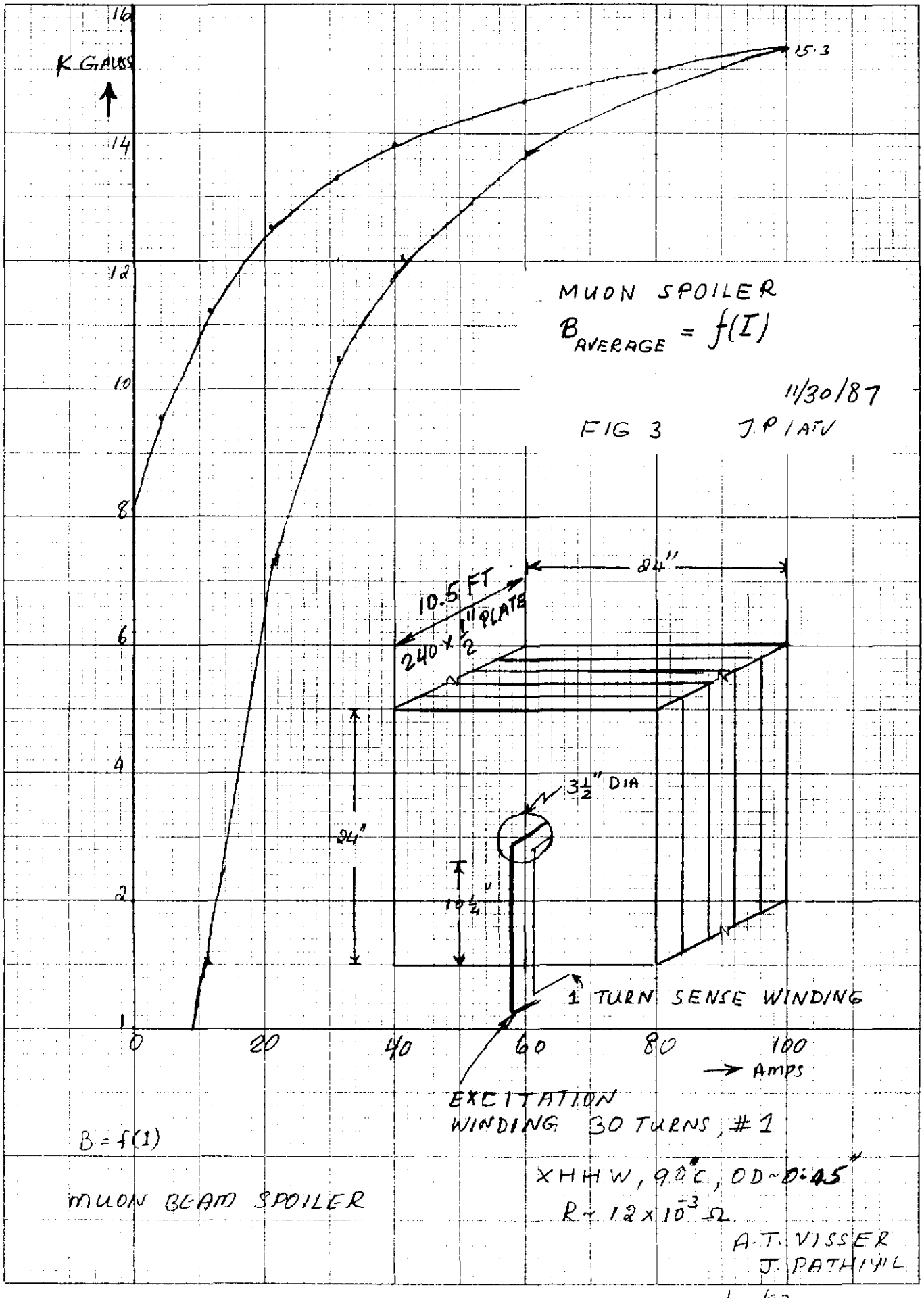
K GAUSS
16
14
12
10
8
6
4
2
1
0
20
40
60
80
100
Amps
15.3
MUON SPOILER
$B_{AVERAGE} = f(I)$
11/30/87
FIG 3 J.P/A.T.V
84"
10.5 FT
240 x 1/2" PLATE
24"
3 1/2" DIA
10 1/4"
1 TURN SENSE WINDING
EXCITATION WINDING 30 TURNS, #1
B = f(I)
MUON BEAM SPOILER
XHHW, 90°C, OD ~ 0.45"
R ~ 12 x 10⁻³ Ω
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FIG 3

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