Title
COIL CALIBRATION OF 10 COILS - TEST RESULTS DRAWING NO. 19M5696

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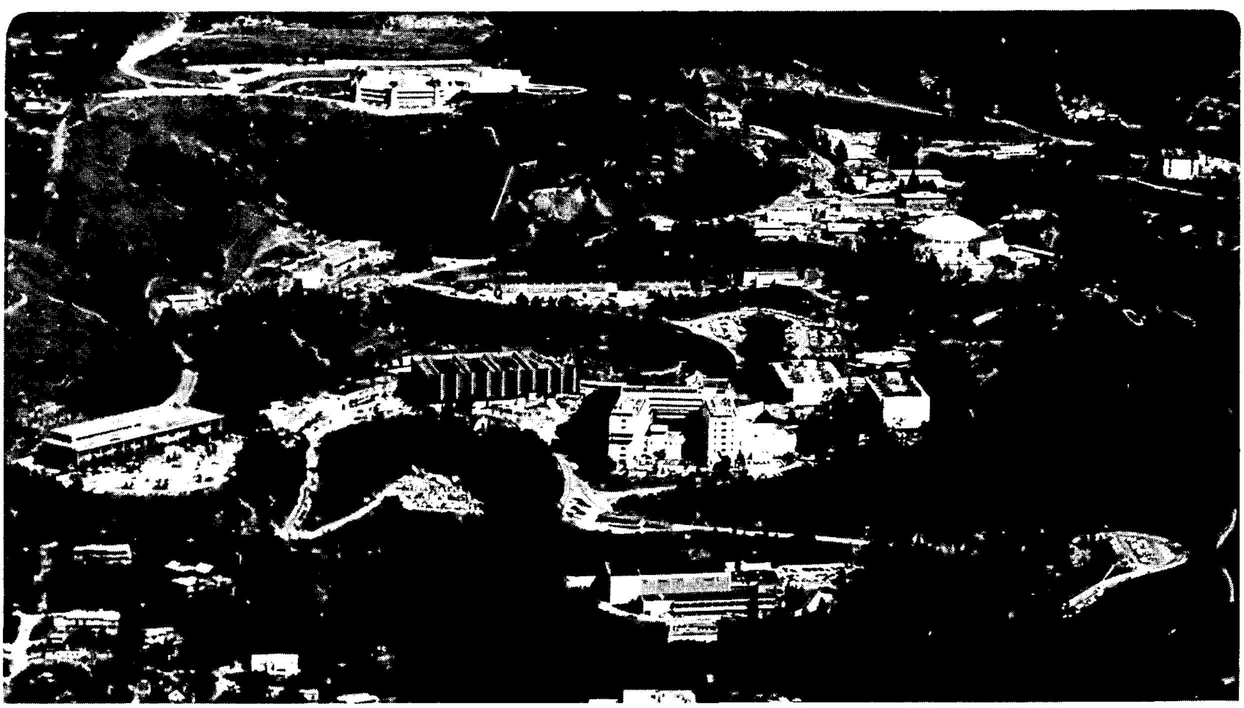

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SUBJECT: Coil Calibration of 10 Coils - Test Results
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Introduction

On May 20, 1981, Ed Cyr and I calibrated (i.e., determined the area of) 10 coils. Six of these coils are to be installed in a six coil array to be used for harmonic measurements of a superconducting magnet Isabelle prototype scheduled for measurements starting August 1, 1981. On May 22nd, we made more accurate determinations of the relative area of coils 2 through 10 (relative to coil 1 arbitrarily selected as the standard for comparison). On May 26th, we demonstrated the measurement technique to M.I. Green, W.V. Hassenzahl and T. Lauritzen.

Results

Table I summarizes the areas as determined by method 1, May 20th. See Test Plan - MT 295.

Table II shows the results of the comparative measurements (method 2 of MT 295) made on May 22nd and May 26th. For comparison I have included relative areas based on the absolute (but less accurate) measurements represented by Table I data in Table II.

Based on these data, we selected coil pairs and spares as shown in Table III. The choice of which coil of each pair would be selected as the outer coil was left to Lauritzen's discretion. Since the outer radius coils are most sensitive to errors in fabrication, we recommended that coils with loose turns be positioned to the inside position. Engineering drawing no. 19M5696 shows the coil locations in the array.

Method of Measurements

Method 1: We followed the procedures described in the test plan. For method 1, we measured magnetic induction over the 45 cm occupied by the coil centerline when in place. Measurements made both before and after the absolute calibration of the coil are represented by Figure 1. I numerically integrated these equally spaced data then

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Coil	Area (m^2)	Area (rpt.) (m^2)	Δ Area (%)	Dev from Average (m^2)	Dev from Average (%)	Dev of (rpt.) (m^2)	Dev of (rpt.) (%)
1	16.722			0.026	0.156		
2	16.682			-0.014	-0.084		
3	16.671	16.658	(-0.08%)	-0.025	-0.150	-0.038	-0.023(
4	16.678			-0.018	-0.108		
5	16.705			0.009	0.054		
6	16.693			-0.003	-0.018		
7	16.677			-0.019	-0.114		
8	16.706	16.704	(-0.01%)	0.010	0.060	0.008	0.048
9	16.691			0.005	-0.030		
10	16.735	16.722	(-0.08%)	0.039	0.234	0.026	0.156
AVG	16.696						

TABLE I Coil Area Summary (Method 1)

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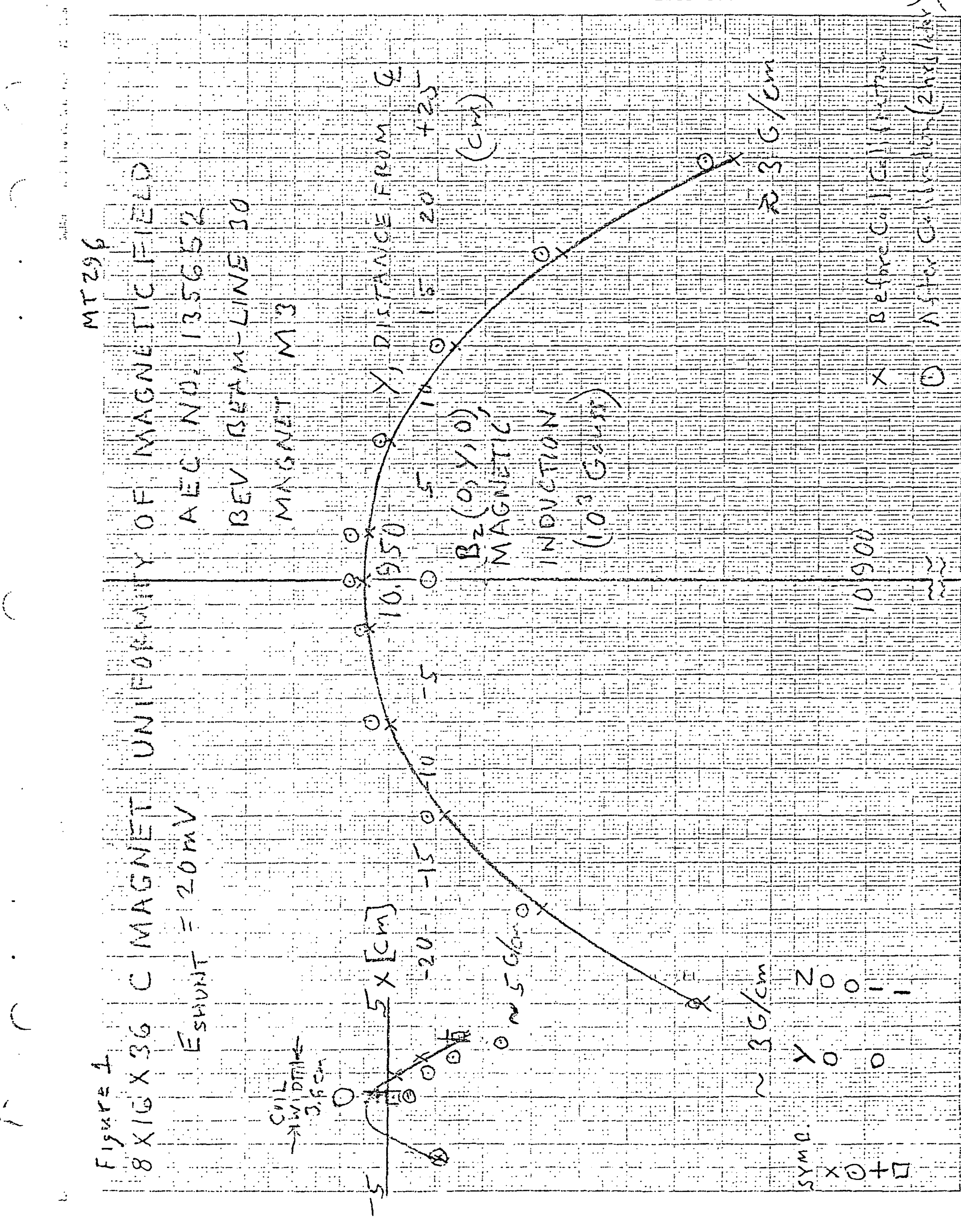
Coil No.	HIGH PRECISION (RELATIVE AREAS) Deviation* (%)	REPEAT No. 1 as Ref	REPEAT No. 8 as Ref	ABSOLUTE AREA DATA DEVIATION* USING TABLE I DATA Main Data (%)	Repeat Data (%)
2	-0.27			-0.24	
3	-0.35			-0.30	-0.38
4	-0.33		-0.29	-0.26	
5	-0.11			-0.10	
6	-0.20			-0.17	
7	-0.30			-0.27	
8	-0.11		(Ref)	-0.10	-0.11
9	-0.24	-0.21	-0.22	-0.19	
10	0.03			0.08	0.00

*Deviation with respect to coil no. 1

TABLE II Comparative Data With Comparisons to Absolute (Table I) Data

Coil Pair	Selected Coils		Spare
A	4	7	3
B	5	8	10
C	6	9	2

TABLE III Pair Selection


MT 296
Figure 1
8X16X36 C MAGNET UNIFORMITY OF MAGNETIC FIELD
AEC NO. 135652
BEV BEAM-LINE 30
MAGNET M3
E SHUNT = 20 mV
Y, DISTANCE FROM ℄ (cm)
X [cm]
Bz(0,Y,0), MAGNETIC INDUCTION (10^3 Gauss)
10,950
10,900
≈3 G/cm
~3 G/cm
~5 G/cm
COIL WIDTH 3.6 cm
X Before Coil
⊙ After Coil
SYM.
Y
Z

divided by 45 cm to determine the average field over the coil volume. The HP 97 program used for performing the integration is saved in MME Data Book No. 630B. The before and after (calibration) determinations of average magnetic induction agreed to 0.02%.

We calibrated the electronic integrator with a flux standard and determined each coil area based on 1) a known flux linkage from the flux standard, and 2) a determination of B_{AVG} from the NMR data by solving equation 1.

$$nA = \frac{\psi_{SLFS}\ 1/2\ E_{Flip\ Coil}}{B_{AVG}\ E_{SLFS}} \qquad (1)$$

nA = turns area of coil under test (m^2)

ψ_{SLFS} = flux linkage provided by the SLFS (Wb)

B_{AVG} = average magnetic induction over the coil length (T)

$E_{Flip\ Coil}$ = output potential of integrator generated by flipping the coil in known magnetic induction (B_{AVG}) (V)

E_{SLFS} = output potential of integrator generated by a known calibration signal from the SLFS, i.e., due to ψ_{SLFS} (V)

Method 2: The second method described in the test plan is inherently a more accurate determination of coil area based on a known area reference coil. In selecting coil pairs, it is more important that the relative areas be known than the absolute, so we did not require knowledge of the area of the reference coil to high accuracy.

Method 2 is more accurate than method 1 because 1) there are fewer variables involved in the calibration, e.g., a knowledge of the magnitude of the field is unimportant, only that it doesn't change over the relatively short time of comparison, 2) only short term reproducibility of both the magnetic field and the measurement system gain are needed for method 2; whereas stability over the entire measurement period is required for method 1.

An HP 97 program using equations from the test plan (Method 2 - V-D) was used to determine the relative areas of the coils. This program is listed in MME Book No. 630B.

Discussion

Based on the few repeats, I estimate that the absolute calibration data is good to ±0.1% as predicted. The high precision data is probably ±0.02%.

The determination of areas by Method 1 was facilitated by the outstanding performance of the LBL/CERN Nuclear Magnetic Resonance Magnetometer. The success of these NMR systems is largely due to the effort of Dr. Michael I. Green

Distribution

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