Title
COIL CALIBRATION OF 10 COILS - TEST PLAN

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LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA ENGINEERING NOTE	CODE MT295	SERIAL MME Book No. 630B	PAGE 1 of 9
AUTHOR Donald H. Nelson / DEPARTMENT Electronics Engineering	LOCATION B25A-124	DATE May 20, 1981	

PROGRAM — PROJECT — JOB
Superconducting Dipole Isabelle Prototype Magnetic Measurements Project

TITLE
COIL CALIBRATION OF 10 COILS - TEST PLAN

PURPOSE: Six coils are to be installed in the multipole-array for testing superconducting dipole - Isabelle prototype.

GOAL: Absolute determination of coils area to ±0.1%
Relative sensitivity (area) to ±0.01% of average

COIL DATA (Prior to calibration): Table 1 lists resistance measurements for the 10 coils (from pages 1 and 4 - fabrication log)

TEST EQUIPMENT & COORDINATE SYSTEM: Figure 1* shows the test equipment and coordinate system. Table II lists the specific equipment.

TEST PROCEDURE FOR ABSOLUTE AREA CALIBRATION (±0.1% of average) (Method 1)*

I. Measurement of BAVG** = average field over volume occupied by coils to be tested.

A. Set and monitor magnet current

1. NMR(ref) ∿1.0 (T) record both magnet current and NMR

2. Check magnetic field stability

a. Measure and record magnet current monitor, i.e., shunt potential (mV)

b. Measure and record magnetic induction at NMR reference location (Tesla)

B. Measure BAVG

1. 10 equally spaced measurements (5 cm centers)

a. Check NMR(ref) periodically (as determined from stability studies - A.2 above)

2. Numerically integrate to compute BAVG; $\text{BAVG} = \int_{-22.5}^{+22.5\text{ cm}} B_z dx / 45$

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*For method 1, one coil is tested at a time, and the reference coil and coil separator shown in Figure 1 are not used. The input from the reference coil to the flux standard is replaced by a "short-circuit".

**Table III defines abbreviations.

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COIL CHECK

DATE	TIME	COIL No.	METER CHECK	$R_{100'}$ KΩ	R_{COIL} KΩ	TEMP.	COMMENTS
5-18-81	9:12	1	✓	.1191	3.7094	22.5	
		2	✓	.1191	3.7435	22.5	
		3	✓	.1189	3.7262	22.4	
		4	✓	.1188	3.7424	22.6	
		5	✓	.1187	3.7165	22.6	
		6	✓	.1189	3.7125	22.5	
		7	✓	.1188	3.7413	22.4	
		8	✓	.1190	3.7122	22.4	
		9	✓	.1190	3.7421	22.5	
		10	✓	.1190	3.7436	22.5	

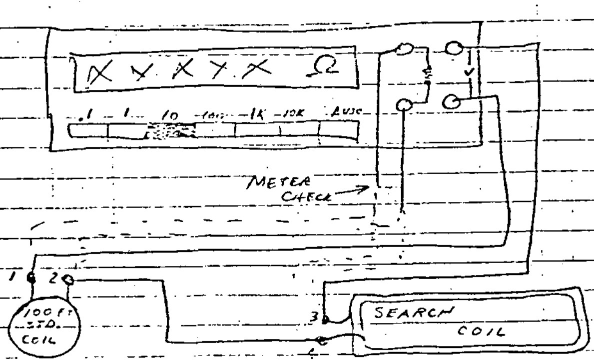
HIGH FIELD MAGNET DEVELOPMENT

SEARCH COILS

1. CHECK RESISTANCE OF WIRE USED TO WIND THE SEARCH COILS.

   A. WOUND 100 FT. OF #40 (PHELPS-DODGE SY-BONDEZE) ON A WOODEN SPOOL. WAS WOUND UNDER SAME TENSION AS SEARCH COILS ARE TO BE WOUND.

2. HOW TO CHECK COIL RESISTANCE



   A. CONNECT CURRENT TERMINALS FROM METER TO 1 & 3

   B. FOR METER CHECK – SHORT OUT RESISTANCE PROBES

   C. FOR R_{100FT} – CONNECT RESISTANCE PROBES TO 1 & 2

   D. FOR R_{COIL} – CONNECT RESISTANCE PROBES TO 3 & 4

TABLE I Resistance Measurements of 10 Coils

SUBJECT

SKETCH
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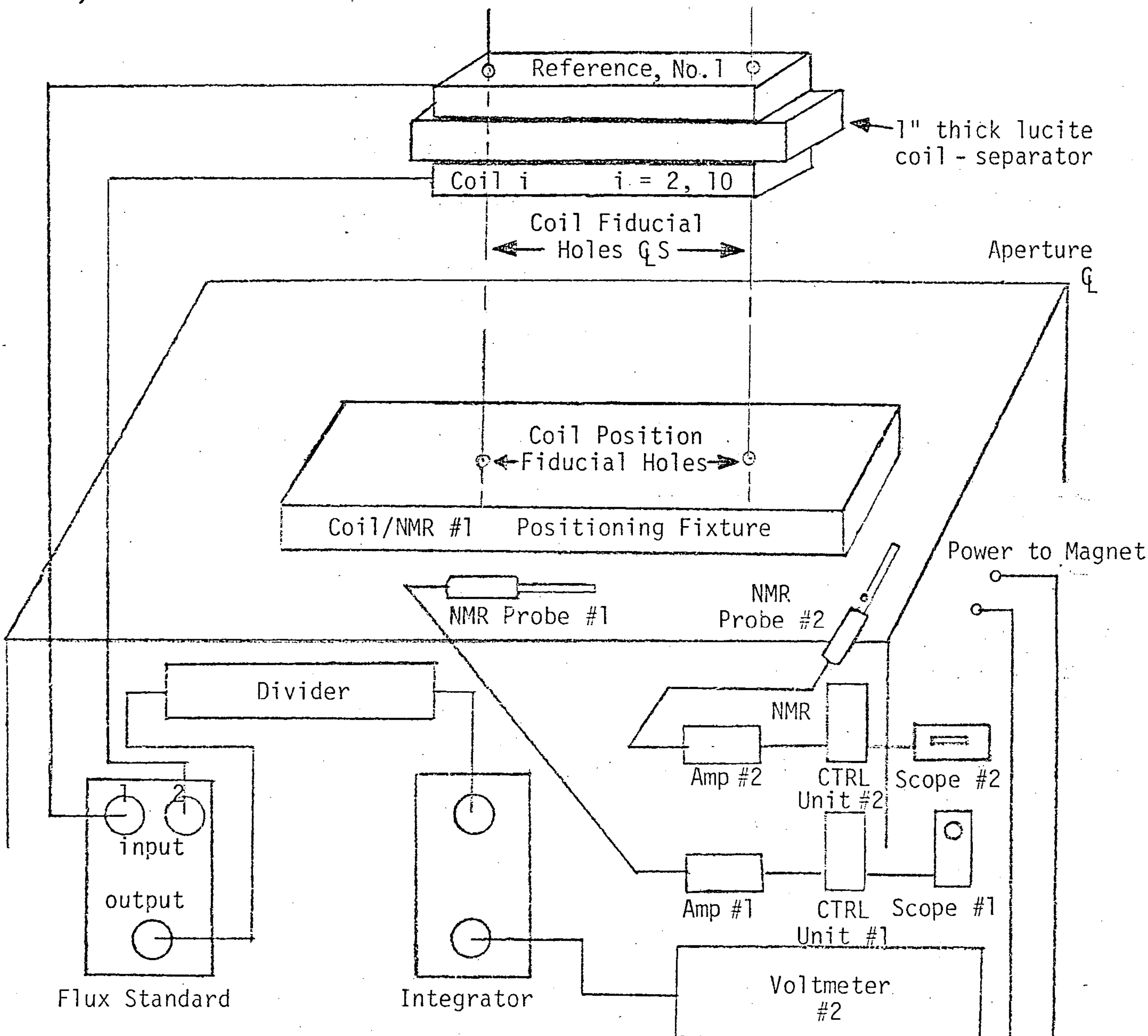
DATE 6/17/81 | BLDG. NO. 25A | ROOM NO. 119 | APPROVED BY | DATE

JOB ORDER INFORMATION: Job No. | Tag No. | Serial No. | No. Reqd. | Date Issued | Date Reqd. | Deliver To



NOTE: The two coils (one in the case of calibration method 1) are positioned within the magnet by 1/2 inch bolts through the coil fiducial holes. The bolt heads (or nuts) contact the fiducial holes in the positioning fixture. The coil(s), two at a time in method 2, are positioned by the snug fitting bolts to $\pm$ 1/32 inch.

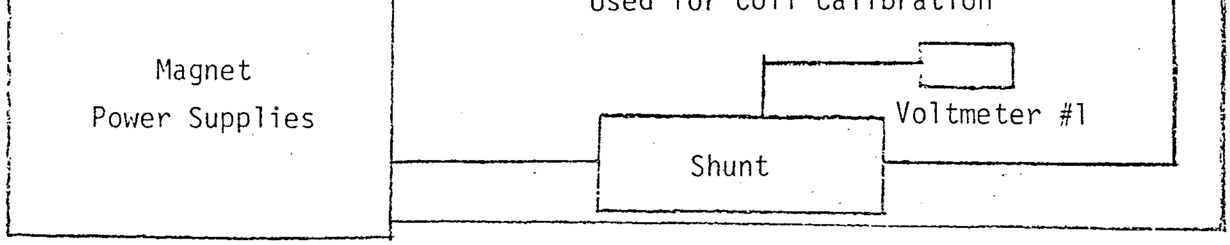


FIGURE 1 Schematic Diagram of Test Equipment Used for Coil Calibration

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EQUIPMENT	DESCRIPTION	IDENTIFICATION	
Magnet	8" x 16" x 36" -C	Bev. AEC No. 135652	
Power Supply		Bev. S/N 707 & 702	
Current Mon. Shunt	2500 A/50 mV	Bev. S/N 25 R = 19.99 μΩ	
Voltmeter #1	Dixson Model VT 200		
Flux Standard	MME SLFS Ø = 1.0144 V.S.	MME S/N 39	
Divider	Dekavider Model RV622A	MME AEC No. 107603	
Integrator	MME Model '71	S/N 2 R = 56.2 k C = 3 μF Div = 1.000	
Voltmeter #2	H.P. Model 3455A	MME AEC No. 517459	
		No. 1	No. 2
NMR Control Unit	LBL/CERN	S/N 023	S/N 025
Amplifier	LBL/CERN	S/N 26	S/N 27
Probe	LBL - Range 5	S/N 151	S/N 014
Scope #1	Tektronix Model 465B	S/N B045512	
Scope #2	NLS Model MS-215		S/N 1793

TABLE II EQUIPMENT LIST

TEST PROCEDURE FOR ABSOLUTE AREA CALIBRATION ($\pm$0.1% of average) (continued)

II. Calibrate 10 coils

A. Calibrate integrator/DVM combination

1. Connect coil to be tested
2. Measure and record E(SLFS)*

B. Measure flux linkage due to flipping coil (single coil)

1. Five measurements minimum

C. Record BNMR (reference location)

D. Calculate turns-area product, nA(i)

1. Unadjusted (for NMR data)

   nA(i) (m^2) = (SLFLUX/BAVG) * 0.5 * E(flip)/E(SLFS)

2. Adjusted (for NMR data)

   nAadj(i) (m^2) = nA(i) * BNMR(i)/BNMR(avg)

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*See Table III for abbreviations and units

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ABBREVIATION (Symbol)	DEFINITION	UNITS
NMR(ref)	Nuclear Magnetic Resonance (at reference locations)	Teslas
BNMR	Magnetic induction measured with NMR magnetometer	Teslas
SLFLUX	Flux-linkage (generated when flux-standard primary current reversed)	Webers
BAVG	Average magnetic induction at location of coil under test	Teslas
E(flip)	Integrator output potential due to flipping coil under test, i.e., turning coil 180 degrees about its long axis	Volts
E(SLFS)	Integrator output potential due to reversing SLFS primary current	Volts
nA(i)	Turns-area product (of coil no. i)	m^2
nAadj(i)	nA(i) adjusted for change in BAVG as determined by NMR(ref)	m^2

TABLE III DEFINITIONS OF ABBREVIATIONS

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TEST PROCEDURE FOR RELATIVE AREA CALIBRATION (±0.01% of Reference Coil)(Method 2)

I. Select a reference coil

II. Mount reference coil and test coil on a fixture which will allow the positions of the two coils to be interchanged. (See Figure 1)

III. Connect coils in aiding arrangement, i.e., as coil positions are interchanged, the signals from the two coils are of the same sign.

A. Divide sum of signals to avoid overloading integrator

B. Calibrate to determine system sensitivity

C. Monitor field changes (throughout calibration procedure) with NMR #2

D. Record a series of integrator output potentials as coil positions are interchanged (7 measurements minimum)

IV. Connect coils in opposing arrangement, i.e., reverse the sense of coil under test by the SLFS input #2 selector/reversing switch

A. Increase fraction of signal input to the integrator

B. Calibrate to determine system sensitivity

C. Monitor field changes (throughout calibration procedure) with NMR #2

D. Record a series of integrator output potentials as coil positions are interchanged (7 measurements minimum)

V. Calculate relative area

A. Quantity of interest:

$$(\Delta nA)_i = 100 \frac{(nA)_{ref} - (nA)_i}{(nA)_{ref}} \qquad (\%) \text{ of } (nA)_{ref}$$

1. $(\Delta nA)_i$ = relative area of i-th coil (% of ref area)

2. $(nA)_{ref}$ = area of reference coil (m^2)

3. $(nA)_i$ = area of i-th coil (m^2)

V. Calculate relative area (continued)

B. Measures quantities

1. $\Delta E_{i+} = \Delta(E_{ref} + E_i)$ (V)

2. $\Delta E_{i-} = \Delta(E_{ref} - E_i)$ (V)

3. E_{SLFS+} = Output potential of integrator due to flux linkage change when SLFS primary current reversed (while recording ΔE_{i+}) (V)

4. B_{NMR+} = Magnetic induction as measured by NMR #2 while recording ΔE_{i+} (T)

5. E_{SLFS-} = Output potential of integrator due to flux linkage change when SLFS primary current reversed (while recording ΔE_{i-}) (V)

6. B_{NMR-} = Magnetic induction as measured by NMR #2 while recording ΔE_{i-} (T)

7. $\emptyset_{SLFS}$ = SLFS flux linkage (Previously determined) (Wb)

C. Requirements to obtain quantity of interest (A1) from measured quantities (B)

1. $B_{NMR+} = B_{NMR-} \pm 0.01\%$

2. Interchange of coils repeatable to $\pm 0.01\%$

3. Coil mounting fixture must not introduce errors of $\geq 0.01\%$

4. $\emptyset_{SLFS}$ is constant to $\pm 0.01\%$ during measurements of 3 & 5 above

5. Integrator/DVM resolution adequate for resolving 0.01%

D. Equations used

1. $$\Delta\emptyset_- = \frac{\Delta E_{i-}}{E_{SLFS-}} \emptyset_{SLFS} = (nA_{ref} - nA_i)\,\Delta B_{AVG}$$

2. $$\Delta\emptyset_+ = \frac{\Delta E_{i+}}{E_{SLFS+}} \emptyset_{SLFS} = (nA_{ref} + nA_i)\,\Delta B_{AVG}$$

3. $$nA_{ref} = \frac{\Delta\emptyset_+ + \Delta\emptyset_-}{2\,\Delta B_{AVG}}$$

Note: To arrive at the quantity of interest, divide 1 by 1/2(1 + 2) and multiply by 100. ΔB_{AVG} cancels, if requirements C 1, 2 are 3 are met.

COIL PHASE DETERMINATION

A test plan for determining the phase of each coil (the angle between the coil's electrical axis and the outward normal of the coils top surface) is given in Appendix A - MT 299 which will be distributed on request.

DISTRIBUTION

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