Title
CALIBRATION OF FIELD MONITORS FOR BEVATRON BEAM-LINE 30 MAGNETS M3 AND M4

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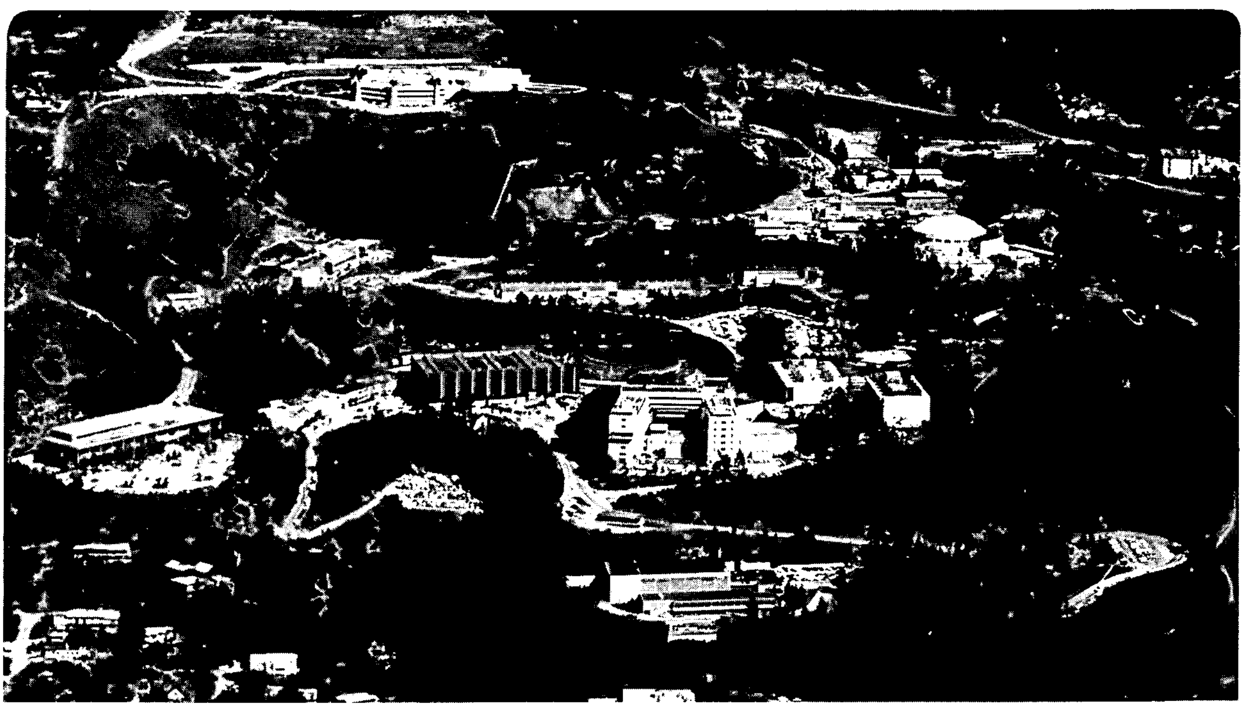

LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA
ENGINEERING NOTE

CODE	SERIAL	PAGE
MT 297	MME Book No. 636	1 of 8

AUTHOR	DEPARTMENT	LOCATION	DATE
Donald H. Nelson	Electronics Engineering	B25A-124	July 7, 1981

PROGRAM — PROJECT — JOB

TITLE
Calibration of Field Monitors For Bevatron Beam-Line 30 Magnets M3 and M4

Introduction

In January, 1981, Lee Schroeder requested assistance from Magnetic Measurements Engineering in providing magnets M3 and M4 in beam-line 30 with field monitoring. I advised Lee to purchase two probes and 2 - 100' extension cables to be dedicated to this application. Magnetic Measurements Engineering would then provide a Gaussmeter for reading the probes during experiments using M3 and M4.

On January 12, 1981, MME loaned field monitoring equipment (including probes) to L. Schroeder and he acquired 2 - 100' extension cables from F.W. Bell.

On May 28th, Ed Cyr with assistance from Bob Treuhaft calibrated the probe/extension-cable in M3. On May 29th, Ed Cyr and Bob Treuhaft calibrated the probe/extension-cable in M4.

On June 8th after realizing that these magnets are energized in two polarities, Ed Cyr and Don Nelson collected four sets of calibration data (both magnets energized first in the "negative" polarity and then in the "positive" polarity). In both magnets M3 and M4, positive polarity corresponds to magnetic induction directed downward in order to bend positive particles to the left.

Our primary objectve was to relate magnetic induction as measured by a Hall probe at a fixed reference location on the lower pole tip B_H(ref) to magnetic induction at the magnet center as determined by a NMR magnetometer $B_{NMR}(0, 0, 0)$; i.e., we were calibrating the magnet, not the Hall effect Gaussmeter.

A secondary objective was to correlate current monitoring shunt potential to B(0, 0, 0) for reducing data already acquired.

Method of Setting Magnetic Field

The Hall probes are taped to the lower pole tips. The Gaussmeter zero adjustment is used to provide correct reading of the residual field at the probe location. The calibration adjustment is used to adjust the sensitivity of the Gaussmeter to that used during calibration. The Gaussmeter readout can then be used to set or monitor magnetic induction within the range of calibration.

The calibration of the field monitor would be entirely routine except that (1) the Hall probe zero drift adjustments normally rely on moving the probe (either flipping the probe or placing the probe in a field free region), (2) reproducibility of field monitoring is facilitated by keeping the probe stationary.

We decided to determine the residual field so the zero adjustment could be made to the known residual field of the magnet at the probe location. Since we did not realize that the magnets were powered in both polarities, we only determined residual field for positive polarity (after cycling from 0 A to $+I_{max}$ three times and then waiting for the field to decay $\gtrsim$30 minutes). Adjusting the Gaussmeter zero too soon after cycling the magnet may introduce error, and has introduced an uncertainty in our calibration of about 11 Gauss (0.3% at 0.4 Teslas). (The internal calibration of the Gaussmeters are independent of the field the probe is in.)

Equipment

Figure 1 shows the test equipment used for these calibrations. Table 1 lists specific equipment. (I have asked Lee Schroeder to order Hall probes to replace those provided by Magnetic Measurements Engineering.)

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Results

Figures 2 and 3 summarize the calibration data for magnets M3 and M4 respectively. These figures can be used in two ways:

1. to set a desired value of $B_z(0, 0, 0)$ (A & B below),
2. to determine the value of $B_z(0, 0, 0)$ from the field monitor (A & C below).

A. Zero and Calibration of Field Monitor (Gaussmeter polarity switch normal)

1. Cycle the magnet 3 times between 0 A and I_{max} ∿1600 A for M3, ∿2000 A for M4 (in the polarity of interest).
2. After approximately 30 minutes, set $|E_{Hall}|$ on 100 Gauss F.S. (100 Gauss = 1.000 V) to $\pm$0.03 V, + if positive, - if negative. The correct residual is uncertain and may be determined from additional tests.
3. Adjust Gaussmeter Gain (Calibration Adjust): M3 = 0.7605 V, M4 = 0.8455 V

B. To Set a Desired Field (After Completing Above)

1. Interpret Figure 2 (for M3) and Figure 3 (for M4) abscissa as desired field Teslas, i.e., B(0, 0, 0).
2. Find value of $B(0, 0, 0)/E_H$, i.e., the ordinate corresponding to $B_z(0, 0, 0)$ on the appropriate curve.
3. E_H = abscissa ÷ ordinate
4. Raise current until E_H is reached.

C. To Determine Field From Monitor (After Completing A Above)

1. Interpret Figure 2 (for M3) and Figure 3 (for M4) abscissa as E_H (volts).
2. Find value of $B(0, 0, 0)/E_H$ from corresponding ordinate value of appropriate curve.
3. B(0, 0, 0) = abscissa * ordinate

Tabulated Data

Tabulated data including shunt potential is summarized in Appendix A and is available on request.

Discussion

These calibrations were facilitated by the successful operation of the LBL/CERN Nuclear Magnetic Resonance Magnetometer which were fabricated by Magnetic Measurements Engineering in 1978.

Distribution

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Electronics Engineering Master File
Magnetic Measurements Engineering (4)

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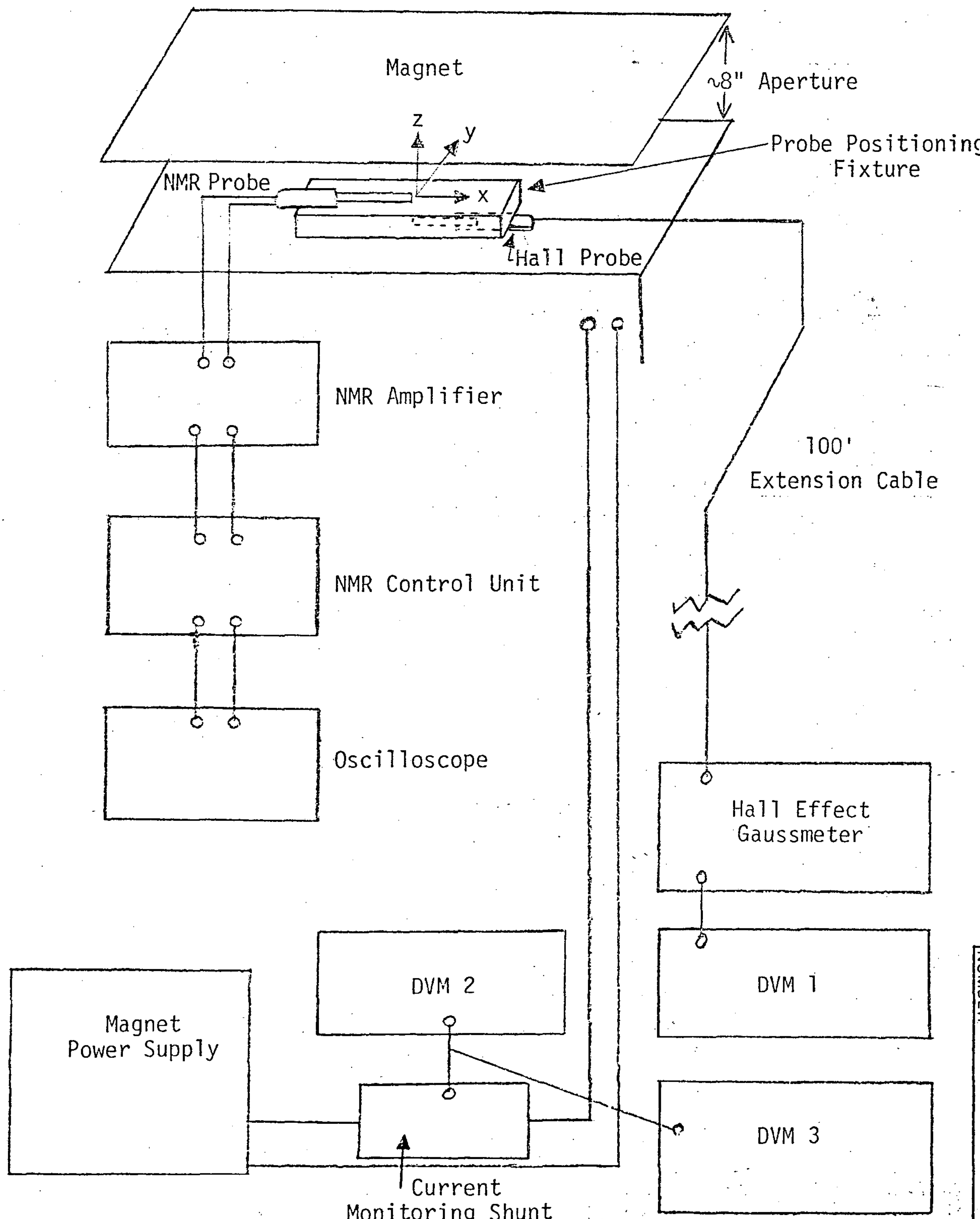
SUBJECT Beam 30 Magnet Calibration		SKETCH LAWRENCE BERKELEY LABORATORY UNIVERSITY OF CALIFORNIA		JOB ORDER INFORMATION	Job No. / Tag No. / Serial No. / No. Reqd. / Date Issued / Date Reqd. / Deliver To
DRAWN BY EAC					
DATE 6/19/81	BLDG. NO. 25A / ROOM NO. 119	APPROVED BY DHN	DATE 6/19/81		

Figure 1 Calibration Setup



SKETCH NUMBER

Equipment	Manufacturer/Model		Identification		
NMR Probe Range 4	LBL/CERN		S/N 132		
NMR Probe Range 5	LBL/CERN		S/N 151		
NMR Amplifier	LBL/CERN		S/N 26		
NMR Control Unit	LBL/CERN		S/N 023		
Oscilloscope	Tektronix Mod 465B		S/N B045512		
	M 3	M 4	M 3	M 4	
Power Supplies					
Current Monitoring Shunt	Bev 2500 A/50 mV	Bev 2500 A/50 mV	S/N 25, R = 19.99 μΩ	S/N 14, R = 20.21 μΩ	
DVM 2	Dixson Mod VT 200	Dixson Mod VT 200	?	?	
DVM 3	Newport	Newport	AEC No. 198532	AEC No. 198531	
Hall Probe	F.W. Bell HTJ4-0608	F.W. Bell HTJ4-0608	S/N 141442 (Probe 2)	S/N 129151 (Probe 1)	
Extension Cable	F.W. Bell XOVO-0100	F.W. Bell XOVO-0100	--	--	
Gaussmeter	F.W. Bell 810	F.W. Bell 810	S/N 138090	S/N 138089	(AEC No. 517835)
DVM	Keitheley 177 DMM	Keitheley 177 DMM	S/N 10450	S/N 10450	

TABLE I Equipment List

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M 4 Negative

'81 June 18

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Tabulation of Calibration Data

'81 June 8 Data

Time	Dixson	Newport		$E_{Hall}^{(ref)}$ [V]	$B_{NMR}^{(0,0,0)}$ [Tesla]	B_{NMR}/E_{Hall}	$\Delta E/E$
8:57	20.01	20.18	—	1.0868			
				~~1.0872~~	1.0874	1.0008	.9999
9:15			—	1.0861			
			—	.3855			
9:33	7.02	7.09		~~.3852~~	~~.3863~~		
9:42					.3867	1.0030	1.0002
9:43	7.02	7.09	—	.3857			
9:45	10.01	10.10	—	.5497		~~1.0033~~	
9:48					.55152	1.0032	1.011
9:57	10.01	10.10	—	.5499			
9:52	18.03	18.17	—	.9820			
9:54 9:57					.98434 .98437	1.0022	1.011
10:02	18.02	18.17	—	.9824			
10:05	30.00	30.27	—	1.5153			
10:10					1.50878	.9957	.9950
10:11	30.00	30.27	—	1.5153			
10:12	40.00	40.34	—	1.7988			
10:17					1.77963	.9894	.9888
10:18				1.7986			

[illegible] MA POSITIVE

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81 June 8 Data

81 June 8	E_{SHUNT} [illegible]		E_H(ref)	B_{NMR}(0,0,0)	B_{NMR}/E_H	Hall Probe Adjusted For Δ 11 G
Time	Dixson	Newport				
	[mV]	[mV]	[V]	[T]	[T/V]	
10:56	7.04	-7.06	.3901			
10:59				.3916	1.0036	1.0059
11:00	7.05	-7.06	.3904			
11:02	15.00	-15.09	.8245			
11:05				.8274/2	1.0038	1.0057
11:10	15.01	-15.09 (10)	.8245			
11:16	Off		+.058			
11:26			+.063			
12:12			+.069			

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M 4 Positive
5/29/81 Data

'81 June

TIME	DIXSON [mV]	NEWPORT [mV]	$E_{calc}^{(ref)}$ [V]	$B_{NMR}^{(0,0,0)}$ [T]	B_{NMR}/E_{cal} [T/V]
11:34	20.03	-20.18	1.0927	1.09285	1.0001
	14.47	-14.59	.7994	.80056	1.0015
11:40	16.57	-16.70	.9114	.9123	1.0010
	20.49	-20.66	1.1143	1.1142	.9999
11:45	22.51	-22.68	1.2124	1.2112	.9990
	24.59	24.76	1.3090	1.3062	.9979
	26.85	-27.06	1.4046	1.3996	.9964
11:52	29.57	-29.79	1.5049	1.4970	.9948
11:55	32.64	-32.90	1.6033	1.5918	.9928
11:57	36.15	-36.42	1.7033	1.6873	.9906
12:00	39.94	-40.25	1.8020	1.7805	.9881
	40.65	-40.96	1.8137	1.7963	.9877
	32.46	-32.71	1.6013	1.5901	.9930
	29.57	-29.79	1.5097	1.5017	.9947
	18.43	-18.56	1.0126	1.0136	1.0010
12:15	14.47	-14.57	.7977	.7990	1.0016
12:18	18.49	-18.56	1.0080	1.0088	1.0008
12:21	26.87	-27.08	1.4057	1.4009	.9967
	40.50	-40.76	1.8156	1.7925	.9873

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M 3 Negative
'81 June 8 Data

Time	Dixson [mV]	Newport [mV]		$E_H^{(ref)}$ [V]	$B_{NMR}^{(0,0,0)}$ [T]	B_{NMR}/E_H [T/V]
11:32	7.03	-7.14	-	.3923		
?					.39357	1.0031
11:42	7.03	-7.14	-	.3923		
11:44	10.02	-10.15	-	.5567		
11:46					.5592	1.0040
11:47	10.02	-10.15	-	.5571		
11:48	15.00	-15.16	-	.8283		
11:50					.83283	1.0052
11:57	15.06	-15.16	-	.8288		
11:52	18.02	-18.21	-	.9880		
11:53					.99479	1.0066
11:58					.99454	1.0062
12:00	18.03	-18.23		-.9888		
12:02	25.01	-25.21		1.3261		
12:04					1.3328	1.0049
12:05	25.01	-25.21		1.3266		
12:07	32.04	-32.33		1.5823		
12:09					1.58512	1.0018
12:11	32.04	-32.33		1.5822		
12:14	off					
13:43	"			+.035 *		

Image AB or AU
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M3 positive
'81 June 8 Data +

Time	Dixson [mV]	Newport [mV]	E_{Hall} (ref) [V]	B_{NMR} (000) [T]	B_{NMR}/E_H
15:22	7.02	7.11	.3894		
15:27				.38987	1.0009
15:28	7.02	7.11	.3896		
15:29	10.03	10.14	.5554		
15:30				.5567	1.0009
15:32	10.03	10.14	.5570		
15:33	15.00	15.16	.8289		
15:35				.83016	1.0013
15:36	15.00	15.17	.8292		
15:37	18.00	18.19	.9886		
15:38				.99038	1.0014
15:41				.99058	1.0016
15:42	18.01	18.19	.9894		
15:43	25.06	25.30	1.3342	~~1.2~~	
15:46				1.33317	.9995
15:47	25.06	25.30	1.3344		
15:48	32.06	32.34	1.5918		
15:50				1.58429	.9953
15:51	32.06	32.35	1.5918		

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M 3 Positive
Data 5/20/81
X
'81 June 18

Time	Dixson	Newport		$E_{Hall}^{(cf)}$	+	$B_{NMR}(0,0,0)$		$\frac{B_{NMR}}{E_{Hall}}$		[illegible]
	20.17	20.27				11.016				542.5
	29.35	29.58				14.992				506.8
	36.04	36.34				16.966				466.9
	14.60	14.73				8.099				549.8
	15.96	16.08				8.805				547.6
	16.88	17.01				9.205				545.9
	17.88	18.03				9.816				544.9
	18.86	19.01				10.334				543.6
	20.33	20.49	+	11.089		11.0??		1.0004		541.3
	21.96	22.01				11.828				537.8
	22.87	23.04	+	12.88?5		12.726		.9997		[illegible]9
	23.89	[illegible].08	+	12.805		12.7??		.999?		531.5
	24.80	25.00	+	13.213		13.201		.9991		528.6
	26.64		+	14.075		14.049		.9981		523.4
	26.87	27.03				"				519.7
	28.79	29.01	+	14.82?		14.780		.9968		509.5
	30.81	31.04	+	15.579		15.450		.9956		497.7
	32.80	33.04	+	16.144		16.052		.9943		485.9

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