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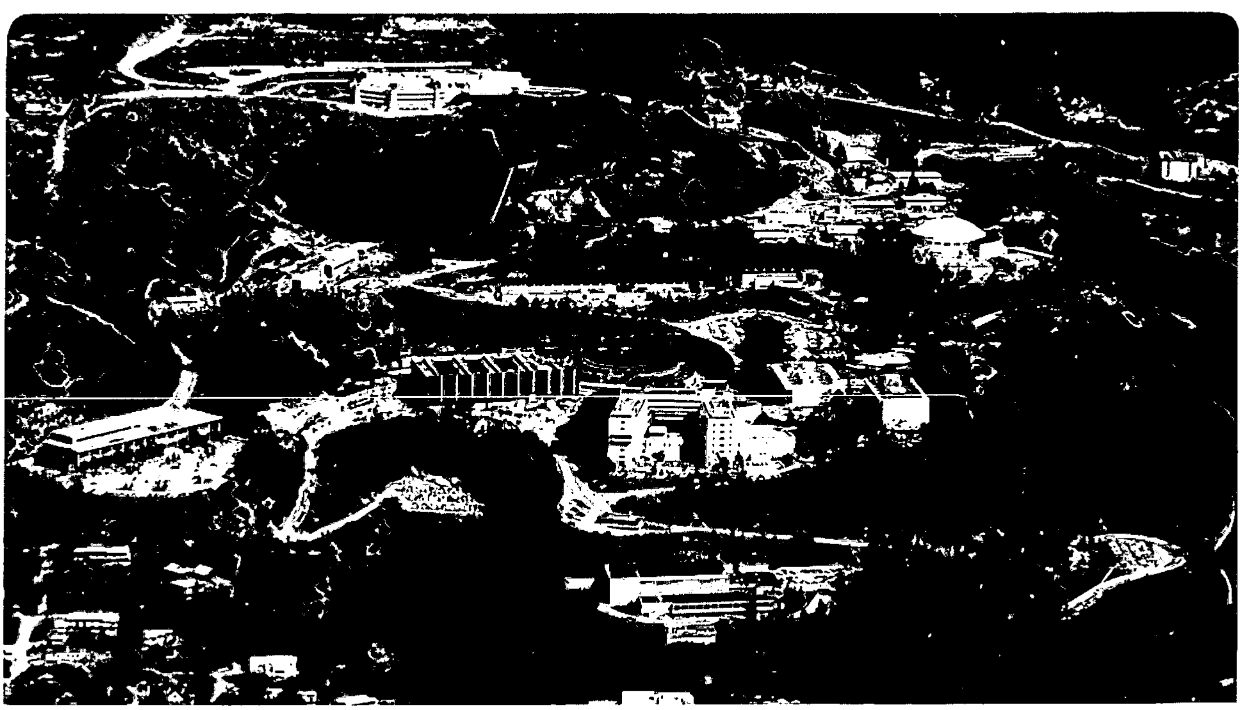

SUBJECT IHM 6 Magnetic Field Measurements
NAME D.H. Nelson & R.B. Yourd
DATE March 1, 1982

INTRODUCTION

In February, 1982, we tested the magnetic field of Bevatron injector magnet IHM 6.[1,2] The purpose of the tests was to determine the "effective field boundary" (efb) in order to establish the bending strength and focusing properties of the magnet.

COORDINATE SYSTEMS

Two coordinate systems were defined by the three fiducials on the top of the magnet to be used for accurately positioning the magnet in the beam-line. As suggested in Figure 1, three holes on the top surface of the magnet define the entrance (y') and exit (-y) directions. We established the right handed cartesian coordinate systems shown in Figure 1 with z = 0, the (nominal) magnet midplane.

TECHNIQUE

To determine the effective field boundary (efb {x,z}), we

1. measured magnetic induction at even intervals on paths parallel to the entrance and exit beam-trajectories, i.e., parallel to y' and -y respectively,
2. numerically integrated over the measured path length (from ∿2 gaps outside to ∿1 gap inside pole edge), and
3. solved equation 1

$$\text{efb}\,(x, z) = y_0 - \int_{-\infty}^{y_0} B_z(x, y, z)/B_z(0, y_0, 0) \qquad (1)$$

where:

efb ≡ effective field boundary

y_0 ≡ a y coordinate where the field is uniform (∿1 gap inside pole edge)

$-\infty$ ≡ a y coordinate where the field is zero (negligible). We approximated this by ∿2 gaps outside pole edge. At that location, the field was ∿1% of $B(0, y_0, 0)$.

$B_z(x, y, z)$ ≡ z-component of magnetic induction at location (x,y,z) (See Figure 1).

SUBJECT	SKETCH LAWRENCE BERKELEY LABORATORY UNIVERSITY OF CALIFORNIA		JOB ORDER INFORMATION	Job No.	Tag No.
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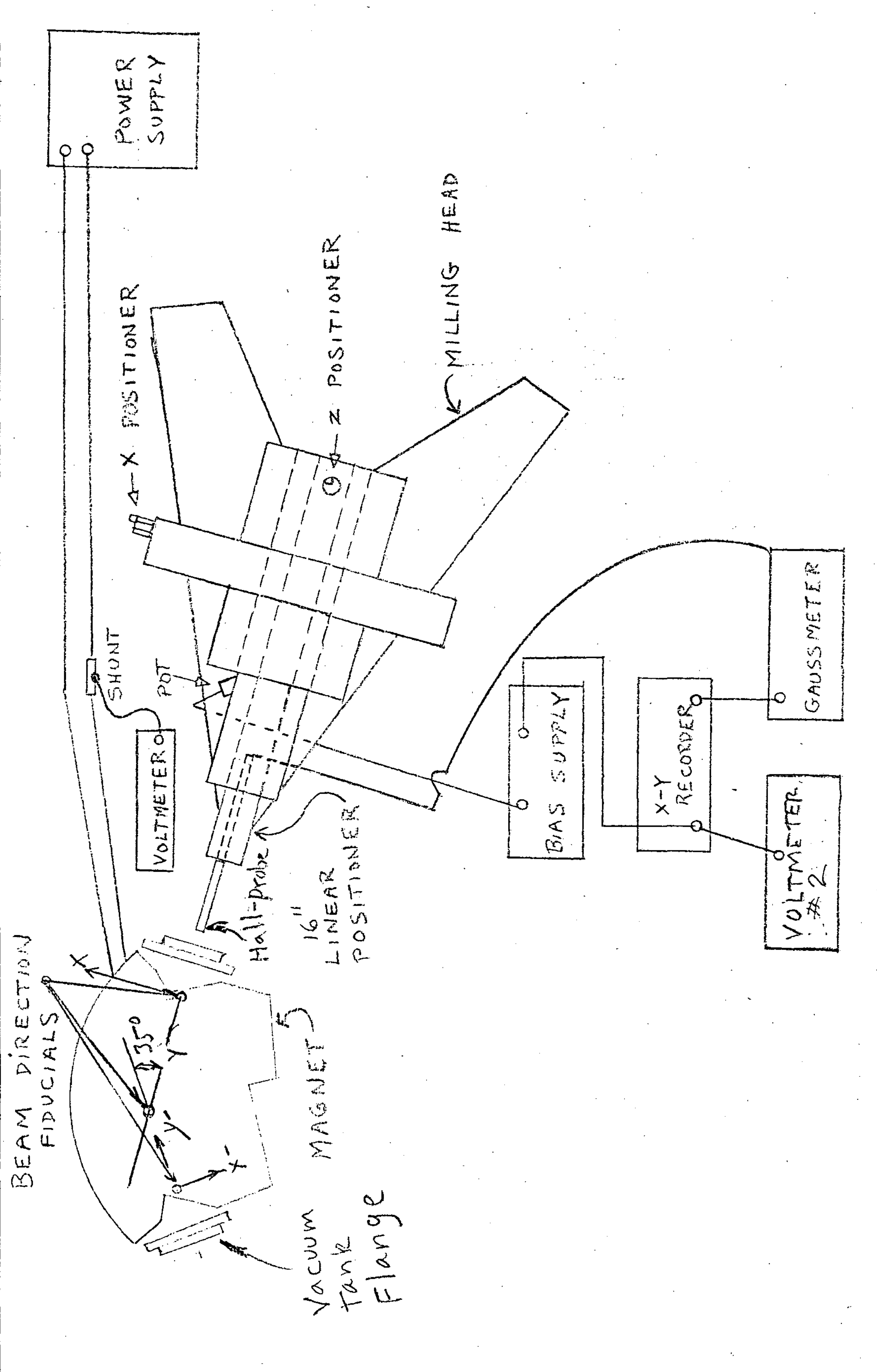


FIGURE I

SKETCH NUMBER

RESULTS

Table I summarizes results based on selected profile data. Figures 2 and 3 are working graphs showing selected profiles and calculations of efb and effective edge angles. Figure 4 displays magnetization data. The total magnetic effective length (the distance between effective field boundaries along the central arc) is 35.46 inches with a circular arc radius of 58.04 inches and a total bending angle of 35°.

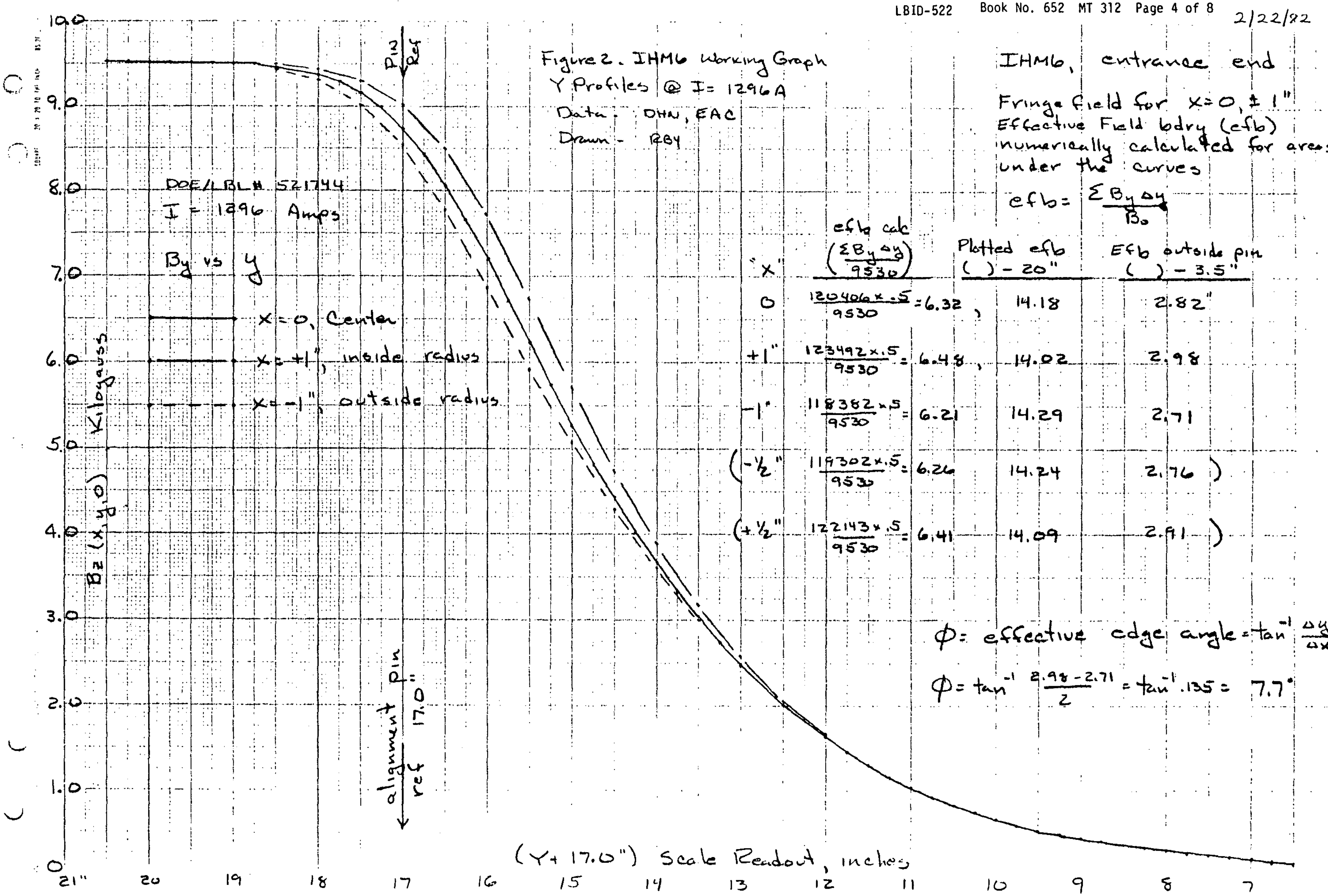
End	I (A)	z (in.)	x (in.)	efb* (in.)	Effective Edge Angle (Calculated from) B(x = ±½") (degrees)	B(x = ±1") (degrees)
Entrance	1296	0	- 1	-2.71		
"	"	"	-1/2	-2.76		
"	"	"	0	-2.82		
"	"	"	1/2	-2.91	8.5°	
"	"	"	1	-2.98		7.6°
"	1296	- 1	- 1	-2.69**		
"	"	- 1	0	-2.83**		
"	"	-7/8	1	-3.00**		8.7°
"	560	0	0	-2.87**		
Exit	1296	0	- 1	-2.93		
"	"		-1/2	-2.87		
"	"		0	-2.78		
"	"		1/2	-2.72	8.5°	
"	"		1	-2.63		8.4°
"	560	0	-1/2	2.78**		
"	"		0	2.65**		
"	"		1/2	2.58**	8.7°	

* efb ≡ effective field boundary

** Calculations marked by asterix used different algorithm than those unmarked and used different approximations (comparisons of efb were within 30 mils, i.e., 0.03 inch)

TABLE I Summary of Profile Data

Figure 2. IHM6 Working Graph
Y Profiles @ I= 1296A
Data: DHN, EAC
Drawn - RBY



IHM6, entrance end

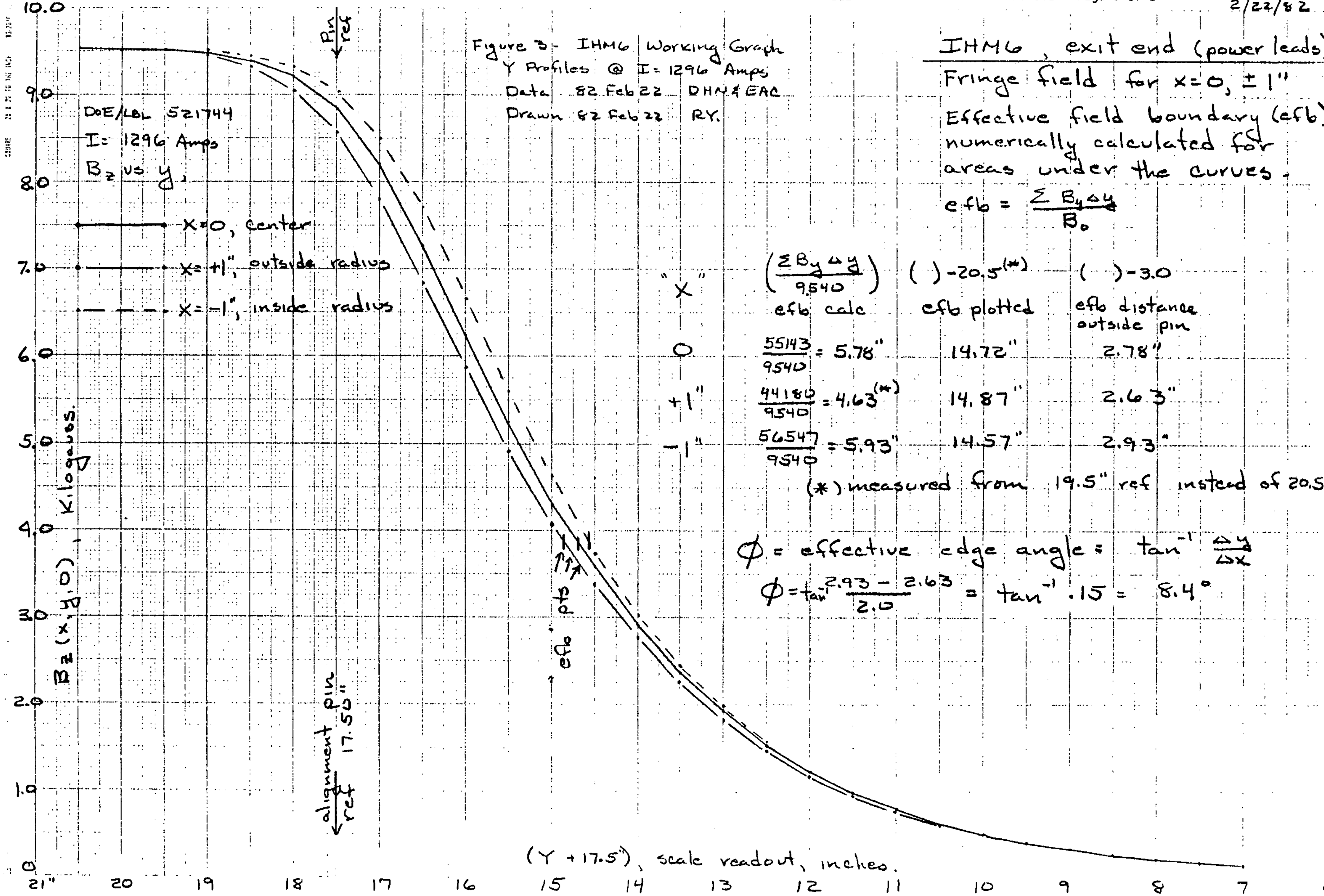
Fringe field for x = 0, ± 1"
Effective Field bdry (efb)
numerically calculated for areas under the curves

$efb = \frac{\Sigma B_y \Delta y}{B_0}$

"x"	efb calc $\left(\frac{\Sigma B_y \Delta y}{9530}\right)$	Plotted efb ( ) - 20"	Efb outside pin ( ) - 3.5"
0	$\frac{120406 \times .5}{9530} = 6.32$	14.18	2.82"
+1"	$\frac{123492 \times .5}{9530} = 6.48$	14.02	2.98
-1"	$\frac{118382 \times .5}{9530} = 6.21$	14.29	2.71
(-½"	$\frac{119302 \times .5}{9530} = 6.26$	14.24	2.76)
(+½"	$\frac{122143 \times .5}{9530} = 6.41$	14.09	2.91)

ϕ: effective edge angle $= \tan^{-1} \frac{\Delta y}{\Delta x}$

$\phi = \tan^{-1} \frac{2.98 - 2.71}{2} = \tan^{-1} .135 = 7.7°$


IHM6, exit end (power leads)
Fringe field for x=0, ±1"
Effective field boundary (efb) numerically calculated for areas under the curves.
efb = Σ B_y Δy / B_0
Figure 3 - IHM6 Working Graph
Y Profiles @ I = 1296 Amps
Data 82 Feb 22 DHN & EAC
Drawn 82 Feb 22 RY.
DoE/LBL 521744
I = 1296 Amps
B_z vs y.
X=0, center
X=+1", outside radius
X=-1", inside radius
"X" | (ΣB_y Δy / 9540) efb calc | ( )-20.5(*) efb plotted | ( )-3.0 efb distance outside pin
0 | 55143/9540 = 5.78" | 14.72" | 2.78"
+1" | 44180/9540 = 4.63"(*) | 14.87" | 2.63"
-1" | 56547/9540 = 5.93" | 14.57" | 2.93"
(*) measured from 19.5" ref instead of 20.5"
Φ = effective edge angle = tan⁻¹ Δy/Δx
Φ = tan⁻¹ (2.93 − 2.63)/2.0 = tan⁻¹ .15 = 8.4°
Pin ref
alignment pin ref 17.50"
efb
B_z (x, y, 0) Kilogauss
(Y + 17.5"), scale readout, inches.
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
21"
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6

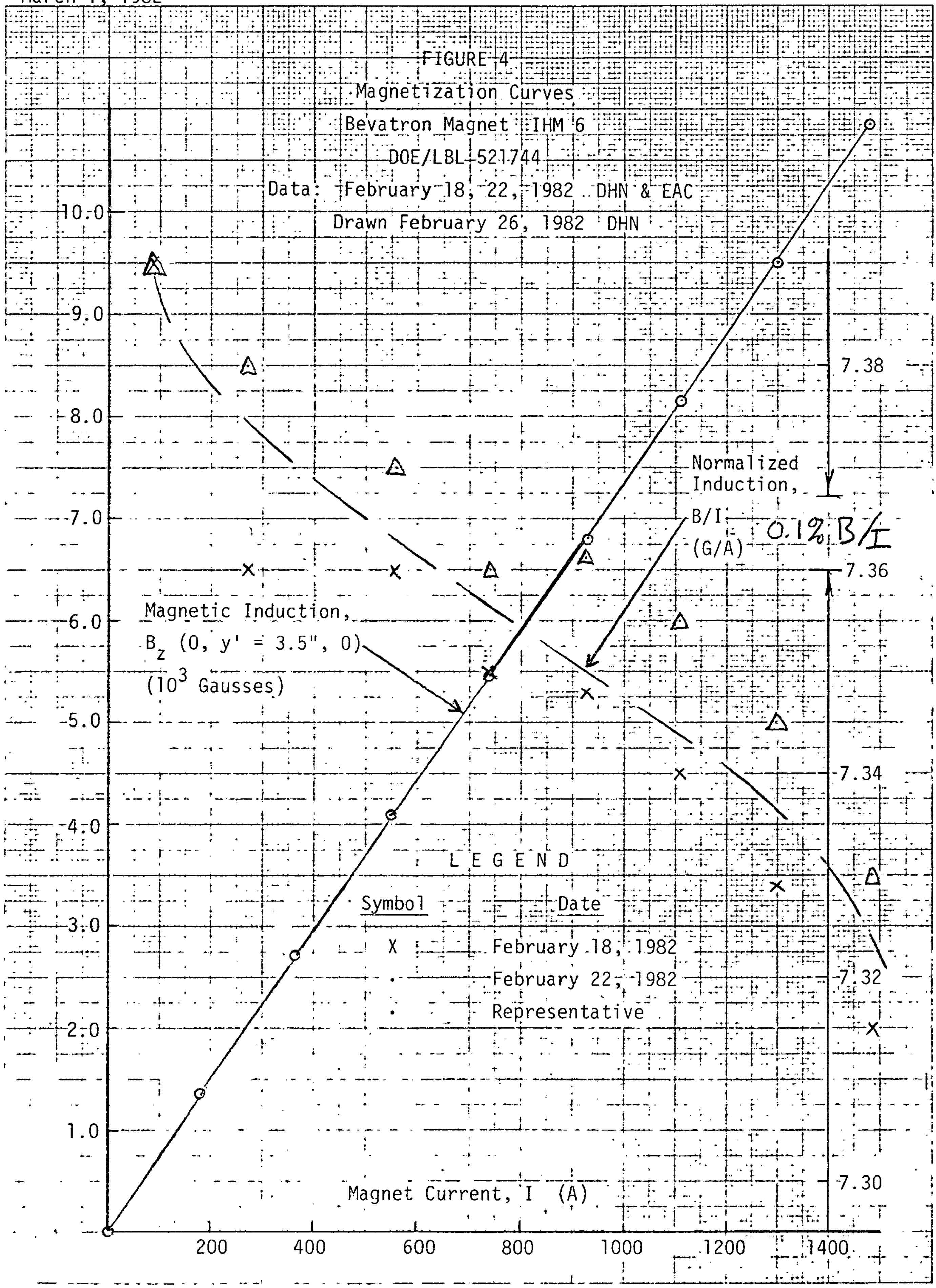


FIGURE 4
Magnetization Curves
Bevatron Magnet IHM 6
DOE/LBL-521744
Data: February 18, 22, 1982 DHN & EAC
Drawn February 26, 1982 DHN
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Magnetic Induction,
B_z (0, y' = 3.5", 0)
(10^3 Gausses)
Normalized
Induction,
B/I
(G/A)
0.1% B/I
7.38
7.36
7.34
7.32
7.30
L E G E N D
Symbol
Date
X
February 18, 1982
February 22, 1982
Representative
Magnet Current, I (A)
200
400
600
800
1000
1200
1400

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TEST EQUIPMENT

Figure 1 is a schematic diagram of our test setup (shown at the exit end; the entrance end setup was similar). Table II lists specific equipment used for these tests.

DISCUSSION

The most challenging aspect of these tests was establishing measurement coordinate systems and relating those to the two magnet coordinate systems. Once established, relative positioning was reproducible to $\pm 1/64$ inch in the y direction and ± 1 mm in x and z. Ed Cyr used a 6' steel rule to extend the y axis and machinist's squares both to translate the y axis to our "zip-track" direction and to establish the x and y location of the hall probe. z position was approximated by surfaces of the vacuum tank flange.

The tedious parts of this project were recording the data by hand and carrying out the numerical integration by keying measured data into a calculator. We could have avoided this tedium by using the MME data logger,[3] but it was unavailable for these tests.

REFERENCES

1. R. Yourd, "Bevatron Vacuum Improvement BL17MH (IHM 6) Magnet Replacement for UBI Project", LBL Mechanical Engineering Note BW7892, Rev. February 8, 1982.

2. A.J. Dancosse, "IHM 6 Magnet 35° Bending Magnet", LBL Engineering Drawing No. 19P5046B,

3. D.H. Nelson, M.I. Green, "LBL/SSRL Undulator Results of 1980 Magnetic Measurements", LBL Electronics Engineering Note MT 292, p. 40, December 15, 1980.

DISTRIBUTION

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Device	Description
Magnet	Bevatron Injector Magnet IHM 6 (BL17MH Assy. Drwg. 19P5046B
Magnet Power Supply	LBL Electronics Drwg. No. 9Y7475
Shunt	Bev 2000 A #36 - 24.96 μΩ July, 1965
Voltmeter 1	Dixson Mod VT200 DOE 196363
Milling Head	LBL x and z lead screws with scales
Linear Positioner	LBL - 16 inches (y - motion)
Bias Supply Module	LBL Electronics Drwg. No. 6V1392
Voltmeter 2	Keithley Mod 6V1392 177 microvolt DMM S/N 10445
Hall Probe	F.W. Bell Mod HTJ40618 S/N 110242
Gaussmeter	F.W. Bell Mod 811A DOE 519117
x y Plotter	Moseley Mod 7000AR DOE 159260
Calculator	H.P. Mod 97 DOE 509819

TABLE II Equipment List

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