Title

MAGNETIC MEASUREMENTS OF A SINGLE 8"" LONG QUADRIPOLE WITH 4"" BORE. SUMMARY OF TESTS MADE FROM 5-5-55 TO 5-10-55. 8"" ASSEMBLY DWG. 5A3686-1 COILS DWG. 5A3576.

Author

Ratner, Lazarus G.

Publication Date

1955-10-03

UCRL 8163 c.1

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

[redacted]

BERKELEY, CALIFORNIA

DISCLAIMER

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

ENGINEERING NOTES

JOB NUMBER	FILE NO.	PAGE
4902-02	MT-32	1/8

SUBJECT: Magnetic Measurements of a Single 8" long Quadripole with 4" Bore. Summary of tests made from 5-5-55 to 5-10-55. 8" Assembly dwg. 5A3686-1 Coils dwg. 5A3576

NAME: L. G. Ratner

DATE: October 3, 1955

Tests were made to check the design flux density of the magnet, to find the magnet current for a field gradient of 3000 gauss/inch, to check maximum power ratings and water interlocks, and to check the aberration and focus for both convergent and divergent rays.

The flux density was measured as a function of current at a point P located at $Z = 0$, $\theta = 45°$, $R = 1\frac{7}{16}$ inches. See page 4 of this note for a drawing of coordinate system. A graph of flux density vs. magnet current is presented as page 5 of this note and a plot of field gradient vs. current appears as page 6. Magnetic field as a function of radius is shown on page 7. These measurements were made using a Rawson-Lush rotating coil gaussmeter whose absolute accuracy is ± 1%.

Maximum power ratings and water interlock requirements are presented in E. N. 7900-61 M1.

For measurements of aberration and focus a wire trajectory method was used. The energy of a particle and its motion in a magnetic field can be represented by the current and tension in a wire.

$$B\rho \text{ (gauss-cms.)} = \frac{T \text{ (dynes)}}{i \text{ (abmps)}}$$

$$B\rho \text{ (gauss-inches)} = \frac{T \text{ (grams)} \times 980}{i \text{ (amps)} \times 0.1} \times \frac{1}{2.54}$$

All tests were made with 504.7 grams providing the tension on a wire consisting of 14 strands of #44 with a silk braid insulation.

$$B\rho \text{ (gauss-inches)} = \frac{1.947 \times 10^6}{i \text{ (amps)}}$$

The quadripole was mounted with axis horizontal and the pole tips at 45° from vertical. Magnet current and wire current were in directions that the rays were convergent horizontally and divergent vertically.

Measurements were made by determining the coordinates of the wire in space at two planes separated by about one hundred inches. From these coordinates the slope of a trajectory for several rays was determined and the image focal distance fi found at the point of intersection. For these experiments the object distance fo was fixed at 151 inches. From this the focal lengths F were calculated.

$$F = \frac{fi\,fo}{fi + fo}$$

Then the effective length L of the quadripole can be determined from

$$F_c = \left(\sqrt{dB/dR\ 1/B\rho}\ \text{Sin}\ L\ \sqrt{dB/dR\ 1/B\rho}\right)^{-1} \quad \text{or}$$

approximately $F = \dfrac{B\rho}{L\ dB/dR}$

From the horizontal coordinates, the convergent fi was calculated, and from the Y coordinates, the divergent fi was calculated.

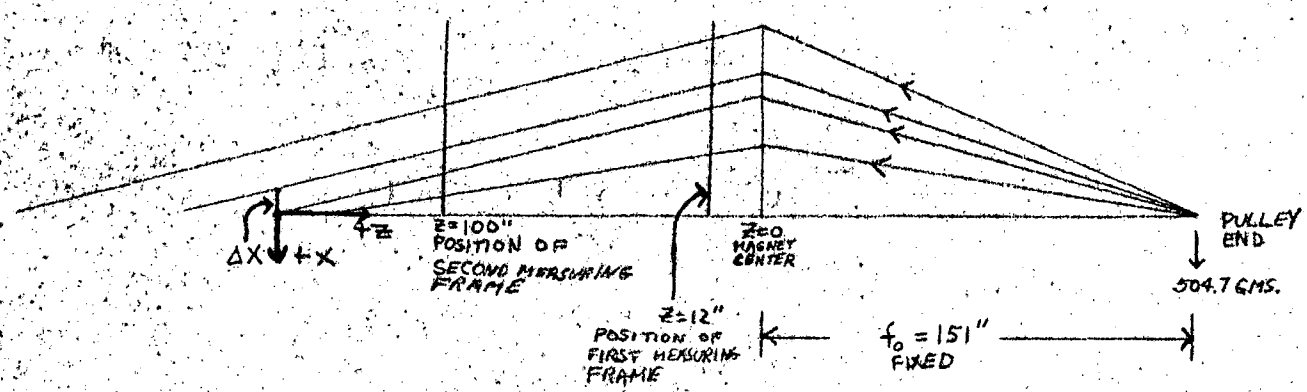
The results of the measurements of focal length are tabulated on page 3 of this note.

The aberration in focus was maximum and measurable in the Y = 0 plane. In other horizontal planes the focus varied only slightly. At Y = ± 3/4 aberration at the limits of the aperture was least and unmeasurable.

In the X = 0 plane no aberration was detected within the experimental error. With divergent rays, the paths cannot approach the limits of the aperture where convergent aberration does occur.

The aberration for Y = 0 was expressed as the distance ΔX that the trajectory missed the focal point of the central rays, as a function of where the trajectory intersected the plane Z = + 4. [An actual trajectory is curved for about 5 inches from center and the actual value of $X_Z = 0$ is about equal to the straight line value at Z = 2½. The projected value of $X_Z = 4$ is only 1% less than $X_Z = 0$]. The results are graphed on page 8.

SCHEMATIC TEST SET UP
PLAN VIEW Y=0 PLANE



Initial Distribution:

MTEN File, Book No. 197
E. Segre
O. Chamberlain
C. Weigand
L. Kerth
J. Vale
J. Sandweiss
W. Salsig
R. Kilpatrick
E. Lofgren
E. Hubbard
E. Kelly
L. Stevenson
R. Young
B. Cork
R. Tripp

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

ENGINEERING NOTES

JOB NUMBER 4902-02 | FILE NO. MT-2 | PAGE 3/8

SUBJECT Magnetic Measurements of a Single 8" long Quadripole with 4" bore. Summary of tests made from 5-5-55 to 5-10-55. 8" Assembly dwg. 5A 3686-1 Coils dwg. 5A 3576

NAME L. G. Ratner

DATE October 3, 1955

Test No.	1	2	3	4	5	6
Date (1955)	5/5	5/6	5/6	5/10	5/10	5/10
Wire Current (amps.)	.753	.848	1.096	1.694	1.390	2.100
$B\rho$ (10^6 gauss-inches)	2.59	2.30	1.775	1.15	1.40	.927
Proton Mev	1250	1050	710	350	490	240
Deuteron Mev	850	700	430	190	280	130
dB/dR (gauss/inch)	3080	3195	2490	1589	1947	1291
F_c measured (inches)	89.14	75.65	75.05	75.37	76.51	75.30
F_d measured (inches)		73.6	72.7	71.9		
Fd/Fc x 100%		96.8%	96.8%	95.4%	See note (2)	
L theorectical	9.61	9.73	9.69	9.81	9.61	9.74 → av. 9.70
L theor. approx. formula	9.43	9.52	9.50	9.60	9.40	9.53 → av. 9.50

(1) Note: The above information applies in the range measured $75" < F_c < 90"$

(2) Note: From theory $Fd/Fc \approx \frac{\sin \phi}{\sinh \phi}$. Within the experimental error this agrees with actual measurements. For a $\phi = .37$ (which is in the range observed) $Fd/Fc \propto \frac{\sin \phi}{\sinh \phi} = \frac{.3616}{.3785} = 95.5\%$

$$\phi = L\sqrt{\frac{dB}{dR}\,\frac{1}{B\rho}}$$

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

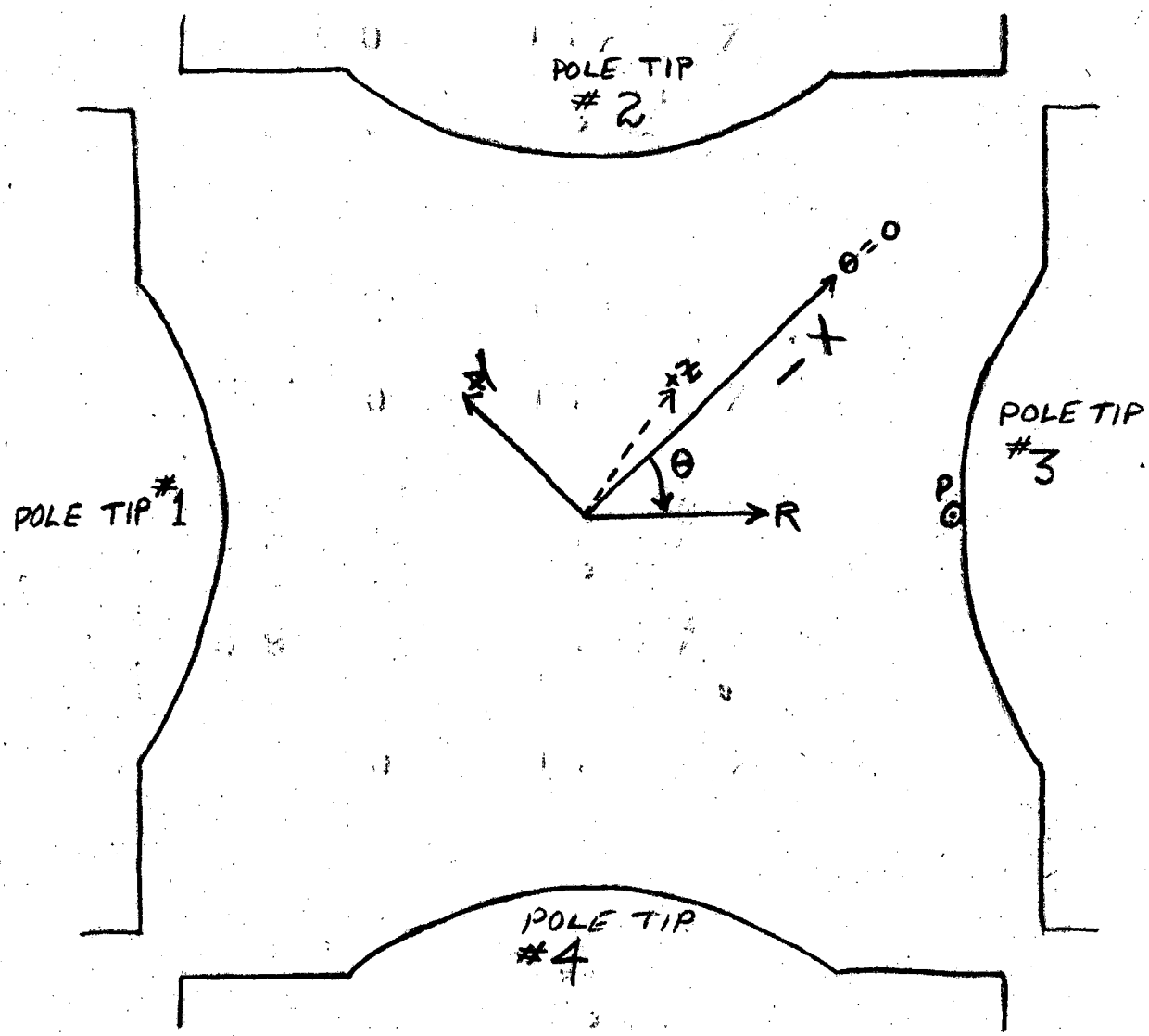
ENGINEERING NOTE

JOB NUMBER	FILE NO.	PAGE
4902-02	MT-2	4/8

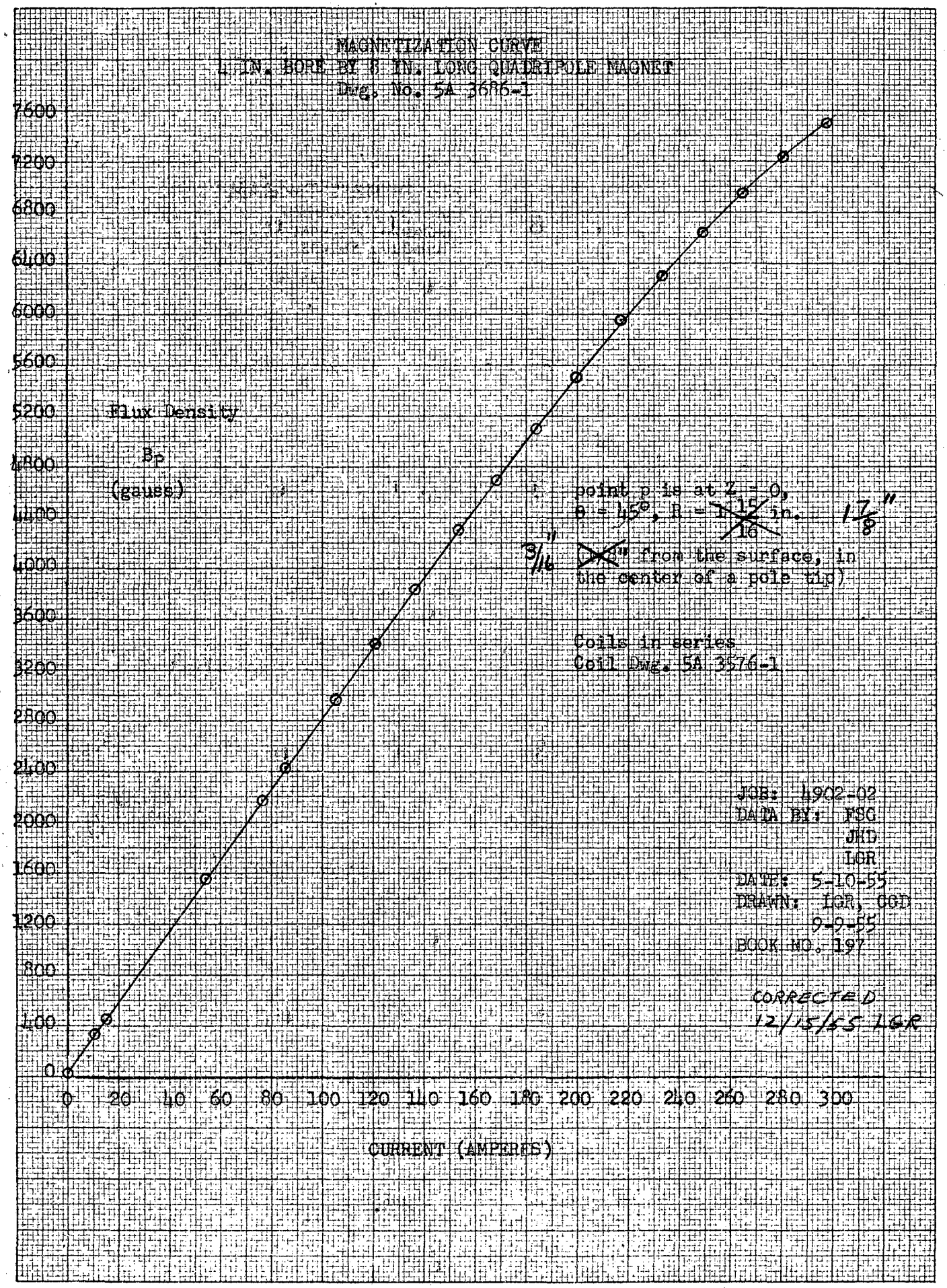
SUBJECT Magnetic Measurements of a Single 8" long Quadripole with 4" bore. Summary of tests made from 5-5-55 to 5-10-55. 8" Assembly dwg. 5A 3686-1 Coils dwg. 5A 3576

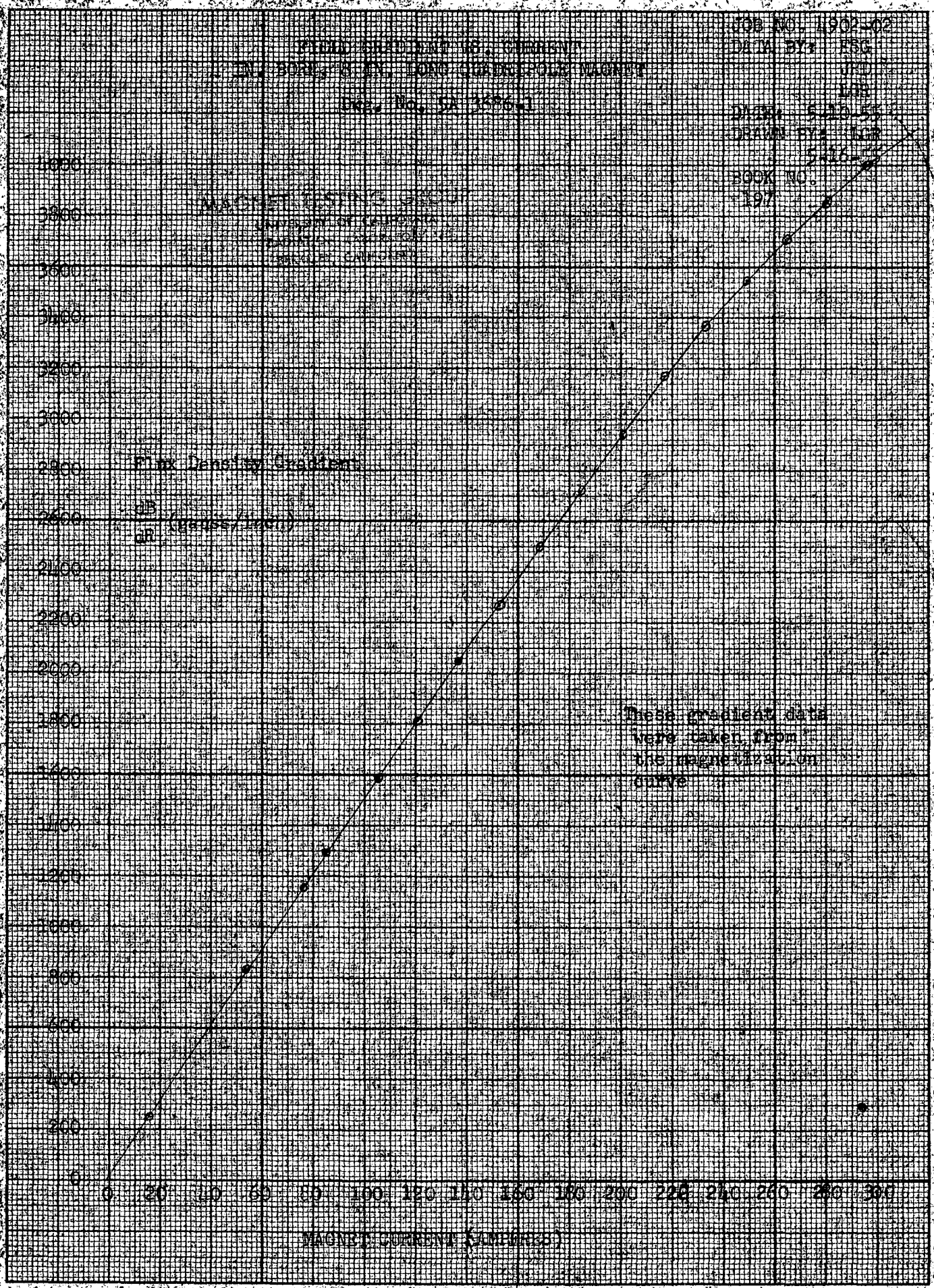
NAME L. G. Ratner

DATE October 3, 1955



RL-398

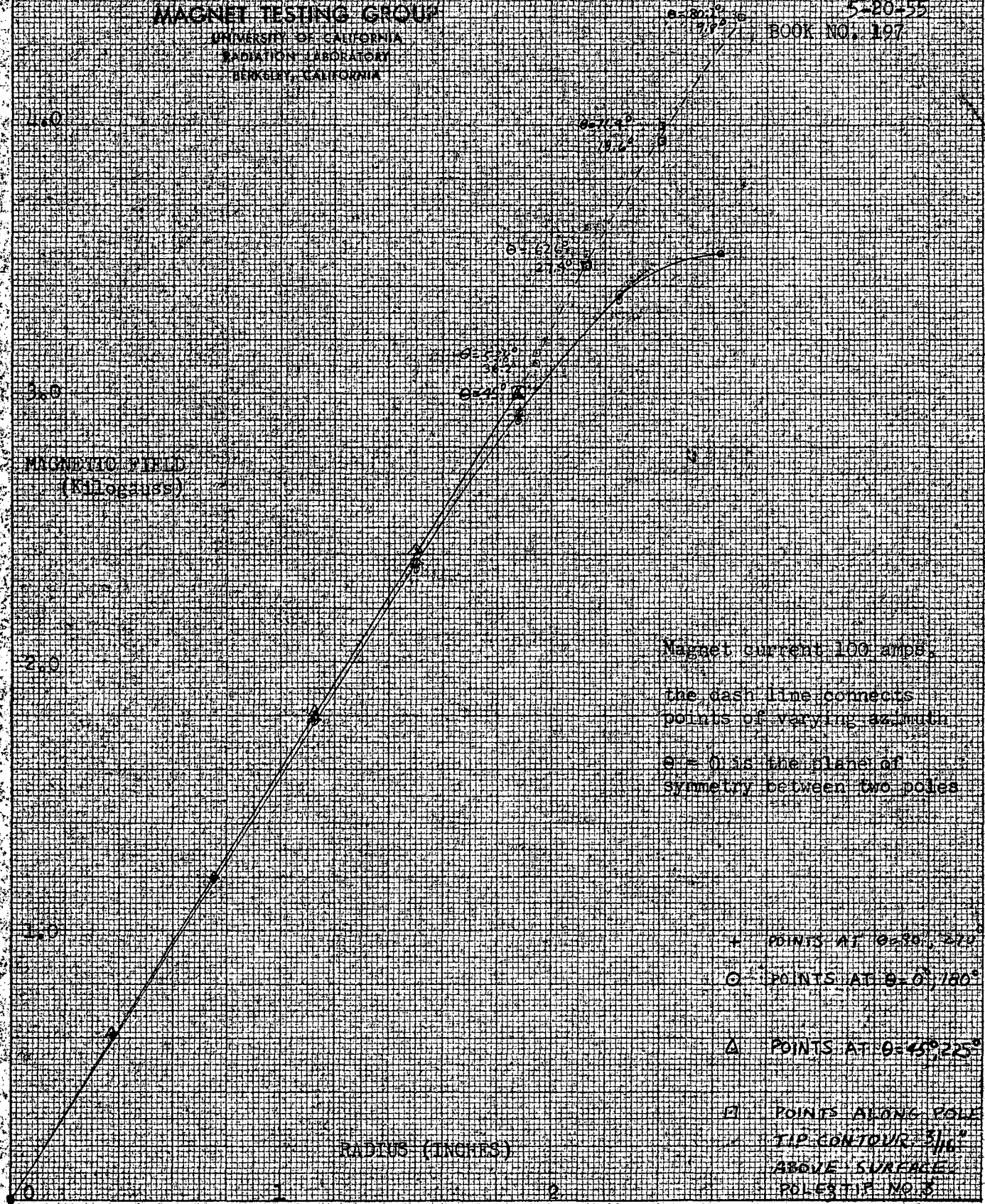



FIELD GRADIENT VS. CURRENT
4 IN. BORE, 8 FT. LONG QUADRUPOLE MAGNET
Dwg. No. SA 34961
JOB NO. 4902-02
DATA BY: FSG
JRO
LGB
DATE: 6-20-55
DRAWN BY: LGB
5-16-55
BOOK NO.
197
MAGNET TESTING SECT.
UNIVERSITY OF CALIFORNIA
RADIATION LABORATORY
BERKELEY, CALIFORNIA
Flux Density Gradient
dB/dR (gauss/inch)
These gradient data were taken from the magnetization curve
MAGNET CURRENT (AMPERES)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300

FIELD VS. RADIUS
4 IN. BORE BY 8 IN. LONG QUADRIPOLE MAGNET
Dwg. No. 5A 3686-1

JOB NO. 4902-02
DATA BY: FSG
JHD
LGR
DATE: 5-10-55
DRAWN BY: LGR
5-20-55
BOOK NO. 197

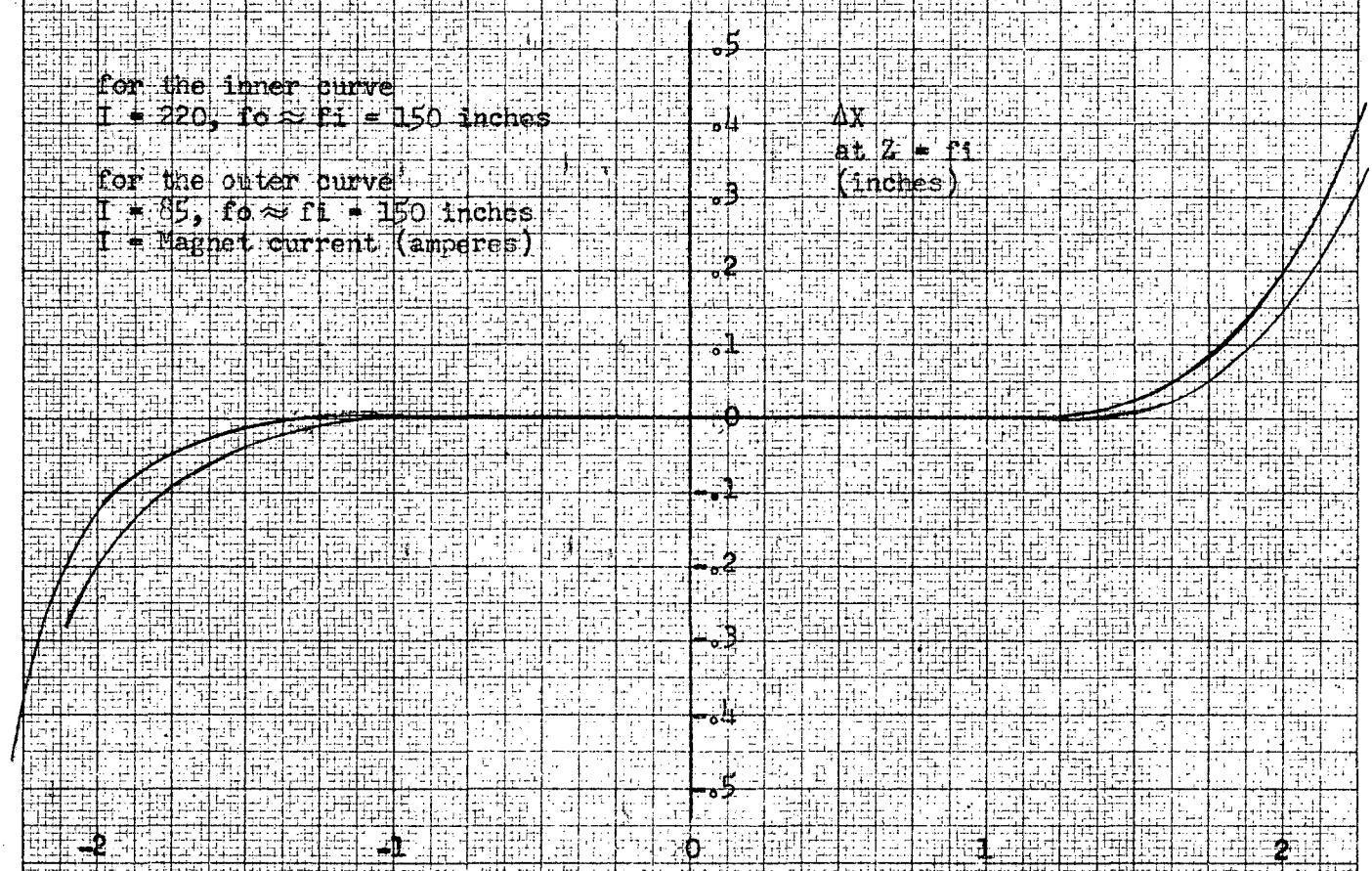
MAGNET TESTING GROUP
UNIVERSITY OF CALIFORNIA
RADIATION LABORATORY
BERKELEY, CALIFORNIA



ABERRATION IN Y = 0 PLANE
ΔX at Z = fi VS. X at Z = 4 IN.

4 IN. BORE BY 8 IN. LONG QUADRIPOLE MAGNET
Dwg. No. 5A 3686-1

JOB NO. 4902-02
DATA BY: FSG
JHD
LGR
DATE: 5-6-55
5-10-55
DRAWN BY: LGR
5-18-55
BOOK NO. 197



X - POSITION AT Z = 4 IN. (INCHES)

ΔX is the radius of the "circle of confusion"
Z = 0 is the center of the magnet
The y = o plane is the θ = 0 plane and is the plane of symmetry between two adjacent poles.
These curves are from interpolations of measurements of the positions of flexible wire "rays".