UCRL 192 Cy 82/A

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

BERKELEY, CALIFORNIA

UCRL-192 c.2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

UNIVERSITY OF CALIFORNIA
Radiation Laboratory

Cover Sheet
Do not remove

INDEX NO. UCRL-192
This document contains 6 pages
and 7 plates of figures.
This is copy 82 of 98. Series A

Issued to: Du Po. D.i.

RESTRICTED

Classification

CLASSIFICATION CANCELLED BY AUTHORITY
OF THE PROJECT ENGINEER
BY THE DECLASSIFICATION COMMITTEE

Each person who received this document must sign the cover sheet in the space below.

Route to	Noted by	Date	Route to	Noted by	Date
	M				

UCRL-192

Physics-Instrumentation

RESTRICTED

CLASSIFICATION CANCELLED BY AUTHORITY OF THE DISTRICT ENGINEER BY THE DECLASSIFICATION COMMITTEE

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

Contract No. W-7405-Eng-48

MAGNETIC DEFLECTOR FOR MESONS PRODUCED IN THE 184-INCH CYCLOTRON

Wolfgang K. H. Panofsky and Ernest A. Martinelli

October 11, 1948

Berkeley, California

Special Review of Declassified Reports
Authorized by USDOE JX Bratton
Unclassified TWX P182205Z May 79

REPORT PROPERLY DECLASSIFIED

J N Green 8/16/79
Authorized Derivative Classifier Date

R K Hunt 8/17/79
By Date

CANCELLED BY AUTHORITY
DISTRICT ENGINEER
FROM COMMITTEE

Standard Distribution	Copy Nos.
Argonne National Laboratory	1-8
Armed Forces Special Weapons Project	9
Atomic Energy Commission, Washington	10-11
Battelle Memorial Institute	12
Brookhaven National Laboratory	13-18
Carbide & Carbon Chemicals Corp. (K-25 Area)	19-22
Carbide & Carbon Chemicals Corp. (Y-12 Area)	23-26
Columbia University (Dunning)	27
Columbia University (Failla)	28
General Electric Company	29-32
Hanford Directed Operations	33-39
Iowa State College	40
Kellex Corporation	41-42
Los Alamos	43-45
Massachusetts Institute of Technology	46
Monsanto Chemical Company, Dayton	47-48
National Bureau of Standards	49-50
Naval Radiological Defense Laboratory	51
NEPA	52
New York Directed Operations	53-54
Oak Ridge National Laboratory	55-62
Patent Advisor, Washington	63
Technical Information Division, ORDO	64-78
UCLA Medical Research Laboratory (Warren)	79
University of California Radiation Laboratory	80-84
University of Rochester	85-86
Western Reserve University (Friedell)	87
Chicago Directed Operations	88
Declassification Procedure	
Declassification Officer	89-92
Publication Officer	93
Patent Department	94-95
E. O. Lawrence	96
Area Manager	97
Information Division	98
Total	98

Information Division
Radiation Laboratory
University of California
Berkeley, California

RESTRICTED
CLASSIFICATION CANCELLED BY AUTHORITY OF THE ENGINEER
BY THE DECLASSIFICATION COMMITTEE

Magnetic Deflector for Mesons Produced in the 184-Inch Cyclotron

Wolfgang K. H. Panofsky and Ernest A. Martinelli

The artificial production of mesons by means of high energy α-particles in the 184-inch cyclotron at Berkeley[1] indicated the desirablility of making mesons available outside the cyclotron tank in order to make investigations possible by means other than photographic plates inside the tank. A magnetic deflector to draw mesons out into a re-entrant chamber in the cyclotron wall was therefore constructed.

The circulating α-particle beam strikes a target at a radius of 80 1/2" from the center of the cyclotron. The magnetic field at the target position is close to 14,000 gauss, so that low energy mesons are unable to leave the cyclotron. The magnetic deflector consists simply of a magnetic shield placed in such a manner that it shields the meson beam and permits it to enter a re-entrant chamber in the cyclotron wall. (Fig. 1).

A magnetic shield for this purpose has to meet four requirements: 1. The field in the channel must be sufficiently low to permit exit of the mesons from the field. 2. It must have a sufficiently high geometrical aperture. 3. The shield must not disturb the field at a radius less than target radius. 4. The shield must not interfere with the electrostatically deflected beam[2] in the cyclotron.

The problem of shielding magnetically to a sufficient extent in an external field of 14,000 gauss is made difficult by the saturation of iron. Saturation effects are reduced if the shield is not circular but has its large dimension perpendicular to the field; this will only give a small increase in flux density in the iron relative to

---

[1] E. Gardner and C. M. G. Lattes, Science, 107, 270, (1948).

[2] W. M. Powell, L. R. Henrich, Q. A. Kerns, D. C. Sewell, and R. L. Thornton, Rev. Sci. Inst., 19, 506, (1948).

the external field. These considerations lead to the choice of a shield approximately an ellipsoid whose smallest axis is parallel to the field. The ellipsoidal shape is superior to any rectangular geometry since corners would saturate and thus not contribute to the shielding while still contributing to the disturbing field.

The ellipsoidal shape can be easily analyzed mathematically for a given magnetization curve of the iron used. Fig. 2 shows a theoretical plot of the shielding ratio attainable with an oblate spheroidal[3] shield with a small cylindrical hole inside the spheroid. The curve is computed for cold rolled steel in an external field of 14,000 gauss. Note the rapid improvement of the attainable shielding ratio with increase in axial ratio of the ellipsoid. An axial ratio of 4:1 was chosen here.

The theoretical disturbance in the field due to the ellipsoid is shown in Fig. 3 for an ellipsoid of 12 in. x 3 in. axis. The shield was placed 3 1/2" from the target radius, thus disturbing the field by approximately 3 1/2%. This disturbance is compensated by shims supported on the cyclotron poles, in accordance with the method of Powell, et al[4]. A radial experimental field plot and the field corrected by the shims is shown in Fig. 4. The position and geometry are also shown in Fig. 4.

Owing to the fact that the shielding action of the iron cannot be computed accurately it was necessary to estimate the meson trajectory first, construct a deflector, compute the trajectory and then build a new deflector to conform to the computed trajectory. The final shape of the shield and the position of the meson trajectory is shown in Fig. 5. Fig. 6 shows the magnetic field in the channel with and without the shield. Owing to the curvature of the trajectory and the ellipsoidal cross section of the shield, the shield is constructed of 12 layers of hot rolled steel plate, flame-cut to proper shape and bolted together. The hole for the trajectory tapers from an initial hole of 1 1/2 in. vertical x 1 in. horizontal to 2 1/2 in. x 2 1/2 in. square at the exit end. Fig. 7

---

[3] For solution of potential problem, see e.g. Smythe, Static and Dynamic Electricity, McGraw-Hill, 1939, pp. 156 ff.

[4] Powell, et al. loc. cit.

shows the assembled deflector.

The deflector is designed for a central trajector corresponding to B x ρ = 147,000 gauss-cm, corresponding to an 8.5 Mev μ-meson (taking the mass of the μ-meson as 215 m_e) or a 6.0 Mev π-meson (taking the mass of the π-meson as 286 m_e). The deflector will accept beams of vertical divergences of $\pm$ 6°, horizontal divergences of $\pm$ 7.2° (at central value of energy); the range of momenta accepted is $\pm$ 12% about the central value.

At this date the deflector has been used only in conjunction with the photographic mesons of detection. With a cyclotron bombardment of 3 x 10^{-7} amp of α-particles for 30 minutes the meson yield is about 30 π mesons in the edge of a 100 micron emulsion; this corresponds to a total flux of about 500 mesons/minute out of the aperture of the deflector.

The problem of deflecting mesons by means of a magnetic shield was suggested by Prof. L. W. Alvarez. We are greatly indebted to the magnetic measurements group of the laboratory, notably D. C. Sewell and A. J. Hulse for making magnetic measurements and to Prof. Wilson Powell for valuable discussion. This work was performed under the auspices of the Atomic Energy Commission.

RLID/hw
10-19-48

Figure Captions

Fig. 1 - Geometrical Distribution of Meson Deflector and Target in the Magnet of the 184-inch Cyclotron. Note the Trajectory of the Alpha-particle Beam and the Mesons Produced in the Target.

Fig. 2 - Theoretical Shielding Ratio of an Oblate-spheroidal Shield with Cylindrical Hole as a Function of Axial Ratio of the Spheroid in an External Field of 14,000 Gauss.

Fig. 3 - Per cent Field Disturbance due to Spheroidal Shield of Axial Ratio 1 to 4 on the Magnetic Field in the Cyclotron.

Fig. 4 - Radial Magnetic Field in the Cyclotron under the Following Conditions: (a) Before Introduction of Meson Deflector. (b) After Introduction of Meson Deflector, but Uncompensated. (c) Meson Deflector in Place and Compensated with Shims as Shown.

Fig. 5 - Meson Trajectories from Target Through Meson Deflector, as Plotted from Field Measurements.

Fig. 6 - Experimental Magnetic Field as a Function of Position Along Meson Trajectory Through Meson Deflector.

Fig. 7 - Photograph of Meson Deflector in Retracted Position.

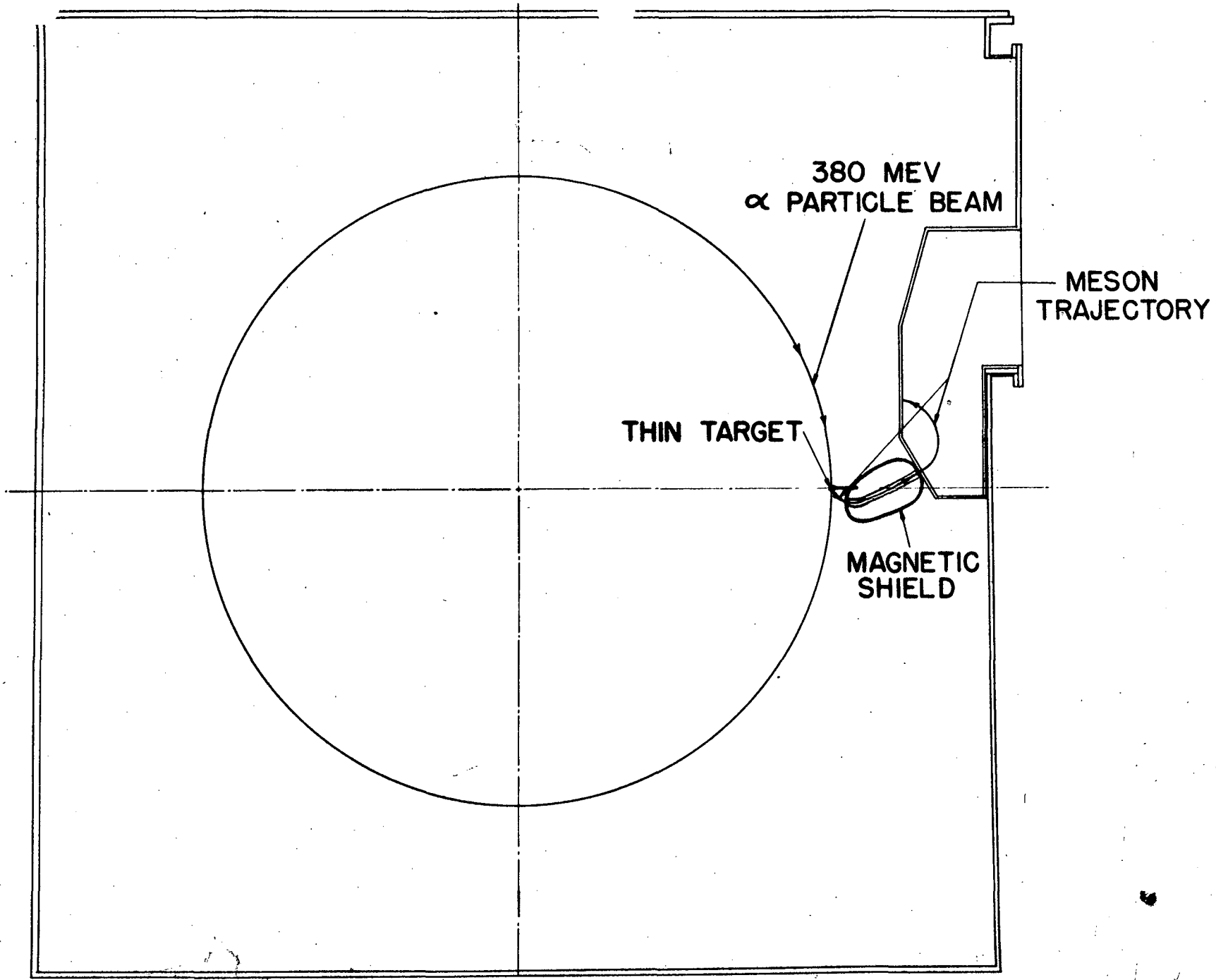

380 MEV
α PARTICLE BEAM
MESON
TRAJECTORY
THIN TARGET
MAGNETIC
SHIELD

FIG 1

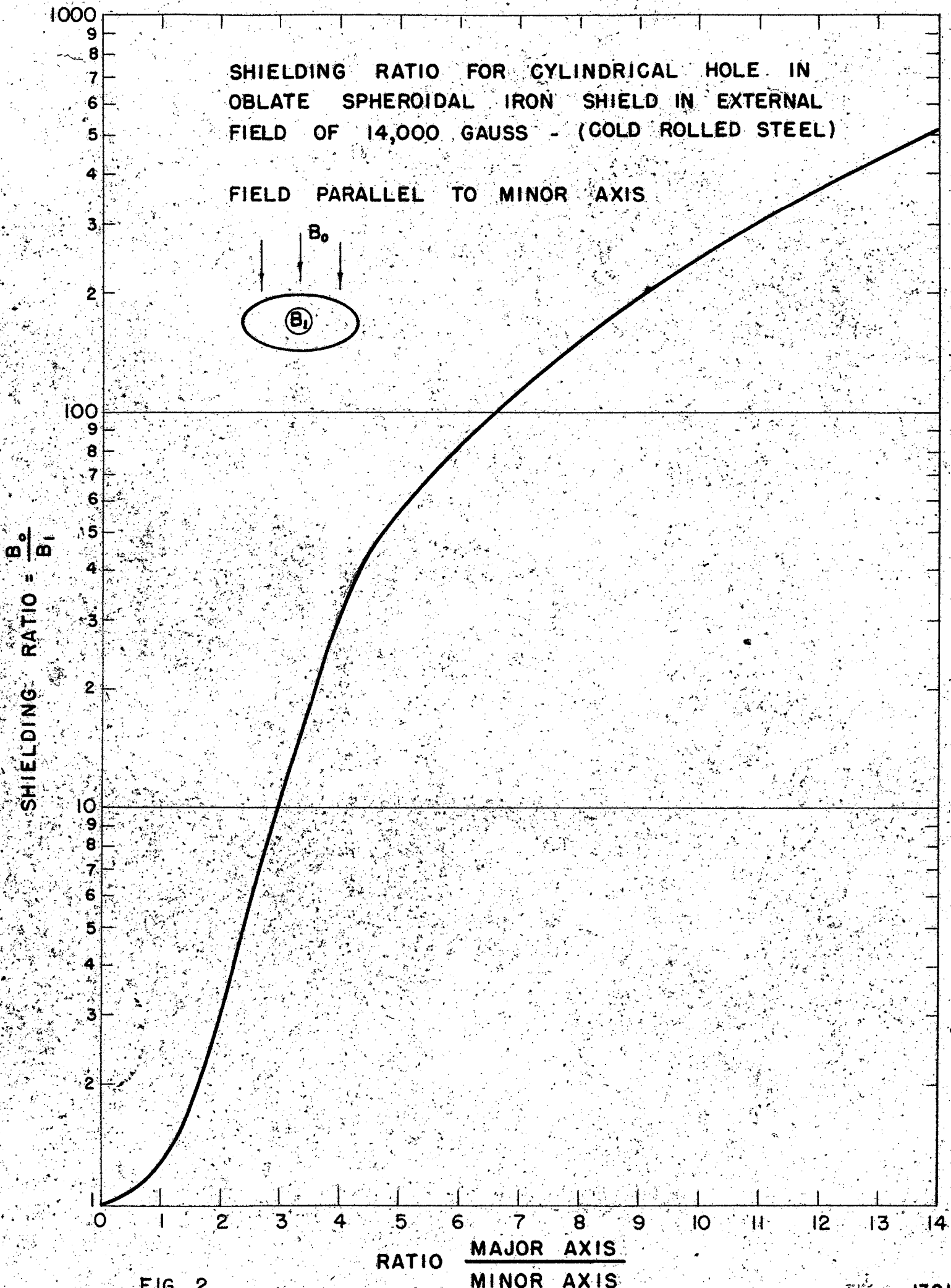

SHIELDING RATIO FOR CYLINDRICAL HOLE IN OBLATE SPHEROIDAL IRON SHIELD IN EXTERNAL FIELD OF 14,000 GAUSS - (COLD ROLLED STEEL)
FIELD PARALLEL TO MINOR AXIS
B_o
B_I
SHIELDING RATIO = $\frac{B_o}{B_I}$
1000
100
10
1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
RATIO $\frac{\text{MAJOR AXIS}}{\text{MINOR AXIS}}$

FIG. 2

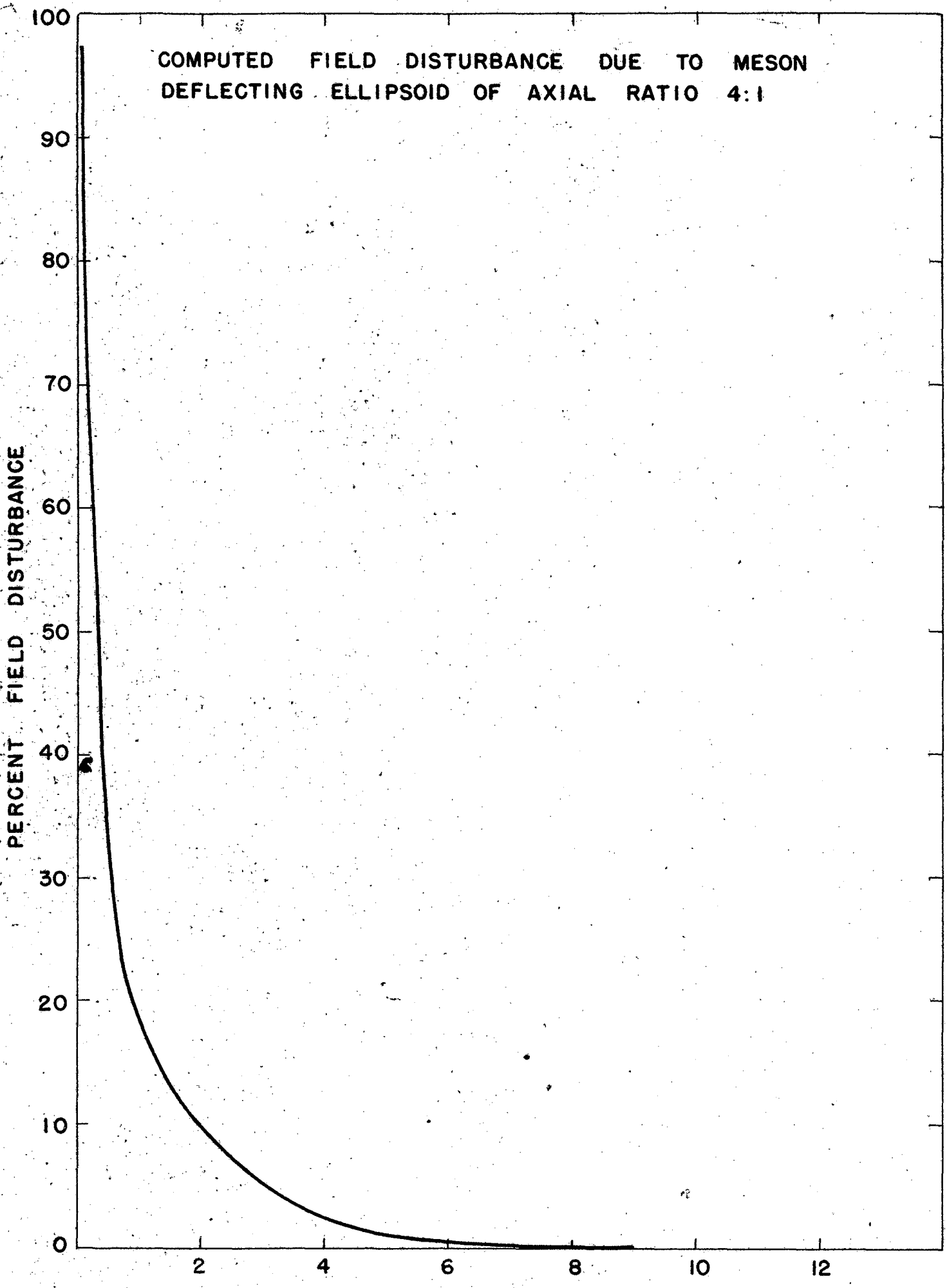

COMPUTED FIELD DISTURBANCE DUE TO MESON
DEFLECTING ELLIPSOID OF AXIAL RATIO 4:1
PERCENT FIELD DISTURBANCE
100
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
RADIAL DISTANCE FROM EDGE OF DEFLECTOR

FIG. 3

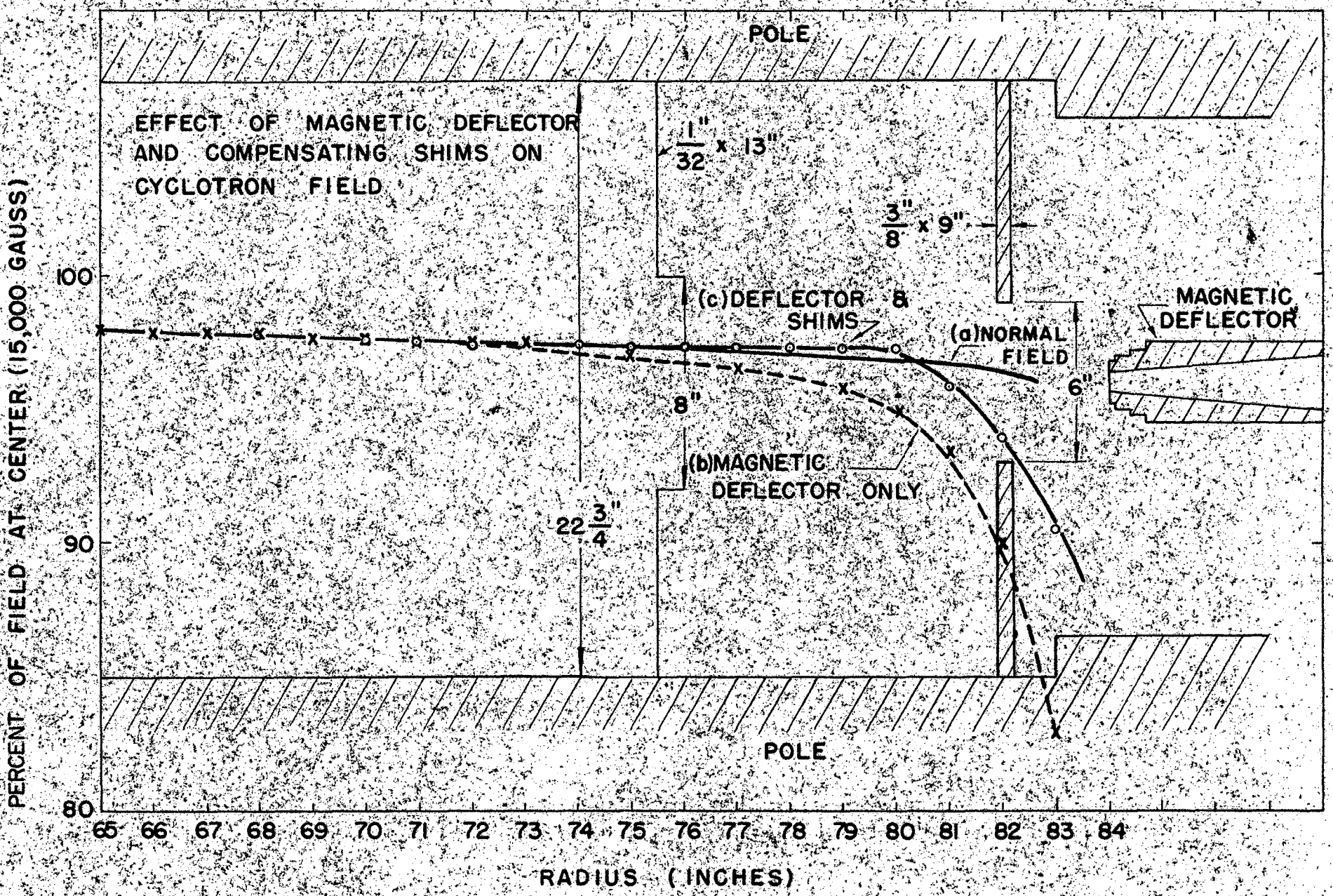
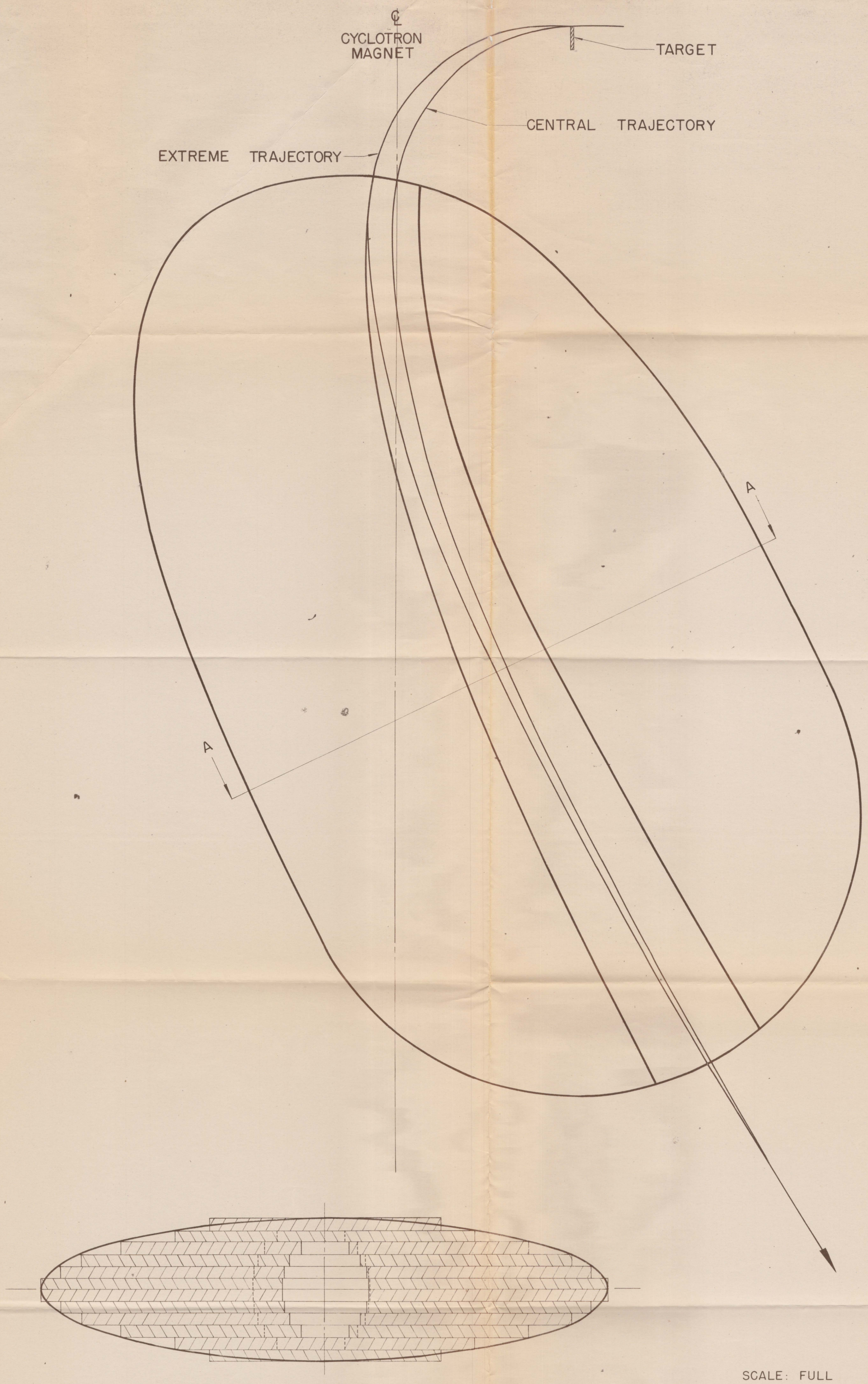

EFFECT OF MAGNETIC DEFLECTOR AND COMPENSATING SHIMS ON CYCLOTRON FIELD
POLE
POLE
1"/32 x 13"
3"/8 x 9"
(c) DEFLECTOR & SHIMS
(a) NORMAL FIELD
(b) MAGNETIC DEFLECTOR ONLY
MAGNETIC DEFLECTOR
8"
6"
22 3/4"
PERCENT OF FIELD AT CENTER (15,000 GAUSS)
100
90
80
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
RADIUS (INCHES)

FIG. 4



SCALE: FULL

FIG. 5

13018-4

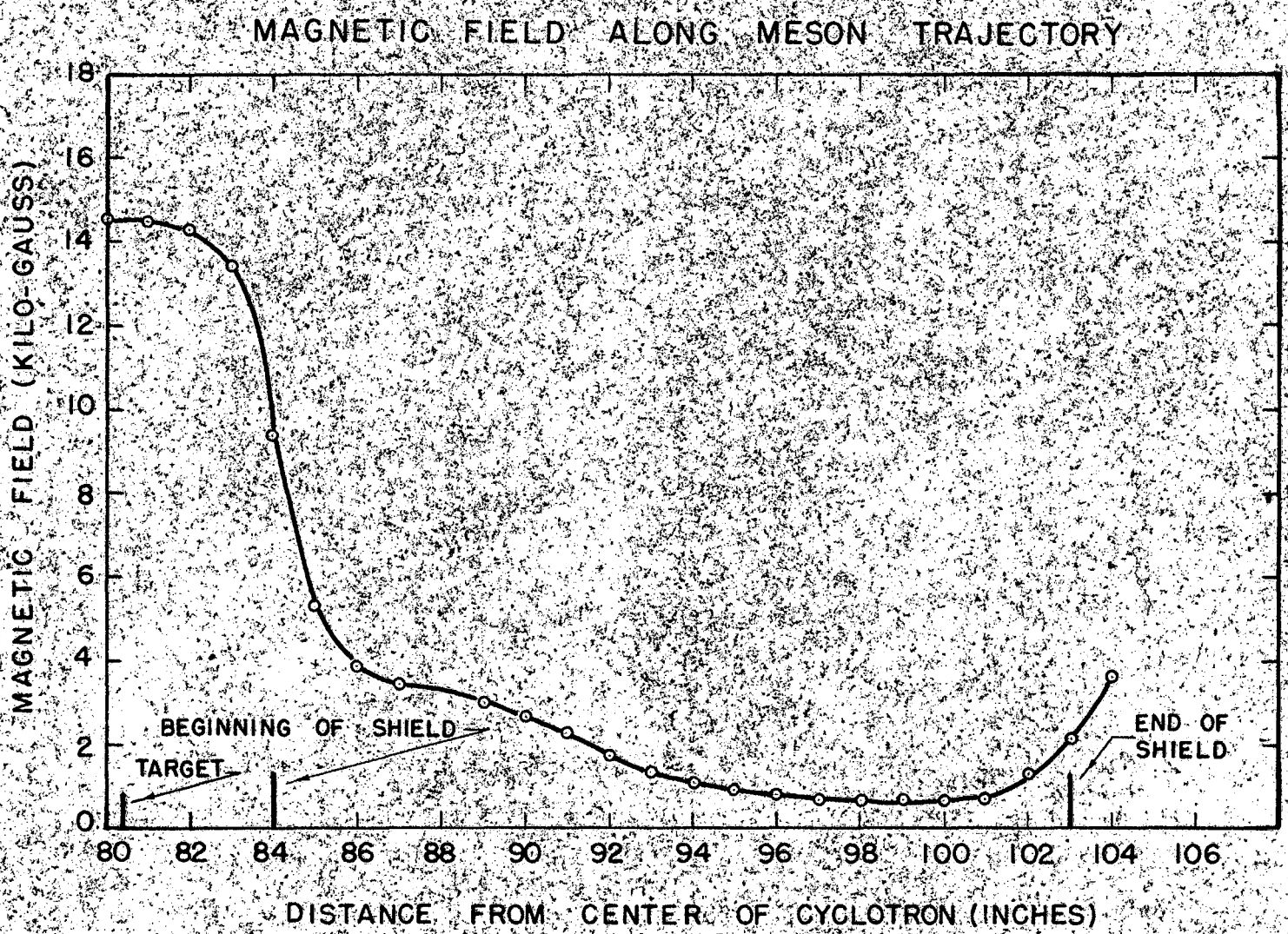

MAGNETIC FIELD ALONG MESON TRAJECTORY
MAGNETIC FIELD (KILO-GAUSS)
0
2
4
6
8
10
12
14
16
18
80
82
84
86
88
90
92
94
96
98
100
102
104
106
DISTANCE FROM CENTER OF CYCLOTRON (INCHES)
TARGET
BEGINNING OF SHIELD
END OF SHIELD

FIG 6

OZ-225

RESTRICTED
CLASSIFI... BY AUTHORITY
BY THE DE... ENGR FOR
BY THE DE... COMMITTEE