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GAMMA RAY ATTENUATION EXPERIMENT REFERENCES

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Contract No. W-7405, eng 26*

ORNL SUMMER SHIELDING SESSION

Gale Young, Leader

GAMMA RAY ATTENUATION EXPERIMENT REFERENCES

J. L. Powell

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DATE ISSUED: JAN 26 1950
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* See Explanation on page 3.

This report is one of a series on shielding and represents part of the work of a summer group working principally at Oak Ridge National Laboratory. Participants are drawn from Nuclear Development Associates (Navy contract), NEPA, Bureau of Ships and Bureau of Aeronautics (Navy Department), AEC, RAND, General Electric, Argonne and Oak Ridge National Laboratory.

*These reports are issued at ORNL on Contract No. W-7405, eng 26.

GAMMA RAY ATTENUATION EXPERIMENT REFERENCES

J. L. Powell

(1) J. H. Roberson, ORNL Central File No. 48-7-380; see Appendix I

(2) L. B. Borst and E. O. Wollan, CP-378; see Appendix II

(3) H. O. Wyckoff and R. J. Kennedy, Concrete as a Protective Barrier for Gamma Rays From Radium, Jour. Res. Nat. Bur. Standards 42, 431 (1949); narrow and broad beam experiments with concrete and lead slabs.

See also 41, 223 (1948) of the same journal, or Nucleonics for November of 1948, for similar experiments with 500 to 1400 kilovolt X rays.

Similar experiments on the attenuation in concrete, lead, steel of gamma rays from Co 60 will be published in the Bureau Journal.

(4) J. H. Roberson, ORNL Central File No. 48-7-330:

"The intensity at four feet from the center of the Lanthanum carrier was measured. The dosage rate is reduced to $\frac{1}{230,000}$ of its no shield value. The carrier is essentially a cylinder, with its height equal to its diameter. The source is in a cylindrical cavity 7 cm in diameter and 9.3 cm long. Absorbing material between the source and instrument was about .8 cm of steel, 23.25 cm lead, 1.7 cm steel in that order."

(5) P. G. Koontz, LA-302; see Appendix III

(6) E. C. Barker, The Average Gamma Energy Emitted per Beta Particle for Several Radio-active Sources, MDDC-838

(7) J. H. Roberson, unpublished data on a 0.18 curie Co 60 source in a series of lead spheres: 1.3 Mev γ rays, absorption coefficient = 0.0585 g/cm^2 or 0.644 per cm

Cm wall thickness	x = number of mean free paths	measured intensity divided by e^{-x}
0	0	1
3.3	2.12	1.67
6.1	3.92	2.27
7.6	4.89	2.39
10.8	6.95	2.68
18	11.6	2.97

The last point is quite uncertain. Roberson does not vouch for the accuracy of this data.

(8) H. Feshbach et al, Final Report on the MIT Project in High Voltage Radiography, OSRD No. 4488, declassified; Vol. 4; Production, Absorption and Scattering of High Voltage X-Rays. Abstract given in Phys. Rev. 60, 691, (1946).

(9) Work of Faust et al at Naval Research Laboratory; e.g. NRL Report No. N-3265, and further work on point and plane Co^{60} sources in water to be published in Physical Review.

APPENDIX I

Excerpts From CF-48-7-380

The experiment was conducted in a large field near the X-10 area by members of the Health Physics Division of Oak Ridge National Laboratory under the supervision of Dr. John H. Roberson.

A strip 10 feet wide and 1,900 feet long was cleared of vegetation and graded by the Engineering and Maintenance Division, Mr. J. C. Stewart, Director. The strip was leveled to within an estimated 1 foot tolerance, except for a dip between 1,300 and 1,700 feet, where the point of minimum elevation was about 6 feet below the source level. Distances from the zero point were measured and staked by a surveying crew.

The source carrier was placed in a hole at the zero point, so that the top of the carrier was at a ground level. The source was raised from the carrier to a height 9 inches above ground level, by means of a rope and pulley on an overhead frame.

Measurements were made at 3, 6 and 12 feet from the ground. The electroscope was used in preference to a Geiger-Muller counter because of its greater accuracy in measuring roentgens. Lauritsen electroscopes were used, the chamber of which was surrounded by 1/4 inch plywood. Distances from source to electroscope are shown on Figure 1, together with the results of the measurements.

The ordinates in Figure 1 were computed by multiplying the reciprocal of the time of discharge of the electroscope by the square of the distance from source to instrument. The values are corrected for background, which was 1/5 of the total intensity at 1,900 feet. The segment of the curve taken with the medium source was fitted to the large source curve at 500 feet. The data on the smallest source

was fitted to the medium source at 100 feet.

A large portion of the drop in the measured value of intensity times distance squared, apparent for all three sources at small distances, is undoubtedly due to non-saturation in the electroscope chamber in high-intensity fields. Time does not permit further investigation of this result.

The readings at 3, 6 and 12 feet do not differ appreciably at great distances, except at the 1,600 foot position, where the 3 and 6 foot elevations were below the ground level and shielded from the direct beam. At near distances any variation would have been obscured because of the high radiation intensity of the direct beam.

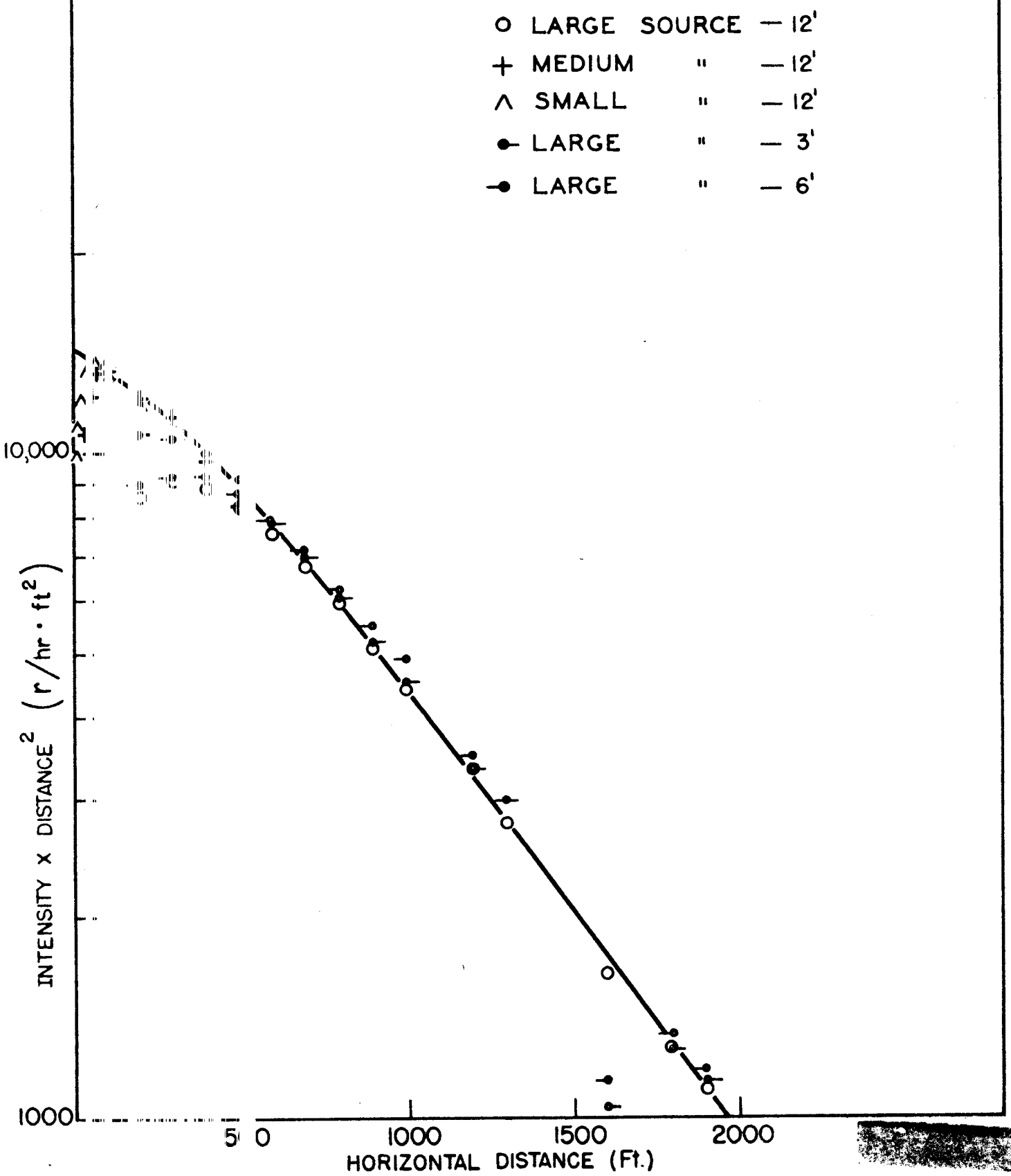
At the 600 foot distance a reading was made beside the truck, and another with the truck moved back to 700 feet. The two readings differed by less than 1% so the scattering from the truck did not introduce a serious error in these measurements.

Each measured value is the average of three readings whose internal consistency was better than 3%. The extrapolated value may be low by as much as 10%, though this is doubtful because of the good agreement between the small and medium source values at 200 and 100 feet.

The half thickness of the straight portion of the curve is 450 feet (130 meters) corresponding to a coefficient of absorption of 5.3×10^{-5} cm^{-1} of air or a relaxation distance of 650 feet (190 meters).

—Fig.1—

La SOURCES



APPENDIX II

Excerpts from CP-378

Absorption measurements have been made in a large body of water to evaluate the contribution to the radiation intensity produced by the degradation of radiation without absorption. Radiation intensities three times those expected from simple exponential absorption were found.

Gamma-ray absorption is usually assumed to involve the complete removal of a photon in a single event. J. A. Wheeler has expanded this theory to include the degradation of quanta by several Compton scatterings and final removal by photoelectric absorption. The absorption law derived for an absorber of large cross section shows positive deviation from exponential absorption. This deviation will be most pronounced when the absorber has a low atomic weight and photoelectric absorption becomes important at low energies. An experimental investigation of the magnitude of this effect has been carried out.

A carbon ionization chamber of 6-1/2" internal diameter and 11-1/2" length was constructed and connected to a Dershem electrometer. The source used was 2 gm. of pure radium placed within a lead cylinder of 1.06 cm = 11.7 gm/cm^2 wall thickness. This source was suspended below the surface of a large body of water so that measurements were taken in a plane perpendicular to the axis of the lead cylinder.

An absorption curve was measured by moving the source to change the absorber thickness. The range of intensities measured was 10^4, and was measured with several electrometer sensitivities. These readings were converted

to the same instrument sensitivity, corrected for electrometer background and corrected for the inverse square law.

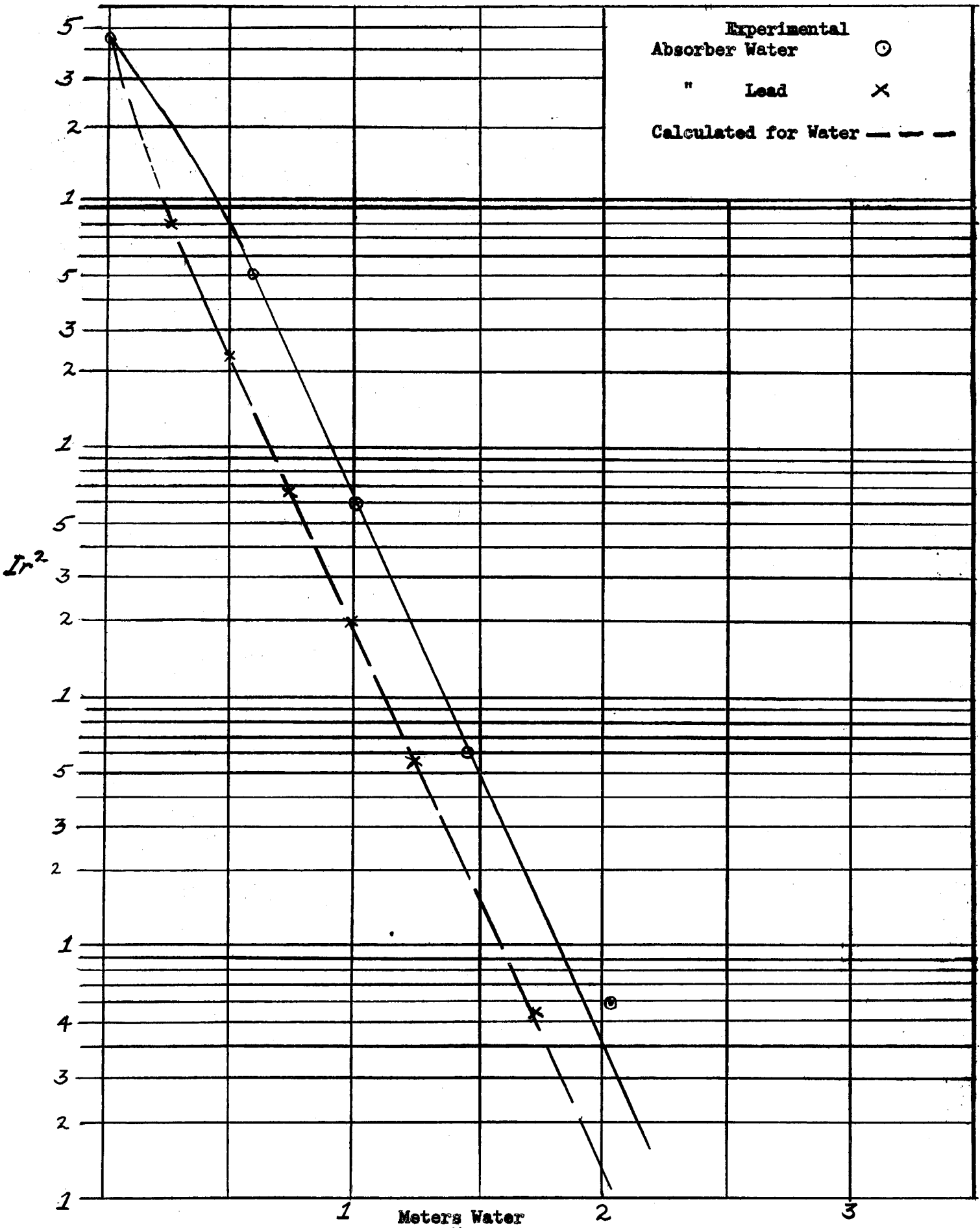
Fig. 1 shows the results plotting Ir^2 against absorber thickness (in meters). A deviation for small absorber thickness was found. The last point was taken with the source resting on a concrete surface and back scattering may in part account for the deviation. The intensity here is equal to the instrument background, and consequently the accuracy of this reading is low.

The absorption coefficient of the exponential part of the curve is 0.0507 cm^{-1}. This is the absorption coefficient given by Heitler for 1.87 MV radiation. A comparison curve has been plotted which was determined from an analysis of the known spectrum of radium B and C. This is not exponential for small thicknesses, but it is exponential in the range from 50 cm to 200 cm of water and the calculated value of the absorption coefficient equals 0.0505 cm^{-1} as compared with the experimental value of 0.0507 cm^{-1}.

An absorption curve was measured using large sheets of lead. The shape of this curve corresponds within experimental error to that calculated. The equilibrium intensity in water is three times that to be expected from exponential calculation.

The reality of this effect could also be tested by placing a sheet of lead alternately over the source and around the chamber. The degraded quanta should be easily absorbed by lead after passing through the absorber. A 0.11 cm sheet of lead was used and a small effect was found. With 2 meters of water the difference was less than 20% of the transmitted radiation.

FIG. 1. Penetration of Gamma Rays through Water



APPENDIX III

Excerpts from LA-302

EXPERIMENTAL ARRANGEMENT

Spheres

The experiment consisted of measuring the γ-ray transmission through the metal spheres as a function of wall thickness. The Ba-La source was placed at the center of the sphere. The detecting equipment consisted of an ionization chamber in conjunction with a DC amplifier or with a Vibrating Reed Electrometer (CP-2141) to measure the ionization. The ionization chamber was cylindrical, being made of a brass tube either 3" or 2" in diameter with a .025" Kovar wire stretched along the axis of the tube to serve as the collecting electrode. The Kovar-glass seals for the wire had guard rings. The chambers were filled with purified argon and 2 to 4 percent CO_2 to pressures of 3 or 4.5 atmospheres, respectively.

Fig. 1 shows the wiring diagram of the DC amplifier. This was essentially a single-stage bridge amplifier that was used as a null instrument by balancing R_1 or R_2. R_g was never larger than 10^{11} ohms. All measurements for any transmission curve were taken with one-resistor R_g. The 959 tubes and R_g resistors were mounted next to the chamber while the rest of the circuit was placed some fifteen feet from the chamber to protect the operator from unnecessary radiation. This amplifier has been quite steady over a period of several months and the zero drift has not been troublesome. It is not as sensitive as the Vibrating Reed Electrometer.

Collimated Beam

Some measurements of the β-ray absorption were made with good geometry

using the arrangement as shown in Fig. 2. The source was placed in a block of lead A and the γ's which emerge from the 1/4" hole in the lead were well collimated before they reached the detecting instrument. The latter was placed in the lead shield B about 120 cm distance from the source. The block of lead C, placed midway between A and B was important in reducing the effects due to scattering. The alignment was made optically. The absorbing material was placed between A and C.

The detecting instrument was a G.M. counter. A brass counter was used for obtaining the curves presented later. However, it should be pointed out that the γ efficiency, for low-energy γ's in particular, does depend upon the atomic number of the material used for the counter wall. Some tests were made with a thin-walled dural counter which was lined with platinum. As expected, this counter had a relatively higher efficiency for the low-energy γ's of the Ba+La than the brass-walled counter. A standard dural counter surrounded by a thick aluminum sleeve gave about the same response as a brass-walled counter. In using a G.M. counter or any counter which counts individual pulses for the absorption measurements, it is important that the initial counting rate for a bare source shall not be large enough to introduce any appreciable counting loss because the shape of the curve for thin absorbers is quite sensitive to these errors.

EXPERIMENTAL RESULTS

Good Geometry - Collimated Beam

The results obtained with Cd and Fe are shown in Figs. 3 and 4, respectively, which show the percent transmission plotted on a log scale against the thickness

of the absorber. For comparison purposes, the values obtained with spheres are given on the corresponding graphs in order to show the large differences in the transmission curves for good geometry and for spheres. A Ba+La source in equilibrium was used for these measurements.

A rough check on the γ-ray energy by using the Klein-Nishina scattering formula and the slope of the transmission curve for good geometry indicated that the energy of the main component of the γ-rays was of the order of 1.5 Mev instead of 2.0 Mev as previously reported. These curves also indicated some low-energy γ's as well as a small amount of γ's having energy higher than 1.5 Mev. Later, these predictions were verified by Wilkinson (CP-2590) using a β-ray spectrograph, who found the following energies and relative intensities:

La	$2.3 \pm .1$ Mev	6 percent
	$1.65 \pm .02$	77 percent
	$0.87 \pm .02$	10 percent
	$0.49 \pm .01$	5 percent
	$0.335 \pm .005$	2 percent
Ba	$0.54 \pm .01$	perhaps 5 percent of Ba+La in equilibrium

Metal Spheres

The transmission curves for dural, Cd and Fe spheres are given in Fig. 5 and similar curves for U and Pb are shown in Fig. 6. These curves were taken with a Ba+La source. Except for the dural, a single chamber was used to measure the ionization. A test made with the chamber at different distances from the source showed no measurable effect. The dural curve was taken with a bank of eight of the 2" chambers connected in parallel.

Fig. 7 shows the transmission curves for the above elements plotted against absorbing thickness.

In the case of the Cd, there is some evidence that the transmission values may depend upon the distance of the absorbing and scattering material from the source.

Composite Spheres

In the case of the composite sphere, the transmission curve for one metal is influenced by the presence of the second element. Fig. 11 shows the transmission curve for dural for 0 cm, 0.63 cm, and 1.87 cm of Cd inside of the dural. It appears that no noticeable change occurs for Cd thicknesses greater than 0.63 cm. This is further borne out by measurements on the absorption of a dural shell for various thicknesses of Cd inside. Fig. 12 shows the variation in the transmission curve of Cd caused by surrounding it by a dural shell.

Figs. 13 and 14 show similar curves for U and dural.

Comparison of Ba+La and La Sources

Since the La has a half-life of 40 hours as compared to 12.5 days for the Ba, it is much more convenient to use a Ba+La source, which is in equilibrium, for the static measurements. The greater part of the γ radiation comes from the La but Wilkinson (CP-2590) estimates that perhaps 5 percent of the total comes from the Ba and has an energy of 0.54 Mev. Figs. 15 and 16 show transmission measurements taken with both Ba-La and separated La sources for dural and Cd, respectively.

DWG. #1697

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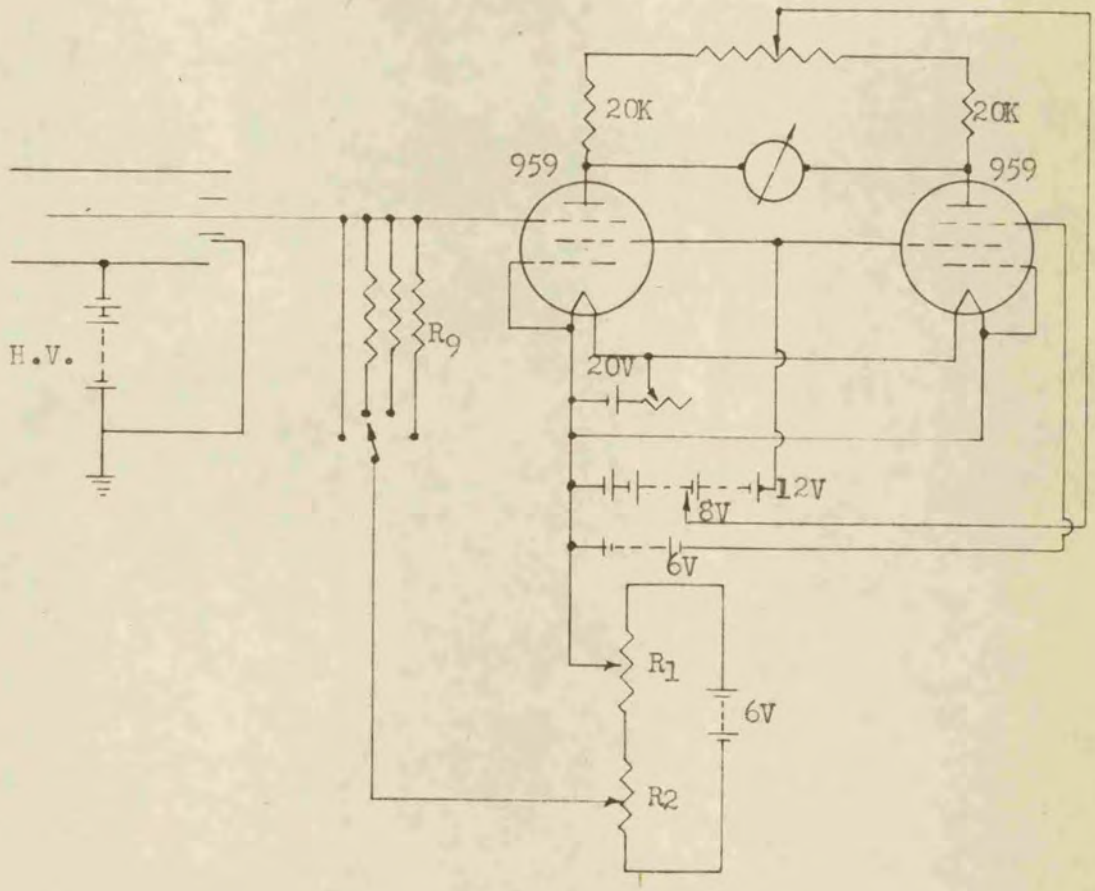

FIG. 1. SCHEMATIC WIRING DIAGRAM FOR D.C. AMPLIFIER

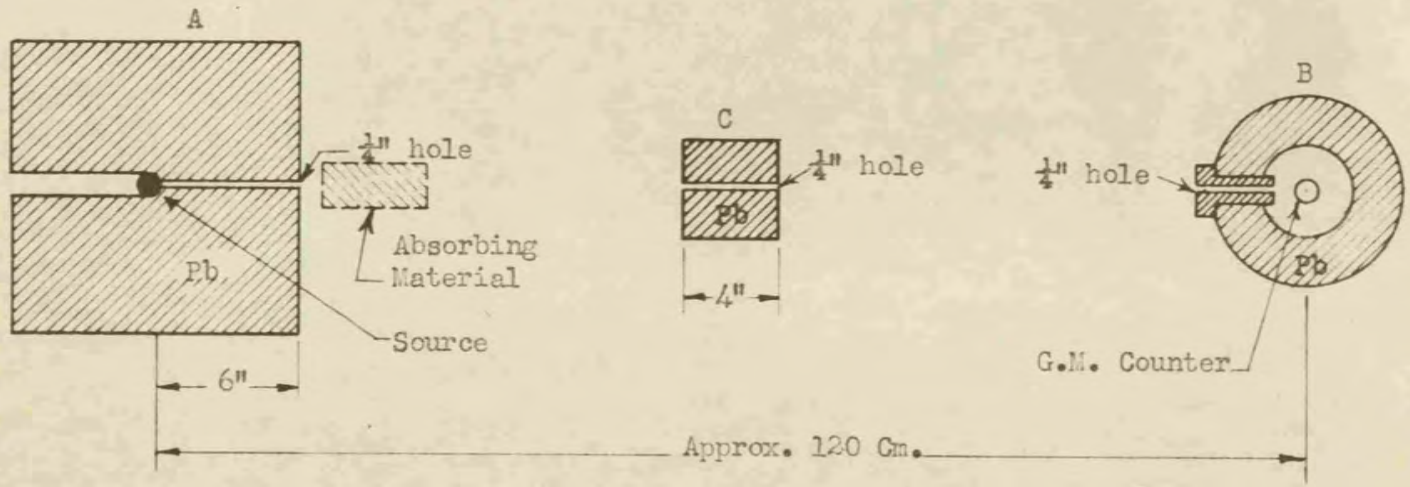

Fig. 2 ARRANGEMENT FOR COLLIMATED BEAM MEASUREMENTS

DWG. #1698

DWG. #7699

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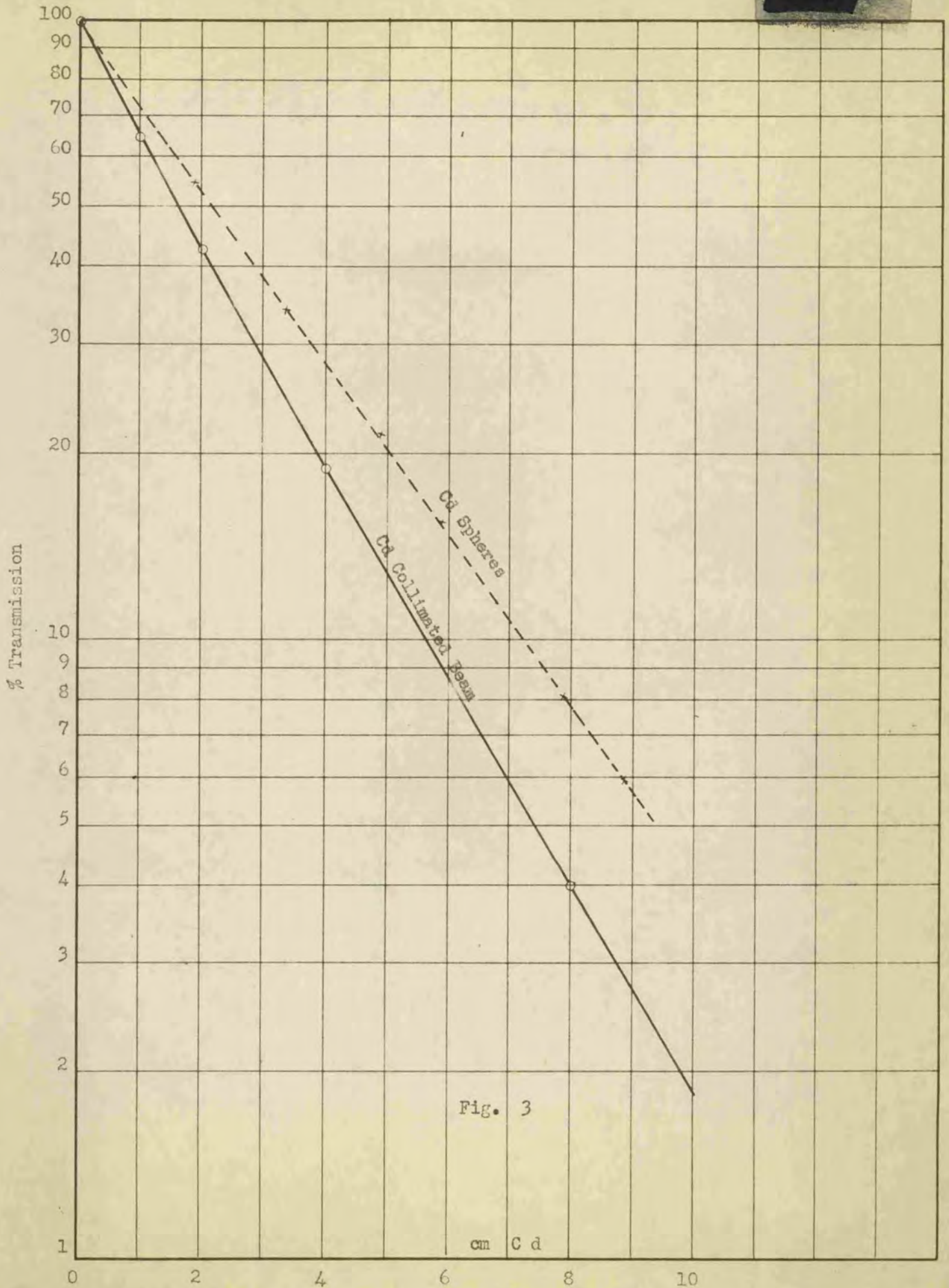

Fig. 3

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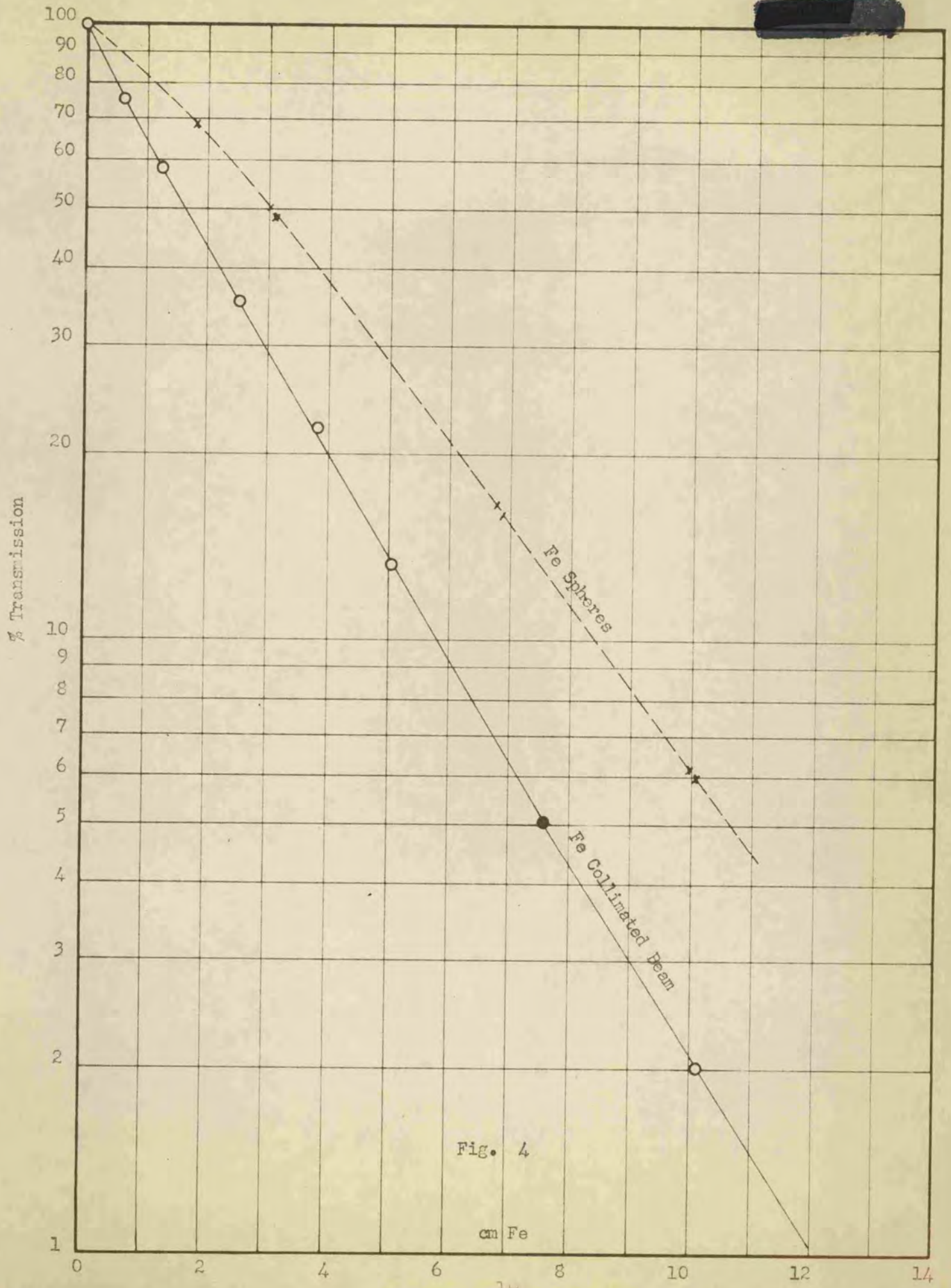

Fig. 4

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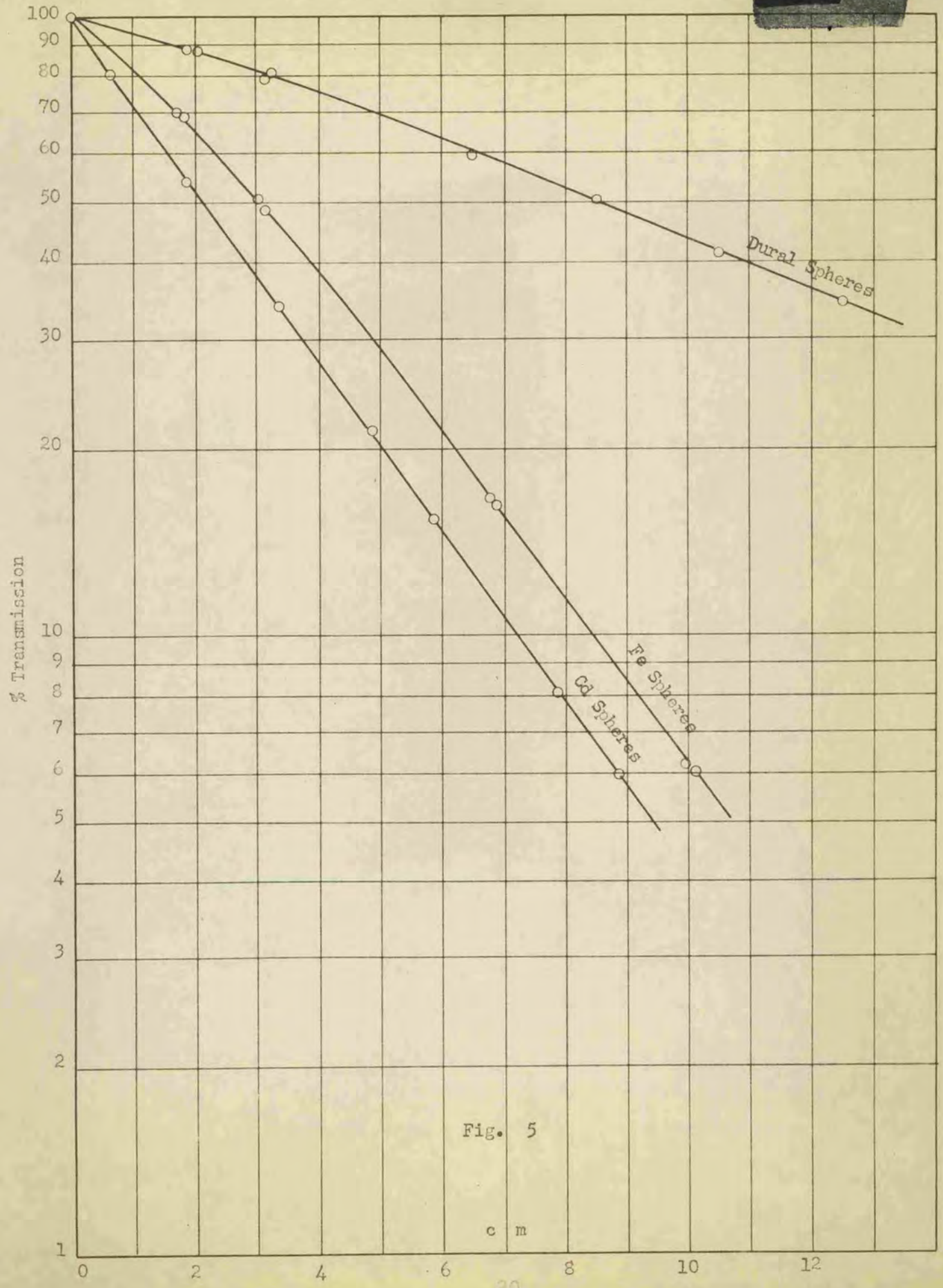

Fig. 5

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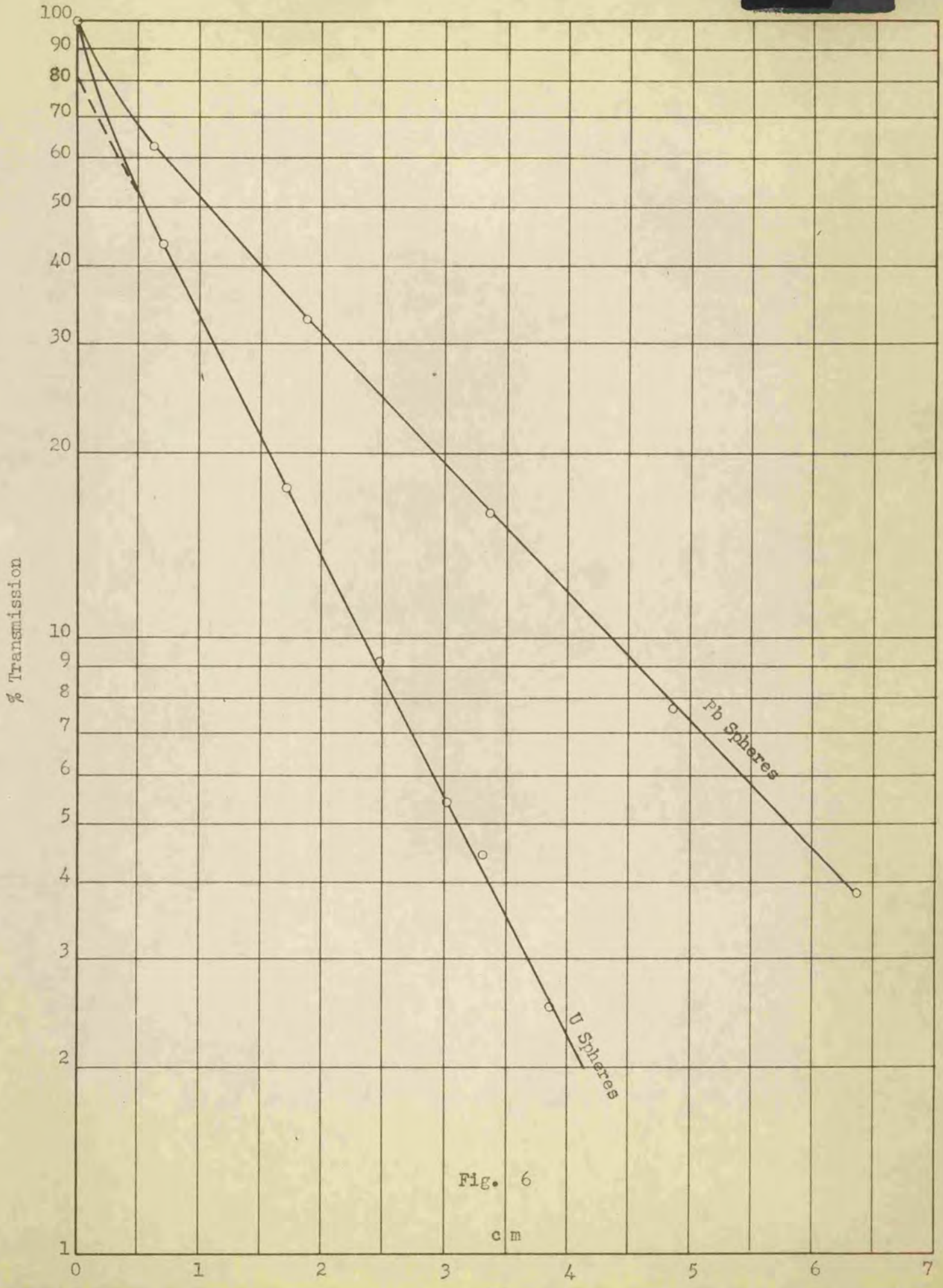

Fig. 6

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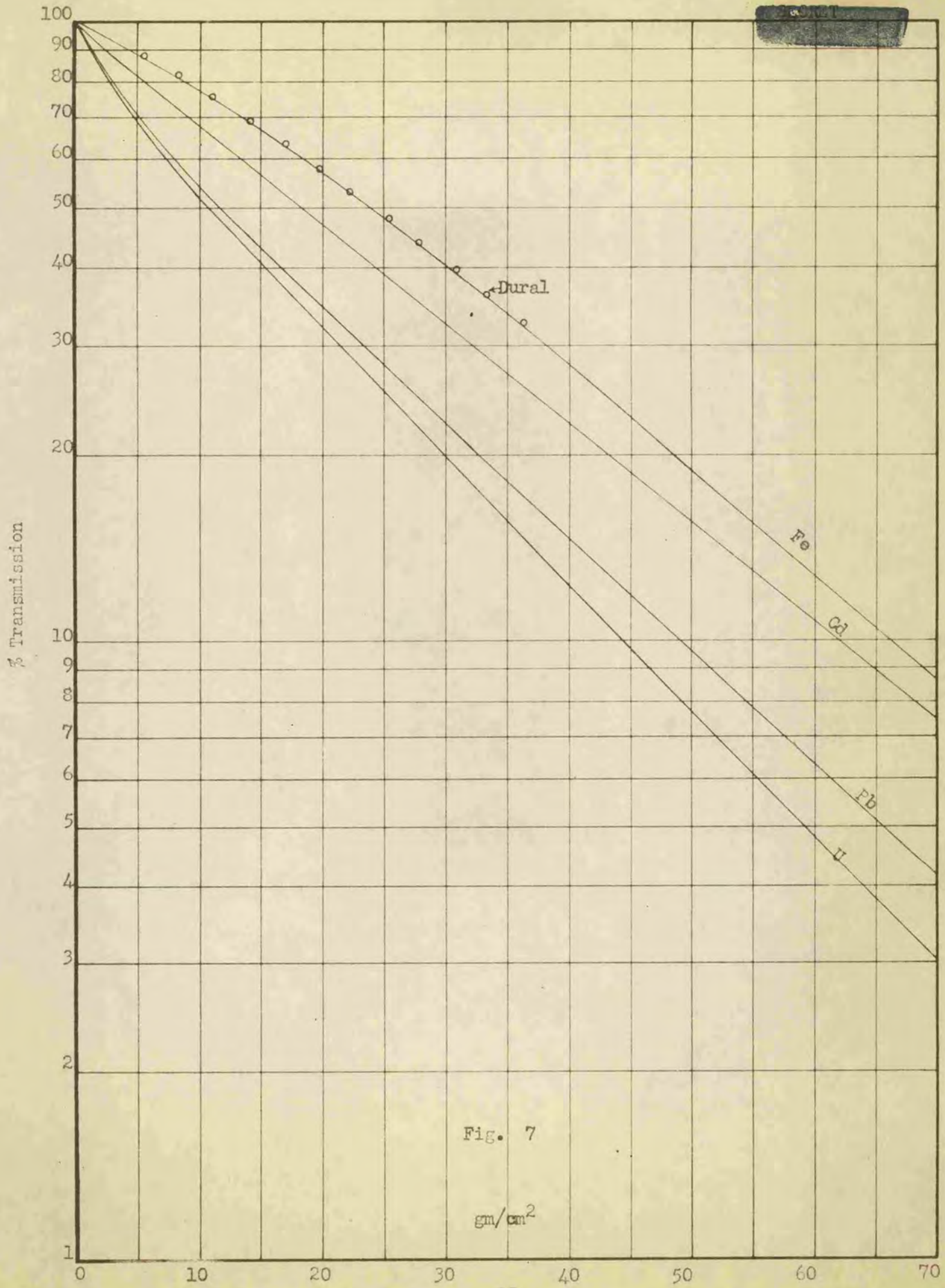

Fig. 7

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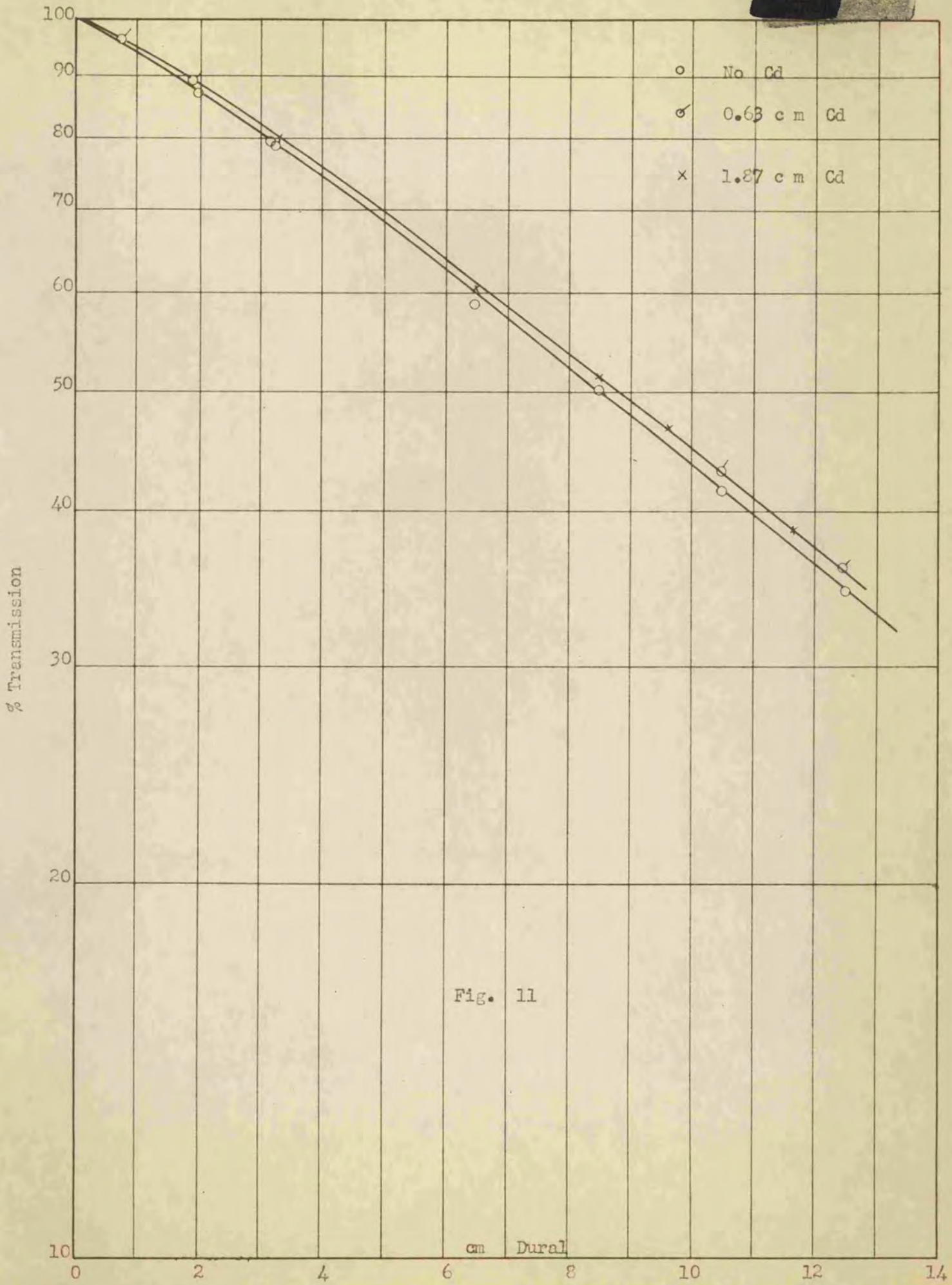

Fig. 11

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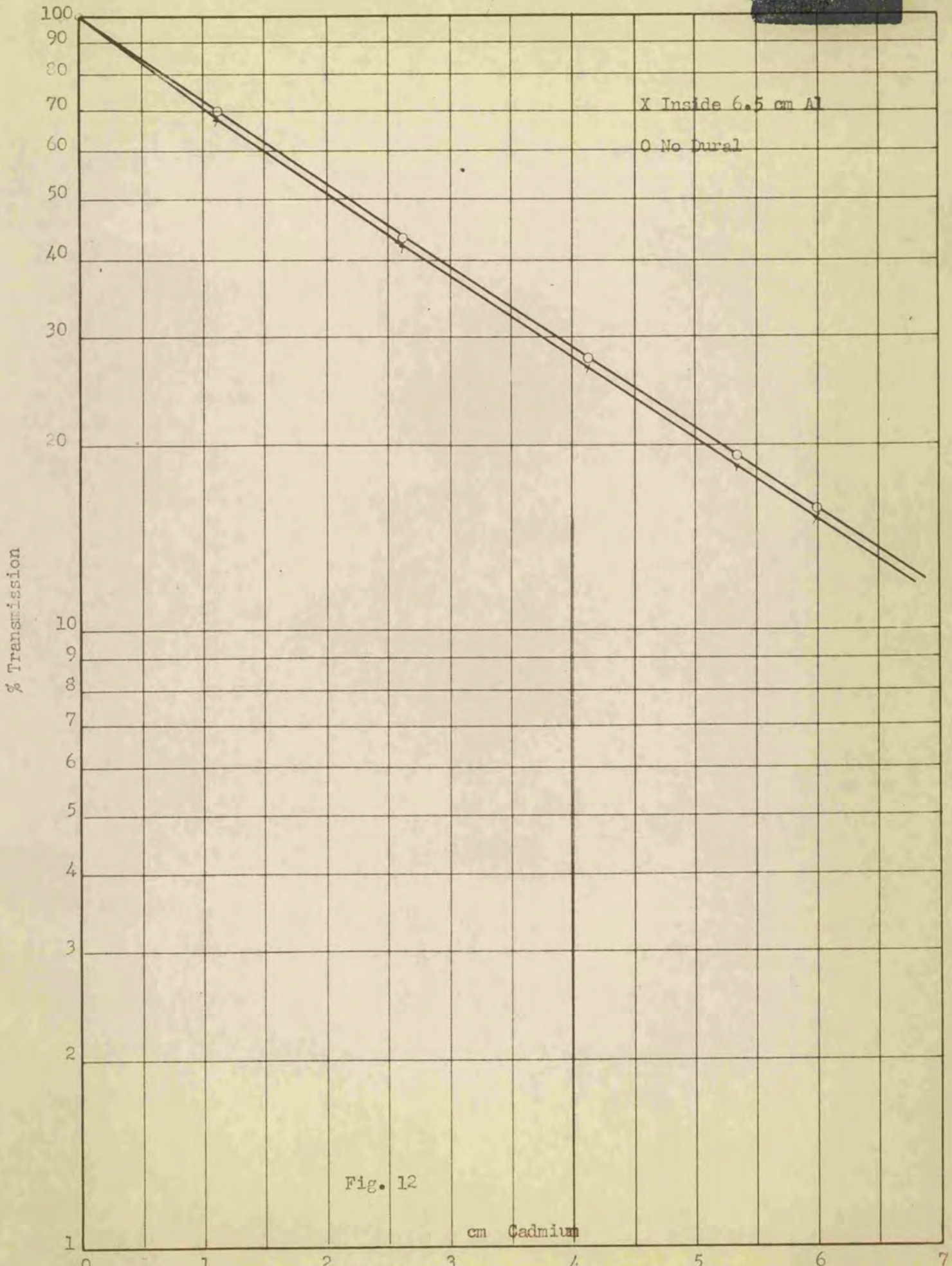

Fig. 12

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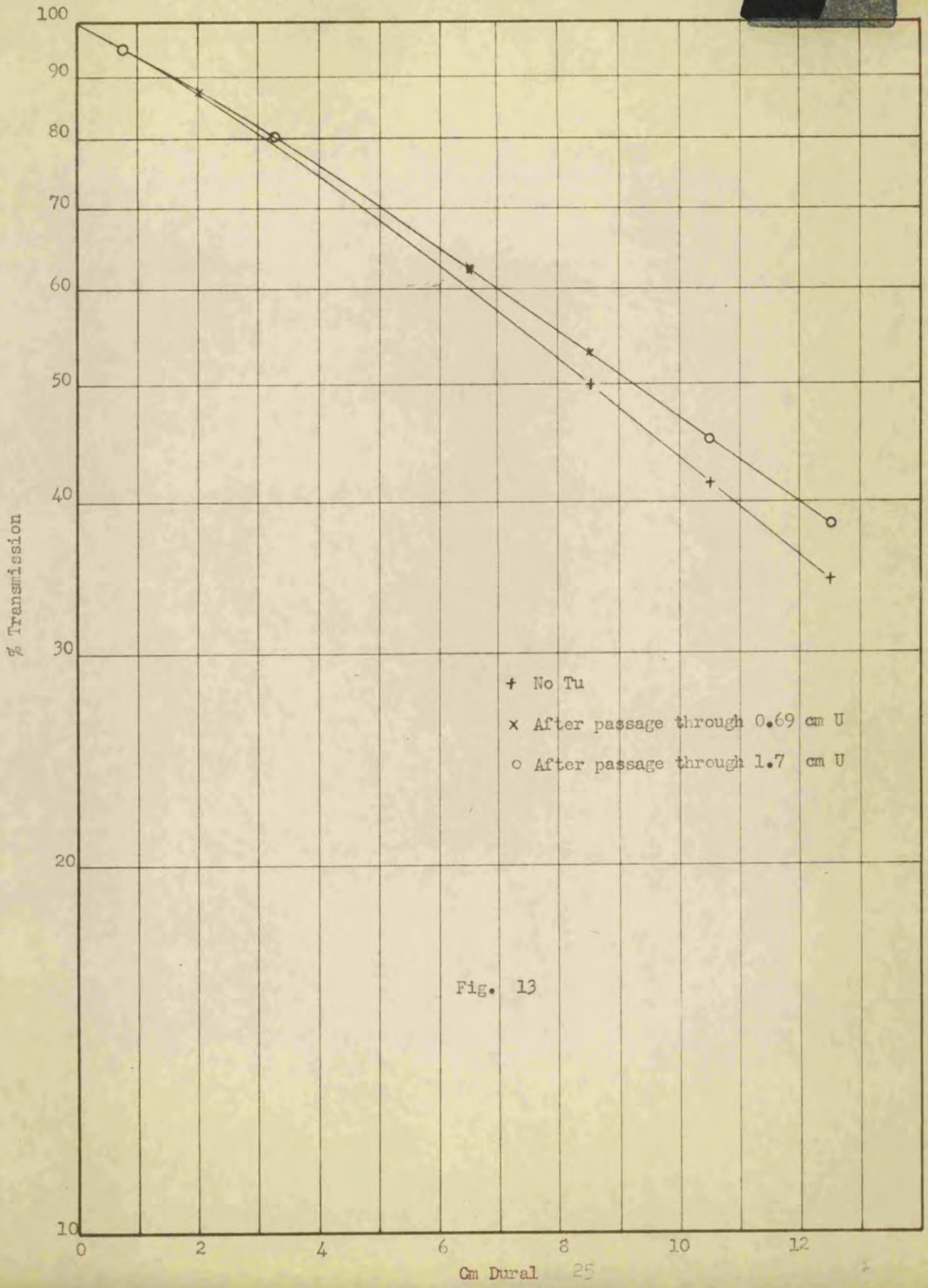

Fig. 13

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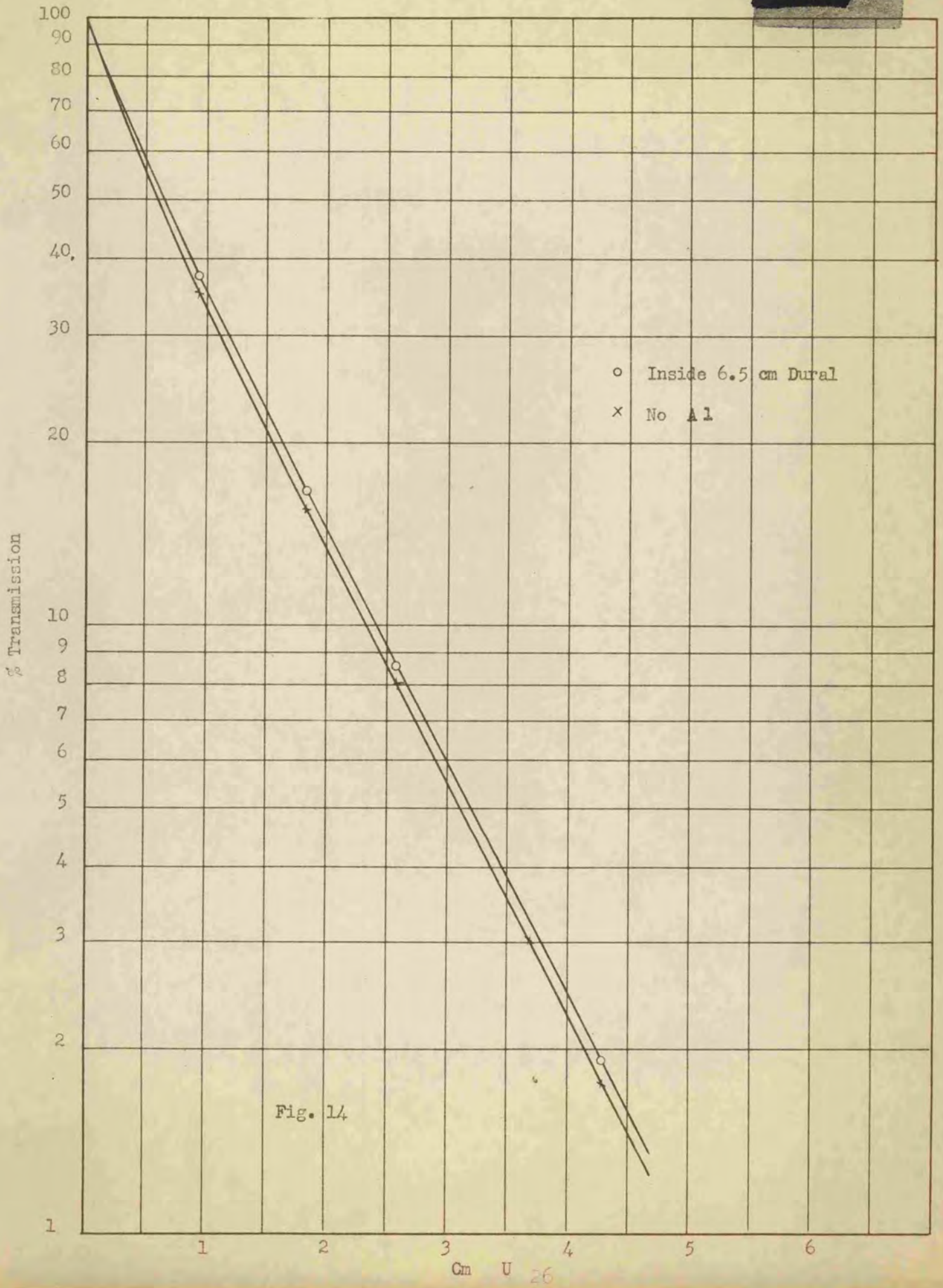

Fig. 14

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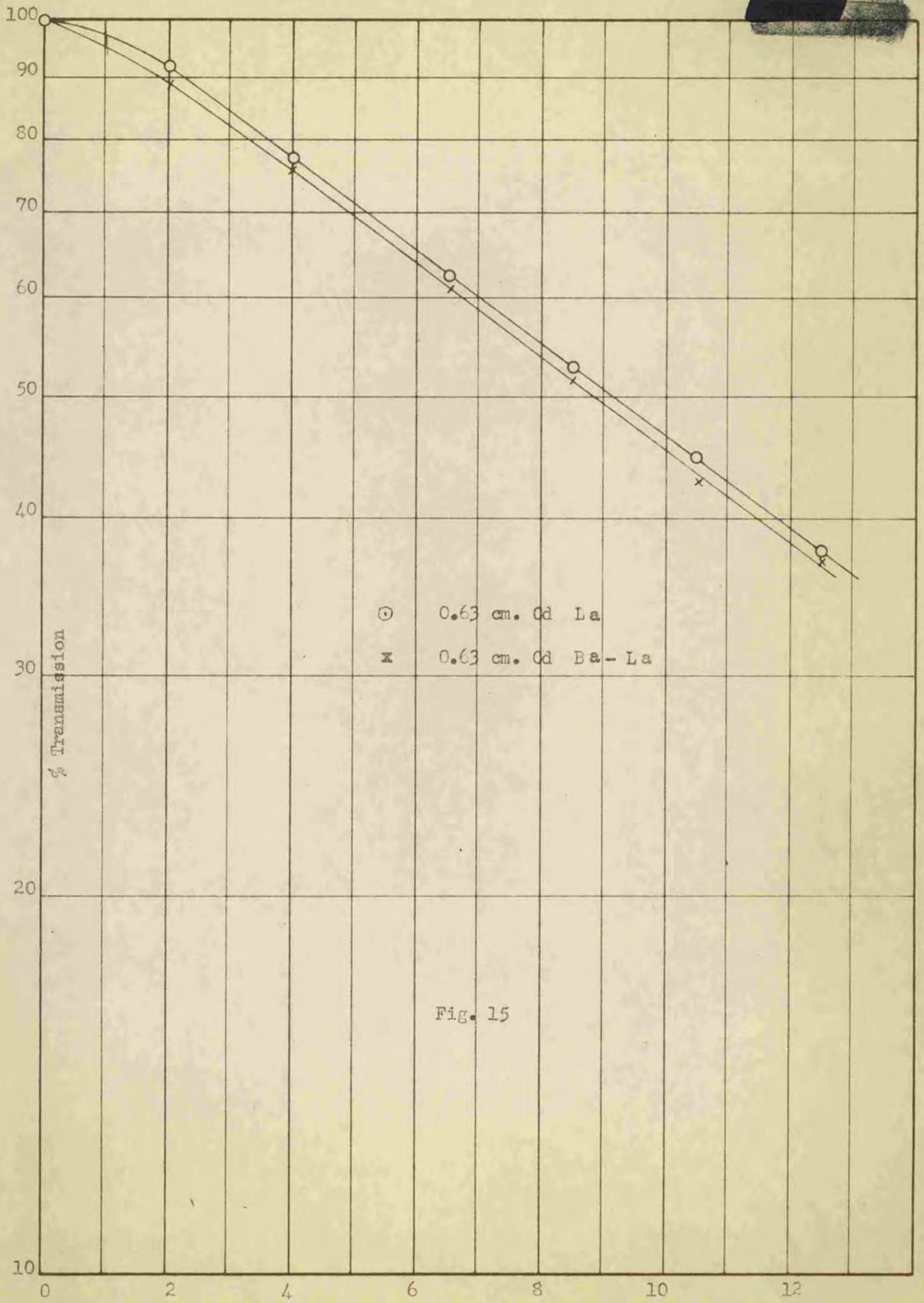

Fig. 15

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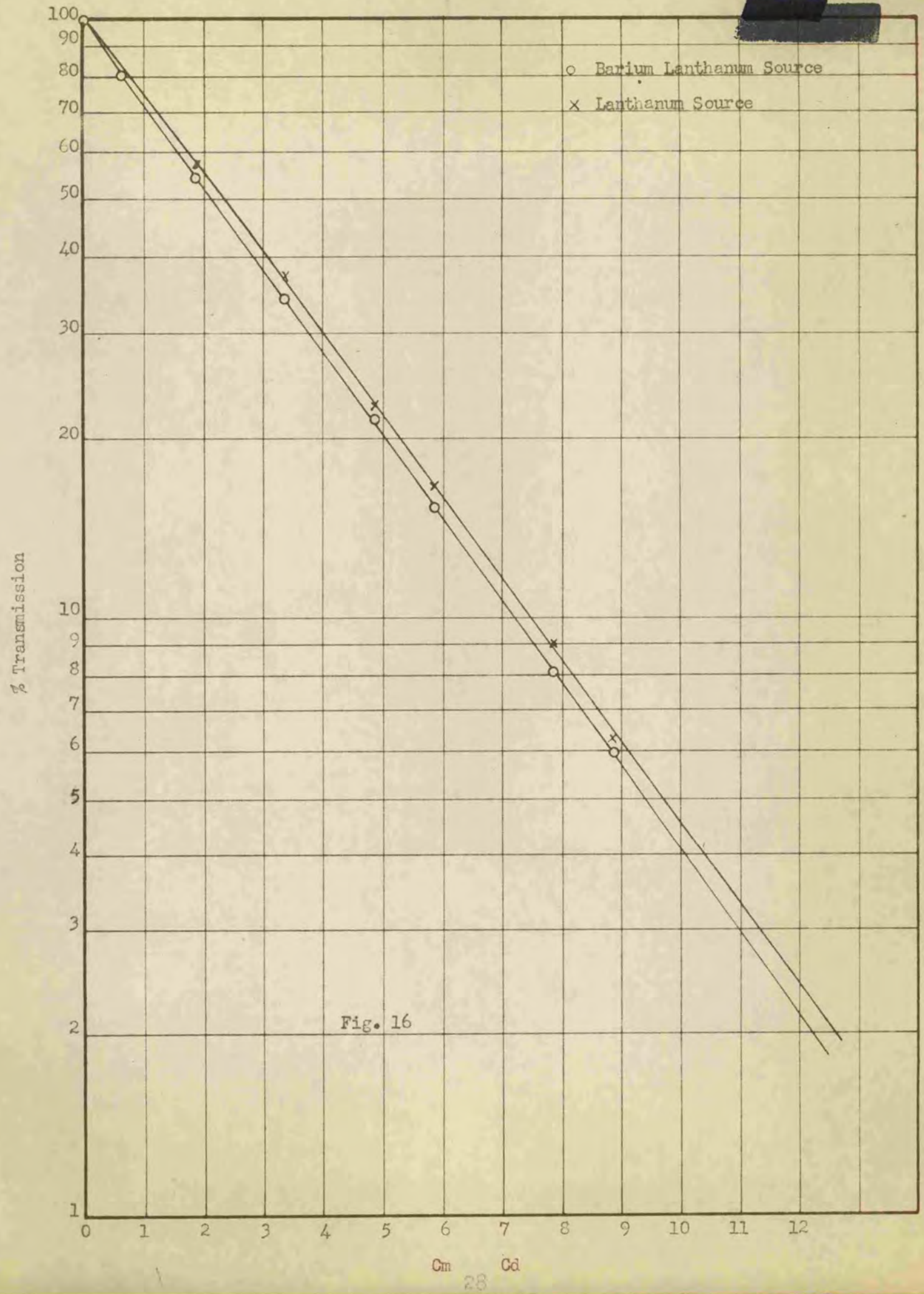

Fig. 16