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PHYSICS DIVISION

PROGRESS REPORT FOR THE QUARTER

DECEMBER, JANUARY, FEBRUARY

1948-49

A.H. SNELL, DIRECTOR
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PHYSICS DIVISION

PROGRESS REPORT FOR THE QUARTER DECEMBER, JANUARY, FEBRUARY

1948-49

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INTRODUCTION AND SUMMARY

Presented herewith is the classified section of this quarterly report. The unclassified section is given in ORNL 325-Supplement 1. Organizational changes are mentioned in the introduction to the latter.

SLOW NEUTRON ABSORPTION SPECTRUM OF Xe^{135}

The Xe^{135} neutron absorption resonance follows the Breit-Wigner formula with the following constants: ~~$E_0 = 0.011$ ev,~~ ~~$\Gamma = 0.011$ ev,~~ $\sigma_0 = 3.4$ megabarns. More data will be taken to improve statistical accuracy. This very difficult experiment has been a major Laboratory effort; its success is now at hand.

SHIELDING

A major new item of equipment has been installed, in the form of a large tank placed against the core hole in the west face of the pile. This tank is arranged for convenient attenuation measurements in mixtures that can be either wet or dry, and is large enough to minimize edge effects. Measurements have been made on MO concrete with added boron. Tests on boron-tungsten shields are being written up.

CRITICAL EXPERIMENTS

The rate of absorption of gamma-ray energy has been measured in the lead reflector of the critical assembly. The effect of a boron absorber in the reflector upon the gamma, fast neutron and slow neutron fluxes was studied; it is concluded that about $\frac{1}{4}$ of the gamma flux 20 cm deep in the reflector arises from inelastic scattering, and $\frac{3}{4}$ from thermal neutron capture.

NEUTRON DIFFRACTION IN U-Be ALLOY

Neutron diffraction patterns have been obtained for the U-Be_9 alloy, and a fitting lattice model is now being sought.

PHYSICS OF SOLIDS

Preparation of enriched samples for Hanford irradiation is being approached by preliminary practice on normal uranium. Studies on the "relax-

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ations" observed in uranium slugs after thermal cycling are continuing in an attempt to see how much of the effect is attributable to the uranium metal. Some samples of U-Al alloys which have been irradiated at Hanford have shown significant and disturbing dimensional changes, leading to overall decreases in density of as much as 3%. The underwater slug-cutter has been used in the canal of the pile building, and works well with stripped slugs. Design proceeds on a chamber for fast neutron irradiation of samples in the pile; it consists of a hollow cylinder of water-cooled enriched uranium, inside of which the samples will be placed. Check experiments have shown that the pile radiations, and not the concomitant heating and aging effects, are the effective agent in producing observed changes in hardness and electrical resistivity of brass.

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NUCLEAR PHYSICS—THE CROSS SECTION OF Xe^{135} AS A FUNCTION OF ENERGY

(S. Bernstein, C. P. Stanford, M. M. Shapiro, J. B. Dial, T. E. Stephenson)

SUMMARY OF RESULTS ACHIEVED TO DATE

During the past quarter we have been taking data very intensively on samples of PdI_2^{135} delivered to us by the chemists. The first chemically successful run took place on November 29. Since this sample was derived from only one slug which had been irradiated in the pile for one hour, no spectrometer measurements were taken using it.

Sample 2 (December 1) consisted of 4 slugs irradiated for 3 hours. Although the amount of Xe^{135} to be expected from these slugs was barely sufficient for spectrometer measurements, sample 2 was observed continuously on a 24 hour per day schedule for about three days. These transmission measurements demonstrated very convincingly to us for the first time the presence of a highly absorbing substance in the sample, the transmission of which varied with the time in accordance with the expected growth and decay of the Xe^{135} from the I^{135}.

A record of all the runs made thus far is given in Table I-1. The date of chemical extraction, the number of slugs, and the irradiation time are given in the various columns for each sample, together with a few remarks.

TABLE I-1

SAMPLE NUMBER	IRRADIATION		DATE	REMARKS
	# SLUGS IRRADIATED	IRRADIATION TIME--HOURS		
1	1	1	11-29-48	No data taken
2	4	3	12-1-48	Data taken and discarded
3	6	20	12-4-48	
4	6	20	12-10-48	Sample too wet to be used
5	6	20	12-14-48	Sample abandoned after about 24 hours of data.
6	6	20		Sample very wet but used.
7	6	20	1-8-49	
8	6	20	1-18-49	
9	6	20	1-24-49	
10	6		2-12-49	Hanford irradiation

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The results of a least squares analysis of all of the data on samples 3, 5, 7, 8, 9, 10 are given in Figures I-1 and I-2. Fig. I-1 shows the experimental points and the least squares fit of the Breit-Wigner formula (solid line) for samples 7, 8, 9, and 10. The Breit-Wigner constants for the solid curve are: $E_0 = 0.0849$ e.v., $\Gamma = 0.114$ e.v., $\sigma_0 = 1.16$ arbitrary units. Fig. I-2 shows the experimental data and the B.W. curve (solid line) for samples 3, 5, 7, 8, 9, 10. The constants for the solid line are: $E_0 = 0.0863$ e.v., $\Gamma = 0.107$ e.v., $\sigma_0 = 1.24$ arbitrary units. For comparison the curve of Fig. I-1 for samples 7, 8, 9, 10 is shown dotted in Fig. I-2. The addition of 3 and 5 to 7, 8, 9 and 10 has very little effect upon E_0, but decreases Γ from 0.114 to 0.107 e.v., and increases σ_0 from 1.16 to 1.24 arbitrary units. It is hoped that several more runs will decrease the limits of uncertainty in these constants suggested by the differences between the two curves of Fig. I-2. A statistical calculation of the probable errors in the B.W. constants is now being made by the computing group.

Preliminary assays of the strength of the samples indicate that the value $\sigma_0 = 1.24$ arbitrary units corresponds to the absolute value, 3.4 megabarns.

ORGANIZATION AND HISTORY OF THE Xe PROJECT

The first attempt to study the cross section of Xe^{135} as a function of energy was made by L. B. Borst some time ago at Oak Ridge National Laboratory. A brief account of the preliminary results obtained in the limited time available to him is given in M-3750.

The problem was then approached on a much larger scale by a cooperative effort of members of the Chemistry and Physics Divisions of Oak Ridge National Laboratory. G. W. Parker, S. Freed, A. R. Brosi, G. M. Hebert, T. DeWitt, G. E. Creek, H. D. Bogard, H. Zeldes, and J. A. Ghormley have been responsible for the chemical process of producing the sample of PdI_2^{135} and for assaying the absolute number of I^{135} atoms contained in it. S. Bernstein, M. M. Shapiro, C. P. Stanford, J. B. Dial, and T. E. Stephenson have been responsible for the crystal spectrometer measurements.

The excellent cooperation of members of the Physics, Chemistry, Operating, and Engineering and Maintenance Divisions has helped very much to bring the experiment to its present state.

Mr. Dan Jones has been very helpful in designing and building special equipment for the remote control chemical operations.

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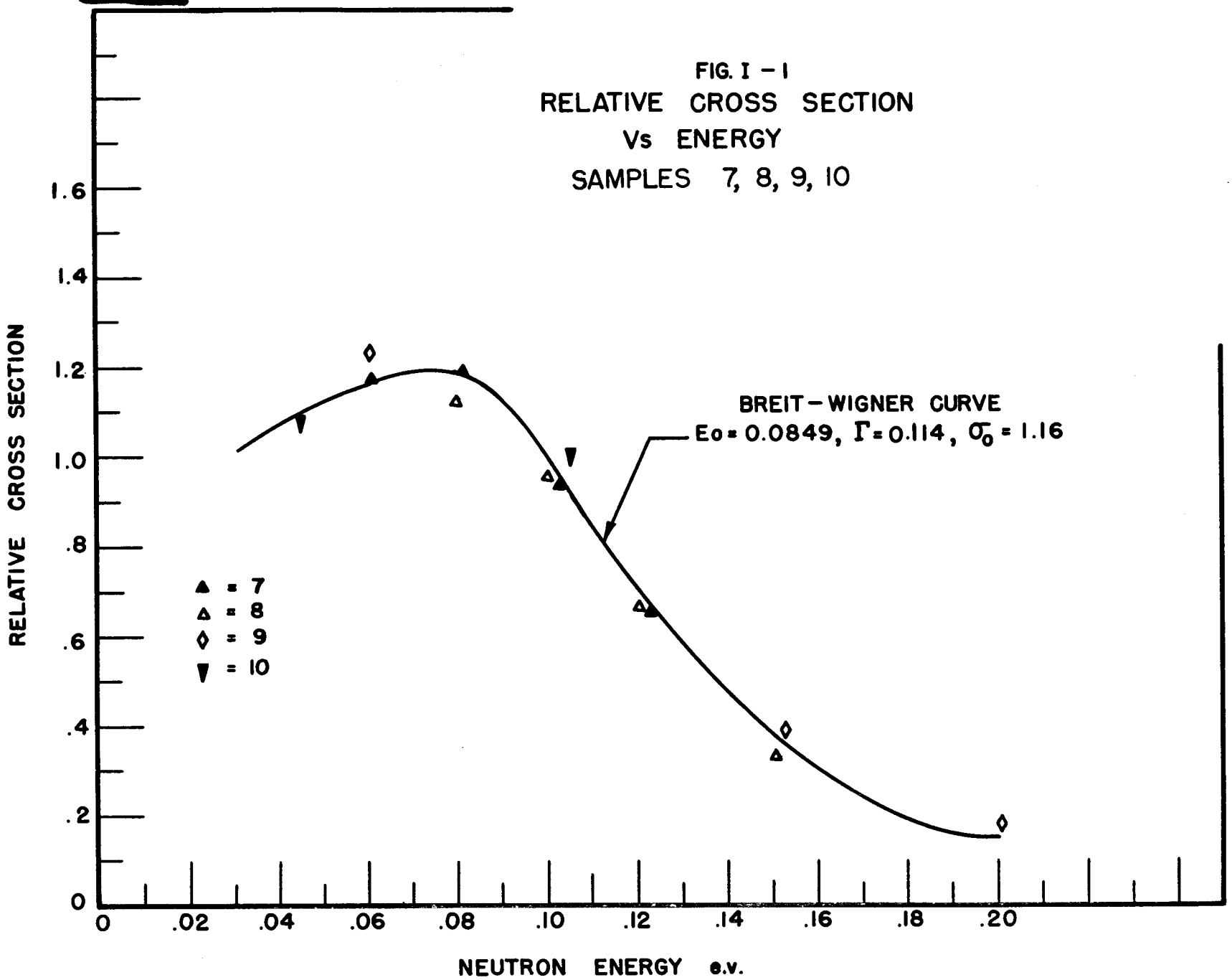

FIG. I - 1
RELATIVE CROSS SECTION
Vs ENERGY
SAMPLES 7, 8, 9, 10

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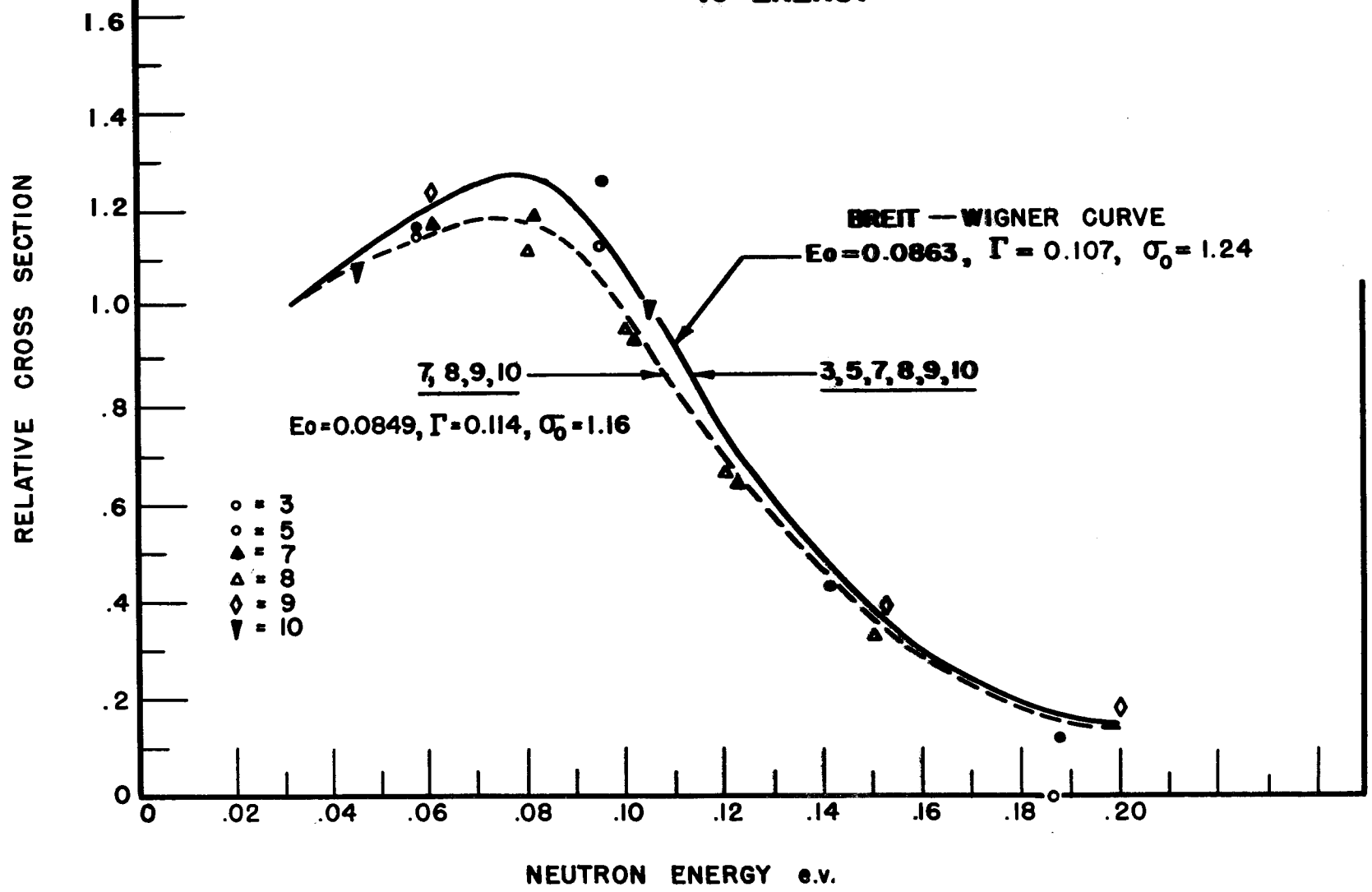
FIG. I-2
RELATIVE CROSS SECTION
Vs ENERGY



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R. H. Lewis and D. I. Weinberg of NEPA have been of great assistance in taking and working up the data.

R. Crook, L. Noderer, A. Forbes, K. Martin, M. K. Hullings and R. Coveyou of Dr. A. Householder's Mathematics Panel have been responsible for the statistical analysis of the data.

G. G. Kelley assumed responsibility for the behavior of the electronic equipment and for taking some of the data in the preliminary stages of the experiment.

The following people have also been very helpful in various aspects of the work:

J. Ruch	C. G. Shull	N. Kropoff	F. Pleasonton
C. D. Moak	R. L. Clark	T. Arnette	N. F. Lansing
T. E. Cole	M. Davis	J. M. Cassidy	

INTRODUCTION

The measurement of the cross section of Xe^{135} as a function of energy is a straightforward but difficult problem. The difficulties arise for the following reasons.

(1) The chemical problem is to extract about 5×10^{-6} gms of iodine from 6×10^{3} gms of uranium immediately upon removal of this material from the pile after twenty hours of neutron bombardment. The final product must be thoroughly dried and deposited in a small diameter capillary tubing suited to spectrometer measurements. The capillary tubing must be sealed.

(2) In order to achieve measurable neutron absorption effects from the 5 microgram sample, the cross sectional area of the neutron beam must be very small (from one to two mm in diameter). Every effort must be made to increase the number of neutrons in the Bragg reflected beam, and to decrease the background counting rates.

(3) Because of the great difficulty of the chemical extraction, each sample becomes very valuable. Moreover, because of its radioactive decay, a sample is available for only a very limited time. The program for the taking of the data must therefore be very carefully planned and carried out so that each sample will be used to best advantage.

(4) The sample is extremely radioactive. The health hazards connected with such high activities make it necessary to provide suitable shielding for carrying out the chemical operations and for handling the sample during the period of the neutron measurements.

It is the purpose of the following material to describe the apparatus and procedure used in taking the transmission measurements and to give some of the detailed results. Descriptions of the chemical extraction process and of the absolute assay of the PdI_2^{135} samples delivered to us by the chemists will be found in the quarterly reports of the Chemistry Division.

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DESCRIPTION AND PERFORMANCE OF THE CRYSTAL SPECTROMETER

The crystal spectrometer used in this work is the same one used by L. Borst. It is an old X-ray crystal spectrometer which has been adapted for use with neutrons. It is of the (approximately) focussing type. Focussing action at a given energy is obtained by varying the curvature of the crystal by exerting a torque upon it by means of adjusting screws. We have overhauled the instrument quite thoroughly with the object of gaining (a) higher counting rates for the Bragg reflected beam, (b) lower background counting rates, and (c) an instrument which can be handled quickly.

Throughout all of this work, we have used the 100 reflections from a 5" × 1" × 1 mm quartz crystal. The grating space of these planes is d = 4.24 Å The energy, E, in e.v. of the neutrons in the Bragg reflected beam from this set of planes is given by the expression:

$$E = \frac{1.136 \times 10^{-3}}{\sin^2 \theta}$$

A photograph of the spectrometer is given in this report (Photo I-1). A schematic diagram of the neutron beam collimator, sample, spectrometer arrangement is shown in Fig. I-3. In this type of spectrometer, for best focussing, a point source of radiation should be used. The Bragg reflected image will then be in best focus at a distance from the axis of rotation of the crystal which is equal to the distance of the source from this axis. The maximum number of neutrons in the incident beam consistent with the requirement of having a "point source" is procured by means of the "hour-glass-like" graphite collimator. It originates deep in the pile as a 4" × 4" cross section graphite stringer containing a hole of 3-3/8" × 3-3/8" square cross section. This hole tapers down uniformly as it emerges from the pile until it reaches the stringer-section carrying the sample shifter box. In this graphite stringer section it finally becomes a circular cross section of 1/8 inch in diameter for a length of about 4" on each side of the ℄ of the sample. The collimator hole then broadens gradually out again until it meets the face of the pile. The sample itself is located at the common apex of the two "cones" of the collimator.

As can be seen from Fig. I-3, the sample is located about 4 feet inside the concrete shield of the pile, so that once a radioactive sample is in place, adequate shielding from the radiations is automatically provided.

The transmission of a radioactive sample might be measured by either of the two following procedures. The number of neutrons coming through the active sample could be measured as a function of time and of the energy of the

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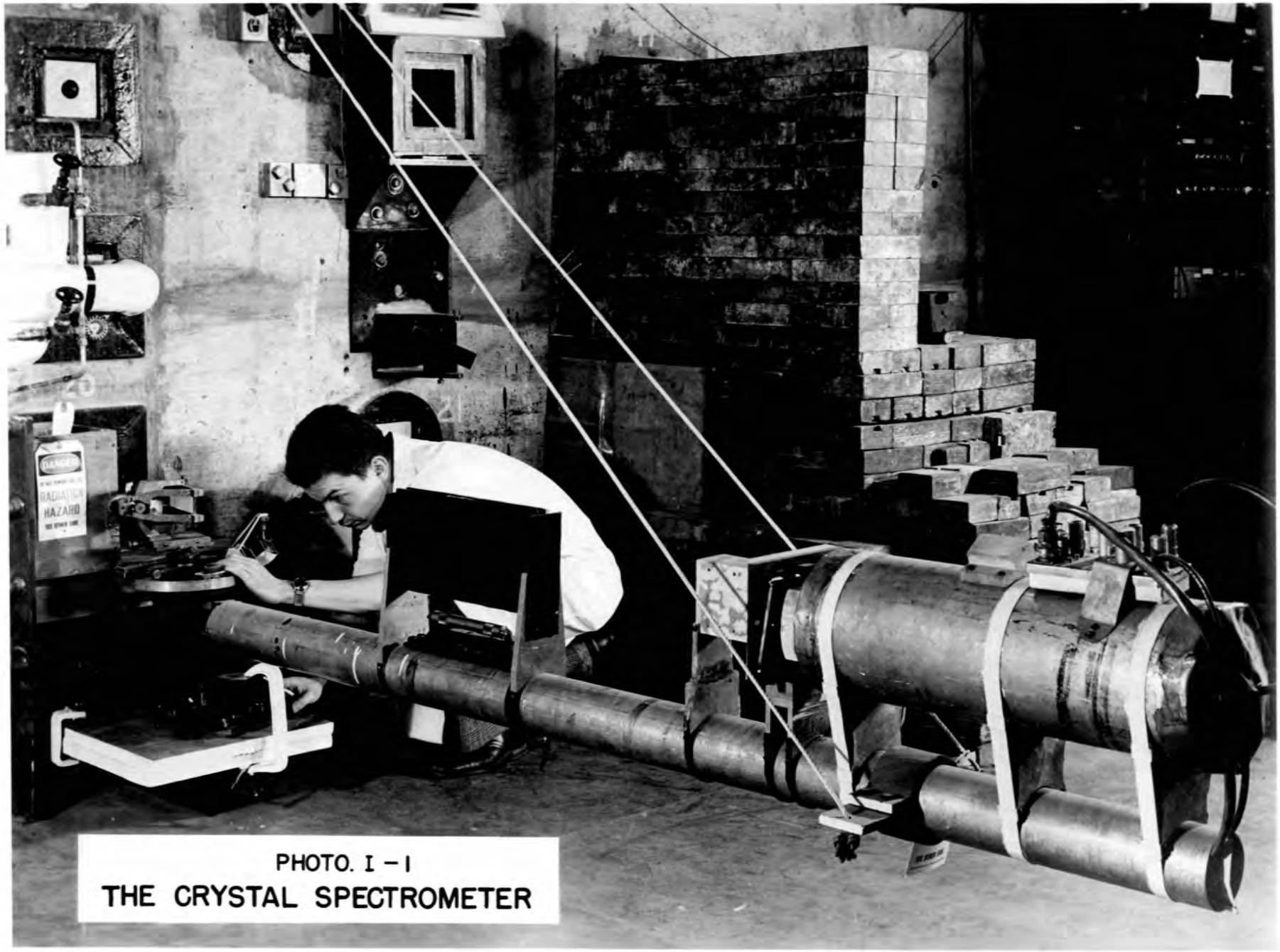

PHOTO. I – 1
THE CRYSTAL SPECTROMETER

Dr. 6246

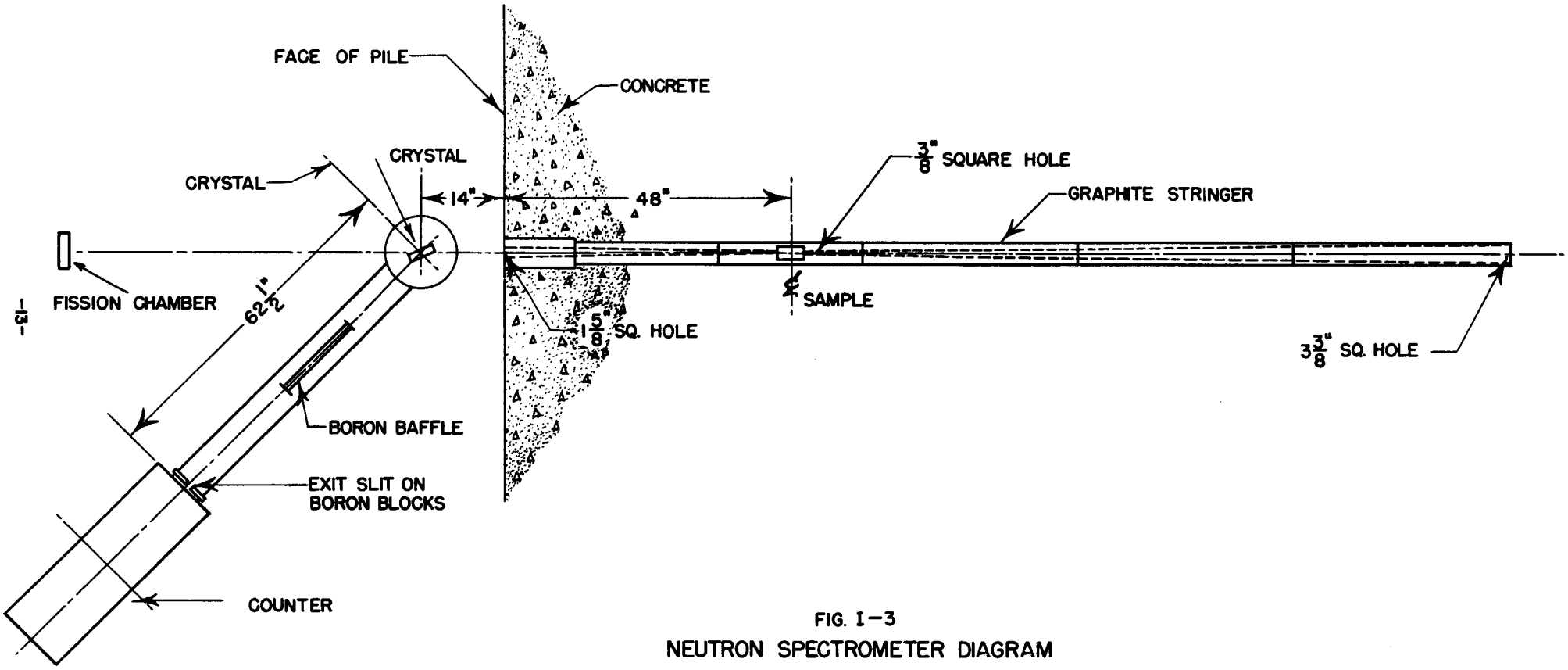

FIG. I-3
NEUTRON SPECTROMETER DIAGRAM

neutrons. At a later time when all of the active material had decayed the number of neutrons coming through the dead carrier material could be measured as a function of time and neutron energy. The transmission of the sample for a given energy is then given by the ratio of these two measurements properly corrected for sample decay. This method has the disadvantage that it assumes that all the variables involved can be accurately reproduced, for example, that the number of neutrons per unit time emerging from the collimator remains the same for several days, that the crystal curvature can be accurately reproduced, that the crystal and counter angular settings can be reproduced to such an extent that two independent settings can be made on the same point of the rocking curve. It was thought that these requirements would be very difficult to meet.

The second procedure for measuring the transmission is to have two tubes, one carrying the active sample, the other carrying either an equivalent amount of carrier material or being completely empty. If then, with the same settings of the spectrometer, two readings can be taken close together in time, first with the active sample in the neutron beam, then with the "monitor" sample occupying identically the same position in the neutron beam, the ratio of these two readings gives immediately a measure of the transmission of the sample. By repeating the measurement of this ratio at various times, a record of the time dependent portion of the "transmission" is obtained. This second method is the one which was chosen since it avoids making the assumptions required by the first method described above. This method, however, imposes rather severe requirements on the "sample shifter." It must remove one sample from the beam and place another in identically the same position. The device described in the following paragraphs and exhibited in the accompanying diagrams and photographs was found to satisfy this requirement of reproducing the sample position very satisfactorily.

The sample holder (or "wafer", as it has been christened) is shown in Fig. I-4. It consists essentially of an aluminum block which holds 2 pieces of thick-walled Pyrex Capillary tubing accurately parallel. An isometric drawing of the wafer is shown in Fig. I-5. The stringer section carrying the sample shifter box is shown in Fig. I-6. The wafer is seated in position on the sample shifter carriage (item labelled 6 in Fig. I-6) as shown in Photo I-2. The wafer assumes a very accurately reproducible position because the three hemispheres on the bottom of the wafer (items 1 and 4 of Fig. I-5) seat themselves in the matching receptacles of the sample shifter carriage (item 6 of Fig. I-6). A permanent magnet in the bottom of the wafer (item 2 of Fig. I-5) "urges" the hemi-spherical supports to seat themselves properly. When the sample shifter stops are properly adjusted (item 4 of Fig. I-6), either one or

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Dr. 6890

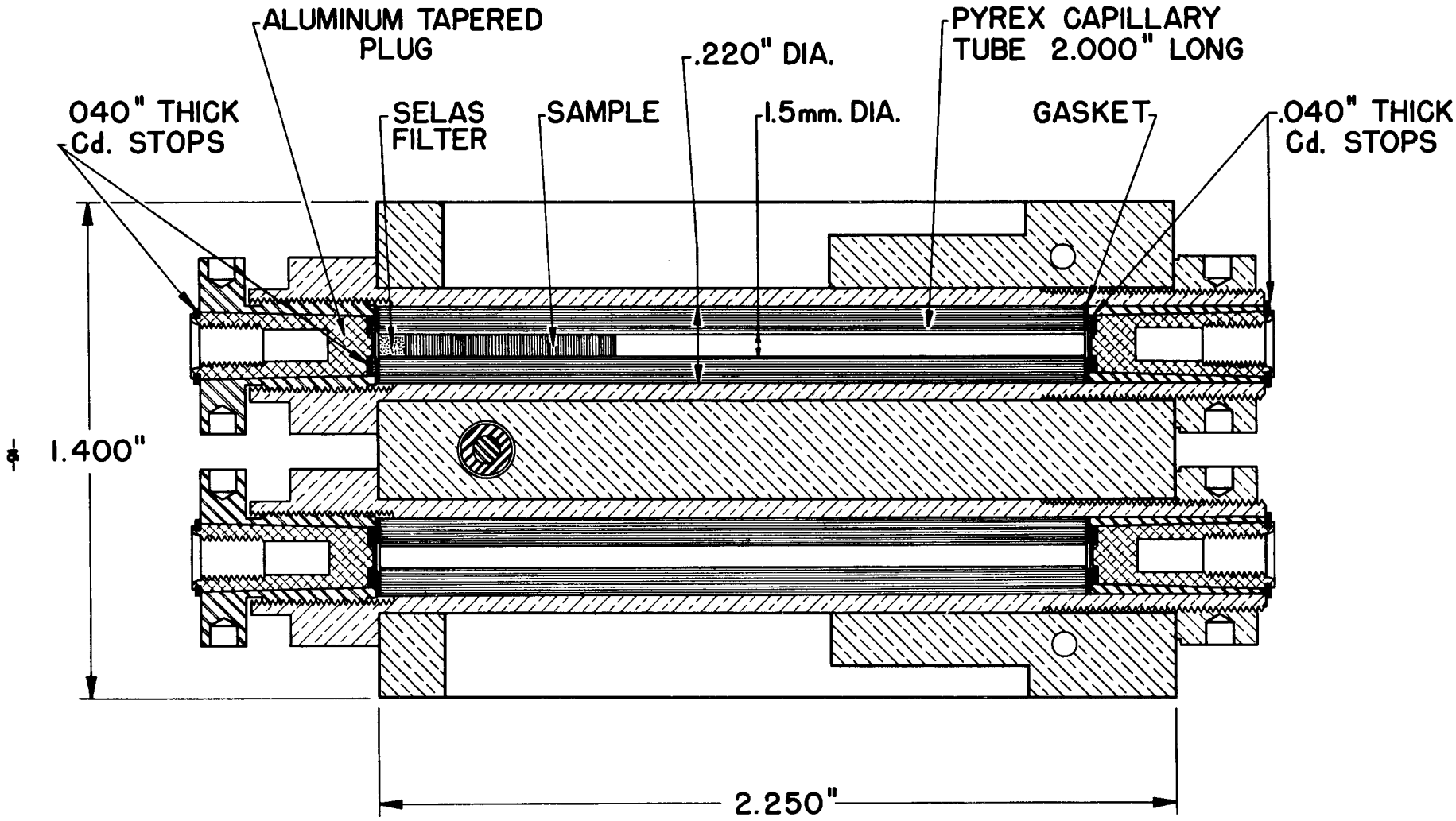
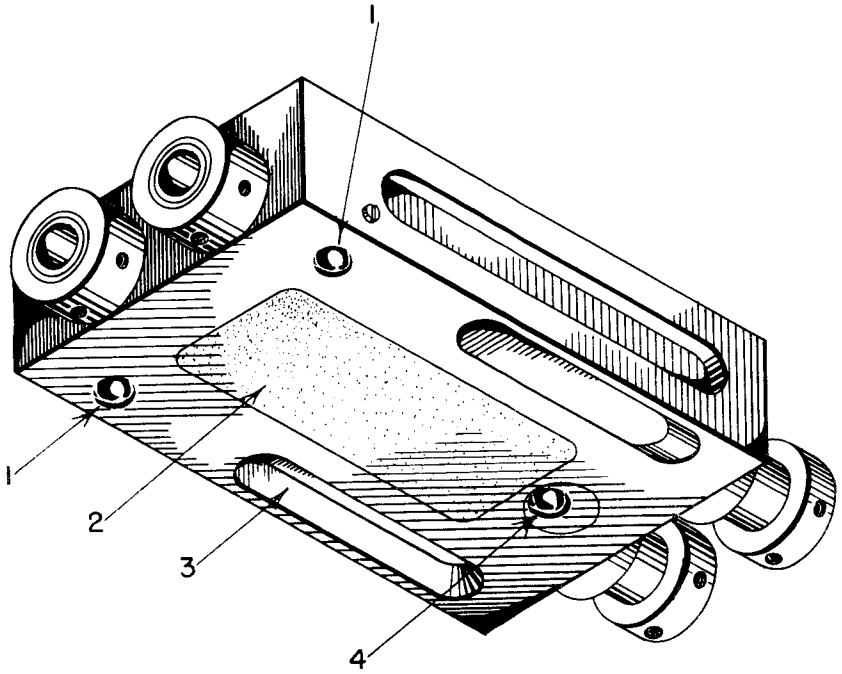


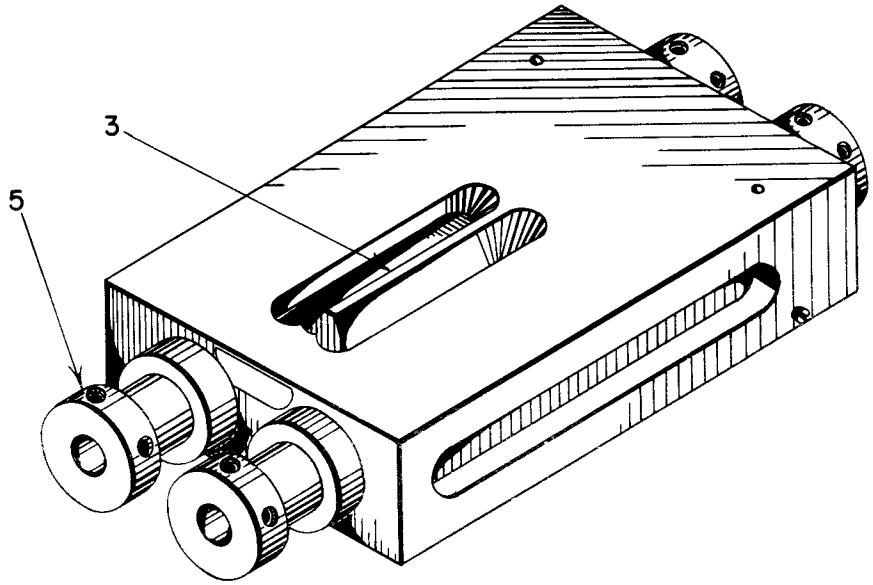
FIG. I-4

SAMPLE HOLDER
HORIZONTAL SECTION

Dr. 6247



BOTTOM VIEW



TOP VIEW

LEGEND

1. STATIONARY HALF-BALL
2. MAGNET - ALNICO - V
3. VIEWING SLOT
4. ECCENTRIC HALF - BALL
5. SAMPLE TUBE

FIG. I—5
SAMPLE TUBE HOLDER

1. REMOVABLE ROD TO OPERATE TOGGLE FOR POSITIONING SAMPLE SHIFTER AGAINST ADJUSTABLE STOP 4.
2. GROOVE FOR ELECTRICAL LEADS
3. ECCENTRIC SHAFT FOR LEVEL POSITIONING
4. ADJUSTABLE STOP
5. STATIONARY SHAFT
6. SAMPLE SHIFTER
7. GRAPHITE STRINGER
8. NEUTRON BEAM HOLE
9. CONNECTOR KEYWAY

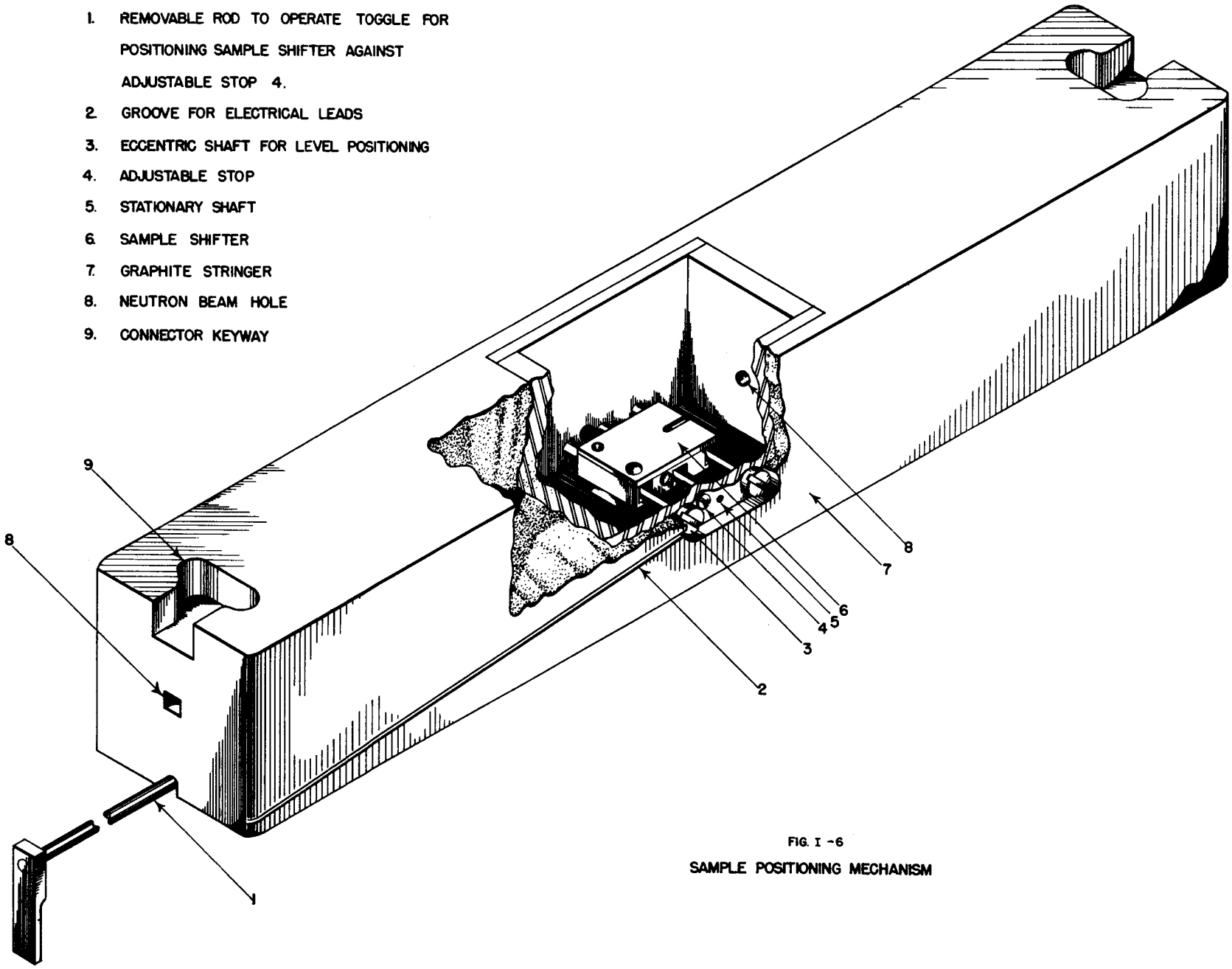


FIG. I -6

SAMPLE POSITIONING MECHANISM

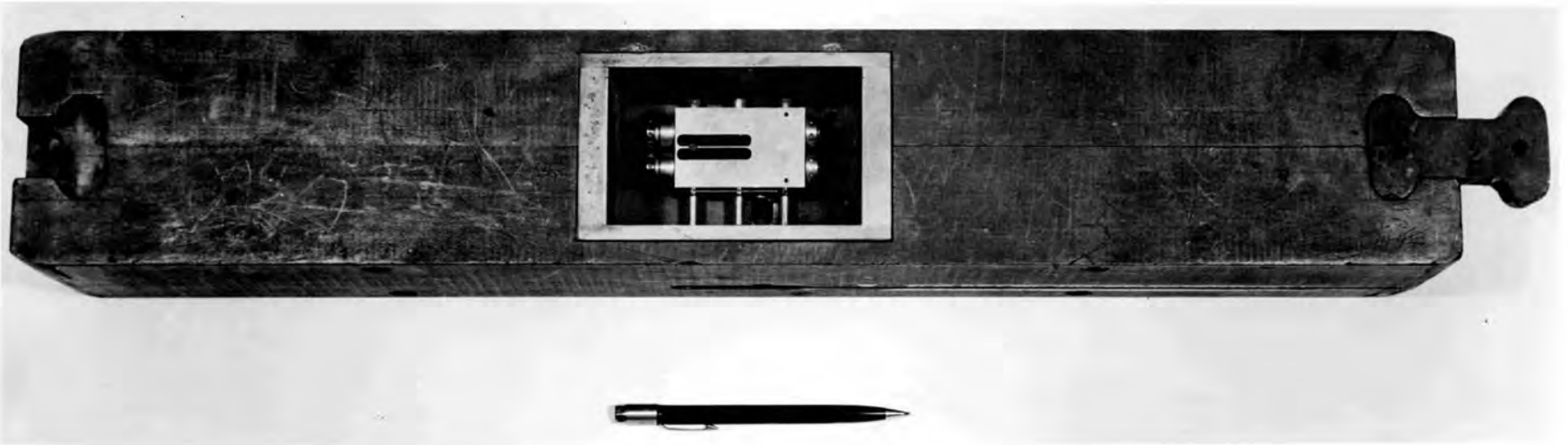


PHOTO. I – 2

SAMPLE SHIFTER SHOWING WAFER IN PLACE

the other of the two capillary tubes can be brought accurately into position in the neutron beam, by manipulating the lever (item 1 of Fig. I-6) which is outside the pile face. The sample shifter and the wafer are sufficiently supplied with adjustments so that the parallel axis of the two capillary tubes can be made accurately parallel to the axis of the collimating stringer.

The performance of the instrument is illustrated by the accompanying graphs. Fig. I-7 shows the counting rate in the reflected beam as a function of neutron energy. At the most favorable glancing angles, counting rates of 6000 counts per minute from a 2 mm inside diameter capillary tube source were achieved. Fig. I-7 shows how the background counting rate varied with glancing angle. The lower branch of the curve in Fig. I-8 at the higher energies represents the "background" rates achieved with various small thicknesses of cadmium over the counter slit.

Fig. I-9 gives the ratio of the counting rate in the Bragg reflected beam to the background counting rate as a function of neutron energy. At the most favorable glancing angle, for a 2 mm diameter capillary, a ratio of beam count to background count of about 180 was achieved.

The effect of crystal curvature on counting rates in the reflected beam is shown in Fig. I-10. The abscissa in this figure is in arbitrary units.

The perfection of focussing can be judged from the curve of Fig. I-11. The ordinate is the number of counts in the reflected beam for a 2 mm diameter source. The abscissa is the width in mm of the entrance slit in front of the BF_3 detector. Presumably if the focussing were perfect the counting rate would reach its maximum value at a slit width of 2 mm corresponding to the width of the source. Instead it reaches about 80% of its maximum value at a slit width of 3 mm.

Samples of rocking curves taken with the instrument are shown in Fig. I-12. These curves were taken by keeping the counter angle at a fixed position and rotating the crystal, first with the incident neutron beam coming through the east capillary tube (solid line), then with the neutron beam coming through the west tube (dotted line). The full width at half maximum of these rocking curves is about eight minutes of arc.

It should be pointed out that the requirements on the accuracy of the reproducibility of the sample shifter are extremely high. The simplest test on this reproducibility might be to measure the number of neutrons coming through each of the capillary tubes when its axis is coincident with the axis of the collimating stringer, and then to see how constant these numbers remain when the sample shifter is changed repeatedly so that the neutron beam is allowed to pass alternately through first one tube and then the other. This test was made very

FIG. I-7

Dr 6264

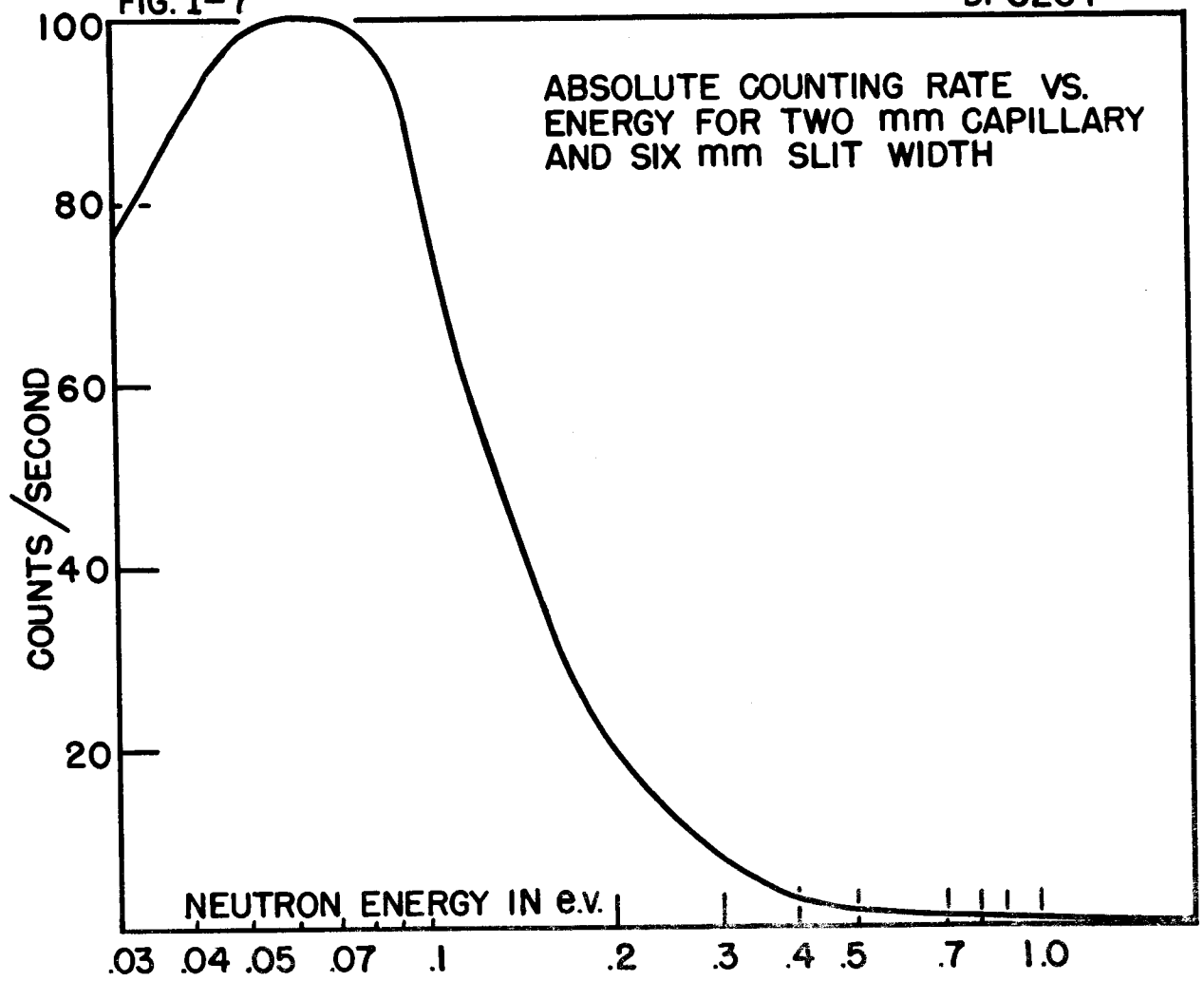


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FIG. I-8 Dr. 6265

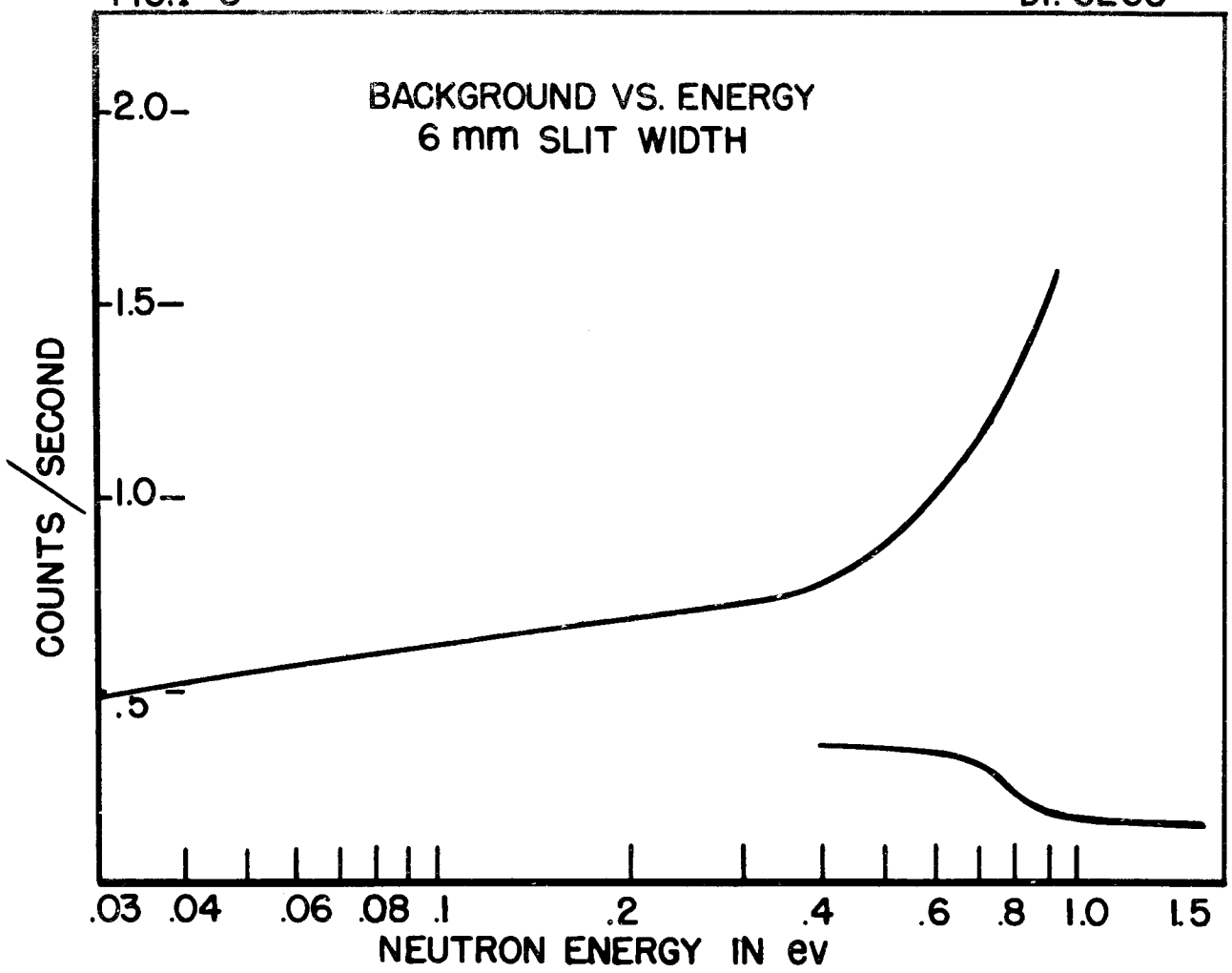


FIG. I-9 Dr. 6266

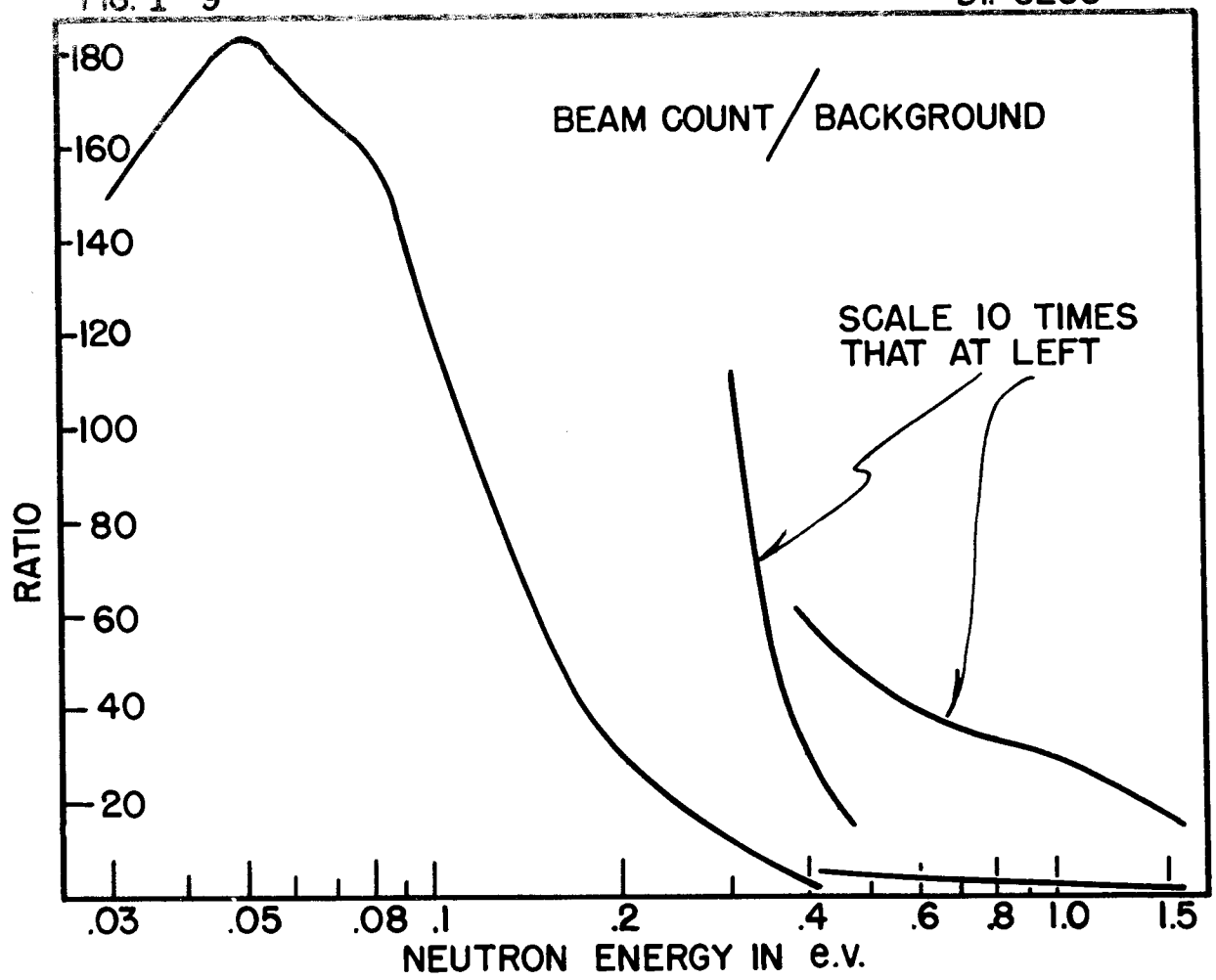


FIG. I - 10

Dr. 6260

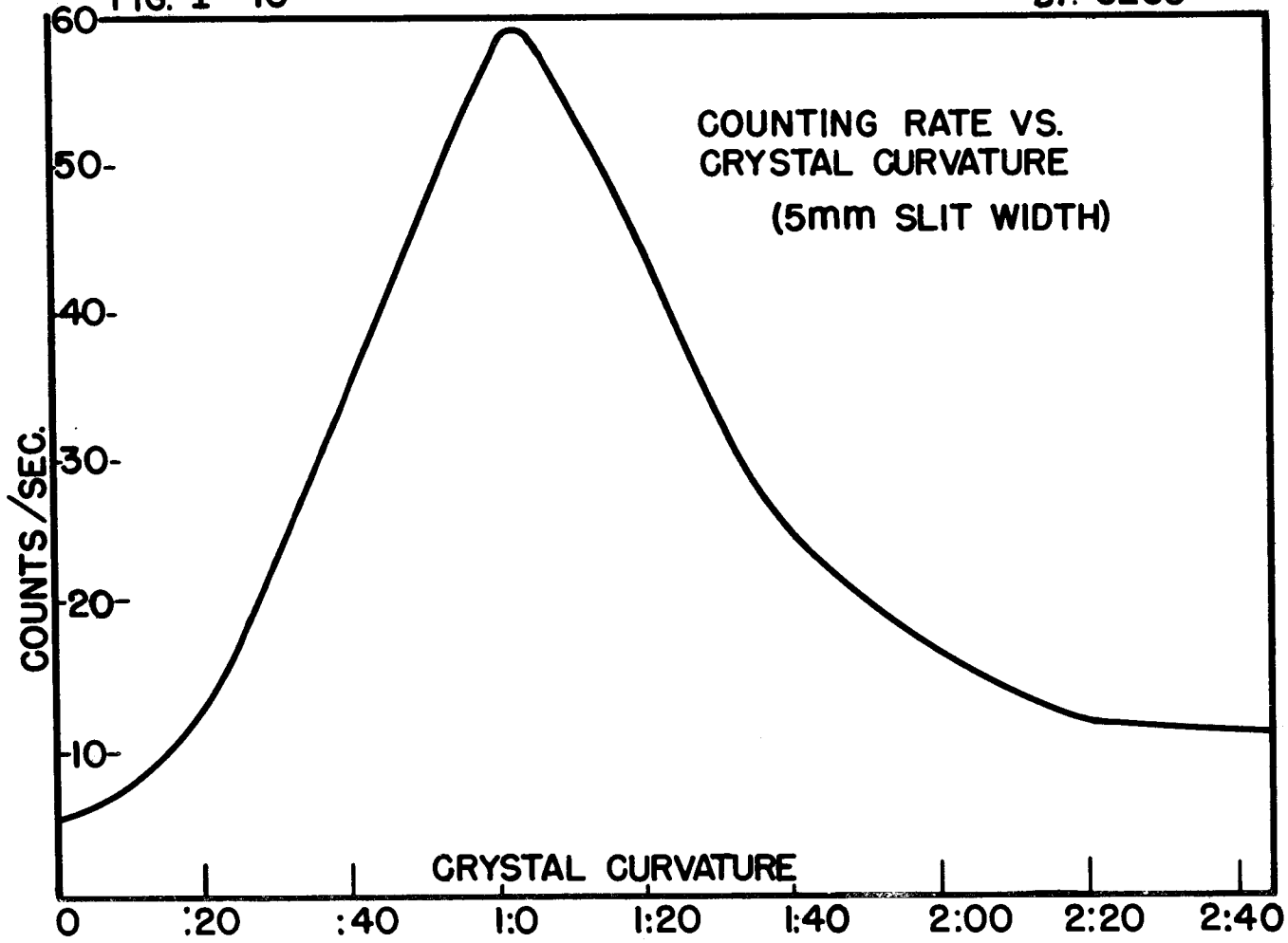


FIG.I-11 Dr. 6259

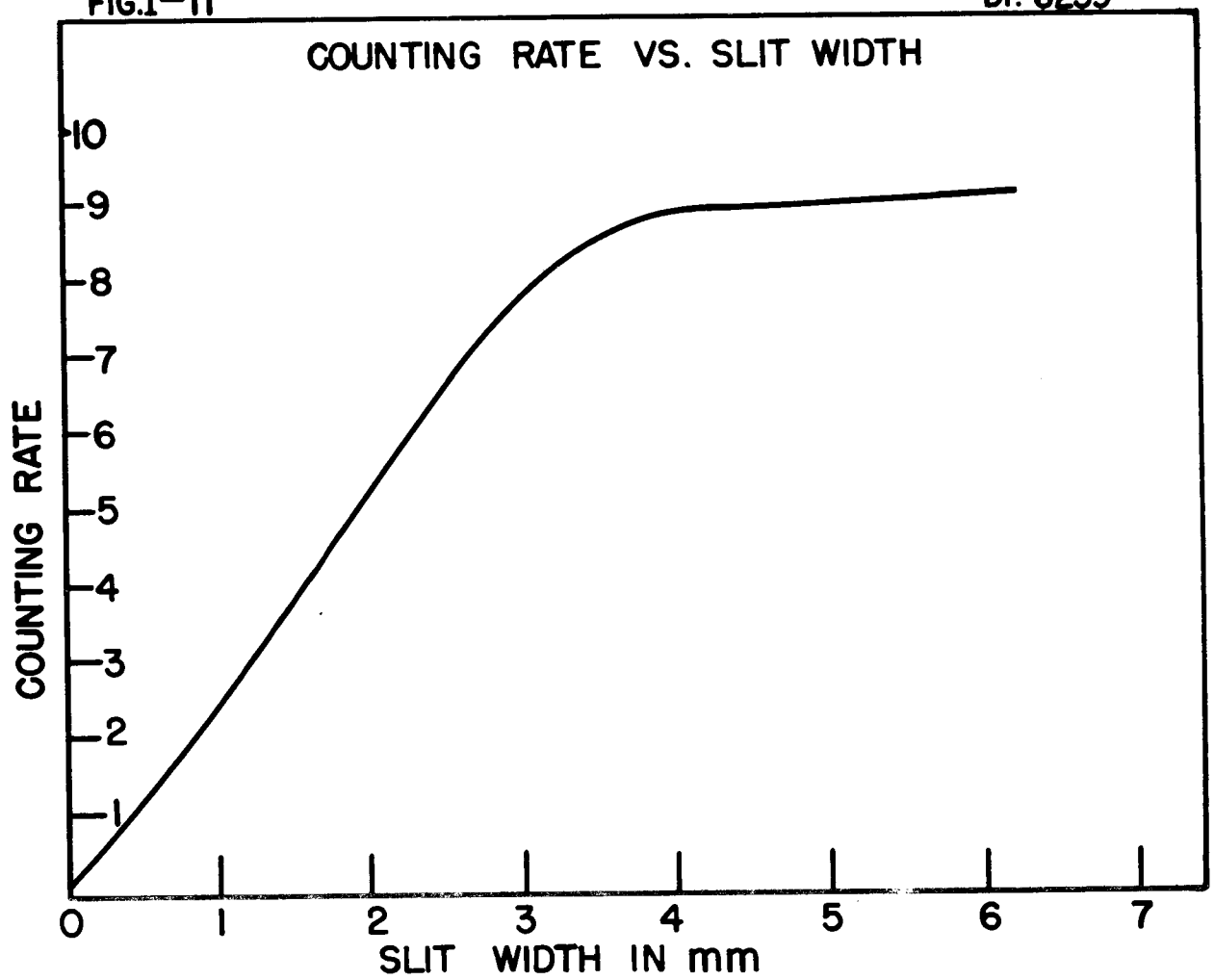
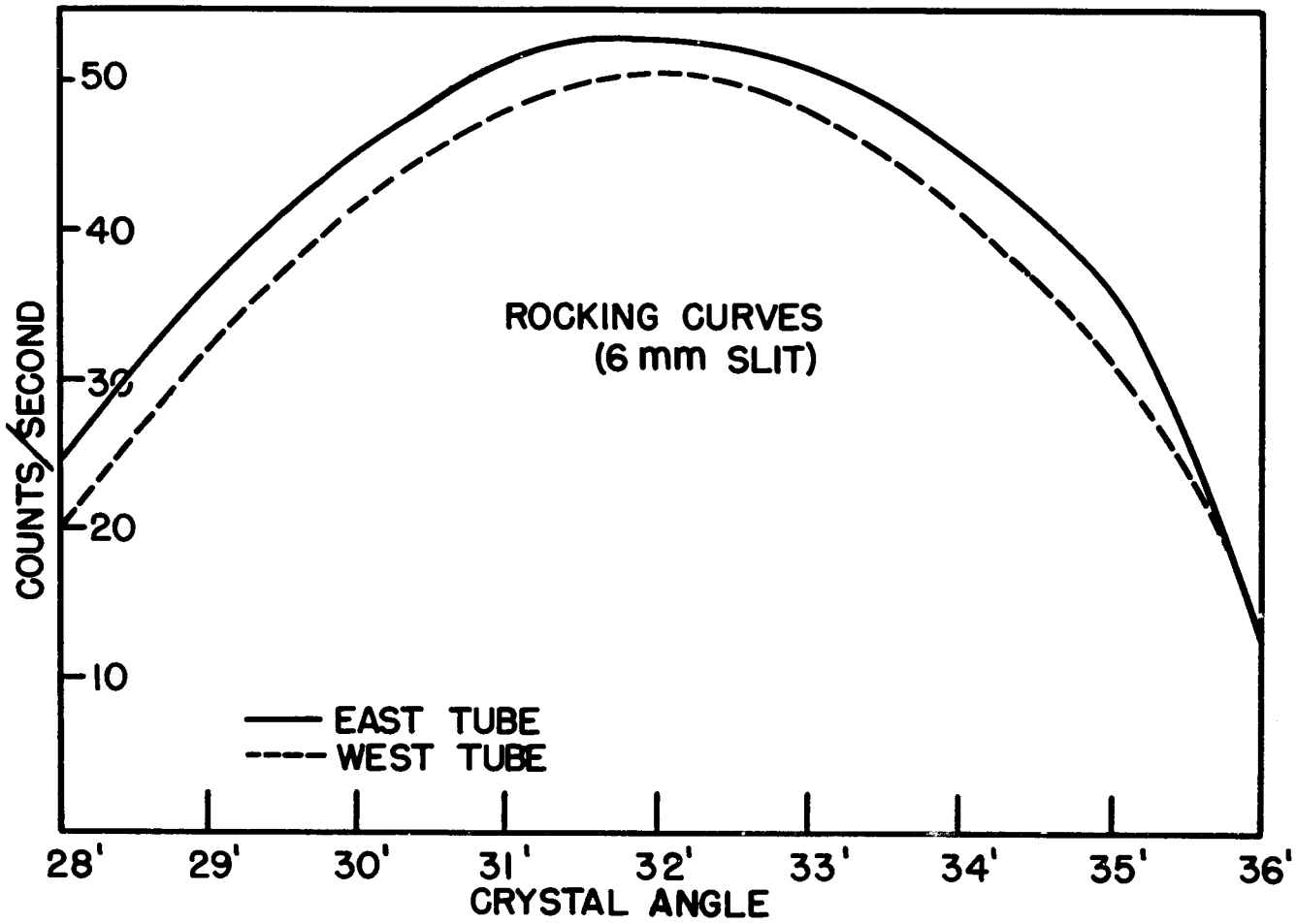


FIG. I-12 Dr. 6261



[redacted]

carefully many times by placing a fission chamber detector in the direct beam close to the pile face and recording the number of counts. It was found, first, that by means of the available adjustments on the sample shifter, the number of counts coming through the two tubes could easily be made to be the same to within 1%, and second, that the number of counts from each of the tubes remained the same to within the statistical accuracy expected from the number of counts.

It was soon realized, however, that this test is not adequate. Since the number of neutrons emerging depends upon the projection of the area of the hole in the capillary tube on a plane perpendicular to the axis of the collimator, the axes of the tubes could be off from being parallel to each other, or each to itself on repeated positioning, by a considerable angle, without affecting appreciably the number of emerging neutrons in the direct beam.

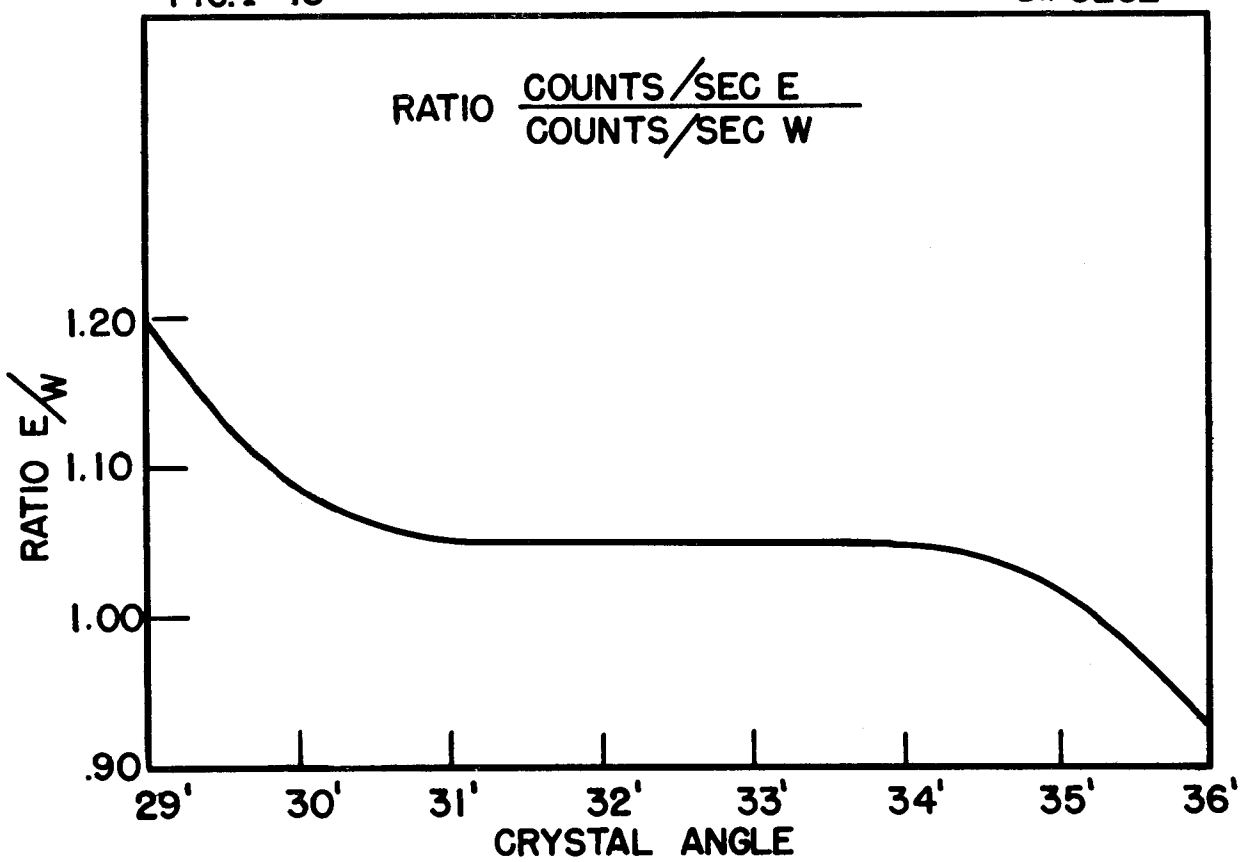
A much more severe test is to work with the beam reflected from the crystal, that is, to check the coincidence of the rocking curves for the two capillary tubes against each other. This test imposes extremely high requirements on the ability of the sample shifter to reproduce identically the same position, for the rocking curve is a very steep function. If the peak of one rocking curve were displaced by only a few minutes of arc from the peak of the other, the two counting rates in the reflected beam would be considerably different.

The result of such a check of the two rocking curves against each other is shown in Fig. I-13, in which is plotted the ratio of the counts in the reflected beam using the east capillary tubing to that using the west capillary tubing as a function of the crystal angle, the counter position remaining fixed. This ratio remained constant through about 4 minutes of crystal angle. Since the spectrometer angular scales permit the setting of angles easily to one minute of arc, the results of this test indicated that the performance of the instrument on this score was satisfactory.

It should be emphasized that with the arrangement used the neutron beam is defined by the Pyrex (boron containing) walls of the capillary tubing. In order to check whether this assumption were really true, the following test was performed. A close-fitting boron steel rod having a length of about 3½ inches was inserted into the hole in one of the capillary tubes. The number of counts in the reflected beam from about .03 ev to 0.5 ev was then measured. This number was found to be equal to background within statistical accuracy, over this energy region. However, the possibility still remains that for a short sample in the capillary tube some neutrons having paths of just the right orientation might succeed in going through only a small thickness of the glass and a portion of the length of the sample and then be reflected by the crystal and counted by the detector.

[redacted]

FIG. I-13 Dr. 6262



[redacted]

In order to reduce this possibility the Cd stops shown in Fig. I-4 on each end of the capillary tubes were inserted.

In order to obtain some estimate of the overall performance of the instrument, the cross section of Cd was measured over the small region of the peak of its resonance from about 0.14 to 0.20 ev. The results are shown in Fig. I-14. The peak value obtained of about 7300 barns agrees very well with the value obtained by other observers, as shown by the dotted line of Fig. I-14. These results suggest that the resolving power of the instrument is adequate in this region of energy.

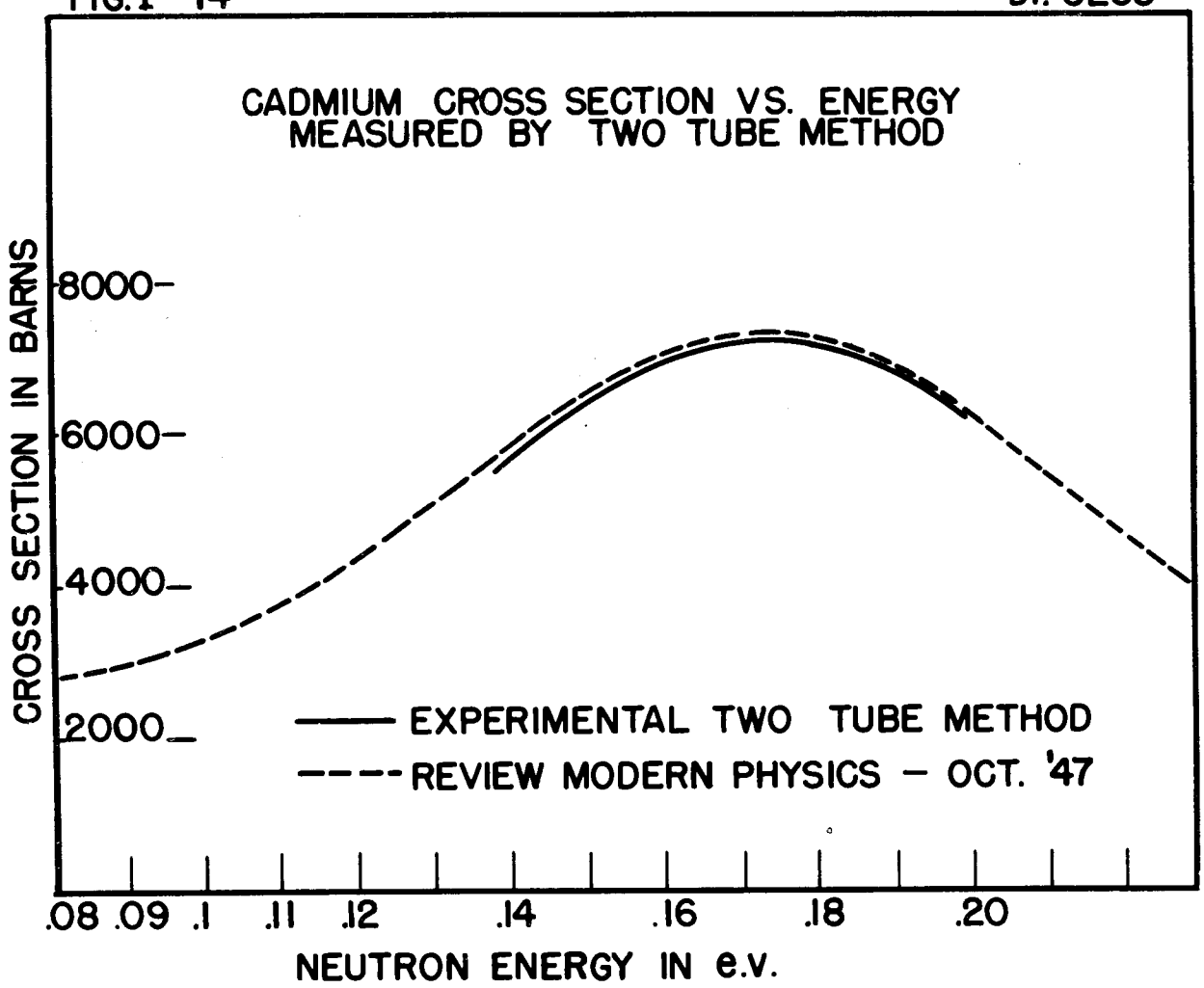
A search for evidence of higher order reflections from the quartz crystal was made by studying the absorption of boron as a function of glancing angle. The boron absorber consisted of various thicknesses of $B^{10}F_3$ in brass containers. The results of these measurements are shown in Fig. I-44, in which relative values of $\sigma\sqrt{E}$ are plotted against E. Since boron is a 1/v absorber, such a plot should give a straight line parallel to the energy axis. The presence of higher orders is indicated by the "falling off" of the data from this line at the lower energies. As can be seen from Fig. I-44, the data suggest that higher order reflections might be appreciable at energies below 0.03 ev. Essentially all of the spectrometer measurements were taken at energies above this lower limit of 0.03 ev.

PROCEDURE USED FOR TAKING AND INTERPRETING THE DATA

The procedure for taking the data soon crystallized into the following routine. An energy was chosen. The crystal curvature was then set at a previously determined optimum value for the glancing angle corresponding to this value of the energy. A rocking curve was then taken. The spectrometer angles were set to within one minute of arc of the peak of the rocking curve. The tube containing the active sample was then put into the neutron beam, and a count taken for a period of five to fifteen minutes. The empty monitor tube was then placed in the beam and a count taken for about the same length of time. Background counts for each of the tubes were then taken. "Background" was defined to be the counting rate obtained with the BF_3 counter when the crystal was deliberately set at an angle 1° less than the Bragg angle corresponding to the position of the counter. Fifteen minutes to one hour were needed to obtain one value of the transmission. Several such values of the transmission were taken without changing any of the spectrometer angles. From one to five hours, depending upon the counting rate available at the particular energy, were required to complete one such "cycle" of three to five values of the transmission. Another energy was then chosen, and the "cycle" of

[redacted]

FIG. I-14 Dr. 6263



[redacted]

three to five transmissions repeated for the new energy. For one sample of Xe, measurements were taken for only 3 to 5 values of energy. Data were taken continuously on each sample for three days to a week. For a given sample at each energy, from four to eight cycles of about five values of the transmissions in each cycle were determined at different times during the growth and decay of the Xenon.

Simultaneously with the spectrometer measurements, measurements were also taken with a fission chamber placed in the direct beam, as shown in Fig. I-3. Readings were taken with the fission chamber both with and without cadmium surrounding it. From these data a value of the cross section of Xe^{135} for the Cd absorbable neutrons being emitted by the Oak Ridge National Laboratory pile was determined. The fission chamber readings were synchronized with the crystal spectrometer readings so that no time was lost.

All detection and electronic equipment used in connection with the spectrometer and the fission chamber were set up in duplicate, so that if some scaling circuit or amplifier failed to function, the standby unit could be used in its place. This duplication of equipment reduced by a large factor the possibility of spending time repairing faulty equipment while the Xe decayed unused.

The Xe^{135} grows from the I^{135} according to the relation

$$N_2 = N_I^{\,0} \frac{\lambda_1}{\lambda_2 - \lambda_1} \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right) \qquad (1)$$

in which

N_2 ≡ number of Xe^{135} atoms present in the sample at time t.

$N_I^{\,0}$ ≡ number of I^{135} atoms present in the sample at time zero. (There are no Xe^{135} atoms present at time zero.)

λ_1 ≡ transformation constant of I^{135}.

λ_2 ≡ transformation constant of Xe^{135}.

A graph of equation (1) in arbitrary units is shown in Fig. I-15. The transmission of the sample is, of course, inverse to the amount of Xe present in the sample, the transmission increasing as the Xe grows, and decreasing as the Xe decays. The growth and decay of the Xe is clearly shown by the data represented in Fig. I-16, the transmission of sample 9 for Cd absorbable neutrons as a function of the time. Similar plots at the various energies are shown in Fig. I-17. The transmission of the Xe itself is given by the vertical distance from the minimum of the curve to the height of the asymptote. The

[redacted]

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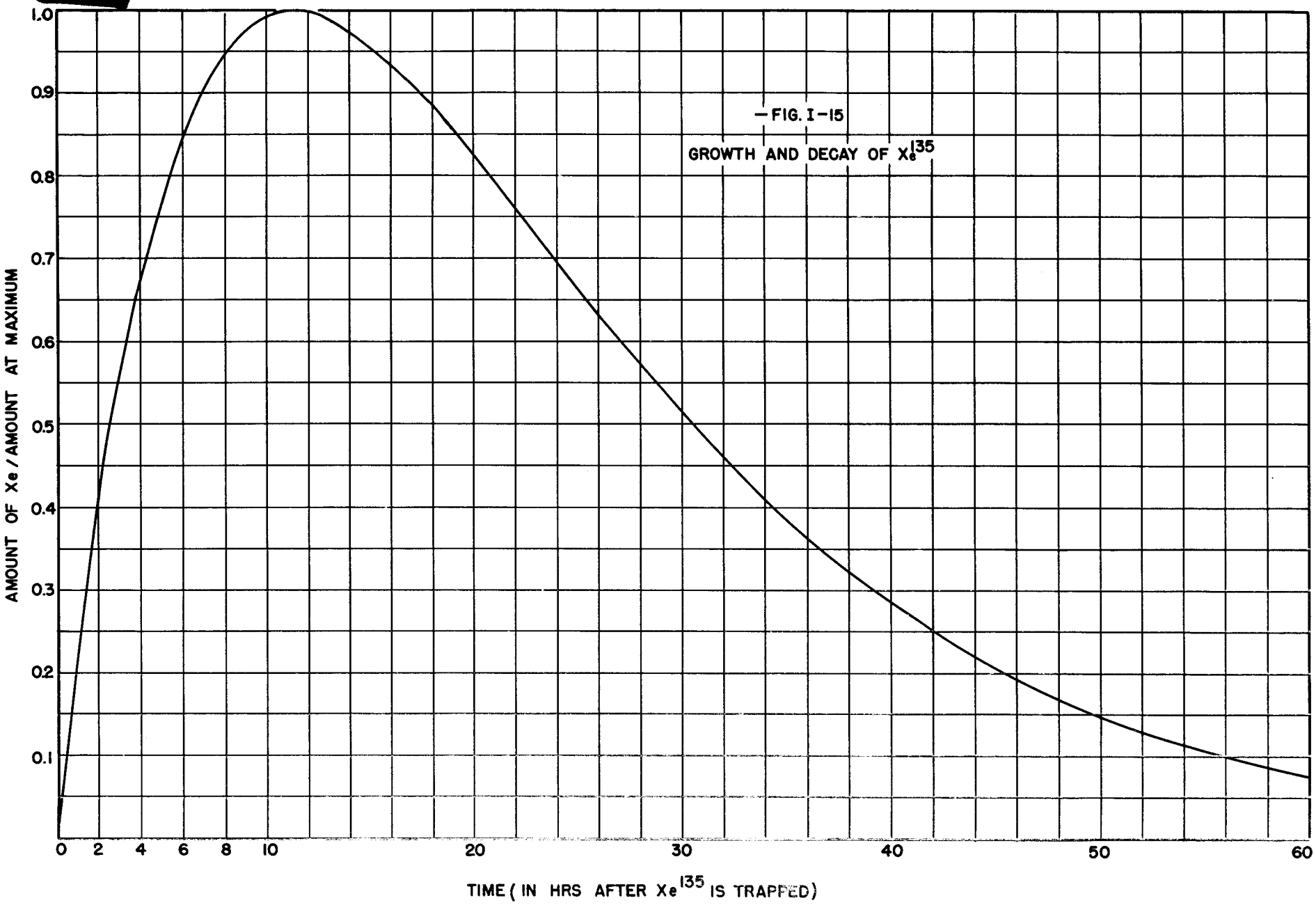
Dr. 6918



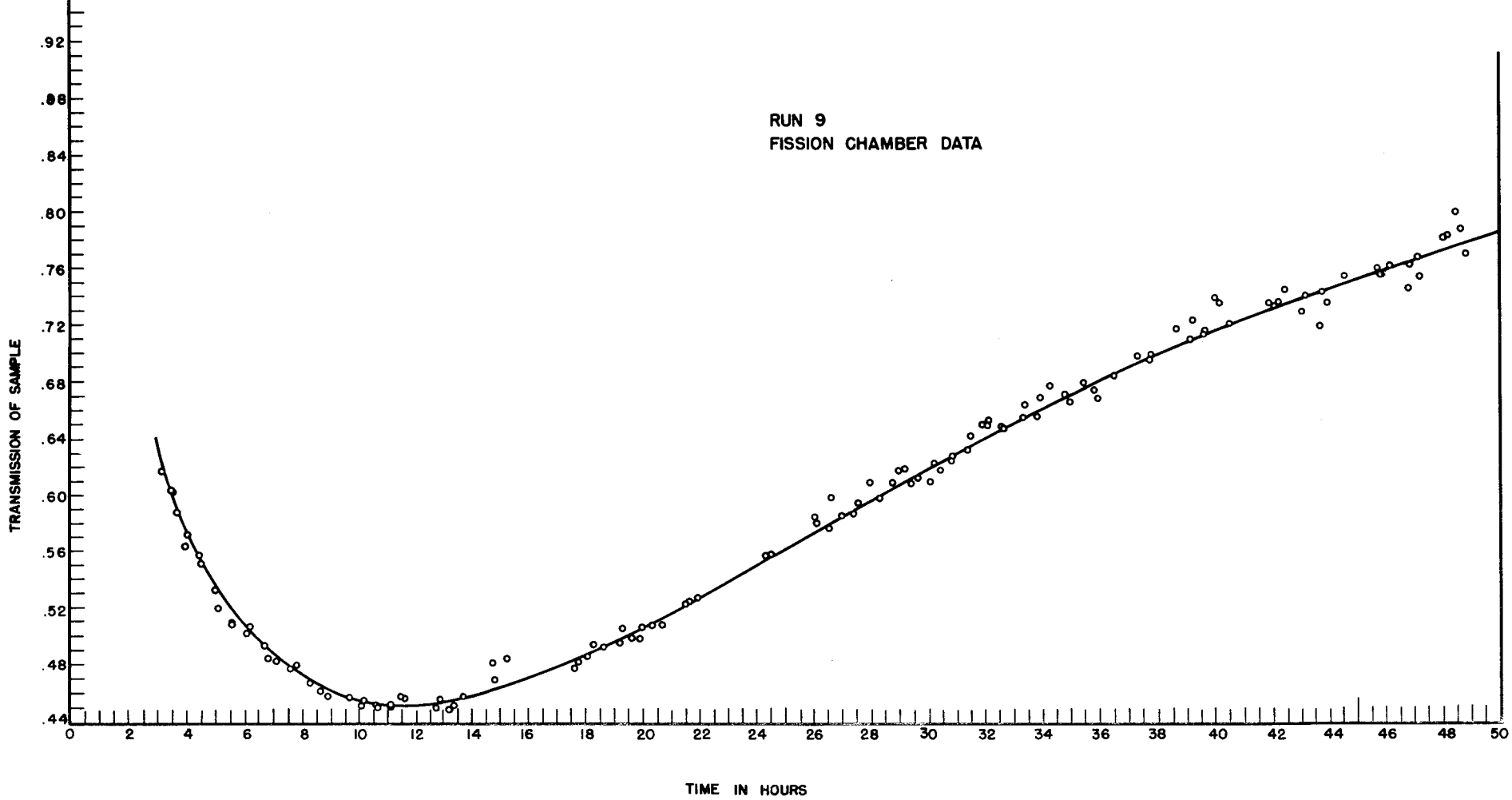
— FIG. I-15

GROWTH AND DECAY OF Xe^{135}

Dr. 6891

FIG. I - 16

TRANSMISSION VS. TIME



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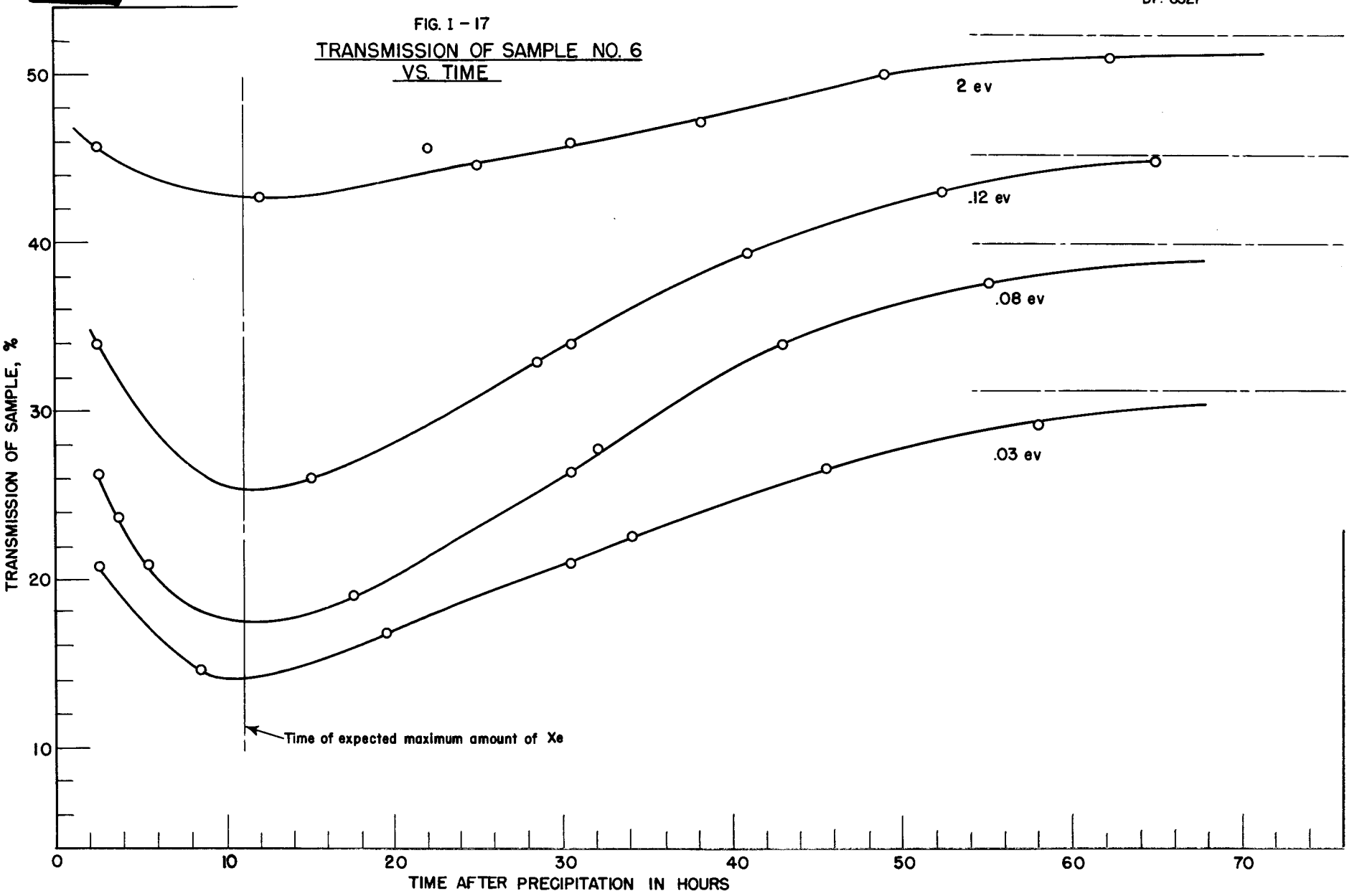
Dr. 6527

FIG. I – 17

TRANSMISSION OF SAMPLE NO. 6 VS. TIME



[redacted]

transmission corresponding to the asymptote is a measure of the product of the total cross section per molecule and the number of carrier (PdI_2) molecules. From Fig. I-17 it can be seen immediately that the cross section of Xe at 0.03, 0.08, and 0.12 ev are very roughly equal, and that the cross section at 0.20 ev is considerably smaller.

Expression (1) can be abbreviated as follows:

$$N_2 = N_I^0 \; f(t) \tag{2}$$

in which

$$f(t) \equiv \frac{\lambda_1}{\lambda_2 - \lambda_1} \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right) \quad . \tag{3}$$

The transmission of the Xe alone is given by

$$T_2 = e^{-N_I^0 f(t) \sigma_{xe}} \quad , \tag{4}$$

in which σ_{xe} is the cross section of the Xe per atom. The transmission of the sample is given by

$$T = T_1 \; T_2 \; (t) \quad , \tag{5}$$

in which T is the observed transmission for the sample, T_1 is the transmission of the carrier material alone, and $T_2(t)$ is the transmission of the Xe alone. The relation

$$ln \; T = ln \; T_1 + ln \; T_2 \; (t) \tag{6}$$

is equivalent to (5), and using (4), one obtains

$$ln \; T = ln \; T_1 - N_I^0 \; f(t) \; \sigma_{xe} \quad . \tag{7}$$

Differentiating (7) with respect to f(t), the result is obtained:

$$\frac{\Delta \; ln \; T}{\Delta \; f(t)} = -N_I^0 \; \sigma_{xe} \tag{8}$$

If, then, the logarithm of the transmission is plotted as a function of f(t), a straight line should be obtained whose slope is proportional to the product of the strength of the sample and the cross section

[redacted]

[redacted]

of Xe^{135}. The values of f(t) were calculated on the assumption that the transformation constants, λ_1 and λ_2, and the "zero time" of the Xe growth were known.

An example of such straight line plots are given in Fig. I-18 for the fission chamber data of sample 9. A similar plot for the individual energies of sample 8 is shown in Fig. I-19. By visual inspection of the slopes of the lines of Fig. I-18, the values of the cross sections given by this run can immediately be put into monotonic decreasing order as follows: 0.08 ev; 0.03 ev; 0.10 ev; 0.12 ev; 0.15 ev. The results of this one run alone suggest at once that the Xe^{135} resonance lies somewhere between 0.03 ev and 0.10 ev. Since the lines for .03 and 0.10 ev are almost coincident, a rough guess might be made from this one run alone that the maximum might lie at about 0.07 ev.

All of the data taken were fitted to the straight line relation (7) by the method of least squares by members of the Computing Panel. The straight lines shown on all the graphs are the least square lines which were fitted to the data. In many of the graphs the experimental points themselves have been omitted.

The figures showing the plots of the results on all the runs will not be discussed in detail here. Only a list of figure numbers and corresponding titles is given in Table I-2 below:

TABLE I-2

LIST OF FIGURES

FIGURE NUMBER	TITLE	SAMPLE NUMBERS	ENERGIES
I-20	Relative Total Cross Section vs. Number of Atoms	5	Cd Absorbable Neutrons
I-21	"	6	"
I-22	"	7	"
I-23	"	8	"
I-24	"	10	"
I-25	"	3	0.03, 0.06, 0.10, 0.15, 0.20 ev
I-26	"	5	0.03, 0.06, 0.10, 0.20 ev
I-27	"	6	0.03, 0.08, 0.12, 0.20 ev
I-28	"	7	0.03, 0.06, 0.08, 0.10, 0.12 ev
I-29	"	3, 5, 6	0.03 ev
I-30	"	7, 8, 9, 10	0.03 ev
I-31	"	3, 5	0.06 ev
I-32	"	7, 9	0.06 ev
I-33	"	7, 8	0.08 ev
I-34	"	3, 5	0.10 ev
I-35	"	7, 8, 10	0.10 ev
I-36	"	7, 8	0.12 ev
I-37	"	3	0.15 ev
I-38	"	8, 9	0.15 ev
I-39	"	3, 5, 6	0.20 ev

[redacted]

FIG. I-18

RELATIVE TOTAL CROSS SECTION
Vs
CALCULATED RELATIVE NUMBER OF XENON ATOMS

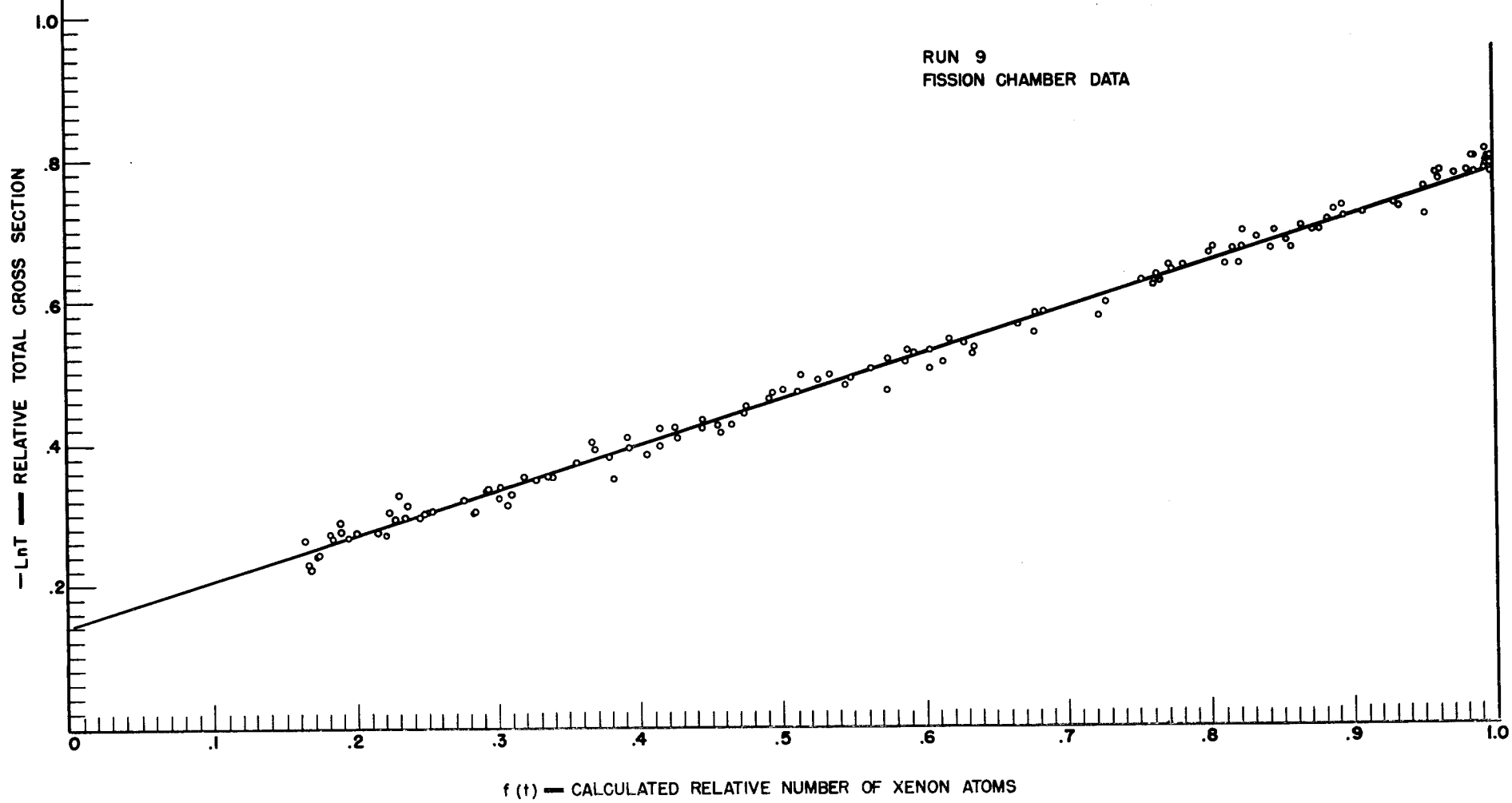


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FIG. I-19

RELATIVE TOTAL CROSS SECTION
VS.
CALCULATED RELATIVE NUMBER OF XENON ATOMS

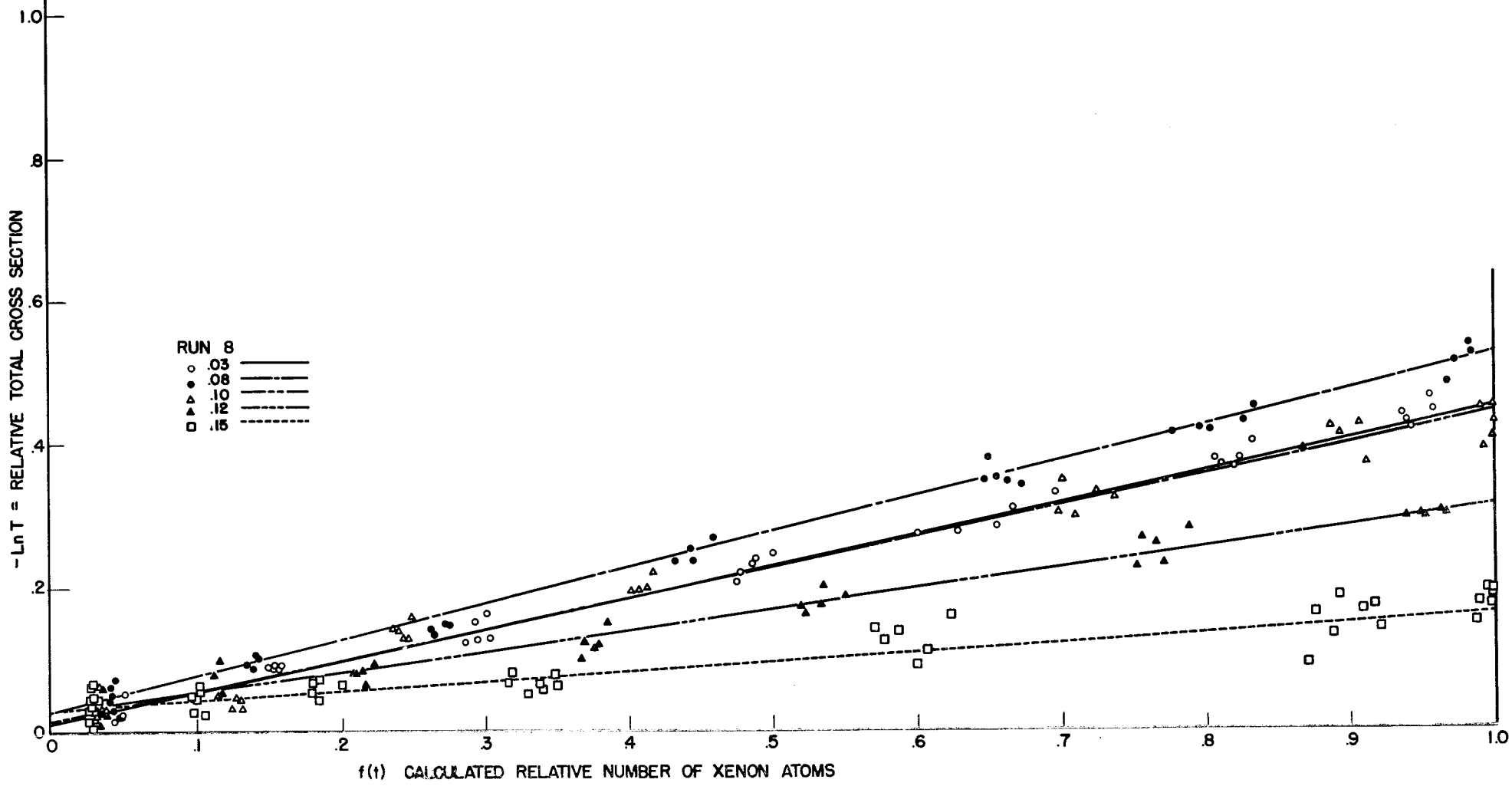


FIG. I - 20

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS

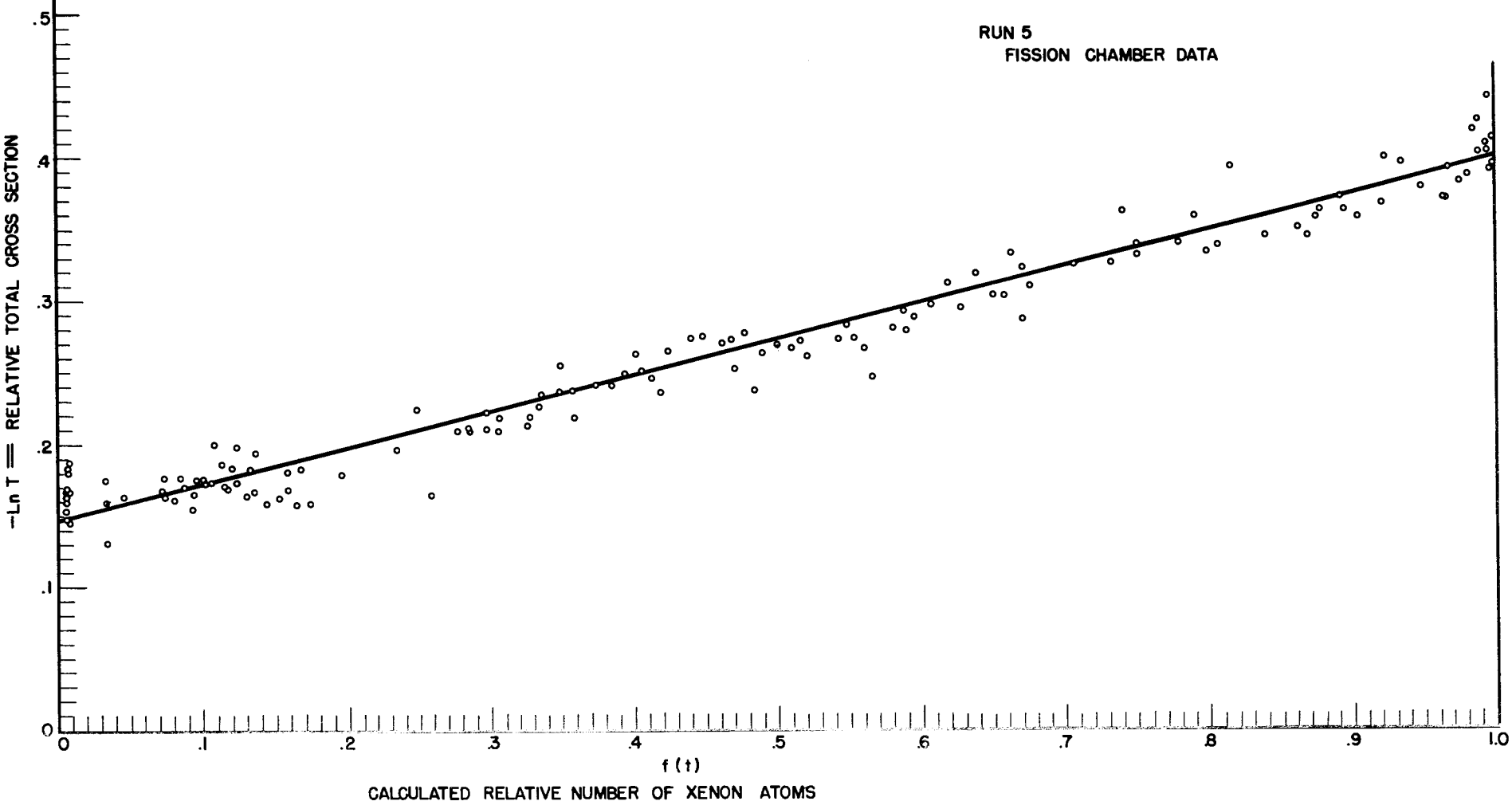
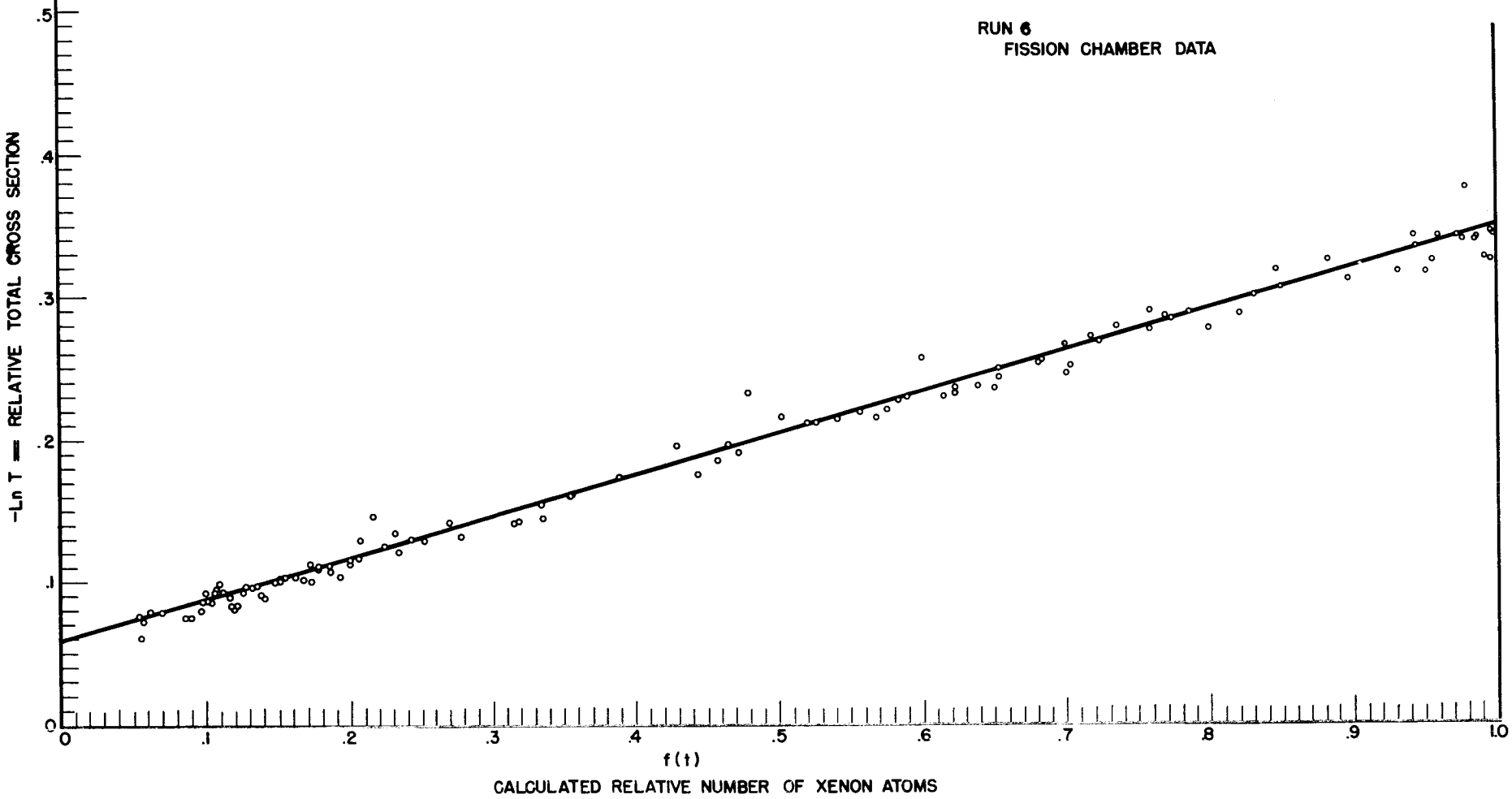


FIG. I - 21

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS



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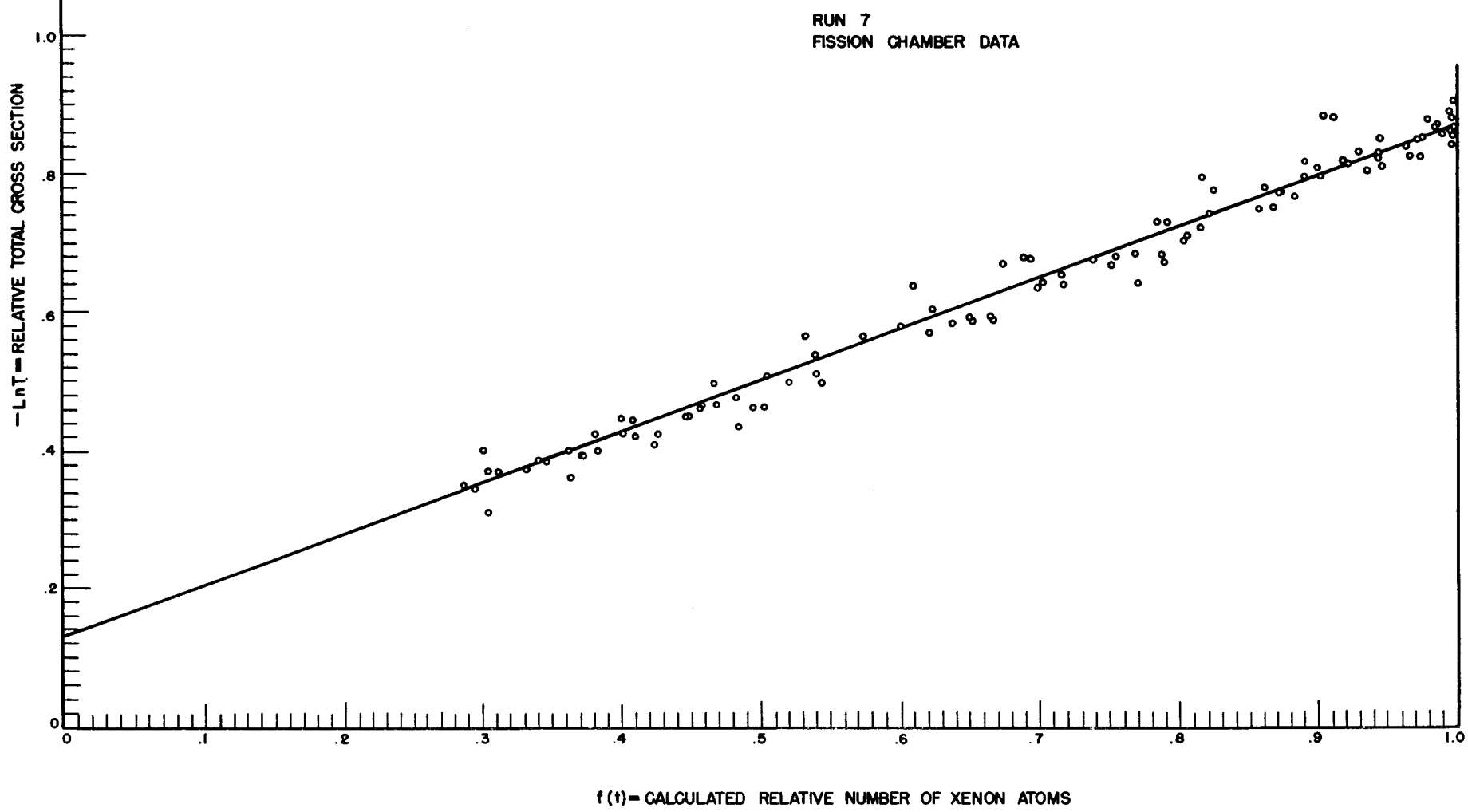
Dr. 6896

FIG. I-22

RELATIVE TOTAL CROSS SECTION
Vs
CALCULATED RELATIVE NUMBER OF XENON ATOMS



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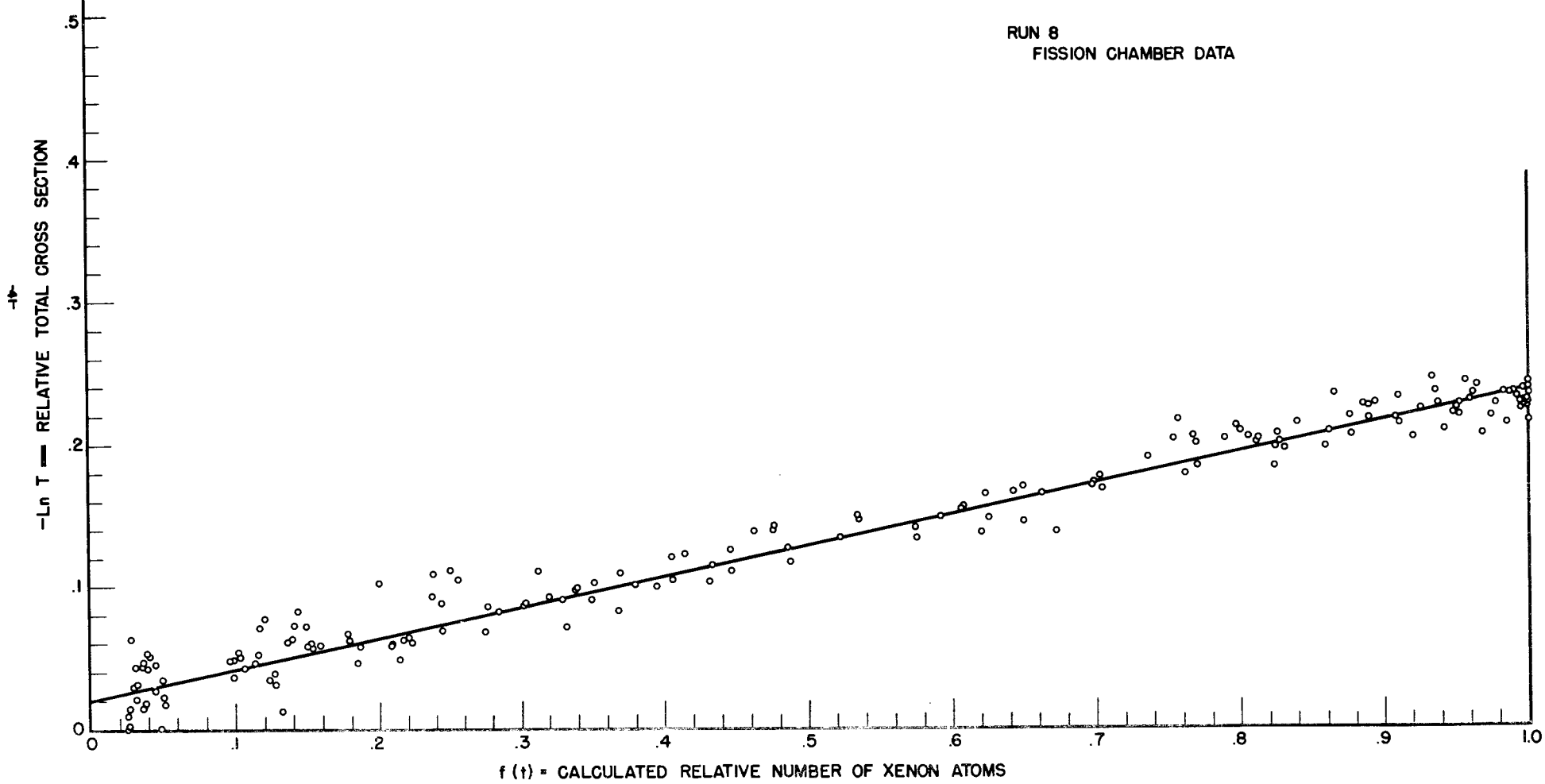
Dr. 6897

FIG. I - 23

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS



Dr. 6898

FIG. I - 24

RELATIVE TOTAL CROSS SECTION
Vs
CALCULATED RELATIVE NUMBER OF XENON ATOMS

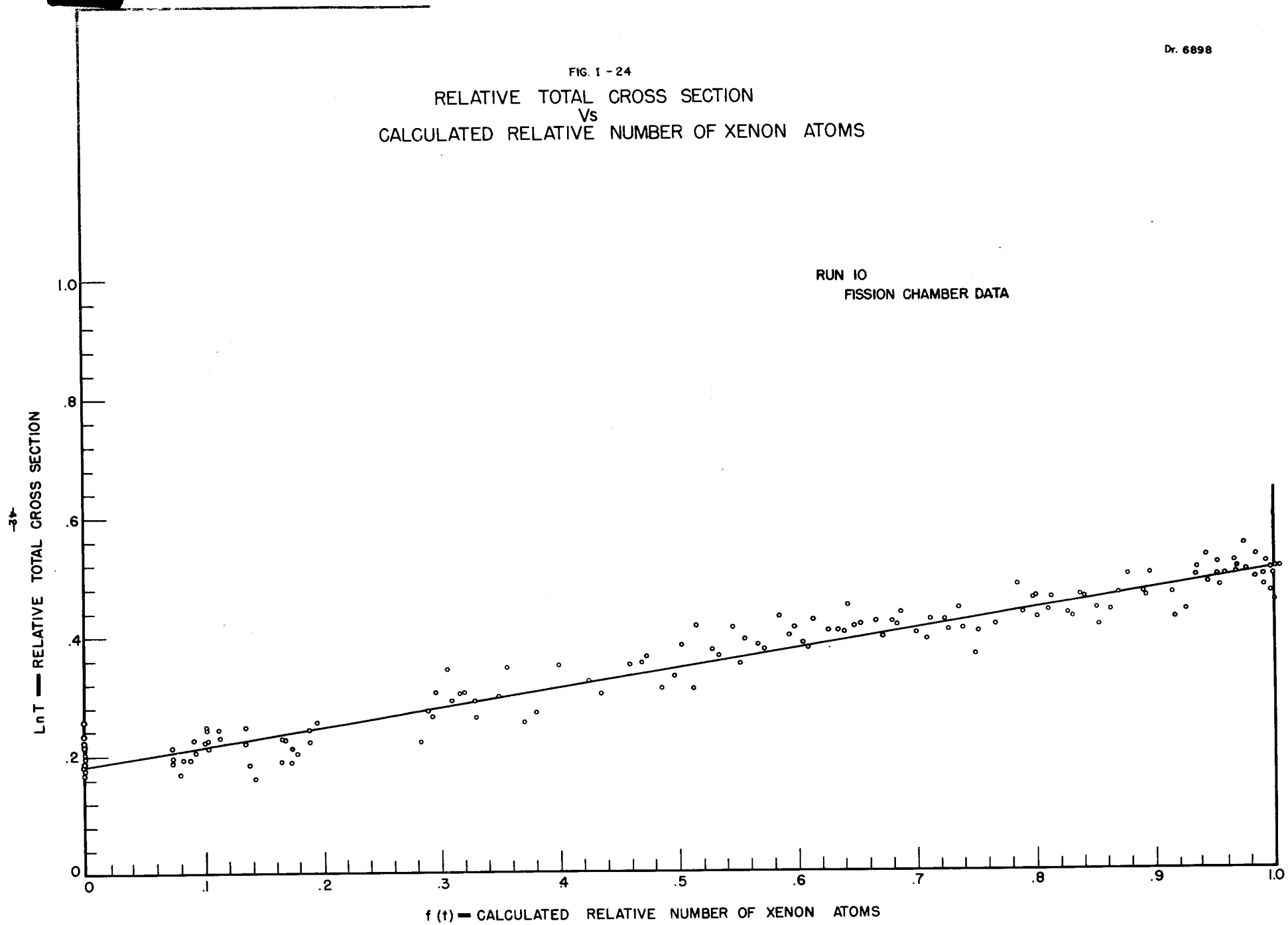


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FIG. I – 25

RELATIVE TOTAL CROSS SECTION
VS.
CALCULATED RELATIVE NUMBER OF XENON ATOMS

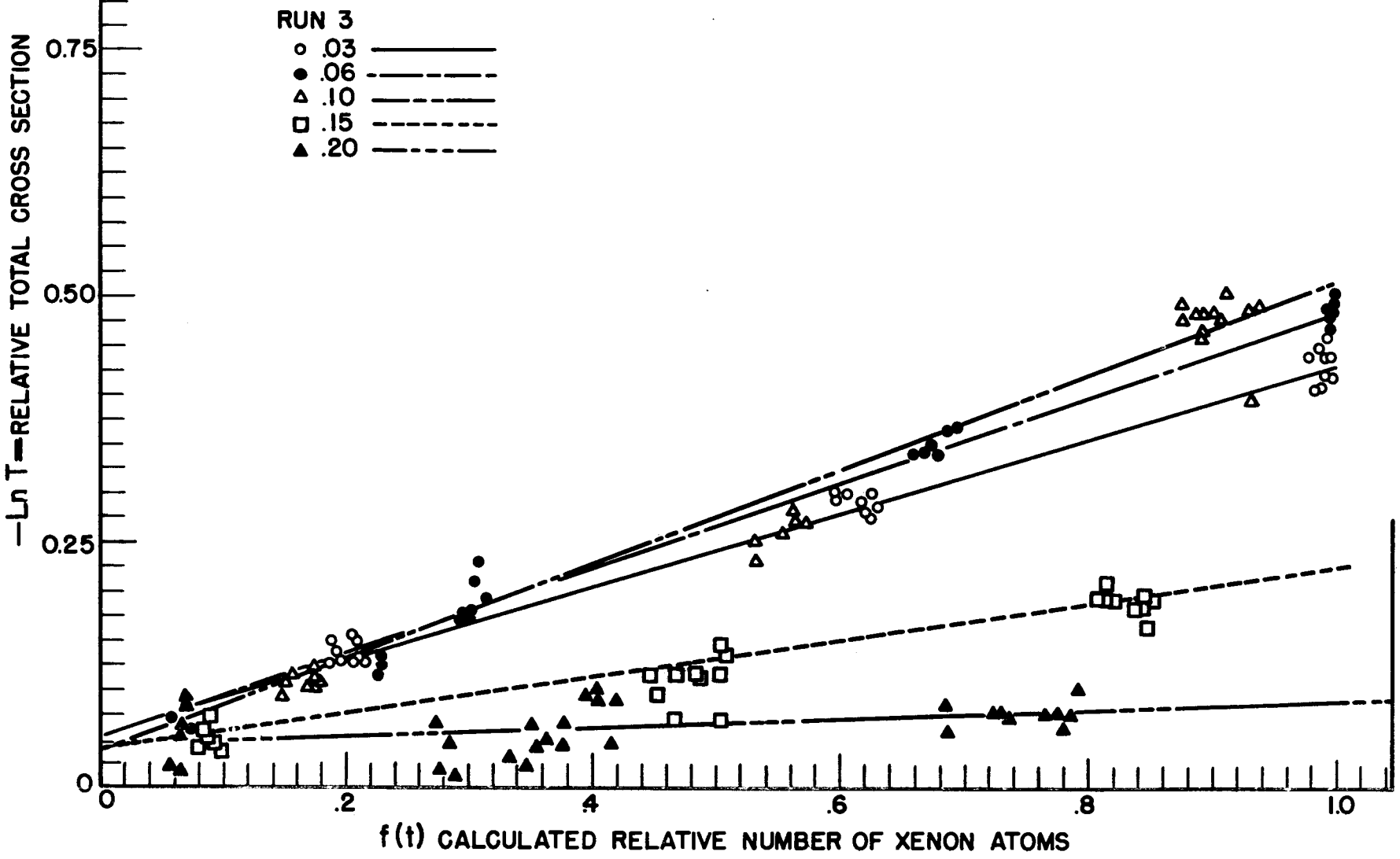

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FIG. I – 26

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS

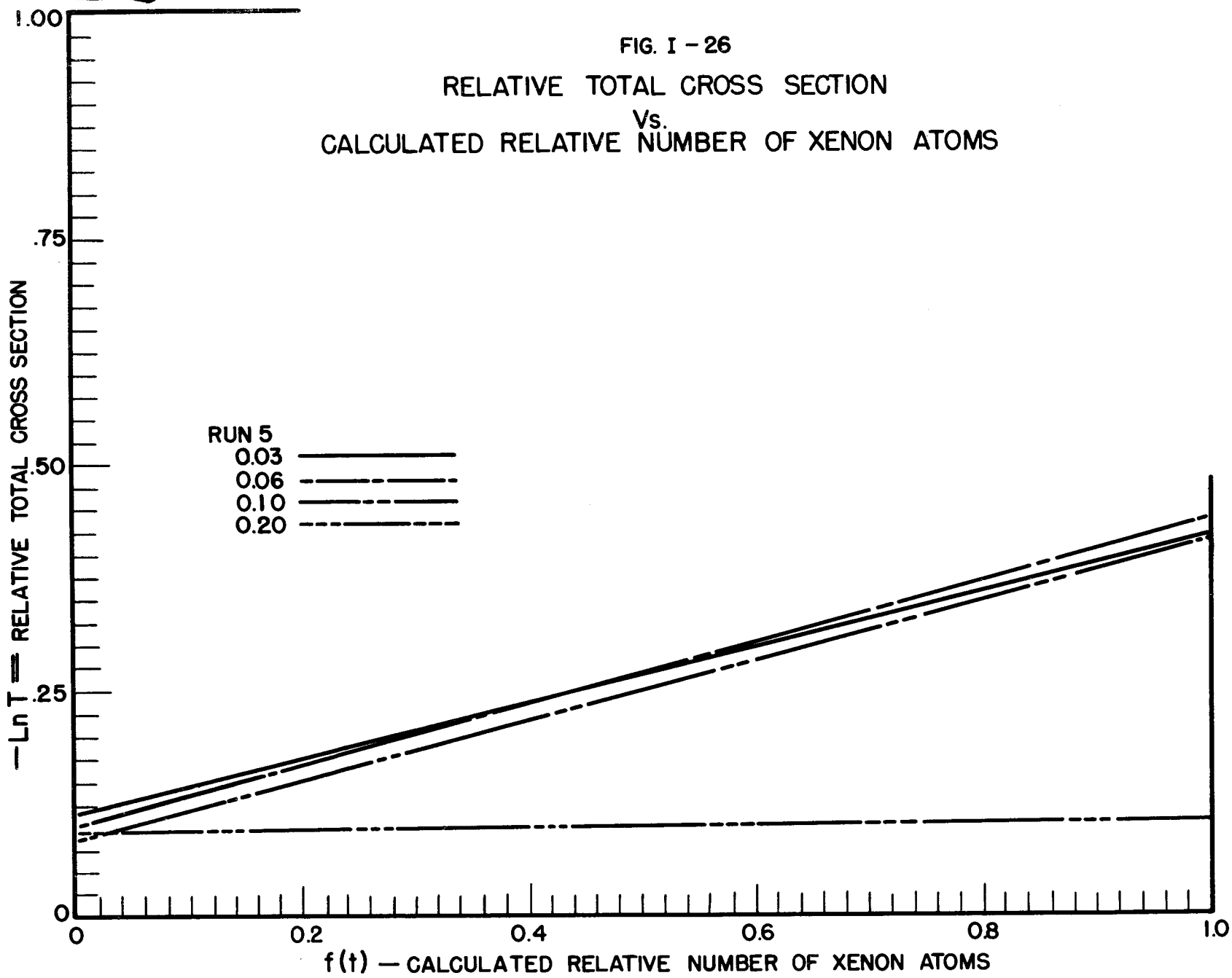

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FIG. I - 27

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS

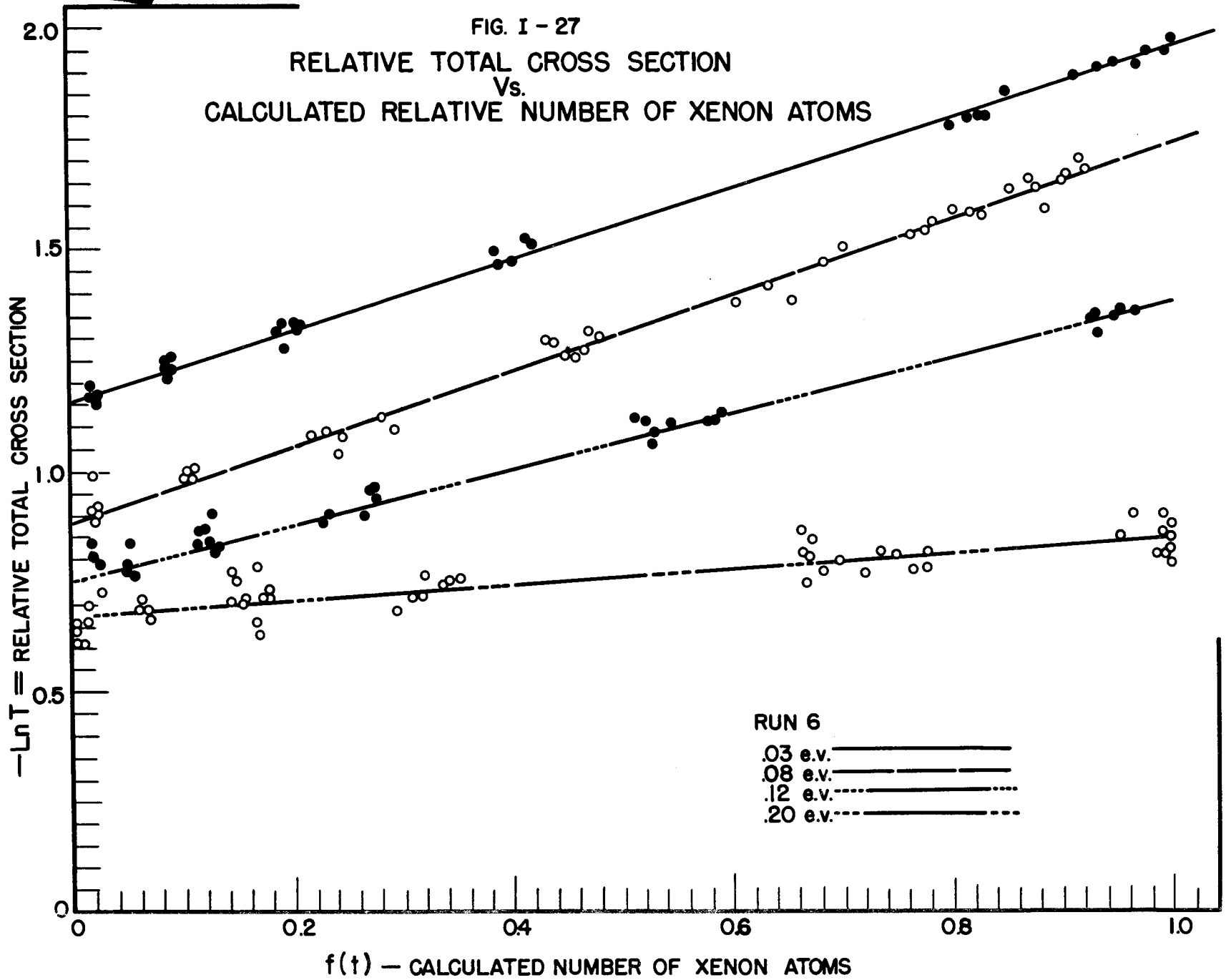
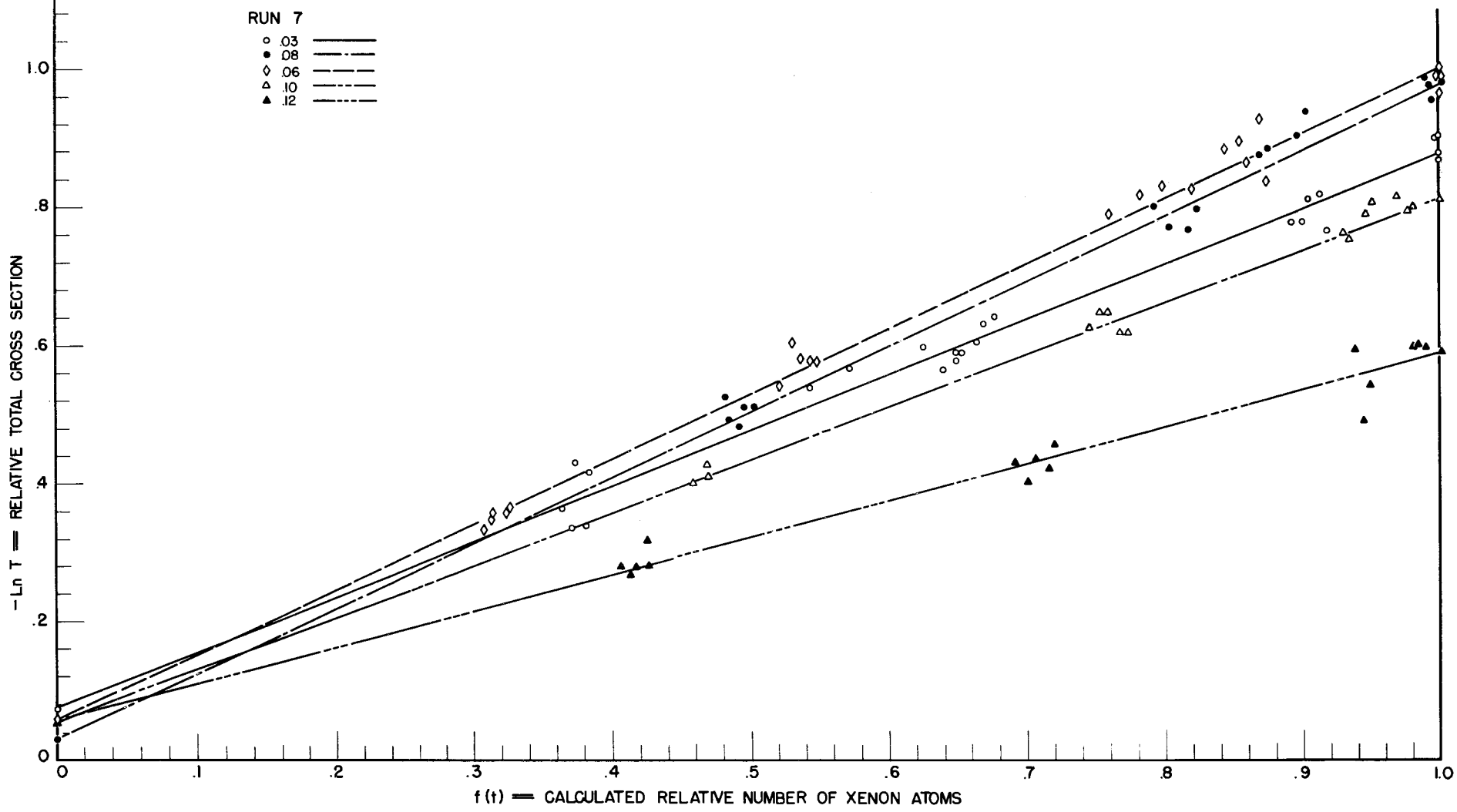


FIG. I - 28

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS



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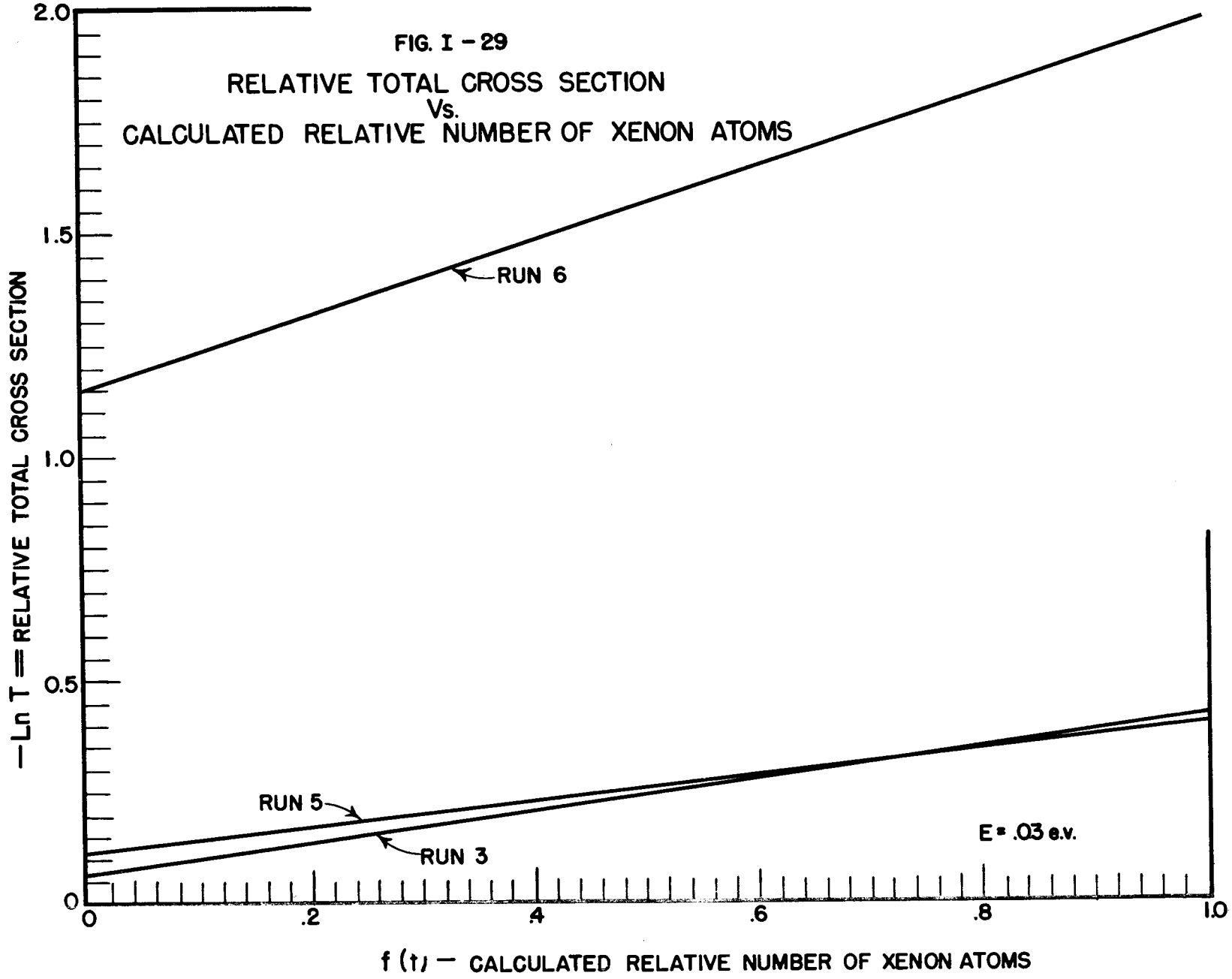

FIG. I – 29

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS

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FIG. I-30

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS

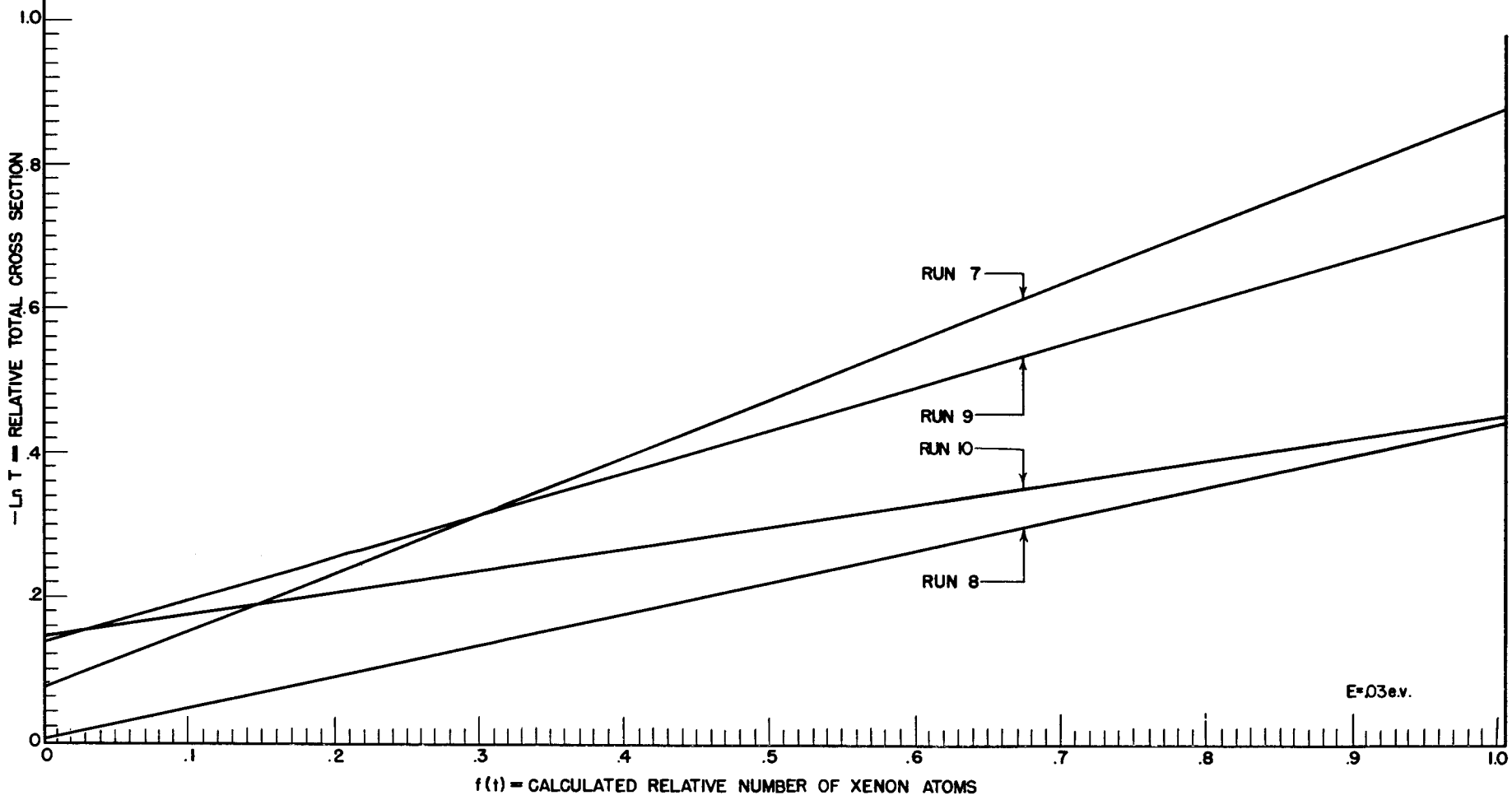

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FIG. I-31

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS

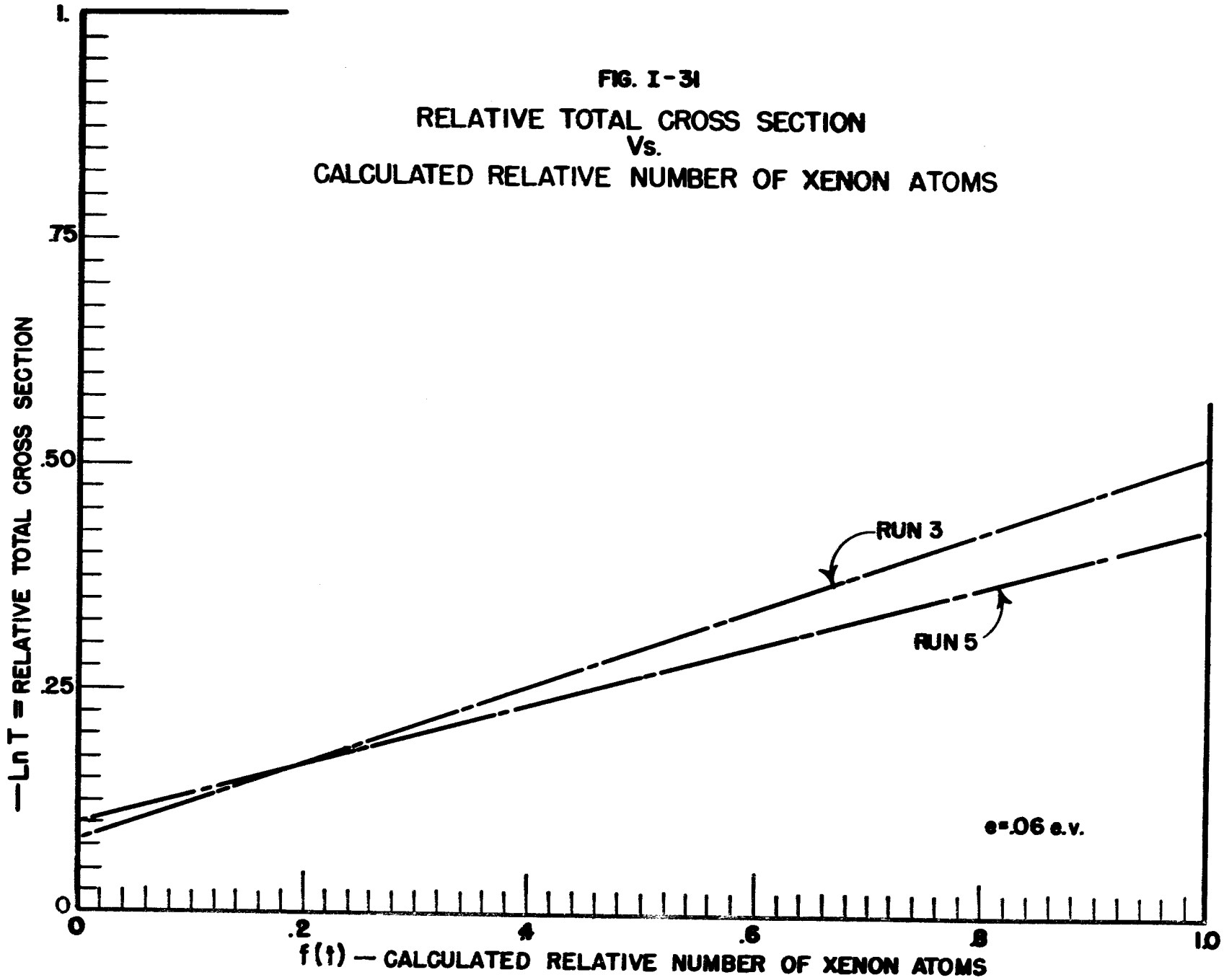

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FIG. I-32

RELATIVE TOTAL CROSS SECTION
Vs
CALCULATED RELATIVE NUMBER OF XENON ATOMS

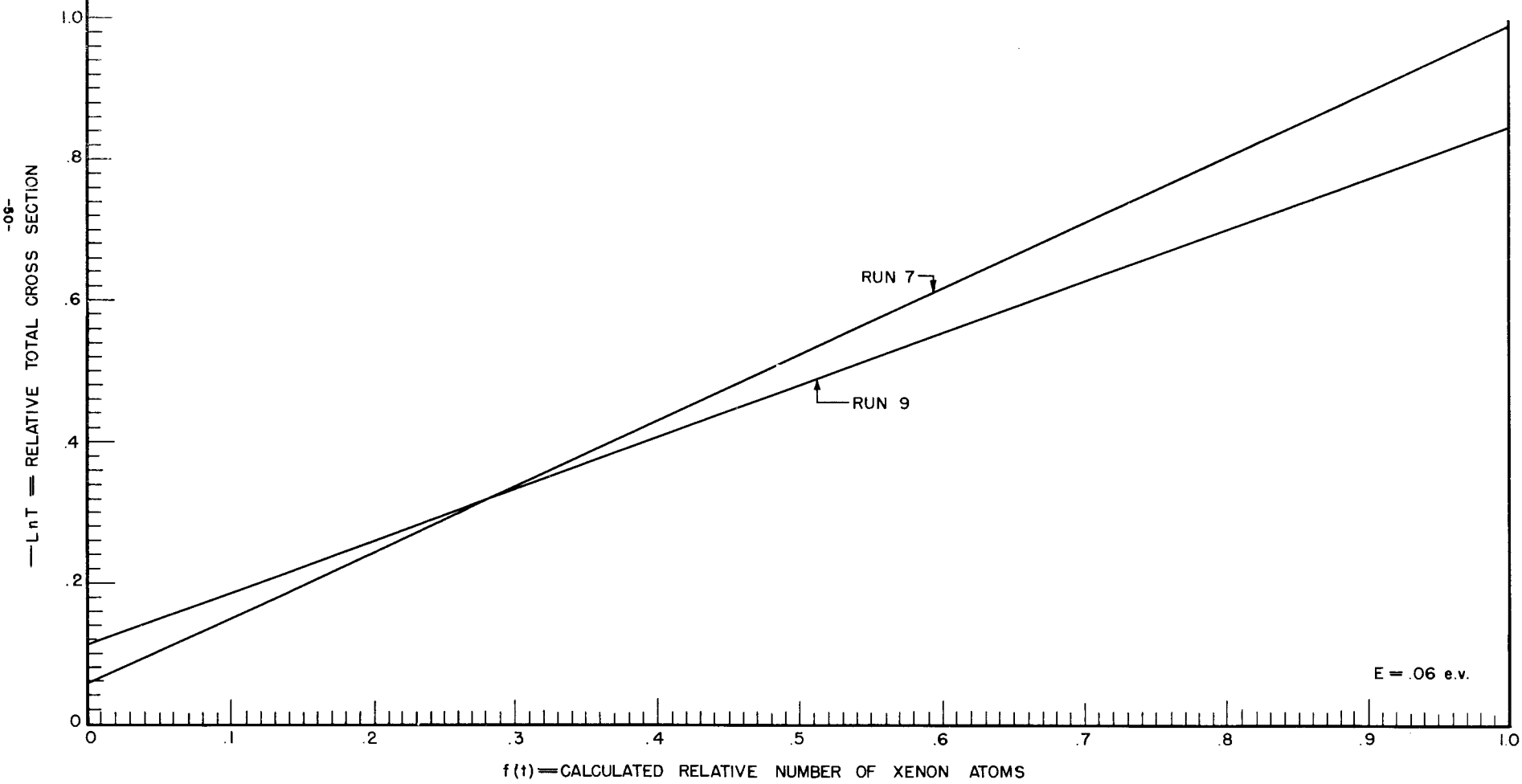

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FIG. I-33

RELATIVE TOTAL CROSS SECTION
Vs
CALCULATED RELATIVE NUMBER OF XENON ATOMS

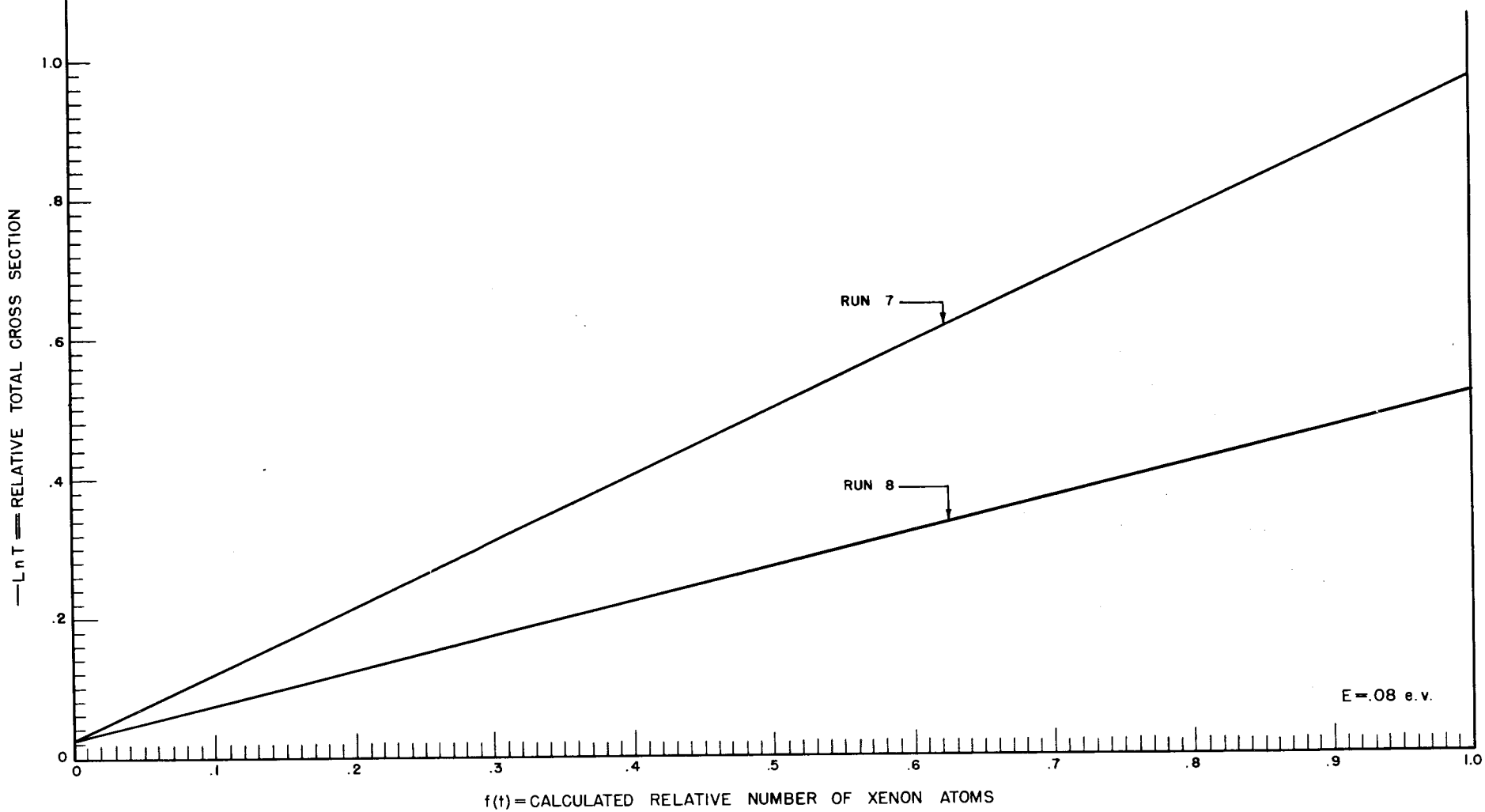

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FIG. I – 34

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS

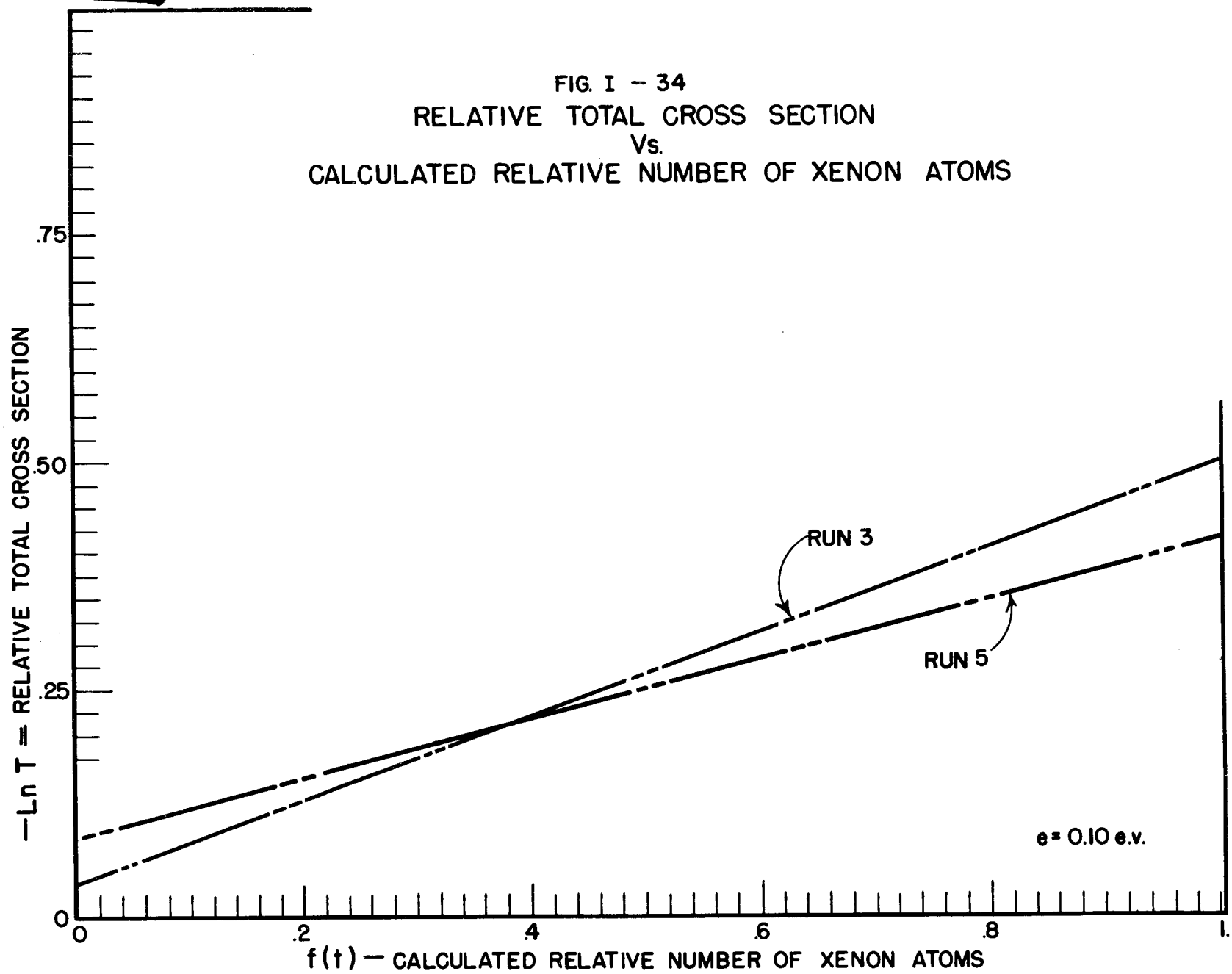

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FIG. I – 35

RELATIVE TOTAL CROSS SECTION
Vs
CALCULATED RELATIVE NUMBER OF XENON ATOMS

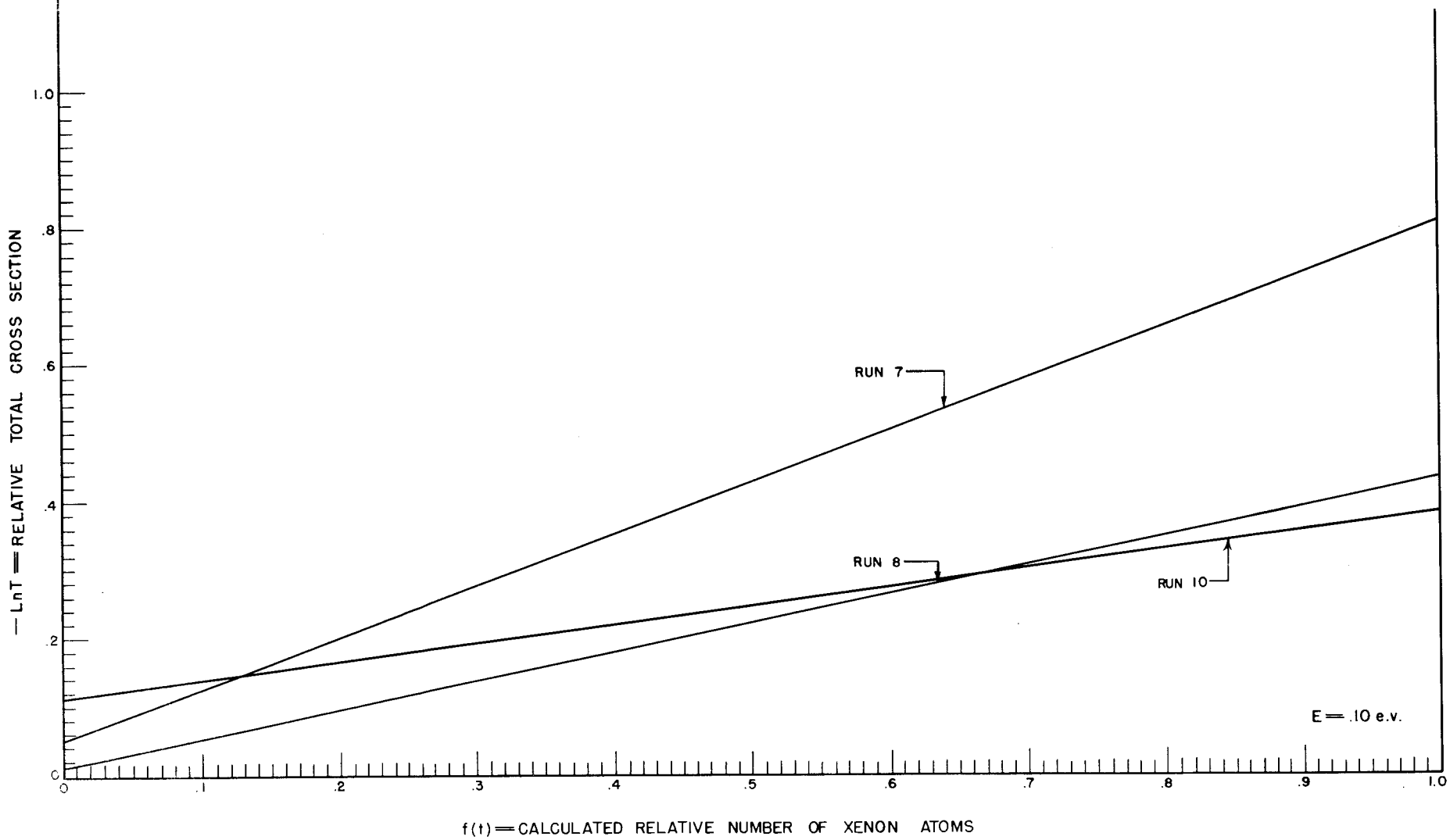

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FIG. I-36

RELATIVE TOTAL CROSS SECTION
Vs
CALCULATED RELATIVE NUMBER OF XENON ATOMS

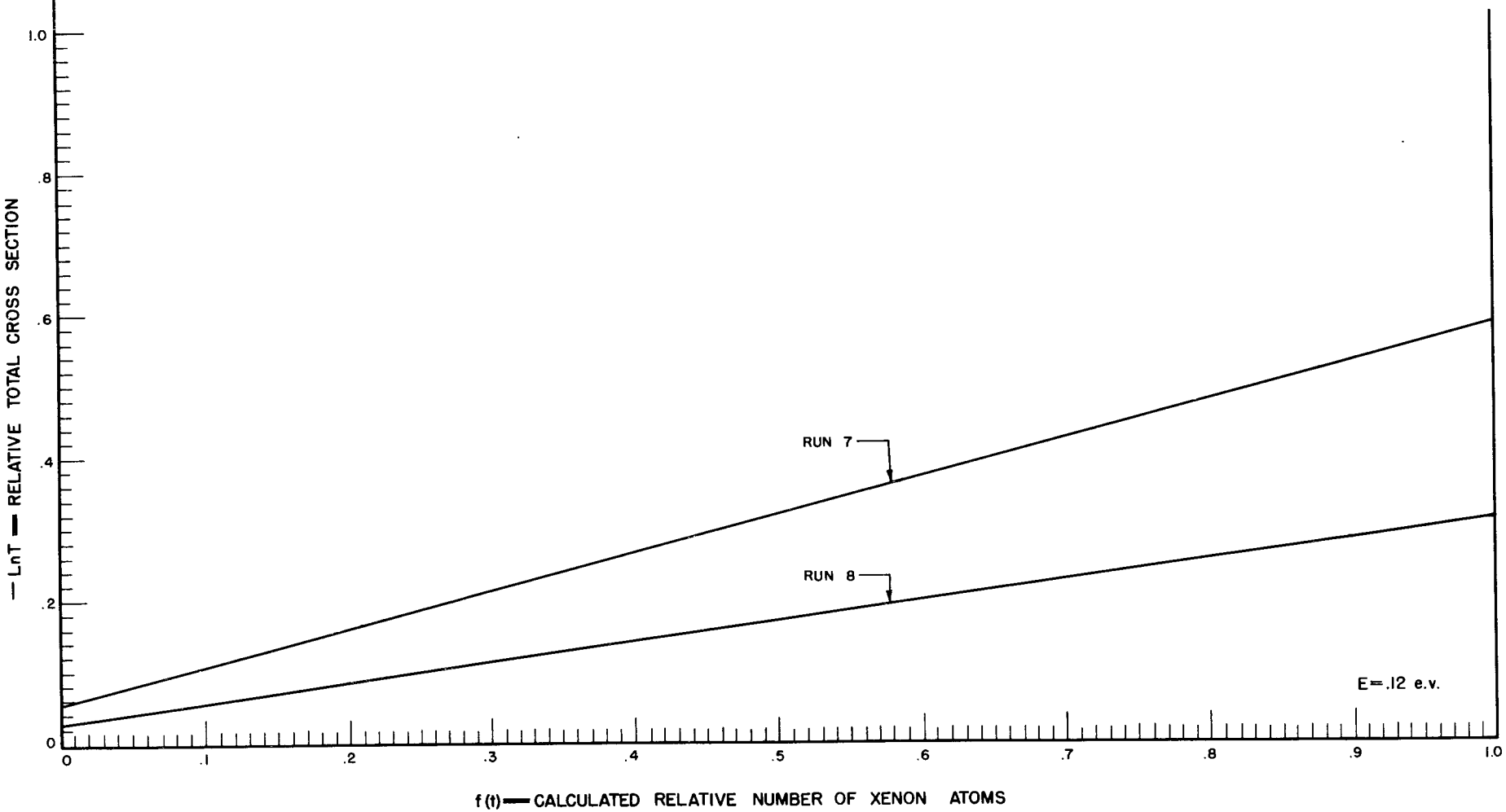

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FIG. I – 37

RELATIVE TOTAL CROSS SECTION
Vs
CALCULATED RELATIVE NUMBER OF XENON ATOMS

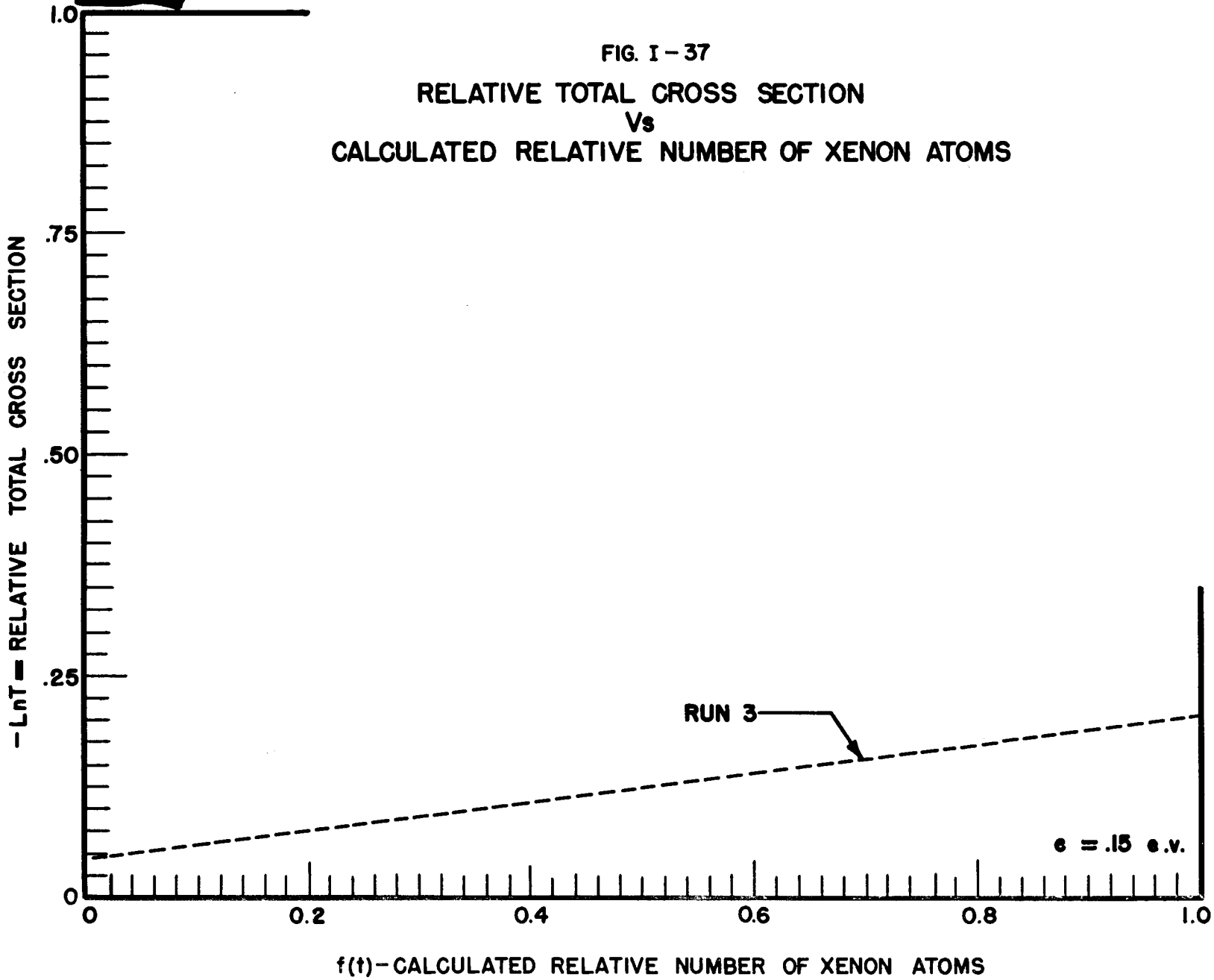

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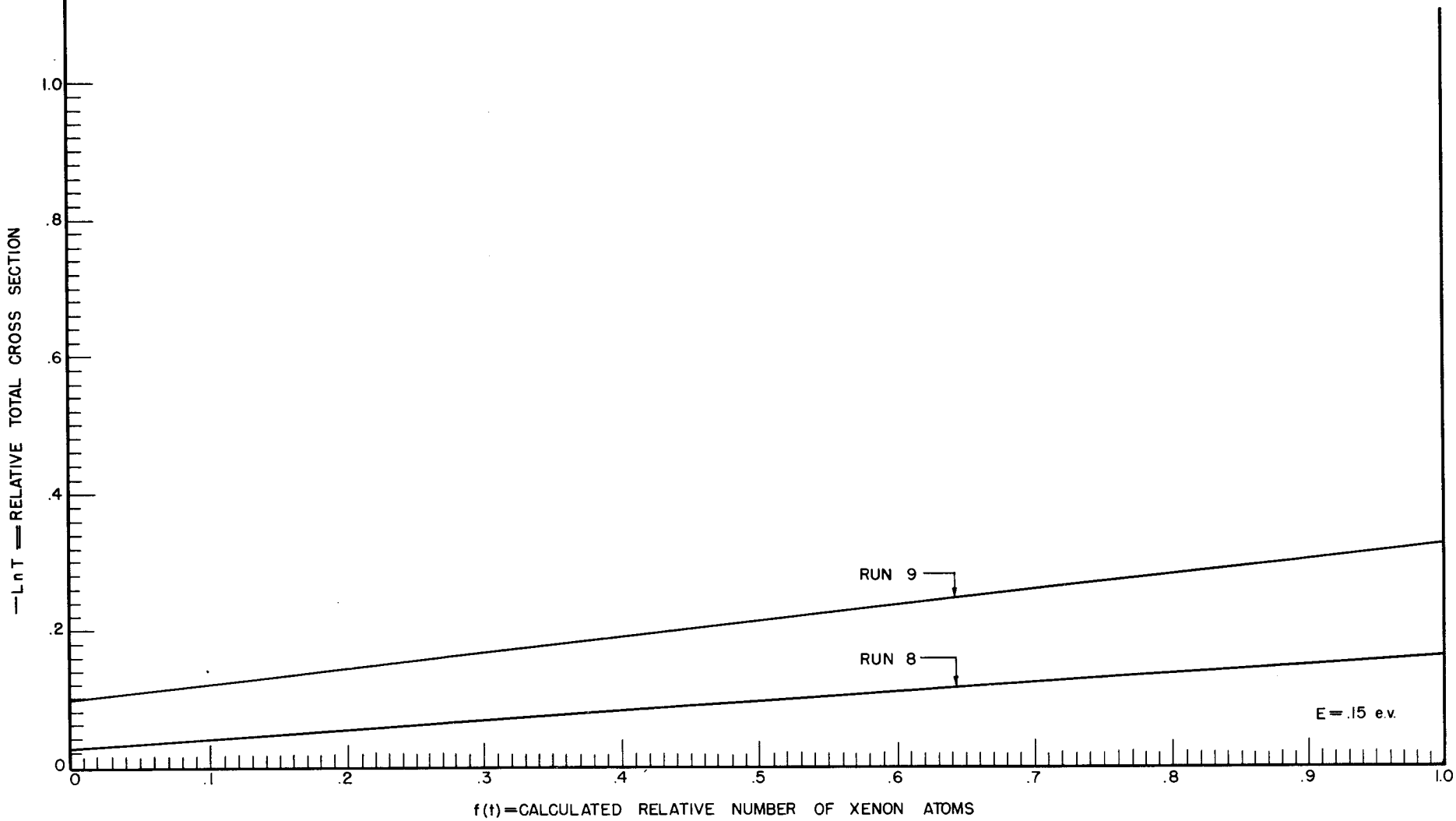
FIG. I - 38

RELATIVE TOTAL CROSS SECTION
Vs
CALCULATED RELATIVE NUMBER OF XENON ATOMS



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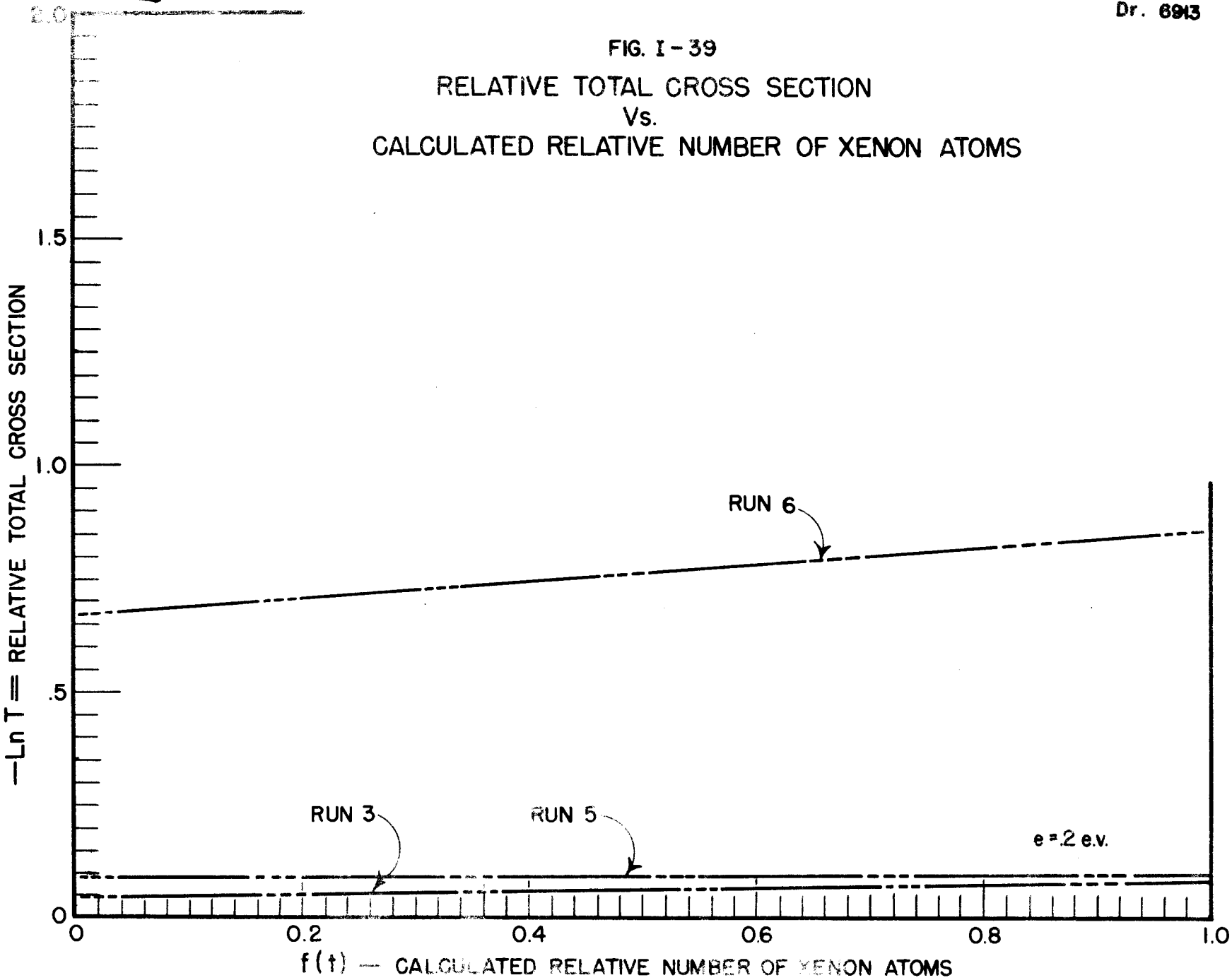
Dr. 6913

FIG. I - 39

RELATIVE TOTAL CROSS SECTION
Vs.
CALCULATED RELATIVE NUMBER OF XENON ATOMS



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The types of graphs can be subdivided as follows: (1) Fission chamber (direct beam Cd absorbable neutrons), *ln* T *vs* f(t), relative number of Xe atoms for an individual sample; (2) *ln* T *vs* relative number of Xe atoms for all the energies of one sample; (3) *ln* T *vs* f(t) for the same energy values of different samples.

As was stated above the slope of the lines is proportional to the product of the strength of the sample and the cross section of Xe^{135}. For the same sample, since the sample strength is the same throughout the run, the ratios of the slopes of the lines gives relative values of the Xe cross section at the various energies. These ratios have been calculated for each run in two ways: setting the slope of the line for 0.03 equal to one; setting the slope of the fission chamber data equal to one.

For the same energy value but for different samples the ratio of the slopes is equal to the relative strengths of the samples. These ratios were calculated and the results compared to the same ratios obtained by R. Brosi of the Chemistry Division from his absolute assays of the sample strengths.

The absolute sample strengths, or the absolute number of Xe^{135} atoms existing at some one time, were obtained by Brosi from absolute beta and gamma ray counting. The Xe^{135} emits a gamma ray which is much harder than any of the other radiations emitted by any of the iodines or its descendants. All other radiations can be filtered out by several inches of lead. The gamma ray activity of an ionization chamber in a standard geometry is proportional to the I^{135} content of the sample. These gamma ray measurements were made absolute by counting absolutely all of the β rays emitted from an aliquot sample. The details of this method and of other methods used to check the results are described in detail by Brosi in the quarterly reports of the Chemistry Division.

The result of the least squares analysis of the data is summarized in Table I-3. In this table, column 1 gives the sample number, and column 2 gives the values of the energies for that run. Column 3 gives a, the slope of the line. Column 4 gives b, the value of the intercept of the line on the y axis. The fifth column V_a^2 is the variance of a. (The relative error in a is given by V_a/a.) Column 6 gives V_b^2, the variance of b. (The relative error in b is given by V_b/b.) Column 7, $a/a_{.03}$, gives the relative values of the Xe cross section in terms of the arbitrary value 1 at 0.03 ev. Column 8 gives the relative values of the cross section of Xe referred to the arbitrary value 1 for the Cd absorbable neutrons (fission chamber data). Columns 9 and 10 give $\sigma\sqrt{E}$ for the two arbitrary scales of relative cross section.

The data on absolute and relative sample strengths are collected in Table I-4. Column 1 gives the sample number. Column 2 gives the absolute cali-

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TABLE I-3

RESULTS OF LEAST SQUARES ANALYSIS OF DATA

SAMPLE NUMBER	ENERGY e.v.	a	b	V_a^2	V_b^2	$\frac{a}{a_{.03}}$	$\frac{a}{a_{av}}$	$\frac{a}{a_{.03}}\sqrt{E}$	$\frac{a}{a_{av}}\sqrt{E}$
3	0.02929	0.3746	.0654	12.43×10^{-5}	1.27×10^{-5}	1.000	1.086	.1711	.1858
	0.05781	0.4377	0.0563	3.72×10^{-5}	0.920×10^{-5}	1.168	1.063	.2691	.2449
	0.1415	0.1614	0.0422	5.10×10^{-5}	0.581×10^{-5}	0.4309	0.392	.1621	.1475
	0.1880	0.0446	0.0452	10.03×10^{-5}	0.85×10^{-5}	0.1191	0.108	.05164	.04683
	F.C.	0.4116	0.0578	1.55×10^{-5}	0.355×10^{-5}	1.10	1.000	----	----
5	0.0292	.2842	0.1135	5.24×10^{-5}	1.331×10^{-5}	1.000	1.016	.1706	.1733
	0.0576	0.3305	0.1006	3.96×10^{-5}	1.346×10^{-5}	1.163	1.182	.2791	.2837
	0.0951	0.3204	0.0820	3.67×10^{-5}	1.386×10^{-5}	1.127	1.145	.3476	.3531
	0.1866	0.000782	0.0921	12.84×10^{-5}	3.54×10^{-5}	0.003	0.003	.001296	.001296
	F.C.	0.2419	0.1483	0.71×10^{-5}	0.21×10^{-5}	0.851	1.000	----	----
6	0.0294	0.768	1.184	10.15×10^{-5}	2.96×10^{-5}	1.000	1.052	.1715	.1804
	0.0770	0.843	0.8974	9.10×10^{-5}	2.37×10^{-5}	1.096	1.154	.3041	.3202
	0.1148	0.619	0.763	13.3×10^{-5}	2.79×10^{-5}	0.806	0.848	.2731	.2873
	0.1894	0.170	0.682	9.85×10^{-5}	3.42×10^{-5}	0.221	0.233	.09618	.1014
	F.C.	0.7303	1.086	2.34×10^{-5}	0.51×10^{-5}	0.951	1.000	----	----
7	0.0304	0.799	0.077	12.43×10^{-5}	1.27×10^{-5}	1.000	1.086	.1743	.1893
	0.0609	0.941	0.057	12.2×10^{-5}	6.1×10^{-5}	1.178	1.279	.2907	.3157
	0.0814	0.945	0.031	37.2×10^{-5}	23.1×10^{-5}	1.183	1.284	.3375	.3663
	0.1023	0.749	0.060	48.2×10^{-5}	32.2×10^{-5}	0.937	1.018	.2997	.3256
	0.1229	0.525	0.059	40.9×10^{-5}	22.6×10^{-5}	0.657	0.713	.2238	.2428
	F.C.	0.736	0.135	2.378×10^{-5}	1.265×10^{-5}	0.922	1.000	----	----
8	.0301	0.446	0.011	5.31×10^{-5}	1.72×10^{-5}	1.000	1.018	0.1735	0.1766
	.0802	0.499	0.023	4.84×10^{-5}	1.38×10^{-5}	1.119	1.139	0.3169	0.3226
	0.1006	0.427	0.014	5.41×10^{-5}	1.84×10^{-5}	0.957	0.957	0.3036	0.3098
	0.1207	0.296	0.0210	8.44×10^{-5}	2.03×10^{-5}	0.664	0.675	.2308	.2346
	0.1505	0.147	0.028	6.72×10^{-5}	2.19×10^{-5}	0.330	0.336	.1280	.1303
	F.C.	0.438	0.041	0.703×10^{-5}	0.281×10^{-5}	0.982	1.000	----	----
9	0.0303	0.599	0.138	12.6×10^{-5}	5.00×10^{-5}	1.000	0.934	.1741	.1626
	0.0606	0.736	0.116	7.66×10^{-5}	2.97×10^{-5}	1.229	1.148	.3026	.2826
	0.1526	0.231	0.040	18.7×10^{-5}	8.44×10^{-5}	0.386	0.360	.1469	.1370
	0.2052	0.108	0.093	29.7×10^{-5}	12.2×10^{-5}	0.180	0.168	.08154	.07610
	F.C.	0.641	0.143	1.28×10^{-5}	0.516×10^{-5}	1.070	1.000	----	----
10	0.01527	0.3269	0.1455	4.11×10^{-5}	1.148×10^{-5}	1.063	0.9790	.1314	.1210
	0.0308	0.3074	0.1512	5.39×10^{-5}	1.65×10^{-5}	1.000	0.9207	.1755	.1616
	0.0453	0.3330	0.1373	3.03×10^{-5}	0.955×10^{-5}	1.083	0.9973	.2305	.2122
	0.1048	0.308	0.105	5.17×10^{-5}	1.77×10^{-5}	1.002	0.922	.3143	.2892
	F.C.	0.3339	0.1809	0.600×10^{-5}	0.191×10^{-5}	1.086	1.000	----	----

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[redacted]

bration of Brosi, in terms of curies of I^{135} activity at the precipitation time of the PdI_2^{135}. Column 3 gives the relative sample strengths from Brosi's measurements setting the strength of sample 7 equal to one. The relative sample strengths from the neutron measurements is given in columns 4, 5, 6, and 7. The relative source strengths for samples 3 and 7 given by the neutron measurements at 0.03 and 0.06 ev agree very well with the ratio determined from measurements of radioactivity. The value for the ratio given by the neutron measurements at 0.10 ev and by the fission chamber data do not agree very well with the radioactivity measurements. There is disagreement in the case of sample 9 between the neutron measurements at all energies and the radioactivity measurements. However, sample 9 gave evidence of leaking very badly so that agreement should not be expected for sample 9. Samples 3 and 7 furnish the only data available now for comparing relative neutron and radioactivity measurements of sample strengths. More such data are needed. In addition, further consideration of existing data is planned. For instance, an average value of relative sample strengths from neutron data could be obtained by weighting the values given by the data taken at different energies in accordance with their proper statistical weights. This has not been done yet. It is believed at the present time that the best values of relative sample strengths that can be obtained from the neutron measurements are given by the data taken at 0.03 ev.

TABLE I-4

ABSOLUTE AND RELATIVE VALUES OF STRENGTHS OF SAMPLES

SAMPLE NUMBER	BROSI		RELATIVE STRENGTHS (NEUTRON MEASUREMENTS)			
	Curies of I^{135} Activity at Precipitation Time	Relative Strength	Energy in e.v.			
			.03	.06	.10	F.C.
3	4.54	0.464	.47	.467	.629	.559
5	--	---	.356	.353	.426	.328
6	--	---	.962	--	--	.988
7	9.78	1.00	1.00	1.00	1.00	1.00
8	--	---	.569	--	.569	.592
9*	9.68	0.979	.751	.785	--	.870
10	--	---	.384	--	.410	.451

* Leaky sample.

[redacted]

[redacted]

The fundamental criticism might be made of the absolute calibration that it measures directly the number of atoms I^{135} present in the sample at some one time. The number of Xe^{135} atoms at any time is then calculated from the known disintegration constants. This calculated value of the number of Xe^{135} atoms may be in error for some reason, for example, if the capillary tube leaked xenon. However, if a leak were present then the plot of *ln* T *vs* calculated relative number of Xe atoms would not give a straight line. The sensitivity of this method of checking for leaky capillary tubes has not yet been considered carefully. A. R. Brosi and H. Zeldes are at present working out another method of assay which should be free of any ambiguity caused by leaks. They are setting out to determine the number of Xe^{135} atoms from the number of Cs^{135} atoms present in the capillary tube after the Xe^{135} has completely decayed.

It should be emphasized that the relative cross section measurements are not affected in any way by the absolute calibration of sample strength or by any capillary leaks. All that is needed for the relative cross section values is that it should be possible to correct all transmission values for the various energy values which were measured at different times for different amounts of Xe to the transmission values which would be measured at a common time and the same amount of Xe. To obtain such correction factors it is necessary to know only the relative amount of Xe present in the tube as a function of time. This information is given by the fission chamber data. It should be pointed out that the fission chamber data can be used also to put the measurements on a rough absolute scale, since the activation cross section of Xe^{135} for "pile neutrons" is known.

It was thought that the absolute and relative values of the intercepts as a function of energy might be of some interest. The values of these intercepts are proportional to the total cross section of the "carrier" material. The "carrier" should consist of normal PdI_2. It might contain some of the water, alcohol, ether, or fluorocarbon used at various times to wash the sample of PdI_2, which had not been removed by the centrifuging of the sample or by the vacuum pumping on the capillary tube containing the sample. If the amount of these substances present in the sample remained constant throughout the run, then their presence would have no effect on the Xe cross section. However, if the amounts varied with time, then the results would be affected. Possibilities such as these prompted the consideration of the values of these intercepts. Plots of them are shown in Fig. I-40 and Fig. I-41 for the various samples. Sample 6 did give some evidence for a time variation of the transmission long after the Xe present should have completely decayed. This variation suggests that the amount of hydrocarbon (which

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FIG. I - 40

INTERCEPTS (NORMALIZED TO .03) Vs ENERGY

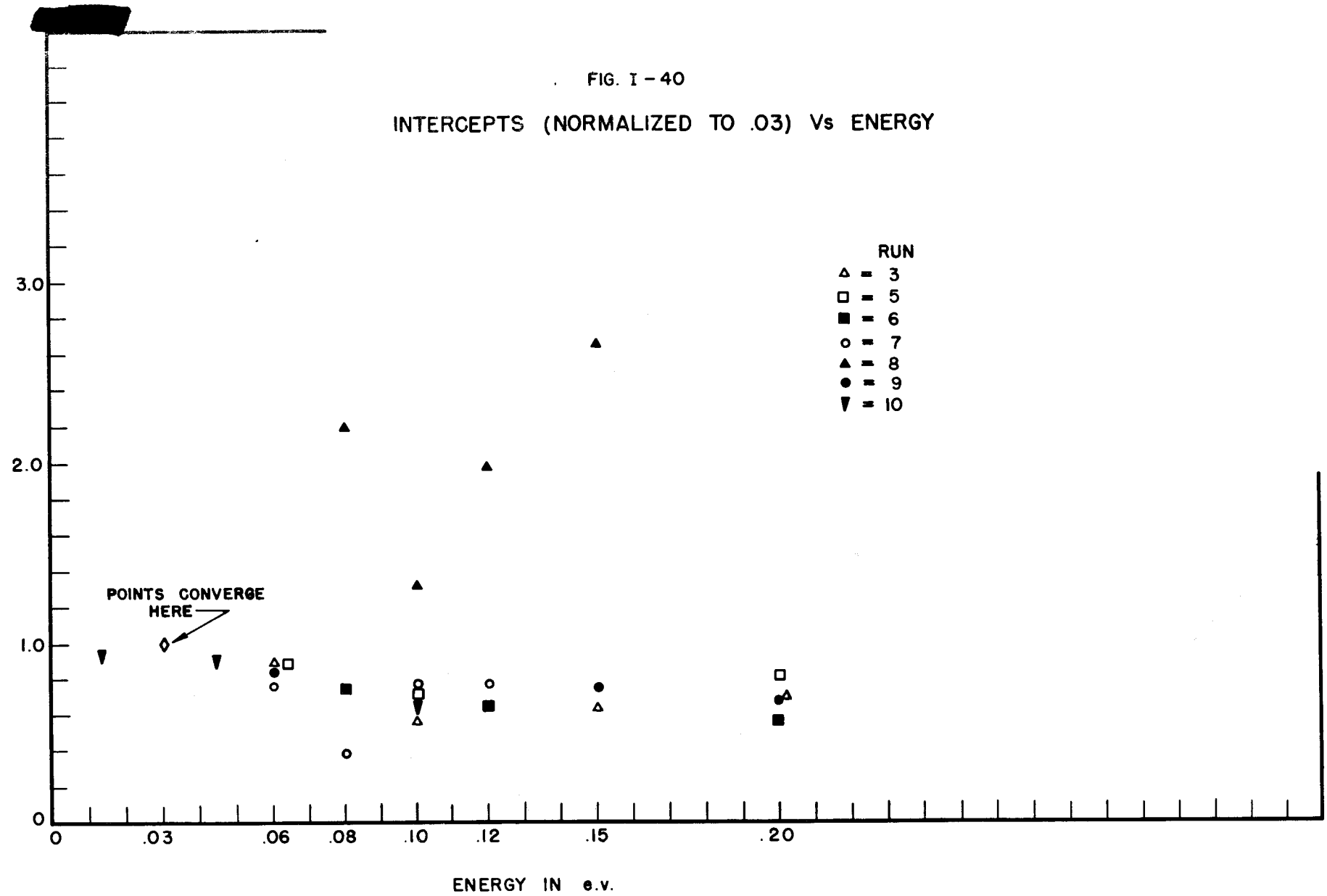

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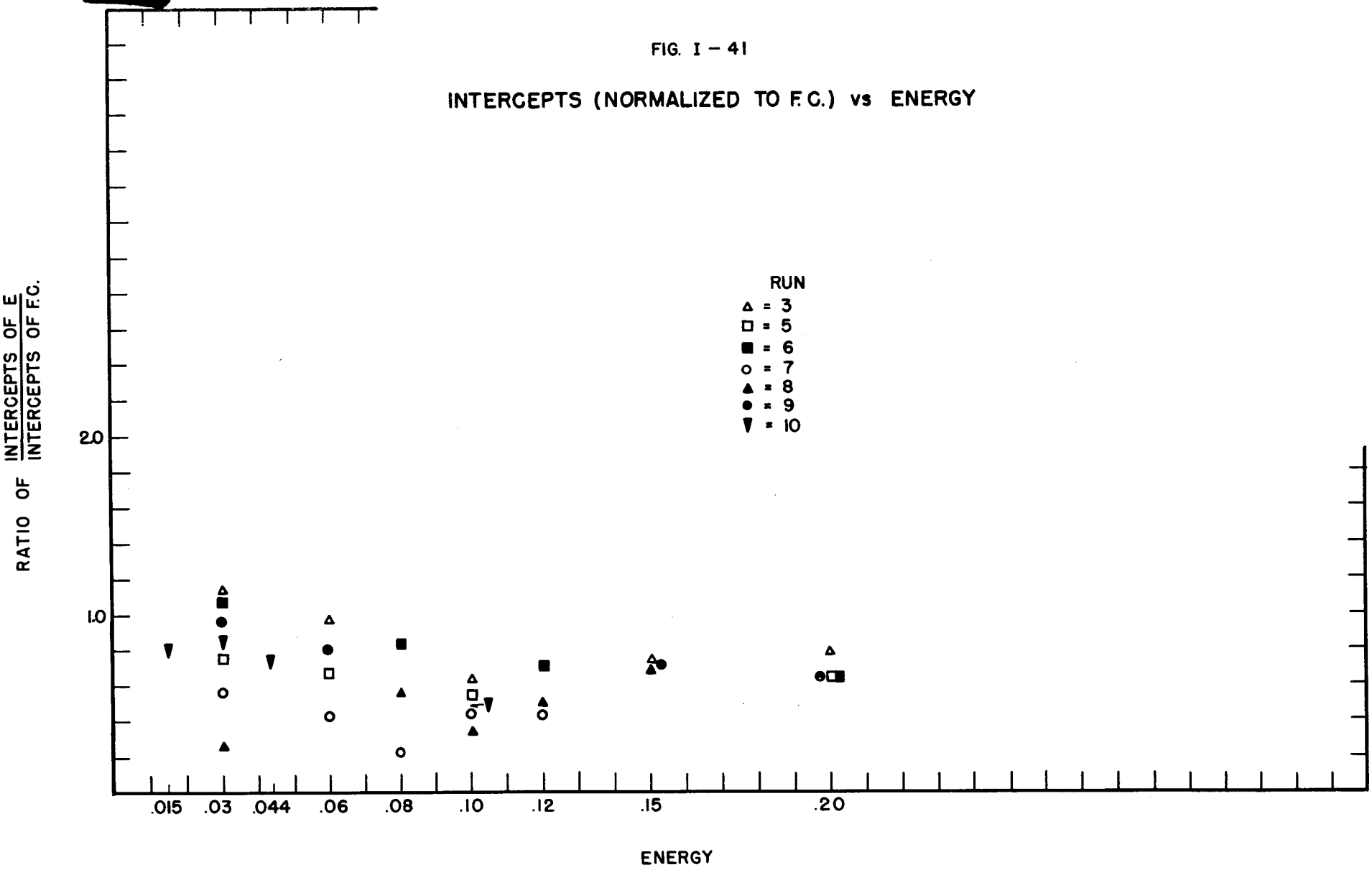
FIG. I – 41

INTERCEPTS (NORMALIZED TO F.C.) vs ENERGY



[redacted]

we know was present in very appreciable quantities in sample 6 because the procedure for drying the sample failed to work on this occasion) varied with the time. It is for this reason that the results for sample 6 are considered to be unreliable and have been excluded from consideration in the summary of results given at the beginning of this report. A more detailed discussion of the intercept plots may be given in a future report.

It was because of the possibilities suggested by the experience with sample 6 that all later samples, in addition to being given the usual treatment for drying, were washed thoroughly with a volatile fluorocarbon. The hope was that this low cross section material might displace from the sample any high cross section hydrocarbon material used in washing, which had not been removed by the previously used drying procedure.

The data on the various runs in terms of the fission chamber data are exhibited in Fig. I-42 and Fig. I-43. Fig. I-42 shows the relative cross section referred to the value 1 for the fission chamber slope. Fig. I-43 is a plot of $\sigma\sqrt{E}$ on this same fission chamber "scale".

Transmission measurements were taken at 0.015 ev in the case of only one run, sample 10. This point seems to fall nicely on the curve of Fig. I-2 for samples 3, 5, 7, 8, 9, 10 having constants $E_0 = 0.0863$ ev, $\Gamma = 0.107$ ev, $\sigma_0 = 1.24$, in spite of the fact that appreciable amounts of higher order reflections were expected to be present in the reflected beam. The value calculated from the B.W. formula is 1.07 arbitrary units; the experimentally measured value is 1.06 units.

The results of the least squares fitting of the Breit-Wigner constants for the individual runs and for the various groupings of the runs is given in Table I-5. E_0 and Γ are given in ev, and σ_0 is given in terms of the arbitrary value 1 at $E = 0.03$ ev.

TABLE I-5

LEAST SQUARES BREIT-WIGNER CONSTANTS

RUNS	E_0 e.v.	Γ e.v.	RELATIVE σ_0
3,5,6	.09392	.1293	1.185
3,5,6,7,8,9	.08905	.1206	1.183
3,5,7,8,9,10	.08635	.1067	1.240
7,8,9	.08309	.1137	1.148
7,8,9,10	.08490	.1137	1.164
3	.08757	.09922	1.333
5	.08653	.1102	1.210
6	.1061	.2483	.9001
7	.08375	.1101	1.173
8	.08421	.1172	1.107
9	.08869	.1052	1.305
10	.08491	.1006	1.286

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FIG. I – 42

RELATIVE CROSS SECTION OF XE^{135} VS. ENERGY

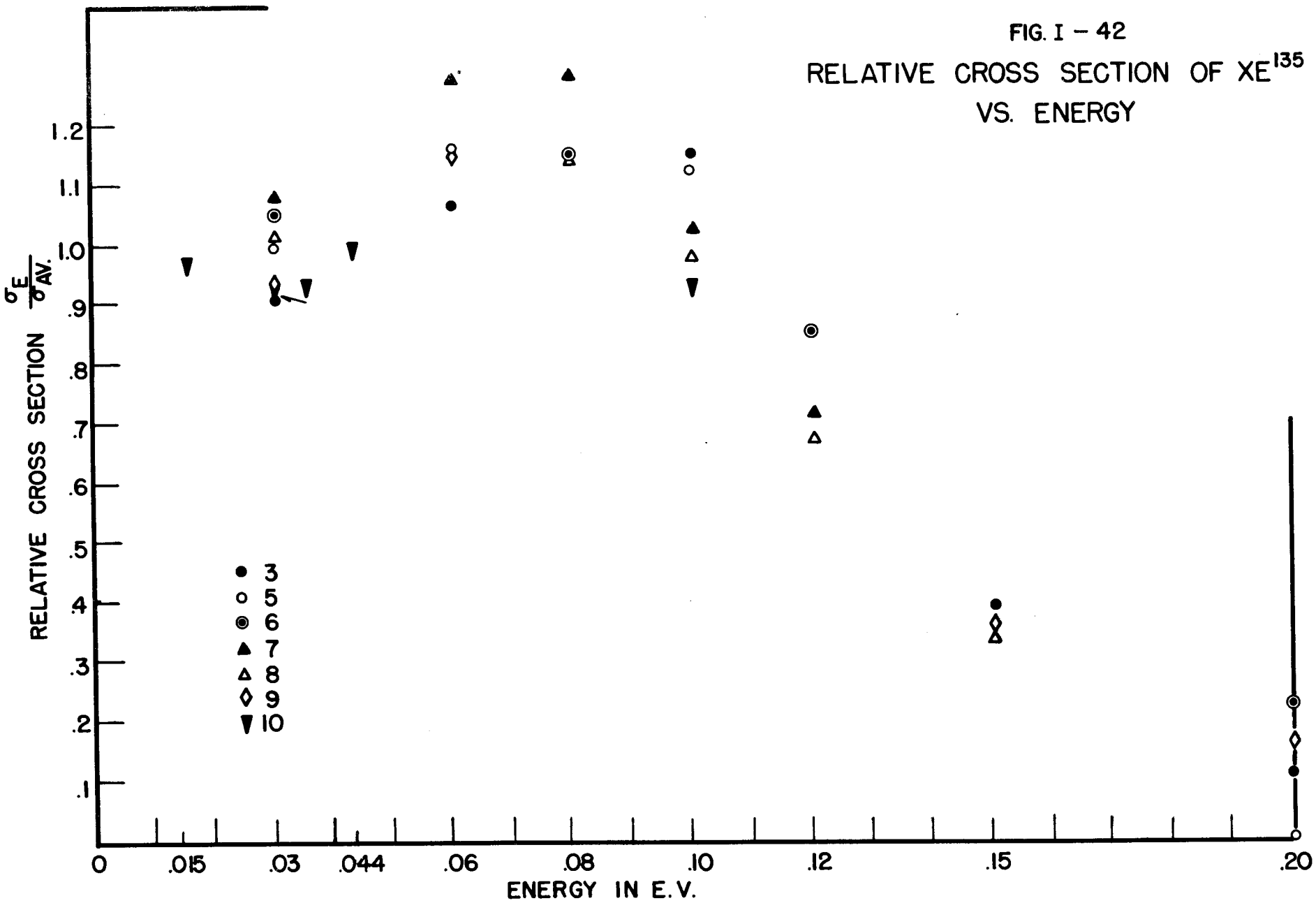

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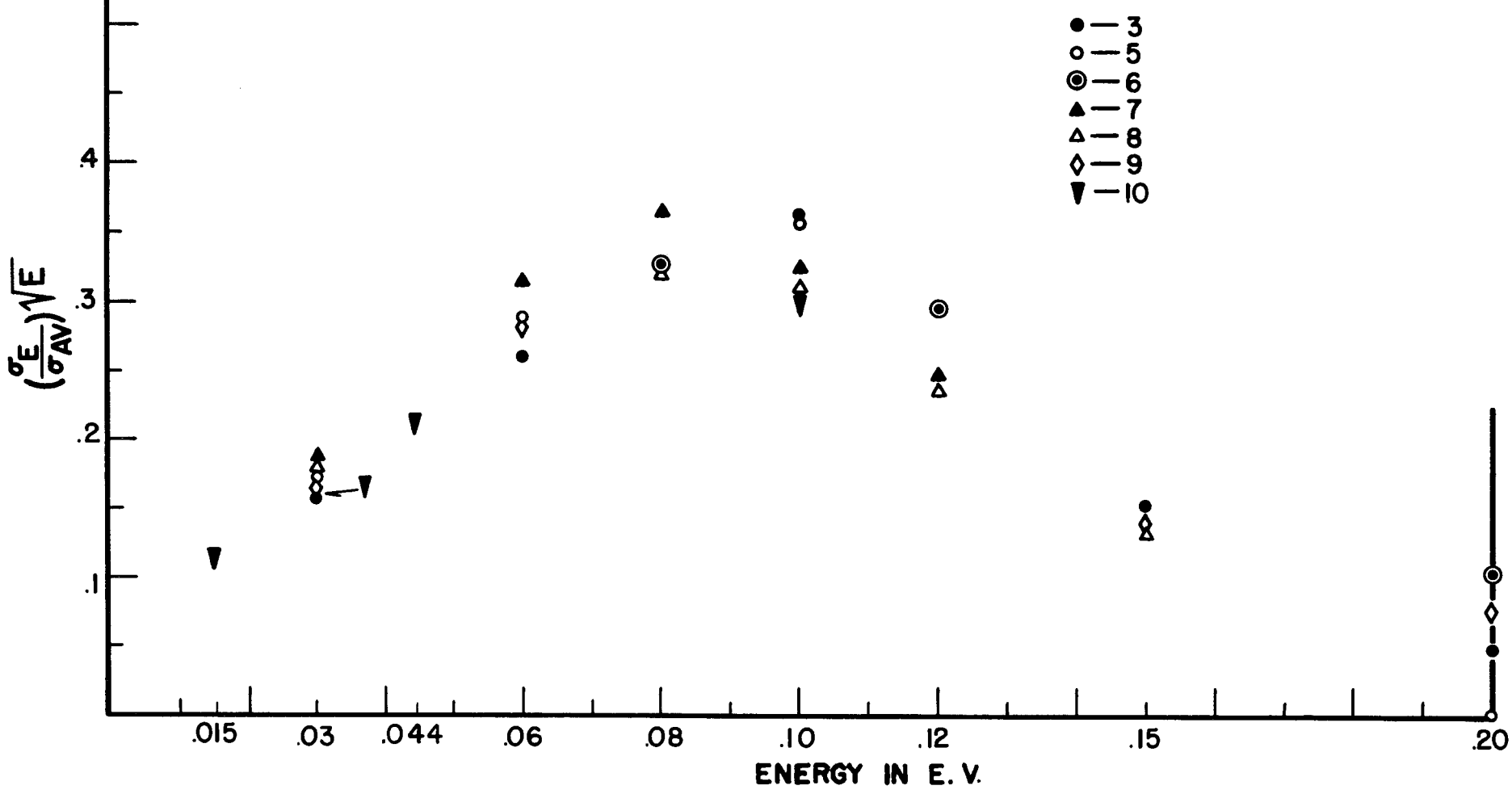
FIG. I - 43

RELATIVE $\sigma\sqrt{E}$ Vs. E



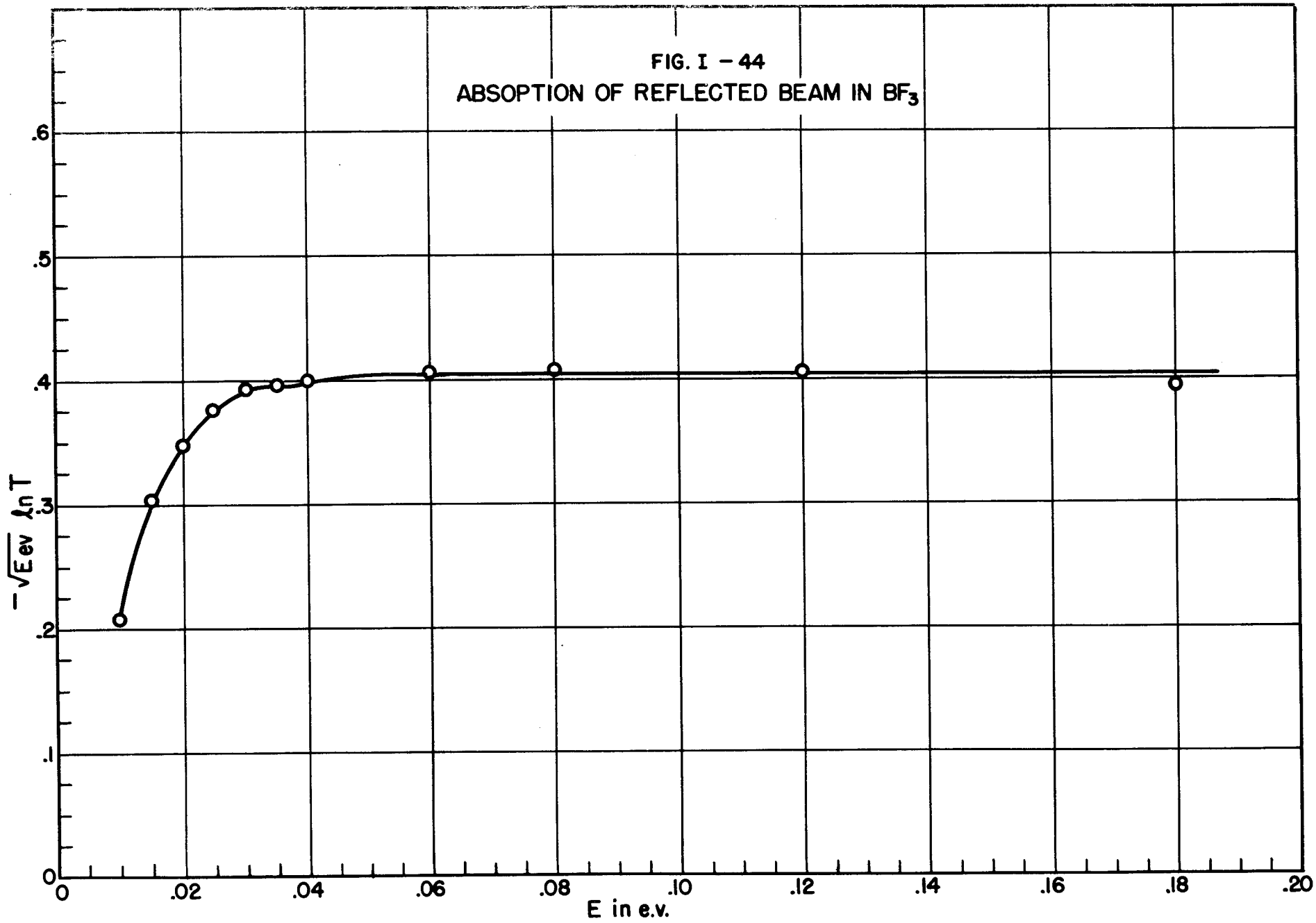


FIG. I - 44
ABSOPTION OF REFLECTED BEAM IN BF_3
$-\sqrt{E\,ev}\ \ln T$
E in e.v.
0
.1
.2
.3
.4
.5
.6
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20

[redacted]

There are five photographs of the apparatus and operations of the experiment shown in this report. Their titles are as follows:

Photo I-1	The Crystal Spectrometer
Photo I-2	Sample Shifter, Showing Wafer in Place
Photo I-3	Placing the Sample—Containing Wafer Into Position
Photo I-4	Showing Tongs and Guide Used in Placing Wafer
Photo I-5	Showing the Sample—Containing Stringer Back Into the Pile

PLANS FOR FUTURE WORK

It is hoped that several more samples used for measurements in the energy region from 0.03 to 0.20 ev will serve two purposes: They should help to increase the accuracy of the determination of the Breit-Wigner constants considerably; they should serve also to increase the accuracy of the absolute scale of the cross section.

Some effort may be devoted to measurements at energies below 0.03 ev. The bent quartz crystal reflections may be used in this energy region, and a quantitative analysis of the effects of higher orders made. Or the relatively higher-order-reflection-free 111 reflections from LiF may be used, if the intensity from a plane crystal will suffice. Some measurements may be taken also in the direct beam using extremely low energy filtered neutrons. An investigation of the feasibility of measuring the total scattering cross section of Xe^{135} may also be made.

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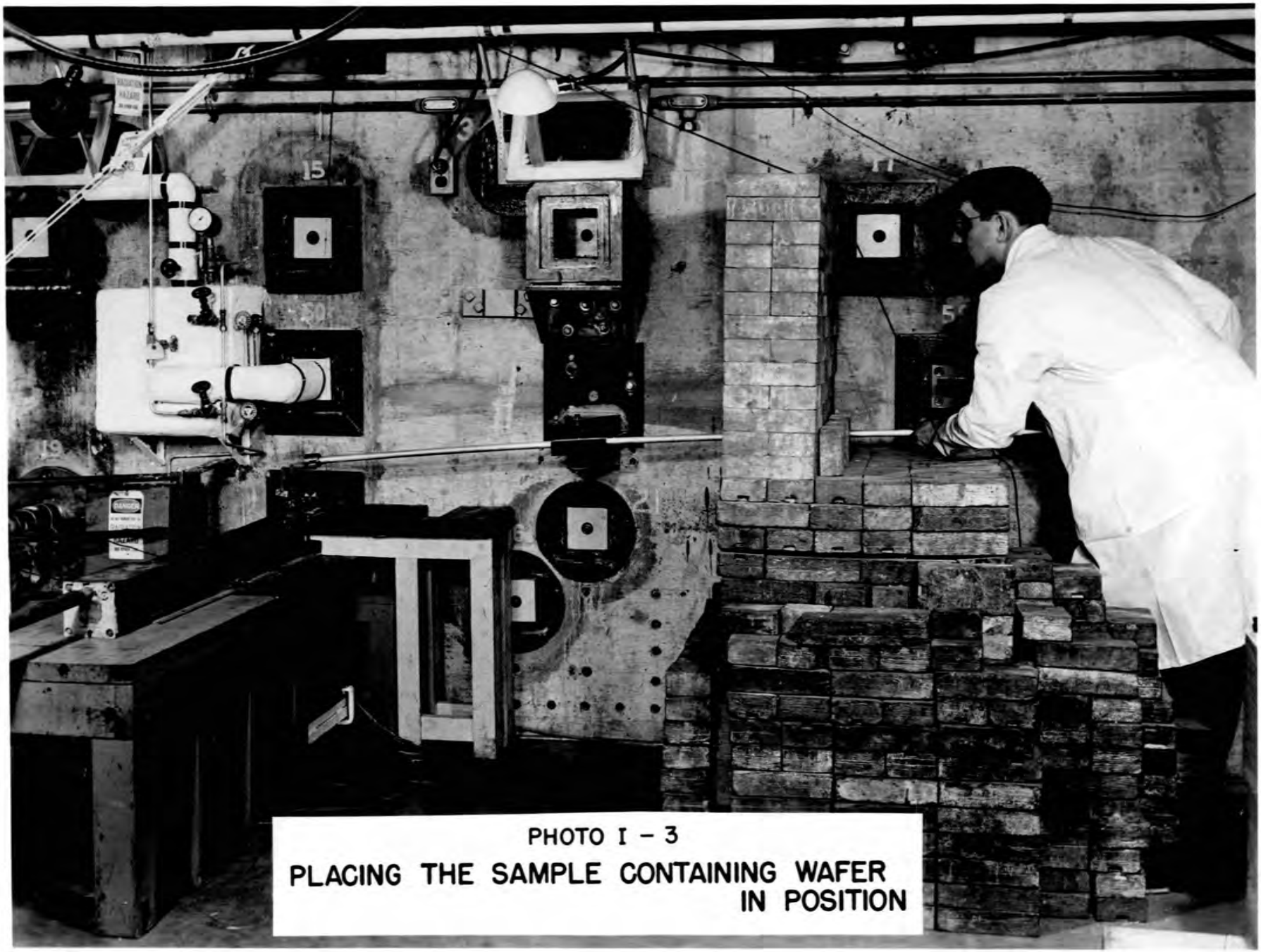

PHOTO I - 3

PLACING THE SAMPLE CONTAINING WAFER IN POSITION

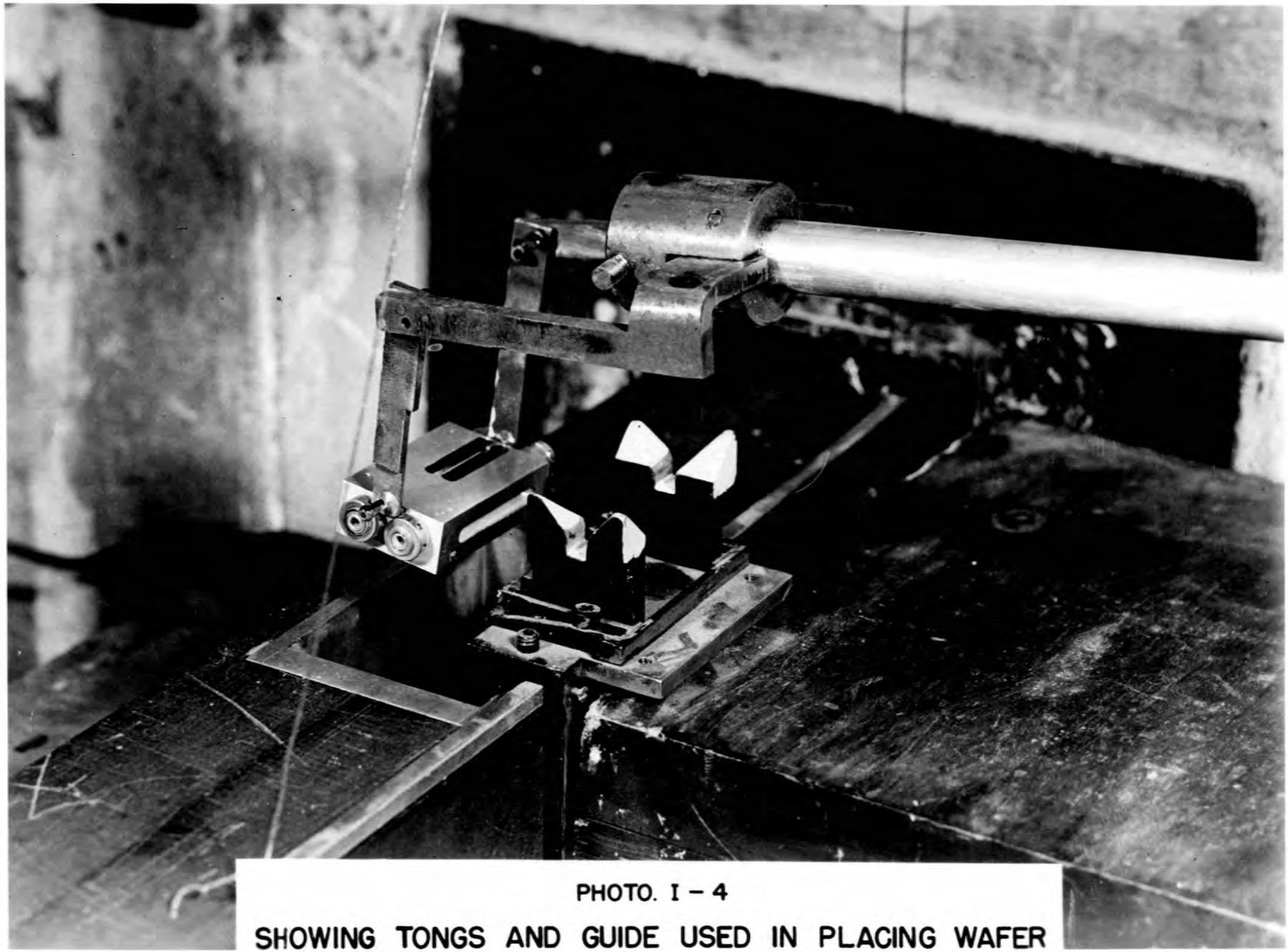

PHOTO. I – 4

SHOWING TONGS AND GUIDE USED IN PLACING WAFER

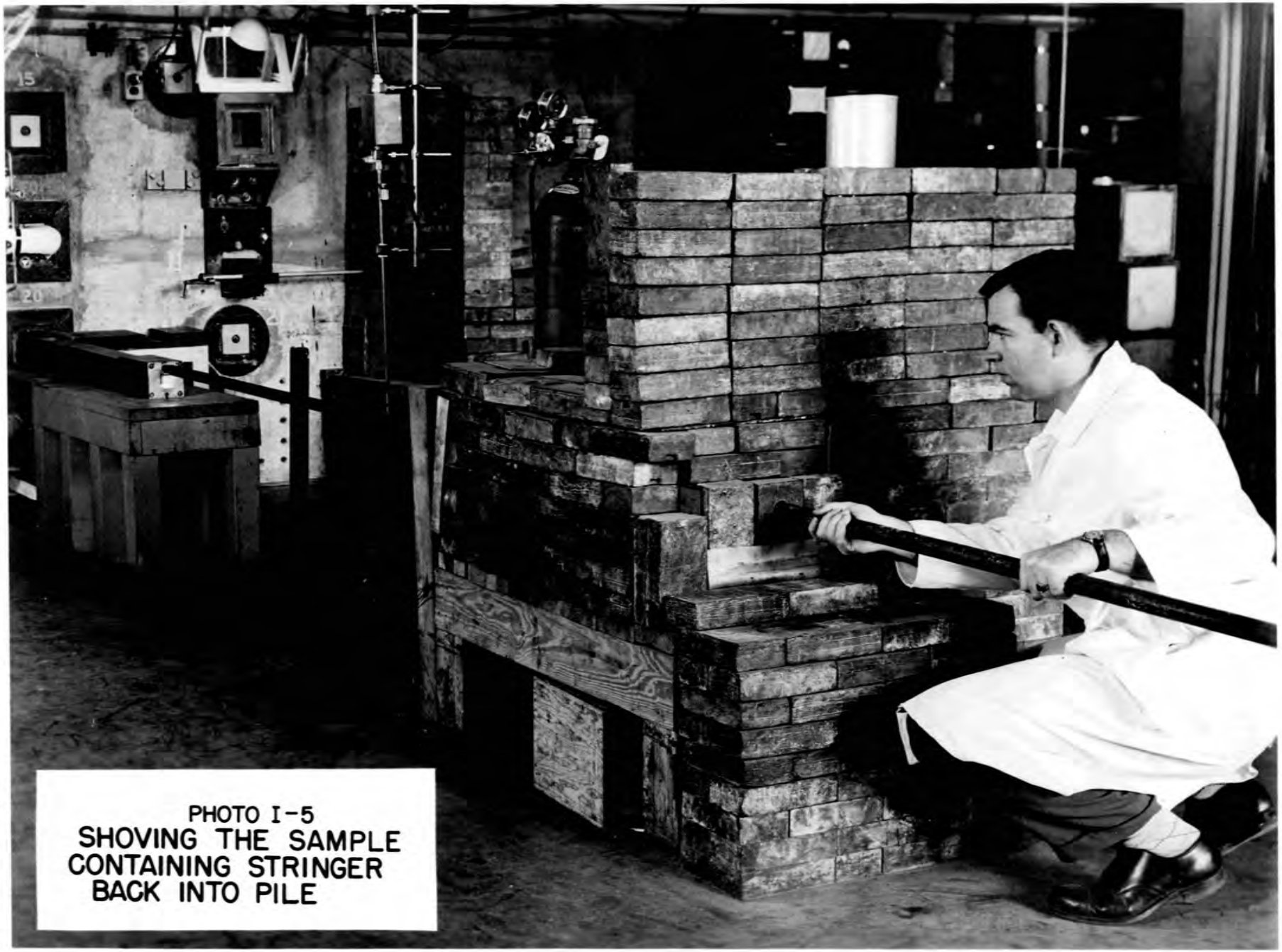

PHOTO I-5
SHOVING THE SAMPLE CONTAINING STRINGER BACK INTO PILE

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NEUTRON DIFFRACTION STUDIES OF U-Be ALLOYS

(C. G. Shull and W. A. Strauser)

Studies have been underway for some time at the Batelle Memorial Institute on the preparation of stable phases of U-Be alloy. It has been found that a stable phase corresponding to $U\text{-}Be_9$ seems to exist and X-ray diffraction data taken for this by Dr. C. M. Schwartz have shown this to possess a cubic structure. In spite of the atomic preponderance of beryllium in this alloy, the X-ray pattern is almost wholly caused by the uranium atoms and it seemed of interest to study this with neutrons where the scattering would be dominantly that of the beryllium atoms. The X-ray data suggest the uranium atoms to be on a primitive cubic lattice of parameter 5.13 Å with one molecule present per unit cell.

The neutron diffraction pattern for this material is shown in Fig. II-1 along with a sketch of an X-ray spectrometer record taken by Dr. Bredig of the Chemistry Division. The relative intensities differ drastically of course, since the X-ray scattering is caused overwhelmingly by the uranium atoms and the neutron scattering most strongly by the beryllium atoms. In principal the two sets of data will permit an unambiguous solution of the crystallographic structure and work towards this solution has started. A few structural models which place an octet of beryllium atoms inside the uranium unit cell cube plus a few beryllium atoms in the cube faces have not shown agreement with the data. Other models will be tried out in hope of improving the intensity agreement.

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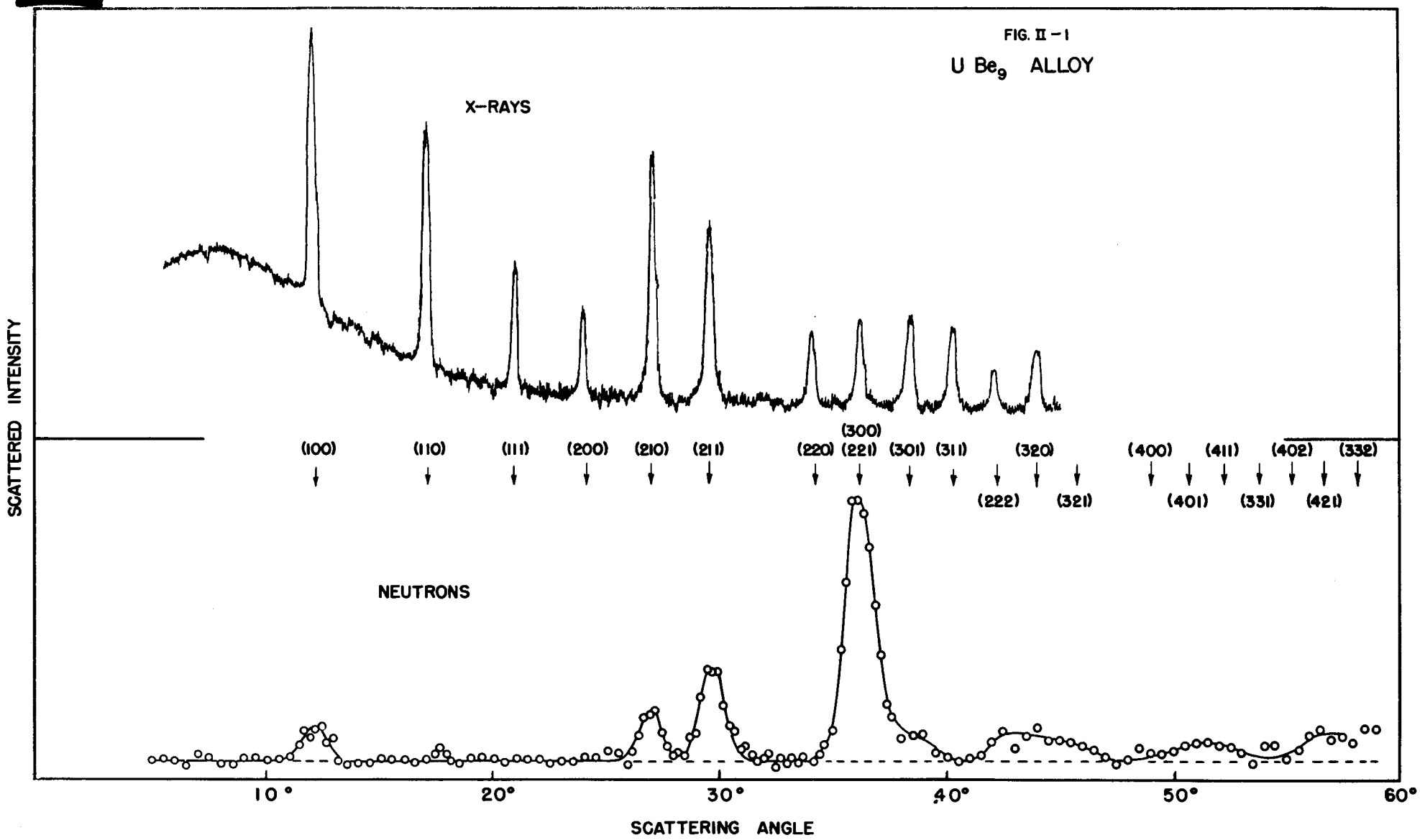

FIG. II – 1

U Be_9 ALLOY

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PHYSICS OF SOLIDS

PREPARATION OF URANIUM SAMPLES (R. W. Coyle*)

Sample fabrication of uranium for Hanford irradiation has progressed. Normal material is being worked down from a 1-1/8" × 1-1/8" × 2" billet by Dr. A. G. H. Anderson of the Metallurgy Division to gain experience and to develop the proper techniques in working the metal prior to any handling of enriched material. Enriched uranium is now on hand in the above size, and it is desired to prepare samples approximately .120" square × 3" having a strongly preferred orientation along their length. To accomplish this with a minimum loss of material, initial working will be by rolling in the alpha region to a 3/8" round, followed by hot swaging to .150" round. Final dimensioning will be accomplished by hand rolling to a square section and drawing to size in special cemented carbide drawing dies using a heated silicone oil as a lubricant and preheat bath.

METALLOGRAPHY OF IRRADIATED SPECIMEN (R. W. Coyle)

The remote control microscope is approximately 40% completed, and it is expected to be finished by about March 15. A few minor changes have been necessitated by difficulties not heretofore noticed and special sample holders are being ordered to facilitate the handling of specimens by the manipulator.

Methods for handling, mounting, polishing, and etching specimens for "hot" lab metallographic work are being investigated.

RELAXATION OF STRAINS IN URANIUM (M. R. Goodman)

Further investigations are in progress concerning the nature of the previously reported "relaxations" in uranium taking place at constant temperature after the temperature of the uranium is changed. Measurements are obtained by changes in resistance of SR-4 bakelite bonded wire strain gauges applied to the uranium samples by means of bakelite cement. It is necessary to establish whether the relaxation effects observed are characteristic of the uranium, of the gauges, the bakelite, the cement, or any combination of them. For this purpose measurements by means of these gauges are being conducted on 100% uranium, on uranium containing 4.5% molybdenum, on Nilvar metal alloy, on copper, and on 2S aluminum. Measurements are also being made on plain gauges with and without

*On loan from NEPA.

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cement and unattached to any kind of specimen. All specimens and gauges are simultaneously undergoing the same treatment which consists of cycling in an oil bath from 32.6 to 60.1°C and holding for four days at each temperature. The time for temperature increase and decrease is one hour. Preliminary results show similar relaxation patterns for all specimens which repeat for each cycle. The magnitude of the relaxations is greatest for the Nilvar and free unattached gauges, followed by aluminum, uranium, and copper, which has the smallest of the relaxations.

ALUMINUM-URANIUM ALLOY (W. E. Johnson, L. C. Templeton, S. E. Dismuke)

Measurements are now being made on two sets of aluminum-uranium alloys which have been irradiated at Hanford for three months and six months, respectively. Each set consists of ten samples: three samples of 5 weight percent 235, three samples of 15 weight percent 235, three samples of 30 weight percent 235, and one sample of 30 weight percent natural uranium. Very careful pre-irradiation measurements of electrical resistivity, thermal diffusivity, density, and dimensions had been made on each sample. To date, post-irradiation measurements have been made on density, electrical resistivity and length. All twenty samples measured show a decrease in density without change in weight. Density changes range from -1.71% to -3.33%. Unirradiated control samples show variations of density of less than .05%. Length measurements on a limited number of samples vary from +.59% to +1.05% change. In general, the greatest change in property per atom fissioned is for the 15% alloy. However, this is not true in particular cases; the natural uranium alloy samples unexpectedly show very large changes in density.

All of these samples were very severely constrained mechanically during exposure in order to prevent temperature rise in the sample. It is felt that perhaps all the change in density may be on the low side due to these constraints. A second set of alloy samples is now being prepared for exposure which will not be constrained during exposure.

SEMI-CONDUCTORS (W. E. Johnson, K. Lark-Horovitz*, J. C. Pigg)

A report is now being prepared which covers in detail all of the work on semi-conductors to date. It is expected the report will be issued in April.

Considerable data on the effect of heat treatment on the irradiated samples have been obtained by the Purdue group. It is found that the energy

*Consultant from Purdue University.

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level introduced in germanium during pile irradiation is about 0.1 e.v. above the filled band, which is much higher than the levels introduced chemically. In silicon the level or levels introduced are about .6 to .8 e.v. above the filled band.

The apparatus for making Hall measurements in the pile is now completed and is being tested outside the pile. It is expected that "in pile measurement" will be made soon.

SLUG CUTTER (L. C. Templeton)

Fabrication of the slug cutter is complete. The installation, in the canal in building 105, is complete except for a few minor details. It is in working order and has been used successfully. Trial runs indicate that the abrasive cutting wheel loads badly when cutting aluminum encased slugs. This loading results in a very slow cutting rate, and often causes the wheel to break. Slugs which have been stripped can be cut easily and quickly. Specimens from both the stripped slugs and the canned slugs are smooth except for slight irregularities at the edge where the cut is completed.

LOW TEMPERATURE EXPOSURE TUBE (R. P. Metcalf)

Testing of the cryostat for pile irradiations at low temperatures has been completed, and the apparatus has been dismantled for inspection. The design of the cryostat appears to be satisfactory in principle, though some details will require modification. Some progress has been made toward improvement of the design.

NEUTRON CONVERTER (R. P. Metcalf)

The engineering and drafting needed for the completion and installation of the neutron converter have now been finished. The converter, comprising a water-jacketed cylinder of enriched uranium alloyed with aluminum, was originally intended to be used with the pile cryostat; present plans are to use it as an independent facility, at least until the cryostat is built. It will provide a space about 12 inches long and $2\frac{3}{4}$ inches in diameter where irradiations may be made in an enhanced flux of fast neutrons.

VACUUM FURNACE (W. E. Johnson, F. A. Sherrill)

A high vacuum furnace suitable for growing single crystals by the Bridgeman method has been completed and used. Several single crystals of alumi-

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num, copper, and nickel have been made. Attempts to grow a large single crystal of germanium have been unsuccessful to date.

EFFECTS OF RADIATION ON VARIOUS METALS (R. H. Kernohan*, D. S. Billington**)

Be-Cu

Back reflection X-ray pictures of irradiated and unirradiated specimens of Be-Cu have been taken using an Fe target to obtain the (222) and (311) lines. At present the interpretation of the pictures is not complete, but there appears to be no change in lattice constant in the irradiated specimens. This work was done in cooperation with Dr. M. Bredig of the chemistry division.

Eighty hardness and sixty-four resistance specimens of Be-Cu have been prepared, measured, and are now in the pile. After irradiation these specimens will be heat treated in various ways in order to investigate the ways in which irradiation effects may be annealed out.

Brass

The previous quarterly report had indicated that annealed brass had shown a considerable increase in hardness and a slight decrease in electrical resistance. The possibility remained that this effect may have been caused by aging at the temperature of the pile irradiation.

Accordingly, unirradiated specimens were treated in a furnace for about four weeks at 65°C. These results and also those of irradiation are compiled in Tables V-1 and V-2.

Table V-1

BRASS ANNEALED AT 600°C FOR 1 HOUR

4 weeks heat treatment and 4 weeks irradiation
Resistance (in ohms) corrected to 20°C and multiplied by 10^6
The first sample number indicates the percentage of zinc

SAMPLE	BEFORE HEAT TREATMENT	AFTER HEATING	% CHANGE	SAMPLE	BEFORE IRRADI-ATION	AFTER IRRADI-ATION	% CHANGE
5-4	1447	1447	0	5-2	1430	1420	-0.7
10-4	1756	1751	-0.3	10-2	1733	1718	-0.9
15-2	2128	2128	0	15-4	2073	2055	-0.9
20-4	2342	2342	0	20-2	2380	2352	-1.2
25-4	2545	2539	-0.2	25-2	Not	2510	
30-4	2750	2748	-0.1	30-2	Measured	2683	

Measurements accurate to 0.3%.

*On loan from NEPA.

**Consultant from Naval Research Laboratory.

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Table V-2

BRASS ANNEALED AT 600°C FOR 1 HOUR

4 weeks irradiation and 4 weeks heat treatment @ 65°C

Hardness numbers are Rockwell F scale

The first of the two sample numbers indicates the approximate percentage of zinc in the specimen.

HARDNESS				HARDNESS			
SAMPLE	BEFORE HEAT TREATMENT	AFTER HEAT TREATMENT	INCREASE	SAMPLE	BEFORE IRRADI-ATION	AFTER IRRADI-ATION	INCREASE
5-4	39.2	39.2	0	5-5	39.6	59.8	20.2
10-4	42.7	45.6	2.9	10-5	45.4	61.4	16.0
15-4	49.9	51.1	1.2	15-5	48.8	59.4	10.6
20-4	52.9	52.3	-.6	20-5	52.9	58.5	5.6
25-6	50.4	52.3	1.9	25-5	50.5	53.6	3.1
30-6	49.7	53.0	3.3	30-5	50.8	55.8	5.0

CREEP EXPERIMENT (R. H. Kernohan)

The creep apparatus designed for use in the "doughnut hole" of the Oak Ridge pile has been under continuous bench test. Because of the severe space limitations an attempt is being made to use the SR-4 strain gauge to measure elongation. The first tests used a 2S annealed aluminum sample at a stress of 3600 psi and at 60°C. After sixty days the elongation as measured by the SR-4 gauge was .005%. The stress on the sample was then increased to 7500 psi and at an elongation of .5%, measured by the gauge, the gauge broke in two. Optical measurements showed an actual elongation of the specimen of 4%. The discrepancy between strain gauge reading and direct measurement is now being studied.

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CRITICAL EXPERIMENTS

(M. M. Mann, A. B. Martin, J. K. Bair*, R. V. McCord, G. McCammon)

In the last quarterly report we mentioned briefly that the rate of gamma ray energy absorption in the lead reflector of the critical assembly had been measured by means of a lead-walled ionization chamber. The volume of the chamber was 10 cc and the filling gas was air at atmospheric pressure. The measurements were taken along a line bisecting one side of the square core and at the mid-height of the assembly. The results are shown in Fig. VI-1 along with the results of similar measurements made in the Be-reflected assembly. For purposes of comparison the two curves have been normalized to the same average power in the core.

In an effort to determine the relative contributions of inelastic scattering and thermal neutron capture to the gamma flux in the Pb reflector, a layer of Boron was inserted in the reflector, and the gamma flux, the thermal neutron flux and the fast neutron flux, with and without the Boron sheet in place, were compared. The absorbing layer was an Al-B-Al sandwich, made up of .040" Al plates enclosing a 35 mg/cm^2 deposit of Boron, painted on the Al from suspension in Amphenol thinner. The sheet was placed 4" away from the core-reflector interface and extended completely across one face of the assembly. Rough calculations indicated that this thickness of Boron would reduce the thermal flux to about 25% of its value in the clean reflector. It is of interest to note that this relatively large thermal absorber, positioned at a distance of 4 inches from the active lattice, had only a very small effect on the reactivity of the assembly. This is understandable when it is remembered that the principal role of the lead is to scatter fast neutrons back into the core, where essentially all thermalization takes place; the lead itself is not an appreciable source of slow neutrons, as are moderating reflector materials.

The thermal neutron flux and the fast neutron flux were measured by means of Indium foils and a U-238 fission chamber, respectively. Both an ionization chamber and a Geiger tube were used to measure the gamma ray flux. The walls of the ion chamber were lead, the volume was 40 cc and the filling gas was air at one atmosphere.

In order to use the Geiger tube it was necessary to reduce the power level of the assembly to about one-tenth of the level at which the other measurements were made. At such low power levels it is not practicable to operate

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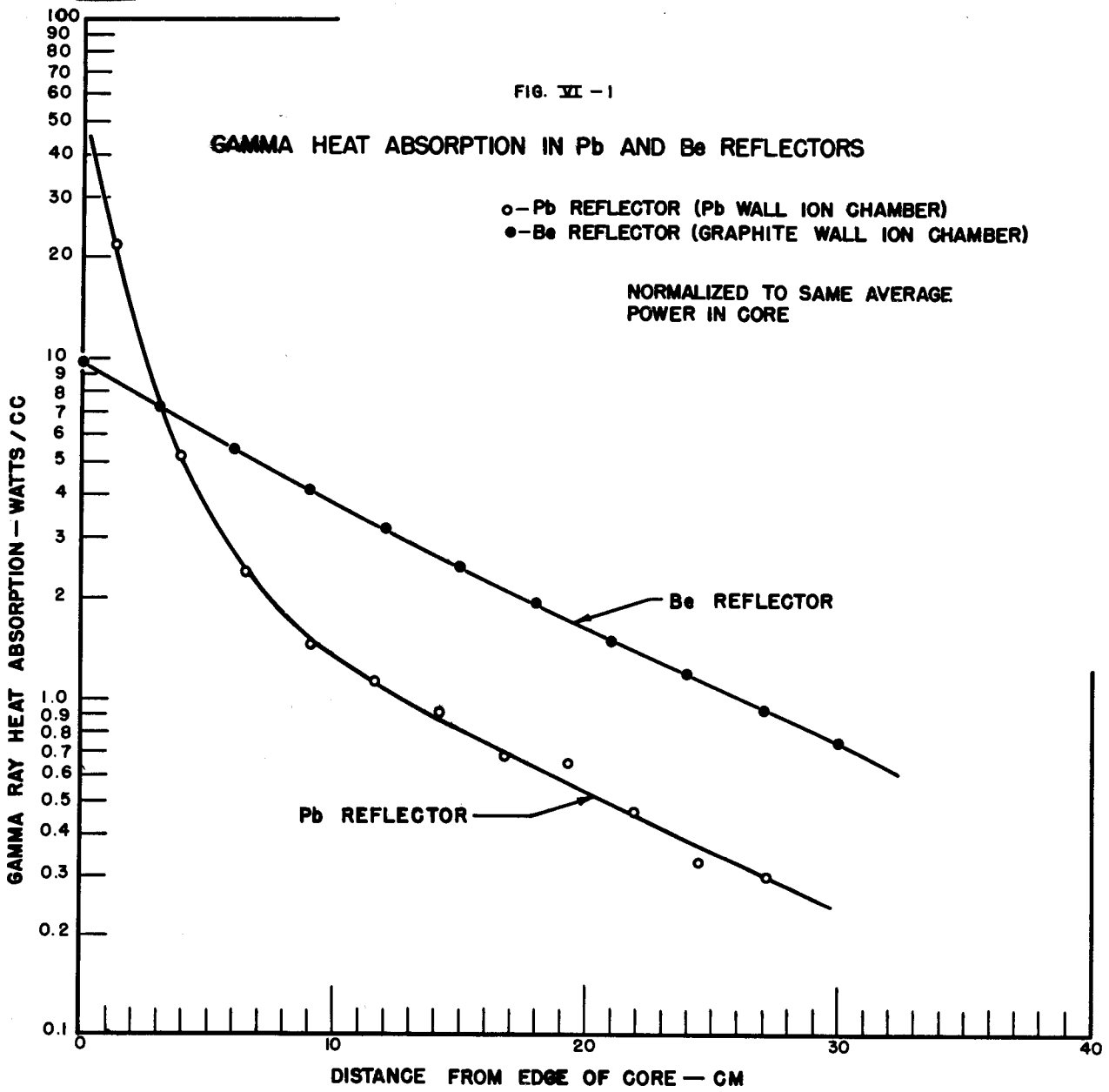

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the assembly at criticality, with no neutron source in position, so the experiment was done in the following manner. The external neutron source normally used in a position just beneath the center of the core was removed and a relatively weak source was placed at the geometrical center of the core. The assembly was then operated as a subcritical machine, but at multiplications of about 300. It can be shown that under these conditions the contribution of the harmonics in the spatial neutron distribution is negligible. The monitors used in these experiments were BF_3 counters rather than the ionization chambers used in normal operation at higher flux levels.

The results of the measurements are shown in Fig. VI-2, where the thermal neutron flux, the fast neutron flux and the gamma ray flux as measured by the Geiger counter have been plotted for the clean Pb reflector and for the reflector with Boron layer inserted. It is evident that the Boron reduced the thermal flux to about 20% of its value in the clean reflector; the gamma ray flux is reduced to about 40% and the fast (E>1 mev) neutron flux is not appreciably changed. In fact, the fast flux appears to be somewhat greater after the Boron sheet is inserted in the reflector. We take this apparent anomaly to indicate that the correction which we have subtracted from the total fission chamber counts to correct for the thermal fissions in the small fraction of U-235 present in the chamber is somewhat too large.

If one considers a region in the reflector about 20 cm from the core, the pile gammas from the active lattice are effectively absorbed out and the gamma flux in this region must be due almost entirely to thermal capture and inelastic scattering of fast neutrons in the lead. A rough estimate of the relative contributions of these two processes to the gamma flux can be obtained from Fig. VI-2 in the following way. In the case of the clean reflector

$$\phi_\gamma \text{ (th)} + \phi_\gamma \text{ (f)} = \phi_\gamma \text{ (total)}$$

and when the Boron absorber is added

$$0.2\, \phi_\gamma \text{ (th)} + \phi_\gamma \text{ (f)} = 0.4\, \phi_\gamma \text{ (total)}$$

Subtracting, $\phi_\gamma \text{ (th)} = 0.75\, \phi_\gamma \text{ (total)}$

$$\phi_\gamma \text{ (f)} = 0.25\, \phi_\gamma \text{ (total)}$$

This result is in general agreement with the observation that the slope of the gamma flux distribution resembles that of the thermal neutron flux distribution more closely than that of the fast flux distribution (see Fig. VI-2).

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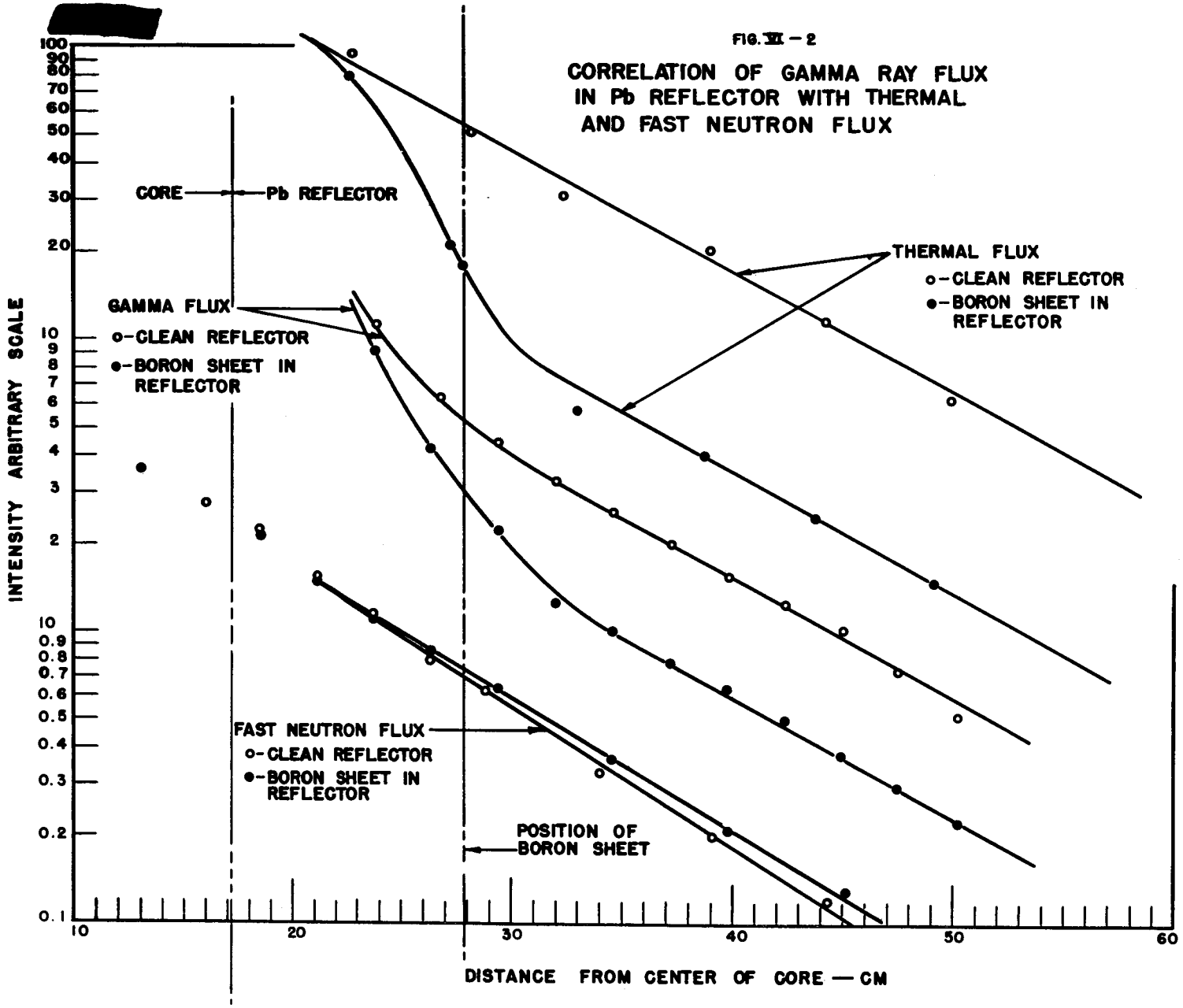
FIG. VI – 2

CORRELATION OF GAMMA RAY FLUX IN Pb REFLECTOR WITH THERMAL AND FAST NEUTRON FLUX



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SHIELDING

LID TANK (E. P. Blizard*, H. P. Sleeper**, C. E. Clifford***, T. Arnette)

Main construction and installation of the lid tank was completed on 3/3/49. Shielding sample containers and some of the instruments to be used are not yet delivered.

A vertical boron carbide diaphragm has been placed between the pile and the source to allow a change in the effective source size. A boron-free circle in the diaphragm shutter determines the effective source. These will be available with several aperture sizes. In addition to this, a horizontal shutter system has been recessed into the concrete pad face to provide a means of cutting off the thermal neutrons from the pile. A layer, 3/16" thick, of B_4C powder mixed with lacquer and thinner is sprayed on aluminum plates in a sandwich to form the shutter. The attenuation of thermal neutrons was measured to be greater than 10^4. This additional shutter will permit difference measurements in order to determine the "background" from the pile. It is also designed to reduce the source radio-activity, so that shield samples can be changed without filling the internal water tank in the core hole of the X shield. Shielding will be placed beneath the core hole balcony to decrease the radiation there from the uranium source plate. Work has been started on the overhead crane system. Iron plates are being cut for attenuation measurement through various configurations of iron and water up to 40" of iron.

INTERPRETATION OF LID TANK DATA (E. P. Blizard)

The "lid" geometry was chosen to minimize uncertainties due to unknown boundary conditions in a finite sample. "Plug" type experiments, in which a plug of material to be tested is introduced into an aperture in the reactor shield, suffer from streaming of radiation in the frequent cases in which the plug differs appreciably from the surrounding shield in attenuation characteristics. Radiation exchange between sample and its surroundings makes measurements in the sample a characteristic of the system and not the sample.

The lid geometry is one in which a sample is placed over a finite plane source and intensities are measured throughout the sample block. Integrals of this intensity over planes parallel to the source are then characteristic of the infinite plane source and infinite sample geometry.

*On loan from Bureau of Ships, Navy Department.
**On loan from KAPL.
***On loan from Technical Division.

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Because the neutron spectrum changes with distance from the source the slowing down length from the first major collision to approximately thermal energies will vary also. Since we must use thermal or near thermal detectors for low intensities, the effect of this distance on our measurements should be estimated, especially if we are to use the thermal flux as a measure of fast flux. With the help of B. I. Spinrad, F. H. Murray and T. Arnette, integrals of exponential "first major collision" distribution with Gaussian slowing down have been evaluated and are compared with a simpler case in which the thermal flux is taken as a constant proportion of the fast current at a point nearer to the source by a fixed small distance. The results are not yet complete.

ATTENUATION TESTS OF M1 CONCRETE (C. E. Clifford, T. Arnette, W. E. Whites, H. P. Sleeper)

Rockwell poured four feet of M1 concrete in 2" slabs to fit the NEPA steel sample boxes. M1 is a mixture of magnesium oxychloride cement, colemanite (boron ore), and iron punchings. The density was 4.7 gm/cm^3, and the boron content in the concrete was about 1% by weight. The boron was added to the MO mix in an attempt to reduce the production of secondary gammas in iron.

Gold foils were placed along the sample axis at two inches intervals over a 24" range. The relaxation length in the last half of the sample was 5.9 cms, nearly identical with that for MO concrete. These measurements should be considered tentative until they can be repeated in the Lid Tank.

Gamma measurements were taken every four inches over a 24" range with a Cutie Pie ionization chamber, as well as with a collimated GM tube. The former yielded a relaxation length of 8.8 cm, and the latter 9.0 cm. These correspond to a relaxation ρt of 42 gm/cm^2, which is almost identical with that for pure iron, 42.7 gm/cm^2, measured by Clifford and Palladino.

SECONDARY GAMMA RAY ENERGY STUDIES (E. P. Blizard, N. F. Lansing)

It is proposed to study the energy of capture γ-rays through measurement of the energy of protons resulting from the photo-disintegration of deuterons. The deuterium may be included in the system either as a constituent of a gas contained within a cloud chamber or embedded in some form in photographic emulsions.

Preliminarily, a cloud chamber containing ordinary methane has been operated and proton recoils from a fast neutron source have been observed.

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BORON-TUNGSTEN TESTS (C. E. Clifford, W. K. Ergen*)

The tests on boron-tungsten shields in the core hole have been completed and a report of the data is being prepared by Ergen and other NEPA personnel. A series of ten configurations were measured in which boron carbide, tungsten carbide, and paraffin were used in different thicknesses and relative positions.

INSTRUMENT CALIBRATION (T. Arnette)

The determination of BF_3 counter characteristics in a high γ flux has been temporarily discontinued due to interfering construction work. Three new ion chambers were calibrated by the use of standardized radium sources. They cover a range of from 0.3 mr/Hr up to 10^4 r/Hr.

*On loan from NEPA.

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