DP - 106

[redacted]

Metallurgy and Ceramics

MEASUREMENT OF LITHIUM IN TARGET SLUGS BY NEUTRON TRANSMISSION

UNCLASSIFIED

by

A. H. Dexter

Instrument Development Division

February 1955

[redacted]

E. I. du Pont de Nemours & Co.
Explosives Department — Atomic Energy Division
Technical Division — Savannah River Laboratory

Classification Ca[illegible]

By Authority of C J Banick AED Classification Officer
Name Title Date
7/17/87

[redacted]

[redacted]

253257

DP - 106

UNCLASSIFIED

METALLURGY AND CERAMICS

~~This document consists of 26 ... Number ... of 163 Copies~~

MEASUREMENT OF LITHIUM IN TARGET SLUGS BY NEUTRON TRANSMISSION

by

A. H. Dexter
Instrument Development Division

February 1955

Classification Cancelled

By Authority of C. J. Banick AED Classification Officer 7/17/87
Name **Title** **Date**

~~Classification Cancelled or Changed TO Confidential RD By Authority of T.I.D. 1113, R.D. 12 ... 5, 3-15-56~~
~~Name Title Date~~ 6-22-56

[redacted]

E. I. du Pont de Nemours & Co.
Explosives Department - Atomic Energy Division
Technical Division - Savannah River Laboratory

Printed for
The United States Atomic Energy Commission
Contract AT(07-2)-1

UNCLASSIFIED

[redacted]

METALLURGY AND CERAMICS

INTERNAL DISTRIBUTION

Copy No.	Name	Location
1-5.	AEC, SROO	Augusta, Ga.
6.	R. M. Evans - B. H. Mackey	Wilmington AED
7.	J. E. Cole - M. H. Smith- J. B. Tinker	"
8.	W. C. Kay - H. Worthington	"
9.	J. C. Woodhouse	"
10.	J. A. Burns	Engineering Department
11.	J. D. Ellett	Savannah River Plant
12.	W. P. Overbeck	"
13.	T. C. Evans	"
14.	K. W. Millett - H. A. Dickerson	"
15.	H. J. Bowman - W. M. Sloan	"
16.	F. M. Allen - A. E. Karnuth	"
17.	R. D. McCrosky - E. C. Laing	"
18.	J. D. Cist	"
19.	J. I. Dick-Peddie	"
20.	PRD File	"
21.	M. H. Wahl - C. W. J. Wende	Savannah River Laboratory
22.	J. W Croach - L. M. Arnett	"
23.	J. N. Wilson	"
24.	P. H. Permar - V. I. Montenyohl	"
25.	A. H. Dexter	"
26-40	TIS File	"
41	TIS File Record Copy	"

METALLURGY AND CERAMICS
(M-3679, 15th Ed.)

EXTERNAL DISTRIBUTION

Copy No.	
42.	AF Plant Representative, Seattle
43.	AF Plant Representative, Wood-Ridge
44.	American Machine and Foundry Company
45-52.	Argonne National Laboratory
53-57.	Atomic Energy Commission, Washington
58.	Babcock and Wilcox Company
59.	Battelle Memorial Institute
60.	Bendix Aviation Corporation
61-63.	Brookhaven National Laboratory
64.	Brush Beryllium Company
65.	Bureau of Mines, Albany
66.	Bureau of Ships
67-68.	Carbide and Carbon Chemicals Company (K-25 Plant)
69-74.	Carbide and Carbon Chemicals Company (ORNL)
75.	Chicago Patent Group
76-77.	Commonwealth Edison Company
78.	Detroit Edison Company
79.	Dow Chemical Company (Rocky Flats)
80.	Duquesne Light Company
81.	Foster Wheeler Corporation
82-84.	General Electric Company (ANPD)
85.	General Electric Company (APS)
86-97.	General Electric Company, Richland
98.	Hanford Operations Office
99.	Iowa State College
100-103.	Knolls Atomic Power Laboratory
104-106.	Los Alamos Scientific Laboratory
107.	Mallinckrodt Chemical Works
108.	Materials Laboratory (WADC)
109.	Monsanto Chemical Company
110.	Mound Laboratory
111.	National Advisory Committee for Aeronautics, Cleveland
112.	National Bureau of Standards
113.	National Lead Company of Ohio
114.	Naval Research Laboratory
115.	New Brunswick Laboratory
116.	Newport News Shipbuilding and Dry Dock Company
117.	New York Operations Office
118-120.	North American Aviation, Inc.
121.	Nuclear Development Associates, Inc.
122.	Nuclear Metals, Inc.
123.	Pacific Northwest Power Group
124.	Patent Branch, Washington
125-128.	Phillips Petroleum Company (NRTS)
129.	Power Plant Laboratory (WADC)
130.	Pratt & Whitney Aircraft Division (Fox Project)
131.	Sylvania Electric Products, Inc.

EXTERNAL DISTRIBUTION (Continued)

Copy No.	
132.	Tennessee Valley Authority (Dean)
133-134.	University of California Radiation Laboratory, Berkeley
135-136.	University of California Radiation Laboratory, Livermore
137	Vitro Engineering Division
138.	Vitro Laboratories
139.	Walter Kidde Nuclear Laboratories, Inc.
140-143.	Bettis Plant (WAPD)
144-158.	Technical Information Service, Oak Ridge
159.	Kaiser Engineers
160.	Bridgeport Brass Company
161.	Engineer Research & Development Laboratories
162.	Pennsylvania Power & Light Company
163.	Westinghouse Electric Corp. (IAPG)

[redacted]

ABSTRACT

An instrument was developed to measure non-destructively the lithium content of target slugs for the SRP reactors. The slugs consist of cylindrical pieces of Li-Al alloy, approximately 0.8 inches in diameter and 12 inches in length, clad with aluminum. The instrument utilizes neutron transmission to determine the Li content in the range three to seven per cent Li.

[redacted]

TABLE OF CONTENTS

LIST OF FIGURES

MEASUREMENT OF LITHIUM IN TARGET SLUGS BY NEUTRON TRANSMISSION

INTRODUCTION

An instrument was required that would measure nondestructively the lithium content of the SRP target slugs. The slugs consist of cylindrical pieces of Li-Al alloy, approximately 0.8 inch in diameter and 12 inches in length, jacketed with 0.035-inch aluminum. The most commonly used target slugs must contain 3.5 ± 0.3 per cent lithium by weight. Since no commercial instrument is manufactured for this type of measurement, the development of such an instrument was undertaken.

SUMMARY

A tester was developed that nondestructively measures the lithium content of target slugs. The target slug is interposed between a source of essentially thermalized neutrons and a neutron detector, and the neutron transmission of the slug is measured. Good correlation is obtained between the neutron transmission of the slug and the actual lithium content as determined by chemical analysis. With a 10-curie Po-Be source and a counting time of 12 minutes, the lithium content is determined to an accuracy of 500 parts per million.

DISCUSSION

A tester was required that would nondestructively determine the lithium content of canned target slugs. W. P. Overbeck suggested that neutron transmission would be a suitable basis for a test.

THEORY

The apparent sensitivity of the neutron transmission to variation in lithium content of the slugs can be estimated from elementary considerations. If a beam of monoenergetic neutrons of intensity I_o is directed through a slab of Li-Al alloy of thickness x, the intensity of the transmitted beam is given by:

$$(1) \quad I = I_o e^{-\Sigma x}$$

where Σ is the total macroscopic cross section of the alloy.

If Σ_{Al} and Σ_{Li} are the macroscopic cross sections of the aluminum and lithium in the alloy, then $\Sigma = \Sigma_{Al} + \Sigma_{Li}$ and

$$(2) \quad I = I_o e^{-(\Sigma_{Al} + \Sigma_{Li})x}.$$

Differentiating (2) with respect to Σ_{Li} and then dividing by (2) yields:

$$(3) \quad \frac{dI}{I} = -x d\Sigma_{Li} = -x\Sigma_{Li}\left(\frac{d\Sigma_{Li}}{\Sigma_{Li}}\right)$$

The fractional change in cross section of the lithium, $\frac{d\Sigma_{Li}}{\Sigma_{Li}}$, is very nearly proportional to the fractional change in concentration of lithium, $\frac{dC}{C}$, where C is the concentration of lithium in the alloy on a weight basis. Therefore,

$$(4) \quad \frac{dI}{I} = -x\Sigma_{Li}\frac{dC}{C}.$$

Equation (4) is only an approximation of the practical case. If the neutrons are partially or completely thermalized in a moderator, they will not be monoenergetic, but will be approximately distributed in energy according to a Maxwellian distribution. Moreover, the neutrons do not form a parallel beam. Finally, the cylindrical slug of lithium alloy is poorly represented as a slab.

Applied to the case in hand, equation (4) gives the following sensitivity of the test:

For slugs of 3.5 per cent Li and 0.8-inch diameter, an increase in Li content of 0.1 per cent will increase the concentration of lithium by:

$$\frac{dC}{C} = \frac{0.1}{3.5} = 0.028.$$

The effective thickness of the slug is approximately $\frac{\sqrt{\pi}}{2}$ times the diameter, or $\frac{\sqrt{\pi}}{2} \cdot 0.8 = 0.71$ inch $= 1.8$ cm. The density of the alloy is approximately 2.4 gm/cm^3. On the basis of a neutron cross section of 67 barns for lithium, Σ_{Li} is computed as 0.48 cm^{-1} for 3.5 per cent Li alloy. The estimated change in transmission for the 0.1 per cent increase in Li is:

$$\frac{dI}{I} = -(1.8)\ (0.48)\ (0.028) = 0.024 \text{ or } -2.4 \text{ per cent.}$$

The approximations that enter into the foregoing calculations are such that the sensitivity is overestimated. In practice, a lower sensitivity is to be expected.

DESCRIPTION OF THE TESTER

The three basic components of the tester are a source of essentially thermalized neutrons, a neutron counter to detect the transmitted neutrons, and a scaler to register the number of neutrons transmitted in a fixed time interval. Other components include a high-voltage supply for the neutron counter and a holder to maintain the target slug and neutron counter fixed with respect to each other and to the neutron beam. The basic layout of the tester is shown in Figure 1.

The thermal neutron source, called a "neutron howitzer", is shown in Figure 2. An intimate mixture of Po^{210} and beryllium, contained in a small capsule at the center of the howitzer, provides fast neutrons with energies of several Mev. "Permanent" sources such as Pb^{210} (RaD), with a 22-year half-life, are preferable to polonium, but are prohibitively expensive ($\sim$\$40,000/curie). Radium is undesirable because of its high output of gamma radiation. Polonium represents the best compromise although it must be replaced periodically as its half-life is 140 days. The fast neutrons from the source are slowed to thermal velocities by the 12-inch cube of paraffin moderator that surrounds the capsule.

A 1.5-inch thick biological shield, containing three parts Borax to one part paraffin, encloses the moderator and serves to absorb most of the thermal neutrons that leak from the moderator. The shielding is more than adequate for a two-curie source; however, the leakage with a ten-curie Po-Be source is such that the operator must work two to three feet from the howitzer. This distance does not represent a problem since the target slugs can be inserted and removed from the tester with a pair of tongs.

The entire assembly is contained in a box that is made from sheet steel of 1/8-inch thickness. A rectangular opening, 1.0 x 2.5 inches in cross section, extends through the top of the box to the source, providing an exit port for the thermalized neutrons. A holder, located over the exit port and fastened to the cover of the box, maintains the target slug and counter fixed with respect to each other and to the neutron beam.

The neutron counter is a $B^{10}F_3$ proportional counter manufactured by the Radiation Counter Laboratories. This counter acts like a Geiger counter over a certain range of applied voltage in that it has an apparent plateau. As a result, the counter is relatively insensitive to fluctuations in high voltage when operated at an appropriate voltage. The relative insensitivity of the counter to fast neutrons and gamma rays is an important feature. It was determined experimentally that only 11 per cent of the total count measured by the counter was due to fast neutrons and gammas.

The amplifier-scaler combination is a Model 1070A "Multiscaler", made by the Atomic Instrument Company. This instrument also provides the high voltage for the $B^{10}F_3$ neutron counter.

The complete tester is shown in Figure 3.

PERFORMANCE

The instrument was initially evaluated in the laboratory with a 0.8-curie Po-Be source. The Li-Al slugs were inserted one at a time and the thermal neutron transmission of each was determined. The slugs were subsequently dissolved and analyzed for lithium content with a flame photometer. The correlation between neutron transmission and the chemically-determined lithium content is shown in Figure 4. The errors indicated on the transmission measurements are the standard deviations (σ) of the counts. The sensitivity is a 1.3 per cent change in neutron transmission per 0.1 per cent change in Li content, in the region of 3.5 per cent lithium content. This is about one-half the sensitivity predicted under "Theory".

The reliability of the instrument was determined in the laboratory by making seventeen 20-minute counts of the neutron flux from the open beam during a period of eight hours. All counts fell within $\pm 2\sigma$ of the average count even though a power-line monitor that was in operation during this period indicated a considerable number of line transients throughout the counting period. A 2KV ultrasonic pulser was

[redacted]

also operated in the proximity of the tester with no apparent effect on the count.

The instrument was evaluated in the Plant by the Works Technical Department. A ten-curie Po-Be source was used. The correlation between neutron transmission and chemically measured lithium content was determined over a greater range of lithium content (3.52-7.50 per cent) than that used in the laboratory. Over this range, the exponential characteristic of the neutron transmission is more evident. The data shown in Figure 6 were furnished by J. I. Dick-Peddie. Good correlation is indicated by the smoothness of the curve. The points on the graph represent the average transmission of each slug as determined by ten counts of one minute each. The indicated error for each point is the maximum spread of the ten counts. The fact that the spread was greater than 2σ for some points on the graph is not considered of consequence since all counts were for one-minute periods; small timer errors contribute a larger percentage-wise error in a one-minute count than in a count taken over a longer time interval.

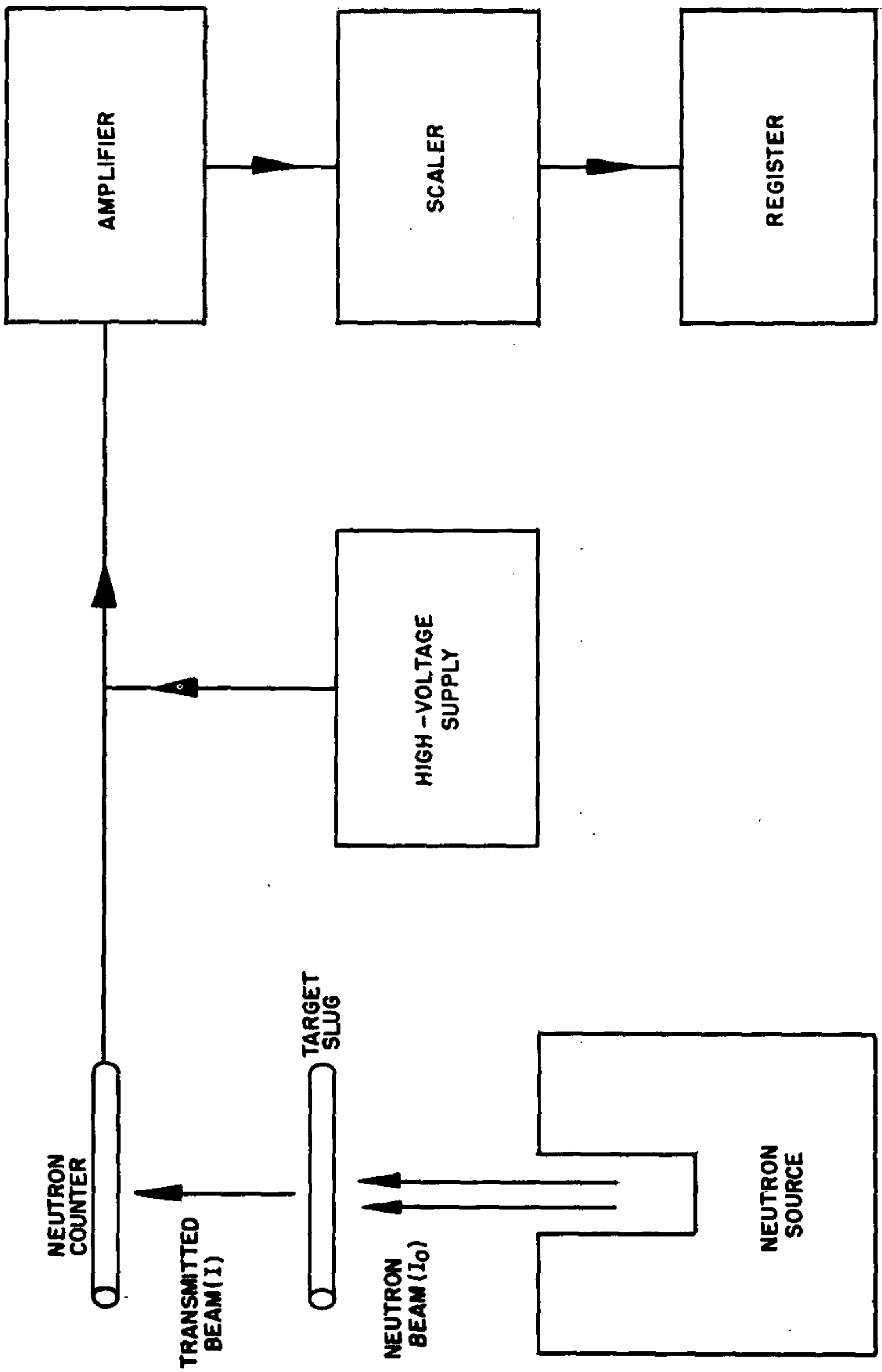
The time required to make a determination of the lithium content to an accuracy of 500 parts per million is dictated by statistical considerations which in turn are dependent upon the strength of the neutron source. A total transmission count of about 90,000 is needed to give the required accuracy at the 95-per cent confidence level. With the ten-curie Po-Be source, the transmitted count of a 3.5 per cent target slug was approximately 7500 c/m; thus, the counting time required per slug is twelve minutes.

A. H. Dexter

A. H. Dexter
Instrument Development Division

UNCLASSIFIED

[redacted]



BLOCK DIAGRAM OF THE TESTER

FIGURE 2

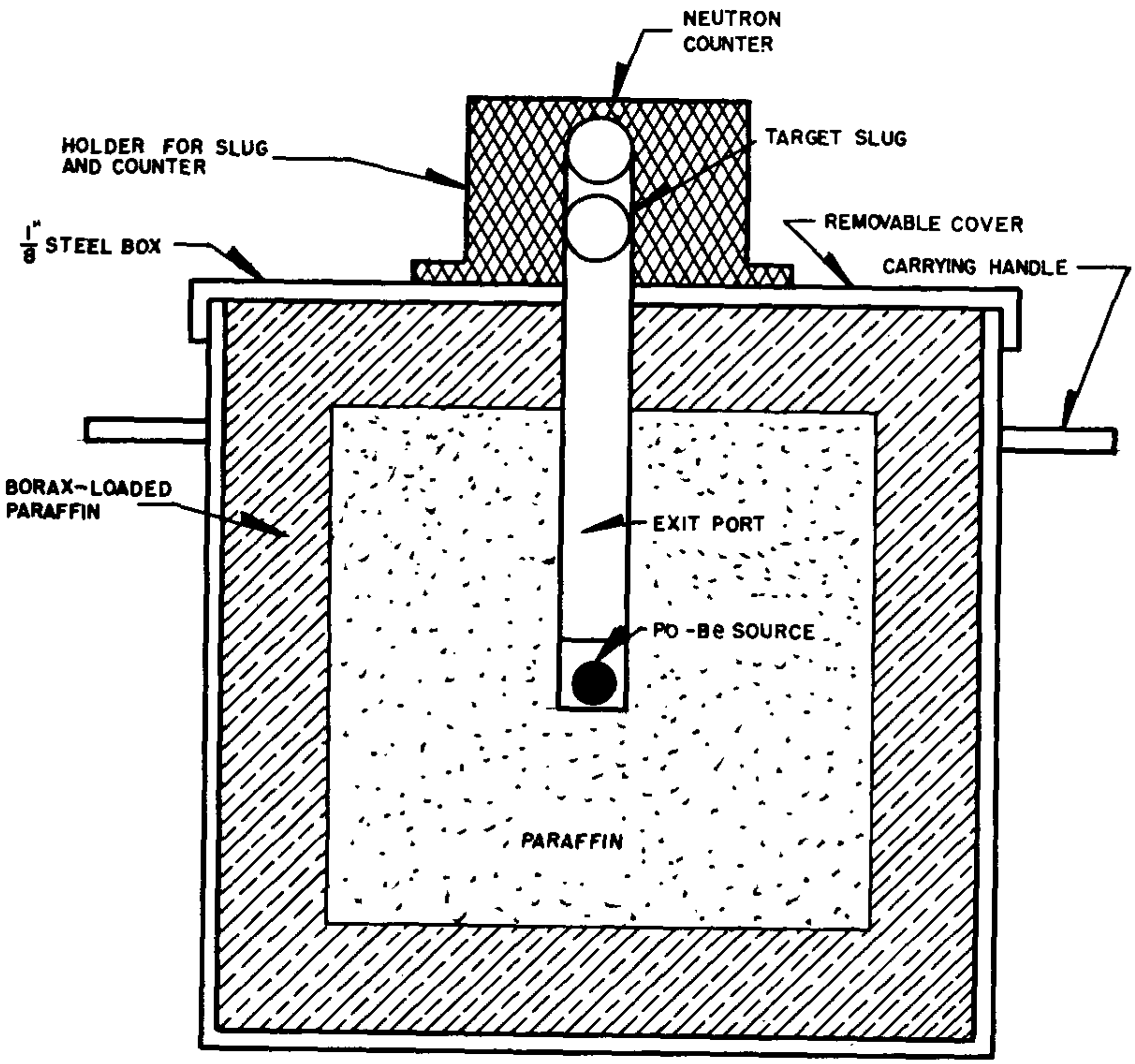
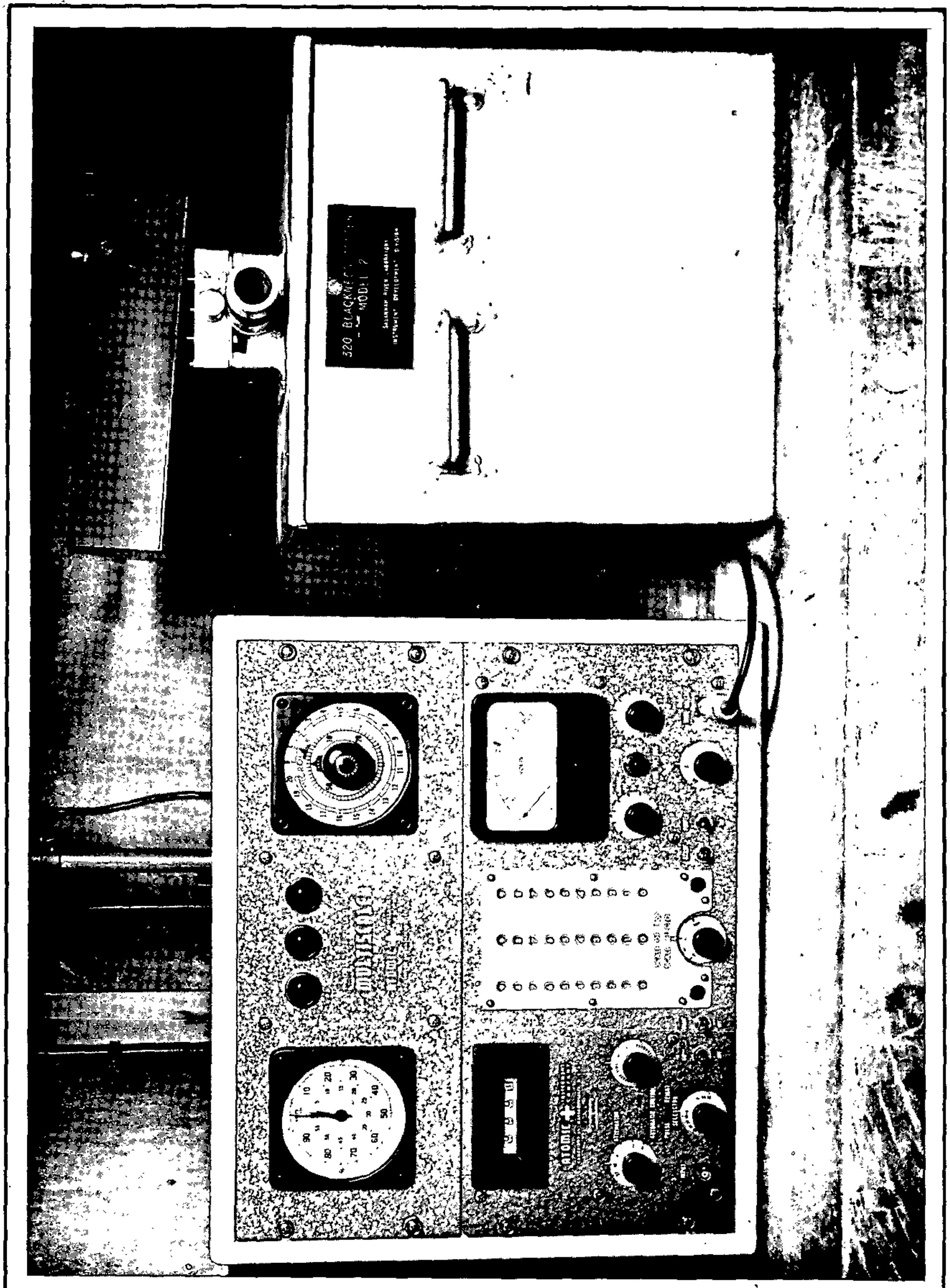


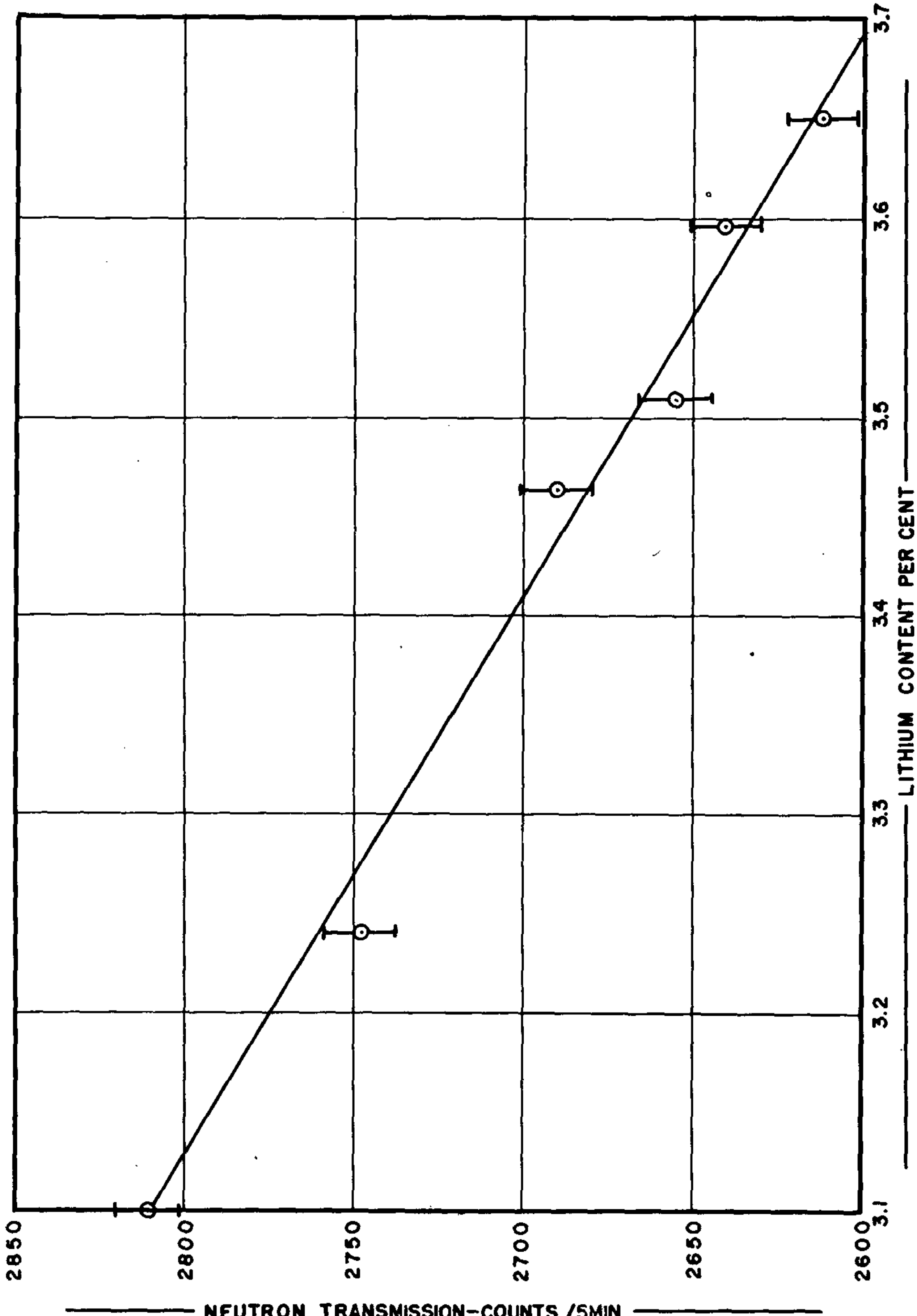
DIAGRAM OF THE NEUTRON HOWITZER - CROSS-SECTIONAL VIEW

FIGURE 2



PHOTOGRAPH OF THE TESTER

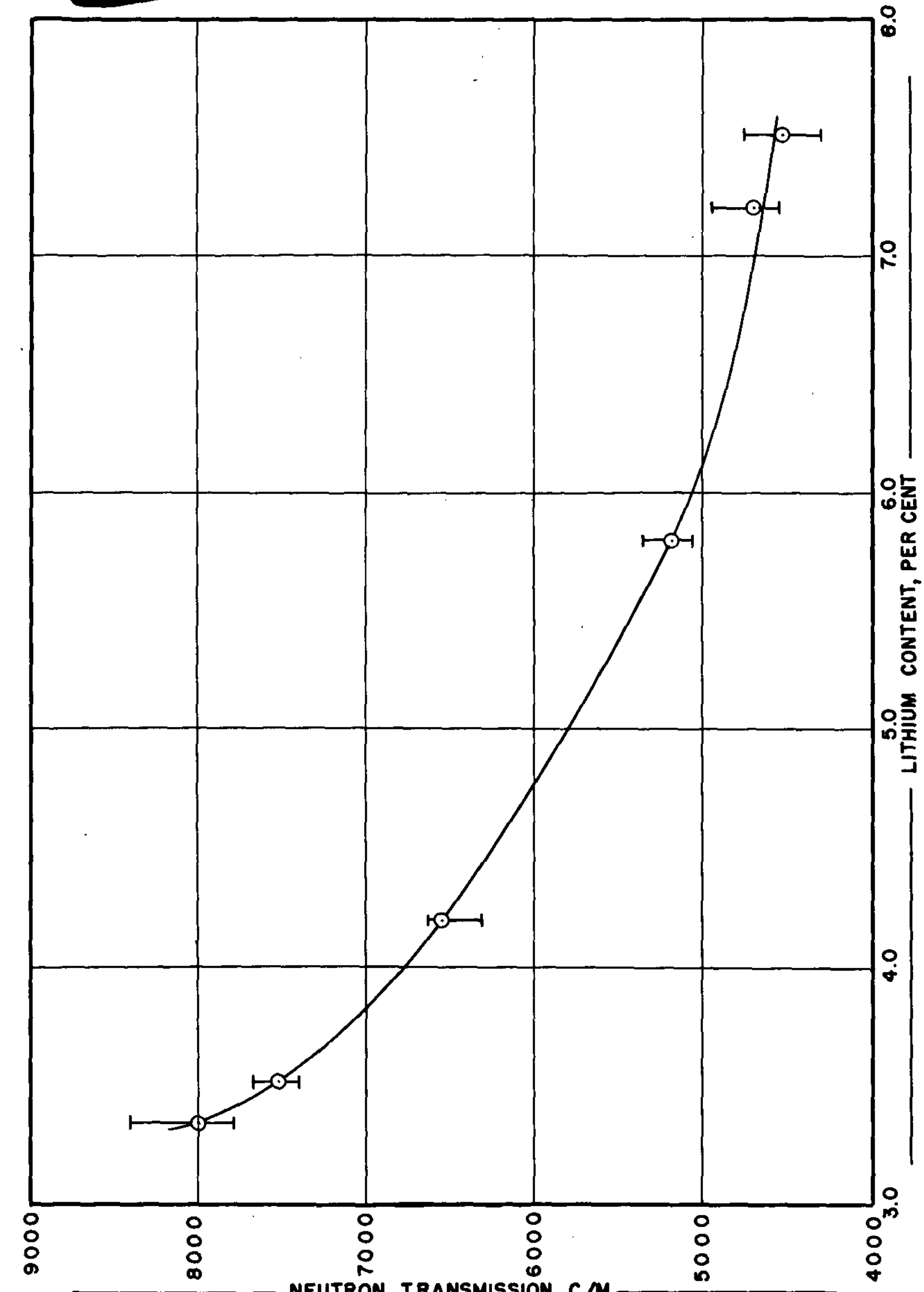
FIGURE 4



GRAPH OF NEUTRON TRANSMISSION vs. Li CONTENT, SRL DATA

[redacted]

FIGURE 5



GRAPH OF NEUTRON TRANSMISSION vs. LI CONTENT-SRP DATA

[redacted]