NEUTRON FLUX DETERMINATION IN THE LOWER REGION OF A NATURAL URANIUM-LIGHT WATER SUBCRITICAL ASSEMBLY

by

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INTRODUCTION

Students in the first year of graduate study in nuclear engineering may gain considerable insight into nuclear phenomena by running experiments using a subcritical reactor assembly. Some of these experiments may include half-life determination, neutron flux determination at a point, or activity of a foil with the flux known. In this thesis, the flux was determined at many points in the lower level of the assembly. The information obtained and recorded herein will allow an instructor to give problems to the students and know in advance the type results expected from the students.

Indium and gold foils were irradiated in the lower region of the subcritical assembly to saturation to obtain the activity of the radioactive samples. There were many calibrations and calculations involved in arriving at the actual activity. The actual activity of the foils was then used to obtain the neutron flux which is the aim of this thesis.

The determination of the neutron flux of a reactor using the activation of metal foils is not a new process. The metal foil activation method is about as old as the nuclear industry; however, there are differences in each reactor. This is one of the first of such experiments to be run in this particular subcritical assembly.

METHOD AND PROCEDURE

Description of Reactor and Counting Instruments

The natural uranium-light water subcritical reactor is classified as a heterogeneous reactor. Reactors are classified according to their neutron energy or relative arrangement of fuel and moderator. In a reactor classified as heterogeneous, the fuel is distributed in a fairly definite geometrical lattice or pattern within the mass of the moderator. The reactor housing is a stainless steel cylinder with a diameter of four feet and a height of five feet. This reactor is a subcritical assembly, or, in other words, it is not self sustaining.

The arrangement of the fuel in the subcritical assembly is in a hexagonal lattice around the source. There are two hundred sixty aluminum tubes that make up the lattice. These tubes are filled with slugs of fuel, five slugs to a tube. A slug is a machined uranium bar, one inch in diameter by eight inches in length and clad with a thin coat of aluminum. The lattice is arranged in such a manner that there is one-half inch between the aluminum tubes in any direction, and the rows of aluminum tubes are staggered so as to allow this uniform spacing between the tubes.

The fuel for the subcritical reactor is natural uranium. Uranium in the natural state is 99.28% U^{238} and the small remaining percentage is U^{235} and U^{234}. Natural uranium has a high affinity for neutrons and as the uranium U^{235} atom absorbs a neutron it is said to be in the excited state. An atom in the excited state may split and if it does, then fission products are formed. This is to say, elements of smaller mass number than uranium are produced and are always radioactive in nature. The excited uranium atom, when forming the fission products, releases neutrons. Neutrons released by fission are absorbed in the moderator or the aluminum tubing, or else the energy of the neutrons is not sufficient to excite an atom of uranium. Since this is not a self sustaining process, a source of neutrons is needed.

A subcritical assembly cannot operate without a source of neutrons. The neutron source in this reactor is a plutonium-beryllium mixture. Neutrons are produced by the action of a radioactive element (plutonium) which emits alpha particals in the presence of a light element such as beryllium, boron or lithium. The reaction producing the neutron is ${}_4Be^9 + {}_2He^4 \longrightarrow {}_6C^{12} + {}_0n^1$.

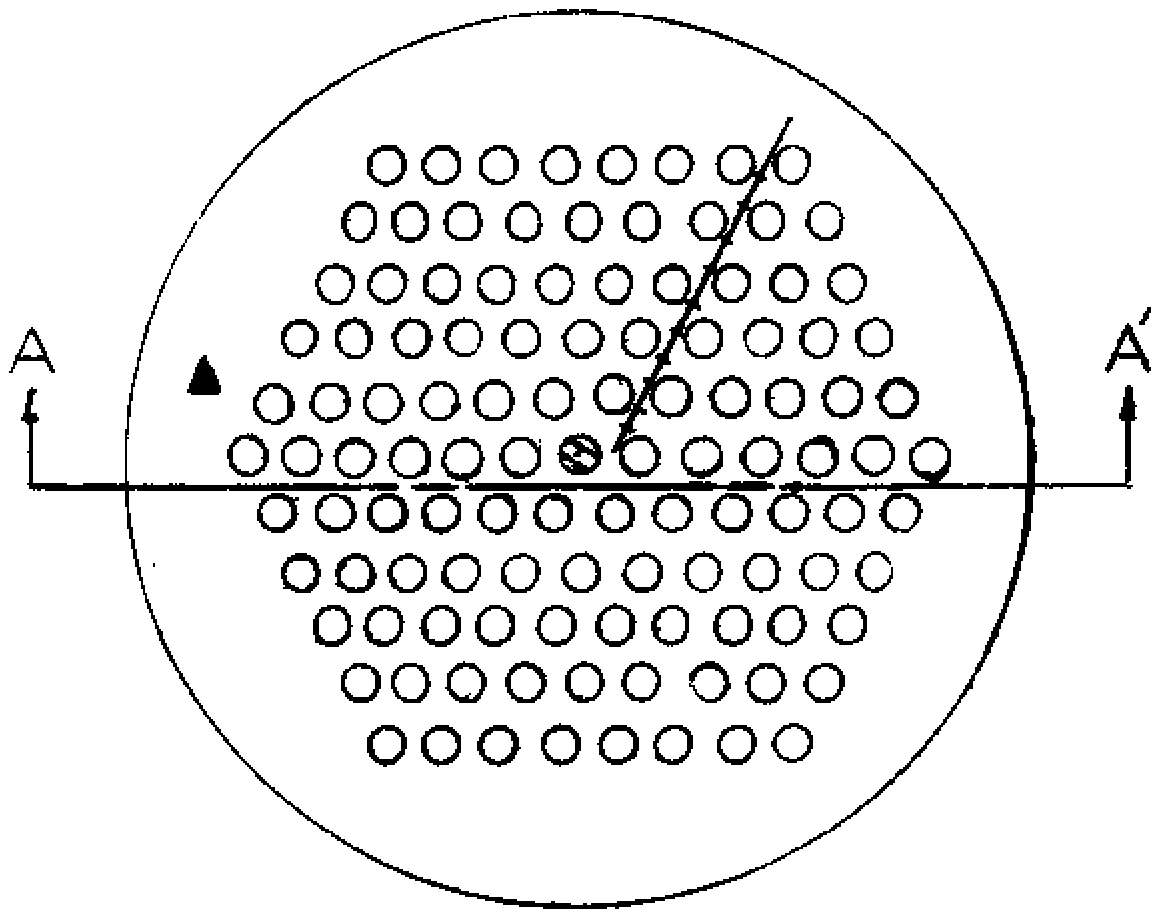
The moderator for the subcritical assembly is light water. Light water is of the molecular formula H_2O, as opposed to heavy water, D_2O. A moderator should have a very low absorption cross-section; this is one disadvantage of water as a moderator. The advantages far outweigh the disadvantages, although the absorption cross-section for neutrons is larger than the ideal moderator. Water has a high scattering cross-section, allowing a good dispersion of the neutrons. Water is a very inexpensive moderator. However, the water must be free of impurities because the impurities in the presence of neutrons become radioactive.

The counting instrument used in this experiment is called an ultra scaler. In the process of counting a radioactive sample, the sample is placed in a lead shield which houses a Geiger-Muller tube. The Geiger-Muller forms the radioactive particles received into electrical impulses. The ultra scaler records the electrical impulses as counts.

In this experiment, gold and indium foils are used in the activation method for flux determination. The lower region of the reactor includes the position of the foils during irradiation. The first irradiation was gold foils at ten inches below the neutron source; the second and third irradiations were indium foils at twelve and fourteen inches below the neutron source. The fourth irradiation was gold foils at sixteen inches below the neutron source, and the fifth irradiation was gold foils in a vertical position of twenty inches from the neutron source.

FIGURE 1

TOP VIEW OF REACTOR



NOMENCLATURE

○ Aluminum tubes of natural uranium

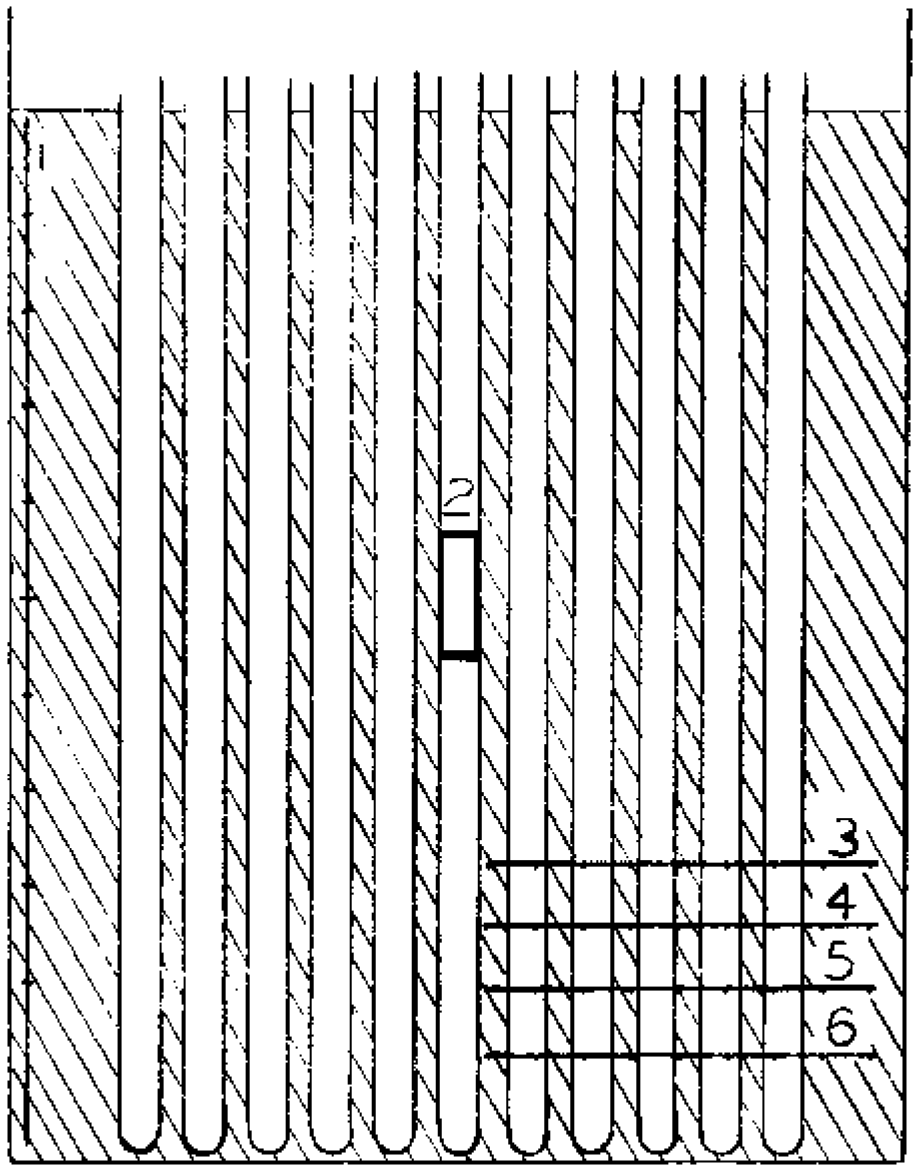
⊘ Location of neutron source

▲ Location of foils in vertical position 20 inches from source

Position of foils in horizonal planes

FIGURE 2

SECTION AA'



▧	Water
1	Relocation of vertical run
2	Relocation of neutron source
3	Location of foils 10 inches below source
4	Location of foils 12 inches below source
5	Location of foils 14 inches below source
6	Location of foils 16 inches below source

METHOD AND PROCEDURE

Sample Calculation

I. Gold and Indium Foils Irradiated in Subcritical Reactor Assembly Until Foils Were Saturated.

Foils used for sample calculations are gold, and numbered 1(s) for the small gold foil which is three-eighths inch in diameter, and 1(L) for the large gold foil which is one inch in diameter. Data were collected using an ultra scaler counter and lead shield. Foils were removed after saturation, 1555 hours, on January 2, 1960.

Table 1 - Gold Foils Irradiated in Subcritical Reactor Assembly Until Foils Were Saturated

Foil	Counts/Minute	Time Counted Hours of Day	Date Counted	Carbon-14 Standard
1(s)	820	1559	1-2-60	1712 c/m
1(L)	3671	1602	1-2-60	1712 c/m
1(s)	683	1555	1-3-60	1792 c/m
1(L)	2527	1606	1-3-60	1792 c/m
1(s)	569	1515	1-4-60	1765 c/m
1(L)	2071	1526	1-4-60	1765 c/m
1(s)	410	1010	1-5-60	1831 c/m
1(L)	1521	1016	1-5-60	1831 c/m
1(s)	362	1507	1-5-60	1780 c/m
1(L)	1436	1513	1-5-60	1780 c/m
1(s)	334	1518	1-6-60	1747 c/m
1(L)	1216	1524	1-6-60	1747 c/m
1(s)	256	0948	1-7-60	1662 c/m
1(L)	927	0954	1-7-60	1662 c/m

A. Correction of Counts for Background

Background is a term used to describe the number of counts recorded by an instrument when no radioactive material is present.

January	Background Counts/Minute
2	32
3	28
4	30
5	30
5	31
6	28
7	32

The number of counts per minute recorded by an instrument less the background counts gives the actual counts per minute of the sample. C/M represents counts per minute.

Table 2 - Correction of Counts for Background

	Gold Foil l(s) c/m	Gold Foil l(L) c/m	Background c/m	Actual c/m l(s)	Actual c/m l(L)
Count 1	820	3671	32	788	3639
Count 2	683	2527	28	655	2499
Count 3	569	2071	30	539	2041
Count 4	410	1521	30	380	1491
Count 5	362	1436	31	331	1405
Count 6	334	1216	28	306	1188
Count 7	256	927	32	224	895

B. Standardization of Counts using Carbon (14) as the Standard.

Carbon (14) is a radioactive element and is used as a standard because of its very long half-life. C-14 represents Carbon (14).

Table 3-A Standardization of Counts using Carbon (14) as the Standard

	C-14 c/m	Background c/m	Actual C-14 c/m	1680 c/m used as Standard for this run
Count 1	1712	32	1680	$\frac{1680}{1680}$ = 1.000
Count 2	1792	28	1764	$\frac{1680}{1764}$ = .953
Count 3	1765	30	1735	$\frac{1680}{1735}$ = .969
Count 4	1831	30	1801	$\frac{1680}{1801}$ = .934
Count 5	1780	31	1749	$\frac{1680}{1749}$ = .960
Count 6	1747	28	1719	$\frac{1680}{1719}$ = .977
Count 7	1662	32	1630	$\frac{1680}{1630}$ = 1.030

Table 3-B Standardization of Counts using Carbon (14) as the Standard.

	Actual c/m l(s)	Actual c/m l(L)	Standardized c/m l(s)	Standardized c/m l(L)
Count 1	788	3639	788	3639
Count 2	655	2499	624	2382
Count 3	539	2041	522	1980
Count 4	380	1491	355	1394
Count 5	331	1405	318	1350
Count 6	306	1188	299	1160
Count 7	224	895	231	922

C. Correction of Large Foil Counts to Small Foil Counts

If two samples of gold are irradiated at the same flux, they are exposed to a constant rate of neutron bombardment. Suppose the samples are A and B. Both have the same thickness, but the weight of A is twice that of B. The radioactivity of an element depends on the number of atoms present. The number of atoms depend on the mass of the element. Then samples A and B are irradiated to saturation at the same neutron flux. The counts per minute of sample A will be twice that of sample B.

With the weight relationship, the counts of the large foils are corrected to counts of a small foil.

Table 4-A Correction of Large Foil Counts to Small Foil Counts

Small Foils	Weight in grams	Large Foils	Weight in grams
1(s)	.1342	1(L)	.6801
3(s)	.1289	1(L)	.6974
4(s)	.1339	1(L)	.7067
5(s)	.1352	1(L)	.6727
6(s)	.1369	1(L)	.6761

Average weight of small foils $\frac{.6691}{5} = .1338$

Average weight of large foils $\frac{3.4330}{5} = .6886$

Counts = Counts of large foil X .196

Table 4-B Correction of Large Foil Counts to Small Foil Counts

	Standardized c/m 1(L)	Corrected to small foil c/m
Count 1	3639	714
Count 2	2382	467
Count 3	1980	388
Count 4	1394	273
Count 5	1350	263
Count 6	1160	227
Count 7	922	181

D. Graph - Extrapolation Curves to Time of Removal of Samples from Reactor

This is a determination of the counts per minute of a foil at the time the foil was removed from the reactor. The logarithm of the counts of a foil is linear function of time.

Table 5 Extrapolation Curves to Time of Removal of Samples

	c/m 1(s)	Tr* hrs.		c/m 1(L)	Tr* hrs.
Count 1	788	0.07	Count 1	714	0.18
Count 2	624	24.00	Count 2	467	24.18
Count 3	522	47.30	Count 3	388	47.48
Count 4	355	66.30	Count 4	273	66.35
Count 5	318	71.20	Count 5	264	71.30
Count 6	299	95.40	Count 6	227	95.48
Count 7	231	113.90	Count 7	181	114.00

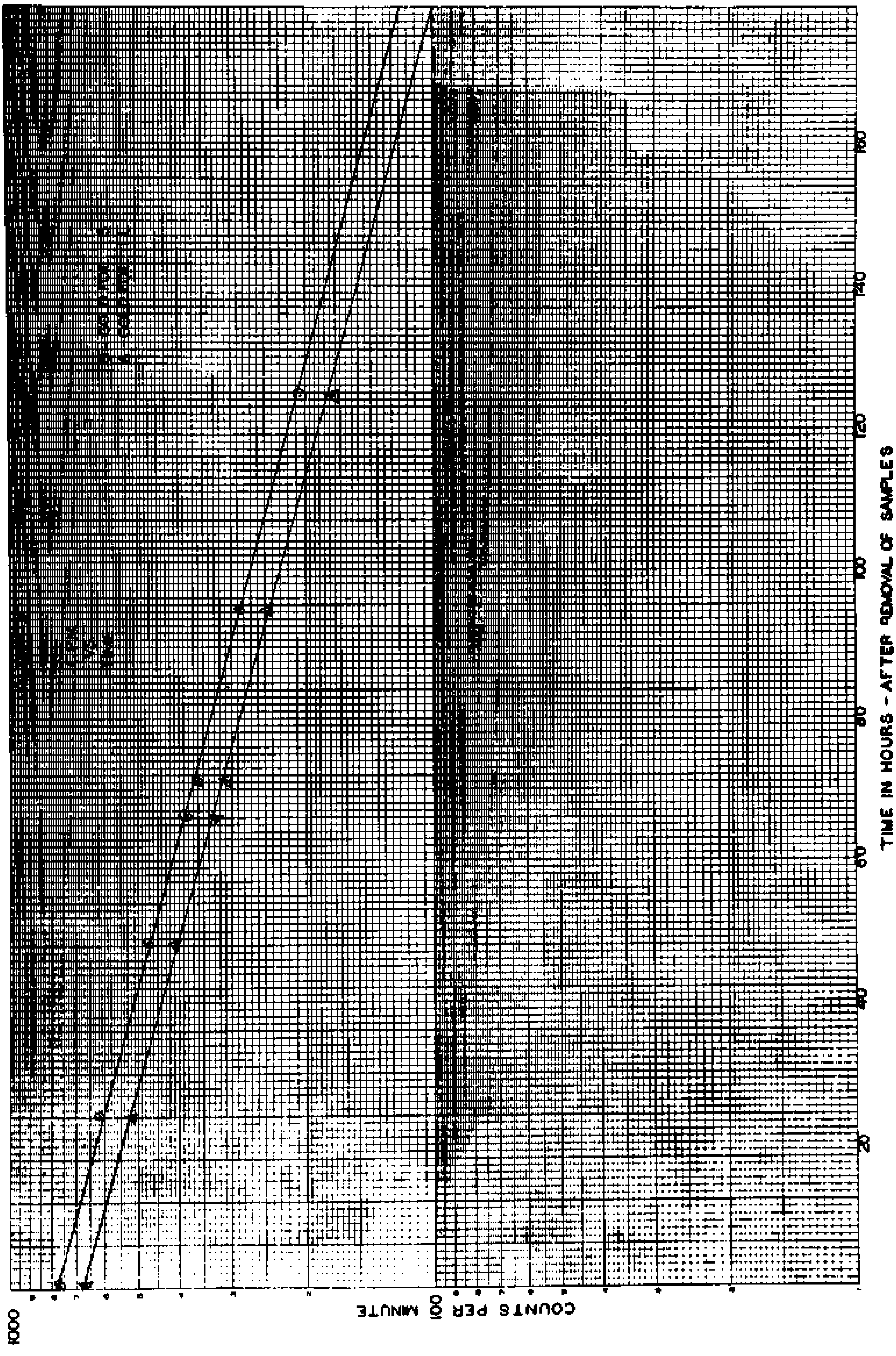
*Tr. represents the time difference between time foil is removed from reactor and the time foil is counted in instrument.

In Figure 3, the counts per minute are plotted on logarithm plot versus time (in hours) sample had been removed from the reactor. Some of the points vary from expected results, so the curves drawn approximate as many points as possible. The curve extrapolates across the line were time equal to zero; this is removal time. The counts per minute at this point is Cr, where Cr represents counts per minute of the sample at removal time.

Results from Figure 3:

Gold Foil 1(s) -- Cr = 780 c/m

Gold Foil 1(L) -- Cr = 675 c/m


TIME IN HOURS - AFTER REMOVAL OF SAMPLES
20
40
60
80
100
120
140
160
1000

II. Determination of the Counting Efficiency Constant

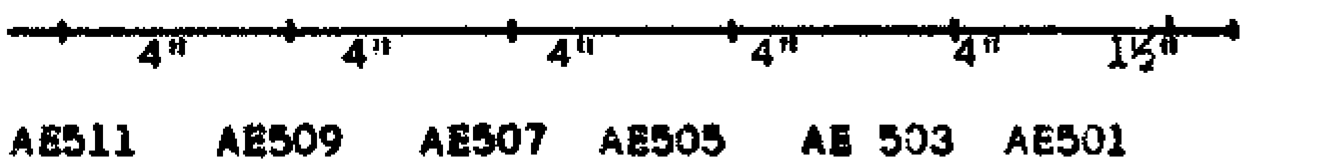
Convair of Fort Worth, Texas, loaned the Nuclear Group at Texas Technological College a quantity of gold foils to irradiate and make two counts on the foils as they were removed from the reactor. The foils were sent to Convair with the data collected at Texas Technological College. Convair counted the foils and determined an activity for each foil.

The activity is equal the counts at removal time of the sample, multiplied by the counting efficiency constant of the counter used. The equation is:

$$Ar = Crk$$

where Ar represents the activity at removal time of the sample. Cr is the counts per minute of the samples at removal time and k is the counting efficiency constant.

The location and gold foil numbers used by Convair, foils AE500 - AE511:



The even numbered gold foils are covered with cadmium foil covers. The purpose of the cadmium covers is to filter out the thermal neutrons; thereby, samples in the cadmium covers retain an activity referred to as the resonance activity. Thermal activity is induced by the low energy neutron present while resonance activity is induced by intermediate energy neutrons.

Table 6 Determination of the Counting Efficiency Constant

Gold Foil Convair Number	Convair Ar per Foil	Determined Cr c/m	Counting Efficiency Ar/Cr	Average Counting Efficiency Constant for Laboratory Counter
AE500	1.087×10^4	1010	10.75	
AE501	3.17×10^4	2990	10.60	
AE502	4.23×10^3	430	9.83	
AE503	1.405×10^4	1440	9.76	
AE504	1.86×10^3	185	10.05	
AE505	6.34×10^3	626	9.95	k = 10.10
AE506	7.16×10^2	75	9.55	
AE507	2.48×10^3	250	9.93	
AE508	$1. \times 10^2$	14.2	7.20	
AE509	1.405×10^3	134	10.50	
AE510	0	0		
AE511	5.15×10^2	51	10.10	

III. Activity of Irradiated Samples

$A_r = kC_r$ = Thermal Activity

Gold Foil
1(s) $A_r = (10.10)(780)$

= 7870 disintegrations/minute/foil

where

k units disintegrations/counts

C_r units counts/minute/foil

Gold Foil
1(L) $A_r = (10.10)(675)$

= 6820 disintegration/minute/foil

IV. Calculation of Thermal Neutron Flux in Units, neutrons/cm²/sec (ϕ_{th})

ϕ symbol used to represent neutron flux

Activity of foils are all at saturation activity

Equation for calculation of neutron flux:

$$\phi = \frac{A_r}{\frac{6.023 \times 10^{23}}{W} \, m \, \sigma_a}$$

where 6.023×10^{23} is the number of atoms per molecule of an element; W is the atomic weight of the foil used in grams per molecule; m is the mass of the foil in grams, and σ_a is the microscopic absorption cross-section of the foil (element) in centimeters squared (cm^2).[1]

Calculation of Thermal Neutron Flux - continued

Gold Foil
1(s) Ar = 7870 dsu/min/foil

dsu = disintegration units

W = 197 for gold

m = .1338 gram/foil

σ_a = 94×10^{-24} cm^2 for gold

$$\phi = \frac{7870}{\left(\frac{6.023 \times 10^{23}}{197}\right)(.1338)(.94 \times 10^{-22})}$$

$$\phi = \frac{7.87 \times 10^3}{(3.05 \times 10^{21})(1.26 \times 10^{-23})} = \frac{7.87 \times 10^3}{3.83 \times 10^{-2}}$$

$\phi = 2.06 \times 10^5$ neutron/cm^2/minute

60 $\frac{\text{seconds}}{\text{minute}}$

$$\phi = \frac{(2.06 \times 10^5)}{60}$$

$= 3.43 \times 10^3$ neutrons/cm^2/second

Gold Foil
1(L) Ar = 6820 dsu/min/foil

$\phi = \frac{6.82 \times 10^3}{3.83 \times 10^{-2}} = 1.78 \times 10^5$ neutrons/cm^2/min

$\phi = \frac{1.78 \times 10^5 \text{ n/cm}^2\text{/min}}{.60 \times 10^2 \text{ sec/min}}$

$= 2.97 \times 10^3$ neutrons/cm^2/sec

V. Correction for Flux Depression and Resonance Flux

A. Calculation of Factor for Depression of Thermal Neutron Flux

The cause of a depression in the thermal neutron flux is due to the type of absorbing material. In this experiment, two types of absorbing material were used. The two materials used were in the form of foils, gold foils and indium foils, and each material has a different flux depression factor.

Bothe's Formulas(2)

$$F_{th} = 1 + \frac{\alpha}{2} \frac{3R}{2\lambda_{tr}} \frac{L}{R+L} - 1 \quad \text{if } R \gg \lambda_{tr} \text{(eq:5)}$$

$$F_{th} = 1 + \frac{.34\,\alpha R}{\lambda_{tr}} \quad \text{if } R \ll \lambda_{tr} \text{(eq:6)}$$

R is radius of foil in centimeters = .476 cm

λ_{tr} is the transport mean free path of the medium = .425

α taken from Figure 5(2)

L = 2.64 + .0061 T (T = degrees Centigrade)
= cm diffusion length of water, at 78°C
= 3.12 cm

d = thickness of foil in grams per centimeters squared

λ_{tr} in water = .425 Table 2(2)

Calculation of Factor for Depression of Thermal Neutron Flux - continued

Physical Property	Gold Foil	Indium Foil	
density (ρ)	19.3 gm/cm^3	7.28 gm/cm^3	(3)
absorption cross-section (σa)	$94 \times 10^{-24} cm^2$	$196 \times 10^{-24} cm^2$	(4)
scattering cross-section (σs)	$9.3 \times 10^{-24} cm^2$	$2.2 \times 10^{-24} cm^2$	(4)
thickness (d)	.0965 gm/cm^2	.0364 gm/cm^2	

In order to obtain α from the Figure 5[2]

graph of α versus μd,

where d is thickness of foil in gm/cm^2 and

$\mu = \frac{N_0 \sigma a}{A}$ cm^2/gm absorption area per foil weight

N_0 is number of atoms per mole 6.023×10^{23}

σa microscopic absorption cross-section in cm^2

A is the atomic weight of foil element in gms/mole

For Gold

$$\mu d = \frac{(6.023 \times 10^{23})(.94 \times 10^{-22})}{197}(.0965)$$

$$\alpha = .0276$$

$$= .048 \text{ from Figure } 5^{(2)}$$

For Indium

$$\mu d = \frac{(6.023 \times 10^{23})(1.96 \times 10^{-22})}{115}(.0364)$$

$$\alpha = .037$$

$$= .067 \text{ from Figure } 5^{(2)}$$

Calculation of Factor for Depression of Thermal Neutron Flux - continued

For Gold Foil

(eq:5, supra)

$$F_{th} = 1 + \frac{\alpha}{2}\left[\frac{3R}{2\lambda_{tr}} \quad \frac{L}{R+L} \quad -1\right]$$

$$= 1 + \frac{.048}{2}\left[\frac{3(.476)}{2(.425)} \quad \frac{3.12}{.476 + 3.12} \quad -1\right]$$

$$= 1 + .024 \quad (1.47 - 1)$$

$$= 1.012$$

(eq: 6, supra)

$$F_{th} = 1 + \frac{.34\alpha R}{\lambda_{tr}}$$

$$= 1 + .34 \quad \frac{(.048)(.476)}{.425}$$

$$= 1.018$$

For Indium Foil

(eq: 5, supra)

$$F_{th} = 1 + \frac{\alpha}{2}\left[\frac{3R}{2\lambda_{tr}} \quad \frac{L}{R+L} \quad -1\right]$$

$$= 1 + \frac{.067}{2}\left[\frac{3(4.76)}{(2)(.425)} \quad \frac{3.12}{.476 + 3.12}\right]$$

$$= 1 + .0333 \quad (1.68)(.868)$$

$$= 1 + .0333(.46)$$

$$= 1.015$$

Calculation of Factor for Depression of Thermal Neutron Flux - continued

$$F_{th} = 1 + \frac{.34\alpha R}{\lambda_{tr}}$$

$$= 1 + \frac{(.34)(.067)(.476)}{.425}$$

$$= 1 + \frac{.01084}{.425}$$

$$= 1.026$$

F_{th} = the thermal neutron flux depression factor for gold = 1.012

Table 7 Calculation of Factor Depression

Foil	Thermal Neutron Flux (ϕ_{th})	Thermal Flux Correction for Depression ($c\phi_{th}$) neutron/cm^2/sec
1(s)	3.43×10^3	3.48×10^3
1(L)	2.97×10^3	3.0×10^3

B. Correction of Neutron Flux for Resonance Neutrons to Obtain Total Flux

<u>Gold Foil</u>		<u>Indium Foil</u>	
2.91	cadmium ratio	3.26	(4)

Table 8 Physical Properties of Foils Irradiated

Property	Gold Foil	Indium Foil
Average weight per foil	.1338 gms	.0994 gms
Cadmium ratio	2.91	3.26
Absorption cross-section (σ_a)	$94 \times 10^{-24} cm^2$	$196 \times 10^{-24} cm^2$
Atomic weight	197	115

Resonance flux was explained earlier and is calculated by dividing the thermal flux by the cadmium ratio. (Sample Calculation II, definition of Resonance Flux for Activity.)

<u>Gold Foil</u>
<u>1(s)</u>

Resonance ϕ = $3.48 \times 10^3/2.91$

= 1.20×10^3 neutron/cm^2/sec

Total ϕ = $(3.48 \times 10^3) + (1.20 \times 10^3)$

= 4.68×10^3 neutron/cm^2/sec

Correction of Neutron Flux for Resonance Neutrons to Obtain Total Flux

<u>Gold Foil</u>
1(L)

$$\text{Resonance } \phi = \frac{3.0 \times 10^3}{2.91}$$

$$= 1.03 \times 10^3 \text{ neutron/cm}^2\text{/sec}$$

$$\text{Total } \phi = (3.0 \times 10^3) + (1.03 \times 10^3)$$

$$= 4.03 \times 10^3 \text{ neutron/cm}^2\text{/sec}$$

SUMMARY OF FINDINGS

The results of neutron flux determination and distibution in the lower region of the subcritical assembly are found in Tables 9, 10 and 11, and Figure 4 herein. In Tables 9, 10 and 11, some of the terms must be shortened to fit into a Table, and these terms are:

Counts per minute at removal time -- Cr c/m;

Activity at removal time in disintegration units per minute per foil -- Ar dsu/m/foil;

Thermal neutron flux in neutrons per square centimeter per minute or second -- ϕ_{th} n/cm^2/m or sec;

Corrected thermal flux for depression -- cϕ_{th};

Resonance flux -- ϕ res; and

Total flux -- ϕ.

The tabulated results in Tables 9, 10 and 11 are derived from the data collected using the activation method of metal foils. The corrections and calibrations used to obtain the results are determined as in the examples given in the Sample Calculations. Table 9 gives the results of the thermal neutron flux corrected for background, standardized to standard, and flux depression. Table 10 gives the results of resonance of flux obtained for each foil and the total flux which is the sum of the corrected thermal flux and resonance flux. Table 11 is the Convair foils used, and the results are as indicated above for Tables 9 and 10.

Figure 4 is an isobaric representation of the total neutron flux around the source in the lower region of the subcritical assembly. The nomenclature of the symbols in Figure 4 indicates the locations of the foils during the irradiation period. Table 10 includes the data used to plot the isobars. The values used are within the margin of standard deviation used in most counting techniques.

Table 9-A Gold Foils Irradiated Ten Inches Below Neutron Source

Foil No.	Cr c/m	Ar dsu/m/foil	ϕ_{th} n/cm^2/m	ϕ_{th} n/cm^2/sec
1(s)	780	7900	2.07×10^5	3.48×10^3
1(L)	675	6820	1.78×10^5	3.0×10^3
3(s)	540	5450	1.42×10^5	2.37×10^3
3(L)	490	4940	1.29×10^5	2.15×10^3
4(s)	332	3350	8.75×10^4	1.46×10^3
4(L)	260	2630	6.86×10^4	1.14×10^3
5(s)	160	1615	4.22×10^4	7.04×10^2
5(L)	140	1415	3.69×10^4	6.15×10^2
6(s)	79	798	2.08×10^4	3.46×10^2
6(L)	34	343	8.96×10^3	1.50×10^2

Table 9-B Indium Foils Irradiated Twelve Inches Below Neutron Source

Foil No.	Cr c/m	Ar dsu/m/foil	ϕ_{th} n/cm^2/m	ϕ_{th} n/cm^2/sec
1	1480	1.49×10^4	1.99×10^5	3.31×10^3
3	1210	1.22×10^4	1.62×10^5	2.70×10^3
4.	1080	1.09×10^4	1.45×10^5	2.42×10^3
5	900	9.09×10^3	1.21×10^5	2.02×10^3
6	750	7.57×10^3	9.98×10^4	1.66×10^3
7	580	5.86×10^3	7.80×10^4	1.30×10^3
9	400	4.04×10^3	5.37×10^4	8.95×10^2
11	330	3.33×10^3	4.43×10^4	7.38×10^2
12	272	2.75×10^3	3.66×10^4	6.10×10^2
8	85	8.59×10^2	1.14×10^4	1.90×10^2

Table 9-C Indium Foils Irradiated Fourteen Inches Below Neutron Source

Foil No.	Cr c/m	Ar dsu/m/foil	ϕ_{th} $n/cm^2/m$	ϕ_{th} $n/cm^2/sec$
1	930	9.39×10^3	1.25×10^5	2.08×10^3
2	860	8.69×10^3	1.16×10^5	1.93×10^3
3	780	7.88×10^3	1.05×10^5	1.75×10^3
4	615	6.22×10^3	8.27×10^4	1.38×10^3
5	450	4.54×10^3	6.04×10^4	1.01×10^3
6	345	3.48×10^3	4.63×10^4	7.72×10^2
7	280	2.83×10^3	3.76×10^4	6.27×10^2
9	234	2.36×10^3	3.14×10^4	5.23×10^2
11	208	2.10×10^3	2.79×10^4	4.65×10^2
12	86	8.68×10^2	1.15×10^4	1.92×10^2

Table 9-D Gold Foils Irradiated Sixteen Inches Below Neutron Source

Foil No.	Cr c/m	Ar dsu/m/foil	∅ n/cm^2/m	∅ n/cm^2/sec
43	298	3010	7.86×10^4	1.31×10^3
63	226	2280	5.95×10^4	9.92×10^2
33	208	2100	5.48×10^4	9.13×10^2
61	156	1575	4.12×10^4	6.86×10^2
30	129	1300	3.39×10^4	5.65×10^2
31	67	838	2.19×10^4	3.65×10^2
59	52	676	1.77×10^4	2.95×10^2
34	30	303	7.91×10^3	1.32×10^2
58	10	106	2.77×10^3	4.62×10^1

Table 9-E Gold Foils Irradiated Twenty Inches from Neutron Source in Vertical Position

Foil No.	Cr c/m	Ar dsu/m/foil	ϕ_{th} n/cm²/m	ϕ_{th} n/cm²/sec
7(L)	8	81	2.12×10^3	3.53×10^1
7(s)	25	253	6.61×10^3	1.10×10^2
8(L)	34	344	8.88×10^3	1.48×10^2
8(s)	76	767	2.00×10^4	3.33×10^2
9(L)	82	828	2.16×10^4	3.60×10^2
9(s)	79	798	2.08×10^4	3.47×10^2
10(L)	48	485	1.27×10^4	2.12×10^2
10(s)	33	333	8.69×10^3	1.45×10^2
11(L)	14	145	3.79×10^3	6.32×10^1

Table 10-A Gold Foils Irradiated Ten Inches Below Neutron Sources

Foil No.	$c\phi_{th}$ n/cm²/sec	ϕ_{res} n/cm²/sec	Total Flux ϕ n/cm²/sec
1(s)	3.52×10^3	1.21×10^3	4.63×10^3
1(L)	3.03×10^3	1.04×10^3	4.07×10^3
3(s)	2.40×10^3	8.25×10^2	3.23×10^3
3(L)	2.17×10^3	7.50×10^2	2.92×10^3
4(s)	1.48×10^3	5.08×10^2	1.99×10^3
4(L)	1.15×10^3	3.95×10^2	1.45×10^3
5(s)	7.11×10^2	2.45×10^2	9.56×10^2
5(L)	6.22×10^2	2.14×10^2	8.36×10^2
6(s)	3.46×10^2	1.19×10^2	4.65×10^2
6(L)	1.52×10^2	5.23×10^1	2.04×10^2

Table 10-B Indium Foils Irradiated Twelve Inches Below Neutron Source

Foil No.	$c\phi_{th}$ n/cm^2/sec	ϕ_{res} n/cm^2/sec	Total Flux ϕ n/cm^2/sec
1	3.35×10^3	1.03×10^3	4.38×10^3
3	2.73×10^3	8.37×10^2	3.57×10^3
4	2.45×10^3	7.51×10^2	3.20×10^3
5	2.04×10^3	6.25×10^2	2.67×10^3
6	1.68×10^3	5.16×10^2	2.20×10^3
7	1.32×10^3	4.05×10^2	1.73×10^3
9	9.05×10^2	2.77×10^2	1.18×10^3
11	7.46×10^2	2.29×10^2	9.75×10^2
12	6.16×10^2	1.89×10^2	8.05×10^2
8	1.92×10^2	5.89×10^1	2.51×10^2

Table 10-C Indium Foils Irradiated Fourteen Inches Below Neutron Source

Foil No.	$c\phi_{th}$ n/cm^2/sec	ϕ_{res} n/cm^2/sec	Total Flux ϕ n/cm^2/sec
1	2.10×10^3	6.44×10^2	2.74×10^3
2	1.95×10^3	5.98×10^2	2.55×10^3
3	1.77×10^3	5.43×10^2	2.31×10^3
4	1.40×10^3	4.29×10^2	1.83×10^3
5	1.02×10^3	3.13×10^2	1.33×10^3
6	7.80×10^2	2.39×10^2	1.02×10^3
7	6.34×10^2	1.94×10^2	8.28×10^2
9	5.29×10^2	1.62×10^2	6.91×10^2
11	4.70×10^2	1.44×10^2	6.14×10^2
12	1.94×10^2	5.95×10^1	2.54×10^2

Table 10-D Gold Foils Irradiated Sixteen Inches Below Neutron Source

Foil No.	$c\phi_{th}$ n/cm2/sec	ϕ res n/cm^2/sec	Total Flux ϕ n/cm^2/sec
43	1.32×10^3	4.54×10^2	1.77×10^3
63	1.00×10^3	3.44×10^2	1.34×10^3
33	9.23×10^2	3.17×10^2	1.24×10^3
61	6.94×10^2	1.38×10^2	8.32×10^2
30	5.71×10^2	1.96×10^2	7.67×10^2
60	3.69×10^2	1.27×10^2	4.96×10^2
31	2.98×10^2	1.02×10^2	4.00×10^2
59	2.30×10^2	7.91×10^1	3.09×10^2
34	1.33×10^2	4.55×10^1	1.79×10^2
58	4.67×10^1	1.61×10^1	6.28×10^1

Table 10-E Gold Foils Irradiated Twenty Inches From Neutron Source

Foil No.	$c\phi_{th}$ n/cm²/sec	ϕ_{res} n/cm²/sec	Total Flux ϕ n/cm²/sec
7(L)	3.57×10^{1}	1.23×10^{1}	4.80×10^{1}
7(s)	1.11×10^{2}	3.81×10^{1}	1.49×10^{2}
8(L)	1.50×10^{2}	5.15×10^{1}	2.02×10^{2}
8(s)	3.37×10^{2}	1.16×10^{2}	4.53×10^{2}
9(L)	3.64×10^{2}	1.25×10^{2}	4.89×10^{2}
9(s)	3.51×10^{2}	1.21×10^{2}	4.72×10^{2}
10 (L)	2.14×10^{2}	7.35×10^{1}	2.88×10^{2}
10(s)	1.47×10^{2}	5.05×10^{1}	1.98×10^{2}
11(L)	6.39×10^{1}	2.20×10^{1}	8.59×10^{1}

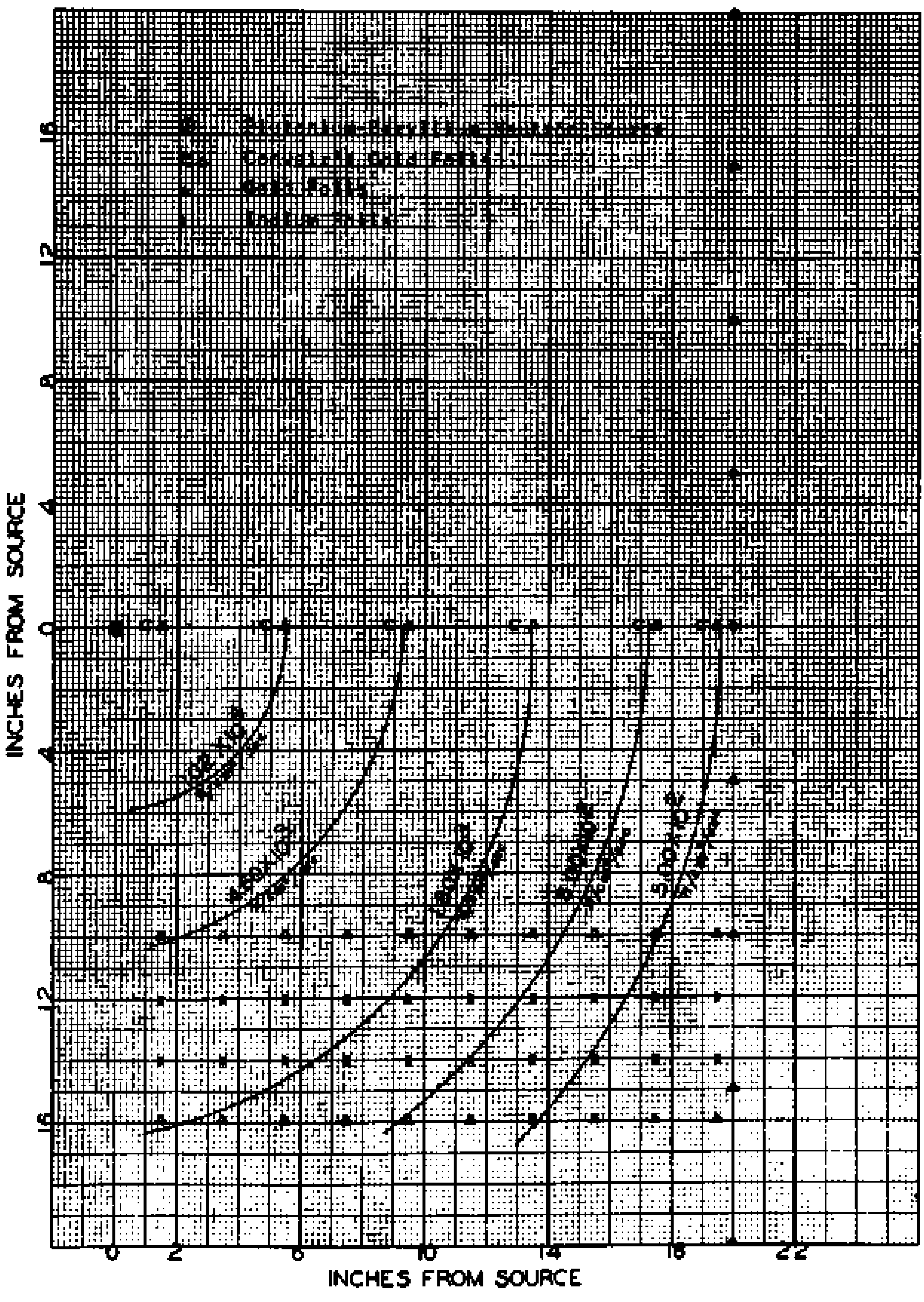
Table 11 Correction of Foils for Thermal Flux Depression of the Convair Foils

Gold Foil	ϕ_{th} n/cm^2/min	F_{th} for gold $=1.012\ \phi F_{th}$	$c\phi_{th}$ n/cm^2/sec	Thermal Flux plus Resonance Flux-Total Flux
501	1.05×10^6	1.062×10^6	1.77×10^4	2.38×10^4
503	4.67×10^5	4.72×10^5	7.87×10^3	1.024×10^4
505	2.07×10^5	2.09×10^5	3.48×10^3	4.52×10^3
507	8.24×10^4	8.32×10^4	1.39×10^3	1.79×10^3
509	4.67×10^4	4.72×10^4	7.87×10^2	8.43×10^2
511	1.71×10^4	1.73×10^4	2.89×10^2	2.89×10^2

Cadmium Covered	Resonance Flux by cadmium absorption	Depression Correction	Resonance ϕ n/cm^2/sec
500	3.6×10^5	3.64×10^5	6.06×10^3
502	1.4×10^5	1.42×10^5	2.38×10^3
504	6.18×10^4	6.25×10^4	1.04×10^3
506	2.38×10^4	2.41×10^4	4.02×10^2
508	3.32×10^3	3.36×10^3	5.6×10^1

Figure 4

Isobaric Plot of the Neutron Flux Distribution Around the Neutron Source



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(2) C. W. Tittle, Slow Neutron Detection by Foils -II *Nucleonics, Vol. 9*, July, 1951, pp. 60-67.

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APPENDIX

Presentation of Original Data Collected

Table 12

Table 12 includes samples of gold foils irradiated ten days. The foils were removed from the reactor at 1555 hours on January 2, 1960. All of the foils in Table 12 were irradiated in the reactor at a position ten inches below the neutron source. Each foil was counted for five minutes in the lead shield and this give an average of the counts per minute per foil. Actual counts refer to counts per minute minus background counts.

Table 12-A

Counting Date: January 2, 1960, 1559 hours

Background Count 6527 for 201 Minutes

= 32 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1(s)	4098	820	1559	788
1(L)	18356	3670	1605	3639
3(s)	2842	568	1611	536
3(L)	12215	2443	1617	2411
4(s)	1785	257	1623	325
4(L)	6568	1314	1629	1282
5(s)	931	186	1635	154
5(L)	4056	811	1641	779
6(s)	547	109	1647	77
6(L)	987	197	1653	165
C-14 (Standard)	8560	1712	1659	1680

Table 12-B

Counting Date: January 3, 1960, 1555 hours

Background Count 554 for 20 Minutes

= 28 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1(s)	3413	683	1555	655
1(L)	12637	2527	1601	2499
3(s)	2306	461	1607	443
3(L)	8395	1679	1613	1651
4(s)	9395	279	1619	251
4(L)	4545	909	1625	881
5(s)	716	143	1631	115
5(L)	3128	626	1637	598
6(s)	473	95	1641	67
6(L)	656	131	1647	103
C-14	8961	1792	1653	1764

Table 12-C

Counting Date: January 4, 1960, 1515 hours

Background Count 1204 for 40 Minutes

= 30 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1(s)	2845	569	1515	539
1(L)	10354	2071	1521	2041
3(s)	1695	339	1527	309
3(L)	6204	1241	1533	1211
4(s)	1050	210	1539	180
4(L)	3363	673	1545	643
5(s)	585	117	1551	87
5(L)	2281	456	1557	426
6(s)	370	74	1603	44
6(L)	581	116	1609	86
C-14	8823	1765	1615	1736

Table 12-D

Counting Date: January 5, 1960, 1010 hours

Background Count 901 for 30 Minutes

= 30 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1(s)	2048	410	1010	380
1(L)	7607	1521	1016	1491
3(s)	1280	256	1022	276
3(L)	5187	1037	1028	1007
4(s)	905	181	1034	151
4(L)	2599	540	1040	510
5(s)	450	90	1046	60
5(L)	1808	362	1052	332
6(s)	328	66	1058	36
6(L)	539	108	1104	78
C-14	9156	1831	1110	1801

Table 12-E

Counting Date: **January 5, 1960, 1507 hours**

Background Count 780 for 25 Minutes

= 31 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1(s)	1811	362	1507	331
1(L)	7178	1436	1513	1405
3(s)	1322	264	1519	233
3(L)	4584	917	1525	886
4(s)	884	177	1531	146
4(L)	2500	500	1537	469
5(s)	447	89	1543	58
5(L)	1762	352	1549	321
6(s)	341	68	1555	37
6(L)	472	94	1601	63
C-14	8900	1780	1607	1749

Table 12-F

Counting Date: January 6, 1960, 1518 hours

Background Count 551 for 20 Minutes

= 28 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1(s)	1672	334	1518	306
1(L)	6078	1216	1524	1188
3(s)	1130	226	1530	198
3(L)	3845	769	1536	741
4(s)	659	132	1542	104
4(L)	2176	435	1548	403
5(s)	376	75	1554	43
5(L)	1345	269	1600	241
6(s)	299	60	1606	32
6(L)	370	74	1612	42
C-14	8735	1747	1618	1719

Table 12-G

Counting Date: January 7, 1960, 0948 hours

Background Count 952 for 30 Minutes

= 32 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1(s)	1281	256	0948	224
1(L)	4635	937	0954	895
3(s)	839	168	1000	136
3(L)	3066	613	1006	581
4(s)	608	122	1012	90
4(L)	1667	333	1018	301
5(s)	363	72	1024	40
5(L)	1069	214	1030	182
6(s)	255	51	1036	19
6(L)	361	72	1042	40
C-14	8311	1662	1048	1630

Table 13

Tables 13A through 13F include samples of indium foils irradiated sixteen hours and twenty minutes. The foils were removed from the reactor at 0850 hours on April 3, 1960. All of the foils in the following tables numbered 13 were irradiated in the reactor at a position twelve inches below the neutron source. The activity of each foil was counted for three minutes in the lead shield and this gives an arithmetic average of the counts per minute per foil. The actual counts refer to counts per minute minus background counts.

Table 13-A

Counting Date: April 3, 1960, 0855 hours

Background Count 898 for 30 Minutes

= 30 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	4187	1396	0855	1366
3	3656	1219	0859	1189
4	2810	937	0903	907
5	2299	766	0907	736
6	1787	596	0911	566
7	1358	453	0915	423
9	920	307	0919	277
11	760	253	0923	223
12	588	196	0927	166
8	267	87	0931	59
C-14	4665	1555	0850	1525

Table 13-B

Counting Date: **April 3, 1960, 0935 hours**

Background Count **898** for **30** Minutes

= **30** Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	2616	872	0935	842
3	2236	745	0939	715
4	1856	619	0943	589
5	1515	505	0947	475
6	1139	380	0951	350
7	861	280	0955	257
9	598	199	0959	167
11	501	157	1003	137
12	390	130	1007	100
8	200	67	1011	37
C-14	4665	1555	0850	1525

Table 13-C

Counting Date: **April 13, 1960, 1015 hours**

Background Count **898** for **30** Minutes

= **30** Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	1608	536	1015	506
3	1535	512	1019	482
4	1185	395	1023	365
5	895	298	1027	268
6	787	262	1031	232
7	469	156	1035	126
9	375	125	1039	95
11	351	117	1043	87
12	277	92	1047	62
8	172	57	1051	27
C-14	4975	1658	1055	1628

Table 13-D

Counting Date: April 3, 1960, 1059 hours

Background Count 898 for 30 Minutes

= 30 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	922	307	1059	277
3	798	266	1103	236
4	621	207	1107	177
5	551	184	1111	154
6	459	153	1115	123
7	337	112	1119	82
9	277	92	1123	62
11	246	82	1127	52
12	191	64	1131	34
8	115	38	1135	8
C-14	4975	1658	1055	1628

Table 13-E

Counting Date: **April 13, 1960, 1139 hours**

Background Count 898 for 30 Minutes

= 30 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	602	201	1139	171
3	468	156	1143	136
4	446	149	1147	119
5	375	125	1151	95
6	305	102	1155	72
7	271	90	1159	60
9	205	68	1203	38
11	202	67	1207	37
12	159	53	1211	23
8	114	38	1215	8
C-14	5200	1733	1219	1703

Table 13-F

Counting Date: April 3, 1960, 1223 hours

Background Count 898 for 30 Minutes

= 30 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	366	122	1223	92
3	310	101	1227	71
4	289	96	1231	66
5	245	82	1235	52
6	229	76	1239	46
7	148	49	1243	19
9	128	43	1247	13
11	125	42	1255	12
12	116	39	1255	9
8	112	37	1259	7
C-14	5200	1733	1219	1703

Table 14

Tables 14A through 14E include samples of indium foils irradiated eighteen hours, thirty minutes; the foils were removed from the reactor at 1120 hours on March 13, 1960. All of the foils in the following tables numbered 14 were irradiated in the reactor at a position fourteen inches below the neutron source. The activity of each foil was counted for three minutes in the lead shield and this gives an arithmetic average of the counts per minute per foil. The actual counts refer to counts per minute minus background counts.

Table 14-A

Counting Date: **March 13, 1960, 1125 hours**

Background Count **1241** for **40** Minutes

= **31** Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	2685	895	1125	864
2	2394	798	1128	767
3	2097	699	1131	668
4	1632	544	1134	513
5	1737	379	1137	348
6	924	308	1140	277
7	735	245	1143	214
9	588	196	1146	165
11	552	184	1149	153
12	270	90	1152	59
C-14	4929	1643	1122	1612

Table 14-B

Counting Date: March 13, 1960, 1155 hours

Background Count 1241 for 40 Minutes

= 31 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	1279	640	1155	609
2	1585	528	1158	497
3	1438	479	1202	448
4	1178	393	1206	362
5	887	296	1210	265
6	701	234	1214	203
7	461	154	1218	123
9	398	133	1222	102
11	366	122	1226	91
12	189	63	1230	32
C-14	4929	1643	1122	1612

Table 14-C

Counting Date: March 13, 1960, 1238 hours

Background Count 1241 for 40 Minutes

= 31 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	1017	339	1238	308
2	980	327	1238	296
3	768	256	1246	225
4	615	205	1250	174
5	565	188	1254	157
6	408	136	1258	105
7	274	91	1302	60
9	287	96	1306	65
11	227	76	1310	45
12	140	47	1314	16
C-14	4866	1622	1234	1591

Table 14-D

Counting Date: March 13, 1960, 1318 hours

Background Count 1241 for 40 Minutes

= 31 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	639	213	1318	182
2	586	195	1322	164
3	539	180	1326	149
4	477	159	1330	128
5	331	110	1334	79
6	247	82	1338	51
7	221	74	1342	43
9	178	59	1346	28
11	180	60	1350	29
12	96	32	1354	1
C-14	4866	1622	1234	1591

Table 14-E

Counting Date: March 13, 1960, 1402 hours

Background Count 1241 for 40 Minutes

= 31 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
1	387	129	1402	98
2	415	138	1406	107
3	356	119	1410	88
4	276	92	1414	61
5	257	86	1418	55
6	168	56	1422	25
7	159	53	1426	22
9	121	40	1430	9
11	117	39	1434	8
12	97	32	1438	1
C-14	4986	1662	1358	1631

Table 15

Tables 15A through 15G include samples of gold foils irradiated eleven days, three hours, ten minutes. The foils were removed from the reactor at 1430 hours on January 16, 1960. All of the foils in the following tables numbered 15 were irradiated in the reactor at a position sixteen inches below the neutron source. The activity of each foil was counted for five minutes in the lead shield and this gives an arithmetic average of the counts per minute per foil. The actual counts refer to counts per minute minus background counts.

Table 15-A

Counting Date: January 16, 1960, 1505 hours

Background Count 918 for 30 Minutes

= 31 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
43(s)	1490	298	1505	267
63(L)	5665	1133	1516	1102
33(s)	1171	234	1527	203
61(L)	4003	801	1538	770
30(s)	774	155	1549	124
60(L)	2183	437	1600	406
31(s)	485	97	1611	66
59(L)	1401	280	1622	249
34(s)	301	60	1633	29
58(L)	395	79	1644	48
C-14	7831	1566	1454	1535

Table 15-B

Counting Date: January 17, 1960, 1045 hours

Background Count 1198 for 40 Minutes

= 30 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
43(s)	1213	243	1045	213
63(L)	4576	916	1056	886
33(s)	929	186	1107	156
61(L)	3218	644	1118	614
30(s)	643	129	1129	99
60(L)	1848	370	1140	340
31(s)	421	84	1151	54
59(L)	1198	240	1202	260
34(s)	273	55	1213	25
58(L)	389	78	1224	48
C-14	8199	1640	1039	1610

Table 15-C

Counting Date: January 18, 1960, 1600 hours

Background Count 912 for 30 Minutes

= 30 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
43(s)	937	187	1600	157
63(L)	3331	666	1606	636
33(s)	742	148	1612	118
61(L)	2346	469	1618	439
30(s)	509	102	1624	72
60(L)	1275	255	1630	225
31(s)	365	73	1636	43
59(L)	949	190	1642	160
34(s)	257	51	1648	21
58(L)	338	68	1654	38
C-14	7969	1594	1554	1564

Table 15-D

Counting Date: **January 19, 1960, 0904 hours**

Background Count 485 for 20 Minutes

= 25 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
43(s)	597	149	0904	124
63(L)	2039	510	0909	485
33(s)	597	119	0914	94
61(L)	1940	388	0920	363
30(s)	437	87	0926	62
60(L)	1181	236	0932	211
31(s)	330	66	0938	41
59(L)	791	158	0944	133
34(s)	231	46	0950	21
58(L)	285	57	0956	330
C-14	8546	1709	1003	1684

Table 15-E

Counting Date: January 19, 1960, 1718 hours

Background Count 1495 for 50 Minutes

= 30 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
43(s)	778	156	1718	126
63(L)	2830	566	1724	536
33(s)	635	127	1730	97
61(L)	1680	350	1736	330
30(s)	430	86	1742	56
60(L)	1065	213	1748	183
31(s)	305	61	1754	31
59(L)	730	146	1800	116
34(s)	230	46	1806	16
58(L)	265	53	1812	23
C-14	8685	1737	1818	1707

Table 15-F

Counting Date: January 20, 1960, 1508 hours

Background Count 950 for 30 Minutes

= 32 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
43(s)	532	106	1508	74
63(L)	1768	354	1514	322
33(s)	475	95	1520	63
61(L)	1309	262	1526	230
30(s)	371	74	1532	42
60(L)	869	174	1538	142
31(s)	279	56	1544	24
59(L)	625	125	1550	93
34(s)	218	44	1556	12
58(L)	235	47	1602	15
C-14	7020	1404	1451	1372

Table 15-G

Counting Date: **January 22, 1960, 1250 hours**

Background Count **1368** for **40** Minutes

= **34** Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
43(s)	460	92	1250	58
63(L)	1365	273	1300	239
33(s)	370	74	1305	40
61(L)	970	194	1310	160
30(s)	295	59	1315	25
60(L)	575	115	1320	81
31(s)	240	48	1325	14
59(L)	470	94	1330	60
34(s)	170	34	1335	1
51(L)	210	42	1340	8
C-14	8728	1746	1244	1712

Table 16

Tables 16A through 16F include samples of gold foils irradiated ten days, eighteen hours, forty minutes. The foils were removed from the reactor at 0940 hours on February 20, 1960. The foils in the following tables 16 were irradiated in the reactor at a location vertical to and twenty inches from the neutron source. The activity of each foil was counted for four minutes in the lead shield and this gives an arithmetic average of the counts per minute per foil. The actual counts refer to counts per minute minus background counts.

Table 16-A

Counting Date: **February 20, 1960, 0944 hours**

Background Count **812** for **20** Minutes

= **27** Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
7(L)	278	70	0944	43
7(s)	210	53	0949	26
8(L)	805	201	0954	174
8(s)	416	104	0959	77
9(L)	1720	430	1004	403
9(s)	426	107	1009	80
10(L)	1050	263	1014	236
10(s)	238	50	1019	33
11(L)	406	102	1024	75
C-14	6568	1642	1029	1615

Table 16-B

Counting Date: **February 20, 1960, 1558 hours**

Background Count 534 for 20 Minutes

= 27 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
7(L)	230	56	1558	29
7(s)	215	54	1605	27
8(L)	826	207	1608	180
8(s)	392	98	1613	71
9(L)	1468	367	1618	340
9(s)	380	95	1623	68
10(L)	959	240	1628	213
10(s)	249	62	1633	35
11(L)	419	105	1638	78
C-14	6400	1600	1643	1573

Table 16-C

Counting Date: February 21, 1960, 1241 hours

Background Count 877 for 30 Minutes

= 29 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
7(L)	259	65	1241	36
7(s)	199	50	1246	21
8(L)	677	169	1251	140
8(s)	345	86	1256	57
9(L)	1205	301	1301	272
9(s)	341	85	1306	56
10(L)	840	210	1311	181
10(s)	201	50	1316	21
11(L)	339	85	1321	56
C-14	6839	1710	1326	1681

Table 16-D

Counting Date: **February 23, 1960, 0851 hours**

Background Count 863 for 30 Minutes

= 29 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
7(L)	168	42	0851	13
7(s)	140	35	0856	6
8(L)	464	116	0902	87
8(s)	208	52	0908	23
9(L)	716	179	0914	150
9(s)	240	60	0920	31
10(L)	536	134	0926	105
10(s)	188	47	0932	18
11(L)	272	68	0938	39
C-14	5568	1392	0944	1363

Table 16-E

Counting Date: February 24, 1960, 1536 hours

Background Count 540 for 20 Minutes

= 27 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
7(L)	151	38	1536	11
7(s)	150	38	1541	11
8(L)	345	86	1546	59
8(s)	256	64	1551	37
9(L)	551	138	1556	111
9(s)	207	52	1601	25
10(L)	455	114	1606	87
10(s)	159	40	1611	13
11(L)	196	49	1616	22
C-14	6907	1752	1621	1725

Table 16-F

Counting Date: February 25, 1960, 1614 hours

Background Count 1163 for 40 Minutes

= 29 Counts per Minute

Sample Number	Total Counts	Counts per Minute	Time of Count	Actual Counts per Minute
7(L)	141	35	1614	6
7(s)	116	29	1619	0
8(L)	256	64	1623	35
8(s)	200	50	1627	21
9(L)	404	101	1631	72
9(s)	180	45	1635	16
10(L)	352	88	1639	59
10(s)	148	37	1643	8
11(L)	192	48	1647	19
C-14	6676	1669	1651	16