BOOK41R

Notes:
"U-Teflon 1966" on spine

Blank pages: inside front cover sheets, 1-4, 6, 8-10, 12, 14, 16, 18, 20, 24, 26, 28, 30, 38-40, 42-50, 52, 58-60, 62, 68, 70, 74, 78, 79, 112, 114, 116-308, inside back cover sheets

-page 9 has 1 (8.5x11) sheet taped
-page 18 has 1 (8.5x11) sheet taped
-page 31 has 1 graph glued
-page 36 has 2 graphs glued
-page 37 has 1 sheet of paper glued
-page 72 has 1 sheet of paper glued
-page 96 has 1 graph sheet glued/taped
-page 97 has 1 graph sheet glued
-page 101 has 1 graph sheet glued
-page 110 has 1 sheet taped

Scanned by:
Sheila Finch
RSICC /Oak Ridge National Lab.
August 10, 1999

SHAW'S

PIONEERS SINCE 1831

Account Book

No. S 149

NO UNITS

Journal . . . . . .

Ledger, Single Entry . .

Ledger, Double Entry .

Record Ruled (27 Lines)

Made in 150, and 300 Pages

MADE IN U. S. A.

TO REORDER, SPECIFY NUMBER, RULING AND THICKNESS INDICATED ON BACKBONE OF THIS BOOK.

September 23 1966 — Completed checking experiments at 37.5% and 4.89%.

Oct 7, — Calculations (S_n) completed.

Oct 10-13 — Int. Conf on Fast Critical Experiments, ANL

Talked with C. E COHN Re Computers in Crit Exp.
Reactivity meas and Rod Calibration using
digital es de similer to RTF code (Lockheed)
Noise analysis, various to mean etc.
Ion chamber current converted to FM signal
to improve statistics of counting.

Talked with E Bennett re: Neutron energy spectra
with H recoil prop; counters.

Oct 14 — Zeller - discussed H recoil prop counter; referred me
to Verbinski who will loan us one which
he had made for testing so called Mark O
0.002" anode 55, 17/16" cathode brass
150 cm Hg CH_4

Volts	A
2000	1.6
2500	3.6
3000	16.
3500	86.
4000	530.

counter not designed but built for testing.

17 — Verbinski - counter + copies of response to neutrons on polaroid
camera photo of PHS data. & Zeller's amp. curve.

Nov 31, 1966

After discussions with ADC, looked into low moderation experiments with layers of C, CF_2 and CH_2 in fully enriched metal systems. Ideal situation would be homogeneous CH_2 (paraffin) - UO_2 (or UO_3 or UF_4) blocks but cost may be prohibitive, est. to be 40-50 k$. JTT has considerable supplies of 7/8 X 5 X 10 metal pieces. Layers of 7/8 X 10 x 10 could be used. (2ea 7/8 x 5 x 10 on split table apparatus)

A "Gedanken" experiment, calculated using DTF code to compare ke homogeneous to k heterogeneous of 7/8 in. layers of C, CF_2 and CH_2 in 7/8 layers of U metal.

Metal 7/8 in = .875 = 2.22 cm

10 in x 10 in = 25.4 x 25.4 cm

NSE 8, 575 $k_\infty = 7.73$ cm $\lambda_s = 2.15$

$d = 35.9$ cm $r = 17.95$ cm $\lambda_c = 2.10$ cm

$$B^2 = \frac{\pi^2}{(11.93)^2} + \frac{2.405^2}{20.05^2} = .26334^2 + .11995^2$$

$$B^2 = .069348 + .014388 = .083736$$

For Sphere $B = .2894$ $\tilde{R} = 10.86$ $R = 8.71$ cm

$\frac{4}{3}\pi R^3 d = 18.74 = 51.87$ kg U @ 93% = 48.34 kg

$$B_x^2 = B_y^2 = \left(\frac{\pi}{29.6}\right)^2 = .10614^2 = 0.011266$$

$B_z^2 = .061204$ $B_z = .2474$ $\tilde{Z} = 12.70$

Vol = 5483.86 ^{235}U x 17.466 = 95.78 kg ^{235}U ← $Z = 8.50$ cm $\frac{Z}{2} = 4.25$ cm

$\frac{8.5}{2.22} = 3.83$ Layers

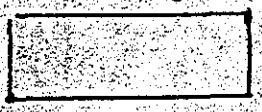
4.440 cm $k = .9934$

4.218 $k = .9663$

93.470

Machined Slabs, 18.72 g/cc 235 U

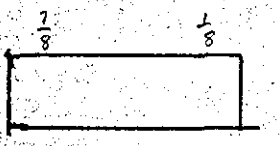
Size (Thickness) 7/8 and 1/8 | 1/2 and 1/4 | Length x Width



Amt. 10 ea.

2 ea.

5" x 10"



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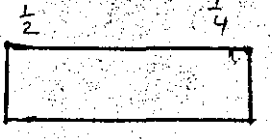
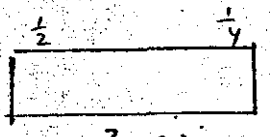


2 ea.

3" x 10"

4 ea.



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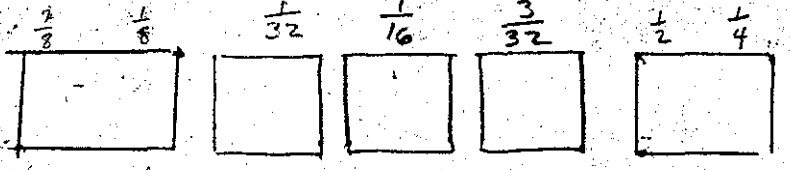
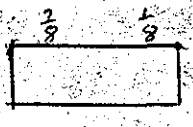
2" x 10"



4 ea. 2 ea 25 ea 25 ea 4 ea.

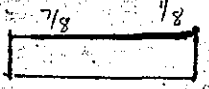
5" x 5"



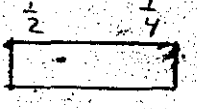
4 ea.

4 ea.

2" x 5"

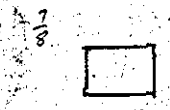


2 ea



2 ea.

1" x 5"



4 ea.

1" x 1"

Metal 93.4 wt% ^{235}U × 18.74 (density) = 17.50 g $^{235}U/cm^3$

6.6 wt% ^{238}U = 1.24 g $^{238}U/cm^3$

$$\frac{17.50 \times .60228 \times 10^{24}}{235.05} = 0.04484 \times 10^{24}$$

$$\frac{1.24 \times .60228}{238.06} = 0.00314 \times 10^{24}$$

Graphite 1.7 g/cm^3

$$\frac{1.7 \times .60228}{12} = 0.08532 \times 10^{24}$$

CF_2 2.17 g/cm^3

C = .24 × 2.17 = .5208 F = .76 × 2.17 = 1.6492

$$C = \frac{.5208 \times .60225}{12} = 0.02614 \times 10^{24}$$

$$F = \frac{1.6492 \times .60225}{19} = 0.05228 \times 10^{24}$$

CH_2 0.92 g/cm H = $\frac{1}{7} \times .92 = .1314$

C .7886

$$C = \frac{.7886 \times .60228}{12} = 0.03957 \times 10^{24}$$

$$H = \frac{1314 \times .60228}{1} \quad .07914 \times 10^{24}$$

Amos

OTF Calculations S_4 Approx.

$B_x^2 = B_y^2 = 0.011266$

Half Slab Calculation in Z direction

Mesh Spacing 0.222 cm

Case A1 20 Mesh Spaces 4.44 cm half thickness

HOMOGENEOUS $^{235}U = 4.484 \quad E-2$

$^{238}U = 3.140 \quad E-3$

A2 also 19 Mesh Spaces 4.218 cm half thickness

CASE B REGION 1, 5 Mesh Spaces (1.11 cm)

Material 1 $^{235}U = 4.484 \quad E-2$

$^{238}U = 3.140 \quad E-3$

Region 2, 10 Mesh Spaces (2.22 cm)

Material 2 $C = 8.532 \quad E-2$

Region 3, 10 Mesh Spaces (2.22 cm)

Mat'l 1

Region 4, 10 Mesh Spaces (2.22 cm)

Mat'l 2

Region 5, 5 Mesh Spaces (1.11 cm)

Mat'l 1

CASE C HOMOGENEOUS 40 Mesh Spaces

(8.88 cm) $^{235}U = 2.242 \quad E-2$

$^{238}U = 1.570 \quad E-3$

$C = 4.266 \quad E-2$

CASE D (Same as B except for Mat'l 2) CF_2

Material 2D = C = 2.614 E-02

F = 5.228 E-02

CASE E HOMOGENEOUS

^{235}U	2.242	E-02
^{238}U	1.570	E-03
C	1.307	E-02
F	2.614	E-02

CASE F (Same as B except for Mat'l 2) CH_2

Mat'l 2F C = 3.957 E-02

H = 7.914 E-02

CASE G HOMOGENEOUS

^{235}U	2.2420	E-02
^{238}U	1.5700	E-03
C	1.9785	E-02
H	3.9570	E-02

1:1 UCF_6-CH_2 Blocks

(actual vol ~1.5% greater) → 27661 cm^3

12 × 12 × 12 (−) 1688 Blocks (vs 1728)

$B^2 = 3 \times \frac{\pi^2}{(30.5+5.0)^2} = 3 \times (0.08885)^2 = 2.3496 \times 10^{-2}$ $\quad S = 2.5$

$\tilde{R} = \frac{\pi}{B} = 20.49 = 20.5$ $\quad B = 1.533 \times 10^{-1}$

$S = 2.5$

$R = 18.0$ cm

			Atom Density $\times 10^{-24}$
M_c = 41.2 kg	^{235}U	$\rightarrow 105.57 \times 10^{24} / 27661 =$	3.8166 E-03
2.0 kg	^{238}U	$5.06 \times 10^{24} / 27661 =$	1.829 E-04
Total U = 3.9995 E-03			
	C		(3.9945) E-03
	F (x6)		23.997 E-03

$C H_{1.92}$ blocks density ? 0.91

2.09 gm H / 16.387 = .12754 $\quad$ ~~7.685 E-02~~ / 2

15.11 − 2.09 = 13.02 gm C = .79453 $\quad$ (3.9844) E-02 / 2

12.01 $\quad$ 16.387 $\quad$ Total C $\quad$ ~~4.3844 E-02~~

Block volumes are ~1½% greater than nom —

Assume actual stacking densities are less by 0.5%

∴ All densities above reduced 2%, use 98% of theoretical

^{235}U	3.7403	E-03
^{238}U	1.7920	E-04
C	~~2.3444~~ 2.3444	E-02
F	2.3517	E-02
H	~~3.7639~~ 3.7639	E-02

$H/U^{235} = 10.063$

$UCF_6 - CH_2$ (29.8)

16.582
16.632
.07

1.015
1.005

16.584
16.632
.09
16.70
16.387

$1.0065^2 = 1.019 = \frac{16.7}{16.387}$

		ω^+ (g)	$\frac{1}{16.70^2} = 0.05988$	$\times .00228$ / A^+						
235	U	15.38	.9210	2.3598	E-03		1.5732	E-03	1.1799	E-03
238	U	36.18	2.1664	5.4809	E-03		3.6540	E-03	2.7404	E-03
	U	51.56	3.0874							
	F	24.69	1.4784	4.6863	E-02		3.1242	E-02	2.3431	E-02
	C	2.64	0.1581	0.7928	E-02		.5285			
	O	0.08	.0048							
			C T.T	4.7[illegible]4	E-02					
	AL	0.56	.0335							
poly.	C	13.02	.7796	3.9096	E-02		1.3032			
poly.	H	2.09	.1251	7.5345	E-02		2.5115	E-02	3.7672	E-02
						C TOT	1.8317	E-02	2.3512	E-02
						$\frac{H}{X}$ =	15.9%		31.93	

B^2 for $16 \times 16 \times 16 + 121$

$16 \times 16 = 256$

Assume sig = $1.0065 \times 16 = 16.104$

$\times 16.5 = 16.607$

$\times 14 = 14.091$

$\times 13 = 13.085$

$\times 13\frac{1}{2} = 13.588$

for $14 \times 13 \times 13 + 98$

$\times 2.5\sqrt{}$ | $+5.0\sqrt{}$ | $(14 \times 13) = 182$

40.904	45.90		
42.182	47.18		
35.79	40.79		
33.24	38.24		
34.51	39.51		

$B^2 = \frac{\pi^2}{45.90}$ | 6.844×10^{-2} | 4.684×10^{-3}

$B^2 = \left(\frac{\pi}{40.79}\right)^2$ | 7.701 | 5.931

$\frac{\pi^2}{47.18}$ | | 4.684 | | $\frac{\pi}{38.24}$ | 8.215 | 6.749

6.659 | 4.434 | $\frac{\pi}{39.51}$ | 7.951 | 6.322

B^2 | .013.802 $\times 10^{-3}$ | | 19.002 $\times 10^{-3}$

B | .1175 | | B | 1.379 $\times 10^{-1}$

$\tilde{R}$ | 26.74 | | $\tilde{R}$ | 22.78

1:2 $UCF_6 - CH_2$ Blocks (95%)

	.66667 ×	^{235}U	3.7403	E-03	2.4935 E-03
		^{238}U	1.7920	E-04	1.1947 E-04
				2.6130	
	× 98	C	3.9995	E-03	
		F	2.3517	E-02	1.5678 E-02
				2.6032	
k	1.2333 × 98	C	1.9922	E-02	
1.015 092	16.8 cm	H	3.7437	E-02	5.0185 E-02
1.005 183	16.6	Total C			2.7615 E-02

2:1 $UCF_6 - CH_2$ (29.8%)

^{235}	U	1.5732	E-03
^{238}	U	3.6540	E-03
	F	3.1242	E-02
	H	2.5115	E-02
	C	1.8317	E-02

$\frac{H}{X} = 15.96$

Buckling set to 1.3802×10^{-2}

Sphere Radius = 24.24

k	R (cm)
.903 768	24.24
.902 138	24.00

Assum $\lambda_c = 2.5$ cm

1:1 $UCF_6 - CH_2$ (29.8%)

^{235}	U	1.1799	E-03
^{238}	U	2.7404	E-03
	F	2.3431	E-02
	H	3.7672	E-02
	C	2.3512	E-02

Buckling 1.9002×10^{-2}

Sphere Rad = 20.28

k	R
.923 481	[illegible]
922 495	22.02

Interpretation of NSE 8 588 (Dec 1960)

~~Hansen Wood Byers & Osborne Critical Masses~~

Hansen Wood & Ware, Crit Masses of Enriched Uranium Cylinders with Multiple Reflectors.

H:U = 2.59 polyethylene 15 in o.d x 0.125 in., ~6.5 kg each

100% Ni end reflectors C.M. = 76.3 kg U

SS " " 79.6 "

Fe " " 82.0 "

H:U = 4.88 polyethylene 15 in o.d.

100% Ni end Refl. CM = 59.4 kg U

SS " " 62.0 "

Fe " " 62.5 "

H:U = 0 Hansen Paxton & Wood 15.0 in o.d 3.25 in high CM = 165.7 kg U

$\frac{3.25}{.125} = 26$ plates ~~26~~ 6.373 kg/plate

Stated plates were 0.120 weighing ~6.5 kg

$\frac{3.25}{.12} = 27.08$ plates $\times 6.5 = 176.0$ kg

or $\frac{165.7}{27.08} = 6.123$ kg/plate

Something is not understood.

15 in o.d x 0.125 in $\equiv \pi \frac{d^2}{4} L = 22,089$ in^3 → 361.97 cm^3

$6.5/361.97 = 17.96$ g/cm^3

93.2 wt% ^{235}U = 16.74 (4.289 − 02) 10^{-24}

^{238}U 1.22 .309

4.598 − 02

godiva mass corrected to 17.96 density = $\left(\frac{18.8}{17.96}\right)^2 = 1.0958 \times 48i$

$= 52.6$

H:U = 2.59 $\frac{76.3}{6.5} = 11.74$ layers, $\frac{79.6}{6.5} = 12.25$, $\frac{82.0}{6.5} = 12.62$

H:U = 4.88 $\frac{59.4}{} = 9.14$ $\frac{62.0}{} = 9.54$ $\frac{62.5}{} = 9.62$

$2.59 \times 4.598 = 11.91\text{-}02$ Poly ethylene H density = 7.90 - 02

$9.88 \times 4.598 = 22.44\text{-}02$ → 1.51 cm CH_2/cm U

→ 2.84 cm CH_2/cm U

.125 in U = .3175 × 1.51 = .479 cm (.189 in)

× 2.84 = .902 cm (.355 in)

2.1 one end only

ESTIMATE REFLECTOR SAVINGS ≈ 1.5 cm

Ni	11.74 × (.3175 + .479)	= 9.35 cm	11.50 + (δ = 2.10, 2δ = 4.2)
SS	12.25 × .7965	= 9.76 "	
Fe	12.62	= 10.05 "	

15.0 → 38.1 cm

Ni	9.14 (.3175 + .902)	= 11.15 cm	13.30 + (δ = 2.10, 2δ = 4.2)
SS	9.54 × 1.2195	= 11.63	
Fe	9.62	= 11.73	

$B^2 = \frac{2.405^2}{(19.05+2.1)^2} + \frac{\pi^2}{15.7^2} = .1137^2 + .2001^2 = .05293$

21.15

.01293

.04004

B = .2301

$\tilde{R} = 13.65 \frac{2.15}{11.5}$

$B^2 = \frac{\pi^2}{17.52^2} = .01293 + .1795^2 = .04515$

.03222

B = .2125

$\tilde{R} = 14.78 \frac{2.15}{12.63}$

$\frac{4\pi R^3}{3} = 6.3706\,\ell \times 17.96 \times \frac{.3175}{.7965} = 45.61$ kg U @ 2.59

7.159

vol frac .3986

4.682

$= 8.439\,\ell \times 17.96 \times \frac{.3179}{1.2195} = 39.5$ kg U

vol frac .261

~ Jan 20-24.

ANISN Calculations of UCF_6 (37) show flux in groups 10 → 7 approx. ∝ to E and not 1/E as H.R x sections are weighted calculations were made for estimating the errors involved in using 1/E weighting for 1/v x sections instead of constant flux or flux prop. to E.

$$\langle\sigma(1/v)\rangle_c/\sigma(E_1) = 2\left[(E_2/E_1)^{1/2} - 1\right]\Big/\left[(E_2/E_1) - 1\right] \qquad \text{const } \phi$$
$$= .714 \quad \text{for } E_2/E_1 = 3.24$$

$$\langle\sigma(1/v)\rangle_{1/E}/\sigma(E_1) = 2\left[1 - (E_2/E_1)^{-1/2}\right]\Big/\ln(E_2/E_1) \qquad \phi \propto \frac{1}{E}$$
$$= .756 \quad \text{for } E_2/E_1 = 3.24$$

$$\langle\sigma(1/v)\rangle_E/\sigma(E_1) = 4\left[(E_2/E_1)^{3/2} - 1\right]\Big/\left[(E_2/E_1)^2 - 1\right] \qquad \phi \propto E$$
$$= .678 \quad \text{for } E_2/E_1 = 3.24$$

Jan 31

ANISN Calc. of UCF_6 with Rew F x section and $\sigma_p(238) \simeq 89$ and $\sigma_p(235) = 54$ using mixtures of 238 - 2R - 3R and 235 3R-4R rather than original H.R x sections. k_{eff} = 1.037 668 S_4 43.5

	− .001 810	S_8 corr
	1.035 858	
	− .008 61	13.0 pad
	1.027 248	
	+ .005 93	H correct

Best value is now 1.033 178

Errors due to incorrect flux weighting may be as large as 20% of the absorption in groups 9 − 10 − 11 − 12. and perhaps 10% in groups 5 6 7 8.

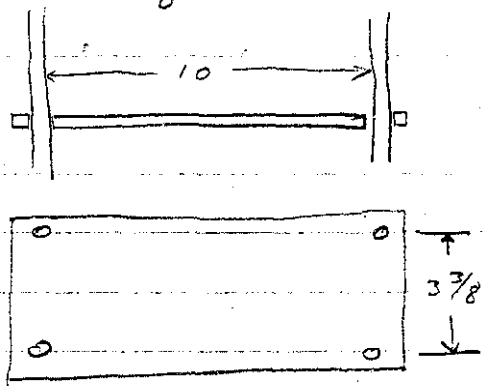
Feb 2

Design of supports for low mod exp.

10×10 slab $\rightarrow$ 3.32 in ht $\rightarrow$ 95.1 kg ^{235}U

$5 \times 10 \times 3.32 \sim 50$ kg

Use "tinkertoy" supports with 1/16 x 5 x 10 base plate suggested by Tunnel.



Feb 7 Calculation concerned with safety of stacking - $10 \times 10 \times 3.32$ crit JTM

$5 \times 5 \times 9.13$ crit JTM

with 1" plexiglas $10 \times 10 \times 2.32$ crit JTM

Assumed reflector savings = 0.5 cm

Buckling for 2.1 cm	B^2	exchange dist	B^2
5"	.03456	$10 \times 10 \times 3.33$	.08437
10"	.01126	$5 \times 5 \times 9.13$	.08228
3.32"	.06185	$5 \times 10 \times 4.32$	.08854
9.13"	.01316	$= 5 \times 10 \times 3.32$ plus reflector.	
4.32"	.04272		

Conclusion — no problem with bare stacking, $5 \times 10 \times 3.32$

August 23, 1967

Idea! Suggestion!

Measurement of ^{238}U resonance integrals as a function of σ_s, scattering cross-section per ^{238}U atom. Use a poisoned flux trap for the 1/E spectrum source with a central region which will contain solutions or mixtures of ^{238}U with scattering materials. Some boron or cadmium or suitable poison could be added to the uranium to reduce thermal capture. eliminate thermal capture in uranium

Range of interest for σ_s values would be 100 to 100 000

For $UO_2(NO_3)_2$ dilutions 935 g/liter corresponds to $H:^{238}U$ ratio of 20 and $\sigma_s = 400$ -- Impossible

374 g/liter → 62 → 1240 b

3.74 g/liter → 7000 → 139 000b

> primary range of interest

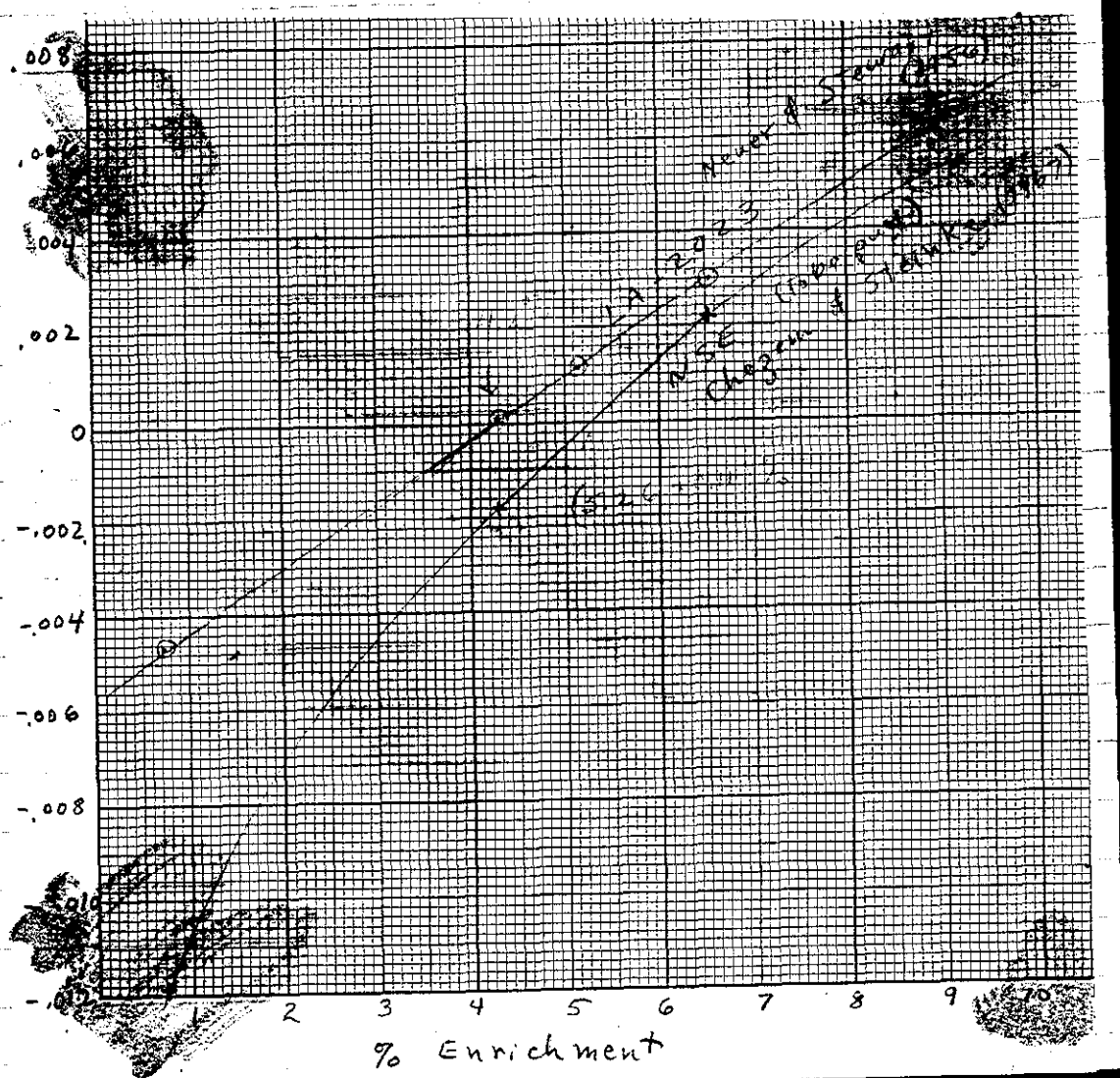
Nov 21, 1967

Fast source reactor for k_∞ measurements on unmoderated and low values of moderation for uranium compounds at various enrichments.

One problem is

Enrichment for U metal for which $k_\infty = 1$

Exponential experiments should be confirmed!



A wide variety of enrichments and moderation values for many chemical compounds could be investigated.

Determine enrichment for which $k_{\infty} = 1$

1. for uranium compounds i.e. U metal, UF_6 UO_2, UC, UCF_6, U_3O_8 and other compounds and <u>alloys</u>.
2. for uranium compounds with various amounts of hydrogen and other moderators
3. for uranium compound with various diluents having high absorption cross section
4. for various combinations of 1, 2 & 3.
5. for various configurations for fast reactors.

A simplified description of the theory of the k_∞ measurement

For the reactor with a central void at delayed critical

$$k_1 = \frac{\text{production}}{\text{absorption + leakage}} = \frac{P_r}{A_r + L_r} \equiv 1$$

$$P_r = A_r + L_r$$

With sample having $k_\infty \neq 1$ in general in void

$$k_\infty = P_s / A_s$$

$$k_2 = \frac{\text{production (reactor + sample)}}{\text{absorption (reactor + sample) + leakage (reactor + sample)}}$$

$$= \frac{P_r + P_s}{A_r + L_r + A_s + L_s}$$

$$\Delta k = k_2 - k_1 = \frac{P_r + P_s - (A_r + L_r + A_s + L_s)}{A_r + L_r + A_s + L_s}$$

$$= \frac{P_s - A_s - L_s}{P_r + A_s + L_s} = \frac{P_s/A_s - 1 - L_s/A_s}{P_r/A_s + 1 + L_s/A_s}$$

$$= \frac{k_\infty - 1 - L_s/A_s}{\frac{P_r}{P_s} k_\infty + 1 + L_s/A_s}$$

$$L_s/A_s \ll 1 \ll P_r k_\infty / P_s$$

$$\Delta k \approx \frac{k_\infty - 1 - L_s/A_s}{\frac{P_r}{P_s} k_\infty + 1}$$

The leakage L_s can be made small by flux flattening techniques, or can be evaluated from flux traverse.

If typically, 1% of the fissions occur in the sample then the minimum detectable $(k_\infty - 1)$ would be (100 x) the minimum reactivity change detectable. The latter can be reduced to ≈ 0.2 cent. $(k_\infty - 1)_{min}$ = 20 cent = 0.001_3. $k_\infty = 1.0 \pm 0.001_3$, for $k_\infty \neq 1$, the errors will be larger because of the difficulty in measuring reactivities with precision. (Also the ± 0.2 cent can be reduced near critical with sample oscillation techniques.)

Suggested calculations:

B. Spherical shells of

$r_1 = 9$ cm 1. void and sample, k_1 and k_2, (10 mesh

$r_2 = 12$ cm 2. buffer region of sample (10 mesh

$r_3 = 14.5$ cm 4. enriched uranium metal shell (10 mesh

$r_4 = 19.5$ cm 5. steel reflector to reduce leakage (10 mesh

20.5 cm
20.5 cm
21.0 cm and for control region

Calculate k_1 and k_2 for best guess of enrichment of metal for $k_\infty = 1$
note flux in sample region, flatness & spectrum
note flux in buffer region, " " "

A. k_∞ calculations for various enrichments to find k_∞ (calc) = 1. for U-metal and other compounds, alloys, etc.

ESTIMATE OF CRITICAL SHELL THICKNESS.

Critical spherical shell thickness will be greater than 1/2 the thickness of an ∞ critical slab.

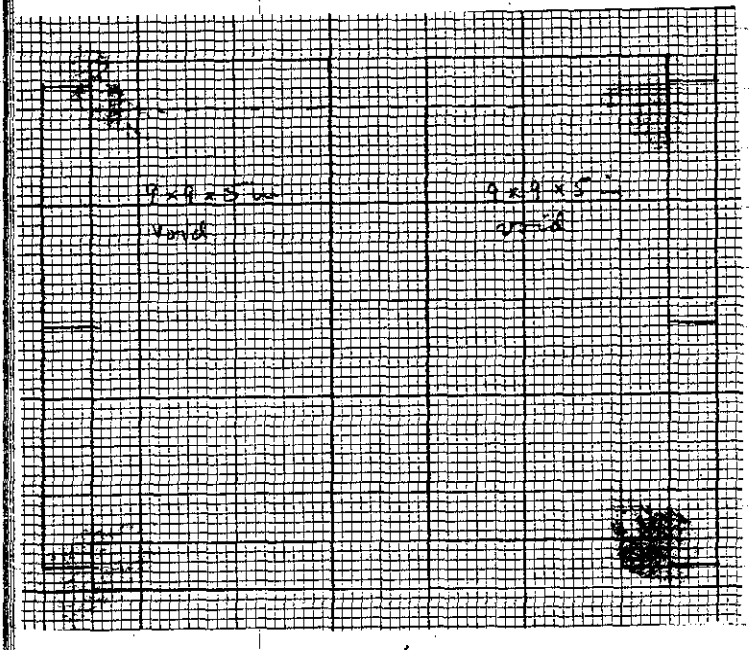
t (∞ slab) = 6.66 cm

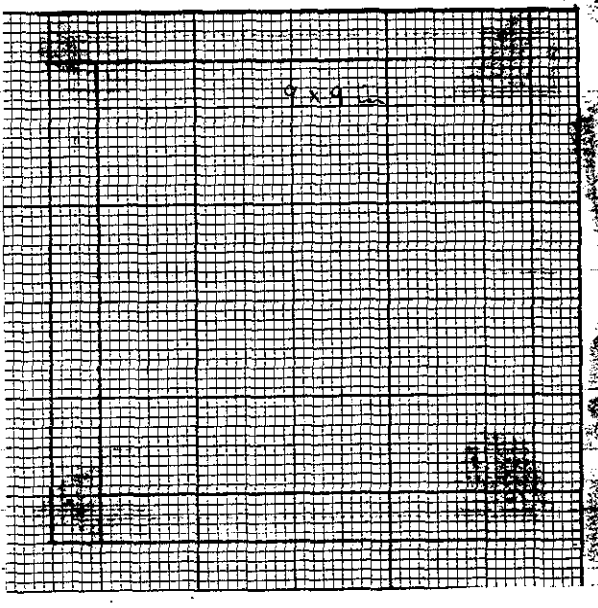
$\therefore t/2$ = 3.33 cm

$\therefore$ 1" thick spherical shell can be made critical with suitable reflector ~~thickness~~. ∞ Steel reflector savings $\approx$ 1.5 – 1.8 cm (∞ H_2O ~ 2.1 cm)

It should be possible to construct a rectangular, hollow parallelopiped from the uranium slabs, 5x10 and 5x5 having various thicknesses. Inside dimensions 9x9x10 outside dimensions 11x11x12 except for some corners missing, using 9 ea 3x3 ☐ al tubing 5" long on each half of assembly. Buffer region could be 3", or 2 7/8" if placed in Tubing. Void and sample could be 2 7/8 x 2 7/8 x 4" long. 12 ea 1x5x10 uranium slabs needed.

10 ea	7/8 x 5x10	Other slabs available
10 ea	1/8 x 5x10	4 ea 1/2 x 5x5
2 ea	7/8 x 3x10	2 ea {7/8 x 5x5} 2 ea {1/8 x 5x5}
2 ea	7/8 x 2x10	2 ea 1/2 x 5x10
2 ea	1/8 x 3x10	2 ea {1/2 x 3x10, 2x10}
2 ea	1/8 1/4 x 2x10	





Keno calculations of this geometry surrounded by various steel reflectors would be appropriate to guide in the construction or assembly of a critical experiment. Keno code must be changed to get flux output after it will be useful!!

An alternate would be a $9\frac{1}{8} \times 9\frac{1}{8} \times 10$ surrounded by 7/8" enriched Uranium metal with more steel for reflector to achieve criticality. O D would be $10\frac{7}{8} \times 10\frac{7}{8} \times 11\frac{3}{4}$, except for some missing corners. (7/8" → 2.22 cm and reflector savings will have to be greater than 1.1 if crit thickness is > 3.3 cm.)
(Keno calculations are also possible)

Nov 21, 1967
Drafted

Nov 24, 1. Depleted UCF_6 blocks available for filler.

2. Anisn 58 calc. for 6 region reactor.

Region		Sample 1	Buffer 2	Filter 3	Driver 4	Reflector 5	Control 6
Outer Rad. (cm)		5.0	12.5	13.5	16.0	18.5	21.0
A		VOID	VOID	VOID	1	2	VOID
B		"	"	"	"	"	2
C		"	4	"	"	"	"
D		4	"	"	"	"	"
E		VOID	"	2	"	"	"
F		4	"	"	"	"	"
G		VOID	4	3	"	"	"
H		4	4	"	"	"	"
I		VOID	"	4	"	"	"
J		4	"	"	"	"	"

Mat 1 $235\text{-}1R = 4.463 E\text{-}02$
$238\text{-}1R = 0.324 E\text{-}02$

Mat'l 2 $Fe = 8.476 E\text{-}02$

3 $235\_1R = 0.0342 E\text{-}02$
$238\_1R = 4.7226 E\text{-}02$

Mat'l 4 $U235\text{-}1R = 0.2356 E\text{-}02$
$238\text{-}1R = 4.5238 E\text{-}02$

March 25, 68 Problem of $k_\infty = 1$ for UF_6

Exponential column measurements could be made in existing UF_6 cylinders as a function of enrichment to determine when $B_m^2 = 0$. This concept was discussed with C. Newton & Q. Mallett but it is a large undertaking -- not enough pressure yet, but the work needs to be done.

An A-30 shipping container, modified to include several diametral radii restraint tubes and one axial tube, should be filled with 4.5 wt% UF_6. The Radial flux $\varphi(r) = A J_0(B_r, r)$ and the z flux $\varphi(z) = C e^{-\gamma z}$ away from boundaries will define

$$B_m^2 = B_r^2 - \gamma^2$$

If $B_m^2 = 0$, $k_\infty = 1$

$B_m^2 > 0$ $k_\infty > 1$

$B_m^2 < 0$ $k_\infty < 0$

On basis of these measurements next enrichment can be chosen for measurements. Repeating this step the enrichment for $B_m^2 = 0$ can be found

L. Otis Hargrove

March 25, 1968

On Friday, discussed with Dixon Callihan and Charles Crowne an experimental program for 15 wt% ^{235}U. A production problem involves 10 wt% ^{235}U but to get that, critical requires an estimated 400 kg or 4000 kg of U. At 15 wt% the estimate is 200 kg or 1333 kg of U, still a sizeable amount.

Buckling calculations

Total U = 1333.3 kg

Vol = 1333.3/18.7 = 71.301 liter

$R^3 = 17022$

$R = 25.7$ cm

Assume Extrap Dist $\delta = 3$ cm

B^2 (Sphere) $= \left(\frac{\pi}{28.7}\right)^2 = .10946^2 = .011982$

Cube Size -

$B_x^2 = .011982/3 = .003994$

$B_x = .06320$

$\tilde{x} = 49.7$ cm

$25 \frac{6}{43.7}$ cm $= 17.2$ in

For 18 x 18 base area

$B_y^2 + B_z^2 = 2\left(\frac{\pi}{45.72+6}\right)^2 = 2 \times .06074^2 = 2 \times .003689$

$B_z^2 = B^2 - B_x^2 - B_y^2 = .004604$ $B_z = .06785$

$\tilde{z} = 46.30$ cm $z = 40.3$ cm (15.86)

For 18 x 24 in base area

$B_z^2 = .006092$

$B_z = .07805$

$\tilde{z} = 40.25$

25 6

34.25" (13.25 in)

$B_g^2 = \left(\frac{3.1416}{60.96+6}\right)^2 = .04692$

$= 00220/$

B_x 3689

00 5890

For 24 x 24 in base area

$B_z^2 = 011982$

4402

$= .007580$

$B_z = 08706$

$\tilde{z} = 36.09$

6

30.09 → (11.85 in.)

For Reflected Assemblies

ΔH 93% ~ 2.5 cm

ΔH 45 ~ 3.5

Assume 4.0 cm $\delta + \Delta H = 7.0$ cm

Sphere $B^2 = .011982$ $\tilde{R} = 28.7$ $R = 21.7$

Vol = 42.802 47 ℓ

Mass = 800.4 kg

Cube size = 43.7 cm − 4 cm = 39.7 cm, Vol = 62.571 ℓ

Mass = 1170 kg

Dw Magnuson Mar 25, 1968

For Base area 12 x 12 — 25 = 14 cm

$B_x^2 + B_y^2 = 2\left(\frac{3.1416}{30.48 + 14.}\right)^2 = 2 \times (.07063)^2 = 2 \times .004989$

011982
9978

$B_z^2 = .002004$ $\quad B_z = .04477$

$\tilde{z} = 70.17$ $\quad z = 56.17$

(22.1 in.)

For Base Area .12 x 18

$B_y^2 = \left(\frac{3.1416}{45.72 \atop 14 \over 59.72}\right)^2 = .05261^2 = .002768$

4989
007757

$B_z^2 = .004225$ $\quad B_z = .06500$

$\tilde{z} = 48.33$ $\quad z = 34.33$

(13.5 in.)

For Base Area 18 x 18

$B_z^2 = .011982$
5536
.06946

$B_z = .08029$

$\tilde{z} = 39.13$ cm $\quad z = 25.13$ cm

(9.89 in.)

Summary

Bare Sphere 10.12 in

" Cube 17.2 in

① 15.86 x 18 x 18 in (bare)

② 13.25 x 18 x 24 in (bare)

③ 11.85 x 24 x 24 in (bare)

④ 22.1 x 12 x 12 in reflected

⑤ 13.5 x 18 x 18 in. "

⑥ 9.9 x 18 x 18 in. "

Calculation of required 1/2 in. thick pieces

	ht	Layers	12 x 12	6 x 12	6 x 6
①	17 1/2	35	35	70	35
②	15 1/2	31	62	62	
③	13 1/2	27	108		
④	25 1/2	51		102	
⑤	15 1/2	31		93	
⑥	13 1/2	27	27	54	27

Total required plus added contingency

1/2	58	80	40
1/4	2	3	2
1/8	2	3	2
1/16	2	3	2

Note for all pieces 2 ea 6 x 6 = 1 ea 6 x 12

2 ea 6 x 12 = 1 ea 12 x 12

and this substitution can be made.

Also 2 ea 1/4 can be used for 1/2 in. thick.

Nom ½ x 12 x 12 pieces weighs 48.55 lbs.
or 22.064 kg

WCT set the specifications
±.005 on rectangular Dimn.
±.002 on thickness
Flat and Parallel within ±.004 TIR on large pcs
±.002 TIR on 6 x 6 sizes

Suggested Experimental Program for 15 wt% metal

1. Unreflected Critical Mass
   a) for core area of 18 x 18 in.
   b) for " " " 18 x 24 in
   c) " " " " 24 x 24 in.

2. Reflected Critical Mass
   a) Polyethylene
   b) Plexiglass
   c) Graphite
   d) Depleted Uranium
   e) Stainless steel

   } for base dimensions of
   (1) 12 x 12 in.
   (2) 12 x 18 in.
   (3) 18 x 18 in.

3. Moderated experiments, layer experiments reflected and unreflected
   a) Polyethylene
   b) Plexiglass
   c) graphite
   d) Teflon

4) Additional Experiments on many of the above
   a) Rossi - α
   b) Pulsed neutron
   c) Delayed neutron fraction
   d) Fission ratios
   e) Neutron spectra
   f) Resonance absorption in ^{238}U
   g) Flux shapes for Buckling approx.
   h) Danger coefficients and reactivity worths.

Mar 25, 1968 DLW.

Plutonium Critical Experiments Mar 14, 1969

Poisoned solutions and Pyrex tube fixed poisons and gadolinium - stainless steel fixed poison experiments

a. Use 20 in. i.d SS sphere mock for 5% solution exp. for boron - Cd - Pu solutions.

b. Use Pyrex tubing in 20 in. i.d. Cylinder 6 ft high (Pyrex 4ft)

c. Gd-Steel can be made up to 5% without seriously altering corrosion and rolling prop. (Bur. of Mines Report WCT)

Possibly one can use TURF cell for critical experiment

Design of a single solution system.

a. 3ft i.d x 4ft hi storage tank packed with glass tubes 50% glass. Webster calculates 30% subcritical up to 450 g/l with no ^{240}Pu.

b. Metering pump having flow capability from 0.2 l/min to 20 l/min. No leakage when stopped. Positive disp and suction. a minimum. Positive indication of rate setting at all times!

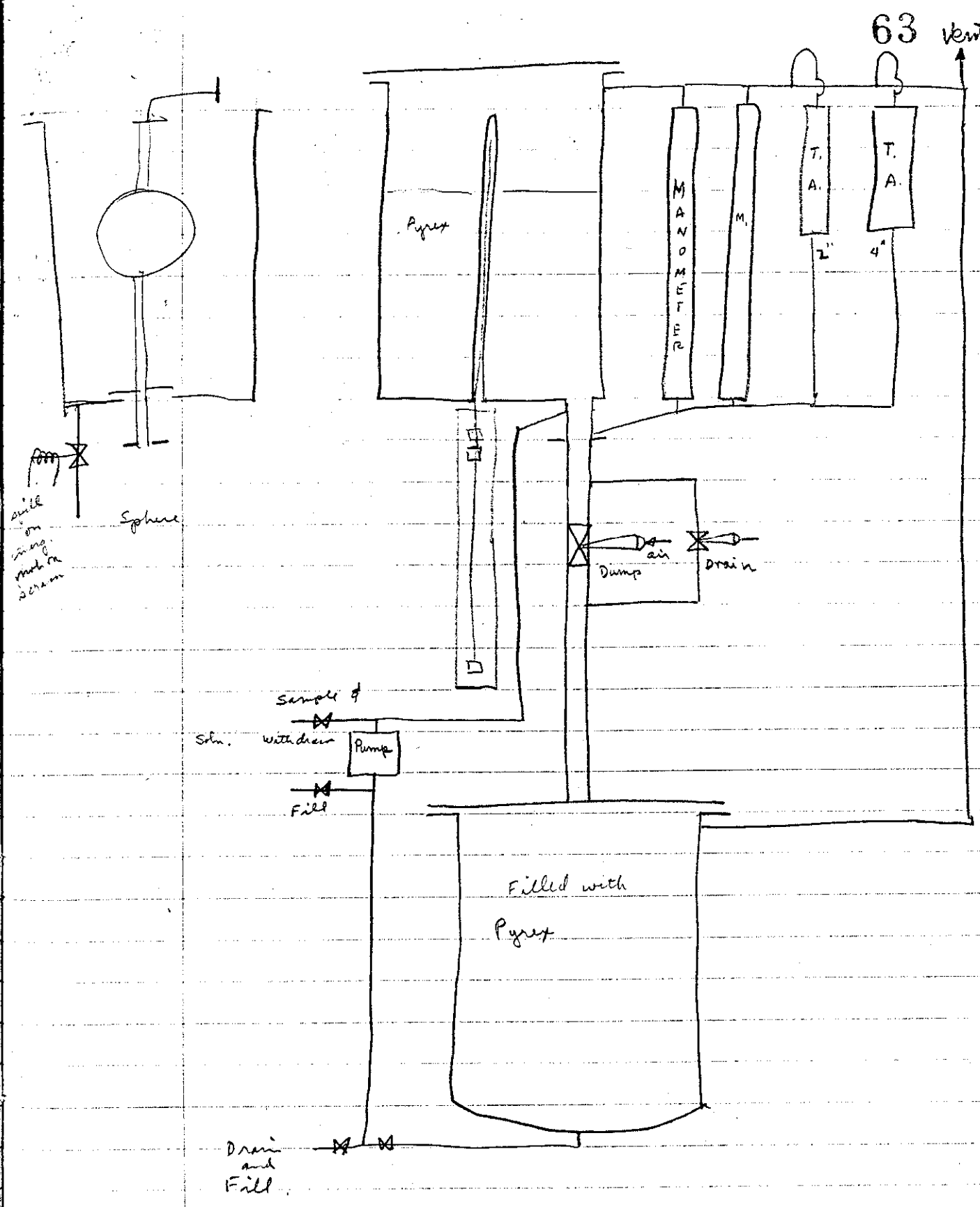
c. 2 air operated valves + manual valves.

d. 2 each liquid level manometers, remote reading

e. 2 each Tad Adders, 2 in. od and 4 in o.d., fins control.

f. 1 each 4ft stroke counter, tracing for slip col. flux meas.

g.


Vent
Pyrex
MANOMETER
M.
T. A.
2"
T. A.
4"
Sphere
Dump
air
Drain
Sample &
Soln. withdrawn
Pump
Fill
Filled with
Pyrex
Drain
and
Fill

For 30% glass $\left(\frac{.3 \; [.3307]}{.907} - 1\right) = -\left(\frac{r_1}{r_2}\right)^2$

$\left(\frac{r_1}{r_2}\right)^2 = .6693 \quad \frac{r_1}{r_2} = .818$

$.818 \, r_2 = r_1 \qquad r_2 = 1.222 \, r_1$

$r_2 - r_1 = .194 \, r_2 = .2347 \, r_1$

~~If glass fraction = .3; $\left(\frac{r_1}{r_2}\right)^2$ = .3307 ...~~

Pyrex Tubing -

$r_2 = o.d$

$r_1 = i.d$

glass Volume $= 3 \times \frac{1}{6} \times \pi (r_2^2 - r_1^2)$

Total Volume $= 2 r_2 \times .866 \times (2 r_2) \times \frac{1}{2}$

glass Fraction $= \frac{\frac{\pi}{2}(r_2^2 - r_1^2)}{1.732\, r_2^2} = \frac{.907}{}\left(1 - \frac{r_1^2}{r_2^2}\right)$

for 50% glass, $\frac{.5}{.907} = 1 - \left(\frac{r_1}{r_2}\right)^2 \;;\; \left(\frac{r_1}{r_2}\right)^2 = .4487$

$.5513$

$\frac{r_1}{r_2} = .67$

For various Std pyrex tubing

o.d	wall	i.d	$\frac{r_1}{r_2}$	$(\;)^2$	$1-(r_1/r_2)^2$	glass Fract
54	2.4	49.2	.9111	.830	.17	.154
35	2.0	31	.8857	.785	.215	.195
30	1.8	26.4	.8800	.774	.226	.205
22	1.5	19.	.8636	.746	.254	.230

Raschig Rings have 4 wt% nat. Boron.

If glass density is ~2.6 g/cm^3

$N\delta = \frac{.04 \times 2.6 \times .6025 \times 755}{10.82} = 4.37 \text{ cm}^{-1}$

$\frac{1}{N\delta} = 0.229$ cm

or 2.3 mm

Assume glass rods radius r_1 not in contact $\quad \frac{\text{glass}}{\text{Total}} = \frac{\frac{1}{2}\pi r_1^2}{1.732\, r_2^2} = .907\left(\frac{r_1}{r_2}\right)^2$

If glass fract $= 0.5 \quad (r_1/r_2)^2 = .5513$

$d_1/d_2 \;\; r_1/r_2 = .7425$

$d_2 = 1.347\, d_1$, $d_2 - d_1 = .347\, d_1$, $d_2 - d_1 = .258\, d_2$

For sheets of glass spacing = thickness for 50%

		soln	glass
50%	glass	1	1
33%	"	2	1
25%	"	3	1

For sheets of perforated glass

Area Removed	thickness soln	glass	
$\frac{1}{4}$	1	1	37.5% glass
$\frac{1}{4}$	2	1	$\frac{1}{3}-\frac{1}{12}=\frac{3}{12}=25\%$ glass
$\frac{1}{4}$	3	1	$\frac{1}{4}\times\frac{3}{4}=\frac{3}{16}=18.75\%$ glass

Telephone conv. with JPV on 3-18.

1. Pu solutions will be stored at conc. less than 200 g/l
∴ the single datum of Schmidt et al is adequate and no more work needs to be done with Raschig rings or Pyrex glass tubes.
2. The interest in poisoned solutions does not exist, but it is in poisoned slurries in the H:Pu range of 10 - 50 when the Pu critical mass begins to decrease, i.e. there is interest in data which proves that there is a poison concentration which keeps the critical mass high (~20-100 kg, perhaps) for all values of moderation ~~greater than~~ 10. There is also need for similar data for mixed oxides of Pu & U
These data are related to dissolver criticality problems!
3. Interest remains in the poisoned pulsed column. Willing to support 235 exp. if Pu experiments cannot be set up quickly and cheaply.

Gadolinium $\sigma = 46\,000$ b

@ 1 gm / cm^3 density = $\frac{.6025 \times 46000}{156.9} = 176.64 = N\sigma$ cm^{-1}

@ 0.1 gm/cm^3 $= 17.7$ cm^{-1} $= N\sigma$

1 = (1.2 wt% Gd SST.)

For 1.2 wt% Gd SST.)

If SST = 1 mm thick (.040") $N\sigma t$ = 1.77

2 mm thick (.080") 3.54

3 mm (.120") 5.31

If gadolinium occurs as an intermetallic compound, precipitated as a small crystallite self shielding will occur.

For pure gadolinium crystallite ρ = ~7.0 (not in Chem Rubber Addk.)

$N\sigma$ = 1236 cm^{-1}

$1/\mu = 10^{-4}$ cm ; $N\sigma$ = 0.1236 per micron.

ρ (Gd) = 6.7 exp. or 6.9 calc

ρ (La) = 6.15

Er. 4.77?

Nd. = 6.9

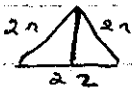
Pr = 6.5

Sa = 7.7

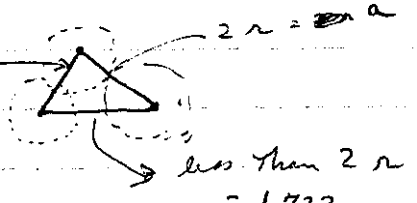
It appears that there will be problems in dispersing the gd above a few tenths wt% in SST where the intermetallic compounds precipitate out in small crystallites. It would be desirable to know the solubility limit, accurately, for Gd in S.S.T below which a solid solution exists.

It has been reported that PuO_2 microspheres do not spread much contamination. Therefore, $(Pu+U)O_2$ microspheres will spread even less. Cost permitting, microsphere-paraffin compacts could be used or microspheres-$(CH_2)_n$

For close packed spheres layer separations =



= less than 2r = 1.732r



$S = \frac{1}{2}(a+b+c) = \frac{1}{2}(5.464)r$

$S = 2.732r$

$S-a = 0.732r$

$S-b = r$

$S-c = r$

$2.0000\ r^4$

$\sin A = \frac{2}{bc}\sqrt{S(S-a)(S-b)(S-c)}$

$= \frac{2 \times 1.4142\ r^2}{3.000\ r^2}$

$= 0.94280$

altitude of Δ and layers separation

$= 1.732r \times .9428 = 1.6329r$

Area of hexagon $= 2.59808\ l^2$ (l = side)

$r = .8660\ l$, $l = 1.1547\ r$

Area $= 3.4653\ r^2$ $\quad l^2 = 1.3333\ r^2$

$HT = 1.6329r$

$Vol = 5.6585\ r^3$

$\frac{4.1888\ r^3}{5.6585\ r^3} = .74027$

Void = 26.0%

For perfect Spheres ~26% void volume

Assume PuO_2 25%
UO_2 75%

$\ln (CH_2)_n$

$PuO_2 \rightarrow 0.2548$
$CH_2 \rightarrow 0.790$
$\} \frac{H}{Pu} = 3.10$

CH_2	oxide solids PuO_2 / UO_2	vol fraction PuO_2	Vol ratio $\frac{CH_2}{PuO_2}$	x 3.1 H:Pu	Pu density kg/liter	(10x10x10) cm³ blocks = 1 liter Volume / 100 kg (liters)
30	70	.175	1.714	5.31		
35	65	.1625	2.154	6.68		
40	60	.15	2.667	8.26	1.62	61.7
45	55	~~.1375~~				
50	50	.125	4.0	12.4	1.35	
55	45	.1125	4.89	15.2		
60	40	.100	6.0	18.6	1.08	92.6
65	35	.0875	7.43	23.0		
70	30	.075	9.33	28.9	0.81	123.5
75	25	.0625	12.0	37.2		
80	20	.05	16.0	49.6	0.54	185.2
85	15	.0375	22.67	70.3		
90	10	.025	36.0	111.6	0.27	370.4

Void volumes in sphere compacts of the order of 50% will give H:Pu ratios for $\left[\frac{3}{4}UO_2 - \frac{1}{4}PuO_2\right] - (CH_2)_n$ mixtures of 12.4. Pu density = 1.35 g/cm^3

Meeting with ADC JPN & DWM

JPN outlined problems of interest for crit. exp. with Pu.

1. For mixed oxides & variable ^{240}Pu, crit. mass data are needed for H/Pu ratios from 20 - 100. Solutions not possible. Effect of poisons should be evaluated in H/Pu range of ≤ 100 so that mass values will be larger than dry oxide.
2. Pulsed column design problem -- effect Gd - SS ft. plates in column for increasing critical diameters. solution concentrations less than 120 g/l. Possibly substitute ^{235}U experiments if Pu is impossible. for checking calculation methods.
3. $UO_2 - PuO_2$ rod lattices. high and low ^{240}Pu content. (Dissolver problem), in H/Pu range similar to (1). Does burning reduce critical mass?
4. More data for pure plutonium in low moderation range for high ^{240}Pu content. H/Pu ~ 10 to 50 for 11.46 % ^{240}Pu (Hanford has completed 5, and 15 for 2.2 and 8.0 % ^{240}Pu)

ADC and JPN agreed that the proper way to proceed was to fill form 189a or at least prepare them prior to informal discussion with ORNL management and/or AEC Washington (Nanmum - LMFBR reactor physics.) ADC & JPN believe that a single contamination control system can be installed in one of the cells at 9213 suggestions include a large tank as a glove box which is final primary containment. I am not clear on how it works. I still prefer the TURF facility modified or rather with the installation of the crit exp. and instrument & control.

Both methods with be looked at!

Note that both solutions, plastic compacts and rod lattices are involved in the experimental program.

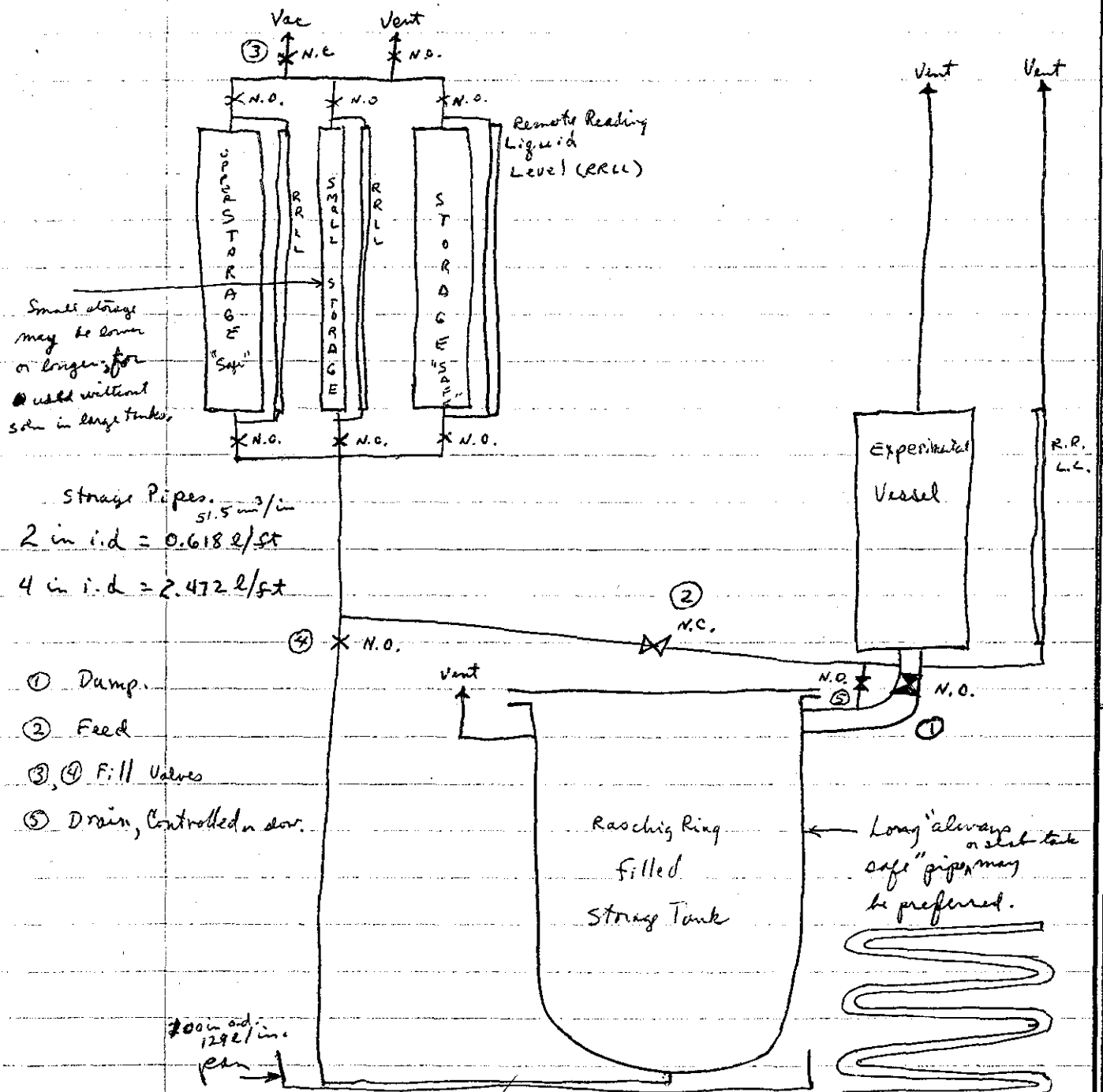
Mar 25, 69

Later conversation with JPN allowed that to get started, solution experiments may include

1. gd poisoned plates, Pu and Pu+U
2. Soluble poisons, Pu and Pu+U
3. Raschig Rings and Glass tubes, Pu and Pu+U

March 26, 1969 AWDR

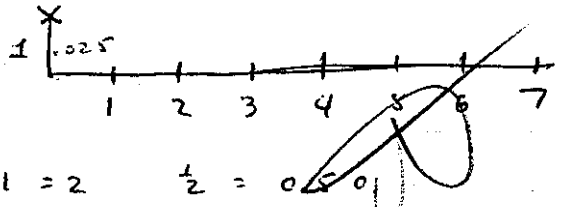
Concept of pumpless system for handling liquids -- Vacuum lifts to (Feed) storage vessels, selective "drain" (feed) to experimental vessel



October 28, 1969

Summary of thoughts on using
Alpha Radiography as a means of measuring
Power Distributions in HFIR Critical Experiment.

① Estimate of Resolution from a Point Source
or response of film relative to the response at the point



no of plate half-thicknesses

1	1+1 = 2	$\frac{1}{2}$ =	0.5 0
2	1+4 = 5	$\frac{1}{5}$	0.2 0
3	1+9 = 10	$\frac{1}{10}$	0.1 0
4	1+16 = 17	$\frac{1}{17}$	0.05882
5	1+25 = 26	$\frac{1}{26}$	0.03846
6	1+36 = 37	$\frac{1}{37}$	0.02703
7	1+49 = 50	$\frac{1}{50}$	0.02000
8			
9			
10		$\frac{1}{101}$	~0.01

② Film Blackening proportional to Absorbed Dose.
therefore β dose should be principal dose from
fission products in an irradiated fuel plate.

Most film av. speed when exposed to IR should be in mid range of density.
E. Guyton

(3) In discussions with Fitzgerald, Y-12 Radiography using careful calibration, reproducibility errors could be reduced to 2–5%. Confirmed by E. Guyton ORNL H.P. (Y-12) (gave me Type M-2 Industrial X-RAY Film (Kodak) to try.)

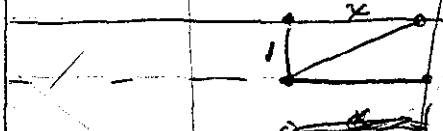
(4) Micro densitometer at Y-12,

Max scan speed 5 cm / MIN (too slow)
Max Slit size 0.05 × 2 mm. (too small)
Max plate length ~25 cm (too short)
Max plate width ~25 cm adequate

Surely there are others to do the job at hand.

(5) Assume $\frac{1}{x^2}$ law for intensity at a point

Assume uniform plate, infinite in x & y



$$\int_0^{\infty}\int_0^{2\pi} x\,d\theta\left[\frac{dx}{1+x^2}\right] = 2\pi\int_0^{\infty}\frac{x\,dx}{[1+x^2]} = -\frac{2\pi}{2}\int_0^{\infty}\left[\frac{-2x\,dx}{1+x^2}\right]$$

$$= -\pi\left[\frac{1}{1+x^2}\right]_0^{\infty} = \pi$$

Intensity due to infinite plate

Intensity at a point 0 due to immediate area having radius R

$$\frac{-\pi\left[\int_0^R \frac{-2x\,dx}{(1+x^2)}\right]}{\pi} = \frac{\pi\left(1-\frac{1}{1+R^2}\right)}{\pi} = \frac{R^2}{1+R^2}$$

R	x.025 inches	Intensity Fraction		of source has circular hole
1	.025	1/2	0.50	unit rad. .50
2	.05	4/5	0.80	rad x2 .20
3	.075	9/10	0.90	x3 .10
4	.100	16/17	0.94 12	x4 .0588
5	.125	25/26	0.96 15	x5 .0385

96. The response of a point detector to an infinite planar source is due to 5 x the distance of detector from plane source.

This resolution should be adequate for the flux measurements and power distribution as well as the uranium distribution.

For the latter, highest film speed + long exposure times are expected to be required.

DWM

^{234}U decay Assume 0.01 fraction

Assume 50 mg sample / cm^2

$$\frac{dN}{dt} = N\lambda = 1.25 \times 10^{-6} \times 10^{24} \text{ atoms} \times \frac{2.196 \times 10^{-8}}{2.48 \times 10^{5} \text{ years}}$$

$$= 0.885_{48} \times 10^{-13} \times 1.25 \times 10^{18} = 1.107 \times 10^{5} \frac{\alpha}{sec}$$

from 50 mg

Decay scheme → 47 keV γ 26%

gamma decay = 2.878×10^{4} (47 keV γ)/sec

^{235}U decay assume 100% and 50 mg sample

$$N = 50 \times 10^{-3} \times 2.563 \times 10^{-3} \times 10^{24} \text{ atoms/gram} = 1.28_{15} \times 10^{20} \text{ at.}$$

$$\lambda = \frac{2.196 \times 10^{-8}}{7.13 \times 10^{8} \text{ y}} = .308 \times 10^{-16}$$

$$\frac{dN}{dt} = N\lambda = 3.947 \times 10^{3} \ \alpha/sec$$

Decay scheme is complicated — not given in Old Reactor Physics Handbook —

Assume ~ 1 γ per α, ~4 x 10^3 γ/sec from ^{235}U

If so ^{234}U has ~~largest~~ contribution to low energy counting and dose at film surface!

Gordon

Jim Henry – Y-12

Auto radiograph of ^{90}Sr point source gave spot ~ 2 mm in diameter. 2 mc strength

$2 \times 3.7 \times 10^{-3} \times 10^{10} = 7.4 \times 10^{7}$ β / sec

Geom Factor = 2.5

$$\sim \frac{3. \times 10^{7}\ \beta}{\text{area}\quad \pi\, 0.1^{2}} \approx 1 \times 10^{9}\ \beta/cm^{2}$$

HFIR CE #3

171 inner plates $171 \times 20 \times 3.0 \times 6.45_{16} = 66\,193\ cm^{2}$

369 outer " $369 \times 20 \times 2.65 \times$ " $= 126\,174$ "

$1.92367 \times 10^{5}\ cm^{2}$

$\frac{1}{A} = 5.2 \times 10^{-6}$

If critical exp = 1 watt for 1200 sec (20')

$3.1 \times 10^{10} \times 1.2 \times 10^{3} \times 10\ \beta/\text{fission} = 4 \times 10^{14}$ total β.

$4 \times 5.2 \times 10^{14} \times 10^{-6} = 2.08 \times 10^{9}\ \beta/cm^{2}$ delayed

or 2.08×10^{8} fiss. ms/cm²

If fuel plate has 50 mg/cm²

and 2.08×10^{8} fissions/cm²

$\phi\, \sigma N t = 2.08 \times 10^{8}$ $\quad \sigma = 580 \times 10^{-24}\ cm^{2}$

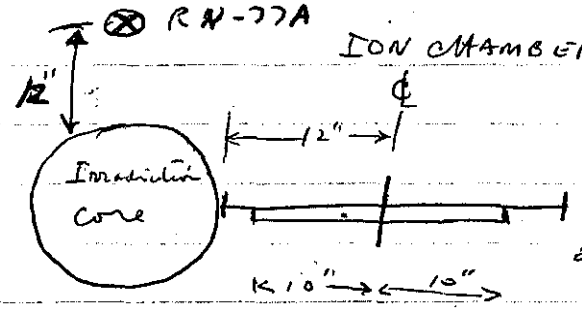
$N = 1.25 \times 10^{-4} \times 10^{24}$

$\phi = \frac{2.08 \times 10^{8}}{5.80 \times 10^{2}\ 1.25 \times 10^{-4} \times 1.2 \times 10^{3}}$ $\quad t = 1200$

$= 2.2 \times 10^{6}\ n/cm^{2}\ sec$

DWM

Preliminary Irradiation Plan



ION CHAMBER SENS = 3×10^{-13} amp / NV

$3 \times 10^{-13} \times 2.2 \times 10^{6} = 6.6 \times 10^{-7}$ amp.

Oct 31, 1969

Estimate of dose from X ray absorption in Water

(Curve does not go down to 47 keV - APEX 1716)

μ = ~20% per cm at ~~47~~ 9.4 keV per cm

$\times$ 2.88 $\times 10^{4}$ R / cm^2

~~1.35~~ 2.7 $\times 10^{8}$ N / cm^3 $\times$ 1.59 $\times 10^{-12}$ erg / eV

$= ~~2.75~~ 4.312 \times 10^{-4}$ erg / cm^3

Exp. Time for 100 erg / cm^3 $\rightarrow$ $\frac{~~.764~~ 2.32 \times 10^{8}}{.864 \times 10^{5}}$ sec / day

$= ~~337~~ 268$ days

~~[redacted]~~ If Mass Abs Coeff is 1.0 (Most elements increase rapidly at low energy) then Exp. Time is 54 days.!

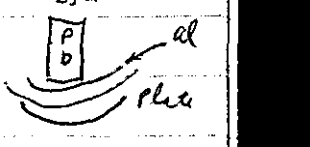
EXP #1 Film

@ 11^{35} AM Oct 31, 1969 Film in contact with iron plate

I

@ 11^{55} AM Nov 10, 1969 Film removed from plate

240.5 hours.

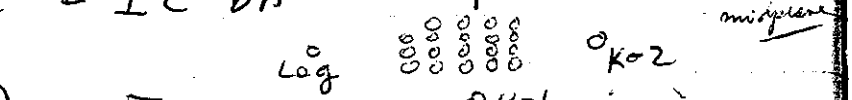


10-31-69

Inner Annulus Fuel Plate Irradiation

(No foils in HFIRCE #3 Removable

Plate # IE-8A



19 Slug (3.85) in □ array

K-1 @ 12" K-2 @ 19½ in. Log @ 18 in.

On period Scram by faulty Instr

Recovered and back up on longer period

2[42] @ 1×10^{-7} on K-1 @

Level at 2.4×10^{-7}, Droop to ~ 2.0×10^{-7}

3[12] Shut down Assembly

~3[20] Cutie Pie read 5 r at hot end.

3[25] Film #2 in contact with Plate dummy Plate & Pb weights

4[25] Remove Film #2, 60 MIN Exposure ~1 R at hot end.

4[30] Film # 3 in contact with plate > 13' exp.

4[43] Film # 3 removed.

DWM

November 3

Films #2 & 3 developed by Fitzgerald & Smith

#2 Hot end very black, #3 underexposed some detail on hot end only.
Cold end very light

Ideal exposure greater than 2×10^{6} n/sec cm^2 at mid point for 30 minutes.

A halo appears inside of each Foil hole

explanation is no 10 mil aluminum attenuation of the radiation from the sandwich.

Film appears mottled when the O.D. is ideal

a) Due to non uniform uranium dist.

b) Due to non uniform 10 mil thickness

c) Due to non uniform paper thickness.

Nov 11, 1969

a fuel scan with Metal & Ceramics X-Ray Absorption fuel scanner showed fuel inhomogeneities similar to the variations in power density.

b) and c) most likely do not apply.

DW Magnuson

X-10 Inspection Engineering or Metallurgy group
of Radiographers
Discussions with Mr. K. Klindt (Ken) & _____ ?

Factors which affect reproducibility of Film
Optical Density can be reproduced to ± 0.02 by

a) Developing in Fresh Developer
b) Using film all from the same batch
and recalibrating each batch
c) Developing film from same run all
at the same time.
d) Independent of film type.
e) Type M, Type AA, Medical No Screen
and Type K are all high contrast film
Faster film becomes "graining"
f) Type AA ~ 4 × faster than M
Medical No Screen ~ 16 × faster
Type K faster yet but is definitely
graining.
g) Calibration should probably be done
with same spectrum; however
it will be a 2nd order effect for small
changes in film from batch to batch.
h) Recommend by setting up this
Developing at 9213, and use
fresh developer for each batch of
10–15 films constituting one

irradiation and exposure.

Since Medical No Screen is 16× faster, it would be best to use Type K probably is too grainy, but would be useful for auto-radiographing the uranium activity in unirradiated plates.

Exposure for Optimum Calibration of Type M

55 mc ^{60}Co Source 86 mR/HR @ 1 meter
8,600 R/HR @ 10 cm
34.4 R/HR @ 5 cm

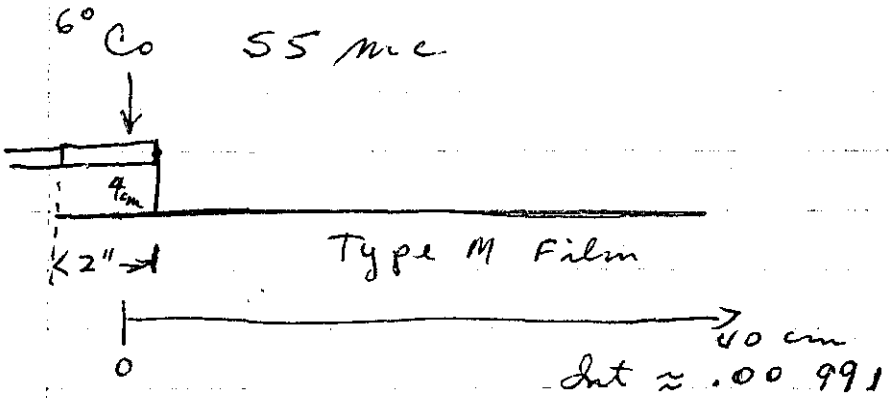
5 cm 10 cm 4 cm

R^2 R_2^2/R_1^2 40 cm × 4.56_{25} = 53.75

	R^2	R_2^2/R_1^2	40 cm × 4.56_{25} = 53.75		
0	100	1.0		2.	
10	200	.5	4 cm	1.69897	2.69
20	500	.2	8 cm	1.30103	2.30
30	1000	.1	12 cm	1.0	2.0
40	17	.0588		0.769838	1.769838
50	26	.038		0.57978	
60	37	.027		0.43136	
70	50	.020		0.30103	1.30103
80	65	.01538			
90	82	.0122			
100	101	.009901	0		1.0

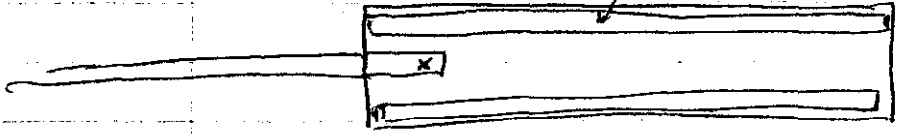
¼ 4 cm
1.6 × 2.54 =

1.524
2.54
4.064



11:51:40 Start Irradiation
Film #4. ½ hr 30'
1:21:40

Top view



Second film # 5
Start 1:24 PM } 1 hr Exposure.
Stop 2:24 PM

Re Telephone Calvin Hoggan

#18 24 mc Two pellet — radiograph shows 1 /
63 40 mc
20 55 mc Body sw.
181 mc '63 — radiograph shows 2 /

Assume Opt Density at Mark of 3.6

Type M @ 5' development

O.D. 3.6 log rel exp = 2.81

O.D. = 3.0 log rel exp = 2.7

$$\text{Slope} = \frac{0.6}{0.1} = 6$$

Δ O.D. = 0.02

Δ log Rel exp = .1/6 = 0.01667

Rel exp = 1.039

all lean approx same slope

Type AA.

O.D. 3.57 log rel exp. = 2.20

2.95 — 2.10

$$\frac{.62}{.10} = 6.2 \text{ Slope}$$

Med. No. Screen

3.6 ~ 1.75 ~~3.6~~ 2.81 / 1.75

3.0 ~ 1.64 1.06

~~1.0~~ 11.48

Type K Most sens or fastest but grainy ×faster

2/ Film Berger 3-4203 Wilson

Eastman Kodak Repres for 2nd Xray

Tom Gilliland 584-5393

7752 Evanshire Dr.

GAF sold Microdensitometer rights to Technical Operations, Inc Sno Nov 11, 1969

Nov 11, 1969

Previous irradiation of foil plate

30' @ 2×10^{-7} amps on K-2 @ 12" from core

Estimated current required for optimum irradiation which was perhaps 6" from core

$$\sim \frac{2 \times 10^{-5} \text{ amps}}{\times 3 \times 10^{-13} \text{ amps/nv}} = 0.67 \times 10^{8} \text{ nv}$$

If in critical experiment chamber is placed where flux is 0.67×10^{7} (1/10 of core)

current = $0.67 \times 10^{7} \times 3 \times 10^{-13} = 2 \times 10^{-6}$

If Chamber is 7½" from core factor is 20,

$$\frac{0.67 \times 10^{7}}{20} = 0.33 \times 10^{6}$$

$$\times 3 \times 10^{-13} = 1.0 \times 10^{-7}$$

∴ Find Outside location where flux is down by a factor of ~100 so that chamber current can be ~ 1.0×10^{-9}, a decade below saturation.

Nov 11, 1969 R. Phone

3-4203 Wilson purchasing

Ready Pack Type M 4½ x 24"

75 sheets per box

min order 3 boxes @ $31.73 per box

45 day Delivery

Nov 18, 1969

Jesse Erwin -- Fillet sides of impeller plates for HFIRCE #2 plates were badly blistered. Therefore convex side is filler side and concave is fuel side.

1 U-9
2 T-7
3 U-11
4
5 U-13
6 U-10

Films 7 & 9 should be denser than 6 & 8, respectively.

Eddy current method could detect difference in plates sides, but lacking a standard no interpretation could be made. (Dodd of Metallurgy)

Nov 12, 1969

HFIR CE #2 in Tank at West End Reedy & Cannon

Critical water height determined prior to irradiation exp. ~ 2½ in H_2O above fuel

After 10 min at critical plate read 25 mr on Cutie Pie for 10 min decay. #4 Plate used other side up in corner of annulus

Log N hanging outside tank. not moved

$= 1.1 \times 10^{-10}$

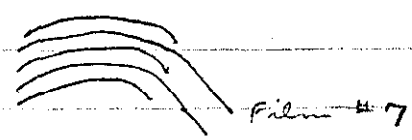
Plate #6 (U-10) interchanged 30' hr @ log N = 10.

will go to* Log N = 10 if Eldg alarms will permit OK

Start hr @ 10^{45} @ 3.7 n log N > 20'

Stop hr @ 11^{15}.

Expose Film #6 and #7 Start @ 11^{27}



Stop @ 1:00 PM

Plate read ~2.5 R on contact with Cutie Pie

only 0.600 R/HR thru 50 mil of Al

are mounted in film holder.

Start #8 bottom } insd @ 1:00 PM } 19½ hrs.

± 9 Top 8:30 AM

60 MR/HR thru 50 mil of Al

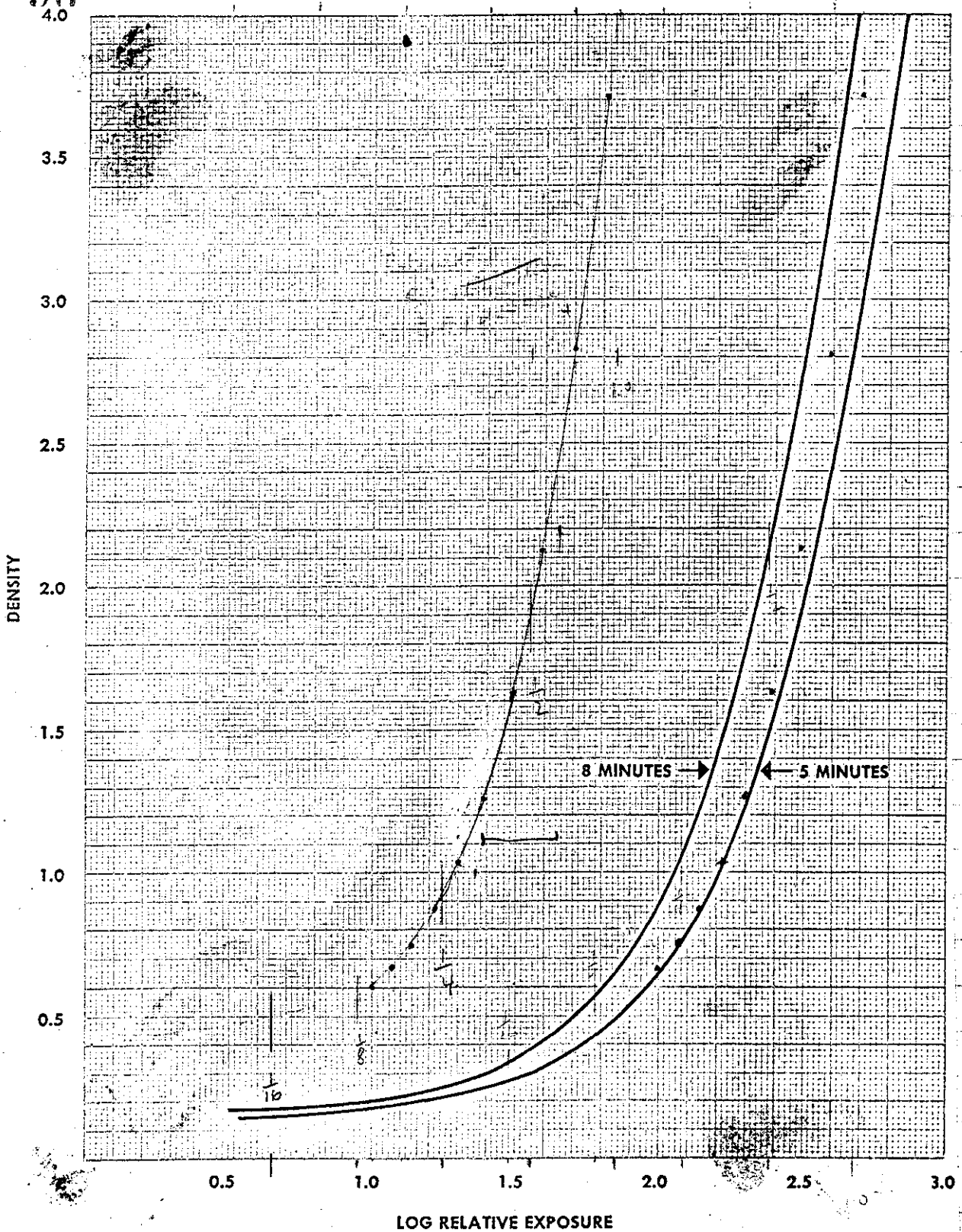


Fig. 87—Characteristic curves of Kodak Industrial X-ray Film, Type M, for direct or lead foil screen exposures to x-rays or gamma rays. (Kodak Rapid X-ray Developer or Kodak Liquid X-ray Developer and Replenisher at 68 F.)

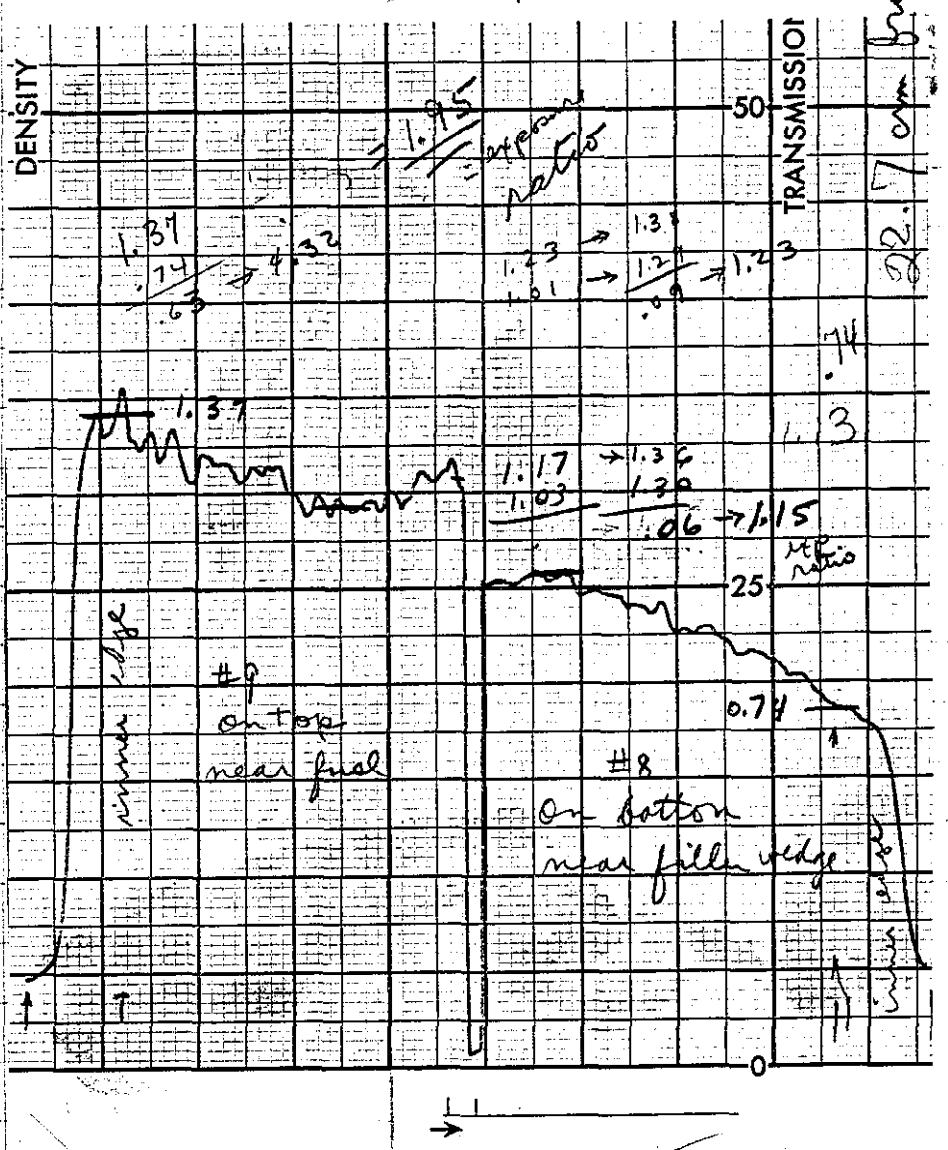
Nov 19, 1969

Observed #9 film has greater O.D. (Hacker) than film #8

Densitometer trace between 8 and 9

a) Difference is greatest on inside edge where filler wedge is thickest, thereby attenuating exposure to #8. Source is also closer to No 9.

b. Difference between 8 and 9 is smallest where filler wedge is thinnest -- near plate middle.



	Exp Ratio
Inner	4.32
Mid	1.15
Outer	1.23

Nov 19

Discussions with T. O. Gilliland, Eastman Kodak, Nov 13, 69 reaffirmed the following

a) Film response should be reproducible to 0.01 - 0.02 OD

b) Medical No Screen film, which is ~16X faster than Type M, will not show grain structure

c) Attenuation of filler strips and the location of the fuel strips will give rise to different responses at various positions across the plate and a film calibration (or response) curve will have to be determined for each axial section (strip) of the fuel plate.

d) Automated film developer should give better results than hand developing.

e) Calibration with different energy sources should be the same for O.D. vs log relative exp. that is by normalizing at one point the calibration curves should have same shape! will check with Kodak Technical representative!

f) He offered to supply me with some Med No Screen for some experiments.

g) Medical No Screen should be available in any of the sizes that Type M is available. i.e. a 24 in. ready pack could be supplied. Also as a 200 ft roll (or longer)

h) Report — Autoradiography Spec Train Div ORINS June 15-27, 1953 Overman Boyd Smith Dunn

Dec 11, 1969

M. Sims discussed with WCT DOWN locations of points on fuel plates where information is needed for input to the heat transfer code, a total of 203 points per plate. Included are measurements of the power distribution if the maximum is located above the top or bottom of the core. Ways of getting this information were discussed

a) shifting normal plate up or down in order to get fuel above or below nominal core

b) making an extra long plate from two plates.

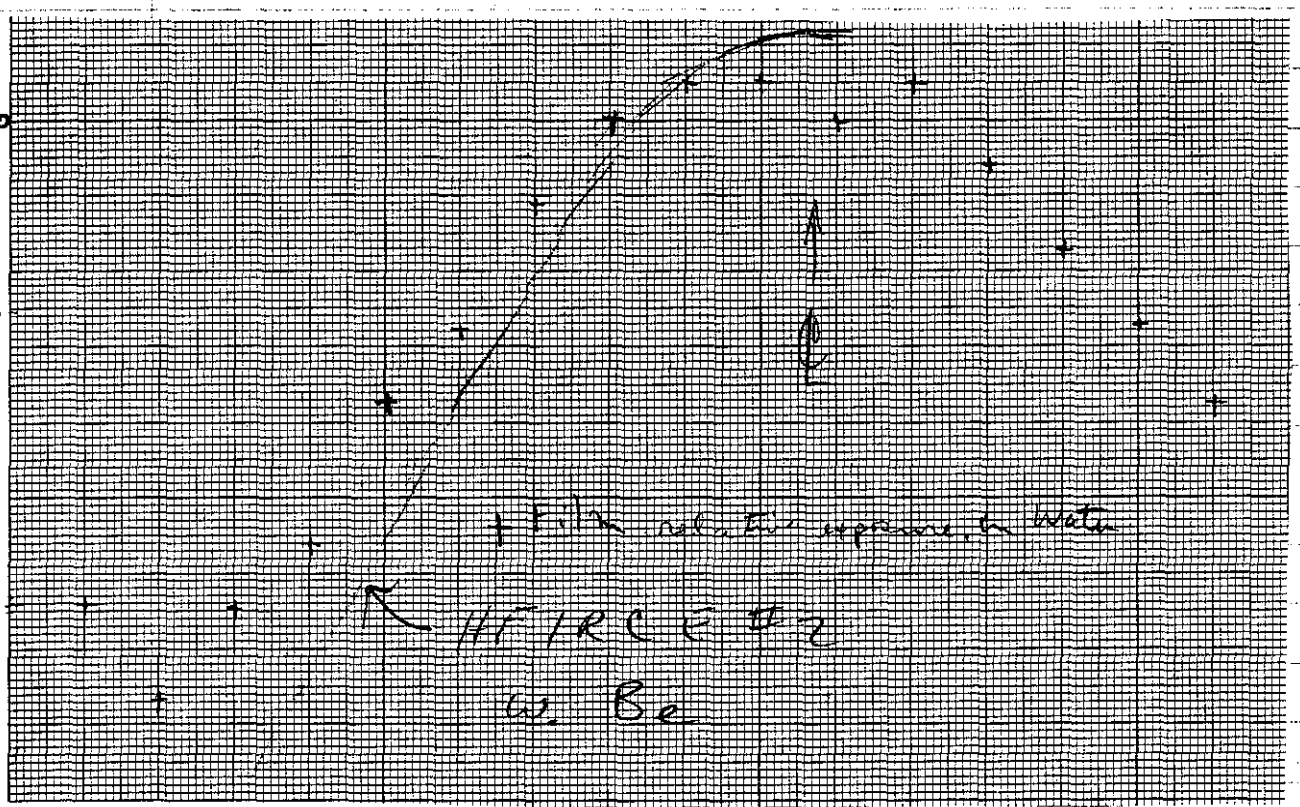
The latter is probably preferred, one method would be to take two plates cut them to the proper length - weld them together, form into the proper shape -- decide later on preferred method a) or b). (making a maximum section ~ 21" long)

Ralph Turner of Eastman Kodak pointed out that No Screen could not be developed in the Y-12 automatic film processor -- therefore will use Type A

December 11, 1969

Borrowed (from M. Silverman), Macbeth Quantalog TD-100 A Densitometer with 2 mm aperture (1 & 3 mm lost?)

Built table around side covered with graph paper so that film edge could be moved by increments easily in X and Y direction thereby scanning plate easily. Using calibration from Kodak, Radiography in Modern Industry, an axial distribution was measured from the film exposed in HFIR CE # 2 without Beryllium and compared to orig crit exp results.



Dec 1, 1969

Recheck of count rate for ^{235}U in SA-2
for ~ 50 mg Sample 5' 167789
BKG 730
167059/5 = 33,400 c/m

Baseline 0.55
Upper level 0.60
Window x1
Memory 1/4

Foil area of 1/8 × 3/2 in = 1.21 cm²
contain a minimum of 25.5 mg ^{235}U

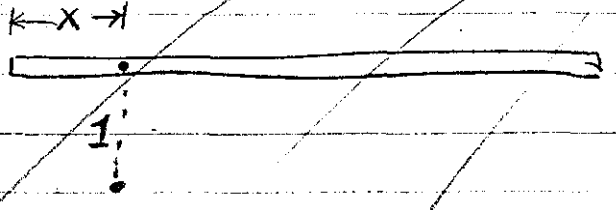
1/4 in o.d. foil area = .3167 cm²
minimum of ~ 6.4 mg
6.4/50 = .128 ~ 1/8 or ~ 4000 c/min

N.B. Scintillators could be adjusted to be closer to the sample thereby increasing count rate

5/16 in foil → area = .4948 cm²

High background on SA-1, ^{137}Cs peak
Disconnect lower Scintillator — no peak
Disconnect upper " — peak remains
Perhaps ^{137}Cs has been "spilled" on lower scintillator — should be investigated.

Calculated response at edge of foil from line source!

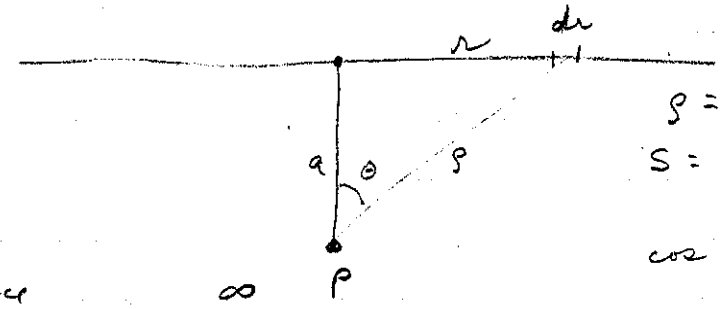


$$\frac{\int_0^X \frac{dx}{(1+x^2)} + \int_0^\infty \frac{dx}{(1+x^2)}}{2\int_0^\infty \frac{dx}{(1+x^2)} = \pi} = \frac{\tan^{-1}X\Big]_0^1 + \frac{\pi}{2}}{\pi}$$

If X =	$\tan^{-1} X$ =	× 1/180	+ .5
1	45°	.25	.75
2	63° 26	.3524	.8524
3	71° 34	.3976	.8976
4	75° 58	.4221	.9221
5	78° 41	.4372	.9372
6	80° 32	.4474	.9474
7	81° 52	.4548	.9548
10	84° 16	.4683	.9683

Response at edge of fuel is 50%
at 5 x the source distance inside, the response is 93.7% of the value for infinite plane source.

December 12, 1969
Finite & infinite plane source



$\rho = \sqrt{a^2 + r^2}$

S = source strength per unit area

$\cos\theta = \frac{a}{\rho}$

Infinite source

$$\text{Flux at } P = \int_0^\infty \frac{S \times 2\pi r\, dr}{4\pi \rho^2} \times \frac{a}{\rho}$$

$$= \frac{aS}{2} \int_0^\infty \frac{r\, dr}{(a^2 + r^2)^{3/2}}$$

$$= \frac{aS}{2} \left[\frac{-1}{(a^2 + r^2)^{1/2}} \right]_0^\infty = \frac{S}{2}$$

Finite Source

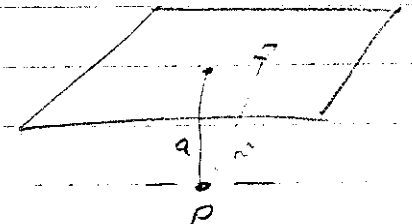
$$= \int_0^R = \frac{aS}{2} \left[\frac{-1}{a(1 + R^2/a^2)^{1/2}} + \frac{1}{a} \right]$$

$$= \frac{S}{2} \left[1 - \frac{1}{(1 + R^2/a^2)^{1/2}} \right]$$

Infinite Source with hole

$$= \int_R^\infty = \frac{S}{2} \times \frac{1}{(1 + R^2/a^2)^{1/2}}$$

Finite and Infinite Plane source, Rect geometry



Infinite source

$$\text{Flux at } P = \int_{-\infty}^{\infty} dx \int_{-\infty}^{\infty} dy \frac{S\,dy}{4\pi(a^2+x^2+y^2)} \times \frac{a}{(a^2+x^2+y^2)^{1/2}}$$

$$= \frac{aS}{\pi}\int_0^{\infty} dx \int_0^{\infty} \frac{dy}{(b^2+y^2)^{3/2}} \quad \text{where } b^2 = a^2+x^2$$

$$= \frac{aS}{\pi}\int_0^{\infty} dx \left[\frac{y}{b^2(b^2+y^2)^{1/2}}\right]_0^{\infty} \quad \text{or } \frac{1}{b^2\left(\frac{b^2}{y^2}+1\right)^{1/2}}$$

when $y=0 \to 0$

$y=\infty \to \frac{1}{b^2}\infty$

$$= \frac{aS}{\pi}\int_0^{\infty} dx \times \frac{1}{(a^2+x^2)} = \frac{aS}{\pi}\left[\frac{1}{a}\tan^{-1}\frac{x}{a}\right]_0$$

$x=\infty$
$\tan = \infty$
$\theta = 90 = \frac{\pi}{2}$

$$= \frac{S}{\pi} \times \frac{\pi}{2} = \frac{S}{2}$$

Finite source $x = X$ width X

$$= \frac{aS}{\pi}\left[\frac{1}{a}\tan^{-1}\frac{X}{a}\right] = S\,\frac{\tan^{-1}\frac{X}{a}}{\pi}$$

$$S(a^2) = \int_0^{\infty} dx \int_{-\infty}^{\infty} \frac{S\,dy}{4\pi(x^2+y^2+a^2)} = \frac{S}{\pi}\int_0^{\infty} dx \int_0^{\infty} \frac{dy}{(b^2+y^2)} \quad \text{where } b^2 = a^2+x^2$$

$$= \frac{S}{\pi}\int_0^{\infty} dx \left[\frac{1}{b}\tan^{-1}\frac{x}{b}\right]_0^{\infty} \quad b = (a^2+x^2)^{1/2}$$

$x=0 \quad \tan^{-1}0 = 0$

$x=\infty \quad \tan^{-1}\infty = \frac{\pi}{2}$

$$= \frac{S}{\pi}\frac{\pi}{2}\int_0^{\infty} \frac{dx}{(a^2+x^2)^{1/2}} = \frac{S}{2}\left\{\log\left[x+(a^2+x^2)^{1/2}\right]\right\}_0^{\infty}$$

$$= \infty \quad x\left[1+\left(1+\frac{a}{x^2}\right)^{1/2}\right]$$

Relative Flux for

R/a	Circular Source	Hole in Lf. Plane
1/10	.0050	.9950
1/5	.0194	.9806
1/4	.0299	.9701
1/3	.0413	.9587
1/2	.1056	.8944
1	.2929	.7071
2	.5528	.4472
3	.6838	.3162
4	.7675	.2425
5	.8039	.1961
10	.9005	.0995

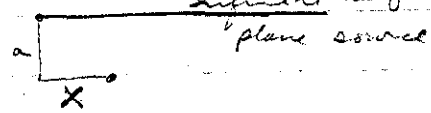
Omitting eqn 0 $q = \frac{S \times 2\pi}{4\pi} \int_0^\infty \frac{r\,dr}{(a^2+r^2)} = \frac{S}{2}\left[\frac{1}{a}\tan^{-1}\frac{r}{a}\right]_0^\infty$

$r = 0 \quad \tan^{-1} = 0$

$r = \infty \quad \tan^{-1} = \frac{\pi}{2}$

$= \frac{S\pi}{4a}$

Relative Flux near Plane edge



X/a	tan⁻¹			Relative Flux
-20				.0159
-15				.0211
-10				.0317
-5				.0628
-4				.0771
-3				.1074
-2	-63°26			.1426
-1	-45			.2500
0	0			.5000
1	45°	.5000		.7500
2	63°26			.8524
3	71°34			.8976
4	75°58			.9221
5	78°41			.9372
10	84°18	84.30	.4683	.9683
15	86°11	86.183		.9789
20	87°8	87.13		.9841

If film is $\approx .035$ in from source of radiation, then at a dist of .175 in. (5a) from edge the film response is 93.7% of an inf plane.

Feb 26, 1970

Auto Radiograph of Source No 20 55 mc of Co^{60} showed that there were two pellets in the source one of which was 2.2 x the other. The stronger source was located 1/2 in. from the tip; the weaker source 1 7/16 in from the end.

According to Calvin Hopper, the source No 20 55 mc Co^{60} showed to only one pellet.

Film No 10

Source #18, according to his records, 28 mc was comprised of two pellets. Using the Curlie Pie, the two source strengths are correct and labels have not been switched.

Film # 11 . 30 sec exposure with No #18 source 28mc in contact to locate source in holder.

5x7 type AA. Film — Source 15/16" from Tip

Weaver -- @9204-4 No latent image fading between exposure and developing for life of film! Therfore wait time before developing is unimportant

Densitometer Measurements on #10

1 minute irradiation on Type M film

O.D 1.24	0.61
.17	.17
1.07	.44
.44	

.34 → 2.2 X ratio of source strength

$\frac{55}{3.2} = 17.1875$ mc 17mc

x2 34.375

x.2 3.4375

x2.2 37.8125 mc 38mc

30 sec Irradiation with 28mc source on Type AA

O.D = 2.49 → 1.65

Base or fog = .7

Net Density ~2.3 AA Film is $\frac{60}{30} \times \frac{55}{28} \times 1.6$ faster than M

= 6.29 X faster than M

	Log Rel Exp.	
	2.49	1.65
Est O D	1.42	1.44
		.21

Relative speed Kodak

$\frac{HA}{M} \quad \frac{100}{15} = 6.67$

in 1/20 (55mc) sources were one pellet

Cobalt Source Calibration Method

$$\varphi = \frac{S}{4\pi R^2} = \frac{S}{4\pi}\,\frac{1}{a^2+x^2} = \frac{S}{4\pi a^2}\,\frac{1}{1+(x/a)^2}$$

x	$(x/a)^2$	$1+(x/a)^2$	$\frac{1}{(1+(x/a)^2)}$	log $\frac{1}{(1+(x/a)^2)}$
0	0	1	1	2
a	1	2	0.50	1.699
2a	4	5	0.20	1.301
3a	9	10	0.10	1.000
4a	16	17	0.05882	.7695
5a	25	26	0.03846	.5850
6a	36	37	0.02703	.4319
7a	49	50	0.02	.301
8a	64	65	0.015 385	.1871
9a	81	82	0.012 195	.0862
10a	100	101	0.009 901	.9957

March 2, 1970

Set $a = 3.125$

set $x = 0$ 1 in from edge of film #12

set $x = 8\frac{3}{4}$ in at edge of film #13

Irradiate film for 60 minutes (Elect Timer

1 38 Start

2 38 Stop

March 30

Exposed film with 3 Cf sources

B	= 1.7cm Diam	120000 c/s
A	0.5	30000 c/s
C	0.5	8000 c/s

June 1, 71

Quantalog returned to M. Silverman (serial ?)
months ago.

Dennis