BOOK20R 10129 on bottom spine

Notes:

Blank pages: inside front cover opposite page 1, 3, 4, 92-117, 134-152, inside back cover.

-page 122 has graph sheet taped to it
-inside back cover has sheet taped to it

Scanned by:
Sheila Finch
RSICC /Oak Ridge National Lab.
August 2, 1999

10129

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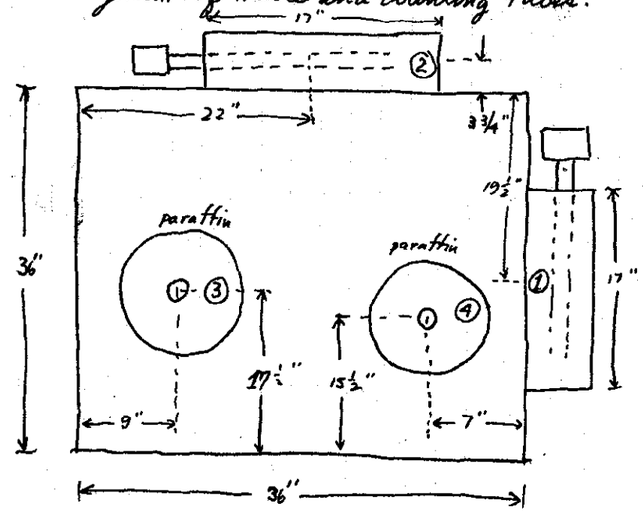
This notebook #4 assigned for Critical assembly data at Panajarita Canyon. April 4, Clifford Beck

Index to Summary -

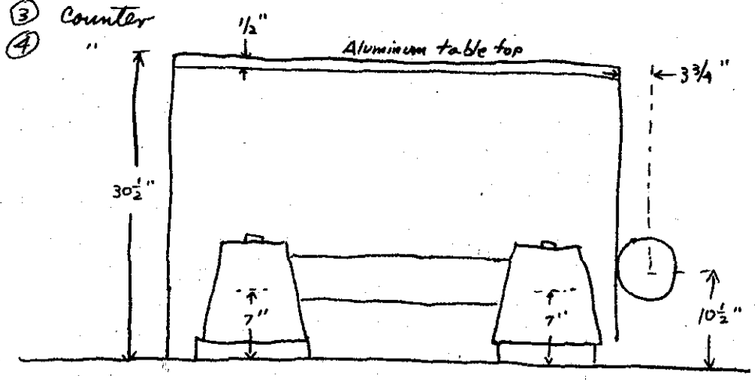
April 4, 1946 Critical assembly Experiments.

Physical arrangement of table and counting tubes.



counting equipment

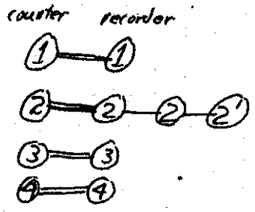
1 - Ionigation chamber
2 "
3 Counter
4 "



Electrical equipment

1 ~~Recording~~ millimeter
4 recording millimeter
2 millimeter
2 recording millimeter
2' recording millimeter

3 mechanical counter
4 mechanical counter



6 april 4, 1946.

Calculation of distances from centers of counters to center of a 10" cube.

① 33"
② 34"
③ 30"
④ 31"

Pile 1 (T cubes only, untamped) (0% tamped)

Began piling selected cubes (eliminating 95 on the basis of low or high density, ±2% ~~4.65~~ 4.64 - 4.81 used in experiment, and on height, 0.994 - 1.013 used in experiment) in center of table. Source put at base of pile, center, counter ① side of pile. Mock fission Po-Be. ~ 5×10^5 neutrons/sec. 1/2 - 1 curie

1a took counts on pile 3 blocks high, 10 long, 10 wide.

④ top counter - Δt = 10 minutes Counts 1253
1218
35 x 64 = 2240
interpolation 46
total 2286
counts/minute = 228.6
reciprocal x 1000 = 4.36

③ Bottom counter Δt = 10 minutes Counts 4495
4488
7 x 64 = 448
interpolation 33
481
c p m. 48.1
recip x 1000 ~2.08

1b 4 blocks high

④ top counter Δt = 10 min. counts 1311
1273
38 x 64 = 2432
interpolation 33
2465
cpm 246.5
recip x 1000 4.07

pm

Apr. 4, 1946

③ bottom counter Δt = 10 min counts 4507
4500
7 × 64 = 448
interpolation 23
total 471
cpm 47.1
recip × 1000 = 21.2

height		counter ④	counter ③
1c 5	counts	12390	4421
	"	348	4414
	Δc	64 × 42 = 2688	64 × 7 = 448
	interp	3	11
	total	2691	459
	c/m	269.1	45.9
	1000 m/c	3.72	21.8
1d 6	counts	1460	4434
	"	20	4427
	Δc	64 × 40 = 2560	64 × 7 = 448
	interp	8	11
	total	2568	459
	c/m	256.8	45.9
	1000 m/c	3.88	21.8
1e 7	counts	1528	4447
	"	1496	4441
	Δc	64 × 42 = 2688	64 × 6 = 384
	interp	22	62
	total	2710	446
	c/m	271.0	44.6
	1000 m/c	3.69	22.4
1f 8	counts	1615	4460
	"	1573	4454
	Δc	64 × 42 = 2688	64 × 6 = 384
	interp	14	23
	total	2702	417
	c/m	270.2	41.7
	1000 m/c	3.70	24.0

8 April 4, 1946

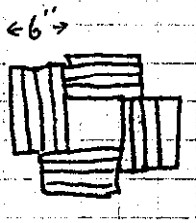
height	Counter ④	Counter ③
1 g 10	counts 1745	4482
	" 1699	4475
	Δc 64 x 46 = 2944	64 x 7 = 448
	interp. 43	20
	total 2987	468
	c/m 298.7	46.8
	1000 m/c 33.5	21.4

[17] Concluded that further additions of layers would probably never make the pile go critical. See graphs 1 and 2

Pile 2 (Tubes only, stamped)
Surrounded pile 10 x 10 x 10 cubes with single slabs of 1 1/2+" paraffin. four sides, not on top or bottom. (50%) Po-Be ~~made from~~ source placed on top of pile. 19-20 curies

	Counter ④	Counter ③
counts	1837	9500
"	1817	4495
Δc	64 x 20 = 1280	64 x 5 = 320
interp	32	52
total	1312	372
c/m	131.2	37.2
1000 m/c	7.6	26.8

added three more layers of 1 1/2+" paraffin to the 4 sides (67%)



counts	1880	4512
"	1856	4506
Δc	64 x 24 = 1536	64 x 6 = 244
interp	51	56
	1587	400
c/m	158.7	400
1000 m/c		

pm

14 April 1946

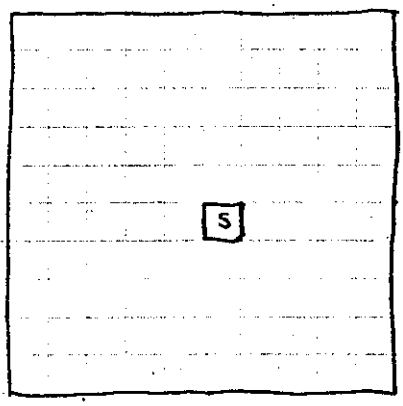
added four slabs of paraffin 10" square on top of the pile.
Source buried in lowest layer (84% tamping)

	Counter ④	Counter ③
Counts	1956	4536
"	1910	4522
ΔC	64 x 46 = 2924	64 x 14 = 896
interp	58	4
total	2982	900
C/m	298.2	90.0

covered roof of pile more completely – no apparent increase in reactivity.

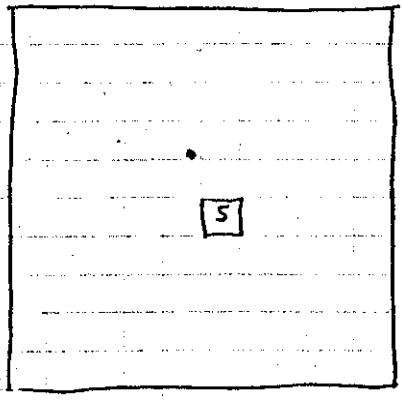
Unloaded
Removed paraffin, installed strong source in the place of the cube lying ~~six cubes from the lower ① ② corner, in each direction.~~ near the center - See diagram

2a Pile 10 x 10 x 10 = 1000 cubes ② 84% tamping



①

Top view



①

pm

10 April 4, 1946.

	Counter ④		Counter ⑤	
clicks	3437		4973	
"	2655		4741	
counts	64 × 782 = 50098		64 × 232 = 14848	
c/m.	5009.8	(2.03) *	c/m = 1484.8	(2.~~20~~ 46) *
1000/c/m	0.200	(~~5.41~~ 4.93) ≠	0.673	(4.~~53~~ 85) ≠

Removed one layer of pile from top, front, left side ~~8~~

2b Pile 9×9×9 = 729 cubes (84%)

	Counter ④		counter ③	
clicks	4571		5295	
"	3879		5107	
counts	64 × 692 = 44288		64 × 188 = 12032	
c/m	4428.8	(1.79)	c/m = 1203.2	(2.00)
1000/c/m	.226	(5.58)	1000/c/m = .830	(5.00)

Removed another layer of pile from top ~~front~~ back, right side ~~8~~(40%)

2c pile 8×8×8 = 512 cubes

	Counter ④		Counter ③	
clicks	5356		5499	
"	4744		5343	
counts	64 × 612 = 39168		64 × 151 = 9664	
c/m	3916.8	(1.58)	9664	(1.61)
1000/c/m	.256	(6.32)	1.035	(6.23)

2c' Supported source only, with cubes removed, in same location ~~as~~ previously. (84%)

	Counter ④		counter ③	
clicks	6051		5663	
"	5665		5869	
counts	64 × 386 = 24709		64 × 94 = 6016	
c/m	2470.4		c/m = 601.6	
1000/cm				

Extrapolates to 270 cubes (~14 cubes on a side) when plotted on 1/multiplication vs T cube graph

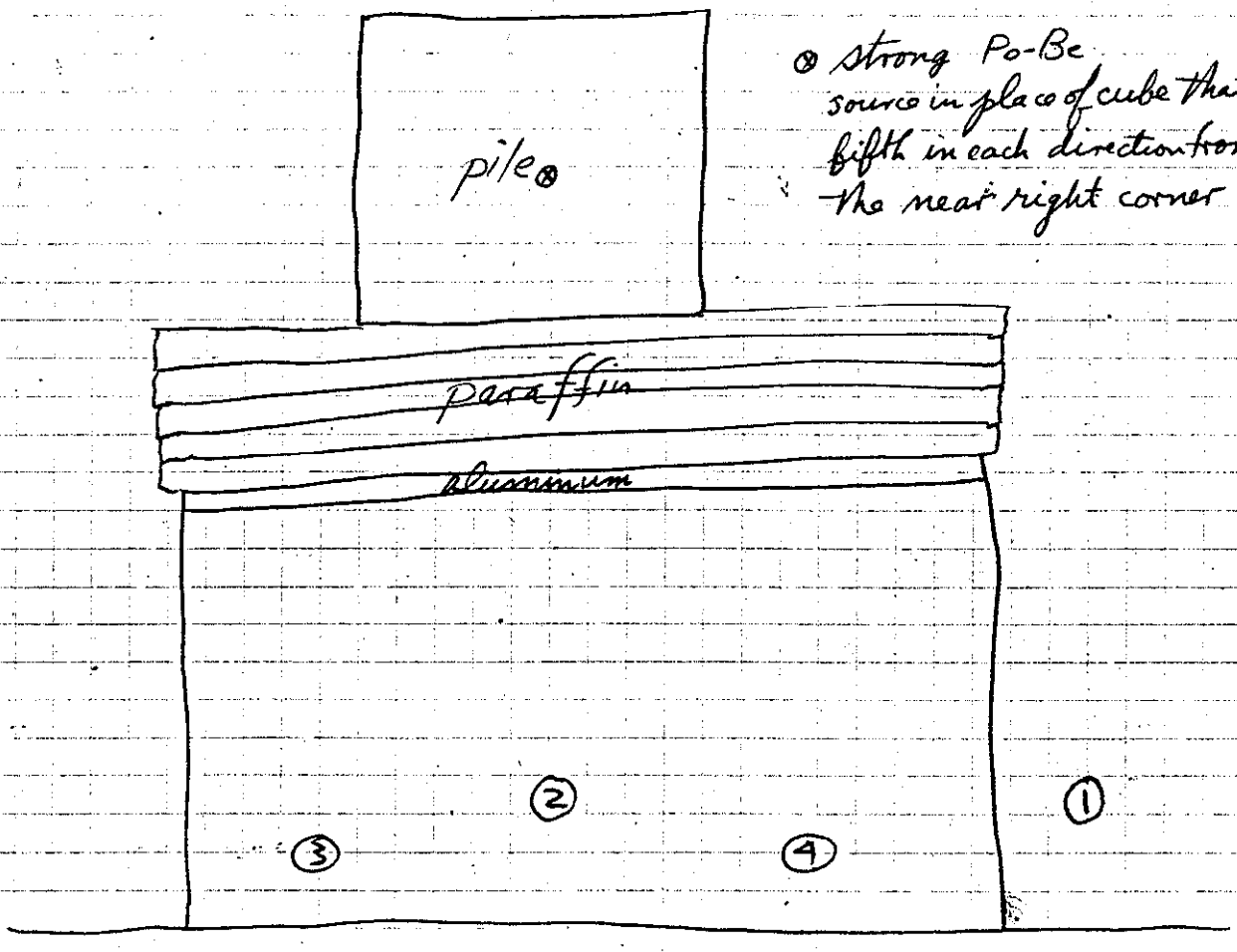
april 4, 1946

* + Pile 3 (T cubes only, completely tamped)

figures in parentheses are counting rates divided by background counting rate, ie multiplication, and reciprocal ~~coun~~ multiplication x 10. Latter are plotted ~~on~~ graph 3. Curves extrapolate to 13.6 (③) and 17.2 (④) cubes for critical.

Piled cubical array, base 10 x 10 cubes on a support of five layers of 1½" paraffin, all on same table as in previous test.

3a added layer of cubes with defective heights and densities on front (16%)



⊗ strong Po-Be source in place of cube that is fifth in each direction from the near right corner

Count on array 11 x 10 x 10 : counter ④ Counter ③

clicks	5935	5749
"	5860	5733
counts	64 x 75 = 4800	64 x 16 = 1024
c/m	480.0	c/m 102.4

pn

12 April 5, 1946

Resoldered connection on #4 scalar.

10:12-10:22 AM

	Counter ④	Counter ⑤
clicks	5951.0	7141.0
"	6004.3	7148.8
counts	64 × 53.3 = 3411.2	64 × 7.8 = 499.2
c/m	341.1	49.9

repeated observations

10:26-10:36 AM

	④	③
clicks	6062.0	7166.6
"	6004.3	7148.8
counts	64 × 57.7 = 3692.8	64 × 17.8 = 1179.2
c/m	369.3	117.9

Bursts of counts observed →

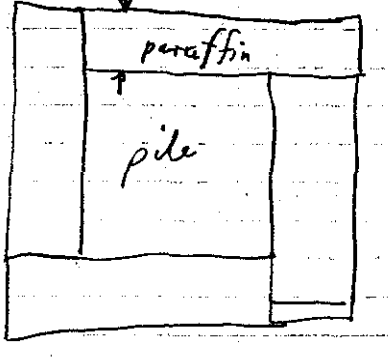
Repeated observations

10:39-10:49 AM

clicks	6062.0	7168.0
"	6119.7	7187.5
counts	64 × 57.7 = 3692.8	64 × 20.5 = 1312.0
c/m	369.3	131.2

Bursts of counts observed →

Covered pile over completely with paraffin (100%). In addition to the five slabs forming the base, five slabs each arranged in a swastika shape to cover the sides, also 5 slabs on top. to simulate spherical symmetry of tamping, another swastika composed of 4 slabs per side was added to the top.



top view

pr

April 5, 1946

12:00-12:10 PM		Counter ④	Counter ③
	clicks	679.3	305.8
	"	590.0	290.0
	counts	64 × 89.3 = 5715.2	64× 15.8 = 1011.2
	c/m	571.5	101.1
12:14-12:24 PM	clicks	775.0	323.9
	"	686.0	308.0
	counts	64 × 89.0 = 5696.0	64× 15.9 = 1017.6
	c/m	569.6	101.8

3b Removed the extra 11th row (see p. 11) of the cubes. Replaced paraffin. pile now 10×10×10 cubes, paraffin tamped. (100%)

12:38-12:48 PM			
	clicks	902.8	349.9
	clicks	828.0	335.0
	counts	64× 74.8 = 4780	64 × 14.9 = ~~868~~ 954
	c/m	478	~~86.8~~ 95.4
average c/m = 488			
	clicks	980.9	363.7
12:52-1:02 PM	"	903.0	350.0
	counts	64× 77.9 = 4980	64× 13.7 = 868
	c/m	498	86.8

3c Reduced pile size to 9×9×9, paraffin tamped (100%). Took off back, left side, top.

	clicks	176.0	460.5
	"	114.0	391.0
	counts	64× 62.0 = 3970	64× 69.5 = 4450 ?
	c/m	397	445
	clicks	7253.3	7574.4
	"	7191.0	7483.0
average c/m = 406	counts	64× 62.3 = 4000.	64× 91.4 = 5840 ?
	c/m	400	584
	clicks	~~7574.4~~ 7317.6	7582.1
	"	~~7483.0~~ 7253.0	7574.0
	counts	64× ~~14~~ 64.6 = 4200	64× 8.1 = 510 ?
	c/m	420	51.0

#3 counter gives very erratic readings.

14 April 5, 1946

3d Reduced pile size to 8×8×8, paraffin tamped. (100%) took off right side, front, top.

		④	③
	clicks	508.0	608.6
	clicks	459.0	601.0
		~~461.0~~	
average c/m=313.2	counts	64×49.0 = 3140	64×7.6 = 485
	c/m.	314.0	485

clicks	556.8	618.1
clicks	508.0	609.0
counts	64×48.8 = 3125	64×9.1 = 581
c/m.	312.5	58.1

Removed Pile, substituted 8"×8"×8" plywood box (1/4" stock), source supported on cylinder in same position 100% tamped.

3:15 PM	clicks time zero	634.0	661.0
		>40	>12
	10 min	674.0	673.0
		>34	>8
	20 min	708.0	681.0
		>37.5	>6.6
	30 min	745.5	687.6
	Δclicks	111.5	26.6
	clicks/min	37.2	
	counts/min	238	

Multiplication 8×8×8 $= \frac{48.9}{37.2} = 1.31$

Substituted 10"×10"×10" plywood box.

April 5, 1946

	~~790.0~~			
4⁰⁰ pm	clicks 791.0	> 39	695.0	> 5
4¹⁰ pm	" 830.0	> 41	700.0	> 7
4²⁰ pm	" 871.0	> 38.9	707.0	> 4.9
4³⁰ pm	" 909.9		711.9	
	Δ Clicks 118.9		16.9	
	clicks/min 3.9x6			
	counts/min 253			

Multiplication $\frac{488}{253} = 1.93$

assumed "no-pile" count for 9×9×9 box – 3.8×4 clicks/min, by 10-8 interpolation (or 245 counts/min)

Resulting multiplications and reciprocals ×10

	c/m/c/m ↘	↓
10×10×10	488/253 = 1.93	5.18
9×9×9	406/245 = 1.66	6.02
8×8×8	313/238 = 1.31	7.62

Plotted reciprocal multiplications on graph 4 — Extrapolated to ~14" cube for critical.

Removed source –

Background

4⁵²PM	clicks 19.0	> 2	713.0	> .5
5⁰⁰ pm	" 21.0		713.5	
5¹² pm				
5²² pm.				
5⁵² pm	62.8		721.9	
	clicks/min 1.04		9.5	
	counts/min 67			

probably residual found source nearby!

43.8 - clicks total - 8.9

April 5, 1946

Direct & Reciprocal Multiplications corrected for Background

10×10×10	$\frac{421}{\cancel{225}\ 126} = 2.26$	probably invalid found source nearby !
9×9×9	$\frac{339}{178} = 1.90$	
8×8×8	$\frac{246}{171} = 1.44$	

Repeat of Background count

	④	③
6 05 pm	63.0	22.0

invalid – crane operated – surges in line.

April 6, 1946

Background ④

	clicks : integration
8:39	19.00
9:09	19.59

$\Delta = \frac{59 \text{ counts}}{30 \text{ min}} \approx 2 \frac{\text{counts}}{\text{min}}$ negligible

Therefore, correction for background not necessary.

Multiplications given on page 15 accurate

Saturday April 6 - 1946

Turned over to security for week end
1108 cubes packed as follows.

$y_1 - y_{10}$ inclusive 10 yellow buckets
7-9-10-12 S

80 cubes in each bucket except 7S which has 68

13
80
1040
68
1108 total

E.T.(B —

CO 3:00 AM

Voltages, gain settings on counters

(3) 615 18

(4) 630 24.

11:12 AM Changed counter ③. New voltage setting 600 v, gain setting 18

Monday April 8, 1946.

Data on counters - small source.

top (#4)		Bottom (#3)	
Clicks/5 min	deviation	Clicks/5 min	deviation
21	1.8	26	1.1
22	0.8	27	2.1
23	0.2	24	0.9
22	0.8	28	3.1
22	0.8	23	1.9
24	1.2	25	0.1
22	0.8	25	0.1
26	3.2	22	2.9
23	0.2	24	0.9
ave 22.8	1.09	ave 24.9	1.4

counts $24 \times 64 = 1540$

$\frac{1}{\sqrt{1540}} = 25\%$ 39 c/5 min

Monday April 8, 1946

Pile 4 ($\frac{T}{H}$ = 1:1, tamped)

Constructed 1/4" plywood box 10"x10"x10" I.D. to hold cubes of T and polyethylene.

Started with 1-1 ratio.

no of T's = 500

no of H's = 500

$\frac{500}{1000} = 10^3$

T	H	T	H	T	H	T	H	T	H
H	T	H	T	H	T	H	T	H	T
T	H	T	H	T	H	T	H	T	H
H	T	H	T						

etc.

uniform

top view, facing bank of instruments.

T = Uranium H = polyethylene

4a With 1000 total cubes - 1:1 sitting on paraffin - not critical without tamper. (16%)

1:20 pm. 4b With 1000 cubes in box 1:1 Greenwald to plastic cubes. Most critical with 5 layers of paraffin tamper built (85%) up on 4 sides of cube. Bottom of cube covered with paraffin 4 layers of tamper complete - ½ of one side added (one paraffin block). Next experiment - remove 1 layer of cubes leaving 10 x 10 x 9. - Restack paraffin tamper go test for Critical.

10x10x9 Critical 6 layers completed on 4 sides, ½ of one additional slab advanced. (90%)

Tuesday April 9, 1946

4d Built up 9x9x9 assembly ½ plastic, half polyethylene in plywood box. front also plywood

total no T cubes 365

" H cubes 364

729 = 9^3

Neutron Dosage meters (Zeroed at 10:20 AM)

	#		24 hr dose
Callihan	6	6 divisions	0
Booth	9	9 divisions	0
Murray	5	3½ divisions	0
Gabri			
Guard	3	< 1 division	
Slotin	8	5 divisions	
Klein	2	—	

Dimensions of assembly $9\frac{1}{16}$" x $9\frac{1}{16}$ x $9\frac{1}{16}$

time for 5 clicks.

57	16
47	14
43	10
41	10
39	8
36	fast
33	
30	
29	
27	
27	
26	
23	
Reflector 21	
33	
31	
29	
29	
27	
27	
24	
25	
27	
22	
29	

Went critical at 4½ layers of 1½" paraffin on the sixth side top, bottom, other 4 sides completely tamped with ~ 6" paraffin. (95% tamping)

 April 9, 1946

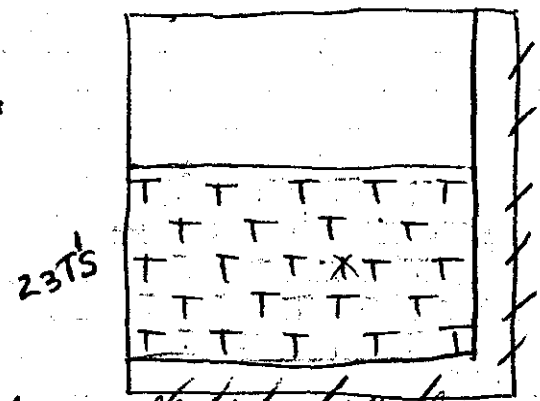
(18 green cubes)

4e Removed $\frac{4}{9}$ of front face – replaced vacant space with polyethylene filler.

time for 5 clicks: 30, 27, 27, 26, 25, 22, 18, 15, 13, 8, 7, 6, too fast

Critical at $5\frac{3}{4}$ layers of paraffin on 6th side. (98%)

total T's 347
Total H's 346
H's as tamper 36
total 729 = 9^3



4f Removed polyethylene filler to determine effect on criticality. Vacant space left

time for 5 clicks: 35, 29, 30, 29, 29, 21, 21, 15, 15, 13, 9, 9, 8, 6, 6

Remained very slightly Below critical with complete tamping.

remained fairly constant

April 9, 1946

4g Removed all of front face, replaced vacant space with polyethylene filler.

time for 5 clicks
34
32
28
26
20
16
16
13
13
12
Steady

Did not come as near critical as with previous assembly.

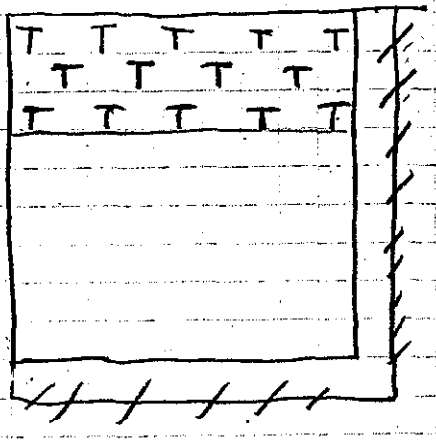
total T's - 324
Total H's - 324
H's as tamper - 81
729 = 9^3

4h Removed 6/9 of front face instead of 9/9 (see p 20) replaced with polyethylene filler. (leaves 14 T cubes)

time for 5 clicks
34
26
24
24
26
18
15
14
12
9
8
7
6
5
4
4

total T's = 338
total H's = 337
H's as tamper = 54
729 = 9^3

14 T's



Did not go critical - very close

See Summary, next page.

22 April 9, 1946

First point:
Best estimate of critical mass of T for cubical arrangement, at volume ratio of "TF_6" to polyethylene of 1:1 = 342 x.051kg = 17.5 Kg
Tamped with at least 6" of paraffin. Dimensions of array ≃ 9"x 9"x 8.44" (or cubes).
(ie 9 x 8 18/41)

Calculation of wt of T per cube of mix.

Average density = 4.73 grams/cm³
Average height = 1.003 ~~cm~~ in
" length ≃ 1.004 ~~cm~~ in
" width ≃ 1.003 ~~cm~~ in
" volume ≃ 1.010 ~~cm~~ in³ ≃ 16.55 cm³
Calculated wt = 78.3 grams of mix (78.442 g = average of 1013 usable cubes)
x .652 = 51.0 grams of T (51.16 g of T calculated)
x 95% X = 48.5 grams of X

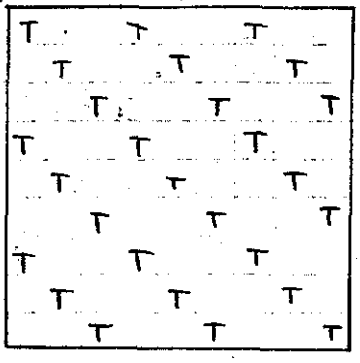
95.3% gives 48.7% gm T/cube.

April 9, 1946

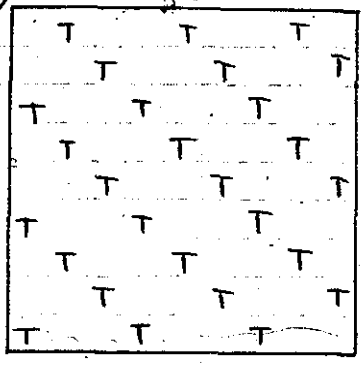
Started assembly of 9×9×9 array with $\frac{T}{H} = \frac{1}{2}$

Pile 5 ($T/H = 1.1$, tamped)

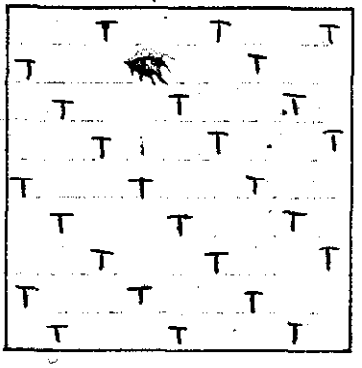
The following diagrams indicate plans for layers, starting with layer ① as the bottom. Packed in plywood box



①

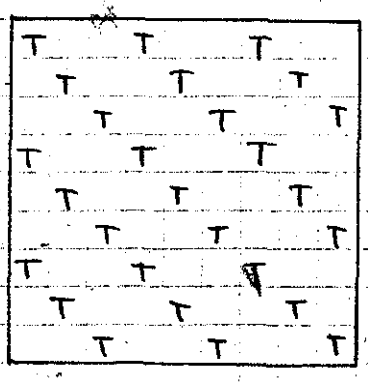


②



③

27 T's, 54 H's = 81 total



④ = ①

∴ ① = ④ = ⑦
② = ⑤ = ⑧
③ = ⑥ = ⑨

Total T's 243
H's 486
729 = 9^3

Completed the array.

5a Critical with bottom and 4 sides completely paraffin-tamped, hand tamping on ~~top~~ ~~90%~~ (85%)

24 Wednesday 10 April 1946

Neutron Meters

	#	start day	fully charged	next AM
Booth	10	(+1)	3½	4½
Callihan	11	(+1)	5	5
Murray	7	(−1)	4	5

6 & #9 recharged and put on rack for observation

5b Removed 27 T cubes from front face, filled with H cubes.

Resulting array 216 T's
432
216 H's
648 total = 9×9×8

Time/5 clicks

47	13
37	11
35	10
38	10
34	9
30	7½
30	7
28	6
29	6
27	5
25	5
23	
22	
21	
20	
18	
18	
18	
18	
19	
16	
16	
14	
14	

Critical — with 7 slabs paraffin on 2 sides, 6 on one, 5 on one, 4 on top.

(89% tamping)

10 Apr. '46

5c Removed top layer, replaced with H cubes (24 T cubes)

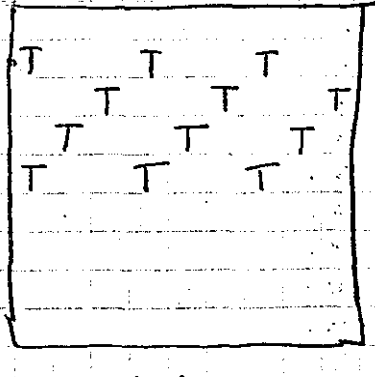
Resulting array 192 Ts
384 Hs
576 total = 9×8×8

Did not go critical with full paraffin tamping.

t/10	Clicks
	37
	30
	26
	29
	27
	27
	26
	23
	23
25	top
	21
	19
	18
	17
	18
	19
	17
	16
	16
	15
	17
	16

5d Replaced ~~27~~ 12 T cubes in front. (4 rows)

Thus assembly now 9 × 8 × 8½

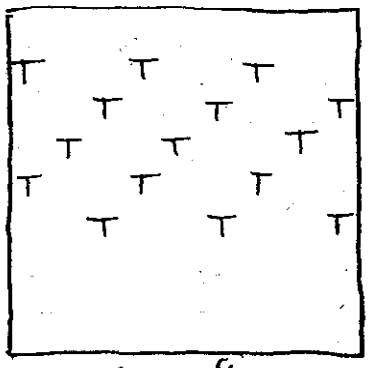


front view

Did not go critical – very close with full paraffin tamping

10 April, 1946.

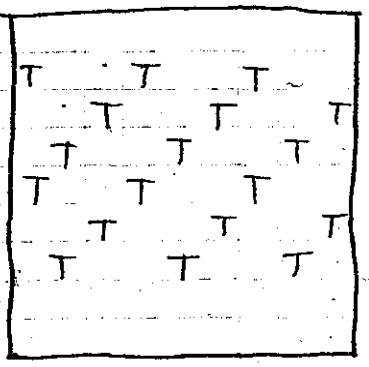
5e added 3 more cubes to front, making a total of 15.
Thus, assembly $9 \times 8 \times 8\frac{5}{8}$



front view.

did not go critical with complete tamping

5f added 3 more cubes to front, making a total 17/8
Thus, assembly $9 \times 8 \times 8\frac{3}{4}$



front view

critical with 6 layers of paraffin on 6th side. $\frac{5}{6}$ (96%)

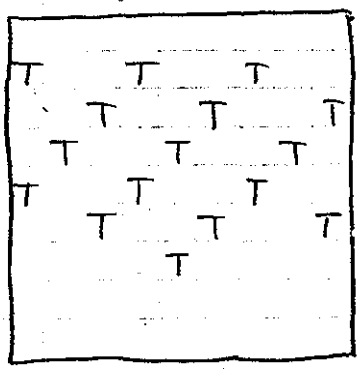
5g removed two cubes, leaving a total of 16.
assembly $9 \times 8 \times 8\frac{16}{24}$

T's $8 \times 24 + 16 = 208$
layers / layer

H's ~~16~~ $8 \times 48 + 32 = 416$

$624 = 9 \times 8 \times 8\frac{2}{3}$

10 Apr 1946



Critical with almost 7 layers of paraffin on two sides, other sides, top & bottom completely tamped. (98% tamping)

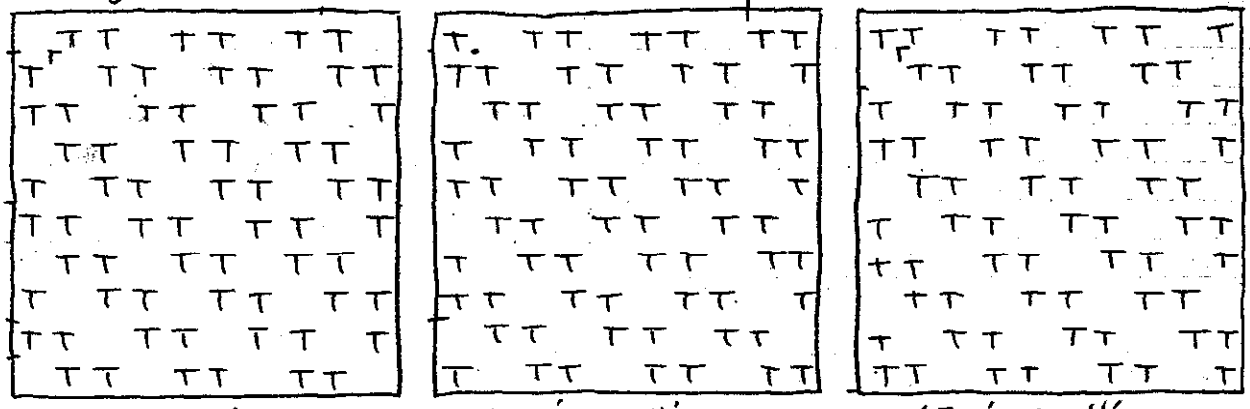
Second point:

Best estimate of critical mass of T for cubical arrangement, at volume ratio of "TF_6" to polyethylene of 1:2 = 208 × .05 kg = 10.6 kg
Tamped with at least 6" of paraffin. Dimensions of array — 9 × 8 × 8 2/3

28 10 April 1946

Pile 6 (T/H = 2:1 tamping)

6a Piled array 10 x 10 x 10, ratio of TF_6" to H cubes 2:1. in plywood box



66 Ts 34 Hs
① = ④ = ⑦ = 10

67 Ts 33 Hs
② = ⑤ = ⑧

67 Ts 33 Hs
③ = ⑥ = ⑨

no. of Ts $66 \times 4 = 264$
$67 \times 6 = 402$
666

no of Hs $33 \times 6 = 198$
$34 \times 4 = 136$
334

total $1000 = 10^3$

11 april 1946

Critical with a little less than 7 layers of paraffin on 6th side. (98% tamping)

DATA ON BORON PLASTIC

4.3% Boron by weight
Density 1.6 grams/cm^3

Boronas $Na_2B_4O_7 \cdot 10H_2O$

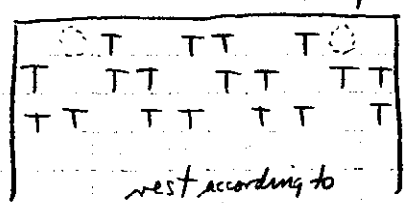
34½% cellulose acetate by weight
25% unknown plasticizer.

11 April 1946

Neutron dosimeters recharged 9:30 AM

Booth	10	0	4
Callihan	1	0	+2
Murray	7	0	4½
Guard	3	0	discharged at noon meter when shaken given #2 at 1 PM - 0
Slotin	9	0	
Klein	6	0	
Young	8	0	3
guard	2	0	9 recharged to 0 at 5pm

6b Removed 2 T cubes at ends of top row, front.

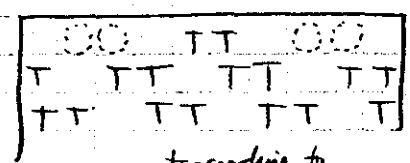


no of Ts 664
no of Hs 336
1000 = 10^3

Array now 10 x 10 x 9 64/66 in T

Critical at ν same tamping (98%)

6c Removed two more T cubes from top row front

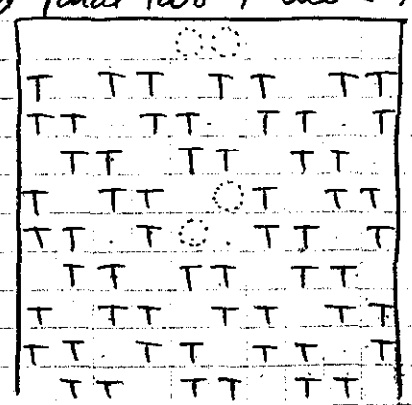


no of Ts, 662
no of Hs 338
1000 = 10^3

Array now 10 x 10 x 9 63/66 in T

Critical at ν same tamping. (98%)

6d Removed final two T cubes from top row front, also two more near center



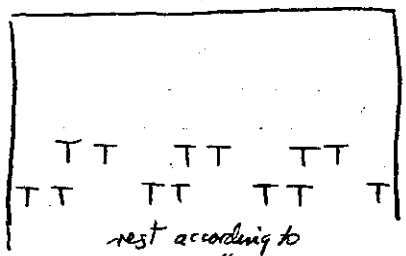
no of Ts 658
no of As 342
1000 = 10^3

Array now 10 x 10 x 9 58/66 in T

Critical at ν same tamping (98%)

11 April, 1946

6 = Replaced two middle cubes – took out down to 7th row, ie took out 3 complete rows, top, front face



no of T's = 646
no of H's = 364
1000 = 10^3

Array now $10 \times 10 \times 9\ ^{46}/_{66}$ in T

Just critical full tamping

Method of estimating % of tamping –

Each side contributes 1/6
Each layer of each side contributes percentwise.

Third point:

Best estimate of critical mass of T for cubical arrangement, at volume ratio of "TF_6" to polyethylene of 2:1 = 646 × .051 = 32.9 kg. tamped with at least 6" of paraffin. Dimensions of array $10 \times 10 \times 9\ ^{23}/_{33}$

Summary of data on variation of critical mass with hydrogen proportion $v = \frac{H}{T}$

$v = \frac{1}{2}$ $T_c = 646$ $(T+H)_c = 969$ Average dimension 9.90 Mass of T = 32.9 kg, of X 31.2
$\frac{N_H}{N_U} = 4.68$

$v = 1$ $T_c = 342$ $(T+H)_c = 684$ Average dimension 8.80 Mass of T = 17.5 kg, of X 16.6
$\frac{N_H}{N_U} = 9.36$

$v = 2$ $T_c = 208$ $(T+H)_c = 624$ Average dimension 8.54 Mass of T = 10.6 kg, of X 10.1
$\frac{N_H}{N_U} = 18.72$

11 Apr. 1946

Measurements of weight and dimensions of polyethylene cubes. (by Callihan)

cube #	wt (grams).	l x w x h (in)	Vol	Emmanuel density	density
1.	15.076	1.003 × 1.002 × 1.007	1.012	16.584	.910
2.	15.141	1.007 × 1.0035 × 1.005	1.015	16.632	.910
3.	15.107	1.003 × 1.006 × 1.006	1.015	16.632	.908
4	15.164	1.009 × 1.000 × 1.008_5	1.017	16.665	911
5	15.139	1.007 × 1.004_5 × 1.005_5	1.017	16.665	.910
6	15.064	1.006 × 1.000 × 1.005_5	1.011	16.568	.910
7	15.134	1.005_5 × 1.007 × 1.003	1.015	16.632	.910
8	15.094	1.007 × 1.007 × 1.002	1.016	16.648	.906
9	15.098	1.007 × 1.006 × 1.001	1.014	16.616	.907
10.	15.119	1.002 × 1.007 × 1.006_5	1.015	16632	.909
	1136	ave dimensions 1.006 ± .002 × 1.005 ± .002 × 1.005 ± .002	147		

weight ave. 15.114 grams

volume ave = $\frac{\text{ave } 1.015 \text{ in}^3}{16.63 \text{ cm}^3}$ ~~1.49~~ $= 16.62 \text{ cm}^3$

ave density = $\frac{15.114}{16.62} = .909$ gms/cm^3

Calculation of $\frac{N_H}{N_V}$ per cube. assume polyethylene $CH_{1.87}$

$$N_H = \frac{(1.87)(1.008)}{12.01 + (1.87)(1.008)} \quad \frac{(15.114)}{1.008} = \frac{2.04}{.217_5} = 9.3\checkmark = \text{~~9.36~~} \text{ per cube}$$

$$N_V = \frac{5 \text{~~1.05~~} 1.14}{235.15}$$

for $\frac{H}{T} = 1$ $\frac{N_H}{N_V} = 9.36$ 9.3

$\frac{H}{T} = 2$ $\frac{N_H}{N_V} = 18.72$ 18.70

$\frac{H}{T} = .5$ $\frac{N_H}{N_V} = 4.68$

32 11 april 1946

Pile 7 (Cadmium II)

assembled 11×11×11 assembly T/H = 1/1 in plywood box

Ia 1/64" Cadmium on all 6 sides. — Critical on 65% tamping

No of T's 666
" H's 665
1331 = 11^3

Cadmium actually 0.016$_5$" thick

Ib Removed front face, pushed Cd in, filled space with polyethylene cubes.

No of T's 685
H's. 605
1210 = 11×11×10

Not critical with complete tamp

Neutron meters — Zeroed 9 AM 5:30 pm

Callihan #1	13,5 div	#6 9:22 placed next to source
Booth #10	16 div.	
Murray #7	9 div	
Security #8	3	
Young. #3		

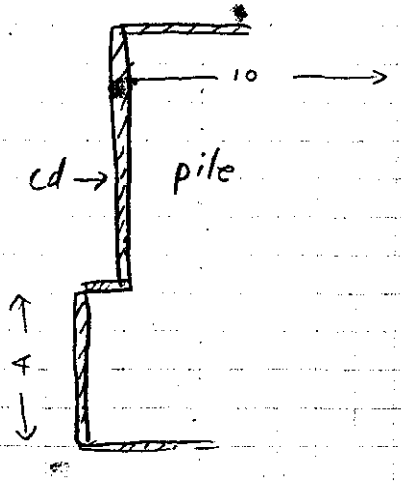
12 April 1946
Pattern for 11×11×11 array

a front layer 61 T's 60 H's 1=3=5=7=9=11 Totex ts' 666
b next layer = 60 T's, 61 H's 2=4=6=8=10 total H's 665
1331 = 11^3

7c Replaced 4 rows in bottom front face, ie 22 T's, 22 H's

new array 627 T's
627 H's
1254 = 11×11×10 22/61 in T

put Cd over faces as indicated — side view
filled space left with polyethylene cubes
Critical with 92% tamping

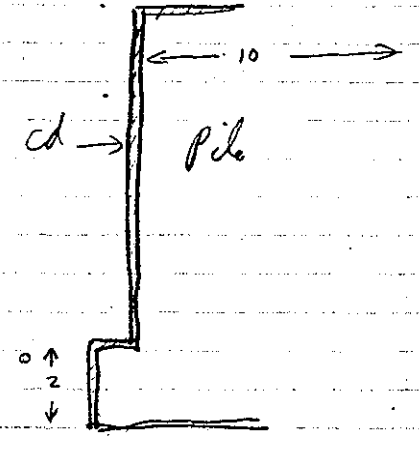


7d Removed two of rows of 7c., leaving 11×11×10 plus 11 T's, 11 H's

new array 616 T's,
616 H's
1232 = 11×11×10 "/61 in T

Put Cd over faces as indicated, — side view.
filled space left with polyethylene cubes

Not critical with complete tamping



34 12 April 1946

7c Replaced 1 row of 6 T's, 5 H's, leaving 11x11x10 plus 17 T's, 16 H's

New array 622 T's
621 H's
1243 = 11x11x10 17/61 in T

Cadmium lined in same manner as 7c, 7d. Space filled with polyethylene cubes

Critical with 95% tamping

Point

Best estimate of critical mass of T for cubical arrangement, at volume ratio of "TF_6" to polyethylene of 1:1 = 619 x.05 kg = 31.6 kg, X = 30.2
1/64" sheets of Cd metal between pile and 6" of paraffin tamper.
Dimensions of array 11x11x10 9/61.

Calculation of amount of Boron / cm² (Thickness 3/4") Data p. 28

amt of plastic / cm² = (.75 · 2.54 = 1.805)(.6) = 2.89 g

amt of boron / cm² = (2.89)(043) = .124 g/cm²

Calculation of amount of Cadmium / cm² (Thickness 0.0165")

Weighed piece 2" x 2 1/64" = 26.0 cm², 9.27 grams

amt of Cd / cm² = 9.27/26.0 = .356 g./cm²

Density of metal = 9.27/(26.0)(.042) = 8.5 g/cm³

Ratio of no of atoms B / cd per cm² = (.124/10.8)/(.356/112.4) = 36

12 April 1946

Pile 8 (Boron Lining)

8a assembled 11×11×11 at 1:1 ratio in 5 sided Boron plastic box. (3/4" thick) Critical without additional paraffin tamper (other than 6" bottom) and when front face (cover of box) 3/4 of way on.

T's 666
H's 665
1331 = 11^3

8b Removed front face, 61 T's 60 H's

Critical with 80% tamping with paraffin – completely Boron plastic lined.

T's = 605
H's 605
1210 = 11×11×10

8c Removed two layers (original array 8a) ie 121 T's, 121 H's

one layer of polyethylene outside the front Boron lid.

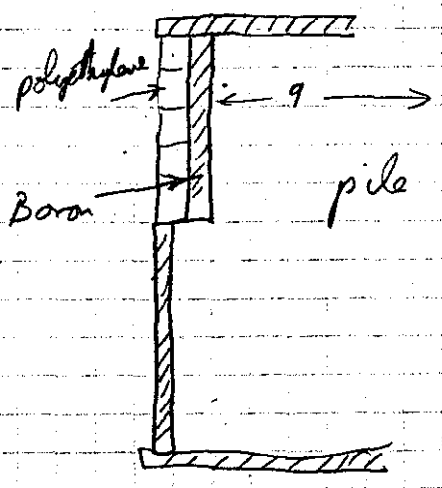
T's, = 545
H's = 544
1089 = 11×11×9

Not critical – fully tamped.

8d Replaced 6 layers, starting at bottom see diagram. Space filled with polyethylene is added 33 T's, 33 H's

array now T's 578
H's 577
1155 = 11×11×9 6/11

Not critical, fully tamped

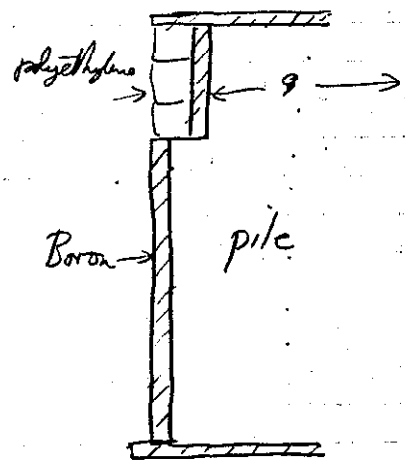


12 April 1946

8e added two more layers 11 T's, 11 H's, making total of 8. See diagram

array now T's 589
H's 588
1177 = 11 x 11 x 9 8/11

Critical with 98% tamping



Point

Best estimate of critical mass of T for cubical arrangement, at volume ratio of "TF_6" to polyethylene of 1:1 = 583 x 051 = 29.8 kg
3/4" sheets of Boron plastic between pile and 6" of paraffin tamping.
Dimensions of array 11 x 11 x 9 38/61.

15 April 1946

Pile 9 (effect of density)

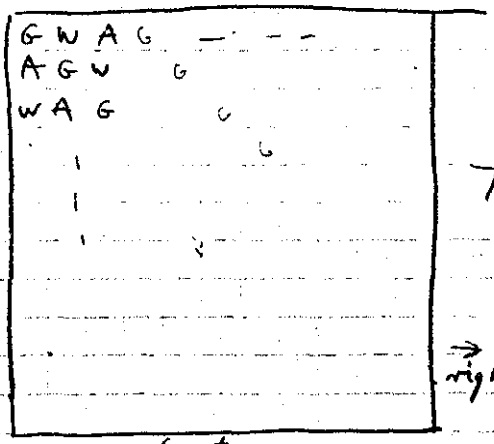
9a Stacked 11" I.D. plywood box (with top and front removed) with 1 green cube, 1 white cube and 1 air space.

Purpose to test effect of density on criticality. 12.5 mil Al sheet inserted between each horizontal layer to allow stacking.

Neutron meter 10^{30} As

#1 Murray	+1	+4
#7 Booth	+1	+3
#5 Callihan	0	7
#10 guard	0	—

assembly 11x11x11 cubes



top view

as layers piled up cube colors shift to the right

Dimensions of completed assembly $11\frac{1}{8} \times 11\frac{1}{8} \times 11\frac{1}{4}$" (height)

10 sheets of 0.012$_5$" Al = 1/8".

Not critical Minimum time for 5 clicks (x64 = counts) = 20 sec

9b added one more layer to top, making assembly 11x11x12

not critical Minimum time for 5 clicks = 18 sec.

9c Rebuilt assembly in box 12" I.D. Same pattern

12x12x12 array did not go critical

9d added layer to top —

12x12x13 array did not go critical, full tamping.

38 15 April 1946

9e added layer to front, array now 12×13×13, actual dimensions $12\frac{1}{8} \times 13\frac{1}{8} \times 13\frac{1}{4}$ height.

Critical @ 20¢. (45 sec. doubling time)

676 T's or 34.6 kg T
676 H's
676 airspaces
2028 = 13×12×13

Calculation of "density factor" appearing in the relation:

$$\frac{(M_c)_1}{(M_c)_2} = k\left(\frac{\rho_2}{\rho_1}\right)^x$$

According to X-10 report x should be 1.6 for the tamped case. assume M_c's c

average volume of T and H cubes 16.6 cm^3

total volume

$(M_c)_1$: no of cubes 1:1 ratio = 684 $684 \times 16.6 = 11354\ cm^3$

$(M_c)_2$: no of cubes 1:1:1 ratio = 2028 $(12\frac{1}{8} \times 13\frac{1}{8} \times 13\frac{1}{4})(16.387) = 34554$ cc

Mass of "TF_6" in (1). $(342)\left(\frac{349}{361}\right)(78.44) = (342)(75.83) = 25934$ g.

Mass of "TF_6" in (2) $(676)\left(\frac{349}{361}\right)(78.44) = (676)(75.83) = 51261$ g.

$\rho_2 = \frac{51261}{34554} = 1.48$ $\left(\frac{1.48}{2.28}\right)^x = \frac{25934}{51261}$ or $.649^x = .506$

$\rho_1 = \frac{25934}{11354} = 2.28$ $x = \frac{\log .506}{\log .649} = \frac{9.7042 - 10}{9.8122 - 10} = \frac{.2958}{.1878} = 1.5$

alternative calculation: variation in critical mass of 235 as a function of density of 235 (mass of 235 / unit volume of assembly)

$(M_c)_1 = 16.7$ kg of X $vol_1 = 11354\ cm^3$ $\rho_1 = \frac{1.47}{1.23}$ g/cm^3

$(M_c)_2 = \frac{32.}{26.8}$ / 33.0 kg of X $vol_2 = 34554$ $\rho_2 = 0.954$ g/cm^3

$$\left(\frac{1.47}{0.954}\right)^X = \frac{34554}{16.7}\ \frac{33.0}{}$$

$$X = \frac{1.57}{2.64}$$

third calculation - variation in critical mass of UCF_6 (mix) as a function of density of UCF_6. (mass / unit volume of assembly)

$(M_c)_1 = 26.8$ kg of UCF_6 $\rho = 2.36$ g/cm^3 (same vol. as above)

$(M_c)_2 = 53.0$ kg of UCF_6 $\rho = 1.54$ g/cm^3

$$\left(\frac{2.36}{1.54}\right)^X = \frac{53.0}{26.8}$$

$X = 1.61$

Note: All these should give identical X factors — differences are due to limits of accuracy of calculations

h meters q @ A4

#1 Murray 0

#7 Callahan 0

#9 Booth 0

#8 guard 0

40 16 April 1946

D/ Density of B_4C = 251 from Handbook of Chem. & Physics.
Assume ρ 80% of this density as packed
∴ density ≃ 2.0 g/cm³

17/11/46 – Precise density of B_4C measured at T = 25 → 0.77 gm/cm³

Started stacking 11×11×11 I.D. Boron box with H:T = 1:1.

Description of "B_4C" box:

Calculations on B_4C and B

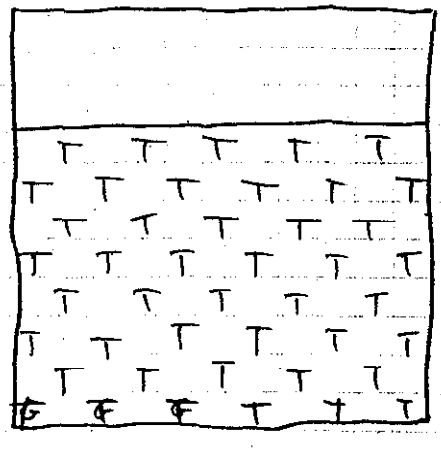
Thickness of powder layer = 3/4" = 1.9 cm.
Mass/cm² = 3.8 grams of boron carbide.
Mass/cm² = 4(10.8)/55.3 · 3.8 = 2.95 grams of boron.
Mass B_4C/cm³ = 0.77 × 55.3/4 = 1.46 gm/cm³
Mass B/cm³ = 1.46 × 4×10.8/55.3 = 1.14 gm/cm³ Density

A Critical with no tamping on top, other 5 sides tamped.

Removed six layers from front face, i.e. 30 T's, 30 H's, ~~replaced with H filler~~ Left space vacant.

B not critical

C Replaced 3 layers – array (front new) now total layers in front row now 8



not critical

D Replaced one more layer. total layers in front row now 9

Critical with about 1/2δ six th face not tamped

~~Removed two layers (East end) until morning.~~

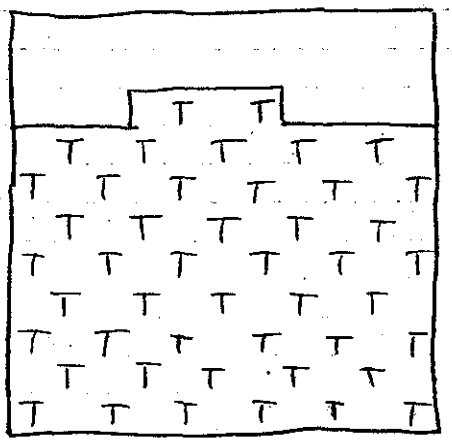
16 April 1946

Removed two Tuibas from each end of top layer front face

array now as shown

T's 46/64 front face
H's 46/64 front face

T's 605 body assembly 11×11×10
H's 605 " " " "



total T's ~~669~~ 651
" H's ~~664~~ 651
~~total 1338~~ 1302

Just critical, full tamping

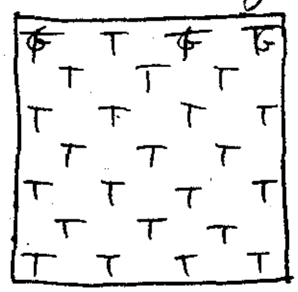
Point:

Best estimate of critical mass of T for cubical arrangement at volume ratio of "TF" to polyethylene of 1:1 = 651 x .051 = 33.4 Kg
B_4C powder between pile and 6" of paraffin tamping
Dimensions of array 11×11×10 46/61

comparision	$B_{.124}$,	$Cd_{.356}$,	B_{295}	Paraffin & Plywood for no shielding	paraffin	untamped Core
Critical # of T's	~~342~~ 583	619	651	342		
Ratios to no shielding	1.70	1.80	1.90	—		
Critical mass of mix ~~TF~~	46.6	48.4	51.0	26.8		
Critical mass of T	29.9	31.7	33.4	17.5		
Critical mass of X	28.5	30.3	31.9	16.7	15.7	41.0

 16 April 1946

// assembled rectangular parallelopiped without plywood box.
7×7×16 cubes. 1:1 ratio T:H



first layer of the 16

25 T's.
24 H's
49 total

total T's $8 \times 25 = 200$
$8 \times 24 = 192$
392
H's $= 392$
$784 = 7 \times 7 \times 16$

Not quite critical with full Hanging

added one layer of 49 on end. 24 T's, 25 H's to make array 17 long

new total T's $= 416$
H's $= 417$
$833 = 7 \times 7 \times 17$

Critical only partially tamped on one end, other sides completely tamped

Removed ~~two East~~ three west layers until morning

What final answer?
(page-44)

16 April 1946

Purported rule of thumb for criticality of circular cylinder:

If a sphere of ~~radius R~~ diameter D just goes critical, and its volume is arranged in a circular cylinder of diamter d and length 3d, the cylinder will go critical at infinite length.

$$\frac{4}{3}\pi\frac{D^3}{8} = 3d \cdot \pi\frac{d^2}{4} \qquad d = \sqrt[3]{\frac{2}{9}}\,D \quad \text{or} \quad d \simeq .6\,D$$

assuming a similar rule holds for rectangular parallelopipeda,

$$L^3 = 3l \cdot l^2 \qquad l = \sqrt[3]{\frac{1}{3}}\,L \quad \text{or} \quad l = .7\,L$$

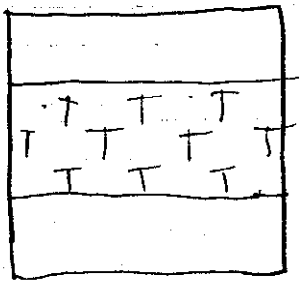
If a 1:1 8.8 cube went critical, then $l = (0.7)(8.8) \simeq 6$ cubes (crossection 6×6) would go critical only at infinite length.

44

4/17/46

Neutron detectors zeroed + issued 2:50 P-

Beck	#8	+4
Young	#2	+11
Slotin	#6	
Cecchini	#10	+4
Munay	#9	+3
Leland	#1	+5



assembled array 7×7×16 + 10 T's, 11 H's

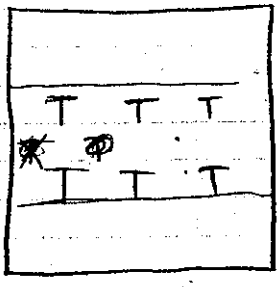
Total T's = ~~784~~ 392 + 10 = 402

H's = = 403

806 = 7×7×16 3/7

Critical with almost full tamping

Removed middle rows 3 (see above) to leave end view as indicated →

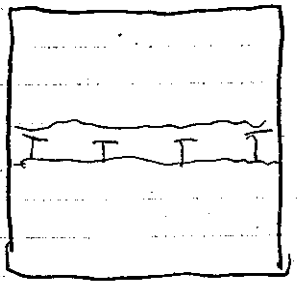


T's = 398

H's ≃ 398

Critical with approx. same tamping as previous assembly

Substituted 4 instead of 6. →



T's = 396

H's ≃ 396

Critical.

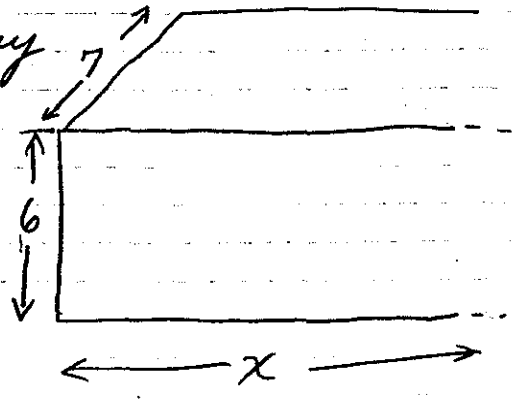
Point

Best estimate of critical mass of rectangular parallelopiped 7" × 7" cross-section at volume ratio of "TF6" to H of 1/1 = 394 × .051 = ~~20~~ 20.1 kg

Length 16 1/12

4/17/46

Took off top layer, leaving array 7
7×6 cross section
Cubes/layer 21 T's
21 H's



to determine x for criticality

Initial length 19

T's = 19 × 21 = 399
H's = 19 × 21 = 399
798 = 7×6×19

Not Critical - fully tamped

add · four 7×6 layers & north end - dimension
now 7×6×23 -

Not critical - fully tamped

add ~~three~~ four 7×6 layers & north end - dimension
now - 7×6×~~26~~ 27

just critical

Point
Best estimate of critical mass of rectangular parallelopiped 6×7 cross section, at volume ratio of TF_6 to H = 1.1 = 567 × .051 = 28.9 kg
Length = 27

46 4/17/46

Summary

Dimensions	T's	(T+H)'s	Mass of T(kg)	Critical mass ratio
9 × 9 × 8.44	342	684	17.5	1.00
7 × 7 × 16 1/12	394	788	20.1	1.15
6 × 7 × 27	567	1134	28.9	1.65

Neutron dosers

#5 Security guard 7 at 9:30 reset to zero. 6 3 30 pm

#7 Murray Zero 14

#6 Calliban " 5

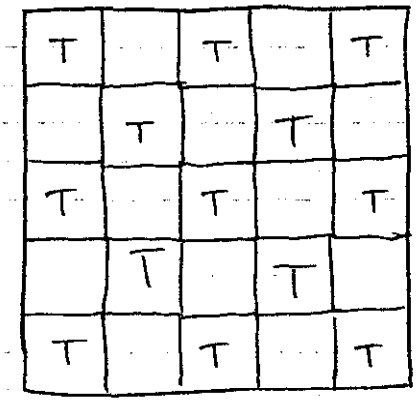
#22 Bach " 11

4/18/46

"J" assembled array composed of groups of cubes of 8.
ie 2:2 in 3 dimensions or
1:1 in zero dimensions.

first array 4 "layers"

total Ts = 400
total Hs = 400
800 = 10×10×8

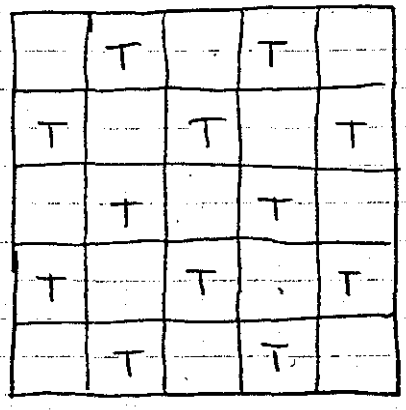


Ts 13×8 = 104
Hs 12×8 = 96

Not critical

added half "layer" to top
ie Ts 52
Hs 48
100

"Bottom "layer" actually 2 layers



Ts 12×8 = 96
Hs 13×8 = 104

new array Ts 452
Hs 448
900 = 10×10×9

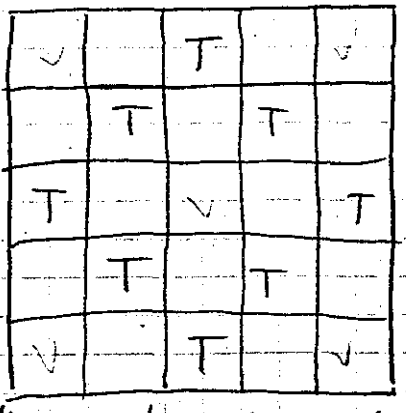
next "layer"

Critical with about .4 tamping on 6th side.

Removed 5 groups of 4 T cubes (at four corners and middle of top row)

repeats

view of top



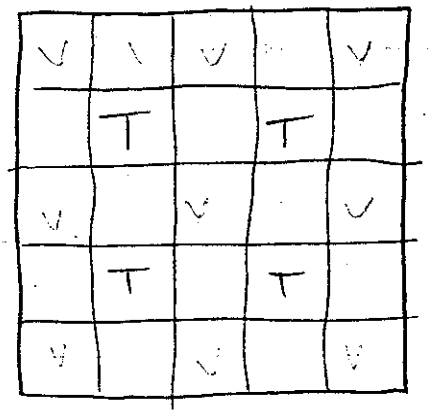
leaves 32 Ts
~32 Hs

new array 432 Ts
432 Hs
864 total

Critical with ~.6 tamping on 6th side

48 4/17/46

Removed 16 more T cubes leaving array top as shown

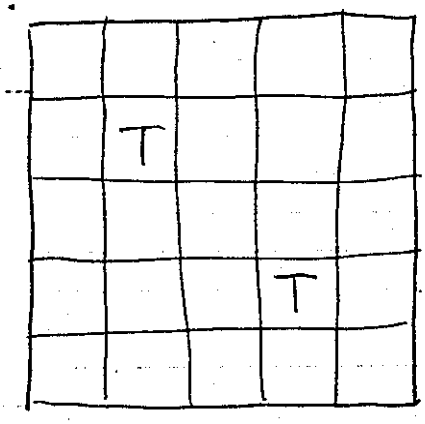


Leaves 16 T's
~ 16 H's

New array 416 T's,
416 H's
832 total

Critical with about .9 of tamping on 6th side.

Removed 8 more T cubes leaving



New array 408 T's
408 H's
816 total.

Not Critical

Point
Best estimate of critical mass of T for cubical arrangement at volume ratio of "TF$_6$" to polyethylene of 1:1, but in which the units of each material were 8 cubes in a cubes 2×2×2, is 412 × .051 = 21.0 kg
Dimensions of array 10×10×8 4/50
The critical mass ratio for the cases - ~~units of 8 / units of 1 = 412 / 342 = 1.2~~

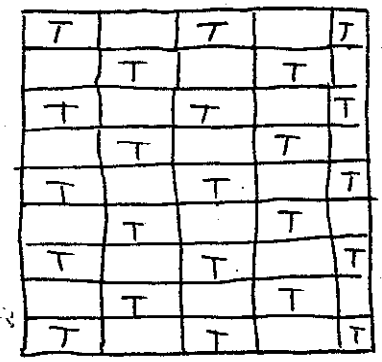
$$\frac{\text{2:2 in Three dimensions}}{\text{1:1 symmetric}} = \frac{412}{342} = 1.21$$

4/17/46

Assembled array with 2:2 ratio of H to T in one dimension and 1:1 in two dimensions. Nominally 9×9×9 assembly.

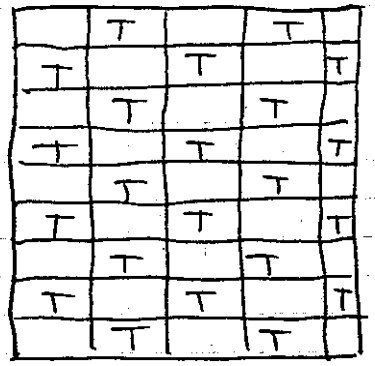
Diagram of bottom layer, viewed from South

T's in bottom layer 41
H's in " " 40
81



bottom

T's in 2nd layer 40
H's in " " 41
81



next layer

repeat.

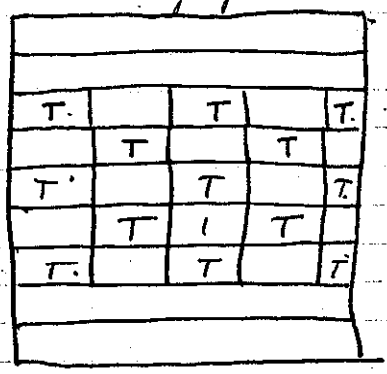
array T's — 41×5 = 205
40×4 = 160
365

H's 41×4 = 164
40×5 = 200
364

total 729 = 9^3

Critical with half-tamping on 6th side.

Second trial: Removed 18 cubes from top layer



Top layer

T = 365 − 18 = 347
H = 364 + 18 = 382 (364 − 18 = 346)

Critical at 80% tamped on 6th side

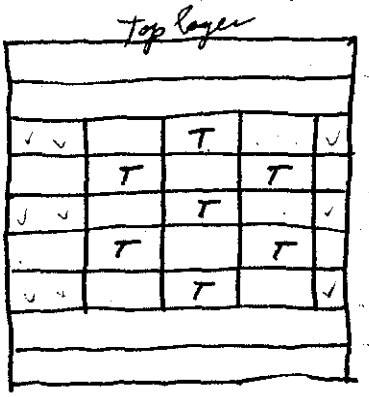
(continued on next page)

50 4/18/46

Third Trial: Removed 9 more cubes from top layer:

$T = 347 - 9 = 338.$

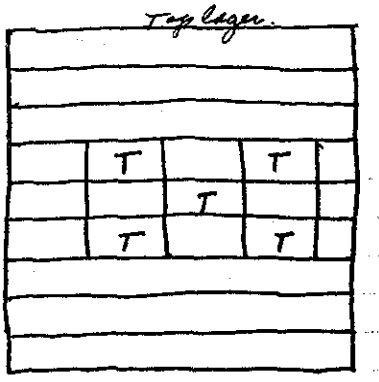
Critical at 90-95% tamped



Fourth trial: Removed 4 more cubes from top layer:

$T = 338 - 4 = 334$ cubes.

Exactly critical !! (Deyon says two cubes)
(completely tamped)



Point

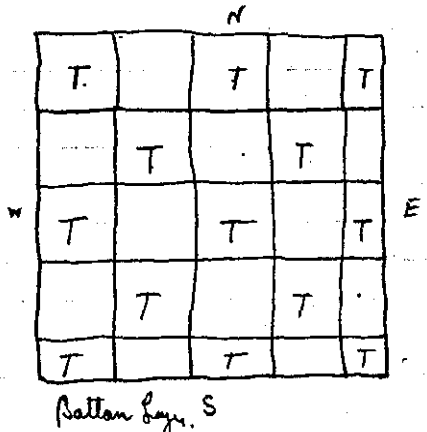
Best estimate of critical mass of T for cubical arrangement, at volume ratio of "TF_6" to polyethylene of 1:1, but in which the units appear in a 2:2 ratio in one dimension is $334 \times .051 = 17.0$ kg
Dimensions of array $9 \times 9 \times 8\ 10/41$

Critical mass ratio for cases $\frac{2:2 \text{ in one dimension}}{1:1 \text{ symmetric}} = \frac{334}{342} = .98$

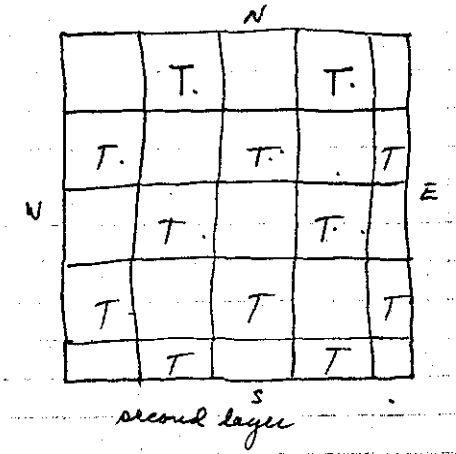
4/18/46. Assembled array with 2:2 ratio H/T in Two dimensions and 1:1 ratio in 3rd dimension. Begin with 9×9×9 assembly.

T cubes: odd layers = 41 green cubes each = 41×5 = ~~210~~ 205
even layers = 40 " " " = 40×4 = ~~160~~ 160
Total green cubes = ~~370~~ 365

H cubes: odd layers = 40 white cubes each = 40×5 = 200
even layers = 41 white cubes each = 41×4 = 164
Total White Cubes = 364



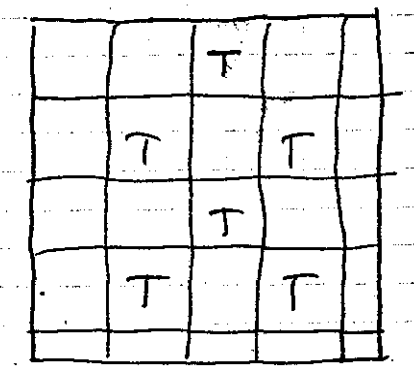
Critical with 80% tamping on 6th side.



~~2nd trial~~ —
Removed 17 cubes from top layer, leaving array as diagramed

Leaves 24 Ts in top
~ 29 Hs in top

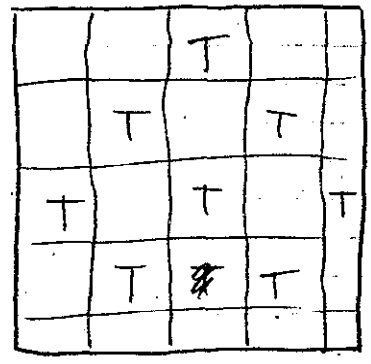
new array Ts — 348
Hs ~ 348
696



Not quite critical.

52 4/18/46

Third trial: added 6 cubes to give as shown:



top rows now 30 Ts,
~30 Hs

Array 354 Ts
~354 Hs
708 total

Critical at 95% tamping on 6th side.

Point:

Best estimate of critical mass of T for cubical arrangement, at volume ratio of "TF_6" to polyethylene of 1:1, but in which the units are arranged to give 2:2 in two dimensions, is 350 Ts × .051 = 17.9 kg
Dimensions of array 9 × 9 × 8 ~~26/41~~.

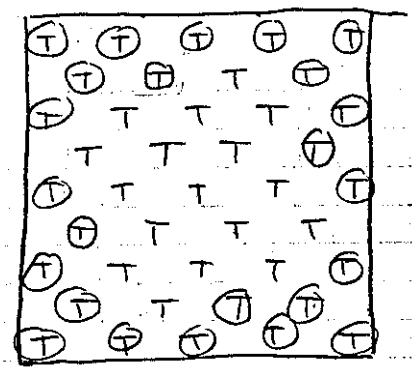
Critical mass ratio for $\frac{\text{2:2 in two dimensions}}{\text{1:1 Symmetric}} = \frac{350}{342} = 1.02$

4/18/46

16/ In view of the fact that a 2.2-in-one-dimension array gives a critical mass apparently lower than the 1:1 symmetric array, the latter was assembled for a check test. See p. 22 Apr 9, 1946 for initial experiment. Only differences between previous and present assemblies is that 1/4" plywood box not used in present, and that in the recent series, cubes have been chosen to simulate spherical symmetry rather than removing by layers from one side.

Basic array 9×9×9.

Trial 1 Removed 24 T (circled) cubes from periphery of top layer leaving as indicated, leaving 17 Ts.

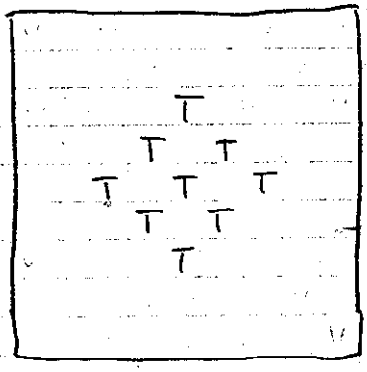


front (s)

Critical with about 60% tamping on sixth side.

Ts 4×40 = 160
4×41 = 164
17 17
341

Trial 2 Removed 8 more cubes, leaving top →

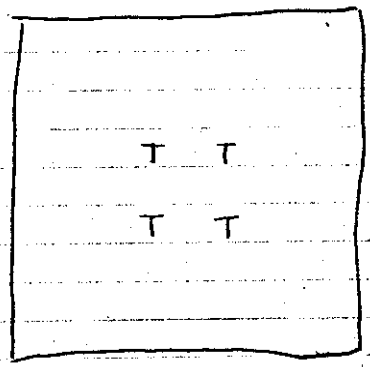


array now 9×9×8 9/41

Ts 4×40 = 160
4×41 = 164
+9 = 9
333

Critical with about 75% tamping on 6th side.

Trial 3 Removed 5 more cubes, leaving top →



array now 9×9×8 4/41

Ts 324
4
328

Critical with about 80% tamping

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Trial 4 Removed remainder of top layer Ts and ~~four~~ four Ts from next layer (one from next to corner)
Not quite critical.

Trial 5 Replaced four Ts Array now 9×9×8.
Critical 98% tamping on last side.

Point:

Best estimate of critical mass of T in cubic arrangement 1:1 TF_6/Polyethylene ratio, but without plywood box = 324 × 0.51 = 16.5 kg
Dimensions of array 9×9×8.

Ratio of critical masses $\frac{\text{with box}}{\text{without box}} = \frac{342}{324} = 1.055$

4/19/46

Neutrons 6:30 PM

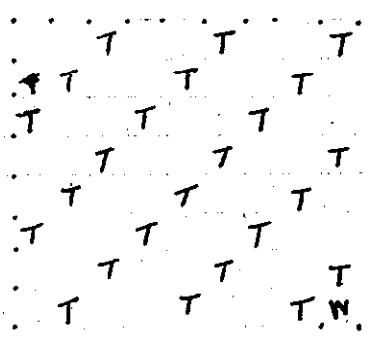
Beck #10	7½
Murray #3	4½
Young #1	4
Caliban #8	5
Guard #5	2

4/19/46

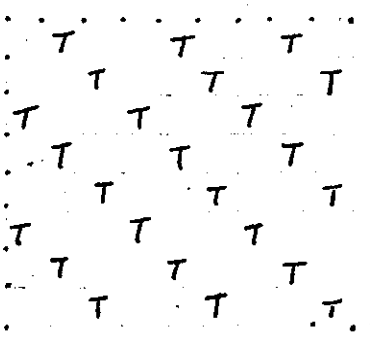
17

Stacked 8×8×8 array of 2H/1T cubes: (no plywood box).
Repeat of previous experiment, see p. 23

Front face



Top (viewed from front face).

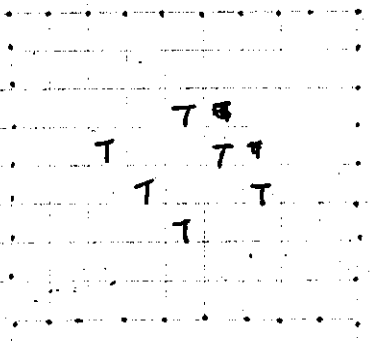


Contains - 192 T cubes
384 H "
576

ARRAY WAS NOT CRITICAL WITH 100% TAMPING -

ADDED another horizontal layer (meaning an 8×9×9) consisting of 6T cubes and 66 white cubes -

Top view:



Contains 192 + 6 = 198 T cubes
384 + 66 = 450 H "
648

is Equivalent to 2H/1T array 9×8×8 1/4

Just critical with full tamping.

Point
Best estimate of critical mass of T in cubical arrangement 1:2 "TF_6" to polyethylene ratio, but without plywood box = 198 × 0.051 = 10.1 kg.

Ratio of critical masses $\frac{\text{with box}}{\text{without box}} = \frac{208}{198} = 1.050$

56 4/19/46

8/11 Stacked 10×10×9+ array TF_6/polyethylene = 2.1. Repeat of previous Exp. on p. 28, but without plywood box.

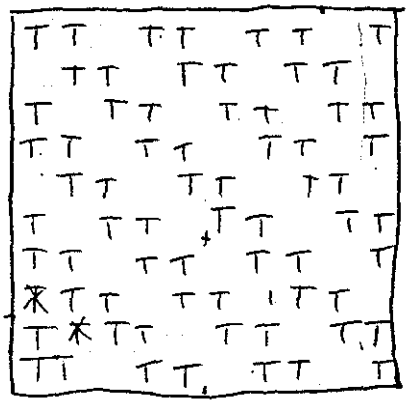
Ts in Basic 10×10×9 array

Ts 67×6 = 402
66×3 = 198
600

~~Hs 66×6 = 396~~
~~67×3 = 201~~
~~597~~

Hs 33×6 = 198
34×3 = 102
300

total 900 = 10×10×9



--- Bottom row = 4 = 7 = (10)
67 Ts, 33 Hs

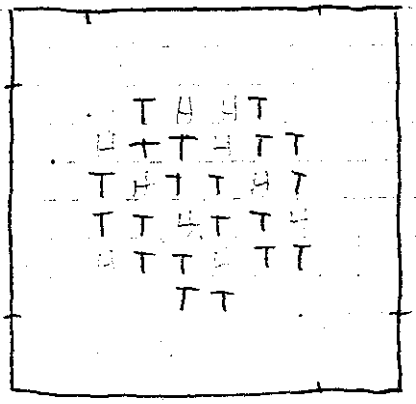
2 = 5 = 8
66 Ts, 34 Hs

3 = 6 = 9
67 Ts 33 Hs

First trial: added 20 Ts to top layer

Ts 620
Hs 310
930

Critical with ~ half tapping on 6th side

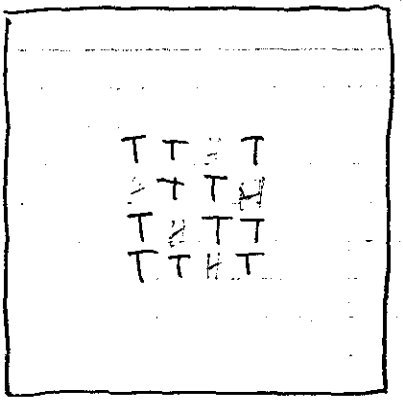


top row (10th) viewed from south

4/19/45

Removed 16 T cubes from top.

leaves →
array Ts 611, Hs ~ 305
Critical with 5½ layers of stamping on 6th side.



viewed from S.

Removed remaining 19 T cubes from top.
Array now 10 × 10 × 9 exactly

Ts 600
Hs 300
total 900

Very near critical ~2 more Ts would have made it critical

Point – Best estimate of critical mass of T in cubical arrangement 2:1 "TF_6" to polyethylene ratio, but without plywood box = 602 × .051 = 30.7 kg

Ratio of critical masses $\frac{\text{with box}}{\text{without box}} = \frac{646}{602} = 1.072$

19// 9/19/46.

Purpose to test the multiplication method – to see if extrapolation from reciprocal multiplication on cubical arrays 9×9×9, 8×8×8 and 7×7×7 gives the same critical mass as observed directly

"TF6" / polyethylene = 2:1; no plywood box; complete paraffin tamping.

Strong source – orig 2c curies, now 10 curies at present.

Removed white cube* in 5th row, layer and side, i.e. in middle of 9×9×9 array substituted source.

1=4=7= 54 Ts 27 Hs
2=5=8= 54 Ts 27 Hs
3=6=9= 54 Ts 27 Hs
162 + 81 = 343
total 343 × 3 = 729

Counter voltages
#4 650 v.
#3 630 v.

9×9×9	Ts 486	Hs 242*	total 728

#4 (top) #3 (bottom)

Start 3em 10 minute count.

Clicks end 722.1 541.1
begin 505.0 472.0
Counts = 64 × 217.1 = 13900 counts 64 × 69.1 = 4420

Start 3:12 pm 10 minute count.

Clicks end 944.6 609.3
begin 722.0 541.0
counts 64 × 222.6 = 14270 counts 64 × 68.3 = 4320

Average counts/min = 1410 Average counts/min = 437

Removed front, right and top layers.

1=4=7 43 Ts 21 Hs
2=5=8 42 Ts 22 Hs
3=6 43 Ts 21 Hs

4/19/46

8×8×8 Ts 341 Hs 170* total 511

	#4 (top)	#3 (bottom)
Start 3:23 pm	10 minute count	
Clicks	end 157.4	end 683.4
	start 070.0	start 656.0
counts	64× 87.4 = 5590	counts 64× 27.4 = 1750
Start 3:55 pm	10 minute count	
Clicks	end 243.3	712.1
	start 157.0	start 683.0
counts	64× 86.3 = 5530	counts 64× 29.1 = 1860
Average counts/min =	556	Average counts/min = 180.5

Removed top, back, left. Source shifted down, green cube removed, white instead of *

1=4=7 33 Ts 16 Hs
2=5 33 Ts 16 Hs
3=6 33 Ts 16 Hs

7×7×7 Ts 230 ** **Hs 112 total 342**

	#4 (top)	#3 (bottom)
Start 4:37 pm	10 minute count.	
Clicks	end 477.2	end 810.7
	start 414.0	start 809.0 (?)
counts	64× 63.2 = 4040	counts 64× 1.7
Start 452 pm	10 minute count	
Clicks	end 545.7	end 941.3 (?)
	start 487.0	start 824.0
Counts	64× 58.7 = 3760	counts 64× 117.3
Start 5:05 pm	5 minute count	
	end 584.7	end 974.8 (?)
	start 546.0 Burst	start 941.0
Counts	64× 38.7	counts 64× 33.8
Start 5:12	5 minute count	
	Start 614.8	end 1026.9 (?)
	end 586.0 368	start 975.0
Counts	64× 28.8 = 1840	counts 64× 51.9
Average counts/min =	386	Unreliable result

60 4/19/46

Supported source (in some position) in 7×7×7 cavity. Top layers of paraffin supported by 1/32" Aluminum sheet:

Start 5 37 pm 10 minute count

Clicks end 740.7
begin 694.0
Counts 64 × 46.7 = 2990

end 135.9
begin 129.0
Counts 64 × 6.9

Start 5 48 pm 10 minute count

Clicks end 786.1
begin 741.0
Counts 64 × 45.1 = 2890

end 170.5
begin 136.0
counts 64 × 34.5

~~Multiplication~~

Average counts/min = 294

unreliable

Supported source in proper position in 9×9×9 cavity. Top layers of paraffin supported by 1/32 Aluminum sheet

Start 6 12 pm 10 minute count

Clicks end 886.0
begin ~~818.0~~ 841.0
Counts 64 × 45.0 = 2880

no further observations on this counter

end
begin

Start 6 24 pm 10 minute count

Clicks end 928.8
begin 886.0
Counts 64 × 42.8 = 2740

Average counts/min = 281

Assume average for 8×8×8 case = 287

4/19/46

Multiplication — based on #4 counter.

	T	multiplication	R 10/multiplication	Kg 25
9×9×9	Ts 486	1410/281 = 5.02	~~2.00~~ 1.99	23.7
8×8×8	Ts 341	556/287 = 1.94	5.16	16.6
7×7×7	Ts 230	386/294 = 1.31	~~7.64~~ 7.62	11.2

Least squares line and extrapolation:

~~$R = aT + b$~~

~~$= 12.67\,T - 0.02$~~

$R = a + bT$

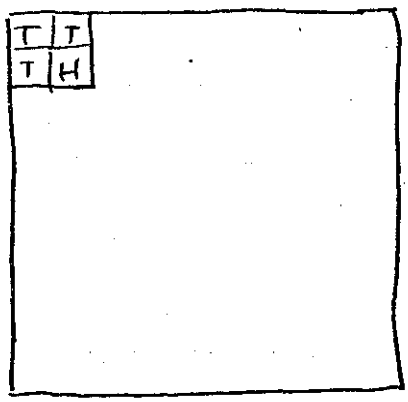
$= 12.67 - 0.022\,T$

intercept $-a/b = 576$

∴ Critical mass = 576 T cubes, by extrapolation.

62 4/22/46

Assembled 10x10x10 array with 1:7 ratio H/T.



South

a unit of 1 H, 7 T's always has the white cube in the upper, front, right corner.

Each "layer" of 25 x 8 cubes = 200
has 25 H's
25 x 7 = 175 T's

total array 875 T's
125 H's
1000 total = 10^3.

No evidence of multiplication with complete paraffin tamping.

4/23/46

added layers to front (south) and left side.

front	110 T's	no H's
side	75 T's	25 H's
	185	25 H's
new array	1060 T's	150 H's

Bad cubes used in front top two rows (except two on left side) also top assembly.

Put cluster of T cubes on top ($7\times7-1=48$) surrounded by H cubes as stamping.

Final array

1108 T's 158 H's (assumed 8 H's in top as effective moderator)

Ratio $\simeq 7$

Some multiplication but did not come near critical.

Took down part of array to insert source in 6th row from every direction.

Removed green cube, but put it on top.

(1) Multiplication Array 1108 T's 158 H's 1266 total 11x11x11

B-1

Start 10:08 10 min. count

Clicks end 2401.7
start 1953.0
counts 64 × 448.7

Start 10:19 10 min. count
end 2845.0
start 2402.0
Counts 64 × 443.0

L-1

Start 10:08 10 min. count

Clicks end 0826.9
start 9537.0
counts 64 × 1289.9

Start 10:19 10 min. count
end 2125.0
start 0827.0
counts 64 × 1298.0

Average = 64 × 44.58 = 2853 c/m

Average = 64 × 129.40 = 8282 c/m

64 4/23/46

(2) Removed the 49 cubes on top. Array now 1059 T's 11x11x10
150 H's
1209 total

Start 10:40 10 min. count

	B-1	L-1
clicks end	3336.7	3643.8
start	3015.0	2697.0
counts 64x	321.7	946.8

Start 10:53 10 min. count

clicks end	3667.2	4596.0
start	3337.0	3644.0
counts 64x	330.2	952.0
Average	64 x 32.59 = 2086 c/m	Average = 64x 94.94 = 6076 c/m

(3) Removed nightside, ~~10~~ 10x11 containing 25 H-cubes, 85 T's

Array now 10x10x11, 974 T's
125 H's
1099 total

Start 11:20 10 min. count

clicks end	4058.5 (39)	5424.2
start	~~3739.0~~ 3743.0	~~4807.0~~ 4817.0
counts 64 x	315.5	607.2

Start 11:33 10 min. count

end	4182.8	6044.4
start	~~4059.0~~ (39)	5424.0
counts 64 x	223.8	620.4

Start 11:46 10 min count

end	4406.5	6672.7
start	4183.0	6044.0
counts 64 x	223.5	628.7
Average	64 x 2209 = 1415 c/m	Average 64 x 6188 = 3960 c/m

4/23/46

④ Removed front 10×10 containing 100 T's, no H's

Array now 10×10×10 = 875 T's (one removed from 875 for source)
125 H's
B- 999 total

Start 1:26 pm 10 min count

clicks	end	6394.6	2314.9
	start	6220.0	1866.0
counts 64×		174.6	448.9

Start 1:38 pm 10 min count

clicks	end	6561.9	2766.4
	start	6395.0	2315.0
counts 64×		166.9	451.4

Average 64× 17.07 = 1092 c/m Average 64× 4501 = 2880

⑤ Removed front, top, right side, leaving 9×9×9 array

right side -	100 T's	no H's	(10×10)
front	65 T's	25 H's	(9×10)
top	61 T's	20 H's	(9×9)
	226 T's	45 H's	

leaves 648 T's 80 H's = 728 total

Start 2:27 10 min. count

clicks	end	6880.9	3603.7
	start	6756.0	3302.0
counts 64×		134.9	301.7

Start 2:40 10 min. count

clicks	end	7009.3	3909.3
	start	6881.0	3604.0
counts 64×		128.3	305.3

Average 64× 13.21 = 846 Average 64× 303.5 = 1940

66 4/23/46

10×10×10½ cavity Source in center

B-1 L-1

start 3[18] [20]15 min count.

	B-1	L-1
clicks end	7141.1	4227.0
start	~~7009.0~~ 7014.0	~~2909.0~~ 3922.0
	127.1	305.0
c/m =	64 × 6.350 = 406	64 × 15.250 = 976

Assume that c/m same for each cavity - range is 11×11×11 to 9×9×9, above test is on average.

Multiplication and 10× reciprocal multiplication vs no. of T cubes.

	(counter B-1) c/m		Kq·25
$\frac{2853}{406} = 7.01$	1.42	1108	54.0
$\frac{2086}{406} = 5.13$	1.95	1059	51.6
$\frac{1415}{406} = 3.48$	2.87	974	47.5
$\frac{1092}{406} = 2.69$	3.72	874	42.6
$\frac{846}{406} = 2.08$	4.80	648	31.6

4/23/46

counter L-1

Multiplication and reciprocal multiplication vs No of T cubes

$\frac{8282}{976} = 8.48$	1.18	1108	= 54.0 Kg 25
$\frac{6076}{976} = 6.22$	1.61	1059	= 51.6
$\frac{3960}{976} = 4.06$	2.46	974	= 47.5
$\frac{2880}{976} = 2.95$	3.39	874	= 42.6
$\frac{1940}{976} = 1.99$	5.03	648	31.6

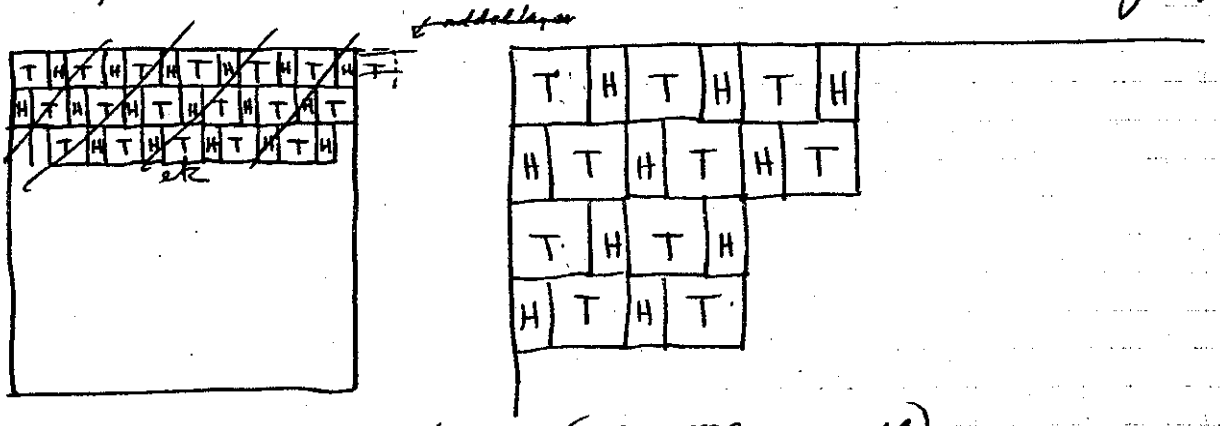
Extrapolations B-1 1235
L-1 1225 average 1230 T cubes.

Point:
Estimate of critical mass of cubical array with $\frac{H}{I} = \frac{1}{7}$, completely tamped by extrapolation of reciprocal multiplication, is $1230 \times .051 = 63.0$ kg.

If a 20% inhomogeneity correction were made, M_c would be 50.3 kg.

4/23/46

assembled cubical array basically 9×9×9, with $\frac{H}{T} = \frac{1/2}{1}$. Trial 1 not critical full tamping



Trial 2 added layer 9×9 to right side (viewed from south) composed of 1:1 H/T. Assume that half of H cubes are used as moderator, half as tamper. Added layer has thus 41 T's 40 half H's (= 20 full H's).

	T's	½ H's	H's	total
Array thus	486	486	243	
	+ 41	40	20	
	527	526	263	790

Critical with ~ full tamping.

Point: Critical mass of cubical array with $\frac{H}{T} = \frac{1/2}{1}$, fully tamped
= 527 × .051 = 26.9 kg

Ratio, mass $\frac{H/T = 1/2}{H/H_1 = 1/2/1} = \frac{602}{527} = 1.14$ = effect of inhomogeneity

4/23/46 ~~22~~
24

assembled cubical array — 10×10×10 with $H/T = \frac{1}{2}$

1st layer & 4th layer.

T	T	H	T	T	H	T	T	H	T	T	H
T	H	T	T	H	T						
H	T	T	H	T							

Etc.

2nd layer

T	H	T	T	H	T	T	H	T	T	H	T
H	T	T	H	T	T						
T	T	H	T	T							

Etc

3rd layer

H	T	T	H	T	T	H	T	T	H	T	T
T	T	H	T	T							
T	H	T	T	H							

Etc.

10×10×10 array
Contains 800 T cubes
400 H cubes
(½ size).

Not critical when
1000% damped.

2nd trial: Added eleventh layer bringing
totals to 880 T cubes
440 H cubes (½ sized).

Not Critical with 100% damping.

4/24/46
3rd Trial -
Added (vertical) layer to front making
assembly 11" high
10" wide
11" deep

Containing 968 T cubes
484 H Cubes (½ size).

Not critical with 100% tamping.

4th Trial -

Added 5/11 vertical layer to right face - feeling
out face with CHx tamper - (5 rows filled in from bottom).
This new layer contains 37 green cubes and 18 ½ size white cube

Total: 1005 T cubes
502 H cubes (½ size).

Critical with 98% tamping.

5th Trial

Changed 5/11 vertical layer (See 4) to leave only 22 T's in layer

total: 990 T cubes
495 H cubes (½ size)

Critical with 98+% tamping

4/24/46

6th ~~critical~~ trial.

Removed 12 more cubes leaving 10.

total 978 TS
~~989~~ HS (half size)

Critical with 99% tamping

7th Trial – 10 DG 7/14/46

Removed all (2), but left a side of polyethylene to check whether polyethylene is better tamper than paraffin. Slightly more reactive than trial 3, but still not critical

Point

Best estimate of critical mass of cubical array containing $\frac{H}{1} = \frac{1/2}{2} = \frac{1}{4}$ completely tamped = 970 TS × .051 = ~~50~~ 49.5 kg

$\frac{N_H}{N_a} = \frac{9.36}{4} = 2.34$

72
4/24/46

Assembled cube $\frac{H}{1} = \frac{7}{1}$

125 T's
875 H's
1000

top layer of H's missing however. assume tamper will act as moderator.

∴ 125 T's
715 H's
900 = 10×10×9

Trial 1

Not near critical

Trial 2

added 25 T's on right side as viewed from front; 65 H's = 90 total
30 T's on front face. 69 H's = 99 total
121 H's = 121 total

added ~~12 T + H~~ to top

~~Array contains 180 T's actually~~
~~999 H's~~
~~1089 total = 11×11×9~~

~~Array contains 180 T's~~
~~1260 H's theoretically~~
~~1440 total = 12×12×10~~

Array contains 180 T's } actually
1030 H's
1210 total = 11×11×10

Array contains 180 } theoretically
1260
1490 total = 12×12×10

Not critical

Trial 3

added layer of (85)(36) T+H, one of 121 H only to top.

Array contains 216 T's, } actually
1236 H's
1452 total = 11×11×12

216 T's } theoretically
1512 H's
1728 total = 12×12×12

Critical with 95% tamping

4/24/46

Trial 4 Removed 20 T cubes out of 30 from front face, replaced with Hs.

array contains 196 T cubes } actually
1256 H " }
1452 = 11×11×12

196 T
1372 H } theoretically
1568 ≅ 11.6 on a side.

Not critical with full tamping

Trial 5 added 4 T cubes.

array now 200 T's. actually
1252 Hs
1452 = 11×11×12

Not critical with full tamping

Trial 6 added 6 T cubes

array now 206 T's } actually
1246 Hs }
1452

206 } theoretically
1442
1648

Critical

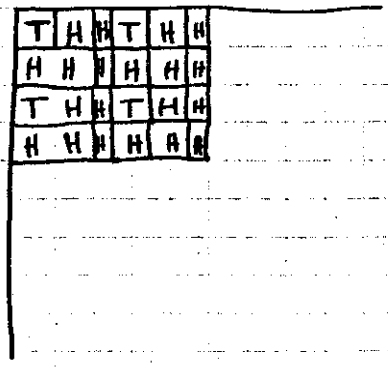
9.3
6.245

Point

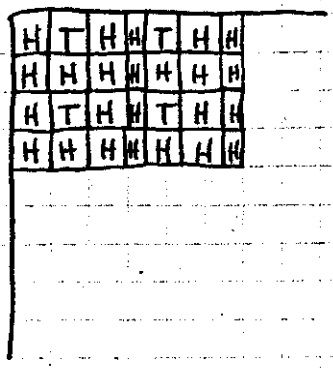
Best estimate of critical mass in cubical array, with $\frac{H}{T} = 7$
= 203 × .051 = 10.4 kg.

74 4/28/46 ~~5~~

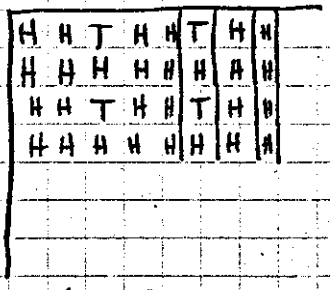
Assembled $\frac{4}{1} = \frac{H}{T}$. based 12x12x12 array



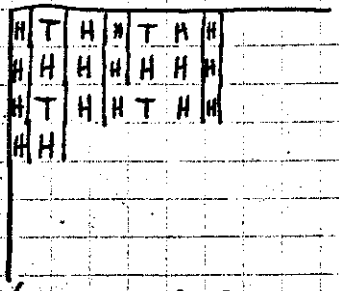
114H's, 30T's layer 1 = 6 = 11



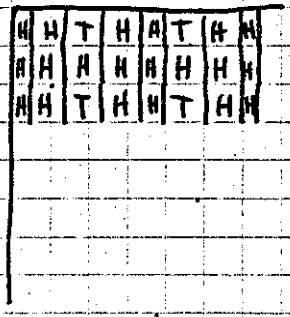
114H's, 30T's layer 2 = 7 = 12



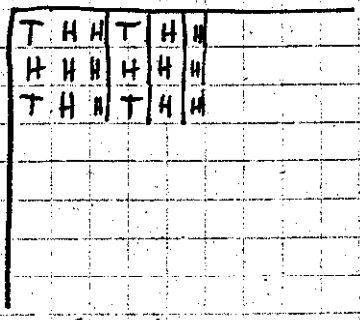
120H's, 24T's layer 3 = 8



114H's, 30T's layer 4 = 9



120H's, 24T's. layer 5 = 10



layer 6 = layer 1

total in 12x12x12 array	T's	H's	total T+H
	30 × 8 = 240	114 × 8 912	
	24 × 4 = 96	120 × 4 = 480	
	336	1392	1728

4/28/46

Trial 1 Built only 9 high to start, due to reactivity
Critical with 20% tamping

1044 H's
252 T's
1296 total = 9×12×12

Trial 2: took off two front faces, first all white and ~~2 white~~,

9×12 = 108 H's 0 T's
66 H's 42
174 H's 42 T's

Array now 210 T's
870 H's
1080 total = 12×10×9

Critical with 60% tamping.

Trial 3 Removed 10 T cubes from each end, total of 20
on one end, pulled greens, substituted half whites, removing 9×10 half whites, reducing length by ½ inch.
on other end, substitutes full whites for greens, no change in length.

Array now 190 T's
845 H's
1035 total = 9×10×11½

could consider that one side has ½" of tamping 9×10 = 45 H's

Critical with 85% tamping.

Trial 4 Removed 10 T cubes from each end, total of 20 - Effectively shortened one end 1"; other none.

Array now 170 T's
775 H's
945 = 9×10×10½

could consider that one side 9×10 has 1" of tamping

Critical with 99% tamping.

4/24/46

Trial 5 Removed 4 Ts from end, substituted full Hs.

Array 166 Ts
779 Hs
945 total

Could still assume one side has 1" of tamping.

Not quite critical

Point

Best estimate of critical mass in cubical arrangement at $\frac{H}{T} = \frac{4}{1}$

$= 168 \times .051 = 8.6$ kg of T. Dimensions $9 \times 10 \times 10\frac{1}{2}$, 777 Hs

$\frac{N_H}{N_U} = 375$

Numbers of H cubes on hand

652 $\frac{1}{2}$ size ~ 326 whole cubes

947 full size

total 1273 whole.

4/26/46

$\left.\begin{matrix} 34 \\ 59 \end{matrix}\right\}$ full size

1366

4/25/46 25½ (a)

assembled parallelepiped $\frac{H}{T} = \frac{2}{1}$ with cross-section 6×6.

(T = 198 H = 396 went critical, average side 8.5
total = 594

If same mass 6×6 went critical it would be $\frac{594}{36} = 16\frac{1}{2}$ long.
If same mass were put in array three times the short side, the latter would be
$\sqrt[3]{\frac{594}{3}} = \sqrt{198} = 5.82$ long, the long side would be 17.5)

Trial 1 array 6×6×20 = 720; 240 T's, 480 H's.

layer 1 = 4, 2 = 5, 3 = 6

not critical with full tamping – little multiplication, if any.

Trial 2 array 6×6×29 = 1044, 348 T's, 696 H's

not critical with full tamping – some multiplication.

Trial 3 array 6×6×53 = 1908, 636 T's, 1272 H (actual length 53½")

not critical with full tamping.

Mass of T = 636 × .051 = 32.5
Compare with cubical 198 × .051 = 10.1 } ratio 3.2

Point:
Assembly in rectangular parallelopiped form, 53 cubes long, 6×6 cubes cross section, $\frac{H}{T} = \frac{2}{1}$ does not go critical with full tamping.

Mass of T = 636 × .051 = 32.5 Kg, 3.2 times the mass that went critical in cubical form, i.e. length also 3.2 times that it would be if the previous mass were put in 6×6 array.

78 4/28/46 76(b)

Trial 1 Assembled 6×7×20 at $\frac{H}{T} = \frac{2}{1}$

Critical, 99% tamping. Each layer along length has 14 T's, 28 H's

total array 280 T's, 560 H's, 840 = 6×7×20.

Trial 2 Removed one layer of 14 T's, 28 H's, now 6×7×19

total array 266 T's, 532 H's, 798 = 6×7×19

$\frac{594}{756} = \frac{594}{42}$ = 14 length of unit with same mass that went critical.

Critical about same tamping

Trial 3 Removed another layer of 14 T's, 28 H's, now 6×7×18

total array 252 T's, 504 H's, 756 = 6×7×18

Not quite critical

assume 3 more cubes would have gone critical ie 255 T's, 510 H's, 765 = 6×7×18 1/5

Point

critical mass of parallelopiped 6×7 cross section, 18.2 long,

$\frac{H}{T} = \frac{2}{1}$ = 255 × .051 = 13.0 kg

$\frac{\text{Mass of T critical as cube}}{\text{Mass of T critical as 6×7 parallelopiped}} = \frac{255}{198} = 1.29$

4/29/46 25(c)

Trial Assembled 7×7×15 at $\frac{H}{T} = \frac{2}{1}$

Each Horiz. layer has 35 T's 70 H's; with 7 layers, 245 T's, 490 H's
total 735

Critical with about 97% tamping.

trial 2 Removed 16 T's, 33 H's ie one layer, now

7×7×14 229 T's, 457 H's
total 686

Not quite critical

Trial 3 added 4 T's, filled with Polyethylene to make complete layer

7×7×14¼ 233 T's 466 H's total 699

Critical with almost complete tamping

Point

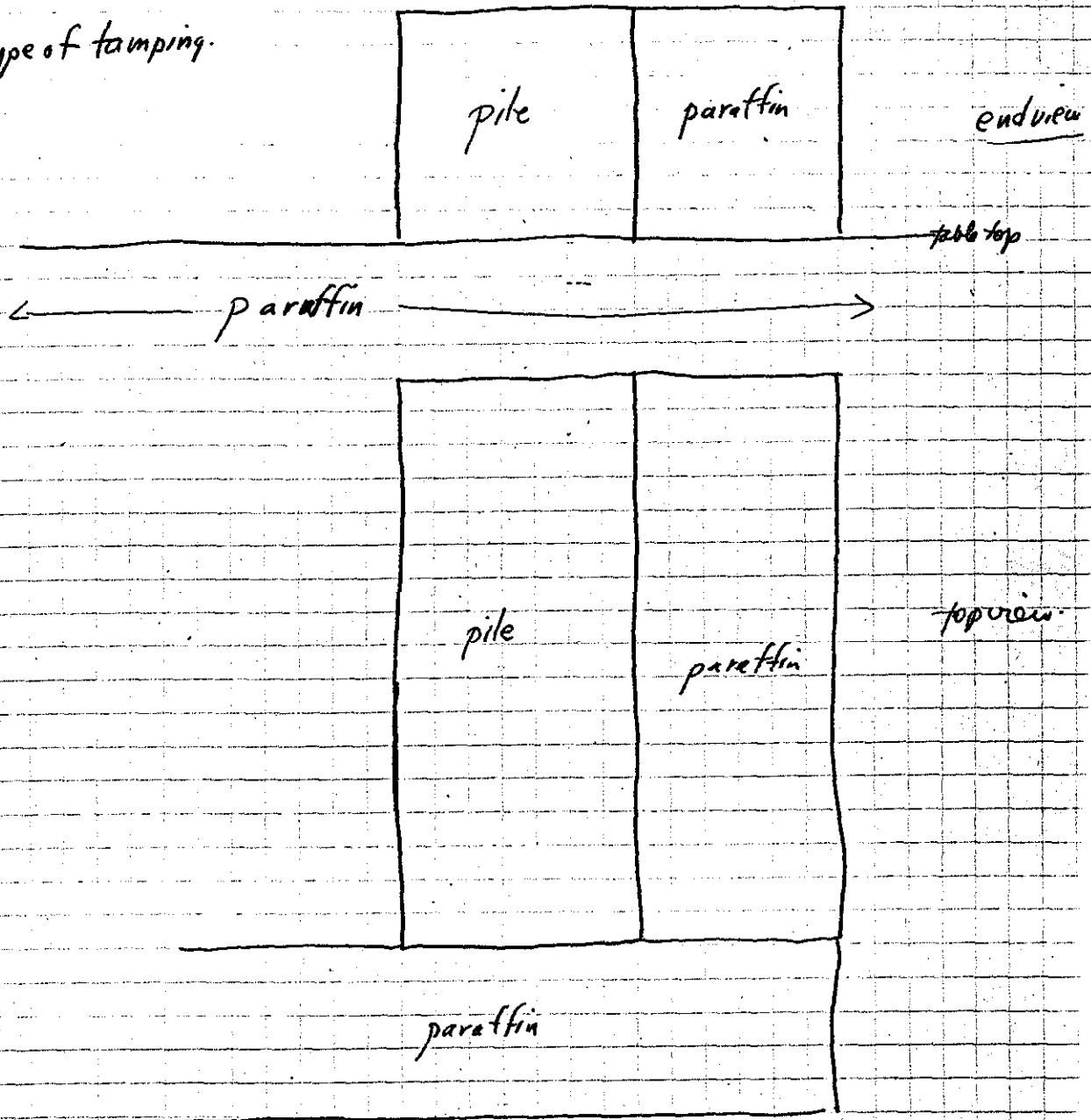
Best estimate of critical mass in rectangular parallelopiped arrangement, cross-section 7×7, length 14¼, $\frac{H}{T} = \frac{2}{1}$ = 231 x .051 = 11.8 kg.

4/26/46
4/29/46

Added more layers to previous array to obtain qualitative idea of effect on critical mass of half-tamping. ~~N~~ $\frac{H}{T} = \frac{2}{1}$

trial
Added 6 more layers – Array now 7x7x20

type of tamping.



not critical

4/24/46

Trial 2 Added 10 more layers, now 7x7x30 = 1470
490 Ts, 9804's

not critical · little multiplication ·

Comment: Tamping of half of array probably causes an increase of critical mass, in this form of a factor of ~~1~~. 5.

Note that this is not true for cubical arrays – see p.75:

60% tamping critical with 210 Ts,
100% tamping critical with 168 Ts } factor of 1.25

82 4/26/46 26/1

Density experiment T:H:A = 1:1:~~6~~ 1/2

Expected configuration

~~$T_c = \left(\frac{\frac{1}{2}}{\frac{1}{9}}\right)^{1.6} T_0 = 2^{16} T_0 = 3.03 T_0 = 303 \times 324 = 983$~~

~~total no of "cubes" = 983 × 4 = 3930 ≃ 15.8 or 16 on a side~~

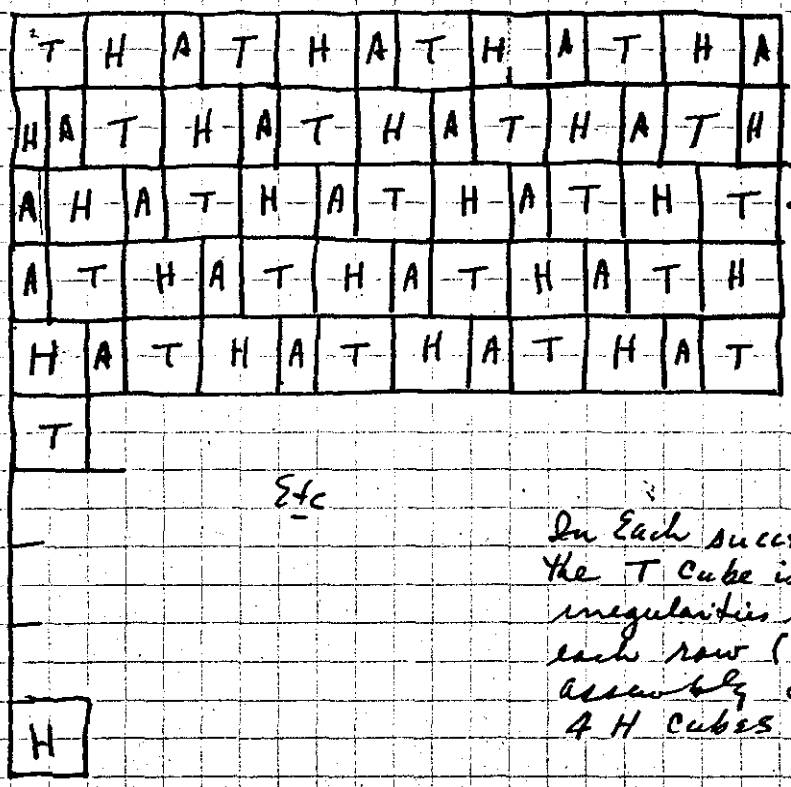
$\frac{M_1}{M_2} = \left(\frac{D_2}{D_1}\right)^{1.6}$ { { 1T:1H:0A ≡ ρ=1, M_c = ~~342~~ 324 T Cubes
{ 1T:1H:½A ≡ ρ=0.8 $M_c = M_1$

$M_1 = 342 \left(\frac{1}{0.8}\right)^{1.6} = 342 \times 1.44 =$ ~~492~~ 466 T Cubes.

Array which is Expected to go Critical: ~~492 T~~ ~~492 H~~ ~~492 ½" air spaces~~ ~~1230 in³ ≃~~

466 T
466 H
466 ½" air spaces -
1165 in³. ≃ 10×10×11+.

4/26/46



Etc

1st layer contains
~~20T, 20H, 10A~~
40 T, 40 H, 20A

irregularity

Each rows contain al suppos

In Each successive layer (horizontal) the T Cube is set 1" to right — irregularities excepted. Therefore each row (left-right) in the assembly contains 4 T and 4 H cubes —

Trial 1. Original array. 10x10x10 = 400 T
400 H
200 A
1000 = 10x10x10

Actual dimensions
$10\frac{1}{8} \times 9\frac{15}{16} \times 10\frac{1}{16}$

Not critical.

Trial 2 added another layer. 10x10x11 = 440 T
440 H
220 A
1100 = 10x10x11

not critical

Trial 3 added 20 more T cubes on top = 460 T
460 H
230 A
1150 = $10 \times 10 \times 11\frac{1}{2}$

Not quite critical.

4/26/46

Trial 4 added 8 more T's to top - 468 T
468 A
234 A
1170 total = 10×10×11.7

over-critical Measurement of dimensions

$12\frac{1}{8}$ high, $10\frac{1}{8}\times 10$; Effective height = $\frac{468}{480}\cdot 12\frac{1}{8}$ = ~~11.82~~ 11.7[illegible]

Point

Best estimate of critical mass in cubical arrangement - H:T:A = 1:1:½, tamp[illegible]
= 464 × .051 = 23.7 kg.

Calculation of "density factor" appearing in the relation

$$\frac{(M_c)_1}{(M_c)_2} = K\left(\frac{\rho_2}{\rho_1}\right)^X$$

1.430 ratio

$(M_c)_1$ = no. of cubes 1:1 ratio = ~~198~~ 324

$(M_c)_2$ = no. of cubes 1:1:½ ratio = 464

648 ~~324~~ ~~594~~ × 16.6 =	total volume ~~5380~~ ~~4800~~ 10750 cm³	Effect. # of cubes 648
~~H8~~ ($10\frac{1}{8}$ × 10 × 11.84 ~~11.72~~ × 16.387) =	~~22600~~ 19650 cm³ = 19 446 DC 7/25/45	~~12~~ ~~H8~~ ~~H84~~ 1171

~~"ρ_1" = no. of cubes per unit volume = $\frac{324\ \text{648 198}}{9860}$ = ~~.0658~~ .03285~~

~~"ρ_2" = no. of cubes per unit volume = $\frac{464}{22600\ 19650}$ = ~~.02050~~ .02360~~ ~~ratio = 1.602~~

~~$X = \frac{\log 1.602}{\log 1.430} = \frac{.20466}{.15534}$ =~~

$$\left(\frac{"\rho_1" = \frac{324}{648}}{"\rho_2" = \frac{464}{1184}}\right)^X = \frac{464}{324}$$

$X = \frac{\log 1.432}{\log 1.282} = \frac{.1559}{.1080} =$ ~~1.45~~ 1.54

4/26/46 27 Density: T:H:A = 1:2:1, 11×11 basic layer.

T's	H's	A's
3	6	2
3	5	3
3	5	3
2	6	3

THHATHHATHH	1=5=9
ATHHATHHATH	2=6=10
HATHHATHHAT	3=7=11
HHATHHATHHA	4=8
THHATHHATHH	5
ATHHATHHATH	6
HATHHATHHA	7
HHATHHATHHA	8
THHATHHATHH	9
ATHHATHHATH	10
HATHHATHHAT	11

aluminium 0.0125" between each layer.

layer 1 - T's 3×3=9, 3×3=9, 3×3=9, 2×2=4 → 31
H's 6×3=18, 5×3=15, 5×3=15, 6×2=12 → 60
A's 2×3=6, 3×8=24 → 30

layer 2 T's 30 H's 60 A's 31

layer 3 T's 30 H's 61 A's 30

layer 4 T's 30 H's 61 A's 30

Repeat after this:
1=5=9
2=6=10
3=7=11
4=8=12

TRIAL 1 11×11×11 not critical T's 333 H's 665 A's 333 Total 1331

trial 2 11×11×12 critical T's 363 H's 667 726 A's 363 Total 1452

actual dimensions. $12\frac{3}{8} \times 11\frac{7}{16} \times 11\frac{1}{8}$ = 1523 m³ = 2495 cc
corresponds to no of cube spaces = 1503

4/26/46

Calculation of density factor

$$\left(\frac{\frac{198}{\cancel{208}}}{\frac{\cancel{534}}{624}}\right)^{x} = \frac{363}{363} = \frac{\cancel{208}}{198}$$

$$x = \frac{\log 1.745}{\log 1.380} = \frac{.2418}{.13988} = 1.73$$

$$x = \frac{\log 1.833}{\log 1.380} = \frac{.2632}{.13988} = 1.88$$

First trial of T:H:A = 1:2:$\frac{1}{2}$ fell down. No aluminum sheets between layers. array came apart, fortunately, rather than together. Later developments see p 89, indicated that probably would not have gone critical anyway.

4/27/46 [illegible]

Stacked T:H:A = 1:2:$\frac{1}{2}$ Basically 10×10.

T	H	H	A	T	H	H	A	T	H	H
H	A	T	H	H	A	T	H	H	A	T	H
H	H	A	T	H	H	A	T	H	H	A	T
A	H	H	A	T	H	H	A	T	H	H	A
A	T	H	H	A	T	H	H	A	T	H	H
H	A	T	H	H	A	T	H	H	A	T	H
H	H	A	T	H	H	A	T	H	H	A	T
T	H	H	A	T	H	H	A	T	H	H
H	A	T	H	H	A	T	H	H	A	T	H
H	H	A	T	H	H	A	T	H	H	A	T

	T	H	A
1 = 8	3	6	1
2 = 9	3	5½	1½
3 = 10	3	5½	1½
4	2	6	2
5	3	5½	1½
6	3	5½	1½
7	3	6	1
8			
9			
10			

layer 1

layer 1
layer 2 composed of rows of type 2,3,4,5,6,7,8,9,10,1
layer 3
layer 4
layer 5 eh.
layer 6
layer 7
layer 8
layer 9
layer 10
total array 6×10×10

T	H	A
29	57	14
28	57	15
28	57	15
28	57	15
29	57	14
29	57½	13½
29	57½	13½
29	57	14
28	57	15
28	57	15
285	571	144

1000

Aluminum between each 2 layers

Critical 93% tamped

88

4/27/46

Trial 2

Removed 14 T's from top layer. Filled in with white cubes as tamper.

Array now 285-14 = 271 T's Critical 96% tamping

Trial 3

Removed 4 T's from top layer

Array now 271-4 = 267 T's Not critical, full tamping

actual dimensions — $10\,1/32 \times 10\,3/32 \times 10\,1/8$

effective dimensions $10\,1/32 \times 10\,3/32 \times \frac{269}{285}(\text{height}) \cdot 10\,\tfrac{1}{8} = 968$ Cubic inches

$\quad = 15863$ cc

Point

Best estimate of critical mass of cubical array with

$H:T:A = 2:1:\frac{1}{2} = 269 \times .051 = 13.7$ kg. completely tamped

Determination of density dependence - Comparison with

2H : 1T : 0A which was critical with 198 T Cubes:

$$M_1/M_2 = \left(\rho_2/\rho_1\right)^x$$

$$x = \frac{\log M_1/M_2}{\log \rho_2/\rho_1}$$

$$= \frac{\log 1.358}{\log 1.187}$$

$$= \frac{0.1329}{0.0745} = 1.78$$

$M_1 = 269$

$M_2 = 198$

$\rho_1 = 269/958 = 0.281$

$\rho_2 = 1/3$

4/29/46 29/1

Untamped H/T = 2/1

Removed paraffin from table, assembled 12×12 layers.

Critical with 10 high, 12 wide, 11 (+23 T's, 46 H's) deep

∴ 10×12×11 23/40 = 1389 total, 463 T's, 926 H's

Point

Critical mass of T in cubical array, H/T = 2/1, untamped

463 x .051 = 23.7 kg.

Ratio $\frac{\text{untamped}}{\text{tamped}} = \frac{463}{198} = 2.34$

90 4/28/46

30 / Untamped H/T = 1:1

assembled cubical array 12x12x11 + 52 T's / 53 H's

844 T's
845 H's
1689 total ✓

Critical

finis

Point:

critical mass of T in cubical array, H/T = 1/1, untamped

844 x .051 = 43.2 kg.

Ratio $\frac{\text{untamped}}{\text{tamped}} = \frac{844}{324} = 2.60$

4/28/46

Dimensions of 1" X 1" X 1/2" polythene cubes —
Ten cubes randomly selected.

Cube #	l in	w in	h in	Volume in³	Volume cc	mass gm	ρ gm/cc
1	1.006	1.007	0.502	0.509	8.34	7.61	0.912
2	1.007	1.006	0	07 9	31	60	15
3	5	6	1	07	31	60	15
4	8	8	2	10	38	63	11
5	7	5	2	08	32	61	15
6	7	6	3	10	38	61	08
7	7	7	2	09	34	62	14
8	6	7	3	10	38	61	08
9	6	4	2	08	32	60	13
10	7	5	2	08	32	59	12
Ave	1.0065	1.0062	0.5049	0.509 in³	8.34 cc	7.61 gm	0.912 gm/cc

Summary of Properties of Materials

Green Salt Cubes –

Average density – 4.74 gm/cm³
" height – 1.003"
" length – 1.004"
" width – 1.003"
" volume – 1.010 in³
– 16.55 cm³
" mass – 78.44 gm of UCF_4

T content of each cube – 78.44 × 0.65218 = 51.16 gm
25 " " " " 51.16 × 0.953 = 48.76 gm.
F " " " " = 24.71 "
C " " " " = 2.57 "

Polyethylene Cubes:

	1"x1"x1"	1x1x½"
Average density	0.909 gm/cm³	0.912 gm/cc
" volume	1.015 in³	0.509 in³
" "	16.62 cc	8.34 cc
" mass	15.114 gm.	7.61 gm.

Summary of Critical Assembly Experiment

(1) Estimation of Critical mass of UCF_6 from the evaluation of the neutron multiplication produced by various sized untamped cubical assemblies having the neutron source at the center (approximately).

Size of Assembly	Counts/min Counter 4	3	Multiplication (M) 4	3	$10 M^{-1}$ 4	3
10×10×10 = 1000 cubes = 48.8 Kg 25	5004.8	1484.8	2.03	2.46	4.93	4.05
9×9×9 = 729 = 35.6 Kg 25	4428.8	1203.2	1.79	2.00	5.58	5.00
8×8×8 = 512 = 25.0 Kg 25	3916.8	966.4	1.58	1.61	6.32	6.23
0	2470.4	601.6				

(See page 10, 4/9/46, for data).

Conclusion:* An extrapolation of the $(M)^{-1}$ – assembly size plot gives a 17.1" (edge) cube as that which will be critical with anti-dilution with Hydrogenous material and untamped. The value arises from the #4 counter data (#3 counter gives 13.6"). The former is weighted and a 17×17×17" assembly is the best estimate. This is equivalent to 385 Kg of UCF_6, 251 Kg of U and 239 Kg of 25. (7844 cubes)

1a) Attempt at direct evaluation of critical mass of undiluted (no moderator) UCF_6:

1099 / 1100 UCF_6 cubes were stacked in an array 11×10×10" (Po-Be n source was in center of array) and fully tamped then multiplication was ca. 2.3×. 1099 cubes contain 86.2 Kg UCF_6, 56.2 Kg U, 53.6 Kg 25.

* Extrapolation of least squares line through M^{-1} – Kg 25 plot gives 133.3 Kg 25 as unmoderated, untamped critical mass.

(2) Estimation of Critical mass of UCF_6 (fully temped) from the evaluation of the neutron multiplication produced by various sized paraffin temped cubical assemblies having the neutron source at the center (approximately). Data from Counter 4.

Size of Assembly.	Counts/min with UCF_6	Counts/min "0"	Multiplication M	$10\ M^{-1}$
10×10×10 = 1000 cubes = 48.8 Kg 25	488	253	1.93	5.18
9×9×9 = 729 = 35.6 Kg 25	406	245 by interpolation	1.66	6.02
8×8×8 = 512 = 25.0 Kg 25	313.2	238	1.31	7.62

See pg. 13-15, 4/5/46 for data.

Conclusion: Extrapolation of the M^{-1} – assembly size plot gives a cubical assembly 14×14×14" as that which when 100% temped would be critical. (No deuteron with H_2). This is (2744 cubes) equivalent to 215 Kg UCF_6, 140 Kg U and 134 Kg 25.

Extrapolation of least squares solution of M^{-1} – Kg 25 plot give 98.7 Kg as critical mass of unmoderated fully temped UCF_6 array.

See pg 130 for revised experiment.

3) To determine critical mass of undiluted, fully tamped UCF_6 from extrapolation of critical masses assembled at various dilutions, all 100% tamped.

A. 1:1 ratio of $UCF_6 - CH_2$ Cubes. (packed in plywood box - 1/4" plywood + 1/16" air between arrays and tamper).

a. 10x10x10 = 1000 cubes (total) Critical at 85% tamping. pg. 19
b. 10x10x9 = 900 " " " " 90% " 18
c. 9x9x9 = 729 " (365 UCF_6 + 364 CH_2) critical with 95% tamping. 19
d. 9x9x8+ = 347 UCF_6 + 346 CH_2 cubes. " " 98% " 20
e. 9x9x8+ = 338 UCF_6 + 337 CH_2 cubes was slightly below critical with 100% tamping 21

Best estimate of critical assembly: one containing 342 UCF_6 cubes and 100% tamped. 342 UCF_6 cubes contain 26.8 Kg of UCF_6, 17.5 Kg of U, and 16.7 Kg of x.

B. 1:2 ratio of $UCF_6 - CH_2$ cubes. (See A above for data on plywood box)

a. 9x9x9 = 243 UCF_6 + 486 CH_2 critical with 85% tamping.
b. 9x9x8 = 216 UCF_6 + 432 CH_2 " " 89% "
c. 9x8x8 = 192 + 384 near " " 100% "
d. 9x8x8+ = 204 + 408 near " " " "
e. 9x8x8+ = 207 + 414 " " " " "
f 9x8x8+ = 210 + 420 critical " 96% "
g 9x8x8+ = 208 + 416 " " 98% "

Best estimate of critical assembly: one containing 208 UCF_6 cubes 416 CH_2 cubes and fully tamped. 208 UCF_6 cubes contain 16.3 Kg of UCF_6, 10.6 Kg U, 10.1 Kg 25.

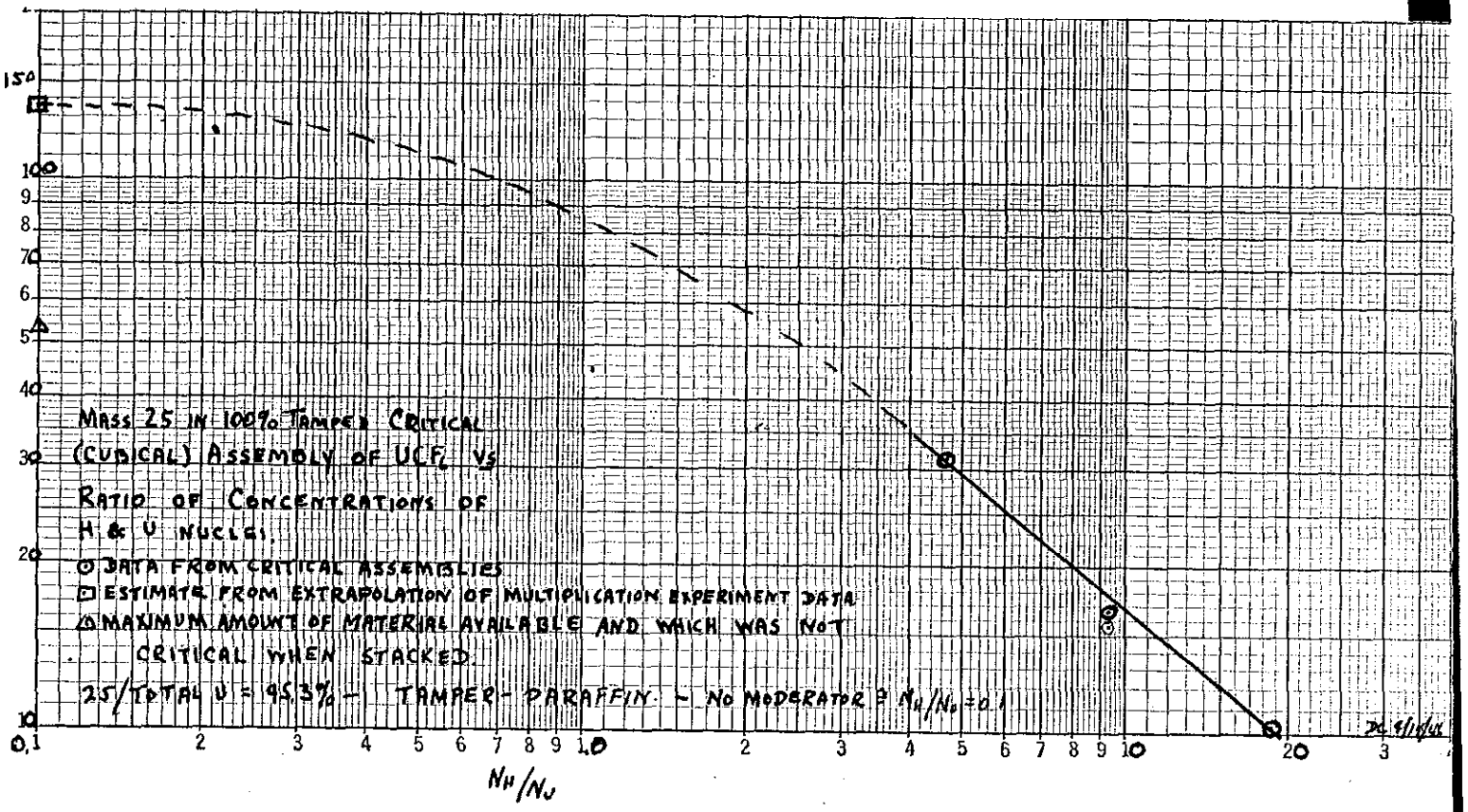
KEUFFEL & ESSER CO. N. Y. N
Logarithmic, 3 x 5 Cyc

r% Tamping. 19
% " 20
l with 100% tamper 21

342 UCF_4
material

208 UCF_4 cubes
16.3 Kg

Kg
25



3 cont).

C. 2:1 ratio of UCF_6 - CH_2 cubes (See A above re- plywood box -

a. 10×10×10	= 666 UCF_6 cubes	+ 334 CH_2 cubes	critical at	98% temp wtg.	~ 29
b. 10×10×9+	= 662	+ 338	"	" " "	29.
c. 10×10×9+ (10:1)	= 646	+ 364	"	" " 100%	" 30

100% tamped cubical array containg 646 UCF_6 cubes was critical - 646 cubes contain 50.7 Kg UCF_6, 33.0 Kg U, 31.5 Kg 25.

To determine ratio of number of H_2 atoms to U atoms assuming polyethylene is $CH_{1.87}$:

$$N_H/N_U = \frac{1.87(1.008)}{12.01+1.87(1.008)} \Big/ \frac{238.15\,m}{1.008} = \frac{1.5114}{m}$$ where m is mass of H atom.

		N_H/N_{25}
= 9.35	when buildup ratio is	1:1 — 9.80
= 18.70	" "	2:1 — 19.60
= 4.68	" "	1:2. — 4.90

~~Plot of N_H/N_U vs mass of 25 extrapolates to 110-140 Kg 25 at zero deviation. This is in agreement with the value determined from the extrapolation of the multiplication data, (pg 121) of the mass of 100% tamped UCF_6 25 in 100% tamped UCF_6 (in cubical array) to give criticality.~~

4) To test the effect on the critical mass of interposing cadmium between the UCF_6 - CH_2 array and the paraffin tamper. UCF_6 - CH_2 cubes in 1:1 ratio -

Shell Cd - 0.016" ("1/64") thick - equivalent to 0.356 gm/cm^2 -

a. 11x11x11 = 666 UCF_6 + 665 CH_2	was	critical	at 65% tamping	32
b. 11x11x10 = 605 " + 605 "	not	"	" 100% "	.
c. 11x11x10+ = 627 " + 627 "	was	"	" 92% "	32
d. 11x11x10+ = 616 " + 616 "	not	"	" 100% "	38
e. 11x11x10+ = 622 " + 621 "	was	"	" 95% "	34

Best estimate: Critical array containing 619 UCF_6 cubes in 1:1 ratio with CH_2 and 100% tamped would be critical. 619 cubes UCF_6 contains 48.55 Kg UCF_6, 31.7 Kg U, 30.2 Kg 25.

The Cd increased the critical mass by 80%. ($30.2/16.7 = 1.8$)

5)a) To test the effect on the Critical mass of interposing boron between the active material and the paraffin jacket. Active material is 1:1 array of UCF_6 and CH_2 cubes.

(~~Case~~) Boron impregnated plastic: 3/4" thick containing 0.124 gm B/cm³ as $Na_2B_4O_7 \cdot 10H_2O$ (See pg 28+34).

a) 11 x 11 x 11 = 666 CUF_6 + 665 CH_2 cubes critical at <15% jacketing pg 35
b) 11 x 11 x 10 = 605 " +605 " " " " 80% " 35
c) 11 x 11 x 9 = 545 " +544 " " not " " 100% " 35
d) 11 x 11 x 9+ = 578 " +577 " " " " " " 35
e) 11 x 11 x 9+ = 589 " +588 " " " " 98% " 36

Best estimate: Cubical array containing 583 UCF_6 cubes in a 1:1 ratio with CH_2 cubes and 100% jacket would be critical. 583 UCF_6 cubes contain 45.7 Kg UCF_6, 29.8 Kg. U, 28.4 Kg 25.

Boron in this form increase the Critical mass by only 28.4/16.7 = 1.7. The plastic acts like a jacket.

5b. Retest of effect of interposing boron between tamper and 1:1 (1 green cube : 1 white cube) moderated assembly:

Boron as B_4C 60 mesh powder in double walled box. Inner wall - brass; outer wall - plywood. 3/4" thick layer of B_4C equivalent to $\frac{2.45}{1.14}$ gm/cm² of B. (pg 40)

When fully tamped, every was critical with 651 UCF_6 cubes and 651 CH- cubes.

651 Cubes $UCF_6 \doteq 31.7$ Kg ±5.

31.7/16.7 = 1.9, is the ratio of masses of 1:1 critical assemblies with and without boron.

6.) To test the effect of density of array on its critical mass -

Method: Stacked green, white and black (air) cubes in 1:1:1 array, each layer separated by 12.5 mil Al sheet, stacked in 4 sided plywood box. (pg 37)

Results: ① $12\frac{1}{8}$" x $13\frac{1}{8}$" x $13\frac{1}{4}$" (overall) array was critical when fully tamped. This contained, in addition to the aluminum, 676 T cubes, 676 CH cubes and 676 air spaces.

676 T cubes Contain 33.0 Kg 25.
Overall density 1.48 gm/cc

[Conclusions: Since 16.7 Kg 25 was critical in a closely packed 1/1 array (density 2.28 gm/cc) these data show $CM \propto \rho^{-1.6}$ —]

② Array: 1T:1H:½A critical when containing 464 T cubes = 22.6 Kg 25
Comparison of these data with 1T:1H:0A array (Exp 3'a). pg 83.
gives $M \propto (\rho)^{-1.54}$

③ Array: 1T:2H:1A critical when containing 363 T cubes = 17.7 Kg 25. pg
Comparison with 1T:2H:0A array (Exp 3'b)
gives $M \propto (\rho)^{-1.86}$ pg 85

④ Array: 1T:2H:½A critical when containing 269 T cubes = 13.1 Kg 25
Comparison with 1T:2H:0A array gives $M \propto (\rho)^{-1.98}$ pg 87

7) To examine criticality of 1 green cube / 1 white cube array when stacked in the form of a parallelopiped.

Method: 1:1 assembly of green and white cubes arranged in parallelopipeds so they were critical when fully tamped. No plywood box.

Results: ① 7" x 7" x 16 1/2" parallelopiped was critical—

Contained 394 T cubes = 19.2 Kg 25 (pg 42)
396 H cubes

② 6" x 7" x 27" critical when fully tamped

Contained 567 T cubes = 27.6 Kg 25 (pg 45)
567 H cubes

③ Exp. 3'a (pg 130) shows 9x9x8 to be critical -

Contained 324 T cubes. = 15.8 Kg 25

Conclusion: Application of rule of thumb for spheres & and cylinders to parallelopipeds says if 9x9x9 is critical 6.3 x 6.3 would be critical at infinite length. This is shown to be approximately correct. (see pg 43).

7a) Same experiment but with 1T / 2H Cube array $N_H/N_0 = 18.7$

① Array 6" x 6" x 53" containing 636 T cubes = 31.0 Kg 25 was not critical with 100% tamping. pg 77

② Array 6 x 7 x 18.2 containing 255 T cubes = 12.4 Kg 25 was critical with 100% tamping. pg 78.

③ Array 7 x 7 x 14 1/4 containing 231 T cubes = 11.3 Kg 25 was critical with 100%. pg 79

Experiment 8) To examine effect of inhomogeneity on the critical mass of a moderated assembly of green and white cubes.

Method: The moderation of green cubes with white cubes can be kept constant ~~to~~ and the homogeneity varies by the dimensions of the basic unit stacked, i.e all cubes may be 1", or all 2" or the units may be 1" x 1" x 2" or 1" x 2" x 2". The first of these is ~~will~~ be called a 1:1 assembly, the next as 8:8, 2:2, 4:4, respectively. These four arrays were stacked to criticality freely ~~tamped~~.

Results: ① 1:1 – Critical ~~with~~ at 9 x 9 x 8 (1953).
with 324 T Cubes ≡ 15.8 Kg 25.

② ~~2:2~~ 4:4 – Critical at 9 x 9 x 8+ (1951)
containing 350 T Cubes ≡ 17.1 Kg T.

③ ~~4:4~~ 2:2 – Critical at 9 x 9 x 8+ (1949)
containing 334 T Cubes ≡ 16.3 Kg T.

④ 8:8 – Critical at 10 x 10 x 8+ (1947)
containing 412 T Cubes ≡ 20.1 Kg 25

Conclusions: Critical Mass	"Homogeneity"	Inhomogeneity factor
15.8	1:1	1
16.3	2:2	16.3/15.8 = 1.03
17.1	4:4	17.1/15.8 = 1.08
20.1	8:8	20.1/15.8 = 1.27

Further, these assemblies were stacked with no wooden boat as support and the 1:1 critical mass is significantly less than that given in Exp 3A, pg 122. Exp. 3 was then repeated.

5

Exp 3': To measure critical mass as function of amount of moderation by hydrogeneous material. (Repeat of Exp 3, pg 122 - the earlier stacking was done inside a plywood box which allowed an air gap between cubes and tamper as well as introduced some nitrogen).

Method: Stack various ratios of green & white cubes until array is critical - tamped.

Results: ⓐ 1 UCF_6 : 1 CH_2 - Critical at 9x9x8 containing 324 green cubes = 15.8 Kg 25 - (pg 53) $N_H/N_U = 9.35$

ⓑ 1 UCF_6 : 2 CH_2 - critical at 9x8x8½ containing 198 T cubes = 9.65 Kg 25 (pg 55) $N_H/N_0 = 18.7$

ⓒ 2 UCF_6 : 1 CH_2 - Critical at 10x10x9+ containing 602 T cubes = 29.4 Kg 25 (pg 56) $N_H/N_0 = 4.68$

[Conclusion - Above effect of plywood box increases critical mass by ca 5%.]

ⓓ 7 UF_6 : 1 CH_2 - Least squares solution of straight line through multiplication experiment data gives 61.7 Kg 25 (31.6 Kg point omitted). (pg 62) (7/1 array containing 1108 T cubes, 54.0 Kg 25 was not critical when fully tamped). $N_H/N_0 = 1.34$

ⓔ 1 UCF_6 : ½ CH_2 - Critical at 9x9x9+ containing 527 T cubes = 25.7 Kg 25. (Compare with ⓒ above $\frac{29.4}{25.7} = 1.14$). (pg 68) $N_H/N_0 = 4.68$

ⓕ 2 UCF_6 : ½ CH_2 - Critical at 11x11x10+ containing 970 T cubes = 47.3 Kg 25 (pg 69) $N_H/N_0 = 2.34$

ⓖ 3 UCF_6 : 7 CH_2 - Critical at [11x11x11+] containing 203 T cubes = 9.9 Kg 25 (pg 72) $N_H/N_U = 65.5$

(R) $1\ UCF_6 : 4\ CH_2$ - Critical at 9 x 10 x 10+ containing
168 T Cubes = 8.2 Kg 25 (pg 74) $NH/N_U = 37.4$

Experiment 9- To compare critical mass obtained from extrapolation of neutron multiplication experiment data with the value directly measured.

Method- Three cubical arrays (9x9x9, 8x8x8, 7x7x7) were stacked with green cube / white cube ratio = 2/1. Source was placed at center of each and count taken with and without active material present. M^{-1} — vs 25 mass plot was extrapolated to $M = \infty$ for CM value. (pg 58)

Results:

Array size	Kg 25	Counts/min Array boundary		M	10/M.
9x9x9	23.7	1410	281	5.02 ±	1.99
8x8x8	16.6	556	287	1.94	5.16
7x7x7	11.2	386	294	1.31	7.62

Least squares extrapolation of M^{-1} - mass 25 plot gives - 28.4 Kg 25 as critical mass.
29.1

Conclusion- This 28.4 Kg is to be compared with 29.4 Kg obtained by direct determination.

Experiment 10: To determine the critical mass of 25 in untamped assemblies of various moderation

Method: Stacked ① $1UCF_6 : 2CH_2$ and ② $1UCF_6 : 1CH_2$ assemblies until they became critical with no tamping.

Results ① $1UCF_6 : 2CH_2$ assembly was critical at 10 x 12 x 11+ containing 463 T Cubes = 22.6 Kg 25 — pg 89

② $1UCF_6 : 1CH_2$ assembly was critical at 12 x 12 x 11+ containing 844 T Cubes = 41.2 Kg 25 — pg 90

Ratio $\frac{CM^{25}\ \text{untamped}}{CM^{25}\ \text{tamped}} = \frac{463}{198} = 2.34$

$= \frac{844}{324} = 2.61$

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966
970
991
997

1007
1010
1028
1035
1036
1037

1097

58

980
51
98
490
4998

970
30
37

1005
15
990

180 Ts
57
1260
1440

775
40
65
61
907

970
351
497
485
4947

55
125
80
121
9
69

180
1447 =

11x9x16
11x11x9
11x11x

36 H
30 Ts 6 5 6×5=30 5×6=30 5-5-25 61

30 T's $\begin{array}{r} 6 \\ \times 5 \\ \hline 30 \end{array}$ $6 \times 5 = 30$ $5 \times 6 = 30$ 36 H $5 - 5 = 25$ $\begin{array}{r} 36 \\ 25 \\ \hline 61 \end{array}$

$\begin{array}{r} 783 \\ 652 \\ \hline 15666 \\ 13915 \\ 1698 \\ \hline 510516 \end{array}$

$\begin{array}{r} 16387 \\ 101 \\ \hline 16387 \\ 163870 \\ \hline 1655087 \end{array}$

$\begin{array}{r} 33 \\ 1655 \\ 473 \\ \hline 4965 \\ 11585 \\ 6620 \\ \hline 782815 \end{array}$