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LAMS - 451

[redacted]

December 6, 1946

This document contains 12 pages

SAFETY TEST FOR STORAGE OF PLUTONIUM-239 IN ANGLE-IRON FRAMES DESIGNED AT DP SITE

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Abstract

Twenty-one iron cylinders, each containing about 4.4 kg of 49 and held at the center of a cubical angle-iron framework 22" on a side, were closely stacked inside a mock concrete vault. It cannot be certain that any definite net multiplication resulting from the stacking was produced; in any event, it was certainly less than ten percent.

SAFETY TEST FOR STORAGE OF PLUTONIUM-239
IN ANGLE-IRON FRAMES DESIGNED AT DP SITE

A test has been carried out at Pajarito Canyon to determine the safety of storing Pu-239 buttons in iron cylinders held at the center of angle-iron frames as designed at DP Site. One of these angle-iron frames, together with an iron cylinder of 1/8" wall, designed to hold ten buttons of Pu-239, each weighing about 450 grams, is illustrated in Fig. 1. The weight of iron in each unit, including the frame and the cylinder, is about 35 pounds. Each button of Pu-239 is put into an aluminum jacket with 1/16" walls; after the ten buttons have been stacked in the iron cylinder, the cylinder is sealed and filled with argon.

The angle-iron frames are cubical in shape, 22" on a side. A mock vault was built to contain 27 of these frames in a cubical array. The "vault" consisted of a room of 6' x 6' x 6' inside dimensions. Three walls and the roof were made of concrete blocks 1' thick. The fourth wall was a section of the concrete wall of the building, with earth piled up against most of the outside. The floor was also of concrete. The "vault" containing the angle-iron frames filled with iron cylinders containing about 5 kg of normal uranium (see below) is shown in Figure 2. The fourth wall is not in place in this figure.

The neutron intensity during the test was monitored by five counters. Three of these consisted of U-235 fission chambers placed in various positions inside the "vault". For identification purposes, these were named pancake, ladle, and big pancake. The other two con[redacted]

baron proportional counters placed outside the vault. One of them, designated L-2, was about 50' away from the edge of the vault on the side shown in Fig. 2. The other counter, designated L-1, was somewhat closer—about six feet from the outer edge of the opposite wall. It was hoped that the distant counter would see the stack of material effectively as a point source. This was not realized, largely because of the different neutron scattering and absorbing conditions throughout the vault. In fact, measurements taken with a neutron source moved into each of the 27 frames indicated that the counting rate of the distant counter varied nearly by a factor of two: from 330 to 630 counts/minute.

The neutron source used throughout the experiment consisted of a polonium-beryllium urchin-type source, with an approximate yield of 5×10^7 neutrons/sec. The source was put into a small aluminum can which was hung so that the source was nearly touching the edge of an iron cylinder designed to hold the 49 near the center of its length. Two three-minute counts were taken on all five counters with the source in each of the 27 positions. The "pancake" varied from 210 to 530; the "ladle" from 230 to 425; the "big pancake" from 500 to 1000; and L-1 from 1330 to 4660, all in counts/minute. These measurements were all made with the 27 cans filled with about 5kg normal uranium. This test was made to calibrate the sensitivity of the detectors to neutrons coming from these 27 positions.

Various other tests were made before Pu-239 was put into the "vault". The neutron yields of the polonium beryllium source and of 4.6 kg of Pu-239 in one of the cans were compared. The latter was about 0.25%

of the former. This means that if twenty-one units should be added, the count could be expected to go up by about 5% owing to the addition (not multiplication) of neutrons.

It was found that the observed increase in counting rate when a cylinder containing 4.6 kg of Pu-239 was placed close to the source in place of one containing about 5 kg of normal uranium was about 10 or 15 percent. It was found that there was no increase in counting rate if the separation between source and 49 was greater than 25 cm. This was true whether the test was made inside or outside of the vault. No increase in the observed multiplication resulted from putting the source close to the 4.6 kg of Pu-239 inside a cubical concrete cavity 2' on a side, with concrete walls and roof 1' thick, the floor being also of concrete (the floor of the room). This test was made with the "big pancake" placed inside the cavity and with L-1 outside.

These preliminary measurements indicated that the interpretation of the results in the stacking measurement should be quite straightforward provided the tuballoy was a sufficiently good mock-up in its scattering and absorption of neutrons. If the counting rate should increase by more than 5% over that obtained with the source and 4.6 kg of Pu-239 placed adjacent to each other in the central position of the lattice, it could be interpreted as a multiplication due to the stacking.

The stacking measurements were begun by having the 4.6 kg of Pu-239 in the central position, with the source nearly touching the side of the can containing it, and with tuballoy in all other positions. Two three-minute counts were taken on all five counters with this configuration.

Then, one at a time, the tubalIoy in the nearest next neighbors was replaced with Pu-239. Only one person handled all of the Pu-239, and at least two people watched counters, observing the time for 10 clicks on the recorders, whenever any changes were being made. This process was carried out with the one wall removed from the "vault". Four of the frames, including the central frame, were removed from the vault whenever any additional Pu-239 was brought in, and the source was put in a fixed position inside the vault as the Pu-239 was introducted. After the nearest next neighbors to the central unit were all filled with Pu-239, no multiplication being observed, two units were filled at a time before the two three-minute counts were repeated. Whenever the four units that were removed were slowly replaced, the counting rate was carefully observed.

When all 21 units of Pu-239 supplied to us had been put into the "vault", the last concrete wall was slowly added. It consisted of concrete blocks $\frac{1}{2}$' x 1' x 2' in size. This wall had been previously added when only the source in its central position and 27 units of normal uranium were in the vault.

The configuration of Pu-239 in the completed stack is illustrated in Fig. 3. The designations B-1, B-2, etc., identify the Pu-239 as the various cans were marked at DF Site. It should be mentioned that a "mock man" consisting of about 260 lbs. of paraffin was placed in positions 8 and 17, replacing the frames in these positions, next to the open side of the vault. Two three-minute counts were also made with this parraffin in place, whenever any Pu-239 had been added to the stack. This was repeated until 19 units of Pu-239 were in the vault, with the one wall of the vault not in place.

The results of the experiment are tabulated below. The numbers give the number of clicks on the recorders occuring in a three minute interval. Scaling circuits with a scale of 64 were used with all of the counters.

An examination of the results indicated that one cannot be sure that any definite multiplication was observed; the slightly positive results could easily be due to uncertainties in the mock-up approximation. In any event, it appears that one can safely say that the multiplication certainly does not exceed ten percent.

It was a little surprising that the concrete walls apparently had no effect upon the multiplication. This would indicate that the Pu-239 in the containers does not "see" the neutrons scattered by the walls. We are planning a series of experiments to see if this is so. If most of the scattered neutrons are absorbed by the iron and aluminum surrounding the Pu-239, it indicates that the neutrons are thermalized; and one might increase this by lining the cans with cadmium.

One can certainly say that 21 of these frames containing on the average about 4.4 kg of Pu-239 in the iron cylinders and aluminum cans, can be safely stacked in any configuration with good concrete tamping surrounding the stack. It is recommended, however, that at least five sides of each frame be covered with a wire mesh or some similar material of small mass to prevent anyone from crawling into the stack.

The test does not show what would happen if the stack were flooded with water; if one wants a positive answer to this question a measurement should be made later when we are prepared to do it by remote control.

The experiment probably indicates that many more than 21 units could be safely stacked, but we leave it to the theoretical physicists to give a positive answer to this question. Our recommendation is that no one stack more than 21 units together until this positive answer is given.

It might be added that Carson Mark of the Theoretical Division estimated that the net multiplication would certainly not exceed 1.7 if 27 units of Pu-239 had been put in the vault. This estimate was made, however, with a very incomplete knowledge of the albedo of concrete and of the degredation of the energy of the neutrons scattered by the concrete.

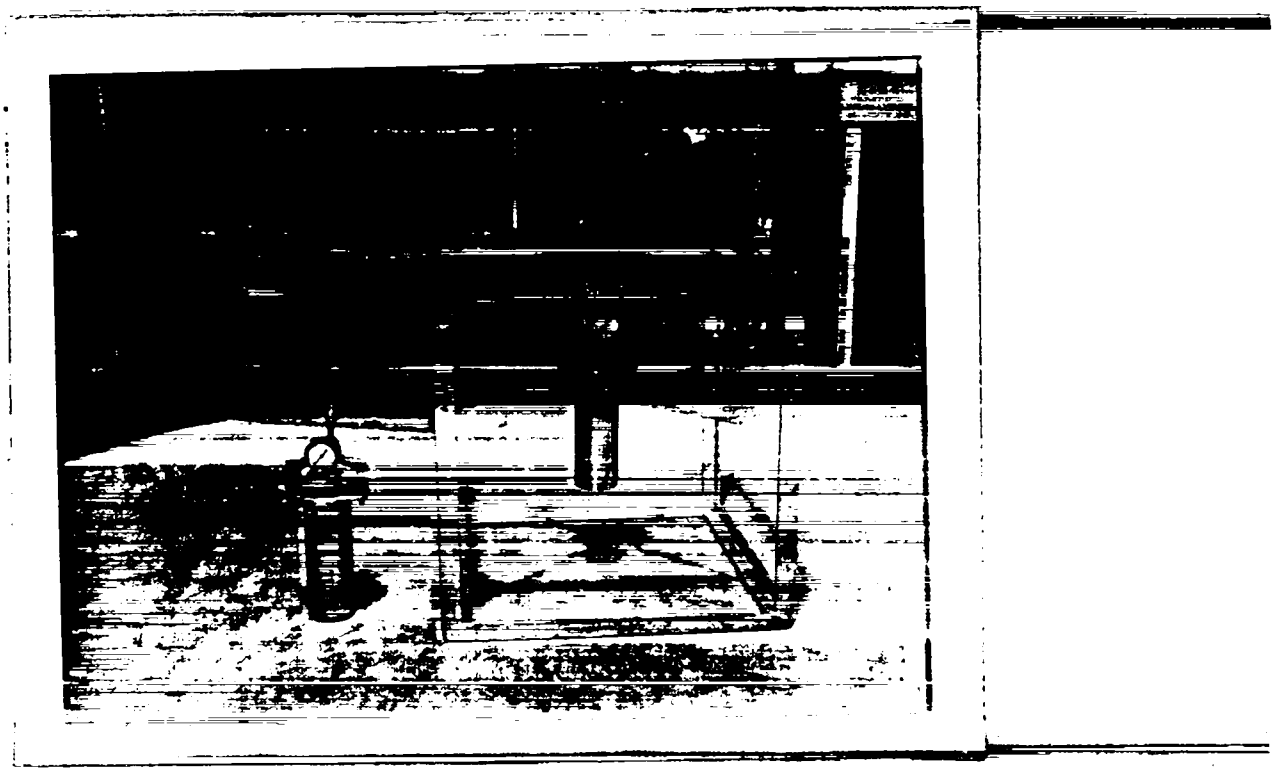

Fig. 1. An angle-iron frame with iron cylindrical can for holding the Pu-239. An extra can is shown to the left.

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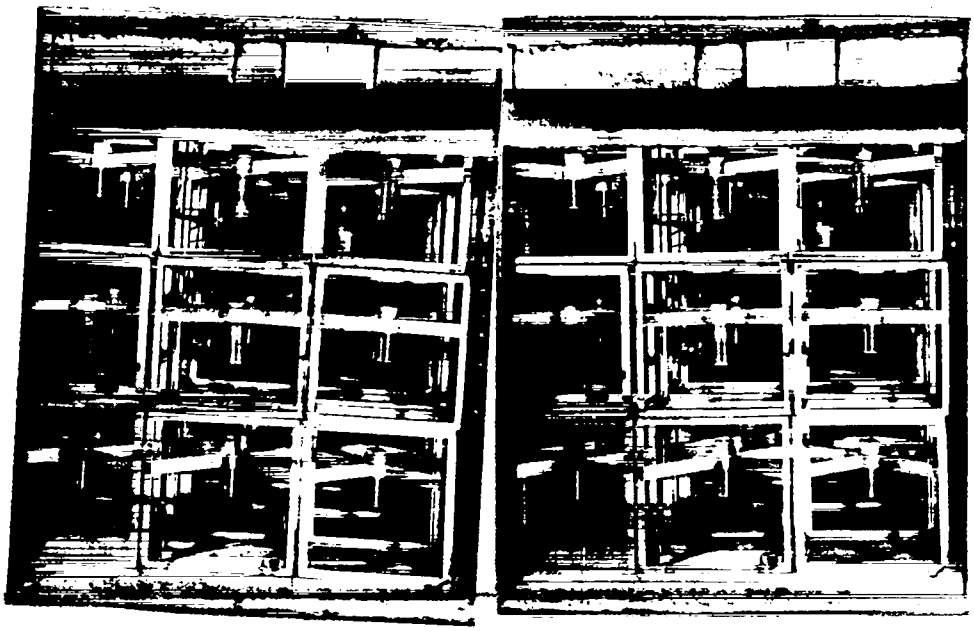
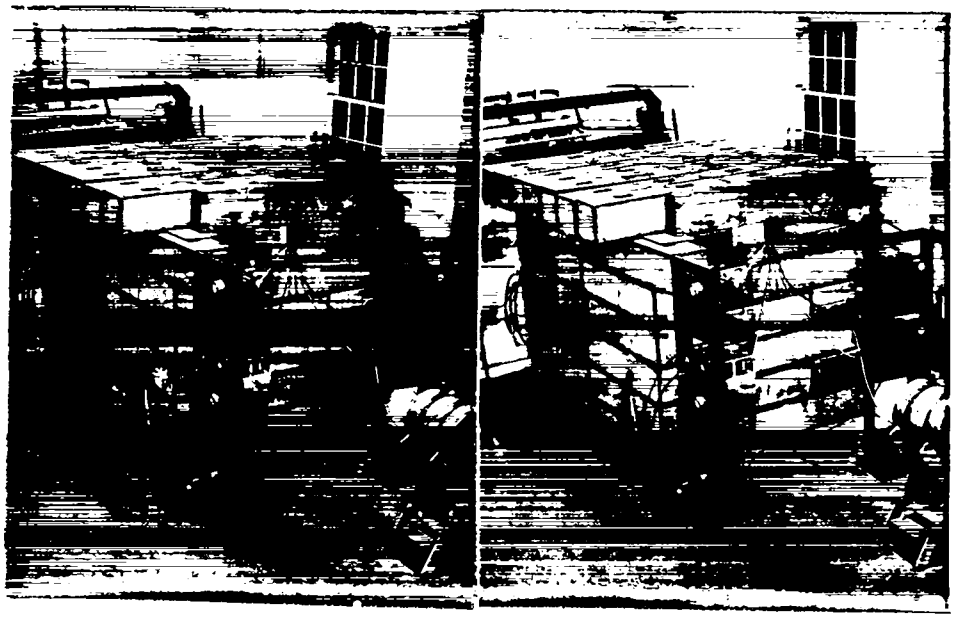


(a)



(b)

Fig. 2. The mock vault containing the angle-iron frames holding the iron cylinders filled with uranium. These are stereographic pictures. (a) gives a view of the interior from the open side. (b) shows the outside of the vault taken from the opposite side. Counter L-1 is shown at the right.

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Figure 3

19 Tu	20 3883.0 g B-10	21 Tu	
22 4559.65 g B-14	23 4355.73 g B-12	24 4509.15 g B-5	TOP LAYER
25 4452.42 g B-21	26 Tu	27 4511.51 g B-20	
10 4474.03 g B-6	11 4516.1 g B-1	12 4514.37 g B-22	
13 4165.75 g B-4	14 4601.87 g B-2	15 4079.7 g B-3	CENTRAL LAYER
16 4562.40 g B-15	17 4113.4 g B-9	18 4449.97 g B-16	
1 Tu	2 Tu	3 Tu	
4 4461.8 g B-8	5 3996.53 g B-11	6 4643.41 g B-13	BOTTOM LAYER
7 4629.26 g B-18	8 4323.35 g B-7	9 4506.45 g B-17	

TABULATION OF RESULTS

No.	Pancake	Ladle	Big Pancake	L-1	L-2	Average
	Vault all closed with source in #14 and tuballoy in all positions.					
1	20	17.7	41.7	140	6	
	All closed. Correct for B-2 in position #14.					
2	23	19.6	47.6	157	7	
	All closed with 21 units of 49 in position. Tu in others.					
3	25	23.5	49	181.5	7.5	
	All closed with 21 units, reduced by 5.25%.					
4	23.7	22.3	46.5	172	7.1	
Ratio of 4/2	1.03	1.14	0.98	Discount	1.01	1.04±0.05
	All 21 units of 49 in vault with one wall missing.					
1	21.5	16	36.5	167.5	25.5	
	(1) reduced by 5.25% for neutrons from 49.					
2	20.4	15.2	34.6	159	24.2	
	Tuballoy in all positions except #14, which contained B-2.					
3	18	16	35	147	23	
Ratio of 2/3	1.13	0.95	0.99	Discount	1.05	1.03±0.05
	About 260 lbs. paraffin in positions 8 and 17. B-2 in #14, Tuballoy in all others. One wall of vault not present.					
1	23	17	42	152	10	
	Same as (1) except 19 units of 49 in place.					
2	23.5	18	43.5	168	13	
	(2) reduced by 4.75% for added neutrons from 49.					
3	22.4	17.2	41.5	—	—	
Ratio of 3/1	0.97	1.01	0.99			0.99±0.05