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# RADIOACTIVITY MEASUREMENTS AT THE 100-TON TRIAL



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ABSTRACT

A Hanford slug was dissolved in nitric acid and pumped into saran pipes distributed inside 100 tons of H.E. About 330 gamma curies and 900 beta curies of fission products were thus distributed in the pile. The explosion created a crater 36 feet in diameter and 4 feet deep from a height of 30 feet above the ground. The radioactivity of samples of dirt taken at various distances from the center of the crater was compared with that of an aliquot of the original solution and it was found that the fraction of radioactive material deposited in the ground was

1.5% up to 150 feet

2.6% up to 400 feet

with a probable error of a factor of 2. The number of milliroentgens per hour of radiation found directly after the shot at a height of 1 foot above the ground could be represented by the expression 12.6(1-r/170 ft) up to r = 150 feet.

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# RADIOACTIVITY MEASUREMENTS AT THE 100-TON TRIAL

## Dissolution of Hanford Slug

The Hanford slug which was obtained was reported to have undergone about $1.8 \times 10^{14}$ fissions per second for an effective time of 116 days prior to its discharge on April 12, 1945.

Its dissolution was successfully carried through by the chemistry team. A first dummy dissolving was started April 27. The saran tubing was layed simultaneously with the piling of the H.E. and completed April 29. A second dummy dissolving was started May 1. This included a trial pumping of the solution into the saran. The final transfer and dissolution of the active slug was started May 4. The solution was pumped into the pile in the late afternoon of May 6 after the detonators were in place. A check of the level at -3 hours showed no leakage up to that time.

The procedure was closely that outlined in the April 19 memorandum "addition #7 to Project TR circular". A stainless steel dissolver was used. This was set inside a concrete pit having three foot thick walls. The pit was covered with seven inches of lead. The slug was admitted into the dissolver through a two inch curved tube into a bed of dry ice. The same tube was used as a lead out for the gas evolving during the dissolution. A 1000 foot lead pipe was used to vent these gases and the rate of dissolution could be followed by observing the colored $NO_2$ gases discharging from the end of this pipe through a telescope. A condenser had to be installed in this line to prevent corrosion of the lead pipe by hot nitric vapors. The coating on the slug was dissolved using dilute nitric acid and mercuric ion as catalyst. The slug itself was dissolved with concentrated nitric acid. The reaction was controlled by a heating coil wrapped around the dissolver. After dissolution was complete the acidity of the solution was reduced by the slow addition of formic acid in order to minimize

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possible injury to the H.E. in case of a leak. The volume of the solution in the dissolver was ascertained by measuring the liquid height by means of a bubbling technique. The liquid was pumped into the saran tubing, which was threaded through the stack of H.E., by first evacuating the tube and then applying pressure behind the liquid to raise it to the required level. The level of the liquid was determined by measuring the conductivity between stainless steel couplings in the saran tubing. The final dissolution proceeded very smoothly throughout. All radiation shielding was adequate and no man received more than two daily doses.

The radiation at the base of the towers was about .15 R/hr but only .05 R/hr at the place where the primacord connections were made, so that the men working there were not over exposed. The wind blew away from the dissolver through most of the operation and no considerable amount of radioactive gas was detected at the work area.

Four 10 ml samples of the solution were withdrawn before pumping the solution into the pile. About 16 liters of the solution were pumped into the pile; about 2 liters were left in the dissolver.

From measurements on these samples, the activity of the solution in the pile (16 liters) on May 7 was 330 gamma curies. The whole solution contained 370 gamma curies and 1000 beta curies. These numbers are somewhat larger than had been anticipated (300 gamma curies) but somewhat less than was calculated from the radiation log of the slug (500 gamma curies).

Crater

The force of the blast displaced a considerable amount of earth and loosened it sufficiently so that it was not too difficult to sketch a profile of the crater and loosened earth down to the hard ground. Such a profile is shown in Fig. 1A. From this profile it can be estimated that the total volume disturbed by the blast was

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about 8600 cubic feet. The total volume of displaced or loosened earth was more than this, 9500 cubic feet, due to the lowered density of loosened earth. The maximum depth of the crater was about 4 feet and the diameter across the highest extremity of the crater edge was 36 feet. Thus, while the blast gouged a hole of about 3600 cubic feet only about 40% of this earth was displaced outside the crater. Taking 1.9 as the density of compacted earth, this gives about $8 \times 10^8$ grams as the amount of earth thrown out of the crater.

The force of the blast pulverized the earth so that it was easy to distinguish the regions so affected. It was found by sieving that this pulverized earth carried most of the radioactivity. Samples taken at 20, 40, and 60 feet by driving a 1" ID pipe through the loose layer to the hard earth had about 16% of material which could pass a 200 mesh sieve. This fine material had a specific activity about 3 times as great as the gross sample. This is probably partly due to the greater area which the fine dust has for collecting radioactive material and partly due to its formation near the surface where it is more exposed to the radioactive material which is thrust down upon it.

Only a small part of this fine dirt could have come from the crater, for the specific activity of the fraction which passed a 200 mesh sieve decreased by a factor of 3 in going from 20 feet to 40 feet and by another factor of 2 in goingto 60 feet. If all the fine dirt came from the crater the activity would have been uniform.

It was also interesting to study the vertical distribution of the activity of the fine dirt. Samples were taken from a series of layers at 20 feet east. The table below gives the fraction of the total activity placed in the pile which was found per gram of dirt finer than 100 mesh.

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SPECIFIC ACTIVITY OF DIRT FINER THAN 100 MESH TAKEN AT 20 FEET EAST

| Depth | Fraction of Total Activity per gram |
|---|---|
| 0" to 1" | $11 \times 10^{-10}$ |
| 1" to 2" | $6.5 \times 10^{-10}$ |
| 3" to 4" | $1.2 \times 10^{-10}$ |
| 5" to 6" | $.24 \times 10^{-10}$ |
| 8" to 12" | $.10 \times 10^{-10}$ |

These data demonstrate the importance of the top surface for extracting samples of high specific activity. They show quite strikingly that the hump at the edge of the crater is mostly due to a crushing of the earth in place by the blast and a general but relatively small movement of the earth outward and upward. The dirt thrown out by the crater evidently contributes only to the topmost layer of this hump.

Fraction of Active Material on the Ground

A radiation survey around the crater showed a fair degree of symmetry in the distribution of radioactive matter. Accordingly, samples for estimating the fraction of radioactive material which deposited on the ground nearby were taken principally along two radii, one directed north, the other west from the crater. In order to include all the activity deposited, samples were removed by driving a one-inch ID pipe into the ground until hard earth was reached. The hard earth served to cap the end of the pipe nicely. The weight of this sample was recorded and usually amounted to about 100 grams. This sample was thoroughly mixed and a flat pellet 1.8" in diameter was pressed from 19 grams of this mixture. Both the beta and the gamma activities of these pellets were observed using dural Geiger counters, the gamma activity being observed through 1/8" of lead.



Calibration of the counting arrangement was obtained by removing an aliquot from the sample of the original solution, mixing it with some inactive dirt and pre-

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paring and measuring a 19-gram pellet in the usual way. Thus, all activities were compared to a pellet which was known to contain $6.1 \times 10^{-10}$ of the solution in the pile. This pellet gave 23,400 beta counts per minute and 1037 gamma counts per minute in our geometry.

The fraction of the total activity deposited per $cm^2$ at a distance r is given by

$$F_r = \frac{I_p N_p}{I_s A} \times 6.1 \times 10^{-10}$$

where $I_p/I_s$ is the ratio of the activities of the sample and standard pellets, $N_p$ the number of pellets which could be made from the sample, and A the area of the sample, in this case 5 $cm^2$. The total fraction of active material deposited in the ground up to a distance r is obtained by integrating $F_r$ over the surface of the region in question.

Unfortunately, the data scattered a great deal and made an accurate determination impossible. In Fig. 1B is a plot of the average values of $F_r$, as obtained from the beta counts, as a function of the distance in feet from the center of the crater. This data was fitted by two straight lines

from 0 to 150 feet

$$F_r = 5.6 \times 10^{-10} (1 - r/170 \text{ ft})$$

from 150 to 400 feet

$$F_r = 1.0 \times 10^{-10} (1 - r/400 \text{ ft})$$

From these data the fraction deposited was obtained to be

up to 150 feet 1.5%

up to 400 feet 2.6%



The probable error of these results is about a factor of 2.

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Fractionation among the Fission Products

Chemistry is now under way to make a detailed study of possible fractionation effects on the various fission products. However, comparison of the beta and gamma activities of the samples gives information on this point.

The gamma activity is due chiefly to the Ba-La chain and the Zr-Cb chain. These contribute about 80% of the gamma activity but only 25% of the beta activity. The other important contributions to the beta activity being Sr, Y and Ce (63%). Since the ratio of beta to gamma activities in the samples was always the same as in the standard pellet, it is demonstrated that probably no fractionation takes place at least among these elements in question for this 100 ton shot. In such a crude demonstration the possibility of compensating effects is not excluded.

Radiation Survey

A radiation survey was made with a Lauritsen-Landsverk electroscope and checked with a Victoreen R-meter. The results are plotted in Fig. 10. The equation which fits the data is

up to 150 feet

$$\text{Number of mR/hr} = 12.6\ (1 - r/170\ \text{ft})$$

Beyond 150 feet the radiation was below the sensitivity of the instrument (1 mR/hr) in both the north and south directions. In the west direction the radiation at 150 feet was 3 mR/Hr and gradually fell to less than 1 at 400 feet.

It is noteworthy that the carboniferous deposit which appeared on the ground after the explosion extended out to 140 feet. Evidently very little material is deposited by the explosion beyond this distance.

The data obtained from the radiation survey can be interpreted to give the fraction of activity deposited over the ground once a correction for the absorption by



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the ground is taken into account. With the same instrument as was used in the radiation survey it was found that the radiation from a 10 ml sample of the solution in the pile of H.E. (16 liters) was 110 mR/hr at 1 meter. This is to be compared with the radiation observed 1 foot above the ground which has a thickness $d$ of dirt having an absorption coefficient $K$ and whose source strength per $cm^3$ is $A$. From such a distributed source the flux of radiation is

$$V_G = \frac{Ad}{2Kd}\int_0^1 (1-e^{-Kd/\mu})\, d\mu$$

while from the sample of solution the flux is

$$V_S = \frac{As}{4\pi r^2}.$$

For the distributed source $d$ was taken to be about 5 $gms/cm^2$ and $Kd \approx .5$. Thus up to 150 feet $V_G \approx .674\ Ad$.

When the integration over the surface was carried out we found for the fraction of active material deposited up to 150 feet

2.3%

in reasonable agreement with the result obtained by sampling.

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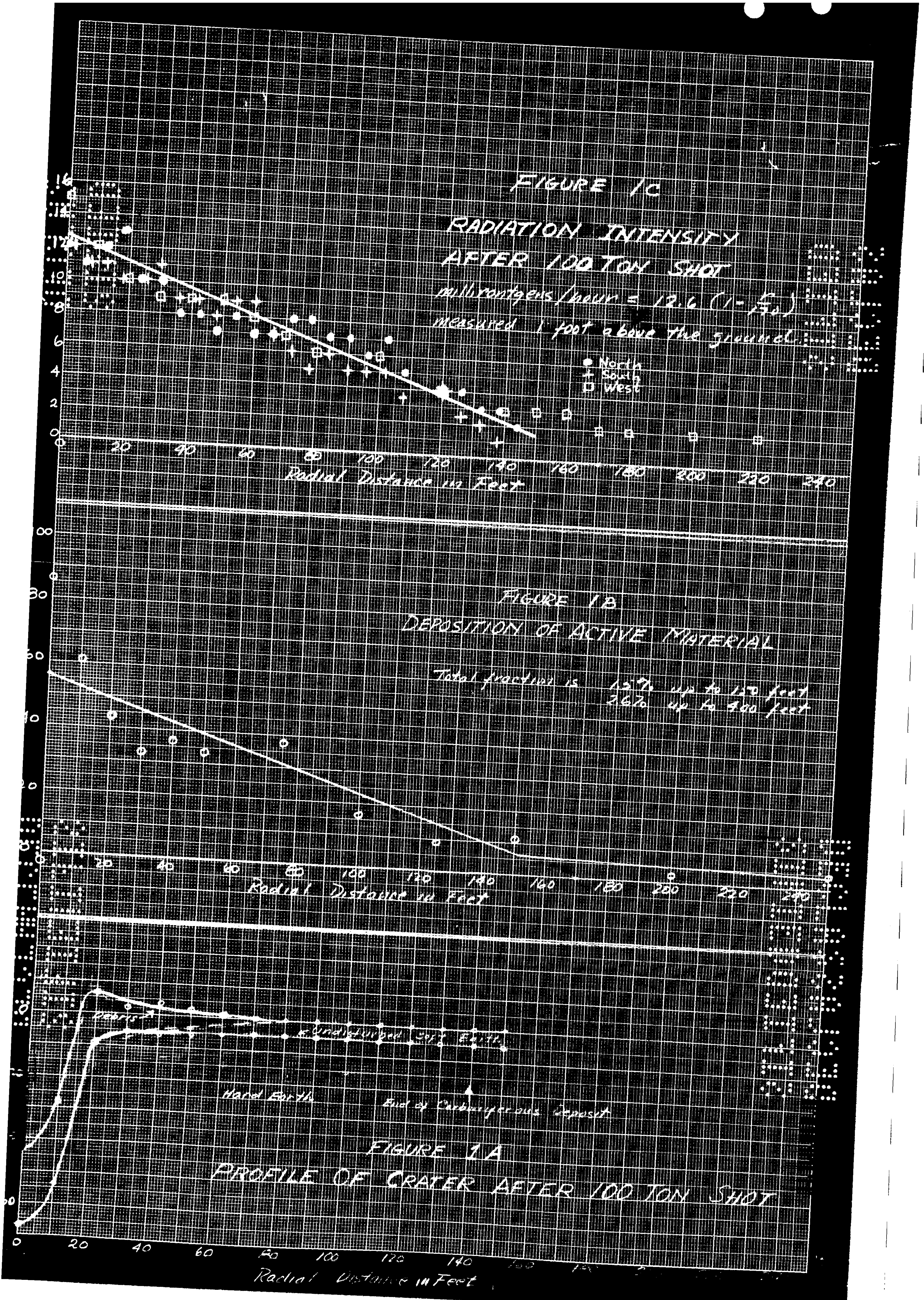
FIGURE 1C
RADIATION INTENSITY
AFTER 100 TON SHOT
millirontgens/hour = 12.6 (1 - r/150)
measured 1 foot above the ground.
North
South
West
Radial Distance in Feet
FIGURE 1B
DEPOSITION OF ACTIVE MATERIAL
Total fraction is 15% up to 150 feet
26% up to 400 feet
Radial Distance in Feet
Debris
Undisturbed Soft Earth
Hard Earth
End of Carboniferous Deposit
FIGURE 1A
PROFILE OF CRATER AFTER 100 TON SHOT
Radial Distance in Feet

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