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RADIATION HAZARDS CONNECTED WITH THE CONTROLLED HYDRIDE EXPLOSION

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ABSTRACT

The radiation hazards accompanying the experiment described in LA-125 have been studied and the necessary precautions have been proposed.

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RADIATION HAZARDS CONNECTED WITH THE CONTROLLED HYDRIDE EXPLOSION

We assume that an explosion releasing 4×10^{14} ergs (10 kg TNT equivalent) takes place in a closed steel chamber having 3" walls (LA-125). The actual Dumbo will probably have thicker walls; thus, the estimates given here on the radiation hazards represent an upper limit for the assumed explosion. On the basis of 160 Mev per fission, this means 1.5×10^{18} fissions involving 3×10^{18} neutrons.

A. Neutron Hazards

It has been estimated that 1/3 of the neutrons involved in the reaction will escape with low energies from the active material to the inner wall of the container. Of these, about 60% will be thermalized to 0.25 volts and the remaining 40% will be distributed as $1/v^2$ above 0.25 volts. An additional 5% of the neutrons will escape with high energies.

Some of these neutrons will be absorbed in the iron wall of the container. We take for the pertinent cross sections of iron

σ_s (Fe) at 0.25 volts ("thermals") = 10 barns = σ_s (Fe) for epithermals

σ_a (Fe) at 0.25 volts ("thermals") = 0.63 barns

Mean σ_a (Fe) for epithermals = 0.32 barns (assuming $\sigma_a \sim 1/v$)

Using these values one calculates that a total of 2×10^{17} thermal and epithermal neutrons and 1.5×10^{17} fast neutrons escape from Dumbo. From report LAMS-49 the dose due to Q neutrons at R meters is $D = 2 \times 10^{-19}\, Qe^{-(R/600)^2}$ roentgens if R is large compared to 600. This gives values of 4.3×10^{-3} and 1.0×10^{-6} roentgens at 1 and 2 km respectively. Compared with these hazards the effects of delayed neutrons and induced activities in the air and ground are negligible.

B. γ-ray Hazards

The amount of γ-ray emission at the time of the burst and for the next few seconds is very uncertain. We assume one hard γ-ray per neutron in the fission process. We also assume one γ-ray per fission from the fission products having a half-life less than 1 sec, following report CC-1128, A-1616, p. 7. From Fig. 9 of that report it is estimated that there are 0.4 γ-rays per fission in the time from 1 sec to 1 min. Thus we take the total number of γ-rays emitted per fission during the first minute to be 4. This is approximately equal to the total radiation from the fission products for a week following the first minute.

We assume the number of disintegrations per sec from the fission products, at a time t sec after F fissions, is $0.5\ F/t$ (see LAMS-44). This relation is supposed to hold from a few seconds to many days. We assume that 30% of these disintegrations give rise to hard γ-rays ($\sim$ 2 Mev) 20% to softer γ-rays ($\sim$ 0.8 Mev), and the remainder to very soft γ-rays which will not penetrate the walls of the container.

Neglecting air absorption, the dose at R meters is taken to be $(2.5 \times 10^{-4})/R^2$ roentgens per sec per Curie. The 3" steel wall transmits 3.7% of the 2 Mev. γ-rays and 2.5% of the 0.8 Mev γ-rays. (Chicago Handbook, XI, D, 2, Fig. 3). For 1.5×10^{18} fissions these values give a dose of $(58/tR^2)$ roentgens per sec. The integrated dosage from time t_1 to time t_2 secs after the explosion is $(58/R^2)\ln(t_2/t_1)$. Table I, part A, gives the dose from radiation of fission products at various distances in roentgens received in 1 hour following time T after the explosion. Part B shows the integrated dose up to time T

including the radiation during the first minute estimated on the assumptions given at the beginning of this section.

TABLE I

Dose at Distance R from Dumbo.

T \ R	A Roentgens in 1 hour following Time T			B Roentgens up to Time T		
	1m	30m	100m	1m	30m	100m
1 min.	240	0.26	2×10^{-2}	600	0.67	0.06
1 hr.	40	0.04	4×10^{-3}	840	0.93	0.08
5 hr.	10.6	0.011	1×10^{-3}	930	1.0	0.09
10 hr.	5.5	6×10^{-3}	6×10^{-4}	970	1.1	0.1
1 day	2.3	2×10^{-3}		1020	1.1	0.1
5 days	0.5	6×10^{-4}		1100	1.2	0.1
10 days	0.24	2×10^{-4}		1170	1.3	0.1

C. Protective Wall and Working Distances

There are five questions to be considered regarding safety of personnel and equipment.

1) Effect of radiation on personnel required to approach the gadget soon after firing.

2) Blast in case the brake does not hold.

3) Effect of radiation on personnel at observation post.

4) Effect of radiation on photographic film in recording devices.

5) Removal of strongly active material to extraction plant.

1) In order for a man to approach the gadget safely within a few minutes after the explosion a protective wall is required. From Chicago Handbook XI, D, 1, Fig. 3, a wall of either 4.5" of lead or 22" concrete will reduce the γ-ray activity by a factor of 400. This will make it safe for a man to work for an hour behind the wall.

2,3) If personnel are to be safe from blast if the brake does not hold, it has been estimated that they should be 2 km from the gadget. It appears that the effect of neutrons and γ-rays (considering air absorption) at 2 km is negligible.

4) A working distance of 30 m from the gadget to recording instruments seems reasonable. Since a few hundredths of a roentgen appreciably blackens fast film, it is recommended that the recording equipment have protection in addition to that mentioned above. This is especially true since the photographic effect of the high neutron level is not known. A covered pit with 2' concrete walls is suggested to house the instruments. Such a pit would protect personnel from the radiation expected from a 10 kg TNT equivalent explosion. Since the effect of internal radiation on preamplifiers, etc., is not well known, it may be necessary to add extra shielding for these items.

5) The answer to question (5) depends on time and method of handling the active material. For instance, if one day after the explosion the solution is dumped into a container shielded by 3.5" of lead, the dose received by an operator one meter away from the active material would be approximately 0.2 roentgens per hour.

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