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GAMMA RADIATION DOSAGE AT HIROSHIMA FROM RECOVERED PHOTOSENSITIVE MATERIAL

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ABSTRACT

Fogged photosensitive materials found at Hiroshima, 1.7 km from the center of the explosion, were compared with nominally identical materials bought in Tokyo and fogged by radium in the laboratory to determine the Hiroshima dosage. The Hiroshima dosage was about 8 Roentgens, within a factor of about 2. Differences in manufacture between nominally equivalent emulsions lend a wide uncertainty to the result.

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GAMMA RADIATION DOSAGE AT HIROSHIMA

FROM RECOVERED PHOTOSENSITIVE MATERIAL

A stock of photographic films and printing papers, all fogged by gamma radiation from the bomb, was found in the Red Cross Hospital in Hiroshima by investigators from this project shortly after the atomic-bomb attack on that city. Nominally equivalent unexposed material was obtained from dealers in Tokyo and sent to Los Alamos, together with Hiroshima material; details are given in Appendix I.

At Los Alamos, an attempt was made to determine the gamma radiation dosage delivered by the bomb from the fogging of the Hiroshima films. It was thought that the Hiroshima dosage could be evaluated by comparison with known doses of gamma radiation given to Tokyo samples from a radium source.

This procedure could yield valid results only if the Hiroshima emulsions and the corresponding ones from Tokyo had the same photographic properties. Nominally equivalent samples were actually in different-appearing packages. Nearly all the films from both sources were outdated by intervals that ranged up to more than a year (Appendix II). Tests to determine whether corresponding emulsions really had identical photographic properties indicated that they differed so greatly as to be incomparable with one another; the contrast factors, or so-called photographic "gamma factors",

d (photographic density) / d (log exposure)

of the Tokyo and the corresponding Hiroshima films were in each case widely different (Appendix III). As a result of this, a Tokyo sample and a Hiroshima sample of the same brand which had received equal exposures and were processed

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simultaneously in the same solutions could be expected, nevertheless, to possess quite different densities. In the case of the bromide paper, the heavy paper backings of the Tokyo papers were found to differ from those of the Hiroshima ones in transmission density by about 0.05, on the average, and there were differences almost as great between densities measured on different parts of the same sheet.

The non-uniformity of these emulsions from one sample to another may have arisen partly from manufacturing differences and partly from differences in storage conditions. In the main, it probably reflects a state of disintegration in the Japanese photographic industry due to war conditions. Whatever the cause, it seems to destroy any hope of finding an accurate value for the Hiroshima radiation dosage by use of these films. A much less serious cause of inconsistency might be the differences in radiation spectrum and exposure conditions between the Hiroshima bomb and the laboratory radium exposure, but in view of the great inconsistency of the results no further consideration need be given to these differences.

In spite of the fact that any comparison was thus found to be invalid, attempts were made to derive a value for the Hiroshima dosage, however crude it might be. There were two methods employed in these attempts, one utilizing what might be called "corrected bad geometry" experiments and the other utilizing "good geometry" experiments. In both methods the principle was the same. Doses were administered to samples of Tokyo material of a given type from a radium source and the resulting photographic densities of these samples were compared with that of a nominally equivalent Hiroshima sample. These doses were adjusted so that the density of one sample would be somewhat less than that of the Hiroshima sample while that of the other sample would be somewhat greater. Then the dosage received by the Hiroshima sample to produce its observed density could be determined through a simple linear interpolation, since it had been established that these exposures were on the linear part of the density-vs-log exposure curves of the emulsions. All materials involved in a given determination were processed simultaneously in the same solutions with continuous agitation, to remove the possibility of errors due to dissimilar processing.

The "corrected bad geometry" experiments were carried out in two parts. First, the exposure plan described above was used to yield "bad geometry" values of the Hiroshima exposure. In the apparatus used in this part of the experiments a sample was situated 6.05 cm above the radium source. The source, however, was at the bottom of a cavity in a lead case, so its radiation encountered lead in every direction except in the neighborhood of straight upward. In that direction, it passed through one-quarter inch of brass before encountering the emulsion. On top of the sample was another block of brass to hold it flat in its designated place. Radiation from the source entering the lead caused the emission of secondary gamma radiation and of beta rays. The secondary gamma radiation was able to reach the emulsion and cause additional darkening. In addition, extra darkening occurred from beta rays excited in the quarter-inch brass plate and from backscattered beta rays excited in the brass block. All this additional exposure was responsible for a "geometry" error, and values obtained using this apparatus had to be corrected for geometry. This apparatus was used in spite of this disadvantage because of the advantage in convenience and safety afforded by the lead case.

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The correction consisted in making exposures on the above-described "bad geometry" apparatus and on "good geometry" apparatus to be described later, and then comparing doses delivered by the two forms of the apparatus in given times. The procedure for this comparison was similar to that already described; an exposure given on the "good geometry" form was compared by interpolation of densities with two exposures given on the "bad geometry" form.

For each emulsion type the results were fairly self-consistent (the random relative probable errors were well under 10 per cent) but, because of the differences exhibited between the Tokyo and Hiroshima samples of correspon ing emulsions, the geometry correction could not be determined with the consistency that was desired. There was considerable scatter in the values obtained for the Hiroshima exposure on different kinds of film by the "corrected bad geometry" experiments. Mean values ranged from 7.5 Roentgens to 15.5 Roentgens (Appendix IVA).

The "good geometry" experiments were performed with apparatus free from the effects of secondary gamma radiation and of beta radiation, but this apparatus had the serious practical disadvantage of setting up a strong field of gamma radiation around the apparatus. This "good geometry" apparatus, like the other apparatus, had the emulsion at a distance of 6.05 cm above the radium source. The same source was used as in the "bad geometry", but there was no lead case to generate secondary gamma radiation. Between the film and the source were a 5.0 cm layer of wood and an 0.2 cm plate of glass to approximate conditions at Hiroshima. On top of the film was a backing of cardboard and on top of that was a brass block used to hold the film flat in its designated

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place. The purpose of the cardboard was to absorb any beta rays backscattered from the brass block. Any radiation set up in the wood or the glass would approximate radiation generated in these media at Hiroshima.

Experiments with this apparatus were performed in accordance with the interpolation procedure described earlier; but no geometry correction was made. The more direct results obtained from these "good geometry" experiments were no more consistent than those obtained in the corrected "bad geometry" experiments; as a matter of fact, the relative scatter was greater, the values ranging from 3.3 to 13.2 Roentgens (Appendix IVB).

There appears to be no reason to believe that the high values for the Hiroshima exposures were any better or worse than the low values, except that the greater age of some of the Hiroshima material slightly favors the low values. Thus, about the best that can be said is that the experiments yield a value of about 8 Roentgens, and that this value may be in error by a factor of about two.

What is undoubtedly the principal cause of uncertainty in this determination i.e., manufacturing differences, would be eliminated if materials with the same emulsion batch numbers (cf. Appendix II) could be found for a repetition of the experiment.

Only a small part of the photosensitive material submitted to us has been used. The rest will remain on file in the archives of the optics group (now M-8). The original data from which this report was compiled are in LA notebook 350.

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APPENDIX I. Letter of Transmittal

To: J. R. Oppenheimer

From: P. Morrison

Subject: Photo-Sensitized Materials Recovered at Hiroshima

1. In the Red Cross Hospital at Hiroshima, located at about 1.6 km from the projected point of the explosion, on the third floor of the building, we found a stock of photographic materials which had been exposed to the radiation from the bomb, but had not otherwise been opened, exposed, or developed. The Japanese technicians told us that all the film they had tried out had been blackened by the shot, and was therefore unuseable. They were quite willing to give us these samples.

2. All the samples from Hiroshima were exposed to the bomb in a direct line. No building wall or other structure intervened. The radiation came through the air, a glass window pane of 2 mm thickness (a sample of which I submit) and the wall of a wooden storage cabinet. In addition, some of the film was stacked among other photographic materials.[1)]

The wooden cabinet and the following mass: 4 mm plywood, 4.2 cm of loose sawdust, and 4 mm plywood.

1) Note added at Los Alamos, October 1945:

The materials were not recovered from the original positions which they had had at the time of explosion. They had been moved to a sheltered location. Interrogation of Japanese eye-witnesses led to the placement here assigned. The window subtended a sizeable solid angle--cone of half-width 30° to 45° -- so that diffuse radiation was not seriously cut down by the concrete building wall. This conclusion rests on apparently reliable but unchecked accounts of Japanese.

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3. In addition to the exposed film from Hiroshima, we have obtained samples of identical film from dealers in Tokyo. These samples may be used to control the development of the Hiroshima film and to calibrate its emulsion by giving known exposures to the Tokyo samples and comparing the densities on development.

At Site Y, the photographic groups should be consulted. In addition, Dr. William Bayles and others at Rochester and at Eastman Kodak have specialized in photometric dosage measurement.

4. As indicated in writing on the packages, the Hiroshima films are a bit old. This may spoil the results. If this is not too bad, I feel that the four types of film obtained should allow sufficient latitude to secure a decent measurement of the dose, which must have been between ten and one hundred r.

5. Identification of the samples (each sample is marked with a letter in red pencil).

A Unexposed 35 mm film intended for photography of fluoroscope screens in indirect chest X-ray work.

B Identical film, exposed at Hiroshima. The can was standing on a shelf.

C X-ray film, sensitivity DIN 13/10. Unexposed Tokyo sample.

D Identical film, exposed at Hiroshima. This package was on top of several other such boxes. See label on end of box. The developer is a normal one, using metol and hydroquinone.

E These Ilford plates were exposed at Hiroshima. The box was on top of a stack of papers. The box was unsealed, and may have been accidentally fogged by visual light. The bottom plate should be most reliable.

F Bromide paper bought in Tokyo. High contrast.

G Identical paper exposed at Hiroshima. About 2 cm of similar envelopes were above this package in the stack.

All Hiroshima samples were in the horizontal plane.

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APPENDIX II

Emulsion batch numbers and expiration dates

35 mm film		X-ray cut film	
(Sakura Film Co. film for chest fluoroscopy)		(Sakura Roentgen film, safety, duplitized, blue base, Rokuoh-sha, Tokyo)	
Tokyo	LR-250 (2606-3)	R-650	August 1945
Hiroshima	LR-213 February, 1945	R-530	July 1944

APPENDIX III

Photographic Contrast Factors

(See LA notebook 350, page 7 for processing details)

	35 mm film	X-ray cut film
Tokyo	1.5	1.0
Hiroshima	0.7	1.5

APPENDIX IV

Hiroshima dosage values, Roentgen units

	35 mm film	X-ray cut film	bromide paper
A Corrected bad geometry	7.2	10.4	13.2
	7.7	12.4	14.3
	7.6	10.6	18.1
		10.9	16.3
		11.9	
mean	7.5	11.2	15.5
B Good geometry	3.3	13.2	

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