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Title: An Attempt to Measure the Gamma Radiation Dosage at Hiroshima from Photosensitive Material

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An Attempt to Measure the Gamma Radiation Dosage at Hiroshima from Photosensitive Material

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Editor's Note

After Japan surrendered in August 1945, a team of Los Alamos scientists entered both Hiroshima and Nagasaki to assess the damage of Little Boy and Fat Man. Two of these scientists, Berlyn Brixner and Edwin McMillan, discovered a stock of photographic film in Hiroshima that had been fogged by the gamma radiation from Little Boy. They devised an experiment that they thought might be used to determine the exposure levels in the city. Below is both their description of the film stock and the attempt to determine the exposure levels at Hiroshima.

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. Unexposed films of the same types were obtained from dealers in Tokyo and sent to Los Alamos, together with the Hiroshima films. Details pertaining to the films are described in a letter from Philip Morrison of the investigating group (Appendix 1).

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 measured doses of gamma radiation could be given to Tokyo film samples with the use of a radium source and that the Hiroshima dosage could be evaluated by determining what gamma-ray exposure from the radium source would fog the Tokyo film samples to the extent exhibited by the Hiroshima films.

This procedure could yield valid results only if the Hiroshima films and their nominal equivalents from Tokyo had the same photographic properties. Tests devised to determine whether the films met these conditions indicated that the films differed so greatly as to be incomparable with each other. It was found that the contrast factors (i.e., photographic "gamma-factors") of the Tokyo and Hiroshima films were different. As a result of this, a Tokyo sample and a Hiroshima sample of the same brand that had received equal exposures and were processed simultaneously in the same solutions would possess quite different photographic densities.

It was found that the heavy bromide paper backings were not the same on the Tokyo samples as they were on the Hiroshima ones. They differed in thickness and therefore in transmission density. What was worse, there were notable differences between densities measured on different parts of the same sheet. Densities of the backings on the Hiroshima papers ranged from 0.93 to 0.97, while those on the Tokyo papers ranged from 0.88 to 0.92. These discrepancies were further aggravated by the fact that nearly all the films, both those from Tokyo and those from Hiroshima, were outdated by several months to more than a year.

In spite of the fact that a comparison would be invalid, experiments were conducted to derive a value for the Hiroshima dosage, however inaccurate it might be. There were two methods employed in these experiments. One method utilized what might be called "corrected bad geometry" and the other "good geometry." In both experiments, the principle was the same. Doses were administered to samples of Tokyo film from a radium source and the resulting photographic densities of these samples were compared with those of the Hiroshima film. The doses from the radium source 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 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 curve of the emulsion. All films involved in a given determination were processed simultaneously in the same solutions to remove any chance of errors due to dissimilar processing.

The "corrected bad geometry" experiment was in two parts. First, the exposure plan described above was used to yield "bad geometry" values of the Hiroshima exposure. The apparatus used in this part of the experiments situated a film sample 6.05cm above the radium source. The source, however, was at the bottom of a cavity in a lead case so that its radiation encountered lead in every direction except straight upward. In that direction, it passed through one-quarter inch of brass before encountering the film. Behind the film was another block of brass that held the film flat in its designated place.

Radiation entering the lead caused emission of secondary gamma radiation as well as beta rays. The secondary gamma radiation was able to reach the film causing additional darkening. The film suffered even more darkening because of the beta rays excited in the quarter inch brass plate and from the backscatter from the brass block. This exposure was responsible for a "geometry" error. Thus, the values obtained using this apparatus had to be corrected for geometry. It appeared that the correction would be easy to determine.

The correction consisted in making exposures on the above described "bad geometry" apparatus and on a "good geometry" apparatus (to be described later) and comparing the doses. An exposure given on the "good geometry" form was compared by interpolation with the densities given by the "bad geometry" experiment.

Because of the relatively high accuracy required in the density measurement, the relatively low accuracy achieved, and the differences in the film stocks, the geometry correction could not be determined with the accuracy. There was considerable scatter in the values obtained for the Hiroshima exposure by the corrected "bad geometry" experiments. Values ranged from about seven Roentgens to about eighteen Roentgens (as shown in Appendix II).

The "good geometry" experiments were performed with an apparatus free from effects of secondary gamma and beta radiation. However, 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 film at a distance of 6.05cm above the radium source. The same source was used in both experiments, but without a lead case to generate secondary gamma radiation. Between the film and the source were a 5.0cm layer of wood and a 0.2cm 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 place. The purpose of the cardboard was to absorb any backscattered beta rays from the brass block. Any radiation set up in the wood or the glass could be tolerated since it would approximate any such secondary radiation generated in these media at Hiroshima.

Experiments with this apparatus were performed in accordance with the interpolation procedure described earlier, but, since there was no geometry error, no geometry correction was necessary. The more direct results obtained from these "good geometry" experiments were no better than those obtained in the corrected "bad geometry" experiments. In fact, the scatter was greater, ranging from three to twenty roentgens. Hence, there appears to be no reason to believe that the high values for the Hiroshima exposures were any better or worse that the low values. Thus, about the best that can be done is to say that the experiments yield a value of about eight roentgens and that this value may be in error by as much as a factor of two.

The failure of these films to exhibit uniformity from one sample to another eliminated any hope of finding an experimentally proved value for the Hiroshima radiation dosage by use of photographic film. The most that can said is the physical condition of the film was symptomatic of the wartime condition in Japan.

Appendix I

To: Dr. J. R. Oppenheimer
From: Philip 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 unusable. 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. The wooden cabinet and the following wall: 4 mm plywood, 4.2 cm of loose sawdust, and 4 mm plywood.

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 (Translated expiration dates are February 1945; August 1945; and July 1945). 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.

Appendix II

EMULSION Batch Numbers and Expiration Dates SAKURA RONTGEN FILM FOR CHEST FLOUROSCOPY	
Tokyo: LR-250 (2606-3)	R = 650 (August 1945)
Hiroshima (LR-213)	R = 530 (July 1944)

Appendix III

Photographic Contrast Factors (See LA Notebook 350, page 7 for processing details)	
Tokyo: 1.5	Tokyo: 1.0
Hiroshima: 0.7	Hiroshima: 1.5

Appendix IV

Hiroshima Dosage Values Roentgen Units		
Corrected Bad Geometry		
35mm Film	X-ray Cut Film	Bromide Paper
7.2	10.4	13.2
7.7	12.4	14.3
7.6	10.6	18.1
	10.9	16.3
	11.9	
$\bar{x}$ = 7.5	$\bar{x}$ = 11.2	$\bar{x}$ = 15.5
Good Geometry		
3.3	13.2	