Chapter 4 Appendix 5

THERMOLUMINESCENCE MEASUREMENT OF GAMMA RAYS

AT ABOUT 2000 m FROM THE HYPOCENTER

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Reevaluation of the neutron and gamma-ray doses from the atomic bombs began in 1981. Gamma-ray kermas at about 2000 m from the hypocenter at Hiroshima were determined by measuring the thermoluminescence (TL) produced in roof tiles collected in Hiroshima. The method used in the present study was the quartz inclusion technique developed in the field of TL dating of archaeological materials.

Within a ground range of 1000 m, the new calculated doses are nearly the same as those of the T65D.[1] The differences between the new data and T65D were in the range beyond 1000 m. For instance, the kerma in tissue in air at 2000 m is 2 rad for T65D and 7 rad for the new Loewe calculations.[2] This fact is important because most epidemiological data have been obtained for ground distances between 1000 and 2000 m. There were few A-bomb survivors within 1000 m because of the heavy destruction there.

TL data for A-bomb exposed samples at 2000 m will give information to test whether T65D or the new calculations are best. All data previously reported in the range between 1000 and 2000 m were obtained using samples located in the southeast direction (SE). Thus, samples in other directions are needed to determine the uniformity of the Hiroshima A-bomb radiations.

In this report, two Hiroshima samples located at approximately 2000 m ground distance in southwest (SW) and east (E) directions are analyzed and discussed. Samples located at

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Table 1. Location and Thickness of Roof Tile Samples

Sample	Notation	Thickness (cm)	Direction	Location[a]	Ground[b] distance (m)	Approximate[c] height from the ground (m)	Angle of the perpendicular of the sample surface to the epicenter (∘)
Meisen-ji "Oni-gawara"	Me-1	1.7	East	746.29×1261.08	1909	7	73.2
Meisen-ji "Oni-gawara" top	Me-2	1.7	East	746.29×1261.08	1909	7	73.2
Hiramoto "Oni-gawara" bottom	Hr-1	1.5	Southwest	742.15×1261.05	2053	4.8	74.4
Kirihara	Ki-1	1.7	West	741.73×1262.48	2453	-	-
Kirihara	Ki-2	1.7	West	741.73×1262.48	2453	-	-
Kirihara	Ki-3	1.7	West	741.73×1262.48	2453	-	-
Kirihara	Ki-4	1.7	West	741.73×1262.48	2453	-	-

[a] Coodinates are estimated from the US Army Map Service map, Series L902, plate number 138,449. Numbers are the east-west and north-sourth coordinates.

[b] Ground distances are from the hypocenter of Hu69, which is used in the project of the reevaluation of A-bomb. Errors are about ±20 m.

[c] Values shown by "-" means unknown.

relatively long distances from the hypocenter (2700 m) were also analyzed, but the A-bomb doses were negligible. These data were used for background evaluations.

Materials and Methods

Samples analyzed were collected from three points: (1) an "oni-gawara" (devil faced ridge-end tile) roof tile of the Meisenji temple, (2) an "oni-gawara" of Hiramoto's house, and (3) roof tiles of Kirihara's house. The location and geometry of the tile samples are summarized in Table 1.

Sample Preparation. One-millimeter thick layers were removed from the outer surface of the roof tiles and the remaining parts were crushed into grains less than 149 μm diameter. Grain sizes between 149 and 74 μm and less than 49 μm were separated using seives. Portions of the 74-149 μm size were used for TL measurements, those less than 49 μm were used for background (BG) measurements. The magnetic granule components of the former portion were removed using a magnetic separator and the remainder washed and etched with 10% hydrofluoric (HF) acid for one hour.

Instruments. A Harshaw 2000 TL reader was used for the measurements. Quartz samples were heated from room temperature to 500° C at a rate of 20° C per second in an oxygen-free atmosphere of nitrogen. BG radiations come from both inside and outside the roof tiles. Cosmic rays and gamma rays from external radioactivity come from outside. This external BG radiation was measured using sensitive TL dosimeters ($CaSO_4$:Tm) packed in

0.5-mm thick polyethylene tubing in a 1-mm thick copper tube. The TL was measured after several months exposure. Beta rays emanating from natural radioactivity inside the tiles irradiate them from inside. The $CaSO_4$:Tm powder was used for measurements as described in Chapter 4 Appendix 2.

Standard Radiation. To determine the ^{60}Co equivalent dose (ED), a ^{60}Co source (3000 Ci) was used at the Research Institute for Nuclear Medicine and Biology, Hiroshima University. The dose rate was measured using Japanese Association of Radiological Physicists chambers, which are annually calibrated at the National Institute for Radiological Sciences with calibration errors of 0.3 to 0.7%.

Table 2. Results for ^{60}Co Equivalent Doses (ED) for Roof Tiles Approximately 2,000 m from the Hypocenter. The Value for Each Sample was Estimated by Additional ^{60}Co Doses of 30 rad for Me-1 and Me-2, and 20 rad for Hr-1. The Last Column Shows the Doses Corrected for Supralinearity

Notation of sample	Ground distance (m)	ED (rad)	I (rad)	Background			GD[a] (rad)
				Beta (rad/yr)	Gamma (rad/yr)	Total (rad)	
Me-1	1909	37.0±5.9	2.3±5.1	0.11	0.14	17.6±0.7	21.7±7.8 (6)
Me-2	1909	36.0±6.3	2.3±5.1	0.11	0.14	17.6±0.7	20.7±8.1 (5)
Hr-1	2053	21.9±3.6	4.1±2.5	0.24	0.10	16.2±0.9	9.8±4.5 (7)

[a]Values in parentheses are the number of glow curves used for evaluations.

Results

Table 2 shows the results estimated for roof tile samples located near 2000 m ground distance. EDs in Table 2 are the ^{60}Co equivalent doses including BG radiation dose (BD). GD means the evaluated dose which was obtained by adding a supralinearity correction and by subtracting BD. The fourth column contains the corrections, I, for supralinearity. Values shown as beta and gamma rays are measured for BG doses per year. Beta corresponds to beta-ray dose rates which were estimated by the measurements of beta rays emitted from activities in roof-tile materials. Doses designated "total" are BDs estimated by multiplying the age of the building by the sum of beta+gamma ray. The last column indicates doses obtained by subtracting BDs from EDs and including supralinearity corrections.

Table 3 shows the results obtained for Kirihara's roof-tile samples. Results for four roof tiles are shown in this table. These values are close to or include zero in the range of errors.

Discussion

These data are ratios of TL responses of the A-bomb relative to the response of ^{60}Co. This is termed the ^{60}Co ED. To compare the kerma in tissue in air, we must correct for gamma-ray absorption in roof tiles and for buildup effects and energy spectrum differences between the A-bomb and the ^{60}Co gamma rays. These effects were calculated without any secondary effects. The correction obtained in the case of a tile of the Faculty of Science,

Table 3. Dose Estimates from Kirihara's Roof Tiles, which were Relatively Distant from the Hypocenter. The Value for Each Sample was Estimated by Addition ^{60}Co Doses of 20 rad

Notation of sample	ED (rad)	I (rad)	Background			GD[a] (rad)
			Beta (rad/yr)	Gamma (rad/yr)	Total (rad)	
Ki-1	18.4±2.6	0.9±1.4	0.25	0.07	21.1±1.8	−1.8±3.5 (5)
Ki-2	11.3±1.3	2.2±1.5	0.11	0.13	15.7±1.6	−2.2±2.6 (5)
Ki-3	19.2±2.1	2.7±1.4	0.17	0.17	19.8±1.7	+2.1±3.1 (5)
Ki-4	18.4±1.9	0.2±1.5	0.17	0.13	19.8±1.7	−1.2±3.0 (6)

[a]Values in parentheses are the numbers of glow curves used for evaluations.

Table 4. Comparison of Various Dose Estimates with Experimental Results

Ground 1909	Direction East	Dose (rad)			Ratio TL/Loewe
		TL experiment	Loewe[2]	T65D[1]	
1909	East	21.7±7.8	10.5[a]	3.0	2.1±0.8
1909	East	20.7±8.1	10.5	3.0	2.0±0.8
2053	West	9.8±4.5	6.2	1.5	1.6±0.7

[a]Extrapolated.

Hiroshima University was within 15%. Table 4 compares T65D doses, the new calculations of Loewe[1] and experimental results without corrections. The results are: (1) different from the T65D doses, and (2) even higher than the new calculations.

Table 3 shows that the BG estimates were made with errors within a few rad.

Discussion of directional dependence should include additional directions such as north and south. The data suggest some difference by directions. We will discuss this more precisely after obtaining data for other directions.

References

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