Comparison of TLD Measured Values to DS02

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Introduction

The comparison of measured TL results *from ceramic materials (bricks and tiles from Hiroshima and Nagasaki) to the doses calculated by A-bomb dosimetry systems requires good, sample-specific calculations for acceptable accuracy. That is, even though investigators typically measured samples with exposed surfaces that had a clear line of sight to the bomb, the actual calculated dose deposited in the measured quartz crystals by bomb gamma rays (the *in situ* dose to quartz) is not always equal to the free-in-air kerma (Kerr *et al.* 1987) at the same location, to an acceptably close approximation. This has been demonstrated independently of the DS86 and DS02 dosimetry systems by both experiment and calculation, e.g., in Hashizume *et al.* (1967) and Uehara *et al.* (1988), which demonstrated that the *in situ* dose to quartz depends on the depth of the measured material below the surface and the angle between the surface and direction of the incident gamma rays. The ratio of 1) the *in situ* dose to quartz, to 2) the free-in-air kerma at the same location, is regarded as a "transmission factor" (TF) in DS02. We can think of the TF as representing the fraction of the free-in-air kerma that reached the quartz crystals whose TL signal was measured.

In this report, as in the DS02 report itself, we consider all of the available measurements that contain useful information about the free-in-air kerma from the Hiroshima and Nagasaki bombs, including those considered in the DS86 Final Report: measurements by the Japan National Institute of Radiological Sciences, identified by the abbreviation "JNIRS" in the tables below, the University of Utah (USA) group, identified by the abbreviation "U of U" in the tables below, the Oxford University (UK) group, identified by the abbreviation "OXF" in the tables below, and the Durham University (UK) group, identified by the abbreviation "DUR" in the tables below, (Hashizume *et al.* 1967, Maruyama *et al.* 1984, Maruyama *et al.* 1987) and the Nara University of Education (Japan) group, identified by the abbreviation "NUE" in the tables below (Nagatomo *et al.* 1987) as well as an important set of early measurements by the Nara University of Education group not considered in DS86 (Ichikawa *et al.* 1966), and various newer measurements reported after DS86 by the JNIRS and NUE groups (Maruyama *et al.* 1988, Hoshi *et al.* 1989, Nagatomo *et al.* 1991, Nagatomo *et al.* 1992, Nagatomo *et al.* 1995, Maruyama *et al.* In Press).

Kaul *et al.* (1987) made detailed calculations of the *in situ* dose to quartz in almost all of the samples included in the DS86 report. Although they did not evaluate TF's explicitly, it is simple to calculate TF's from their calculations of the *in situ* dose to quartz. To calculate the *in situ* dose to quartz they used detailed adjoint Monte Carlo calculations similar to those used for evaluating the shielding of Japanese wooden houses in DS86. Unfortunately, funding was not available to perform such a suite of calculations for DS02. Besides having different gamma ray and neutron fluences from DS86, DS02 includes new, post-DS86 TL measurements at a considerable number of new sites. This resulted in a need for a thorough quantitative analysis of the DS86 calculations, so that they could be adjusted and extended for DS02.

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To analyze the DS86 TF's of Kaul *et al*., we first separated their calculated *in situ* dose to quartz into two portions. The first and most important part is due to incident gamma rays from the bomb, and the second, sometimes called "building gammas," is due to the incident neutrons from the bomb. The key assumption that allows us to extend the analysis of the DS86 TF's to DS02 is that the TF for a given sample is the same in DS02 as in DS86, for the portion of the *in situ* dose to quartz arising from incident bomb gamma rays. That is, the angle and energy distribution of the gamma ray fluences in DS86 and DS02 are similar enough that, using the subscript "BG" to denote "building gammas" and "FIA" to denote "free in air,"

$$TF_{DS02} = \frac{\text{dose}_{quartz,in\_situ,without\_BG,DS02}}{\text{kerma}_{FIA,DS02}} = \frac{\text{dose}_{quartz,in\_situ,without\_BG,DS86}}{\text{kerma}_{FIA,DS86}} = TF_{DS86}$$

, to a very good approximation (< 1% difference). This assumption has been checked and is supported by various observations, beginning with the parallel nature of the curves for calculated free-in-air kerma of DS86 and DS02, suggesting that they are attenuated almost identically in air.

This assumption allowed us to calculate the DS02 *in situ* dose to quartz in a straightforward way, for samples that were calculated for DS86 by Kaul *et al*. That is, we could simply calculate the DS86 TF and multiply it times the DS02 free in air kerma to obtain a DS02 *in situ* dose to quartz. For samples that were not calculated by Kaul *et al*., we needed to take an additional step. That step was to analyze the TF's of Kaul *et al*. by using a simplified model that would allow us to estimate TF's for other samples with reasonable accuracy, although not as accurately as a full, custom adjoint Monte Carlo calculation.

We analyzed the DS86 TF's of Kaul *et al*. as a function of the input variables that we could model in a simple way, which are a few sample parameters: the depth of the measured material below the surface of the sample, the density of the sample material, and the angle between the surface of the sample and a line of sight to the epicenter of the bomb (related to the "angle of incidence"). We could not model the effects of scattering and partial blocking of the incident bomb fluence by the structure in which the sample was situated at the time of bombing, because that requires an adjoint Monte Carlo calculation or a model of some other type that we did not have the resources to develop. However, our simplified model gave good enough results for a useful approximation of the TF's that Kaul *et al*. calculated. We used our simplified model to estimate TF's for samples that were not calculated by Kaul *et al*., and we applied those estimated TF's to the DS02 free in air kerma at the sample locations to estimate the *in situ* dose to quartz under DS02.

DS02 has new sample distances, and new ground elevations at sample locations in Nagasaki, that are based on a careful evaluation of sample locations using the Geographical Information System (GIS) at RERF with the U.S. Army maps, the newer Japanese city maps, and pre-bombing aerial photographs. In addition, DS02 has a 20 m increase in the height of burst (HOB) in Hiroshima, which affects the slant range to any given sample location. To analyze the DS86 TF's of Kaul *et al*., we calculated the DS86 free-in-air kerma for the divisor by using a slant range based on the same sample distances, sample ground elevations in Nagasaki, and HOB that they used: the DS86 ones. To calculate the DS02 *in situ* dose to quartz, however, for all of the samples, whether or not calculated in DS86 by Kaul *et al*., we used the DS02 free in air kerma at a slant range based on the DS02 sample distances, DS02 sample ground elevations in Nagasaki, and DS02 HOB.

We used a somewhat analogous method to estimate the "building gamma" component of *in situ* dose to quartz, which arises from fast interactions (e.g., inelastic scattering, prompt capture gammas) of incident bomb neutrons. In that case, we determined that if we corrected for the inverse square of slant distance from the epicenter of the bomb, the bomb gamma components of Kaul *et al*. were close to a straight line on a semi-logarithmic plot vs. slant distance. Based on this, we used an inverse square of slant distance times an exponential in slant distance to correct for differences between the sample distance assumed in DS86 and that assumed in DS02, and we corrected for the difference between the DS86 and DS02 neutron fluences by using a ratio of calculated ^{60}Co activation values. For samples calculated for DS86 by Kaul *et al.*, we could simply apply these corrections to the building gamma component calculated by them. For samples not calculated for DS86, we used a simple regression model vs. slant distance, based on the inverse square times the exponential as just described, to obtain an estimate of the DS86 building gamma component, and then we corrected it for the ratio of DS02 to DS86 neutron fluence using the ratio of calculated ^{60}Co activation values.

In the following sections, we give some additional details of these calculations. We identify some remaining concerns about particular post-DS86 samples for which we may not be able to calculate acceptably accurate TF's, and we describe several other potential sources of inaccuracy in measured or calculated values that might influence the comparison of one to the other. Finally, we summarize the results of our comparison of measured and calculated values for DS02.

Calculation and Analysis of the TF's Implicit in DS86

As noted above, we defined the DS86 TF as $TF_{DS86} \equiv \dfrac{\text{dose}_{quartz,in\_situ,without\_BG,DS86}}{\text{kerma}_{FIA,DS86}}$. The numerator of this ratio for each sample was taken from Tables 15, 17, 19, 21, and 23 of Appendix 11 to Chapter 4 of the DS86 Final Report. To obtain the divisor, we took the table of free-in-air kerma to tissue values for DS86 (e.g., Table 40 in Chapter 3 of the DS86 Final Report), converted the noted ground distances to slant distances using the DS86 height of burst, converted dose to quartz to dose to tissue by dividing by 0.916, and interpolated the resulting values at the slant distance of the sample, based on its elevation and "new city map" ground distance as given in Tables 1 - 5, Appendix 11 to Chapter 4 of the DS86 Final Report.

In obtaining the calculated free-in-air kerma for the divisor by this method, we assume that the free-in-air kerma "scales as the slant distance" within a few tens of meters height above the elevation of the hypocenter – i.e., that the free-in-air kerma at some ground distance and height (GR_1, h_1) is equal to the free-in-air kerma at some other ground distance and height (GR_2, h_2) if $\sqrt{GR_1^2+(HOB-h_1)^2}=\sqrt{GR_2^2+(HOB-h_2)^2} \Leftrightarrow SR_1 = SR_2$, where GR is a ground distance, HOB is the height of the epicenter above the hypocenter, h is the elevation difference between a sample location and the hypocenter, and SR is a slant distance. DS86 uses this assumption to correct for terrain elevation in Nagasaki, whereas it corrects for sample height above ground implicitly because that height is included in the model of the building containing the sample that is used for forward-adjoint Monte Carlo coupling. For DS02 we removed these corrections so that we could analyze TF's based on sample properties, by using this assumption to calculate a free-in-air quartz kerma at the sample's actual slant range, corrected for both terrain elevation and height above ground. We can use the TF that we estimate by this method to get a "free-in-air-equivalent measured value" at the sample's actual location (ground distance and elevation), and then use the above assumption again, with the DS02 estimate of the sample's elevation, to correct it back to one meter above ground at the same ground distance. The resulting "free-in-air-@1m-equivalent measured value" can then be compared to tabulated values of free-in-air kerma at one meter above flat ground, or plotted versus distance in comparison to a smooth curve of calculated free-in-air kerma at one meter above flat ground. This allows us not only to estimate "free-in-air-@1m-equivalent measured values" for new measurements not calculated in DS86, but to correct DS86 calculated *in situ* dose to quartz for DS02 estimates of terrain elevation that may differ from those used in DS86.

A very important aspect of the analysis was to calculate the angle of incidence accurately for each sample, where the angle of incidence is defined per the usual convention in radiological physics, as the plane angle between a normal to the exposed surface and a ray to the center of the radiation source, with the latter being assumed parallel to unscattered incident radiations. For horizontal samples the angle of incidence is easily calculated from the height of the bomb epicenter above the elevation of the sample and the ground distance from the hypocenter to the sample. For vertical samples and samples tilted somewhat from the true horizontal, we developed formulae based on the trigonometry in three dimensions. For vertical samples the formula requires the azimuthal angle (in the horizontal plane) between the vertical surface and a ray to the hypocenter, in addition to the angle of elevation defined by the epicenter height and ground distance. For "tilted" samples that are neither horizontal nor vertical, the formula requires the azimuthal angle (in the horizontal plane) between the axis about which the sample's surface is tilted and a ray to the hypocenter, as well as the tilt angle, in addition to the angle of elevation defined by the epicenter height and ground distance. These angles are given for the samples calculated in Appendix 11 to Chapter 4 of the DS86 Final Report, in either the text or figures of that section. The formulae and method of derivation are given in the DS02 report (Cullings *et al*. In Press).

The other necessary variables were the assumed depth and density of the measured material as used in Appendix 11 to Chapter 4 of the DS86 Final Report, which are given in the tables of that section. The calculated angles, the density, the measured depths, and the corresponding TF's are given in Tables 1 and 2 below.

Table 1. Type 1 Transmission Factors Implicit in Calculated *in situ* Values of DS86 with Related Angles, Measured Depths, and Density of Sample Material: Hiroshima

Lab	Place Name	Sample ID#	RERF List No.	DS86 GR, m	DS86 ht, m^2	Elev. Angle Theta, deg	Azimuthal Angle, deg	Angle of Incidence tau, deg	Meas. Depth, cm	Density, g/cm^2	TF, no Bldg gamma	TF with Bldg gamma
JNIRS	A-bomb Dome[1]			118.6	4	78.4	NA[5]	11.6	1-2	2.10	0.786	0.944
JNIRS	Togiya-cho Shojun-ji[1]			146.2	3	75.8	90	75.8	1-2	2.00	0.392	0.645
JNIRS	Nenryo Kaikan (Fuel Authority Bldg) [1]			175.4	3	73.1	90	73.1	1-2	2.00	0.451	0.695
JNIRS	Fukuro-machi East Orthopedic Surgical Hospital[1]			406.4	3	54.8	90	54.8	1-2	2.00	0.696	0.861
JNIRS	Naka Telephone Office	3	1-01	506.8	14	48.2	NA[5]	41.8	0.4-0.9	2.10	1.019	1.093
JNIRS	Naka Telephone Office	2	1-19	523.1	14	47.3	69	50.7	0.6-1.3	2.00	0.774	0.870
NUE	Naka Telephone Office	203-3	1-04	523.4	14	47.2	NA[5]	42.8	0.2-1.05	2.10	0.962	1.046
NUE	Naka Telephone Office	204-2	1-04	523.4	14	47.2	NA[5]	42.8	0.2-1.05	2.10	0.962	1.046
NUE	Naka Telephone Office	204-3	1-04	523.4	14	47.2	NA[4]	42.8	0.2-1.05	2.10	0.962	1.046
JNIRS	Tate-machi Sanin Godo Bank[1]			617.5	3	43.1	90	43.1	1-2	2.00	0.793	0.885
JNIRS	Sanin Bank		12-02	621	13	42.4	74	44.8	0.4-1.05	2.00	0.889	0.959
JNIRS	Chugoku Elec Co		2_01	665.4	0.16	41.1	NA[5]	48.9	0.4-1	2.00	0.527	0.582
JNIRS	Chugoku Elec Co	2	2-03	691.8	0.5	40.0	68.3	44.6	0.4-0.8	2.00	0.610	0.672
NUE	Chugoku Electric Co.	3-1-3	2-03	691.8	0.5	40.0	68.3	44.6	0.2-1.2	2.00	0.592	0.647
NUE	Chugoku Electric Co.	3-1-3	2-03	691.8	0.5	40.0	68.3	44.6	0.2-1.2	2.00	0.592	0.647
NUE	Chugoku Electric Co.	3-2-2	2-03	691.8	0.5	40.0	68.3	44.6	0.2-1.2	2.00	0.592	0.647
NUE	Chugoku Electric Co.	3-2-2	2-03	691.8	0.5	40.0	68.3	44.6	0.2-1.2	2.00	0.592	0.647
NUE	Chugoku Electric Co.	3-2-3	2-03	691.8	0.5	40.0	68.3	44.6	0.2-1.2	2.00	0.592	0.647
JNIRS	Nobori-machi Elementary School			710.0	3	39.1	90	39.1	1-2	2.00	0.825	0.893
JNIRS	City Hall[1]			985.5	3	30.3	90	30.3	1-2	2.00	0.876	0.901
NUE	Japanese House (Nobori-cho)		145	1131.2	4.8	27.0	23.455761	69.2	0.1-1.5	2.00	1.037	1.052
NUE	H.U.P.S. (Hiro. Uriv.)	H-1	4-08	1271.3	14.72	24.0	NA[5]	66.0	0.2-2.5	1.87	0.970	0.981
NUE	HUFS "I" Bldg	H1	4-08	1271.3	14.72	24.0	NA[5]	66.0	0.2-2.5	1.87	0.970	0.981
NUE	H.U.P.S. (Hiro. Univ.)	H-2	4-07	1282.1	14.72	23.8	72.9	29.0	0.2-2.5	1.87	0.987	0.998
NUE	H.U.P.S. (Hiro. Univ.)	H-3	4-09	1297.7	14.72	23.5	NA[5]	66.5	0.2-2.5	1.87	0.979	0.990
NUE	H.U.P.S. (Hiro. Univ.)	H-4	4-01	1316.5	14.72	23.2	74.3	27.8	0.2-2.5	1.87	0.987	0.996
NUE	H.U.P.S. (Hiro. Univ.)	H-5	4-03 horizontal	1338.1	14.72	22.9	NA[5]	67.1	0.2-2.5	1.87	0.950	0.959
NUE		H-5B	4-03 vertical	1338.1	14.72	22.9	74.8	27.3	0.2-2.5	1.87	0.852	0.861
NUE		H-5B	4-03 vertical	1338.1	14.72	22.9	74.8	27.3	0.2-2.5	1.87	0.852	0.861
NUE	H.U.P.S. (Hiro. Univ.)	H-5B	4-03 vertical	1338.1	14.72	22.9	74.8	27.3	0.2-2.5	1.87	0.852	0.861
JNIRS	H.U.F.S. (Hiro. Univ.)	7	3-07	1377	13.1	22.4	75.8	26.3	0.5-1.5	2.00	0.981	0.991
NUE	HUFS "E" Bldg	HPl	3-08	1378.4	10.61	22.4	75.8	26.4	0.2-1.9	2.00	0.972	0.982
JNIRS	H.U.F.S. (Hiro. Univ.)	10	3-10	1387.4	13.1	22.2	73.8	27.3	0.5-1.5	2.00	0.951	0.958
NUE	H.U.F.S. (Hiro. Univ.j	H-6-1	3-20	1387.9	13.1	22.2	NA[5]	67.8	0.2-1.9	2.00	0.885	0.892
NUE	H.U.F.S. (Hiro. Univ.j	H-6-2	3-20	1387.9	13.1	22.2	NA[5]	67.8	0.2-1.9	2.00	0.885	0.892
NUE	H.U.F.S. (Hiro. Univ.j	H-6-3	3-20	1387.9	13.1	22.2	NA[5]	67.8	0.2-1.9	2.00	0.885	0.892
NUE	HUFS "E" Bldg	HP2	3-11	1388.5	10.7	22.3	73.8	27.3	0.2-1.9	2.00	0.957	0.964

< Table 1 continued>

Lab	Place Name	Sample ID#	RERF List No.	DS86 GR, m	DS86 ht, m[2]	Elev. Angle Theta, deg	Azimuthal Angle, deg	Angle of Incidence tau, deg	Meas. Depth, cm	Density, g/cm^2	TF, no Bldg gamma	TF with Bldg gamma
NUE	HUFS "E" Bldg	HP3	(3-11)	1388.5	10.7	22.3	73.8	27.3	0.2-1.9	2.00	0.957	0.964
U. 0F U.	H.U.F.S.[3] (Hiro. Univ.)	UHFSO3	3-23	1392.8	13.1	22.1	75.3	60.7	0.25-1.75	2.10	0.982	0.989
NUE	H.U.F.S. [3] (Hiro. Univ.j	H-7	3-36	1393.1	13.4	22.1	75.8	60.7	0.2-1.9	2.00	0.957	0.964
U. 0F U.	H.U.F.S. [3] (Hiro. Univ.)	UHFSO2	3-22	1397.0	13.1	22.1	74.8	60.8	0.25-1.75	2.10	0.959	0.966
NUE	H.U.F.S. (Hiro. Univ.j	H-8	3-18	1422.0	13.1	21.7	NA[5]	68.3	0.2-1.9	2.00	0.885	0.891
JNIRS	H.U.F.S. (Hiro. Univ.)	I	3-29	1424.9	13.5	21.7	74.3	26.5	0.5-1.5	2.00	0.961	0.968
JNIRS	H.U.F.S. [3] (Hiro. Univ.)	IV	3-31	1426.1	13.4	21.7	75.8	61.2	0.5-1.5	2.00	0.942	0.948
NUE	H.U.F.S. (Hiro. Univ.j	H- 9	3-17	1427.9	13.1	21.7	74.3	26.5	0.2-1.9	2.00	0.860	0.867
JNIRS	Red Cross Hospital		5-01	1451.8	7	21.5	56.5	39.1	0.5-1.5	2.00	0.923	0.930
NUE	Red Cross Hospital	HP4	5_01	1451.8	7	21.5	56.5	39.1	0.2-1.4	2.00	0.961	0.969
JNIRS	H.U.F.S.(Hiro.Uriv.)	R1	3-35	1449.1	13.1	21.4	NA[5]	68.6	0.5-1.5	2.10	0.881	0.888
DUR	H.U.F.S. (Hiro. Univ.j	UHFSFT02	3-35	1449.1	13.1	21.4	NA[5]	68.6	0.25-1.75	2.10	0.885	0.892
DUR	H.U.F.S. (Hiro. Univ.j	UHFSFT02	3-35	1449.1	13.1	21.4	NA[5]	68.6	0.25-1.75	2.10	0.885	0.892
OXF H	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	1449.1	13.1	21.4	NA[5]	68.6	0.25-1.75	2.10	0.885	0.892
OXF H	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	1449.1	13.1	21.4	NA[5]	68.6	0.25-1.75	2.10	0.885	0.892
OXF H	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	1449.1	13.1	21.4	NA[5]	68.6	0.25-1.75	2.10	0.885	0.892
U of U	H.U.F.S. (Hiro. Univ.)	UHFSFT02	3-35	1449.1	13.1	21.4	NA[5]	68.6	0.25-1.75	2.10	0.885	0.892
U of U	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	1449.1	13.1	21.4	NA[5]	68.6	0.25-1.75	2.10	0.885	0.892
NUE	H.U.F.S. (Hiro. Univ.j	H-10-1	3-15	1450.5	13.1	21.3	NA[5]	68.7	0.2-1.9	2.00	0.897	0.904
NUE	H.U.F.S. (Hiro. Univ.j	H-10-2	3-15	1450.5	13.1	21.3	NA[5]	68.7	0.2-1.9	2.00	0.897	0.904
NUE	H.U.F.S. (Hiro. Univ.j	H-10-3	3-15	1450.5	13.1	21.3	NA[5]	68.7	0.2-1.9	2.00	0.897	0.904
NUE	H.U.F.S. (Hiro. Univ.j	H-10-4	3-15	1450.5	13.1	21.3	NA[5]	68.7	0.2-1.9	2.00	0.897	0.904
U of U	H.U.F.S. [3] (Hiro. Univ.)	UHFS04	3-24	1456.9	13.1	21.3	15.7	66.9	0.25-1.75	2.10	0.955	0.961
U of U	H.U.F.S. [3] (Hiro. Univ.)	UHFS07	3-27	1457.2	13.1	21.3	75.8	61.6	0.25-1.75	2.10	0.942	0.947
NUE	H.U.F.S. (Hiro. Univ.j	H-11	3-16	1460.9	13.1	21.2	NA[5]	68.8	0.2-1.9	2.00	0.821	0.826
NUE	Chokin-Kyoku (Postal Savings)		6-04	1602.9	20	19.3	28	63.7	0.2-0.7	2.05	0.654	0.657
JNIRS	Chokin-Kyoku[4]		6-00	1605.7	22	19.2	61.5	57.9	0.5-1.5	2.10	0.857	0.860
NUE	HUFE	HP5	8-01	2050.5	6	15.6	87.7	15.8	0.2-1.65	2.00	0.978	0.978

Notes: 1. Hashizume 1967 sample. 2. Includes only height above ground (elevation of ground above hypocenter was assumed = 0). 3. These samples were slanted downward 7.4° in a direction close to the direction to the hypocenter. 4. This sample was "slightly slanted," but neither the angle nor necessary dimensions are given by Kaul *et al.*(1987). 5. Horizontal surface sample.

Table 2. Type 1 Transmission Factors Implicit in Calculated *in situ* Values of DS86 with Related Angles, Measured Depths, and Density of Sample Material: Nagasaki

Lab	Place Name	Sample ID#	RERF List No.	DS86 GR, m	DS86 ht[2], m	Elevation Angle Theta, deg	Azimuthal Angle, deg	Angle of Incidence tau, deg	Meas. Depth, cm	Density, g/cm^2	TF, no Bldg gamma	TF with Bldg gamma
JNIRS	Yamazoto-cho House[1]			88	4	81.2	45	10.0	1-2	2.1	1.018	1.048
JNIRS	Urakami		N4	501	24	42.8	46.9	57.5	0.5-1.5	1.7	0.860	0.869
JNIRS	Urakami Church			508	3	38.2	45	44.5	1-2	2	0.878	0.894
JNIRS	Hachiman jinja nearby house[1]			866	3	29.3	90	30.0	1-2	2	0.957	0.963
JNIRS	Hachiman jinja[1]			891	3	28.1	90	29.3	1-2	2	0.968	0.974
JNIRS	Sakamoto cho Gaijin Cemetery[1]			935	3	27.1	45	28.1	1-2	2	0.986	0.992
JNIRS	Sakamoto-cho Gaijin Cemetery[1]			973	3	24.6	70	27.2	1-2	2	0.986	0.991
JNIRS	Sakamoto		N-6	1054	28	24.0	90	24.0	0.5-1.5	1.7	1.055	1.057
Dur	Ieno wall	NAIEO5	N-2-1	1429	11	19.0	81	20.9	0.3-3.2	1.7	0.992	0.992
Dur	Ieno wall	NAIEO5	N-2-1	1429	11	19.0	81	20.9	3.4-6.4	1.7	0.775	0.776
Dur	Ieno wall	NAIEO5	N-2-1	1429	11	19.0	81	20.9	6.6-10.3	1.7	0.688	0.689
Dur	Ieno wall	NAIEO5	N-2-1	1429	11	19.0	81	20.9	0.3-3.2	1.7	0.992	0.992
Dur	Ieno wall	NAIEO5	N-2-1	1429	11	19.0	81	20.9	3.4-6.4	1.7	0.775	0.776
Dur	Ieno wall	NAIEO5	N-2-1	1429	11	19.0	81	20.9	6.6-10.3	1.7	0.688	0.689
JNIRS	Ieno	A	N-2-2	1431	11	19.0	81	20.9	0.5-1.5	1.7	0.969	0.970
JNIRS	Ieno	B	N-2-2	1431	11	19.0	81	20.9	1-3	1.7	0.965	0.966
NUE	Ieno wall	A	N-2-1	1429	11	19.0	81	20.9	0.2-3.6	1.7	0.959	0.960
NUE	Ieno wall	B	N-2-1	1429	11	19.0	81	20.9	3.6-6.6	1.7	0.817	0.818
NUE	Ieno wall	C	N-2-1	1429	11	19.0	81	20.9	7-10.4	1.7	0.682	0.683
OXF H	Ieno wall	NAIEO5	N-2-1	1429	11	19.0	81	20.9	0.3-3.2	1.7	0.992	0.992
OXF H	Ieno wall	NAIEO5	N-2-1	1429	11	19.0	81	20.9	3.4-6.4	1.7	0.775	0.776
OXF H	Ieno wall	NAIEO5	N-2-1	1429	11	19.0	81	20.9	6.6-10.3	1.7	0.688	0.689
U of U	Ieno wall	NAIEO6	N-2-1	1429	11	19.0	81	20.9	0.4-3.6	1.7	0.955	0.956
U of U	Ieno wall	NAIEO6	N-2-1	1429	11	19.0	81	20.9	3.7-6.9	1.7	0.793	0.794
U of U	Ieno wall	NAIEO6	N-2-1	1429	11	18.8	72	20.9	7-10.2	1.7	0.718	0.719
JNIRS	Zenza		N-7	1424	9	19.3	90	19.1	0.5-1.5	1.7	1.060	1.061
JNIRS	Inasa	A	N-3	2050	0.6	13.9	67.4	26.3	0.5-1.5	1.7	1.025	1.025
JNIRS	Chikugo		N-8	2323	22			11.7	0.5-1.5	1.7	1.009	1.009

When the TF's were divided into groups based on the mass thickness depth to the middle of the measured material and then plotted vs. the inverse of the cosine of the angle of incidence (the angled depth d_{ang} to a perpendicular depth d is given by $d_{ang} = \frac{d}{\cos\tau}$ for an angle of incidence τ), the plot did not show clear and simple trends, as shown in Figure 1.

The key to analyzing these data was to notice that the samples measured by JNIRS and reported in 1967 by Hashizume *et al*., except for one sample in each city, were modeled for DS86 by using the same exact building model, in addition to the same measured depth and density. The TF's for these JNIRS 1967 samples in Hiroshima do lie on a smooth curve, and the identically modeled JNIRS 1967 samples in Nagasaki lie on a different curve. Thinking about this led to the idea of combining all of the depth (d), density (ρ), and angle (τ) information by calculating an angled mass thickness depth $amtd \equiv \frac{d\rho}{\cos\tau}$ to any portion of the measured material at depth d. Then, based on the idea that attenuation should be proportional to $e^{-\frac{amtd}{RL_{E,mat}}}$, where $RL_{E,mat}$ is some characteristic relaxation length specific to the incident gamma energy spectrum and the sample material, we could model the logarithm of the TF as a linear function of quantities based on *amtd*, and other variables of interest. Another inspiration for this concept, and a useful standard for comparison in some respects (although differing from DS86 because of differences in sample environs, beam energy and beam directionality), was a 1988 paper by Uehara *et al*., in which they measured and calculated depth doses for thin layers of sample material in bricks and tiles. We used their depth doses to calculate TF's based on the definitions they used for depth dose vs. our definition of TF, and then we made smoothed curves based on their values, which are included in Fig.1.

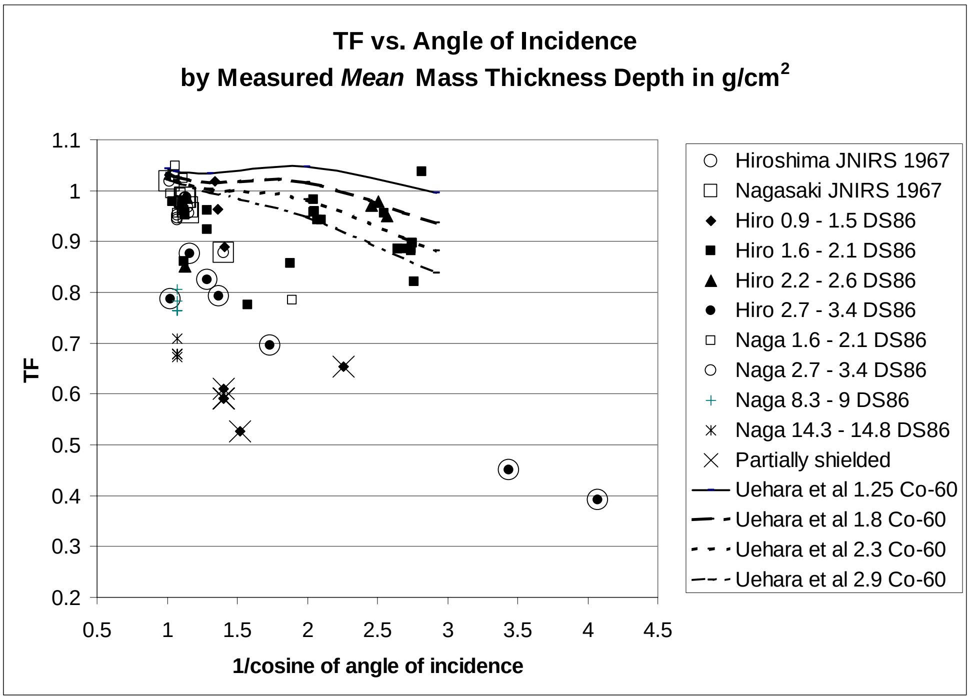

Figure 1. TF vs. inverse cosine of angle of incidence, classified by mass thickness depth.

We therefore analyzed log(TF) by doing a multiple linear regression on the *amtd*'s associated with the minimum, geometric mean, and maximum depths of the measured material in each sample. In Hiroshima, we also included a dummy variable for vertical vs. horizontal samples, to allow for a broad difference between the two. Another important point is that we purposely excluded particular samples at the Chugoku Electric Co. and the Postal Savings Building that had unusually low calculated TF's due to substantial and obvious blocking of part of the incident bomb fluence by part of the modeled structure. The model chosen as best for Hiroshima was:

$$\ln(TF) = 0.130155 - 0.095655 amtd_{\min} - 0.011206 amtd_{\max} - 0.075565 HV ,$$

where the dummy variable HV was taken equal to 0 if the sample was horizontal and 1 if the sample was vertical. The model chosen as best for Nagasaki was:

$$\ln(TF) = 0.0914539 + 0.0998853 amtd_{\min} - 0.1122389 amtd_{geom\_mean} .$$

The positive sign on the term for minimum *amtd* in the Nagasaki equation is apparently due to the fact that the sample population in Nagasaki consisted of relatively thin, shallow samples at various locations and much thicker, much deeper samples at Ieno wall.

The TF values predicted by the regression are compared to the actual values calculated in Appendix 11 to Chapter 4 of the DS86 Final Report, in Table 3 below. The regression-based models are useful because the indicated terms were highly significant in the regressions, and the models correspondingly explained much of the variation among the calculated TF's. The unexplained remainder of the variation is essentially random variation due to the detailed properties of randomly determined building geometries as reflected in the Monte Carlo calculations of TF; i.e., aspects of building geometry that affect the scattering and (minor) partial blocking of incident bomb fluences but are not systematically related to sample angle, measured depth, or density. Therefore these models should give a good approximation of the TF that would be calculated for a different sample not calculated in Appendix 11 to Chapter 4 of the DS86 Final Report, so long as it was not taken from a location with obvious, substantial blocking of part of the incident fluence; i.e., locations like those at the Chugoku Electric Co. that were deliberately omitted from this analysis.

Table 3. Loglinear Model Results for Estimating Type 1 TF

City	Place	Sample ID#	RERF List No.	DS86 TF	TF estimated by loglinear regression model	Ratio of regression estimate to DS86 TF
H	A-bomb Dome			0.786	0.885	1.126
H	Togiya-cho Shojun-ji			0.392	0.405	1.033
H	Nenryo Kaikan (Fuel Authority Bldg)			0.451	0.470	1.042
H	Fukuro-machi East Orthopedic Surgical Hospital			0.696	0.701	1.007
H	Naka Telephone Office	3	1-1	1.019	0.994	0.975
H	Naka Telephone Office	2	1-19	0.774	0.841	1.087
H	Naka Telephone Office	203-3	1-4	0.962	1.044	1.085
H	Tate-machi Sanin Godo Bank			0.793	0.764	0.963
H	Sanin Bank		12-2	0.889	0.917	1.031
H	Nobori-machi Elementary School			0.825	0.779	0.944
H	City Hall			0.876	0.803	0.917
H	H.U.P.S. (Hiro. Uriv.)	H-1	4-08	0.970	0.922	0.951
H	H.U.P.S. (Hiro. Univ.)	H-2	4-07	0.987	0.957	0.970
H	H.U.P.S. (Hiro. Univ.)	H-3	4-09	0.979	0.919	0.939
H	H.U.P.S. (Hiro. Univ.)	H-4	4-01	0.987	0.958	0.971
H	H.U.P.S. (Hiro. Univ.)	H-5	4-03 horizontal	0.950	0.914	0.962
H	H.U.P.S. (Hiro. Univ.)	H-5B	4-03 vertical	0.852	0.958	1.124
H	H.U.F.S. (Hiro. Univ.)	7	3-07	0.981	0.915	0.933
H	H.U.F.S. (Hiro. Univ.)	HPl	3-08	0.972	0.966	0.994
H	H.U.F.S. (Hiro. Univ.)	10	3-10	0.951	0.913	0.960
H	H.U.F.S. (Hiro. Univ.j	H-6-1	3-20	0.885	0.924	1.044
H	H.U.F.S. (Hiro. Univ.)	HP2	3-11	0.957	0.966	1.009
H	H.U.F.S. (Hiro. Univ.)	UHFSO3	3-23	0.982	0.948	0.965
H	H.U.F.S. (Hiro. Univ.j	H-7	3-36	0.957	0.969	1.013
H	H.U.F.S. (Hiro. Univ.)	UHFSO2	3-22	0.959	0.948	0.989
H	H.U.F.S. (Hiro. Univ.j	H-8	3-18	0.885	0.920	1.040
H	H.U.F.S. (Hiro. Univ.)	I	3-29	0.961	0.914	0.951
H	H.U.F.S. (Hiro. Univ.)	IV	3-31	0.942	0.873	0.927
H	H.U.F.S. (Hiro. Univ.j	H- 9	3-17	0.860	0.966	1.123
H	Red Cross Hospital		5-01	0.923	0.894	0.969
H	Red Cross Hospital	HP4	5-01	0.961	0.966	1.005

<Table 3 continued>

City	Place	Sample ID#	RERF List No.	DS86 TF	TF estimated by loglinear regression model	Ratio of regression estimate to DS86 TF
H	H.U.F.S.(Hiro.Uriv.)	R1	3-35	0.881	0.787	0.893
H	H.U.F.S. (Hiro. Univ.j	UHFSFT02	3-35	0.885	0.890	1.006
H	H.U.F.S. (Hiro. Univ.j	H-10-1	3-15	0.897	0.917	1.022
H	H.U.F.S. (Hiro. Univ.)	UHFS04	3-24	0.955	0.906	0.949
H	H.U.F.S. (Hiro. Univ.)	UHFS07	3-27	0.942	0.943	1.001
H	H.U.F.S. (Hiro. Univ.j	H-11	3-16	0.821	0.916	1.116
H	Chokin-Kyoku		6-00	0.857	0.884	1.032
H	HUFE	HP5	8-01	0.978	0.978	1.000
N	Yamazoto-cho House			1.018	0.967	0.961
N	Urakami		N4	0.860	0.941	1.114
N	Urakami Church			0.878	0.929	1.072
N	Hachiman jinja nearby house			0.957	0.957	1.012
N	Hachiman jinja			0.968	0.957	1.001
N	Sakamoto cho Gaijin Cemetery			0.986	0.959	0.984
N	Sakamoto-cho Gaijin Cemetery			0.986	0.960	0.985
N	Sakamoto		N-6	1.055	1.003	0.963
N	Ieno wall	NAIEO5	N-2-1	0.992	0.947	0.971
N	Ieno wall	NAIEO5	N-2-1	0.775	0.784	1.029
N	Ieno wall	NAIEO5	N-2-1	0.688	0.675	0.994
N	Ieno wall	NAIEO5	N-2-1	0.992	0.947	0.971
N	Ieno wall	NAIEO5	N-2-1	0.775	0.784	1.029
N	Ieno wall	NAIEO5	N-2-1	0.688	0.675	0.994
N	Ieno	A	N-2-2	0.961	1.005	1.059
N	Ieno	B	N-2-2	0.957	0.923	0.980
N	Ieno wall	A	N-2-1	0.959	0.955	1.013
N	Ieno wall	B	N-2-1	0.817	0.779	0.969
N	Ieno wall	C	N-2-1	0.682	0.684	1.014
N	Ieno wall	NAIEO5	N-2-1	0.992	0.947	0.971
N	Ieno wall	NAIEO5	N-2-1	0.775	0.784	1.029
N	Ieno wall	NAIEO5	N-2-1	0.688	0.675	0.994
N	Ieno wall	NAIEO6	N-2-1	0.955	0.922	0.984
N	Ieno wall	NAIEO6	N-2-1	0.793	0.765	0.981
N	Ieno wall	NAIEO6	N-2-1	0.718	0.696	0.978
N	Zenza		N-7	1.060	1.006	0.961
N	Inasa	A	N-3	1.025	1.002	0.989
N	Chikugo		N-8	1.009	1.009	1.012

Estimation of DS02 TF's and Calculation of DS02 Dose to Quartz Exclusive of Building Gamma Component

For new samples and locations not calculated in Appendix 11 to Chapter 4 of the DS86 Final Report, we used the loglinear model described in the preceding section. For the JNIRS 1967 measurements, because the TF's calculated in Appendix 11 to Chapter 4 of the DS86 Final Report lie on a reasonably smooth curve vs. the inverse of the cosine of the angle of incidence (they are well approximated over most of the range by a simple exponential), we could adjust the DS86 estimates by calculating a new angle of incidence based on a DS02 ground distance evaluated with the geographical information system (GIS), and new assumptions about the azimuthal angles involved. For the samples and locations that were calculated in Appendix 11 to Chapter 4 of the DS86 Final Report, we did not have a straightforward way to adjust the TF for a re-evaluated angle of incidence. We could have developed a perturbation method based on the TF calculated for DS86 and the log-linear model, but it was not necessary because we confirmed that the adjustments would be very small based on the changes in angle that would apply to the particular samples involved. The TF's that were adjusted or calculated *de novo* for DS02 are summarized in Tables 4 and 5 below. These TF's, and those that were adopted from DS86 without adjustment, were used with DS02 free-in-air calculated values, evaluated at DS02 slant range for all samples, to obtain DS02 *in situ* dose to quartz, exclusive of the building gamma component.

Table 4. DS02 TF's Estimated *de novo* or Adjusted Based on Analysis of DS86 TFs: Hiroshima (does not include height correction)

Lab	Place Name	Sample ID#	RERF List No.	DS02 GR, m	DS02 ht, m	Elevation Angle Theta, deg	Azimuthal Angle, deg	Angle of Incidence tau, deg	Meas. Depth, cm	Density, g/cm^2	TF, no Bldg gamma	TF with Bldg gamma
JNIRS	Togiya-cho Shojun-ji			162	3	74.8	77.7	75.2	1-2	2	0.402	0.584
JNIRS	Nenryo Kaikan (Fuel Authority Bldg)			158	3	75.2	78.9	75.5	1-2	2	0.393	0.573
NUE	Zaimoku cho, Dempuku ji	H-1		410	4	55.5	45	30.0	2.2-3.9	2.1	0.593	0.696
NUE	Zaimoku cho, Seigan ji	H-2		401	4	56.1	45	30.0	2.2-3.9	2.1	0.593	0.698
NUE	Zaimoku cho, Seigan ji	H-2'		401	4	56.1	45	30.0	2.2-3.9	2.1	0.593	0.698
JNIRS	Fukuro-machi East Orthopedic Surgical Hospital			421	3	54.8	69.4	57.4	1-2	2	0.662	0.790
NUE	Zaimoku cho,	H-3		424	4	54.6	45	30.0	2.2-3.9	2.1	0.593	0.694
JNIRS	Tate-machi Sanin Godo Bank			624	3	43.0	74.0	45.9	1-2	2	0.780	0.859
JNIRS	Nobori-machi Elementary School			716	3	39.8	76.3	41.7	1-2	2	0.810	0.872
NUE	Hiroshima Castle, ninomaru	H-4		739	4	38.9	45	33.6	0.2-1.9	2.1	0.991	1.048
NUE	Hiroshima Castle, ninomaru	H-4'		739	4	38.9	45	33.6	0.2-1.9	2.1	0.991	1.048
NUE	Nishitera machi, koen ji	H-6		977	4	31.4	45	37.3	0.2-1.9	2.1	0.987	1.018
NUE	Hiroshima Castle, honmaru	H-8		1000	4	30.8	45	37.7	0.2-1.9	2.1	0.986	1.015
NUE	Hiroshima Castle, honmaru	H-8'		1000	4	30.8	45	37.7	0.2-1.9	2.1	0.986	1.015
NUE	Hiroshima Castle, honmaru	H-8"		1000	4	30.8	45	37.7	0.2-1.9	2.1	0.986	1.015
JNIRS	City Hall			988	3	31.1	72.4	35.3	1-2	2	0.847	0.873
NUE	Nishitera machi, Shozen ji	H-7		1017	4	30.4	45	37.9	0.2-1.9	2.1	0.986	1.014
JNIRS	Hiroshima Univ Radioisotope Facility			1470	4	22.1	NA*	67.9	0.5-1.5	2	0.808	0.814
JNIRS	Hiroshima Univ Radioisotope Facility			1475	4	22.0	NA*	68.0	0.5-1.5	2	0.807	0.813
JNIRS	Hiroshima Univ Radioisotope Facility			1477	4	22.0	NA*	68.0	0.5-1.5	2	0.807	0.813
JNIRS	Red Cross Hospital			1501	20	21.1	56.5	38.9	0.5-1.5	2	0.895	0.901
JNIRS	Red Cross Hospital			1501	20	21.1	56.5	38.9	0.5-1.5	2	0.895	0.901
JNIRS	Red Cross Hospital			1501	20	21.1	56.5	38.9	0.5-1.5	2	0.895	0.901
JNIRS	Red Cross Hospital			1501	20	21.1	56.5	38.9	0.5-1.5	2	0.895	0.901
JNIRS	Red Cross Hospital			1501	20	21.1	56.5	38.9	0.5-1.5	2	0.895	0.901
NUE	Postal Savings (Chokin Kyoku)	A		1596	19	20.0	NA*	70.0	0.2-1.9	2	0.900	0.904
NUE	Postal Savings (Chokin Kyoku)	B		1607	22	19.8	61.5	57.9	0.2-2.1	2	0.971	0.975
NUE	Postal Savings (Chokin Kyoku)	D		1619	19	19.7	NA*	70.3	0.2-1.9	2	0.897	0.901
NUE	Postal Savings (Chokin Kyoku)	E		1637	19	19.5	NA*	70.5	0.2-1.9	2	0.895	0.899
NUE	JEMIC	HP7		1788	14.5	18.1	69	27.5	0.2-0.5	2	1.000	1.002
NUE	Myosen -ji "oni-gawara" top	Me-1		1915	7	17.2	16.8	74.0	0.2-1.6	2	0.808	0.809
NUE	Myosen -ji "oni-gawara" bottom	Me-2		1915	7	17.2	16.8	74.0	0.2-1.6	2	0.808	0.809
NUE	Myosen -ji "oni-gawara" top	A-1		1915	7	17.2	16.8	74.0	0.2-1.6	2	0.808	0.809
NUE	Myosen -ji "oni-gawara" bottom	A-2		1915	7	17.2	16.8	74.0	0.2-1.6	2	0.808	0.809
NUE	Hiramoto "oni-gawara" bottom	Hr-1		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808
NUE	Hiramoto "Oni-gawara"	B		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808
NUE	Hiramoto Oni-gawara	A1-1		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808
NUE	Hiramoto Oni-gawara	A1-2		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808
NUE	Hiramoto Oni-gawara	A1-3		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808
NUE	Hiramoto Oni-gawara	A2		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808
NUE	Hiramoto Oni-gawara	A3		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808
NUE	Hiramoto Oni-gawara	A4-1		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808
NUE	Hiramoto Oni-gawara	A4-2		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808
NUE	Hiramoto Oni-gawara	A5		2067	4.8	16.1	47	45.3	0.2-1.4	2	0.807	0.808

*; Horizontal surface sample.

Table 5. DS02 TF's Estimated *de novo* or Adjusted Based on Analysis of DS86 TFs: Nagasaki (does not include height correction)

Lab	Place Name	Sample ID#	RERF List No.	DS02 GR, m	DS02 ht, m	Elevation Angle Theta, deg	Azimuthal Angle, deg	Angle of Incidence tau, deg	Meas. Depth, cm	Density, g/cm^2	TF, no Bldg gamma	TF with Bldg gamma
NUE	Matsuyama cho	N-1		77	5	81.2	45	39.2	2.2-3.9	2.1	0.827	0.848
NUE	Oka machi	N-2		217	7	66.3	45	32.0	2.2-3.9	2.1	0.848	0.870
NUE	Oka machi	N-2'		217	7	66.3	45	32.0	2.2-3.9	2.1	0.848	0.870
NUE	Yamazoto cho	N-3		307	10	58.1	45	30.2	2.2-3.9	2.1	0.853	0.871
NUE	Yamazoto cho	N-3'		307	10	58.1	45	30.2	2.2-3.9	2.1	0.853	0.871
NUE	Yamazoto cho	N-3"		307	10	58.1	45	30.2	2.2-3.9	2.1	0.853	0.871
NUE	Shiroyama Elementary School	N-4		490	16	44.8	45	31.5	2.2-3.9	2.1	0.850	0.862
JNIRS	Urakami church			517	29	48.1	46.9	60.8	1-2	2	0.677	0.690
NUE	Shiroyama cho	N-6		623	12.5	38.2	45	33.9	0.2-1.9	2.1	0.983	0.992
NUE	Ueno cho	N-7		634	19	37.3	45	34.3	2.2-3.9	2.1	0.842	0.851
JNIRS	Nagasaki University Hospital			655	30	35.8	37	60.8	0.5-1.5	2	0.918	0.926
JNIRS	Nagasaki University Hospital			655	30	35.8	53	49.7	0.5-1.5	2	0.961	0.969
JNIRS	Nagasaki University Hospital			655	30	35.8	53	49.7	0.5-1.5	2	0.961	0.969
NUE	Shiroyama cho	N-8		760	12	32.9	45	36.5	2.2-3.9	2.1	0.836	0.842
NUE	Sakamoto cho	N-9		763	6	33.1	45	36.4	2.2-3.9	2.1	0.836	0.842
JNIRS	Hachiman jinja nearby house			861	16	34.2	74.8	36.9	1-2	2	0.932	0.938
JNIRS	Hachiman jinja			896	18	33.0	74.8	35.9	1-2	2	0.938	0.943
JNIRS	Sakamoto cho Gaijin Cemetery			1040	33	28.6	74.8	32.0	1-2	2	0.959	0.963
NUE	Urakami cho	N-10		967	9	27.1	45	39.9	2.2-3.9	2.1	0.825	0.828
JNIRS	Sakamoto-cho Gaijin Cemetery			1068	33	28.0	74.8	31.5	1-2	2	0.962	0.965
JNIRS	Sakamoto Cemetery			1040	26	24.6	70	31.3	0.5-1.5	1.7	0.997	0.999
JNIRS	Sakamoto Cemetery			1040	26	24.6	70	31.3	0.5-1.5	1.7	0.997	0.999
JNIRS	Sakamoto Cemetery			1040	26	24.6	70	31.3	0.5-1.5	1.7	0.997	0.999
JNIRS	Sakamoto Cemetery			1040	26	24.6	70	31.3	0.5-1.5	1.7	0.997	0.999
JNIRS	Nagasaki University Charnel			1452	9	18.8	72	25.8	0.5-1.5	1.7	1.014	1.015
JNIRS	Nagasaki University Charnel			1452	9	18.8	72	25.8	0.5-1.5	1.7	1.014	1.015
JNIRS	Nagasaki University Charnel			1452	9	18.8	72	25.8	0.5-1.5	1.7	1.014	1.015

For the Myosen temple and Hiramoto residence in Hiroshima, we could not verify the very oblique angle of incidence values that were given by the authors. We can obtain a georeferenced image of the buildings in question from the new city map in the former case and from a pre-bombing aerial photograph in the latter case, such that we can use the GIS to measure horizontal (azimuthal) angles of sides and corners of the buildings vis-à-vis the direction to the hypocenter. But the side(s) of the roof from which samples were taken were not documented well enough to clearly resolve apparent inconsistencies with the apparent angles of the sides and corners of the georeferenced images. In addition, the sample from Myosenji was a relatively small oni-gawara tile that was rounded and protuberant, and would not have the same properties as a sample from a large, flat surface. For these reasons, the TF's that we can calculate at these two sites may be inaccurate. However, because the TF's calculated here are about 0.8, and the true TF could not possibly exceed about 1, errors in these TF's could explain only a small part of the observed amount by which the free-in-air-equivalent measured values exceed the calculated values at these sites.

There are two TF's calculated in Appendix 11 to Chapter 4 of the DS86 Final Report for the Urakami church in Nagasaki. The specific TF calculated using the model described for the "N-4" sample on p. 222 of final report is about 0.86, whereas the generic model used in that Appendix for the JNIRS 1967 samples gives a result of about 0.68 if it is adjusted for the correct angle of incidence using the regression method described above. Unfortunately, it was not possible to determine from available records whether any of the samples measured could have come from the south corner of the west façade, which would have had substantial partial frontal shielding from an adjacent building, or whether there could have been any shielding by the façade itself because of the deep relief of the main wall surface vs. the protruding columns.

For some of the new locations in Nagasaki that were measured after DS86, it was not possible to calculate accurate TF's for some of the samples. These include the portion of the wall tiles that were recessed into the window opening in the case of the tower at Nagasaki University Hospital and were therefore partially shaded by the portion of the same wall that lay in the general direction of the bomb, and some bricks from a gatepost of the Yamada-Furukawa family graveyard in Sakamoto-cho that may have had their exposed surface on a side with a very oblique or even shaded line of sight to the bomb.

Calculation of DS02 Building Gamma Component of Dose to Quartz

When the building gamma component of dose to quartz calculated in Appendix 11 to Chapter 4 of the DS86 Final Report was adjusted for the square of slant distance and plotted vs. slant distance, it was apparent that it could be well fitted with a simple exponential. Furthermore, the exponential obtained by a regression of the logarithm of building gamma on slant distance had a relaxation length typical of bomb thermal neutron activation. This, along with the physics of building gamma production from incident bomb neutron fluence, suggested that the building gamma component for new samples and locations could be estimated by the regression line for the appropriate city, and that the values already calculated could be adjusted in a straightforward manner for DS02 distances by applying a correction based on the same exponential and the inverse square of distance. The values calculated in Appendix 11 to Chapter 4 of the DS86 Final Report and the corresponding regression lines used to estimate DS02 values are shown in Figure 2. These values are evaluated at or adjusted to the DS02 slant distance, using the exponential with the indicated relaxation length divided by the square of distance, and are further adjusted by multiplying them times the ratio of the DS02 ^{60}Co activation to the DS86 ^{60}Co activation, to reflect the difference between the DS02 and DS86 neutron fluences.

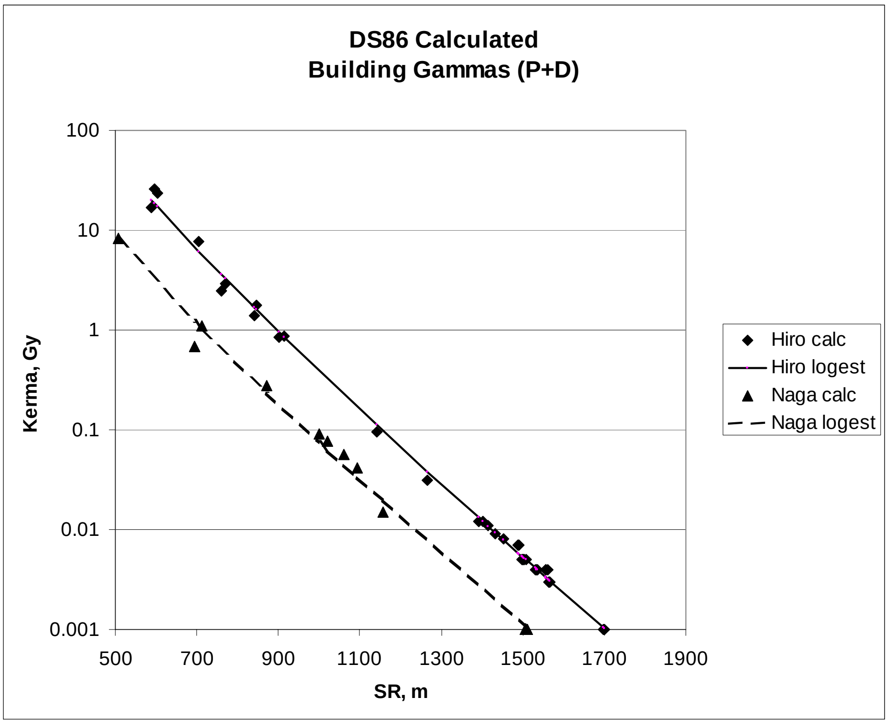

Figure 2. Building gamma component calculated in Appendix 11 to Chapter 4 of the DS86 Final Report, vs. slant distance.

Comparison of Measured and Calculated Values for DS02

The "free-in-air-equivalent" measured values at one meter above flat ground, obtained by dividing the measured value by the TF and correcting for sample height (height above ground and, in Nagasaki, ground elevation at sample location vs. hypocenter) using ground distances and heights as evaluated in DS02, are shown in Tables 6 and 7 and Figures 3 and 4 below. We included a series of measurements published by Ichikawa *et al.* in 1966, for which it was necessary to make considerable adjustments, as well as assumptions for calculating TF's, which are given in DS02 (Cullings *et al*. In Press). Although the uncertainty of these measurements is considerably larger than most of the others included in the DS02 analysis, they are important measurements, both historically and due to the dearth of later measurements at proximal distances in both cities.

Table 6. Measured Values and Measured/Calculated Ratios: Hiroshima

Lab	Place Name	Sample ID#	RERF List No.	in situ Measured Tissue Dose, Gy		Free-In-Air @ 1 m-Equivalent Tissue Dose, Gy		Measured to Calculated Ratio
				Gy	±	Gy	±	
JNIRS	A-bomb Dome			83.805	16.791	99.509	19.938	0.90
JNIRS	Togiya-cho Shojun-ji			70.594	14.149	130.006	26.057	1.25
JNIRS	Nenryo Kaikan (Fuel Authority Bldg)			62.710	12.572	117.691	23.595	1.12
NUE	Zaimoku cho, Dempuku ji	H-1		56.100	11.220	86.516	17.303	1.70
NUE	Zaimoku cho, Seigan ji	H-2		32.610	6.522	50.216	10.043	0.96
NUE	Zaimoku cho, Seigan ji	H-2'		29.739	5.948	45.795	9.159	0.87
JNIRS	Fukuro-machi East Orthopedic Surgical Hospital			32.223	6.475	44.051	8.852	0.90
NUE	Zaimoku cho,	H-3		34.350	6.870	53.135	10.627	1.10
JNIRS	Naka Telephone Office	3	1-01	27.570	2.47	26.180	2.345	0.80
JNIRS	Naka Telephone Office	2	1-19	30.320	1.56	36.595	1.883	1.19
NUE	Naka Telephone Office	203-3	1-04	27.240	2.47	27.190	2.466	0.89
NUE	Naka Telephone Office	204-2	1-04	25.970	3.15	25.923	3.144	0.85
NUE	Naka Telephone Office	204-3	1-04	25.560	3.75	25.514	3.743	0.83
JNIRS	Tate-machi Sanin Godo Bank			12.907	2.612	16.274	3.294	0.76
JNIRS	Sanin Bank		12-02	17.780	1.56	19.496	1.711	0.93
JNIRS	Chugoku Elec Co		2 01	7.140	1.010	13.568	1.919	0.77
JNIRS	Chugoku Elec Co	2	2-03	9.430	1.56	15.489	2.562	0.98
NUE	Chugoku Electric Co.	3-1-3	2-03	11.190	1.328	19.073	2.263	1.20
NUE	Chugoku Electric Co.	3-1-3	2-03	9.480	0.746	16.158	1.272	1.02
NUE	Chugoku Electric Co.	3-2-2	2-03	9.610	0.638	16.380	1.087	1.03
NUE	Chugoku Electric Co.	3-2-2	2-03	9.900	0.677	16.874	1.154	1.07
NUE	Chugoku Electric Co.	3-2-3	2-03	9.290	0.882	15.834	1.504	1.00
JNIRS	Nobori-machi Elementary School			8.535	1.738	10.613	2.162	0.73
NUE	Hiroshima Castle, ninomaru	H-4		8.250	1.650	8.498	1.700	0.65

<Table 6 continued>

Lab	Place Name	Sample ID#	RERF List No.	in situ Measured Tissue Dose, Gy		Free-In-Air @ 1 m-Equivalent Tissue Dose, Gy		Measured to Calculated Ratio
NUE	Hiroshima Castle, ninomaru	H-4'		8.685	1.737	8.946	1.789	0.69
NUE	Nishishin machi*	H-5		7.596	1.519			
NUE	Nishitera machi, koen ji	H-6		5.160	1.032	5.491	1.098	1.18
NUE	Hiroshima Castle, honmaru	H-8		4.074	0.815	4.348	0.870	1.03
NUE	Hiroshima Castle, honmaru	H-8'		2.247	0.449	2.398	0.480	0.57
NUE	Hiroshima Castle, honmaru	H-8"		2.272	0.432	2.305	0.461	0.55
JNIRS	City Hall			2.160	0.572	3.348	0.712	0.76
NUE	Nishitera machi, Shozen ji	H-7		4.116	0.823	4.398	0.880	1.13
NUE	Japanese House (Nobori-cho)		145	1.52	0.088	1.564	0.091	0.68
NUE	H.U.P.S. (Hiro. Uriv.)	H-1	4-08	1.30	0.07	1.408	0.076	1.09
NUE	HUFS "I" Bldg	H1	4-08	1.370	0.10	1.484	0.108	1.15
NUE	HUFS "I"	"HP1"		1.391	0.090	1.509	0.097	1.17
NUE	H.U.P.S. (Hiro. Univ.)	H-2	4-07	1.34	0.13	1.428	0.139	1.15
NUE	H.U.P.S. (Hiro. Univ.)	H-3	4-09	1.31	0.19	1.410	0.205	1.21
NUE	H.U.P.S. (Hiro. Univ.)	H-4	4-01	1.02	0.21	1.092	0.225	1.01
NUE	H.U.P.S. (Hiro. Univ.)	H-5	4-03 horizontal	0.91	0.14	1.010	0.155	1.02
NUE	H.U.P.S. (Hiro. Univ.)	H-5B	4-03 vertical	0.730	0.14	0.902	0.173	0.91
NUE	H.U.P.S. (Hiro. Univ.)	H-5B	4-03 vertical	0.890	0.14	1.100	0.173	1.11
NUE	H.U.P.S. (Hiro. Univ.)	H-5B	4-03 vertical	0.800	0.14	0.989	0.173	1.00
NUE	HUFS "I"	"HP2"		0.905	0.092	1.121	0.115	1.13
JNIRS	H.U.F.S. (Hiro. Univ.)	7	3-07	0.900	0.07	0.970	0.075	1.15
NUE	HUFS "E" Bldg	HPl	3-08	0.620	0.11	0.677	0.120	0.81
NUE	HUFS "E"	"HP3"		0.644	0.092	0.714	0.103	0.86
JNIRS	H.U.F.S. (Hiro. Univ.)	10	3-10	1.010	0.18	1.125	0.201	1.40
NUE	H.U.F.S. (Hiro. Univ.j	H-6-1	3-20	0.77	0.15	0.922	0.180	1.15
NUE	H.U.F.S. (Hiro. Univ.j	H-6-2	3-20	0.75	0.04	0.898	0.048	1.12
NUE	H.U.F.S. (Hiro. Univ.j	H-6-3	3-20	0.84	0.05	1.006	0.060	1.25
NUE	HUFS "E" Bldg	HP2	3-11	0.84	0.07	0.935	0.078	1.17
NUE	HUFS "E" Bldg	HP3	(3-11)	0.87	0.05	0.967	0.056	1.21
NUE	HUFS "E"	"HP4"		0.883	0.092	0.996	0.104	1.24
NUE	HUFS "E"	"HP5"		0.873	0.073	0.942	0.078	1.20
U. 0F U.	H.U.F.S. (Hiro. Univ.)	UHFSO3	3-23	0.990	0.04	1.069	0.043	1.36
NUE	H.U.F.S. (Hiro. Univ.j	H-7	3-36	0.690	0.10	0.764	0.111	0.97
U. 0F U.	H.U.F.S. (Hiro. Univ.)	UHFSO2	3-22	1.030	0.08	1.140	0.089	1.47
NUE	H.U.F.S. (Hiro. Univ.j	H-8	3-18	0.64	0.05	0.767	0.060	1.10
JNIRS	H.U.F.S. (Hiro. Univ.)	I	3-29	0.940	0.12	1.037	0.132	1.50
JNIRS	H.U.F.S. (Hiro. Univ.)	IV	3-31	0.70	0.05	0.789	0.056	1.15
NUE	H.U.F.S. (Hiro. Univ.j	H- 9	3-17	0.57	0.05	0.703	0.062	1.03
JNIRS	Red Cross Hospital		5-01	0.53	0.09	0.615	0.104	0.98
NUE	Red Cross Hospital	"HP6"		0.560	0.101	0.654	0.118	1.04
JNIRS	Red Cross Hospital			0.669	0.128	0.777	0.149	1.24
JNIRS	Red Cross Hospital			0.751	0.137	0.873	0.160	1.39
JNIRS	Red Cross Hospital			0.687	0.110	0.799	0.128	1.27
JNIRS	Red Cross Hospital			0.724	0.110	0.841	0.128	1.34
JNIRS	Red Cross Hospital			0.678	0.119	0.788	0.138	1.26
NUE	Red Cross Hospital	HP4	5_01	0.550	0.077	0.613	0.086	0.98
JNIRS	H.U.F.S.(Hiro.Uriv.)	R1	3-35	0.970	0.16	1.167	0.193	1.87
DUR	H.U.F.S. (Hiro. Univ.j	UHFSFT02	3-35	0.680	0.12	0.815	0.144	1.31
DUR	H.U.F.S. (Hiro. Univ.j	UHFSFT02	3-35	0.690	0.12	0.827	0.144	1.32
OXF H	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	0.730	0.13	0.875	0.156	1.40
OXF H	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	0.760	0.12	0.911	0.144	1.46
OXF H	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	0.760	0.11	0.911	0.132	1.46
U. 0F U.	H.U.F.S. (Hiro. Univ.)	UHFSFT02	3-35	0.710	0.08	0.851	0.096	1.36
U. 0F U.	H.U.F.S. (Hiro. Univ.)	UHFSFT03	3-35	0.660	0.11	0.791	0.132	1.27
NUE	H.U.F.S. (Hiro. Univ.j	H-10-1	3-15	0.70	0.11	0.828	0.130	1.33
NUE	H.U.F.S. (Hiro. Univ.j	H-10-2	3-15	0.66	0.06	0.780	0.071	1.26
NUE	H.U.F.S. (Hiro. Univ.j	H-10-3	3-15	0.60	0.09	0.709	0.106	1.14
NUE	H.U.F.S. (Hiro. Univ.j	H-10-4	3-15	0.66	0.06	0.780	0.071	1.26
U. 0F U.	H.U.F.S. (Hiro. Univ.)	UHFS04	3-24	0.730	0.05	0.812	0.056	1.34
U. 0F U.	H.U.F.S. (Hiro. Univ.)	UHFS07	3-27	0.550	0.08	0.621	0.090	1.03
NUE	H.U.F.S. (Hiro. Univ.j	H-11	3-16	0.44	0.05	0.569	0.065	0.96
JNIRS	Hiroshima University Radioisotope Facility			0.641	0.192	0.855	0.257	1.45
JNIRS	Hiroshima University Radioisotope Facility			0.623	0.266	0.832	0.355	1.44
JNIRS	Hiroshima University Radioisotope Facility			0.513	0.211	0.686	0.282	1.19
JNIRS	Red Cross Hospital			0.669	0.128	0.788	0.151	1.50
JNIRS	Red Cross Hospital			0.559	0.119	0.658	0.140	1.25
JNIRS	Red Cross Hospital			0.641	0.101	0.755	0.119	1.44
JNIRS	Red Cross Hospital			0.678	0.137	0.798	0.162	1.52
JNIRS	Red Cross Hospital			0.605	0.101	0.712	0.119	1.35
NUE	Postal Savings (Chokin Kyoku)	A		0.405	0.019	0.475	0.022	1.32
NUE	Chokin-Kyoku (Postal Savings)		6-04	0.36	0.05	0.581	0.081	1.70
NUE	Postal Savings (Chokin Kyoku)	B		0.352	0.017	0.382	0.019	1.11
JNIRS	Chokin-Kyoku		6-00	0.30	0.06	0.369	0.074	1.07
NUE	Postal Savings (Chokin Kyoku)	D		0.334	0.055	0.394	0.065	1.20
NUE	Postal Savings (Chokin Kyoku)	E		0.283	0.021	0.335	0.024	1.10
NUE	JEMIC	HP7		0.183	0.077	0.197	0.083	1.14
NUE	Myosen -ji "oni-gawara" top	Me-1		0.17	0.036	0.228	0.048	2.20
NUE	Myosen -ji "oni-gawara" bottom	Me-2		0.16	0.035	0.214	0.047	2.07
NUE	Myosen -ji "oni-gawara" top	A-1		0.195	0.070	0.261	0.094	2.52
NUE	Myosen -ji "oni-gawara" bottom	A-2		0.186	0.073	0.249	0.097	2.40

<Table 6 continued>

Lab	Place Name	Sample ID#	RERF List No.	in situ Measured Tissue Dose, Gy (value)	in situ Measured Tissue Dose, Gy (±)	Free-In-Air @ 1 m-Equivalent Tissue Dose, Gy (value)	Free-In-Air @ 1 m-Equivalent Tissue Dose, Gy (±)	Measured to Calculated Ratio
NUE	HUFE clay wall tile	C-1		0.067	0.048	0.075	0.054	1.15
NUE	HUFE clay wall tile	C-2		0.085	0.039	0.095	0.044	1.46
NUE	HUFE clay wall tile	C-3		0.076	0.074	0.085	0.082	1.30
NUE	HUFE	HP5	8-01	0.049	0.032	0.054	0.036	0.86
NUE	HUFE	HP8		0.053	0.054	0.059	0.060	0.92
NUE	Hiramoto "oni-gawara" bottom	Hr-1		0.05	0.010	0.067	0.013	1.12
NUE	Hiramoto "Oni-gawara"	B		0.088	0.040	0.118	0.054	1.97
NUE	Hiramoto Oni-gawara	A1-1		0.113	0.038	0.152	0.051	2.53
NUE	Hiramoto Oni-gawara	A1-2		0.107	0.023	0.144	0.031	2.39
NUE	Hiramoto Oni-gawara	A1-3		0.121	0.055	0.163	0.074	2.71
NUE	Hiramoto Oni-gawara	A2		0.118	0.020	0.159	0.027	2.65
NUE	Hiramoto Oni-gawara	A3		0.085	0.024	0.115	0.033	1.91
NUE	Hiramoto Oni-gawara	A4-1		0.097	0.036	0.130	0.048	2.17
NUE	Hiramoto Oni-gawara	A4-2		0.148	0.058	0.199	0.078	3.32
NUE	Hiramoto Oni-gawara	A5		0.136	0.031	0.183	0.041	3.06

*could not be analyzed due to conflicting map information.

Table 7. Measured Values and Measured/Calculated Ratios: Nagasaki

Lab	Place Name	Sample ID#	RERF List No.	in situ Measured Tissue Dose, Gy		Free-In-Air @ 1 m-Equivalent Tissue Dose, Gy		Measured to Calculated Ratio
				Gy	±	Gy	±	
JNIRS	Yamazoto-cho House			204.154	40.861	195.363	39.102	0.62
NUE	Matsuyama cho	N-1		195.255	39.051	243.174	48.635	0.76
NUE	Oka machi	N-2		160.455	32.091	193.501	38.700	0.82
NUE	Oka machi	N-2'		157.845	31.569	190.354	38.071	0.81
NUE	Yamazoto cho	N-3		135.225	27.045	160.997	32.199	0.89
NUE	Yamazoto cho	N-3'		123.045	24.069	146.496	29.299	0.81
NUE	Yamazoto cho	N-3"		107.385	21.477	127.851	25.570	0.71
NUE	Shiroyama Elementary School	N-4		68.089	13.618	80.182	16.036	0.92
NUE	Shiroyama cho*	N-5		48.225	9.645			
JNIRS	Urakami		N4	40.400	4.40	46.179	5.029	0.60
JNIRS	Urakami			40.579	4.397	46.158	5.001	0.60
JNIRS	Urakami Church			52.918	10.614	76.025	15.249	0.98
NUE	Shiroyama cho	N-6		33.435	6.687	35.371	7.074	0.73
JNIRS	Gokoku jinja (?) house*			35.166	7.064			
NUE	Ueno cho	N-7		31.086	6.217	37.500	7.500	0.82
JNIRS	Nagasaki University Hospital			37.006	3.527	39.475	3.762	0.94
JNIRS	Nagasaki University Hospital			30.594	3.609	31.194	3.680	0.75
JNIRS	Nagasaki University Hospital			22.350	2.336	22.788	2.382	0.55
NUE	Shiroyama cho	N-8		19.515	3.903	24.549	4.910	0.95
NUE	Sakamoto cho	N-9		11.772	2.354	15.051	3.010	0.59
JNIRS	Hachiman jinja nearby house			13.619	2.755	15.247	3.084	0.94
JNIRS	Hachiman jinja			12.210	2.473	13.514	2.737	0.98
JNIRS	Sakamoto cho Gaijin Cemetery			7.719	1.575	8.164	1.666	1.14
NUE	Urakami cho	N-10		7.074	1.415	9.148	1.830	0.91
JNIRS	Sakamoto-cho Gaijin Cemetery			6.774	1.386	7.160	1.466	1.14
JNIRS	Sakamoto Cemetery			5.743	0.769	5.938	0.796	0.83
JNIRS	Sakamoto Cemetery			4.534	0.815	4.688	0.843	0.66
JNIRS	Sakamoto Cemetery			5.478	0.394	5.664	0.407	0.79
JNIRS	Sakamoto Cemetery			5.981	0.540	6.185	0.559	0.87
JNIRS	Sakamoto		N-6	6.920	0.88	6.817	0.867	1.09
JNIRS	Sakamoto			7.099	0.879	6.938	0.859	1.10
Dur	Ieno wall	NAIEO5	N-2-1	0.890	0.116	0.966	0.126	0.70
Dur	Ieno wall	NAIEO5	N-2-1	1.050	0.074	1.457	0.103	1.06
Dur	Ieno wall	NAIEO5	N-2-1	0.780	0.106	1.220	0.165	0.89
Dur	Ieno wall	NAIEO5	N-2-1	0.700	0.056	0.760	0.060	0.55
Dur	Ieno wall	NAIEO5	N-2-1	0.610	0.105	0.847	0.146	0.62
Dur	Ieno wall	NAIEO5	N-2-1	0.740	0.055	1.157	0.086	0.84
JNIRS	Ieno	A	N-2-2	1.06	0.19	1.177	0.211	0.86
JNIRS	Ieno	B	N-2-2	1.04	0.20	1.160	0.223	0.85
NUE	Ieno wall	A	N-2-1	0.970	0.028	1.089	0.032	0.79
NUE	Ieno wall	B	N-2-1	0.860	0.028	1.133	0.037	0.83
NUE	Ieno wall	C	N-2-1	0.910	0.032	1.436	0.050	1.05
OXF H	Ieno wall	NAIEO5	N-2-1	0.850	0.111	0.923	0.120	0.67
OXF H	Ieno wall	NAIEO5	N-2-1	0.700	0.102	0.972	0.142	0.71
OXF H	Ieno wall	NAIEO5	N-2-1	0.620	0.091	0.970	0.143	0.71
U. 0F U.	Ieno wall	NAIEO6	N-2-1	0.930	0.057	1.048	0.064	0.76
U. 0F U.	Ieno wall	NAIEO6	N-2-1	0.730	0.041	0.990	0.056	0.72
U. 0F U.	Ieno wall	NAIEO6	N-2-1	0.580	0.036	0.869	0.054	0.63
JNIRS	Nagasaki University Charnel			1.127	0.192	1.198	0.204	0.99
JNIRS	Nagasaki University Charnel			1.172	0.165	1.246	0.175	1.03
JNIRS	Nagasaki University Charnel			1.072	0.137	1.139	0.146	0.95
JNIRS	Zenza		N-7	0.910	0.22	0.932	0.225	0.70
JNIRS	Zenza			0.907	0.220	0.929	0.225	0.70
JNIRS	Inasa	A	N-3	0.12	0.09	0.128	0.096	1.13
JNIRS	Inasa A			0.119	0.082	0.127	0.088	1.12
JNIRS	Yamada Oil Storehouse			0.110	0.055	0.117	0.058	1.01
JNIRS	Yamada Oil Storehouse			0.174	0.055	0.185	0.058	1.60
JNIRS	Yamada Oil Storehouse			0.156	0.055	0.166	0.058	1.43
JNIRS	Yamada Oil Storehouse			0.156	0.055	0.166	0.058	1.43
JNIRS	Yamada Oil Storehouse			0.082	0.037	0.088	0.039	0.76
JNIRS	Yamada Oil Storehouse			0.119	0.046	0.127	0.049	1.09
JNIRS	Yamada Oil Storehouse			0.174	0.073	0.185	0.078	1.60
JNIRS	Chikugo		N-8	-0.01	0.15	-0.011	0.160	-0.26

*could not be analyzed due to conflicting map information.

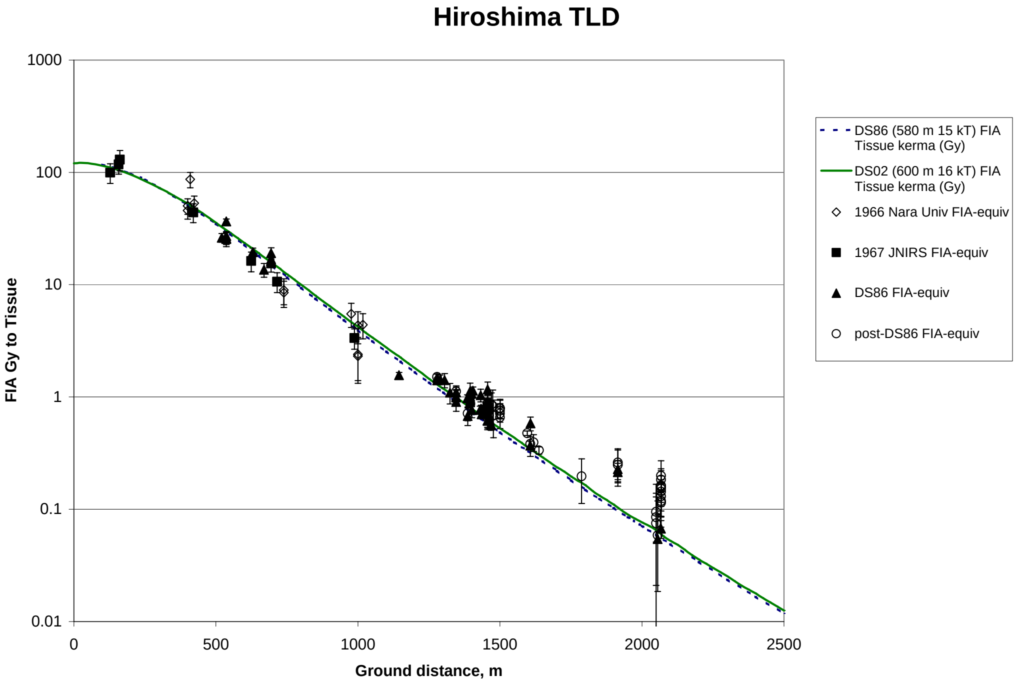

Figure 3. Hiroshima measured free-in-air-equivalent values compared with DS86 and DS02 calculated values, vs. slant distance.

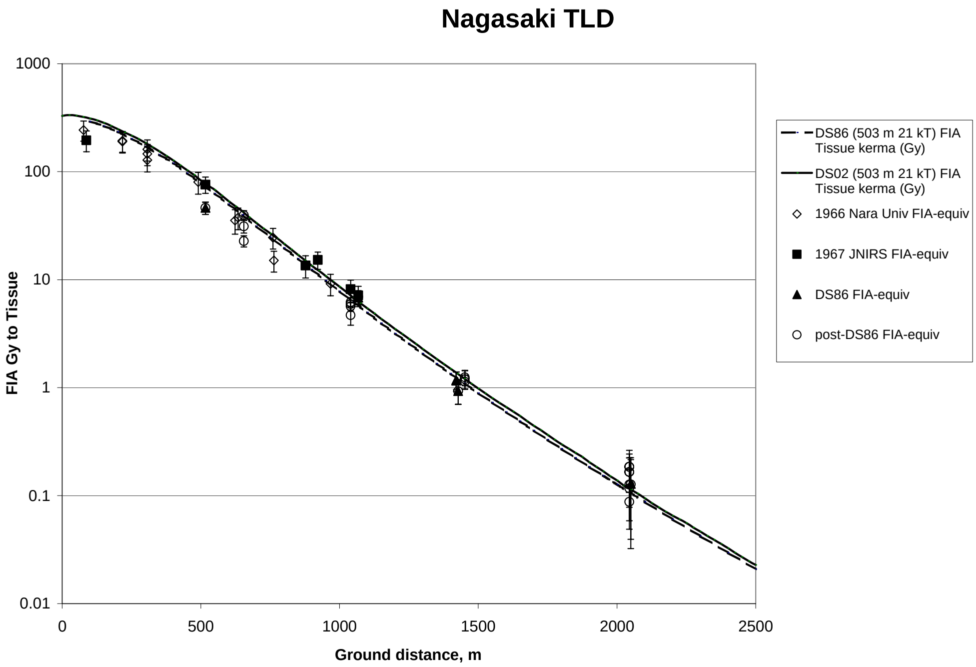

Figure 4. Nagasaki measured free-in-air-equivalent values compared with DS86 and DS02 calculated values, vs. slant distance.

It can be seen in Fig. 3 that the agreement in Hiroshima is very good; overall it is slightly better for DS02 than DS86. There remain some measurements at distances over about 1400 m slant distance and kerma values less than about 1 Gy that exceed the calculated values for both DS86 and DS02, although only the samples at Myosen Temple, at about 1900 m ground distance, stand out clearly in this regard when measurement uncertainty, as indicated by the error bars, is considered. Because accumulated background becomes a substantial fraction of bomb kerma when the latter drops below about 1 Gy, with even the youngest samples dating from pre-war construction having estimated total background doses of at least 0.15 to 0.2 Gy, the accuracy and reliability of background estimates are important concerns.

Agreement in Nagasaki is not quite as good overall as Hiroshima, and is slightly worse for DS02 than for DS86. There is a tendency for measured values to lie below calculated, particularly at distances less than about 800 m ground distance, although it is certainly not clear that this constitutes any kind of a trend with distance, given the errors involved and the small number of sites with DS86 and post-DS86 measurements, particularly at ground distances less than 800 m. In addition, the comparison is made more difficult by a number of other serious concerns:

- As mentioned above in regard to calculating TF's, there is a concern about the ability to calculate accurate and reliable TF's for three important sites of post-DS86 measurements, at 517 m ground distance (Urakami church), 655 m ground distance (Nagasaki University Hospital tower) ,and 1040 m ground distance (Yamada-Furukawa family graveyard gatepost in Sakamoto-cho). All three sites have wide ranges of measured values.
- In the case of Urakami church, the DS86 and 1988 measured values are substantially less than the 1967 value, even though the 1967 sample was deeper and therefore has a much lower calculated TF (0.68 vs. 0.86) if the calculated dose to quartz *in situ* for the 1967 sample in Appendix 11 to Chapter 4 of DS86 is adjusted for angle of incidence. Therefore, because the larger TF applies to the smaller measurement and vice versa, applying the TF's as such gives free-in-air equivalent values for the DS86 and 1988 measurements that are only 61% of those for the 1967 measurement: 46.2 Gy vs. 76.0 Gy, a very large difference in measured values on the same material from the same location.
- The possibility of minor frontal shielding (blocking of some minor portion of incident fluence) at several sites in Nagasaki, by terrain, other buildings, or groves of trees has been discussed, particularly because the sample locations in Nagasaki are so much closer to the ground than in Hiroshima, the terrain is so much more hilly, and the height of the bomb is about 100 m less.

In addition to these concerns about the comparability of existing measurements to calculated values, there has been discussion of the adequacy of the calculated location of fission debris in the fireball that is used to calculated delayed gamma ray kerma, which accounts for a large portion of total gamma ray kerma in Nagasaki.

Conclusions

Measurements and calculated values compare quite well in Hiroshima, with agreement for DS02 being somewhat better than for DS86. There remains some concern about the adequacy of background corrections for measurements substantially below 1 Gy and the indications of some measurements that appear to exceed calculated values at distances beyond about 1400 m.

Agreement in Nagasaki is not as good, and is slightly worse for DS02 than for DS86, but there are substantial concerns about the comparability of measured and calculated values with the presently available information about sample-structure geometry, particularly in light of rather large ranges of measured values on the same samples at several important sites. There may also be some concern about the adequacy of the model used for the delayed radiation calculation in Nagasaki.

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