Table 13. Measured values and measured/calculated ratios: Nagasaki

Lab	Place name	Sample ID#	RERF list No.	*In situ* measured tissue dose		Free-in-air @1 m-equivalent tissue dose		Measured to calculated ratio
				Gy	±	Gy	±	
JNIRS	Yamazoto-cho House			204	40.9	195	39.1	0.62
NUE	Matsuyama cho	N-1		195	39.1	243	48.6	0.76
NUE	Oka machi	N-2		160	32.1	194	38.7	0.82
NUE	Oka machi	N-2'		158	31.6	190	38.1	0.81
NUE	Yamazoto cho	N-3		135	27.0	161	32.2	0.89
NUE	Yamazoto cho	N-3'		123	24.1	146	29.3	0.81
NUE	Yamazoto cho	N-3"		107	21.5	128	25.6	0.71
NUE	Shiroyama Elementary School	N-4		68.1	13.6	80.2	16.0	0.92
NUE	Shiroyama cho[a]	N-5		48.2	9.65			
JNIRS	Urakami		N4	40.4	4.40	46.2	5.03	0.60
JNIRS	Urakami			40.6	4.40	46.2	5.00	0.60
JNIRS	Urakami Church			52.9	10.6	76.0	15.2	0.98
NUE	Shiroyama cho	N-6		33.4	6.69	35.4	7.07	0.73
JNIRS	Gokoku jinja (?) house[a]			35.2	7.06			
NUE	Ueno cho	N-7		31.1	6.22	37.5	7.50	0.82
JNIRS	Nagasaki University Hospital			37.0	3.53	39.5	3.76	0.94
JNIRS	Nagasaki University Hospital			30.6	3.61	31.2	3.68	0.75
JNIRS	Nagasaki University Hospital			22.4	2.34	22.8	2.38	0.55
NUE	Shiroyama cho	N-8		19.5	3.90	24.5	4.91	0.95
NUE	Sakamoto cho	N-9		11.8	2.35	15.1	3.01	0.59
JNIRS	Hachiman jinja nearby house			13.6	2.76	15.2	3.08	0.94
JNIRS	Hachiman jinja			12.2	2.47	13.5	2.74	0.98
JNIRS	Sakamoto cho Gaijin Cemetery			7.72	1.58	8.16	1.67	1.14
NUE	Urakami cho	N-10		7.07	1.42	9.15	1.83	0.91
JNIRS	Sakamoto-cho Gaijin Cemetery			6.77	1.39	7.16	1.47	1.14
JNIRS	Sakamoto Cemetery			5.74	0.769	5.94	0.796	0.83
JNIRS	Sakamoto Cemetery			4.53	0.815	4.69	0.843	0.66
JNIRS	Sakamoto Cemetery			5.48	0.394	5.66	0.407	0.79
JNIRS	Sakamoto Cemetery			5.98	0.540	6.19	0.559	0.87
JNIRS	Sakamoto		N-6	6.92	0.88	6.82	0.867	1.09
JNIRS	Sakamoto			7.10	0.879	6.94	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	1.05	0.074	1.46	0.103	1.06
DUR	Ieno wall	NAIEO5	N-2-1	0.780	0.106	1.22	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	1.16	0.086	0.84
JNIRS	Ieno	A	N-2-2	1.06	0.19	1.18	0.211	0.86
JNIRS	Ieno	B	N-2-2	1.04	0.20	1.16	0.223	0.85
NUE	Ieno wall	A	N-2-1	0.970	0.028	1.09	0.032	0.79
NUE	Ieno wall	B	N-2-1	0.860	0.028	1.13	0.037	0.83
NUE	Ieno wall	C	N-2-1	0.910	0.032	1.44	0.050	1.05

Table 13. Continued

Lab	Place name	Sample ID#	RERF list No.	*In situ* measured tissue dose		Free-in-air @1 m-equivalent tissue dose		Measured to calculated ratio
				Gy	±	Gy	±	
OXF	Ieno wall	NAIEO5	N-2-1	0.850	0.111	0.923	0.120	0.67
OXF	Ieno wall	NAIEO5	N-2-1	0.700	0.102	0.972	0.142	0.71
OXF	Ieno wall	NAIEO5	N-2-1	0.620	0.091	0.970	0.143	0.71
U of U	Ieno wall	NAIEO6	N-2-1	0.930	0.057	1.05	0.064	0.76
U of U	Ieno wall	NAIEO6	N-2-1	0.730	0.041	0.990	0.056	0.72
U of U	Ieno wall	NAIEO6	N-2-1	0.580	0.036	0.869	0.054	0.63
JNIRS	Nagasaki University Charnel			1.13	0.192	1.20	0.204	0.99
JNIRS	Nagasaki University Charnel			1.17	0.165	1.25	0.175	1.03
JNIRS	Nagasaki University Charnel			1.07	0.137	1.14	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

[a]Could not be analyzed due to conflicting map information.

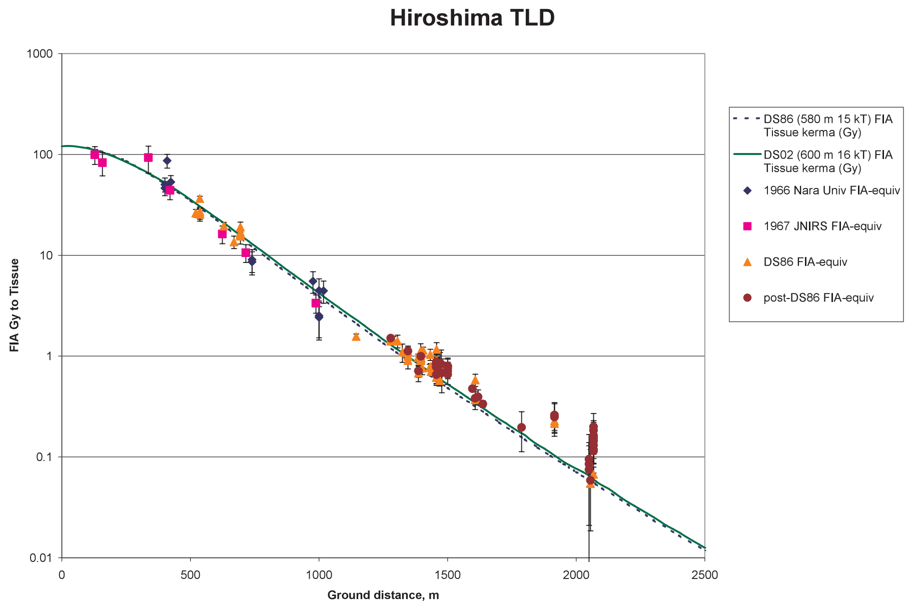

Figure 17. *Measured free-in-air-equivalent values compared to calculated free-in-air values: Hiroshima.*

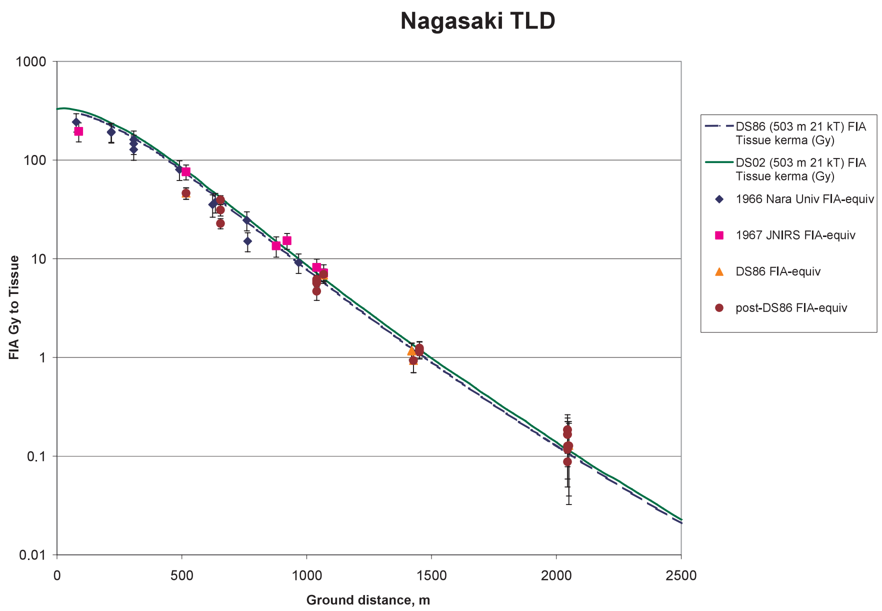

Figure 18. *Measured free-in-air-equivalent values compared to calculated free-in-air values: Nagasaki.*

In Hiroshima, agreement near the hypocenter is quite good by the methods used here to calculate the *in situ* dose to quartz in the samples. In this regard, an important qualification regarding the 1966 and 1967 measurements is that certain adjustments to the measured values that were made by the authors of those papers have been removed and replaced by the calculations of this work as described above.

Measurements remain somewhat above calculated values at the Hiroshima University campus buildings, and more so at some of the more distant locations, particularly at the Myosenji temple and the Hiramoto residence sites, but the situation is improved by DS02. As discussed above, a consideration in regard to this difference is whether there is any kind of a distance-related bias in background measurements. The possible inaccuracy of the TF due to the quality of the angle of incidence information at the Myosenji temple and the Hiramoto residence sites, as discussed above, is only a small potential contributor to this situation, because the TFs estimated for this work are not low enough that they could possibly account for more than about a 20% overestimate of the free-in-air-equivalent measured value at those sites if they are incorrect.

In Nagasaki, measured values are somewhat below both DS86 and DS02 values, at least at distances less than about 800 m. The situation is slightly worse for DS02 than for DS86, because DS02 calculated doses are slightly larger overall, as shown in Figure 18. The comparison in Nagasaki is subject to several concerns:

- Concerns about saturation or partial annealing of samples at close distances by the heat from the fireball are discussed in the first part of this chapter.
- For two of the important sites where new measurements have been made, the tower at Nagasaki University Hospital and the Yamada-Furukawa family graveyard gatepost in Sakamoto-cho, it was not possible to make a reliable estimate of TF using the methods of this work, due to partial shielding by the structure in the first case, and lack of detailed, certain information about azimuthal orientation of the side of the pillar measured for each reported measurement in the second case.
- For the Urakami church at 517 m, where a very important series of measurements was made, measured values reported in the DS86 Final Report and by Maruyama et al. (1988) are substantially less than the 1967 value, even though the 1967 sample was deeper and therefore has a considerably lower calculated TF (0.68 vs. 0.86) if the calculated dose to quartz *in situ* in Appendix 11 to Chapter 4 of DS86 is adjusted for angle of incidence. Therefore, applying the TFs 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. The disparity in these measurements should be a particular concern in light of the possibility of self-shielding of some portions of the samples, as discussed above, due to the complicated geometry of the ornate façade from which the sample was taken.
- The Urakami church, the tower window tiles at Nagasaki University Hospital, and the bricks of the Yamada-Furukawa family graveyard gatepost in Sakamoto cho represent all of the sites except one where post-1960s measurements were made at distances less than 1,400 m in Nagasaki. All three have reported measurements spanning a wide range of values on the same type of sample material from the same location, and all three have specific issues regarding possible partial shielding of some samples by the structure in which they resided *in situ*, as discussed above. It is not clear that we can calculate accurate TFs for any of these sites that we can be certain are applicable to all of the measurements at that site.

- As discussed above, a consideration in regard to the apparent trend in measured values is whether there is any need to further adjust the effective transmission factors to reflect the presence of partial frontal shielding at some of the measurement sites by adjacent terrain, buildings, and groves of trees.
- The Joint Working Group has also extensively discussed the question of whether the current calculation of the delayed source term adequately approximates the dynamic distribution of fission debris in the fireball.

The Joint Working Group had many discussions of the issues involved in making quantitative assessments of the agreement between measured and calculated values in a larger context as part of the process of developing DS02, and those considerations are applicable here. Two types of figure of merit statistics were considered extensively. One is based on the average ratio of measured-to-calculated values, the so-called M/C ratio, based on some form of $\sum_{i=1}^{n} M_i/C_i$ for n measurements. It has the advantage of summarizing in a clear and easily understood way the overall size of measured vs. calculated values, and the disadvantage that it is not inherently sensitive, at least in its simplest formulation, to offsetting positive and negative discrepancies between M and C. Another is based on sums of squared differences between M and C, i.e., some form based on $\sum_{i=1}^{n} (M_i - C_i)^2$. It has the opposite major advantage and disadvantage: it accounts for offsetting positive and negative discrepancies, but it does not summarize in a clear and easily understood way the overall size of measured vs. calculated values. More difficult issues revolve around the question of how to weight the individual terms corresponding to each measurement, given that different measurements have different estimated uncertainty, i.e., using a form of $\sum_{i=1}^{n} w_i \frac{M_i}{C_i}$ or $\sum_{i=1}^{n} w_i (M_i - C_i)^2$. Here, w_i would be a weight that is inversely proportional to some appropriate estimate of the variance of measurement error for the i^{th} measurement. This is a complicated issue, because the measured values span a very wide dynamic range from over 100 Gy to well under 1 Gy, techniques have been repeatedly improved over the years to reduce measurement errors so that smaller values can be measured at longer distances, and samples vary considerably from one location to the next in properties that affect the size of measurement uncertainty. In addition, there are unavoidable errors in the calculation of transmission factors, particularly for samples not calculated with full and accurate geometrical models of the structures containing the samples in Appendix 11 of Chapter 4 of the DS86 Report. These errors, even if they are only on the order of having a standard deviation that is 8% to 10% of the calculated value, are comparable or larger in size than the estimated measurement error for the more precise measurements. Furthermore, as noted above, there are substantial errors in the independent variable of distance, especially for the older measurements made in the 1960s. At the time of this writing there does not appear to be a clear consensus on a single "figure of merit" that distills the agreement in each city into a single number for each city, or even each subset of measurements for each city, that is appropriate for citing in a summary of this chapter, and such values are not critical to the conclusions of this chapter. The reader can form a clear impression of the level of agreement from the plots in Figures 17 and 18, and if interested can refer to the tabulated values, which include measurers' estimates of standard deviations ("±" values) or *measurement error* (as opposed to, say, error in the transmission factor or the distance).

Conclusions

The overall agreement between measurement and calculation continues to be good for DS02, as it was for DS86.

In Hiroshima, the overall agreement is somewhat better for DS02 than for DS86. Agreement near the hypocenter in Hiroshima is excellent with DS02 based on the methods described in this work. Agreement at middle and longer distances in Hiroshima is better for DS02 than for DS86, although there remain some indications of measured values exceeding calculated values at longer distances. These indications must be qualified by a careful consideration of issues related to background as described in this chapter.

In Nagasaki, measured values tend to be somewhat less than calculated values, at least out to about 800 m from the hypocenter, slightly more so for DS02 than for DS86, although the overall agreement is good. The comparison of measured and calculated values in Nagasaki is considerably more difficult than in Hiroshima due to the limited number of measured sites and questions about the applicable transmission factor for most of the sites where DS86 and post-DS86 measurements were made.

Of the four sites in Nagasaki at which DS86 or post-DS86 measurements were made at distances less than 1,400 m, three have unresolved questions about (a) the wide range of the measured values on the same type of sample at the same location, and (b) our ability to calculate an accurate estimate of a TF that applies to all of the measurements at a given site.

There may be some possibility of partial frontal shielding at some measurement sites in Nagasaki.

There may be a need to reconsider the adequacy of the current delayed source term calculation.

As DS02 calculated gamma doses are in good agreement with measured values overall, the gamma-ray doses used in RERF epidemiological studies should be based on DS02.

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Appendix A

Examples of Detailed Sample Calculations

Table A1. Calculation for a sample calculated in DS86, Chapter 4, Appendix 11

1	**A (datum)**	**B (value)**	**C (source or method of calculation)**
2	Site	Urakami church, DS86 JNIRS	
3	Sample ID in DS86	N-4	DS86 Appendix 11 Table 4, new city map value
4	GR in DS86	521.5	DS86 Appendix 11 Table 4 –
5	Height above ground in DS86	3	DS86 Appendix 11 text, p. 222
6	Ground elev above hypo in DS86	**21**	DS86 Appendix 11 Table 4
7	Total height above hypo ground level in DS86	24	h + grd elev
8	SR at sample elev in DS86	708	SQRT(B4^2 + (503 - B7)^2)
9	Total calculated dose to quartz with building γ's in DS86	62.68	DS86 Appendix 11 Table 21
10	Calculated FIA quartz kerma (without building γ's) at sample in DS86	72.096	Interpolate on FIA tissue kerma values in Table 40 for SR in B8, x 0.916
11	Type 1 (@ ht) TF with building gammas in DS86	0.869	B9/B10
12	Total building gammas in DS86	0.691	DS86 Appendix 11 Table 23, 0.294 + 0.397
13	Type 1 (@ ht) TF without building gammas in DS86	0.860	(B9 - B12)/B10
14			
15	GR in DS02	517	GIS with aerial photo
16	Height above ground in DS02	3	RERF sample data
17	Ground elev above hypo in DS02	21	GIS with new city map
18	Total height in DS02	24	h + grd elev
19	SR at sample elev in DS02	704.7	SQRT(B15^2 + (503 - B18^2))
20	Calculated DS02 FIA kerma to tissue without building γ's at sample ht	85.217	Interp on values in DS02 25-m FIA kerma values spreadsheet for SR in B19
21	Calculated DS02 FIA kerma to quartz without building γ's at sample ht	78.059	B20 x 0.916
22	Calculated DS02 in situ dose to quartz without building γ's at sample ht	67.117	B21 x TF (use DS86 TF in B13 if sample was calculated in DS86)
23	DS86 building gamma adjusted to DS02 SR	0.714	B12*EXP((-B19+B8)/148)*(B19/B8)^-2 (use DS86 and adjust for SR if sample was calculated in DS86)
24	DS02/DS86 Co-60 activation ratio at sample SR	0.853	Interp on values in DS02 25-m FIA activation values spreadsheet for SR in B19
25	DS02 building gamma	0.609	B22 x B23
26	Calculated DS02 in situ dose to quartz with building γ at sample ht	67.725	B22 + B25
27			
28			
29	Measured in situ dose to quartz	40.4	DS86 Appendix 11 Table 9
30	M/C	0.600	B29/B26
31	SR at 1 m elev at DS02 GR	720.5	SQRT(B15^2 + (503 - 1)^2)
32	Calculated FIA dose to quartz at 1 m elev at DS02 GR	70.910	Interp on FIA tissue kerma values in DS02 25-m FIA kerma values spreadsheet for SR in B31, x 0.916
33	Type 2 (@ 1 m) TF	0.955	B26/B32
34	Measured FIA-equiv tissue kerma	46.179	B29/B33/0.916

Table A2. Calculation for a sample *not* calculated in DS86, Chapter 4, Appendix 11

1	**A (datum)**	**B (value)**	**C (source or method of calculation)**
2	Site	DS02 Nagasaki Hospital Tower	
3	Sample ID in DS86	-	
4	GR in DS86	-	
5	Height above ground in DS86	-	
6	Ground elev above hypo in DS86	-	
7	Total height above hypo ground level in DS86	-	
8	SR at sample elev in DS86	-	
9	Total calculated dose to quartz in DS86	-	
10	Calculated FIA dose at sample in DS86	-	
11	Type 1 (@ ht) TF with building gammas in DS86	-	
12	Total building gammas in DS86	-	
13	**Type 1 (@ ht) TF without building gammas in DS02**	**0.918**	**Assigned based on analysis in DS02 (loglinear model)**
14			
15	GR in DS02	655	GIS with aerial photo
16	Height above ground in DS02	20	RERF sample data
17	Ground elev above hypo in DS02	10	GIS with new city map
18	Total height in DS02	30	h + grd elev
19	SR at sample elev in DS02	806.83	SQRT(B15^2 + (503 - B18^2))
20	Calculated DS02 FIA dose to tissue without building γ at sample ht	46.188	Interp on values in DS02 25-m FIA kerma values spreadsheet for SR in B19
21	Calculated DS02 FIA dose to quartz without building γ at sample ht	42.308	B20 x 0.916
22	**Calculated DS02 in situ dose to quartz without building γ at sample ht**	**38.845**	**B21 x TF (use DS02 assigned TF in B13 if sample was not calculated in DS86)**
23	DS86 building gamma adjusted to DS02 SR	0.427	64*EXP(-B19/148.3)*(B19/1000)^-2 (use value based on logest regression if sample not calculated in DS86)
24	DS02/DS86 Co-60 activation ratio at sample SR	0.843	Interp on values in DS02 25-m FIA activation values spreadsheet for SR in B19
25	**DS02 building gamma**	**0.352**	**B22 x B23**
26	Calculated DS02 in situ dose to quartz with building γ at sample ht	39.197	B22 + B25
27			
28			
29	Measured in situ dose to quartz	37.006	Maruyama, DS02
30	M/C	0.94	B29/B26
31	SR at 1 m elev at DS02 GR	825.24	SQRT(B15^2 + (503 - 1 - B17)^2)
32	Calculated FIA dose to quartz at 1 m elev at DS02 GR	38.300	Interp on FIA tissue kerma values in DS02 25-m FIA kerma values spreadsheet for SR in B31, x 0.916
33	Type 2 (@ 1 m) TF	1.023	B26/B32
34	Measured FIA-equiv tissue kerma	39.475	B29/B33/0.916

Note: Boldface items are key differences from samples calculated in DS86.