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RADIATION FIELD ASSOCIATED WITH
HIROSHIMA AND NAGASAKI

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ABSTRACT

Accuracy of dosimetric estimates can determine the value of the atomic bomb survivor experience in establishing radiation risks. The status of a major revision of this dosimetry, initiated in 1980, is assessed.

In 1980, dose levels to individual survivors at Hiroshima and Nagasaki were revised by factors as large as an order of magnitude, as shown in Figures 1 and 2.⁽¹⁾ In those figures, T65D is the accepted designation for the old estimates. The most important changes shown there are characterized by an increase in total kerma of a factor of three at 2 km in Hiroshima, and a drop in the proportion of neutrons in the mixed field by a factor of fifteen at 1.5 km, also in Hiroshima. Although the consequences are still unfolding, an immediate result of the new LLNL dosimetry was removal of A-bomb survivor support for large increases in the neutron quality factor, as considered formally by NCRP in 1980.

In the ensuing years, a specially appointed committee of the U.S. National Academy of Sciences, chaired by Professor Frederick Seitz with Professor Robert Christy as primary consultant, has been studying the radiation field at Hiroshima and Nagasaki, in cooperation with a companion group in Japan. Los Alamos National Laboratory (LANL) has made an improved estimate of radiation leakage

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from the Little Boy bomb, which results in adjustment of the LLNL values in Figure 1 by 33% downward at all ranges for neutrons and by 6% downward at all ranges for gamma rays. Oak Ridge National Laboratory (ORNL) has advanced alternative dosimetries, the most recent of which confirms these LLNL adjusted Figure 1 and Figure 2 values to roughly $\pm 30\%$ (after an outstanding controversy over the explosive yield at Hiroshima is discounted. This controversy, over whether the yield was 12.5 kt or 15 kt, is still unresolved, but the present trend is toward agreement on the 15 kt used in Figure 1.) To date, however, no alternative to the adjusted LLNL values has been offered which has not been shown subsequently to be in need of correction or is otherwise unsuitable to use as a replacement for those values as best estimates. Therefore, comparisons in what follows will be made to the Figure 1 and 2 values as reported in 1980 and elaborated in 1981⁽¹⁾, adjusted at Hiroshima to reflect the improved leakage estimates as just described (i.e., reductions of 33% and 6%).

The Little Boy bomb, which exploded 570 m above Hiroshima at 0815 August 6, 1945, generated 15 kt from fission of uranium assembled by a very large metal mechanism in a gun arrangement. The Fat Man bomb, exploded 503 m above Nagasaki at 1058 on August 9, 1945, generated 22 kt, mostly from plutonium assembled by high explosive implosion. Both bombs weighed four to five tons, of which the

Figure 1. Free-in-air tissue kermas at Hiroshima

Figure 2. Free-in-air tissue kermas at Nagasaki

non-fissioning assembly material constituted a thick blanket, surrounding the fissioning core. Neutrons and gamma rays generated in the core had to pass through this thick blanket to reach the atmosphere.

Although there are several reasons for the various errors in the old dosimetry system (T65D), the reason for the biggest error is the assumption that neutrons which have passed through these two different blanket materials then penetrate the atmosphere equally well.

Exiting neutrons, with kinetic energies in excess of about one-half MeV (which determine neutron dose beyond the 1 km ground range where most survivors were located) are actually distributed in energy as shown in Figure 3. In this figure, various Little Boy spectra are contrasted with the spectrum from a bare uranium metal reactor (normalized in intensity so as to force agreement at 0.6 MeV for easy comparison). Although not shown here, the leakage spectrum from the Fat Man bomb has a still larger proportion of higher energy neutrons (relative to those at one-half MeV) than a bare reactor, so that it is clear from Figure 3 that atmospheric penetration must be very different for the two bombs. In fact, the resulting 30% difference in dose e-folding lengths can be thought of as generating the differences shown in the neutron curves for Hiroshima in Figure 1.

Figure 3 also compares (1) the 1D calculations at LANL used to generate Figure 1, (2) the more recent LANL calculations discussed previously, and (3) measurements made by Robitaille and Hoffarth from Defence Research Establishment, Ottawa (DREO) at a replica of Little Boy prepared and operated by LANL as a reactor. Several other groups have confirmed the DREO data shown in Figure 3, including measurement teams led by Hoots and by Griffith at LLNL. These teams generated an improved description of the angular dependence of the spectra (resulting from the cylindrical symmetry of the gun assembly), and also measured neutron dose as a function of range to one-half kilometer. The two dose e-folding lengths derived from these two independent sets of LLNL range data agree to six percent with my calculated value which is based on a recent adaptation of the calculation that generated Figure 1 values.

Static calculations by LANL in 1984, using the same transport representation as in the previous dynamic calculations, lie somewhat lower than the dynamic results shown in Figure 3 and agree quite well with the measured data from DREO and from LLNL. Except for this modest dynamic effect, the Little Boy leakage is now very well known.

Figure 3. Little Boy neutron leakage energy spectra

The accuracy of deep penetration, air-over-ground radiation transport calculations, as used to generate Figures 1 and 2, has been established as better than 25-30% in kerma⁽²⁾, but recent updates by DREO of certain measured values now give agreements as shown in Table I for a bare metal source, with spectral indications that this kind of agreement could be expected for Little Boy as well as for Fat Man sources.

Table I
Bare Metal Reactor, LLNL Calc/Measurement

<u>Range (km)</u>	<u>Neutron Kerma</u>	<u>Gamma Ray Kerma</u>
.100	1.08	1.06
.170	1.06	0.91
.300	1.30	0.94
.400	1.28	0.90
1.080	0.92	0.80
1.618	0.90	0.91

At least half of the somewhat larger neutron disagreements at 0.3 km and 0.4 km have been shown to be attributable to the effects of nearby trees that were not modeled in the calculations. (Absolute accuracies of the data shown in Figures 1 and 2 are not as good due to uncertainties in source intensity and spectral composition, in meteorological conditions, and in terrain configuration and composition.)

One important difference in radiation intensities between a nuclear reactor, as shown in Table I, and the explosions over Hiroshima and Nagasaki is due to atmospheric rearrangement by the blast wave, which permits delayed gamma rays emitted by fission fragments to contribute roughly half of the total dose even though their source strength is very small. The gamma ray data in Figures 1 and 2 include delayed contributions as obtained from a model of this dynamic phenomenology that is based on weapon field tests. The entire calculational chain used for Figures 1 and 2, including this delayed gamma ray model, was tested by comparing its estimates with measured values from the Ranger Fox weapon field test, which was similar to the Nagasaki explosion. Agreement was within four percent at ground ranges of 1.0 km and 1.8 km, even though neither the measured nor the calculated estimates can claim such accuracy. A similar dynamic enhancement of delayed fission neutrons also occurs, but I have recently shown this delayed neutron contribution to be negligible, using the same model of the dynamic atmosphere.

Thermoluminescence dosimetry in Hiroshima and Nagasaki has recently been extended to ranges where most survivors were located, permitting comparisons with the gamma ray data in Figures 1 and 2. The comparisons shown in Figures 4 and 5, which include earlier data at shorter ranges, show a striking confirmation of the essential correctness of the predicted values out to 1.5 km. The abrupt discrepancies at 2.0 and 2.3 km at Nagasaki are thought to result from background contributions to the measurements at these great distances.

Measurements of neutron activation of cobalt have recently been reported by Hashizume in Tokyo on samples exposed to the atmosphere on rooftops in Hiroshima, as an extension of earlier measurements made interior to concrete pillars. If a small adjustment, within the limits of uncertainty, is made in the boron content of concrete (not measured at the time cobalt activation was measured inside pillars), then the pillar and rooftop data form a consistent set to within 10-15%. These data show calculations high by 15% compared to experiment near ground zero, low by 40% at one-half kilometer ground range, and low by a factor of four at one kilometer. This lack of agreement could be attributed to an unknown deficiency in source description due to dynamic effects during the explosion, an unknown deficiency in the calculated transport of sub-kilovolt neutrons responsible for cobalt activation, or an unknown experimental problem. The same kind of dynamic source deficiency would have to apply to the very different Fat Man as to Little Boy, since the Nagasaki pillar comparisons parallel those at Hiroshima. Also, recent work by Woolson and Gritzner at Science Applications, Inc. (SAI) changes fair agreement of calculated and measured values obtained previously for sulfur activation into the excellent detailed agreement shown in Figure 6.

Finally, the attention brought by the 1980 revelation of major error in free field kerma estimates allowed Jess Marcum of RDA to put forth improved estimates of the gamma ray shielding provided by Japanese dwellings. His factor of 1.6, by which previous transmitted gamma ray estimates are to be reduced, has been confirmed by SAI using detailed computer calculations that agree to 10% with selected values measured at weapons tests inside model buildings. These calculations can be used to model in high detail any survivor shielding configuration for which geometry and material records are available.

In conclusion, large changes from the estimates discussed here are increasingly unlikely. However, improvements are expected as a result of the international program currently under way, and the discrepancies noted in cobalt activation must be resolved. It is possible that the absolute accuracy previously attributed to the T650 dosimetry, 30%, might eventually be achieved for the new dosimetry.

I regret that only a few highlights could be included in this severely space-constrained overview, preventing reference to many other important investigations. However, George Kerr at ORNL has recently prepared an exhaustive bibliography for all of this work. (3)

Figure 4. Gamma ray kermas at Hiroshima

Figure 5. Gamma ray kermas at Nagasaki

Figure 6. Sulfur activation comparison.
Preliminary results by SAI

REFERENCES

1. W. E. Loewe and E. Mendelsohn, "Neutron and Gamma-Ray Doses at Hiroshima and Nagasaki", Nuc. Sci. & Eng. 81, 325-350 (1982).
2. W. E. Loewe, W. A. Turin, C. W. Pollock, A. C. Springer, and B. L. Richardson, "Validated Deep-Penetration, Air-Over-Ground, Neutron/Gamma-Ray Transport", Nuc. Sci. & Eng. 85, 87-115 (1983).
3. G. D. Kerr, Bibliography of Literature Relevant to the Reassessment of A-Bomb Radiation Dosimetry in Hiroshima and Nagasaki, ORNL/TM-9138 (1984).