Chapter 5 Appendix 7

IN SITU MEASUREMENT AND DEPTH PROFILE OF RESIDUAL ^{152}Eu ACTIVITY INDUCED BY NEUTRONS FROM THE ATOMIC BOMB IN HIROSHIMA

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The first finding of residual ^{152}Eu activity due to the 1945 atomic bomb explosion was made in 1976,[1] using high resolution in-situ gamma-ray spectrometry under the Hiroshima memorial dome, the "GENBAKU DOME". Since then, studies on this nuclide in Hiroshima and Nagasaki have continued, and have contributed to the reevaluation[2] of the neutron dose resulting from the A-bombing. A previous paper[3] reported details on the specific radioactivity of ^{152}Eu in roof tiles and rocks collected from these two cities, and their variations with the slant range from the explosion point. This paper presents the results for the in-situ measurements made in November 1982 for various points at different distances from the hypocenter of the explosion in Hiroshima, and also the depth profiles of ^{152}Eu in four concrete core samples taken from the walls of a building (now the REST HOUSE in the park for peace) where the in-situ measurements with a low-energy photon spectrometer (LEPS) were made in 1979.[1]

Measurement and Analysis

Four portable germanium detectors were used in 1982 for the in-situ measurements. Three of these were coaxial types, with efficiencies of 43, 15, and 10%, respectively, relative to a 7.6 × 7.6 cm NaI(Tl) detector. The fourth detector was a portable Ge-LEPS with 32 mm diameter by 10 mm high germanium crystal. Locations chosen for the in-situ measurements were as shown in Figure 1a. Initially, the needed calibrations for each detector were performed at the west-side wall of the REST HOUSE (about 150 m from the hypocen-

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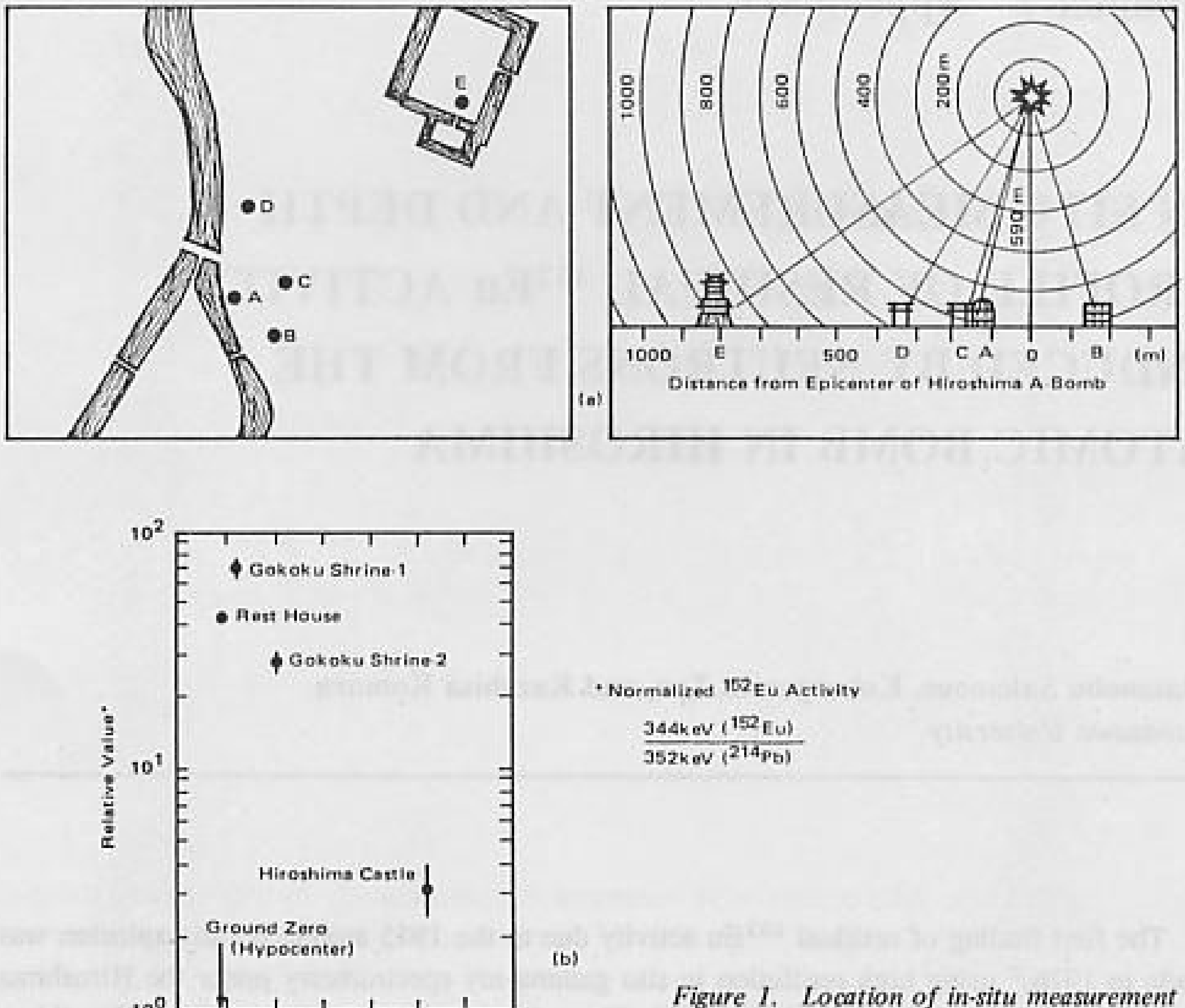

Figure 1. Location of in-situ measurement samples (a) and relative value by slant distance (b)

ter and about 600 m from the epicenter). The 43 and 15% detectors were then used for the in-situ measurements at the pedestals of the two KOMAINUs (guardian dogs of the shrine), situated at different locations at the front of the old GOKOKU SHRINE. (However, they have now been moved to the new location of the shrine inside the HIROSHIMA CASTLE.) One of them is made of bronze (about 180 m from the hypocenter and about 630 m from the epicenter), and the other of stone (about 370 m from the hypocenter and about 710 m from the epicenter). The stone wall of the HIROSHIMA CASTLE still remains today (about 850 m from the hypocenter and about 1020 m from the epicenter). The 10% detector and the Ge-LEPS detector were used for measurements of the inside and outside of the walls of the REST HOUSE. The four concrete cores were drilled out from the walls of the REST HOUSE in the directions of the arrows as shown on the left side of Figure 2. Cores #1, 2, and 3 were all taken from the outer walls on the first floor while core #4 was taken from the inner wall on the third floor. Each core had a diameter of 10 cm. For cores #1, 2, and 3, boring was made to a depth of about 15 cm from the outside surface. For core #4, the first boring was made to about 17 cm deep and the remaining wall thickness of 5 cm was sampled in November 1983. The core samples were cut into sections, each having a thick-

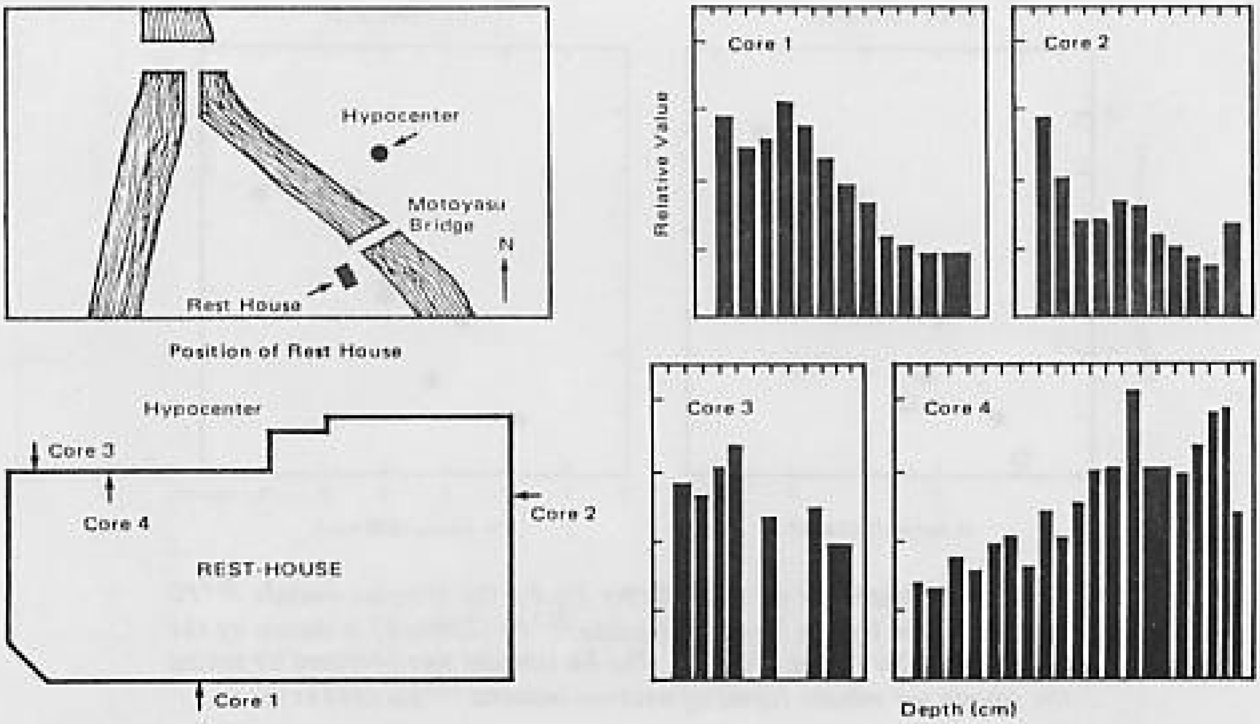

Figure 2. ^{152}Eu concrete core depth profiles in relation to the boring sites of the Rest House, Hiroshima

ness of about 1 cm. All sections were measured nondestructively by the heavily shielded low background 15% Ge(Li) detector. The ^{152}Eu peaks at 122 and 344 keV were identified from the gamma-ray-spectrum for each of the core sections. In order to assess the validity of the normalization of the 344 keV ^{152}Eu peak to ^{151}Eu in the sample by using the 352 keV peak of ^{214}Pb contained in the sample, four sections from each core were subjected to thermal neutron activation by the University Training and Research Reactor (UTR) of Kinki University.

Results and Discussion

After neutron irradiation from the UTR reactor for the core section samples, the peak heights of ^{152}Eu at 122, 344, 778, and 1085 keV were found to have increased considerably. The increased contents (cpm) of ^{152}Eu in the different core section samples were plotted against gamma-ray peaks (cpm) of uranium and thorium series nuclides as shown in Figure 3. The correlation between the 344 keV peak of ^{152}Eu and the 352 keV peak of ^{214}Pb belonging to the uranium series was quite good. In Figure 3, a correlation coefficient of 0.84 was calculated for the data obtained from the different core section samples from the first floor, which had been neutron-irradiated for 47 hours. For the data of core sections samples from the third floor, irradiated for 28 hours, the correlation coefficient was found to be 0.99. Therefore, even if the content of ^{151}Eu in each core section sample was not known, the ratio of the counts in the 344 keV peak to those in the 352 keV peak can be considered to give the relative intensity of the thermal neutron-induced specific activity of ^{152}Eu at the time of the explosion. The variation of the normalized residual ^{152}Eu activity ratio (344 to 352 keV) with the slant range from the epicenter is shown in Figure 1b. Clearly,

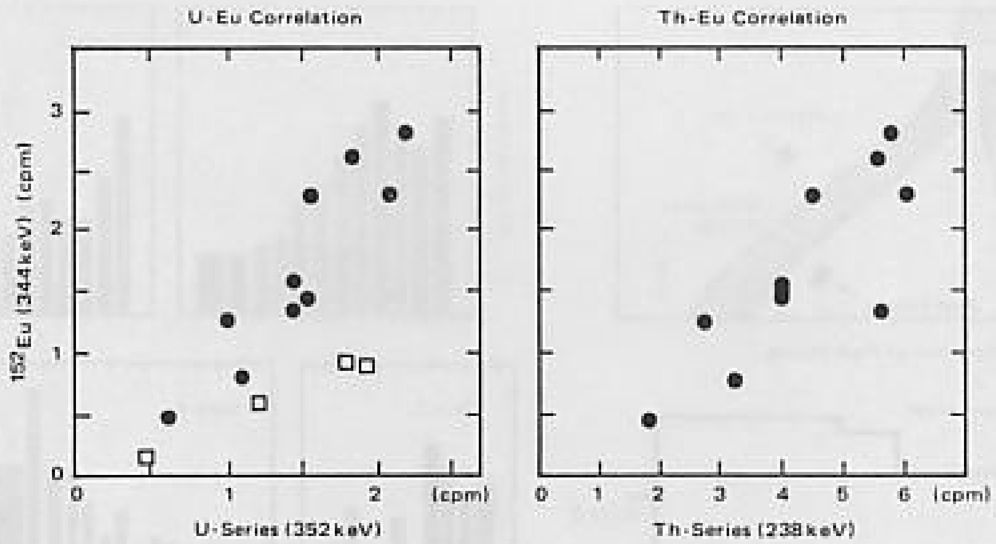

Figure 3. The reasonability of normalizing Eu by the U-series nuclide ^{214}Pb (352 keV) rather than by the Th-series nuclide ^{212}Pb (238 keV) is shown by the good correlation of Eu to the U-series. The Eu content was obtained by taking the counts per minute (cpm) of neutron-induced ^{152}Eu (344 keV)

Table 1. The Activity of ^{152}Eu Determined by In-situ Measurements

Location of measurement	Height of detector (m)	^{152}Eu 344 keV (cpm)	U-series 352 keV (cpm)	Activity ratio of 344/352 keV (^{152}Eu/^{214}Pb)
(1) Wall of the REST HOUSE	1.0	6.19 ± 0.37	44.06 ± 0.72	0.140 ± 0.009
Pedestal of bronze guardian dog of the GOKOKU SHRINE				
(2) Front	0,7	14.91 ± 1.28	64.53 ± 1.32	0.231 ± 0.019
(3) Back	0.7	14.91 ± 0.61	65.91 ± 1.72	0.226 ± 0.010
(4) Lower part	2.2	3.11 ± 1.35	22.86 ± 0.41	0.138 ± 0.061
Pedestal of stone guardian dog of the GOKOKU SHRINE				
(5) Front	1.0	7.77 ± 0.65	84.30 ± 0.98	0.092 ± 0.009
(6) Lower part	8.35	6.30 ± 0.58	87.27 ± 1.99	0.072 ± 0.007
(7) Back	1.8	4.49 ± 1.65	89.59 ± 1.66	0.050 ± 0.018
(8) Stone wall of the HIROSHIMA CASTLE	1.8	8.76 ± 0.17	73.25 ± 0.71	0.010 ± 0.002

this normalized ^{152}Eu activity decreases with increasing slant range, and becomes almost undetectable beyond 1.02 km from the epicenter. The value for position "1", corresponding to the REST HOUSE, was lower than expected. This may be due to the absorption of gamma rays from the ^{152}Eu in the wall by mortar on the newly resurfaced wall, or to the shielding effect of the building during the bombing. The slope of the straight line fitted to the data

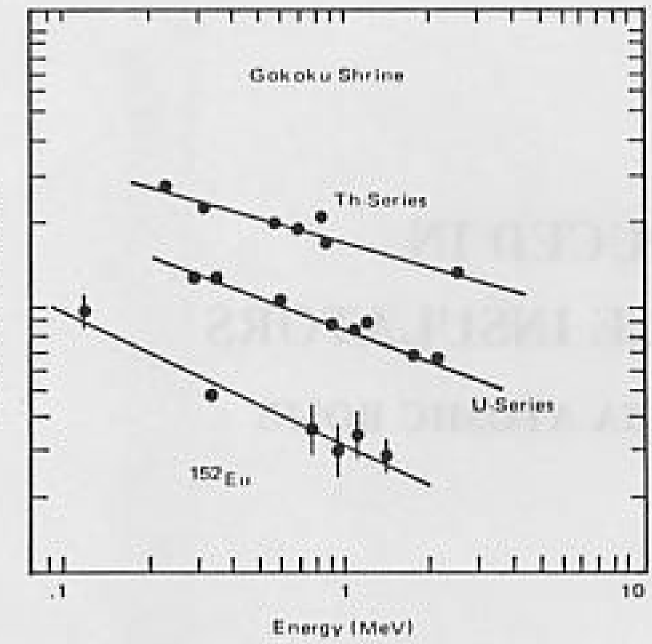

Figure 4. Apparent detection efficiency curve for ^{152}Eu and the U- and Th-Series

points in Figure 1 is similar to the results previously obtained from the measurement of roof tiles (see the Hiroshima data in Figure 3 of the previous report).[3] The results of other in-situ gamma-ray spectrometric measurements of ^{152}Eu and ^{214}Pb are shown in Table 1 along with the normalized ^{152}Eu activities for each object. These data are of use in ascertaining the shielding effect for neutrons. Apparent detection efficiency curves obtained by dividing the gamma-ray peak counts by its corresponding branching ratio were compared for the uranium and thorium series nuclides and the ^{152}Eu nuclide (Figure 4). The somewhat steeper slope of the curve for ^{152}Eu versus the other nuclides suggests that this nuclide is concentrated near the surface.[4] The depth profiles of the normalized residual ^{152}Eu activity in the four concrete cores are shown on the right side of Figure 2. Although, in general, the ^{152}Eu activity decreases exponentially with increasing depth, some differences among the cores taken from the four different positions can be seen, especially near the surface of each wall, where the effect of fast neutrons would be expected to be most pronounced. The fitting of the calculated production rate of the ^{152}Eu with these data will significantly contribute to the reevaluation of the neutron spectrum due to the A-bomb explosion in Hiroshima.

References

1. Sakanoue, M., Maruo, Y., and Komura, K., 1981. In-situ low-level gamma-ray spectrometry and x-ray fluorescence analysis. In *Int. Symp. Meth. Low-Level Counting and Spectrometry,* pp. 105-124. Vienna: International Atomic Energy Agency STI/PUB/592.

2. Loewe, W. E. and Mendelsohn, E., 1982. Neutron and gamma-ray doses at Hiroshima and Nagasaki. Nucl. Sci. Eng. 81:325-350.

3. Nakanishi, T., Imura, T., Komura, K., and Sakanoue, M., 1983. ^{152}Eu in samples exposed to the nuclear explosions at Hiroshima and Nagasaki. Nature 302:332-134

4. Komura, K. and Sakanoue, M., 1982. Rapid measurements of Rn-222 and other radionuclides in water by in-situ Ge(Li) spectrometry. In *Natural Radiation Environment,* K. G. Vohra, U. C. Mishra, K. C. Pillai, and S. Sadasivan, Eds., pp. 376-383. New York: Wiley.