Chapter 6

THE RERF DOSIMETRY MEASUREMENTS DATABASE

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Overview

The Radiation Effects Research Foundation maintains a database containing detailed information on every known measurement of environmental materials in the cities of Hiroshima and Nagasaki for gamma-ray thermoluminescence or neutron activation produced by incident radiation from the atomic bomb detonations. The intent was to create a single information resource that would consistently document, as completely as possible in each case, a standard array of data for every known measurement. This database provides a uniquely comprehensive and carefully designed reference for the dosimetry reassessment. The database itself is maintained as a Microsoft Access 2000 file. The main tables of the database are tables of data related to samples, sub-samples, measurements, and references. Sub-samples are nested within the samples from which they were taken, and measurements within the sub-samples on which they were made. Each measurement is keyed to a primary reference, which is typically the first publication in which it was reported. The complete structure of the database is depicted in Figure 1.

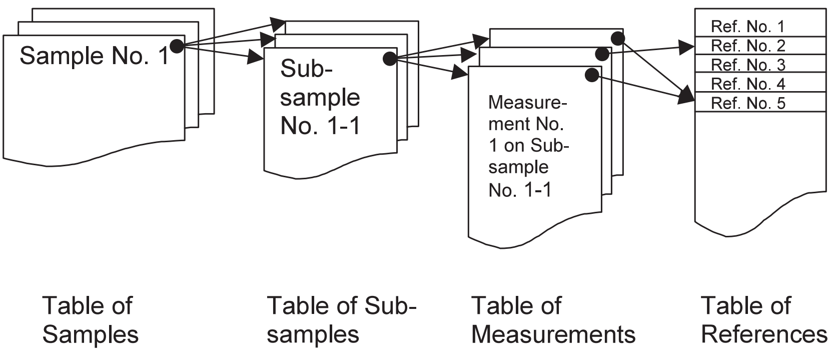

Figure 1. *Structure of the RERF measurements database.*

The philosophy of the database has been to enter data exactly as recorded by investigators in their source documents whenever the information exists, so that this aspect of the database would not reflect any judgment by RERF except to identify the correct datum in each case. Thus, there would be no alteration of the investigator's reported results, even for such purposes as a change in out-dated units. There are many transformations of the data that might be desirable for purposes of analysis, such as units conversions, corrections, adjustments for radioactive decay, and so on. The intent of the RERF database is to provide the requisite information for such transformations whose need can be foreseen, if possible, along with the original data as reported, so that such calculations can be made completely at the discretion of the person using the database. This is the reason for including such information as date of measurement and applicable background levels whenever they are available. In addition to the fields designed specifically to enable such *post hoc* adjustments, comments about the data and relevant information not specifically coded in the various fields may be included in the Notes field of the Sub-samples screen when considered appropriate by the RERF staff member entering or reviewing data.

Custom Screens for Data Entry and Visualization

A custom program was designed to facilitate easy data entry and convenient visualization of the relationships among variables for a given sample, sub-sample, and measurement. The main data entry/visualization screens are shown in Figures 2 and 3: a combined screen for Sample and Sub-samples and in Figure 4: a separate screen for Measurements. Many of the fields for data entry have drop-down arrows to allow quick entry of a selection from an updated list of previous entries for that field. The Measurements screen is opened by selecting the appropriate item under the pull-down menu under "Navigate" or by double-clicking the abbreviated list of measurements in the Sub-sample screen.

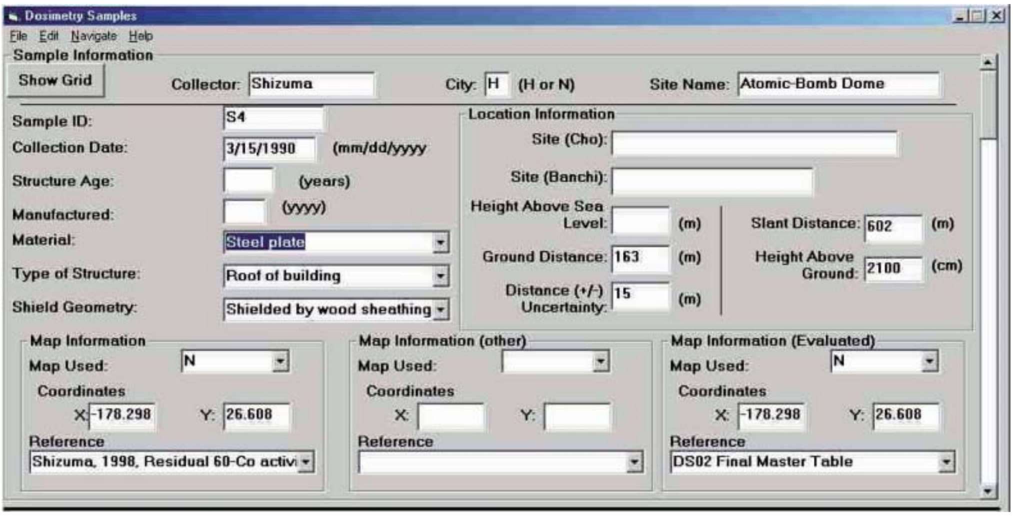

Figure 2. *The Sample information screen.*

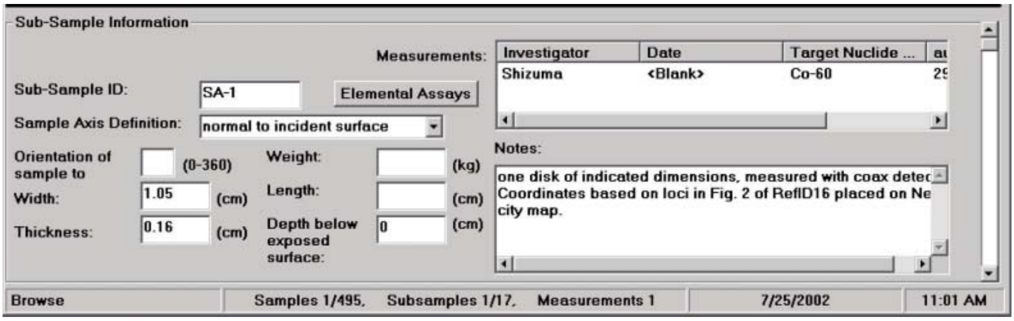

Figure 3. The Sub-Sample information screen.

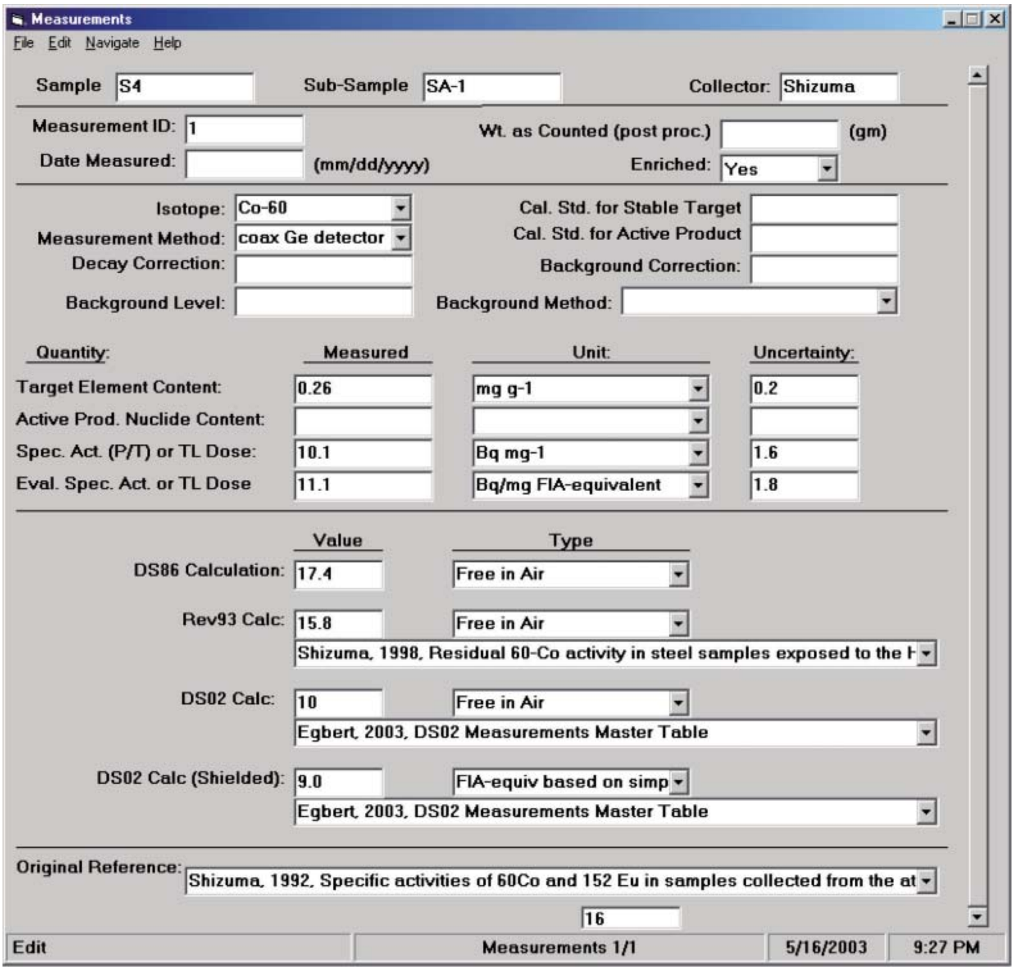

Figure 4. The Measurements screen.

Clicking on the “Show Grid” button displays the table of samples as shown in Figure 5, which can be sorted or filtered using any of the fields in the Samples table, and allows quick navigation to a specific sample or samples based on any desired criterion that can be applied in this manner. A pull-down menu under “Navigate” allows not only the creation of initially blank entries for samples, sub-samples, and measurements, but also the creation of duplicates of previous entries, so that entries differing in only one or a few details can be made quickly and efficiently.

The data entry/visualization screens include an online help function to explain the structure of the database and the intended definition of each item of information. The data entry criteria and guidance are reproduced in Appendix A.

Although the database can be opened and viewed directly in Access without using the custom screens, it is preferable to enter data and edit the database by using the screens, which provide visual feedback for data validation. The screens automatically create the appropriate records in each table and maintain the appropriate relationships among the key fields by which the tables are linked. Furthermore, for many purposes the most convenient way to visualize the

Dosimetry Samples Grid

Refresh | Sort | Filter | Close

SampleID	Collector	City	SiteName	CollectorSampleID	CollectionDate	StructureAge	ManufactureYear	Material
1	Shizuma	H	Atomic-Bomb Dome	S4	3/15/1990			Steel plate
2	Shizuma	H	Atomic-Bomb Dome	G2	3/15/1990			Granite
3	Shizuma	H	Atomic-Bomb Dome	G3	3/15/1990			Granite
4	Shizuma	H	Atomic-Bomb Dome	G4	3/15/1990			Granite
5	Shizuma	H	Atomic-Bomb Dome	G6				Granite
6	Saito	H	Atomic-Bomb Dome,					Iron plate
7	Hoshi	H	Sumitomo Bank	Sumitomo				Iron
8	Hoshi	H	Aioi Bridge	A-1				Iron plate
10	Kato	H	Saikou-ji, grave					andesite rock
11	Fujita	H	Aioi Bridge					Granite
12	Fujita	H	Chugoku Electric Po					Concrete
13	Fujita	H	Hiroshima University					Concrete
14	Fujita	H	Hiroshima Postal Sav					Concrete
15	Fujita	H	Hiroshima City Hall					Concrete
16	Fujita	H	Teishin Hospital (Cor	S-58 (RERF No 3)				Concrete
17	Shizuma	H	Atomic-Bomb Dome	S1	3/15/1990			Steel plate
18	Shizuma	H	Kirin Beer Hall	S2				Iron
19	Shizuma	H	Kodokan	S3				Steel pipe
20	Shizuma	H	Hiroshima City Hall	S4				Steel pipe
21	Shizuma	H	Red Cross Hospital	S5				Steel pipe
22	Shizuma	H	Red Cross Hospital	S6				Steel rail
23	Shizuma	H	Hiroshima Bank of Ci	S7				Steel rail
24	Sakanoue	H	Rest House					Wall
25	Sakanoue	H	Gokoku Shrine, Gua					Bronze
26	ABCC	H	Hiroshima Bank					iron rebar in concrt
27	ABCC	H	Sentry Box					iron rebar in concrt
28	ABCC	H	Water Trough					iron rebar in concrt
29	ABCC	H	Powder Magazine					iron rebar in concrt
30	Nakanishi	H	Shima Hospital	H1				Roof Tile
31	Nakanishi	H	Sanyo Memorial Hall	H2				Roof Tile
32	Nakanishi	H	Seigan-ji	H3				Roof Tile
33	Nakanishi	H	Akisaya-cho	H4				Roof Tile
34	ABCC	H	Honkawa Primary Sc					Iron
35	ABCC	H	Fukuromachi Primary					Iron
36	ABCC	H	Kirin Beer Hall					Iron
37	ABCC	H	Kodokan					Iron
38	ABCC	H	Hiroshima City Hall					Iron
40	Nakanishi	H	Hiroshima University	N				Roof Tile
41	Nakanishi	H	Motoyasu Bridge	G				Granite
42	Nakanishi	H	Fukoku Seimei Buildi	F				Granite and Concrete
44	Nakanishi	H	Naka Denwa-Kyoku	M2				Wall Tile
45	Nakanishi	H	Chugoku Electric Po	P				Wall Tile
46	Nakanishi	H	Tamino's House (Kai	H5				Roof Tile
47	Nakanishi	H	Hiroshima City Hall	Q				Wall Tile
48	Nakanishi	H	Hiroshima University	N1				Roof Tile
49	Nakanishi	H	Hiroshima University	N2				Roof Tile
50	Shizuma	H	Saikou-ji	9	11/15/1945			Roof Tile
51	Shizuma	H	Motoyasu Bridge, Pill	10	1/1/1985			Granite

Figure 5. *The Show Grid button opens the table of samples.*

previously entered data is by use of the custom screens, which avoids the need to program queries or perform other database manipulations to allow viewing of sample/sub-sample/measurement combinations. For example, simple direct viewing of the tables in the database does not make it immediately apparent which measurements were done on which sample; this requires checking the key fields of the three tables of Samples, Sub-samples, and Measurements.

Items of Information in the Database, Their Purpose and Completeness

As every item in the database was chosen with a specific analytical purpose in mind, it seems appropriate to document those considerations. Furthermore, although every item of information included in the database is justified and is available for at least some cases, investigators have almost universally documented some items, while other items have almost never been documented. Some discussion of this issue and its implications seems appropriate in light of the recommendations of, e.g., the National Research Council committee (National Research Council 2001), particularly in the cases of items for which data were generally not available.

Sample Information Screen (Figure 2)

The sample information screen is divided into two portions. The top half applies to a sample and includes all of the information that applies to the entire sample. The other is devoted to measured sub-samples. Each sample can be displayed in the top half of the screen and each of one or more sub-samples taken from that sample can be displayed in the bottom half.

Sample Identification and Provenance

The section entitled *Sample Information* contains fields for *Collector*, *Sample ID*, and *Collection Date*, which are intended to document the most salient aspects of a sample's provenance. Issues related to provenance would include a sample's authenticity and its history since the bombing, including the time of its removal from the *in situ* location in which it resided at the time of bombings (ATB), and its history of custody and storage conditions. The provenance of samples has been identified as a potential issue in uncertainty analysis (National Research Council 2001). The major collectors have been ABCC/RERF and a group at Hiroshima University, although the Peace Museums in both Hiroshima and Nagasaki have also contributed samples in some cases, and other individual investigators have done some collection. While the identity of the collector is usually known and the collector has almost always assigned an identification number of some sort, the date of collection is sometimes not known. Information on sample provenance has improved over the years. More information on sample collection and documentation is given in Chapter 4.

Sample Material and Age

The fields for *Structure Age, Manufactured* (date), and *Material,* as well as *Collection Date,* are intended to document important aspects of the sample's material and history according to standardized definitions. The age of a sample such as a tile or a brick, since its firing in a kiln during its manufacture, is of primary interest in thermoluminescence dosimetry. Near the hypocenter, the gamma dose is large in comparison to background, but at longer distances background and hence sample age is critical. Except in a few cases of materials very close to the hypocenter, investigators have been compelled by this consideration to estimate the ages of samples. In most cases investigators have documented in their publications an estimate of a sample's age that is based on a building's age and the assumption that the brick or tile was fired within a year before the construction in which it was used. Some additional information on many public structures is available from other sources, of which two outstanding examples are the book *Architectural Witnesses to the Atomic Bombing—A Record for the Future*, published in Japanese by the Hiroshima Peace Memorial Museum (Hiroshima Peace Memorial Museum 1996), and Hibakukenzoobutsura no kiroku ("Record of A-bomb Exposed Buildings and Such") published in Japanese by the city of Nagasaki (Nagasaki 1996); however, linking such information to specific sample materials is difficult. The reliability and accuracy of information about the age of TLD samples since firing remains a concern.

In the case of neutron activation measurements, the age of a sample as a manmade object (e.g., since it was mined from the earth) and its time spent in its *in situ* location are at least theoretically germane to its cosmic-ray induced background level of a neutron activation product nuclide, in the cases of radionuclides with half lives on the order of years to tens or hundreds of years, such as ^{60}Co, ^{63}Ni, and ^{152}Eu. Other effects in practical situations may supersede this consideration, i.e., the saturation level of the activation product due to cosmic ray production may be so small in comparison to even the lowest levels being measured as to render it moot. In general, investigators have not thought it necessary to determine the ages of neutron activation samples, and this information is typically not available for them, although recent ^{63}Ni measurements in copper are an exception.

More discussion of technical matters pertaining to background and its relationship to the ages of samples is given in the sections of this report devoted to the particular types of measurements in question.

The entries for *Material* have typically been made fairly detailed and specific, to allow for subset analysis if desired. For the case of thermoluminescence there might be differences between tiles and bricks or among different types of tiles that are not entirely negated by the separations and other corrections of the measurement process. In the case of neutron activation, there may be aspects of a sample's composition, even at the level of the broad categories of classification of *Material* used here (e.g., concrete vs. granite vs. tile) that would be related to differences in background levels of the activation product, or differences in activation per unit incident neutron fluence. Hence these classifications may be useful for subset analysis. Descriptions of sample materials in the relevant source documents are fairly specific in most cases.

Sample Exposure Geometry and Surroundings In Situ

The fields for *Type of Structure* and *Shield Geometry* are intended to document broad aspects of a sample's circumstances that relate its dose or activation to the free-in-air quantity at the same location. The simple generic classification of a sample as shielded or unshielded is of primary importance, as some shielded samples have been deliberately measured for specific purposes, and should be omitted from analyses of the preponderant majority of samples, which are carefully chosen from some superficial aspect of a structure with a direct line of sight to the epicenter of the nuclear burst. Simple classifications of the structure containing a sample's *in situ* location do not substitute for the detailed information that is necessary for calculations such as local scale Monte Carlo modeling, which has been done in many cases to evaluate the effect of a sample's local circumstances on its calculated dose or activation, but may still be useful. In most cases, these items are fairly well described in the publications in which the measurements are reported. One possibility being considered for including detailed information is to link the sample record in the database to a scanned image of a drawing that gives detailed structural shapes, orientations, and dimensions, when such a graphic object is available. In addition, or in lieu of such graphical information, a description of the sample/site geometry can be entered in the *Notes* field of the Sub-sample screen.

Sample Geographical Location and Elevation

The portion of the screen labeled *Location Information* includes an array of information on the sample's location in relation to the hypocenter and epicenter of the nuclear burst: Site *cho*, Site *banchi* (Japanese designations of neighborhood and city block), *Height Above Sea Level*, (investigator's estimate of) *Ground Distance*, (investigator's estimate of) *Distance Uncertainty*, (investigator's estimate of) *Slant Distance*, and *Height Above Ground*. The fields for *Ground Distance*, *Distance Uncertainty*, and *Slant Distance* are intended to document the investigator's original published estimates so that they will be available for any desired analyses and comparisons involving those original assumptions. These variables can be re-estimated at any time, with the additional flexibility of specifying a slant distance based on any chosen height of burst, by using the map coordinates provided in the sections for Map Information.

Investigators always give a ground or slant distance, but height above ground is often not given in publications. Altitude above sea level is frequently given in Nagasaki but not in Hiroshima, where it is generally within 10 m or so of the altitude at ground level at the hypocenter.

The site *cho* and *banchi* are the equivalent of street addresses as used in the United States. Such designations are useful and have been used extensively with survivors' locations at ABCC/RERF, but they are less useful in determining sample locations. The localization of a street address on an accurate full-city map, to a precision of a few meters, depends on having a very detailed map or neighborhood drawing that is contemporaneous with the time period when the sampled structure was in existence. Site *cho* and *banchi* might be helpful for sample locations in some cases where additional research can be done to locate such documents, particularly in cases of structures such as private residences and small shrines and temples that are not shown on the U.S. Army maps and the new Japanese city plan maps. But reliable map coordinates on the U.S. Army maps and the new Japanese city plan maps, previously derived from other sources of information by persons familiar with the local area, are more directly useful.

There are at least two generic types of samples that have been specifically identified by measurers as lacking certain information in these respects. One type is roof tiles that were blown off by the blast and were collected in the vicinity of a given structure, but whose position on that structure at time of bombing (ATB) is unknown. The other type is gravestones that were collected sometime after their removal from the actual location that they occupied ATB. These gravestones were individually removed from the ritual part of the cemetery by persons responsible for the cemetery, because of space limitations and a lack of local descendents to care for them, and it was for this reason that they were generally available to be measured. This leaves a deficit of information about a gravestone's exact location within the cemetery ATB and its relationship to other gravestones or other sources of possible shielding. In both types of cases, it is necessary to address the resulting additional uncertainty in two respects, when measured values are compared to calculated ones:

- The first is that the estimated uncertainty in the sample's distance from the hypocenter must include this consideration, i.e. the horizontal dimensions of the structure (roof tiles) or the graveyard (gravestones);
- The second is that the uncertainty in a calculated dose or activation specific to the sample must include this consideration.

For roof tiles, this means that the angle of incidence and other aspects of the sample's location vis-à-vis the modeled structure, which affect the calculated gamma dose, are uncertain, and for gravestones, this means that the size, number, and locations of adjacent gravestones and other objects that affect the calculated thermal neutron activation are not known.

The sections of the Sample Information screen labeled *Map Information* are for the map coordinates of the sample location. Map information about the locations of samples has been in need of better documentation and standardization. Many publications in which measurements have been reported do not include any explicit map information such as coordinates on the U.S. Army maps or the newer Japanese city plan maps. They often contain map-type drawings, but these are usually very small images and are often of uncertain scale and accuracy. On the other hand, relevant map information is often available from other sources. Most public buildings and other structures of interest are depicted on the maps, especially the newer Japanese city plan maps. Maps useful in finding sample locations relative to other features are also given in the references noted in this chapter.

Materials maintained at RERF are an important source of information on the samples collected by ABCC/RERF. Documentation dating from the 1960s, of locations for samples collected in that time period for the Japanese National Institute of Radiological Sciences (JNIRS), is incomplete in some respects, but documentation on samples collected in later years is extensive. In some cases of collection by others, notes, drawings, and other materials containing information beyond that given in the publication reporting the measurements are available. More information is given in Chapter 4 on the RERF samples database.

The database and screens contain sections for the entry of as many as three versions of map information:

1) map coordinates from the original source document in which the related measurement was published, if such information is given in that document,
2) map coordinates from an alternative source of map information if such a source exists, and
3) an evaluated location in the coordinate of the Japan Land Survey System as used in the new city plan maps, which has been specified by RERF based on a) a careful review of all available information about the particular site and sample collection case in question, and b) checking via the Geographical Information System (GIS) at RERF.

A detailed discussion of issues related to maps and to the GIS is given in Chapter 4.

Sub-Sample Information Screen (Figure 3)

The information contained in this screen is based on the recognition that samples (tiles, bricks, etc.) are often rather large and are then divided into sub-samples for measurement. In some cases, different sub-samples have been distributed to different investigators for measurement, usually as part of a designed exercise in intercomparison among laboratories. The size of a sample is often large enough to be associated with substantial variations in received dose or activation among sub-samples. This is particularly true of cores that are drilled from rock and concrete and divided into sub-samples by transverse cutting (slices). Such cores, which may be several tens of cm or more in length, are intended specifically to allow measurement of dose or activation vs. depth below the exposed surface.

The sub-sample is defined here as the portion of material that was measured, if measured intact, or the portion of material that was processed as a unit during the physical or chemical steps used to prepare the material for measurement. By this definition, a sub-sample is thus typically counted in its entirety, or homogeneously mixed together in its entirety during physical and/or chemical processing prior to measurement, even though the processed material may be further subdivided for individual measurements in the latter case. Therefore, within-sub-sample replicate measurements are likely to reflect less variation due to positional differences or inhomogeneity in chemical composition that existed *in situ* than are measurements on different sub-samples of a given sample, or measurements on different samples of the “same” material from the “same” location

Sub-Sample Exposure Geometry In Situ

The sub-sample screen contains a small array of information to define the position and orientation of a sub-sample relative to the sample and the larger body of material from which it was taken, vis-à-vis the directionality of the incident radiation fluence. A *Sample Axis* is defined, along with an angle of incidence (*Orientation*), which is taken as the angle between the sample axis and a line of sight to the epicenter. Each sub-sample is characterized by its *Weight* and linear dimensions, in addition to a *Depth* below the “exposed surface.” The weight and dimensions apply to the sample material prior to processing—a separate field is included in the Measurements screen for the weight as counted after processing (see below). The “exposed surface” is taken as that surface of the sample that was in contact with air *in situ*, and depth is defined as the distance from that surface to the nearest boundary surface of the material that was actually measured. The sample *usually* has a flat face that was in contact with the air, and whose perpendicular *in situ* was in a direction close to the direction to the epicenter. Furthermore, the face of the sample was *usually* part of a larger contiguous surface of the same material, whose lateral dimensions were large compared to the relaxation length of neutrons or photons in the sample material (Figure 6). Thus the scheme used in the database suffices to unambiguously describe the most important aspects of the sample’s geometry vis-à-vis the incident fluence in the majority of situations encountered. Other situations can be described in the *Notes* field. The values entered here, as in other items of information, are those in the source documents.

Information about the depth of measured sub-samples is usually available, at least to reasonable precision (e.g., “taken from within 2 to 3 cm of the surface”), but sample and sub-sample dimensions and pre-processing weights are often not available. This does not appear to present a major problem in analysis, as it is primarily the depth information that is important for

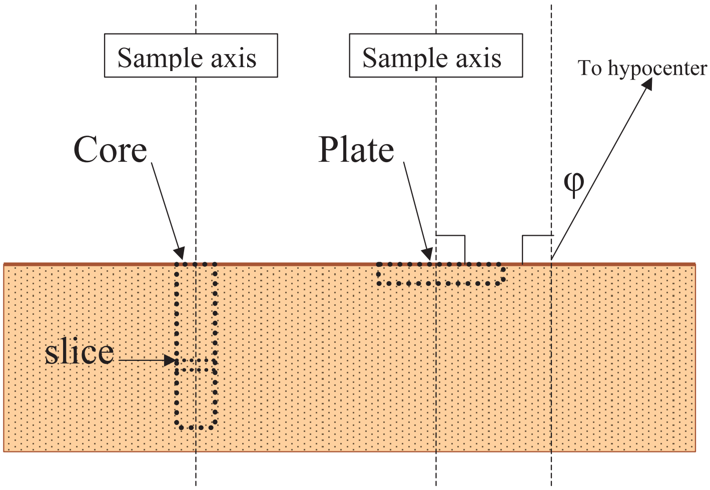

Figure 6. *Sample geometry in situ. The sample usually has a face that was part of an interface between the surrounding air and a larger body*

samples taken from the surface of large bodies of, e.g., rock or concrete. In the case of samples that were smaller in dimension *in situ*, e.g., sulfur paste in electrical insulators, copper metal, or iron or steel bulk metal, information about the size and shape of the sample *in situ* is more often available. Perhaps the worst case in a generic sense pertains to roof tiles, which were not well documented in these respects in measurements made prior to the DS86 effort. Furthermore, it was sometimes not clear whether a given tile, collected from the vicinity of a building after the destructive effects of the blast, was in the topmost layer of tiles *in situ* or in a less exposed position.

Angle-of-incidence information was generally fairly well documented for gamma TLD samples if it was available at the time of sample collection, and the circumstances of copper samples to be measured for fast neutron activation have been carefully documented. Angle of incidence has typically not been documented for thermal neutron activation, except in relation to the axis of cores drilled for depth measurements, as it is not considered to have much effect on "surface" samples.

Sample/Sub-Sample Elemental Composition Assays

The sub-sample screen contains a button *Elemental Assays* for elemental composition assay(s) that may have been performed. In the case of neutron activation measurements, such assays would generally be for elements other than the target element of the neutron activation reaction; the latter are covered in the Measurements screen (see below). Clicking on this button opens a table of elemental composition assay results that are keyed to the various samples in the database. The elemental composition of a sample may have been assayed for a broad array of elements by a commercial laboratory, or may have been assayed for as few as one particular element of interest, other than the target of the activation reaction of interest. In the case of concrete, for example, neutron measurements might be particularly affected by the concrete's content of water, boron, or various other low-abundance trace elements that are considered to be "neutron poisons" due to their unusually large cross sections for, e.g., thermal neutron capture reactions. Another case of interest in relation to concrete is that ^{36}Cl measurements may depend on the sample's content of potassium, due to the fact that concretes with high K content are affected by the alternate production mechanism of the ^{39}K(n,α)^{36}Cl reaction. Similarly, measurements of copper samples for ^{63}Ni production by fast neutrons must consider the size of any nickel impurity due to the competing thermal neutron reaction ^{62}Ni(n,γ)^{63}Ni.

Prior to the current dose reassessment effort, only a few neutron activation samples were subjected to assays of elemental composition for elements other than the target element. In some cases, representative TLD samples were assayed for elemental composition, which is relevant to calculation of transmission factors and energy response (Chapter 7).

Sample/Sub-Sample Notes

The Notes field in the sub-sample screen can be used for any comments that apply to that particular sub-sample, the sample whence it came, or any of the measurements associated with that sub-sample.

The sub-sample screen also contains a window that displays a summary listing of the measurements listed in the database for that sample.

Measurements Screen (Figure 4)

The items of measurement data in the database conform largely to what is typically available in published reports. Although raw data would be useful for analytical purposes, data at this level of detail are voluminous, and investigators have generally felt that it was not practical to provide such comprehensive information. Such raw data might include items such as dates of measurement, the exact length of each counting interval, the number of observed sample or peak and background counts, and even the spectral details relevant to determination of peak vs. background counts by spectral methods in gamma spectroscopy using high-resolution semiconductor detectors. In AMS work, raw data of interest might include numbers of counts in various detectors or as a function of charge/mass ratio, along with the beam current of the ionic species to which the measurement is normalized, and other parameters.

Very few publications in the past have documented the complete raw data for their reported results. Notable exceptions are: 1) ^{60}Co measurements reported in the Oak Ridge Laboratory Report ORNL 6590 (Kerr et al. 1990), and 2) the raw data that were recently made available for the original ^{60}Co measurements made by the Japanese National Institute of Radiological Sciences (JNIRS) in 1965 (Hashizume et al. 1967) [personal communication, Takashi Maruyama, JNIRS, 2001].

Raw data for some measurements preceding the current Working Group effort have been available in the group for limited analytical purposes, but even in those cases the related analysis has not necessarily established the connection between the raw data and specific published results. Thus, with the exceptions noted above and the exception of the intercomparison measurements made for the current reassessment effort, raw data are generally unavailable. Dates of measurement are documented in the database for only the cases just noted, and other items of raw data such as raw counts, counting intervals, and spectral data are not included in the database.

Sample Weight as Counted

The Measurements screen includes a field for *Weight as Counted*, post-processing, and an indication whether the sample was chemically *Enriched*. In radiometric assay of neutron activation products, knowing the weight of the sample as counted is useful, in addition to knowing the sample's post-processing elemental concentration assay for the target element, because it allows calculation of the weight of stable target element present in the sample as measured. This in turn allows generic calculations related to limits of detection. When replicate measurements are available at the same location or even the same distance, this information also allows examination of the relationship between the amount of stable target element in a sample and its measured amount of the neutron activation product. This is an important consideration in demonstrating that the measured signal (activation) is appropriately proportional to the amount of stable target element in a sample, as it should be if it was produced exclusively by neutron irradiation of the sample, by the bomb fluence or from any other source.

The availability of *weight as counted* for radiometric assays depends on the type of measurement. It is implicit in the available information for the ^{32}P measurements of principal interest, viz., it can be deduced from the count rates and reported specific activation values in Table 1 of Hamada (1983), and is generally available for ^{60}Co measurements. For many of the ^{152}Eu measurements preceding the current reassessment effort, this information is not available or is stated as a range. However, sufficient information is usually available to at least determine typical detection limits for a given investigator's methods and equipment during a given calendar period (see, for example, National Research Council 2001).

Date(s) of Measurement and Decay Correction

The *Date Measured* is relevant to concerns about possible temporal trends in measurements, and is particularly germane to the decay calculation that investigators make to correct their measurements for the radioactive decay of the neutron activation product radionuclide that occurred between the date of the bombing, August 6 or 9, 1945, and the date of measurement. This is a large correction for some shorter-lived nuclides that are typically assayed by radiometric methods. Most notably, the decay correction for ^{60}Co, with its half-life of 5.27 y, is on the order of a factor of 1,000 for some recent measurements. It is a smaller but nonetheless substantial correction for ^{152}Eu, half-life = 13.54 y (Iimoto 2001), decay factor in recent years ~15, and ^{63}Ni, half-life = 100.1 y, decay factor ~1.5 for current measurements, but is irrelevant for ^{36}Cl, which has a half-life of 301,000 years (^{63}Ni and ^{36}Cl as cited in the Table of Nuclides at http://nucleardata.nuclear.lu.se/nucleardata/toi/; reference Chu et al. 1999).

A field is provided for *Decay Correction*, which should be subject to easy checking via the half-life, the *Date Measured*, and the decay equation.

In addition to radioactive decay of the activity produced by the bomb neutrons, the *Date Measured* for neutron activation samples of shorter lived radionuclides may have a relationship to the sample's saturation level of background concentrations of the activation product produced by cosmic-ray neutrons as discussed below, or may be related to other temporal variables of interest. The *Date Measured* is similarly germane to calculating the accumulated background dose received by samples being measured for gamma dose by TLD, again as discussed below.

Obtaining information on date(s) of measurement is very difficult, for the reasons discussed above. These data are almost never published, and individual reported values often reflect multiple measurements of many days duration beginning on various dates. Hence this information has generally not been available, except for the cases noted above. Usually, an approximation within a year or two can be made based on the date of reporting of the measurements and on other information about roughly when the measurements were made.

Activation Product Isotope and Measurement Method

The field for *Isotope* designates the activation product nuclide being measured, in the case of neutron activation. In the case of TLD, a simple designation of "quartz" is used throughout, in lieu of an isotope designation.

A field is provided for *Measurement Method*, which is intended to be sufficiently detailed to allow useful distinctions among sub-classifications. For instance, denotations for radiometric measurement of neutron activation could distinguish among various photon energies and detector types. Denotations for AMS measurement of neutron activation could distinguish among different beam energies, levels of ionization or "stripping," and types of bending magnet/detector arrangements. Denotations for TLD would distinguish variants of the high-temperature/quartz inclusion method from the pre-dose method, and so on. Such sub-classifications have many distinctive attributes that may be of analytical interest, such as their detection efficiencies, their assumptions and computational methods, and their susceptibility to various artifacts and sources of spurious signal.

Unequivocal information on measurement method is usually available. One exception of some moment is that a rather large proportion of reported ^{152}Eu measurements prior to the current dose reassessment effort lack clear information about which of the spectral region(s) of interest are those on which a given particular result is based.

Background Measurements and Corrections

Several fields relate to "background," a concept that is much more complicated than the concept of defining a background for a radiation counting system as being the count rate in the absence of a sample (i.e., the count rate with an empty sample chamber). For any given measurement method, there may be different types and methods of background measurements that have different implications with respect to accounting for the portion of a sample's signal that may be attributable to sources other than the bomb fluence of gamma rays or neutrons, as applicable. The field for *Background Method* is intended to offer useful distinctions in this regard when they are known. The fields for *Background Level* and *Background Correction* are intended to quantify, respectively, the background measurement and the correction that is actually applied to bomb fluence measurements. These two quantities are often but not always identical. For example, some ^{36}Cl measurements have been reported as gross values rather than net, with respect to the background level of ^{36}Cl due to cosmic-ray production, although a value measured in other materials and thought to be applicable to the samples is known. In that case, the *Background Level* is the cosmic-ray production measured in other materials, but the *Background Correction* is not applicable.

For gamma TLD measurements, background is well documented in almost all cases except for some measurements close to the hypocenter made in the 1960s. This subject is addressed at more length in the Chapter 7, Part A on TLD measurements. Background is reasonably well described in the ^{32}P work and most of the ^{60}Co work. In the newer ^{60}Co work and the ^{152}Eu work, background is typically estimated for each measurement individually by using a spectral technique, and the corresponding estimates have typically not been published. In AMS measurements of ^{36}Cl and ^{63}Ni, background as regards cosmic-ray production has received much attention and is well documented, although other adjustments to the measured signal are usually not discussed. Counting interval-specific background values in gamma spectroscopy and adjustments to AMS results other than those for cosmic-ray production are subject to the same considerations regarding raw data that are discussed above.

Calibration Standards

Fields are provided to identify the *Calibration Standards* that were used to calibrate the measurement of *Stable Target* element and neutron *Activation Product*, respectively, for measurements of neutron activation. These identifications may be useful in analyzing covariation among measurements. The intent of these fields is not to exhaustively document standards with regard to metrological traceability and so on, but to identify sets of measurements that share a common calibration source and may therefore be correlated with respect to the corresponding error.

In the case of TLD, it is really the calibration of the gamma source or accelerator that was used for the test irradiation, in addition to the batching of samples for test irradiation, that is of interest in this regard, and *could* be given a unique identifying designation under the *Cal. Std. for Activation Product* field. In the case of AMS, the nature of the method requires that various calibrations with blanks and spiked samples be performed concomitantly with every accelerator run.

Unfortunately, calibration data are still not available in most cases, as with other detailed raw data that are discussed above. Although the standards available from commercial suppliers, government agencies, or other reputable organizations are typically quoted to a very good accuracy on the order of 1 to 2%, this alone is not an assurance of obtaining a similar accuracy in practice, and some measurements rely on calibration sources that do not meet such standards. Various sources of concern about the accuracy of calibrations exist, particularly in regard to the calibration of stable isotope content in neutron activation samples (Kerr et al. 1990; National Research Council 2001). Calibration issues among others were addressed for TLD measurements in the DS86 Report (Maruyama et al. 1987) by a thorough intercomparison program, and intercomparisons have been performed for some thermal neutron activation measurements as part of the current dosimetry reassessment and are documented elsewhere in this report. However, the relevant data are still not available in the RERF measurements database for a large portion of existing measurements.

Measured Values

The *Target Element Content* in units of weight concentration (e.g., %, ppm, etc.) of the sample after chemical enrichment, multiplied by the sample's weight as counted, defines the total amount of stable target element (e.g., Co, Eu) present in the final enriched sample as counted. Investigators have often reported an uncertainty of the assay of stable element content. The field for the *Uncertainty* of the assay of stable element content is used to enter the "plus or minus" quantity typically reported by investigators, as it is for the *Uncertainty* fields that are provided for other measured quantities in this section. We have assumed that these values were based on a "one sigma" estimate of error standard deviation unless known to be otherwise, in which case a note is added in the *Notes* field of the Sub-sample screen.

- In radiometric methods of measuring neutron activation, the elemental composition assay is a separate measurement from the radiation counting. It is equally as important as the radiation counting measurement in establishing the sample's "specific activity," which in this application is defined as radioactivity of the activation product per unit mass of the stable target element. In addition, it is important for the reasons discussed with regard to limits of detection and verification of the proportionality of activation and target element content in replicate measurements on the same sample.
- In AMS measurements of ^{36}Cl, the determination of stable Cl and the calculation of the corresponding atomic ratio are intrinsic to the measurement process, being defined by the accelerator detection assembly's cup current of ^{35}Cl.
- For ^{32}P and ^{63}Ni measurements the situation is somewhat different, as the amount of stable target element present is determined by the size of a large amount of stable target element comprising the entire sample, which is considered to be virtually pure S or Cu in most cases and is assayed simply by weighing.

For measurements other than ^{36}Cl, the target element content of the sample is given in the publication reporting the measurement in the majority of cases, usually with an estimated uncertainty. At present the database does not contain any information regarding the measurer's method of making this uncertainty estimate.

A field for *Activation Product Nuclide Content* is provided for cases in which the radioactivity measurement is reported separately from the specific activity, or is reported as activation per unit mass of the bulk sample instead of activation per unit mass of the target element.

Spec. Act. (P/T) designates the field for reporting the measured *Specific Activity* (*Product* nuclide/*Target* nuclide(s)) of a sample in units of radioactivity per unit mass (e.g., Bq/mg), count rate per unit mass (e.g., cpm/mg; technically, this is really a "*specific count rate*") or ratios of atoms (e.g., ^{36}Cl/Cl) or atoms per unit weight (e.g., ^{63}Ni atoms per g Cu). The same field may be used to enter a *TL Dose* to the sample in units of exposure in air or dose to any one of several media (e.g., air, tissue, quartz).

As specific activity or dose is the *sine qua non* of the measurement, it is always provided. An estimated uncertainty is almost always provided, but this estimate is often based solely on a treatment of the radioactivity counting data using the assumptions of Poisson statistics, and thus does not incorporate the uncertainty of other possible sources of error, particularly the assay of stable element content. At present the database does not contain any information regarding the measurer's method of making this uncertainty estimate. More specific and detailed information about uncertainty estimates is given in other parts of this report, in the specific section for each type of measurement.

A parallel set of fields is provided to enter an *Evaluated Specific Activity* or *TL Dose*. This section is for entering results from an extramural *post hoc* evaluation process such as the laboratory intercomparison that was performed for TLD doses in DS86, which resulted in "adjusted" values published in Table 1 of Chapter 4 of that Report (Maruyama et al. 1987). It is anticipated that this field will be useful for recording the results of evaluations performed by the U.S. and Japanese Working Groups in connection with the current dosimetry reassessment.

Calculated Values

Information on the "DS86 calculated value" for a measurement, or other calculated values, such as a "Rev93" calculated value or a value for the new dosimetry system about to be realized, has also been in need of better documentation and standardization. "Rev93" is used here as a designation for values calculated by using DS86 methods and code with updated cross-section sets and other refinements as reported in Kaul (1993). Although the DS86 system as implemented at RERF allows for calculation of the free-in-air gamma dose, it does not allow calculation of neutron activation. However, calculated values obtained by convolving DS86 neutron fluences with activation cross sections were published for ^{60}Co in the DS86 Final Report (Loewe et al. 1987) and other calculated values have been supplied to investigators by Science Applications International Corporation in a number of cases since DS86. Recently, new, sample-specific calculated values for neutron activation have been defined as part of the work of the Japanese and U.S. Working Groups currently performing the dosimetry reassessment. Correspondingly, we have created sections for the entry of as many as four versions of the calculated value for a measurement: two sections for calculated values based on DS86 or "Rev93" that may be available from the original source document in which a measurement was published or from some other source, and two sections for values provided by the Working Groups in the course of the dosimetry reassessment, for free-in-air and shielded calculations, respectively.

The first field for entering a *calculated* as opposed to measured value of Specific Activity or Dose is entitled "*DS86 Calculation*" and is intended to document the value provided in the original reference in which the measurement was reported. Hence the reference for this field is the *Original Reference* given at the bottom of the Measurements screen. This small section, as the others below it, has a field to identify the *Type* of calculation that was done. In addition to a free-in-air value, there are basically two types of calculated values that have been produced, which are successively more sample-specific and should therefore be correspondingly more accurate: (a) a simple shielding type of calculation corrects the measured value for the attenuation (or buildup) provided by any overlying material, even if only a thin layer, and the sample material itself, and (b) a Monte Carlo type of calculation considers the entire sample environment and typically involves a model of the structure in which the sample was constituent *in situ*. A second set of fields denoted "*DS86 Calc: (other)*" allows entry of a "*Rev93 Calc*."

Finally, two sets of fields are provided for evaluated "*DS02 Calc.*," both free-in-air and shielded, that would reflect the work of the current dosimetry reassessment. Each of the last three sets of fields has a provision for a reference different from the primary reference, consisting of the document in which the measurement was originally reported.

Summary of Database Content

Data Collection Efforts

The database began at RERF in 1996 when initial efforts were made to assemble a complete set of reference materials, create the first version of the database structure, and enter the information. The pace of this work accelerated in 1998 when RERF began to collaborate in an organized effort undertaken by the Committee on Dosimetry for the Radiation Effects Research Foundation administered by the Board on Radiation Effects Research, National Research Council (National Research Council 2001). Data collected through a committee questionnaire, laboratory visits and interviews, and further correspondence were entered into the database. RERF has continued to update and refine the database in collaboration with the dosimetry reassessment effort of the Japan and U.S. Working Groups, culminating in the creation of this report.

Summary Statistics

A summary of the numbers of samples and measurements of various types is given in Table 1 for measured samples. The locations of samples are shown in Figures 7 through 11, using the U.S. Army maps for purposes of illustration and also without a map, to allow better visualization of the spatial relationships among the sample locations. It will be noted that the sample locations reflect to a great extent the locations of structures sufficiently massive to have withstood the bombing and subsequent fires, not to mention the extensive reconstruction that took place in the years between the war and the collection of samples, particularly in the northern and western parts of Hiroshima and the factory areas of Nagasaki. In some cases the sample locations are even more limited by the locations of specific types of structures containing the sample element of interest; this is particularly true in the cases of iron and copper samples.

Acknowledgements

The authors are grateful to the measurers who kindly provided information beyond that in their published documents, in support of the dosimetry reassessment. Two of our numbers, Wayne Lowder and Shoichiro Fujita, died during the final preparation of this report, and we mourn their passing.

Table 1. Sample types, numbers and measurements

Radiation	Target	Sample type	Sites[a]	Samples[a]	Measurements[a]
Hiroshima					
gamma	quartz	brick	1	1	1
gamma	quartz	tile	29	58	140
Gamma TLD Total			**30**	**59**	**141**
fast neutron	sulfur	electrical insulator	16	16	17
fast neutron	copper	wire	3	3	3
fast neutron	copper	rain gutter	3	3	3
fast neutron	copper	other	0	0	0
Copper Total			**6**	**6**	**6**
thermal neutron	chlorine	concrete core	15	17	33
thermal neutron	chlorine	granite core	1	2	13
thermal neutron	chlorine	granite (surface)	24	28	94
Chlorine Total			**40**	**47**	**140**
thermal neutron	cobalt	iron ring	7	8	10
thermal neutron	cobalt	concrete reinforcement rod, embedded	5	5	6
thermal neutron	cobalt	bridge/structural plate	5	12	58
thermal neutron	cobalt	ladder rails or hand rails	7	7	17
thermal neutron	cobalt	pipe	3	3	4
thermal neutron	cobalt	rock/concrete/tile	8	8	9
Cobalt Total			**35**	**43**	**104**
thermal neutron	europium	concrete core	3	3	32
thermal neutron	europium	concrete (surface)	16	16	30
thermal neutron	europium	granite core	3	3	38
thermal neutron	europium	granite (surface)	38	46	91
thermal neutron	europium	tile	20	21	53
thermal neutron	europium	other	2	2	7
Europium Total			**82**	**91**	**267**
Nagasaki					
Gamma	quartz	brick	8	10	45
Gamma	quartz	tile	17	19	25
Gamma TLD Total			**25**	**29**	**70**
fast neutron	sulfur	electrical insulator	0	0	0
fast neutron	copper	wire	0	0	0
fast neutron	copper	rain gutter	0	0	0
fast neutron	copper		0	0	0
Copper Total			**0**	**0**	**0**
thermal neutron	chlorine	concrete core	4	4	19
thermal neutron	chlorine	granite core	0	0	0
thermal neutron	chlorine	granite (surface)	0	0	0
Chlorine Total			**4**	**4**	**19**
thermal neutron	cobalt	iron ring	0	0	0
thermal neutron	cobalt	concrete reinforcement rod, embedded	6	6	7
thermal neutron	cobalt	bridge plate	0	0	0
thermal neutron	cobalt	ladder rails or hand rails	2	2	2
thermal neutron	cobalt	pipe	0	0	0
thermal neutron	cobalt	rock/concrete/tile	16	16	23
Cobalt Total			**24**	**24**	**32**
thermal neutron	europium	concrete core	0	0	0
thermal neutron	europium	concrete (surface)	1	1	1
thermal neutron	europium	granite core	0	0	0
thermal neutron	europium	granite (surface)	50	61	75
thermal neutron	europium	tile	8	8	14
thermal neutron	europium	brick	2	2	3
Europium Total			**61**	**72**	**90**

[a]A *site* is defined here as a building or other general location, even though there may be multiple samples within such a location, and the shielding geometry and other attributes may differ among samples at the same "site." A *sample* is defined here as a specific material from a given exact location (i.e., same ground distance within ±1 m and same height above ground) within a site. A *measurement* is defined here as a separate result reported by the investigator, even though some investigators combine multiple measurements of the same sample into one reported result and others do not.

Figure 7. *Hiroshima TLD measurement locations in the RERF database (green squares) and hypocenter (+).*

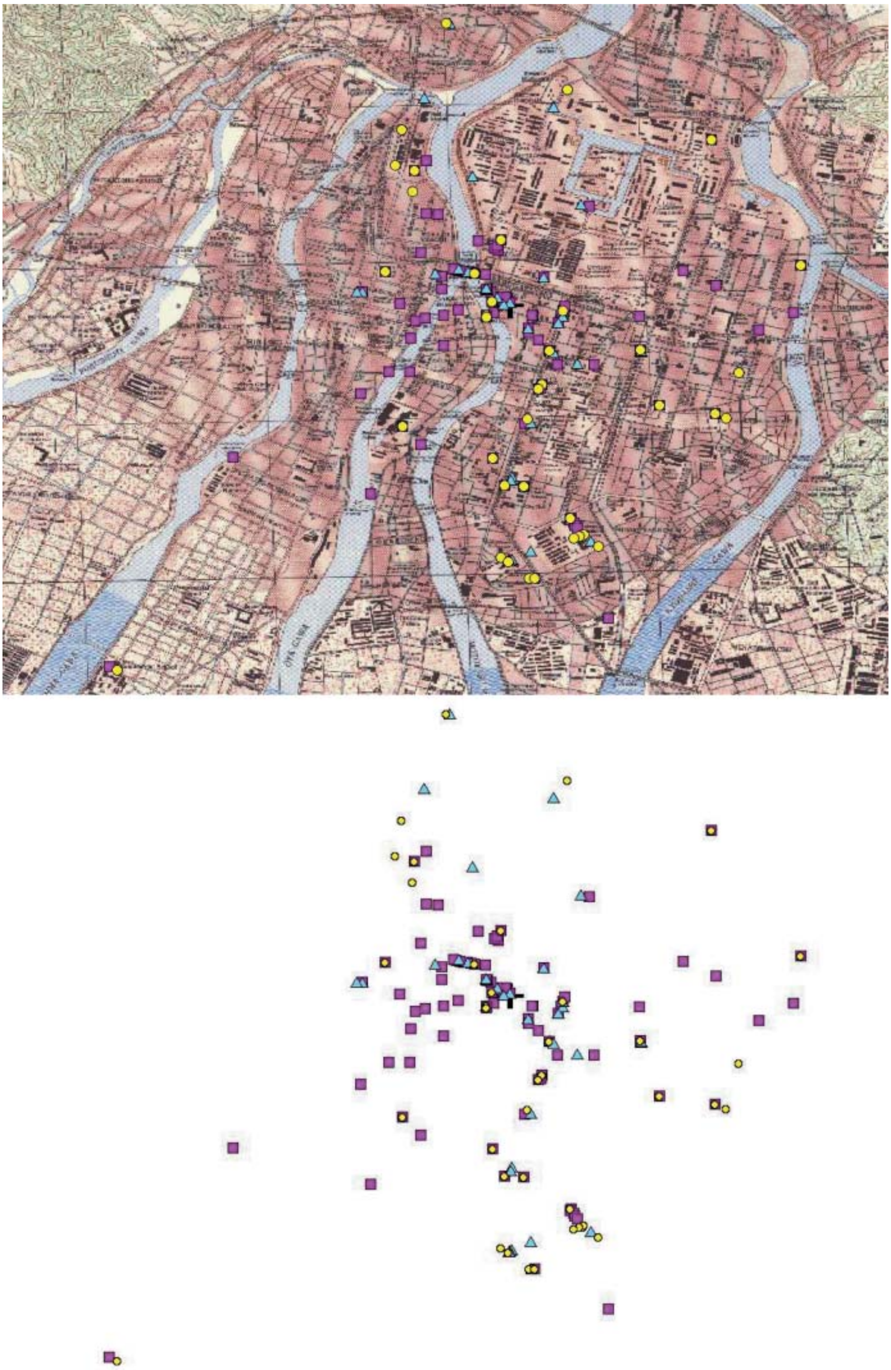

Figure 8. *Hiroshima thermal neutron measurement locations in RERF database (^{36}Cl = yellow circles, ^{60}Co = blue triangles, ^{152}Eu = purple squares) and hypocenter (+).*

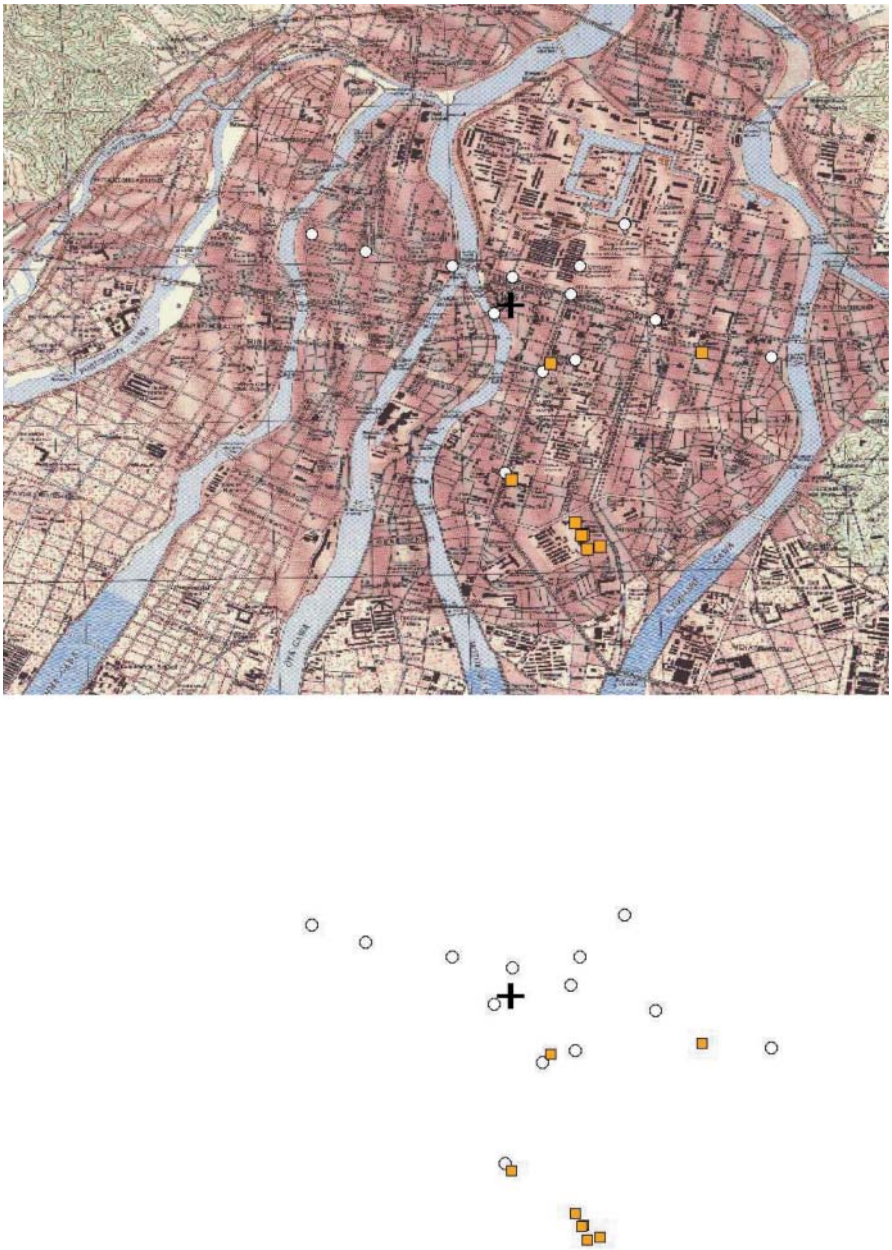

Figure 9. *Hiroshima fast neutron measurement locations in RERF database (^{32}P = white circles, ^{63}Ni = orange squares) and hypocenter (+).*

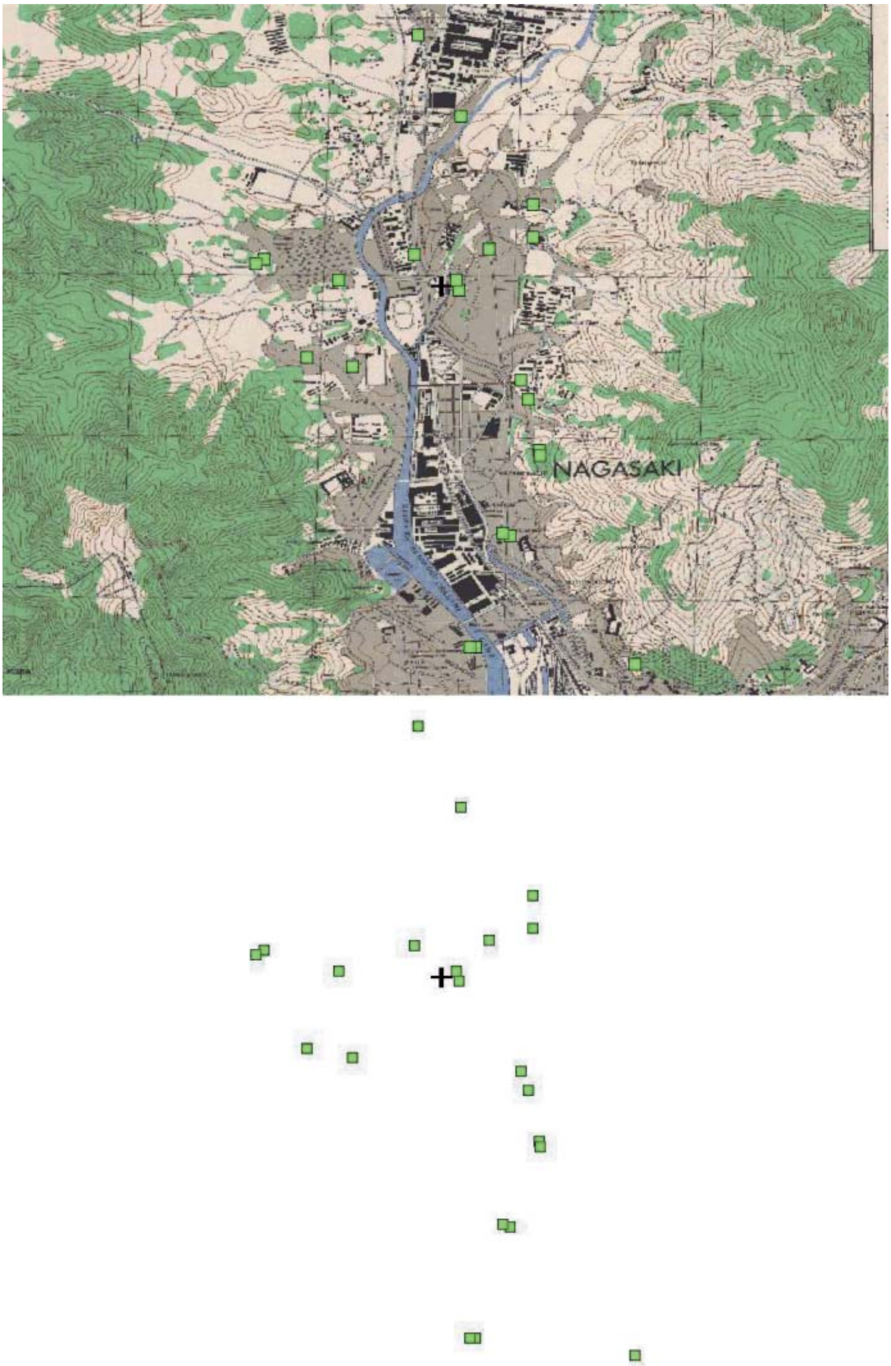

Figure 10. *Nagasaki TLD measurement locations in the RERF database (green squares) and hypocenter (+).*

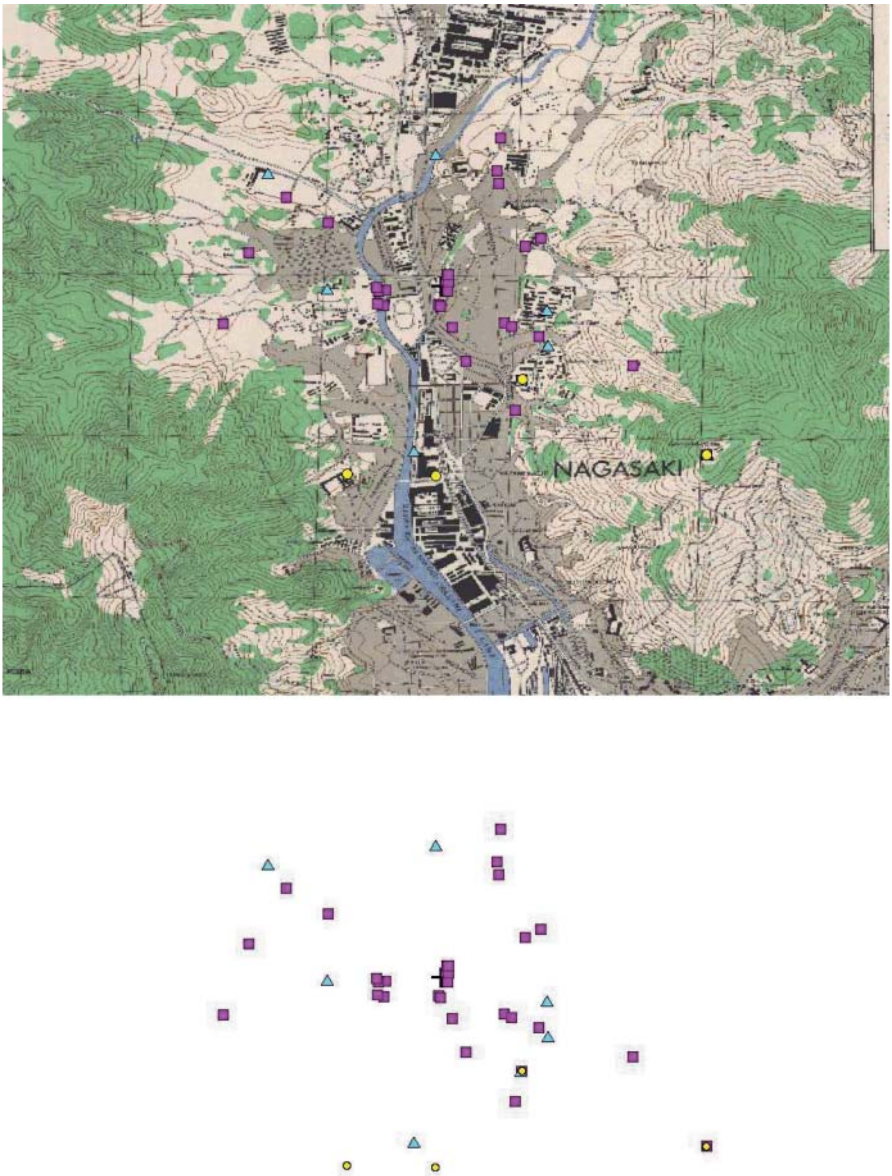

Figure 11. *Nagasaki thermal neutron measurement locations in RERF database (^{36}Cl = yellow circles, ^{60}Co = blue triangles, ^{152}Eu = purple squares) and hypocenter (+).*

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Appendix A

Data Entry Criteria and Explanations for the RERF Dosimetry Measurements Database

Sample Information applies to the physical object originally collected, such as a brick, tile, piece of iron or steel, a core drilled from rock or concrete, etc.

Collector is the name of the person or organization responsible for the collection of the sample.

City is Hiroshima or Nagasaki

Site Name is the name identifying the site of collection and should be as specific as possible. The name of a building, bridge, or other structure should be used when applicable, or the owner's name if a private residence. Less physically distinct locations should be identified by a short description that gives information about the location, such as, e.g., "Honmachi river wall."

Sample ID is the alphanumeric designation used to refer to the sample in published reports of measurements on the sample or in similar documents.

Collection Date is the date when the sample was removed from its *in situ* location that it occupied at the time of the bombing.

Structure Age is the age of the structure in which the sample resided at the time of sample collection.

Manufactured is the year of manufacture for materials not original to the structure.

Material is a short description of the sample that indicates the material of which it is made and its relationship to the structure from which it was taken, such as, e.g., "roof tile."

Shield Geometry is a short physical description of the sample's shielding situation in its location at the time of the bombing.

Location Information

Site (cho) is the cho, chome, machi, or other lowest-level city administrative subdivision in which the site was located.

Site (banchi) is the city block number in which the site was located.

Height Above Sea Level is the elevation above sea level of the ground at the sample site.

Ground Distance is the distance to the hypocenter that is given in the document(s) in which measurements on the sample were reported.

Distance Uncertainty is the " ± " value for distance to the hypocenter that is given in the document(s) in which measurements on the sample were reported.

Slant Distance is the distance to the epicenter that is given in the document(s) in which measurements on the sample were reported.

Height Above Ground is the height above ground level of the sample's location at the time of the bombing.

Map Information is to be used to document the map coordinates, if any, given in the document(s) in which measurements on the sample were reported.

Map Information (other) is to be used to document map coordinates for another map or from a different source of information than that documented in "Map Information."

Map Information (evaluated) is to be used to document map coordinates that were evaluated at RERF using the Geographical Information System in combination with maps, aerial photographs, and all available sources of information.

Sub-Sample Information applies to a physical subdivision of the sample that was used for measurements. The most important distinguishing feature of a "sub-sample" for the purposes of this section is that multiple measurements made on the same sub-sample are made on truly identical material, with respect to both composition and position. Thus, although a sub-sample might be partitioned even further for individual measurements, those aliquots will be of presumably uniform composition, will be at the same depth below the exposed surface of the sample, etc.

Sub-Sample ID is the alphanumeric designation used to refer to the sub-sample in published reports of measurements on the sample or in similar documents.

Sample Axis Definition defines an axis of the sample that may be used for the purpose of specifying an angle of incidence relative to the line of sight to the epicenter. The axis is typically taken as being perpendicular to the exposed surface of the sample.

Orientation of Sample is the angle of incidence of primary radiations traveling straight from the epicenter to the sample, which is defined here as the angle between the axis defined for the sample and the line of sight to the epicenter.

Width is the width of the sample in a direction that is typically perpendicular to the axis specified for the sample.

Thickness is the dimension of the sample in a direction that is typically parallel to its axis.

Weight is the weight of the sub-sample *before* any physical and chemical processing. Note that a separate space for data entry is given in the measurements screen for "weight as measured" that applies to an aliquot *after* all of the physical and chemical processing that produces the material that is actually measured.

Length is the length of the sample in a direction that is perpendicular to width and typically perpendicular to the axis specified for the sample.

Depth below exposed surface is in a direction perpendicular to the exposed surface of the material, from the surface to the nearest boundary of the material that was actually measured.

Measurements designates all of the measurements that have been reported for the particular sub-sample.

Notes is a space for entering any information relevant to the sub-sample or the sample whence it was taken that cannot be entered in the other, specific fields of the data entry screens.

Measurements

Sample repeats the same designation used in **Sample ID** of the **Sample Information** screen.

Sub-Sample repeats the same designation used in Sub-**Sample ID** of the **Sample Information** screen.

Measurer is the investigator responsible for the measurement, typically the first author of the publication in which the measurement was reported.

Measurement ID will typically be a sequential number assigned by the person performing data entry, although the designation may be given by the Date Measured

Wt. as Counted (post proc.) is intended to record the weight of the sample as measured, after all chemical and physical processing that enriches the sample in the particular material of interest.

Enriched is a designation to distinguish chemically enriched samples from those that were measured intact.

Isotope is the activation product radioisotope that is measured. In the case of thermoluminescence measurements, an entry of "quartz" is used in this field for all samples.

Measurement Method is a short description of the method that contains sufficient information to distinguish important attributes. For radiation counting this should include the type of detector and a designation of the sample-detector geometry. For accelerator mass spectroscopy it should include the type of ionization and type of detector if known.

Decay Correction is the correction applied by the measurer to convert results from the time of measurement to the time of the bombing (initial activity). It applies only to measurements of neutron activation products.

Background Level is the background counting result as reported by the measurer, if available.

Cal. Std. for Stable Target is a designation for the calibration standard used to calibrate the measurement of the sample's content of the stable target element, and therefore only applies to neutron activation measurements.

Cal. Std. for Active Product is a designation for the calibration standard used to calibrate the counting system for the actual isotope being detected. In the case of thermoluminescence measurements, this field may be used to designate the radiation source that was used for the test irradiations.

Background Correction is the amount actually subtracted from the gross measurement by the investigator, if any.

Background Method is a brief description of the method used to estimate the background for the sample. For example, in the case of gamma spectroscopy, this entry should distinguish spectral methods from methods using prepared blank samples.

Target Element Content, in the case of radiation counting of neutron activation products, is the concentration of the sample, as counted (after chemical and physical enrichment, if applicable) in the element that is the target nucleus for the neutron activation reaction of interest. In the case of accelerator mass spectroscopy of neutron activation products, this quantity is usually determined as a cup current or similar quantity that is proportional to the actual target element content, and is usually not given separately by the measurer. In the case of thermoluminescence measurements this quantity is not applicable.

Activation Prod. Nuclide Content, in the case of radiation counting of neutron activation products, is the concentration of the sample, as counted (after chemical and physical enrichment, if applicable) in the radioisotope that is the product nucleus for the neutron activation reaction of interest. The divisor is the sample's gross weight. This quantity is often not given separately by measurers. In the case of accelerator mass spectroscopy of neutron activation products, this quantity is a simple count and is usually not given separately by the measurer. In the case of thermoluminescence measurements this quantity is not applicable.

Spec. Act. (P/T) or TL Dose is the measurer's reported value for either the specific activity of the sample in units of radioactivity or count rate per unit mass of the stable target element (neutron activation), ratios of atoms (neutron activation), or the dose or radiation exposure (gamma thermoluminescence), where exposure would be reported by the measurer in units of Roentgens or other units of charge per unit mass. In the case of dose, the medium to which the dose is specified (i.e., air, tissue, or quartz) should be given as part of the **Units.**

Eval. Spec. Act. or Dose is the DS02 evaluated free-field equivalent of either the specific activity of the sample in units of radioactivity per unit mass of the stable target element (neutron activation), ratios of atoms (neutron activation), or the dose (gamma thermoluminescence). This quantity is obtained by taking the measurer's reported values, converting them to the proper units if necessary, and dividing them by the effective transmission factor that was estimated for this particular measurement in DS02. This value is directly comparable to the free-in-air calculated values listed below.

Calculated Values are in the same units as "Eval. Spec. Act. or Dose."

DS86 Calculation is the calculated DS86 value for the sample that is given by the author in the publication in which the measurement was reported. Such a value is almost always given, although it is often only shown on a plot, and the values given are almost always free-in-air values that are not corrected for a transmission factor of any type.

Rev93 Calc. is a calculated value similar to the DS86 value that is given in some published reports of measurements, based on the revised calculations of 1993 and supplied by Science Applications International Corporation (SAIC).

DS02 Calc is the DS02 calculated free-in-air value at the sample's location.

DS02 Calc (Shielded) is the DS02 calculated free-in-air value at the sample's location, multiplied by the effective transmission factor that was estimated for this particular measurement in DS02. This value is directly comparable to the unadjusted measured value reported in "Spec. Act. (P/T) or TL Dose," assuming conversion of the latter to appropriate units.

Original Reference is the publication or other source document in which the measurement was reported.

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