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CIVIL EFFECTS STUDY

ICHIBAN: THE DOSIMETRY PROGRAM FOR NUCLEAR BOMB SURVIVORS OF HIROSHIMA AND NAGASAKI — A STATUS REPORT AS OF APRIL 1, 1964

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Issuance Date: July 31, 1964

CIVIL EFFECTS TEST OPERATIONS
U.S. ATOMIC ENERGY COMMISSION

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PRINTED IN USA
Price $0.50. Available from the Office of
Technical Services, Department of Commerce,
Washington D. C. 20230

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

ICHIBAN: THE DOSIMETRY PROGRAM FOR NUCLEAR BOMB SURVIVORS OF HIROSHIMA AND NAGASAKI - A STATUS REPORT AS OF APRIL 1, 1964

By

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April 1964

ABSTRACT

In 1956, the Health Physics Division of the Oak Ridge National Laboratory undertook the task of developing a method of evaluating the radiation doses received by the survivors of the nuclear bombings of Hiroshima and Nagasaki, Japan. Data for this project, sponsored by the Civil Effects Branch of the Division of Biology and Medicine and designated Ichiban, have been obtained in nuclear weapons tests, Operation BREN, laboratory experiments, physical surveys in Japan, and in calculational studies. The approach to the problem has been as fundamental as possible with emphasis on quantitative measurements and calculations of the energy, angular, and spatial distributions of weapons radiations in an air-over-ground geometry. Spatial distributions of dose in various shields, including Japanese dwellings, have been measured. Techniques have been developed in Japan for verifying the location of survivors and accurately describing their shielding environments. Simple empirical equations have been developed which permit the calculation of the shielding factors for Japanese residential-type structures with a probable error of approximately $\pm$ 6%.

ILLUSTRATIONS

ICHIBAN: THE DOSIMETRY PROGRAM FOR NUCLEAR BOMB SURVIVORS OF HIROSHIMA AND NAGASAKI: A STATUS REPORT AS OF APRIL 1, 1964

Soon after the nuclear bombings of Hiroshima and Nagasaki in August 1945, U. S. military medical teams entered the cities.[1] In 1947 a permanent medical survey-research organization, the Atomic Bomb Casualty Commission (ABCC), was established. Since that time, a comprehensive program has been directed to documenting and analyzing the effects of nuclear weapons radiation on the survivors of the bombings and their offspring.

During "Operation Teapot" at the Nevada Test Site (NTS) in 1955, the Health Physics Division of the Oak Ridge National Laboratory, in collaboration with the Los Alamos Scientific Laboratory, conducted a series of experiments which provided significantly increased understanding of weapons radiation fields. Gamma radiation dosimetry utilized tetrachloroethylene chemical dosimeters,[2] and the neutron flux and dose distributions were measured with threshold detectors.[3,4] The dose-distance relationship, D(R), for fast neutrons and gamma radiation was shown to be[5,6]

$$D(R) = \frac{G_o e^{(-R/L)}}{R^2}$$

for distances greater than about one relaxation length, where G_o is a function of the yield and design of the weapon and L is the relaxation length for the type radiation considered. For a particular detonation

$$L = \frac{\rho_o}{\rho} L_o$$

where ρ is the air density and ρ_o and L_o are the values for these factors at an air density of 1.29 g/liter. Gamma radiation exposure and neutron flux and dose as a function of distance are shown for a typical detonation in Figs. 1 and 2, respectively. It was also shown, for distances greater than $L \sim 1$, that the neutron spectrum was, to a close approximation, constant; i.e., an equilibrium spectrum was obtained, Fig. 2. These data have been discussed in detail by Ritchie and Hurst.[7]

The data from Operation Teapot indicated the possibility of a definitive description of the radiation fields from the Hiroshima and Nagasaki bombs. Consequently, early in 1956, a survey team, including members from the Los Alamos Scientific Laboratory, the Medical College of Virginia, the Atomic Energy Commission (Division of Biology and Medicine), and the Oak Ridge National Laboratory, visited the ABCC in Hiroshima and Nagasaki with the objective of determining the feasibility of a dosimetry study. After reviewing records and examining typical shielding configurations, the survey group recommended that a dosimetry program be initiated. Emphasis was to be placed on persons exposed in Japanese dwelling-type buildings due to the high structural uniformity and the large fraction of survivors exposed in such buildings.

As a result of the recommendations of the survey group, a program was established in the Health Physics Division of the Oak Ridge National Laboratory (ORNL). The program is sponsored by the Civil Effects Branch of the Division of Biology and Medicine, U.S.A.E.C., and is designated as Ichiban.

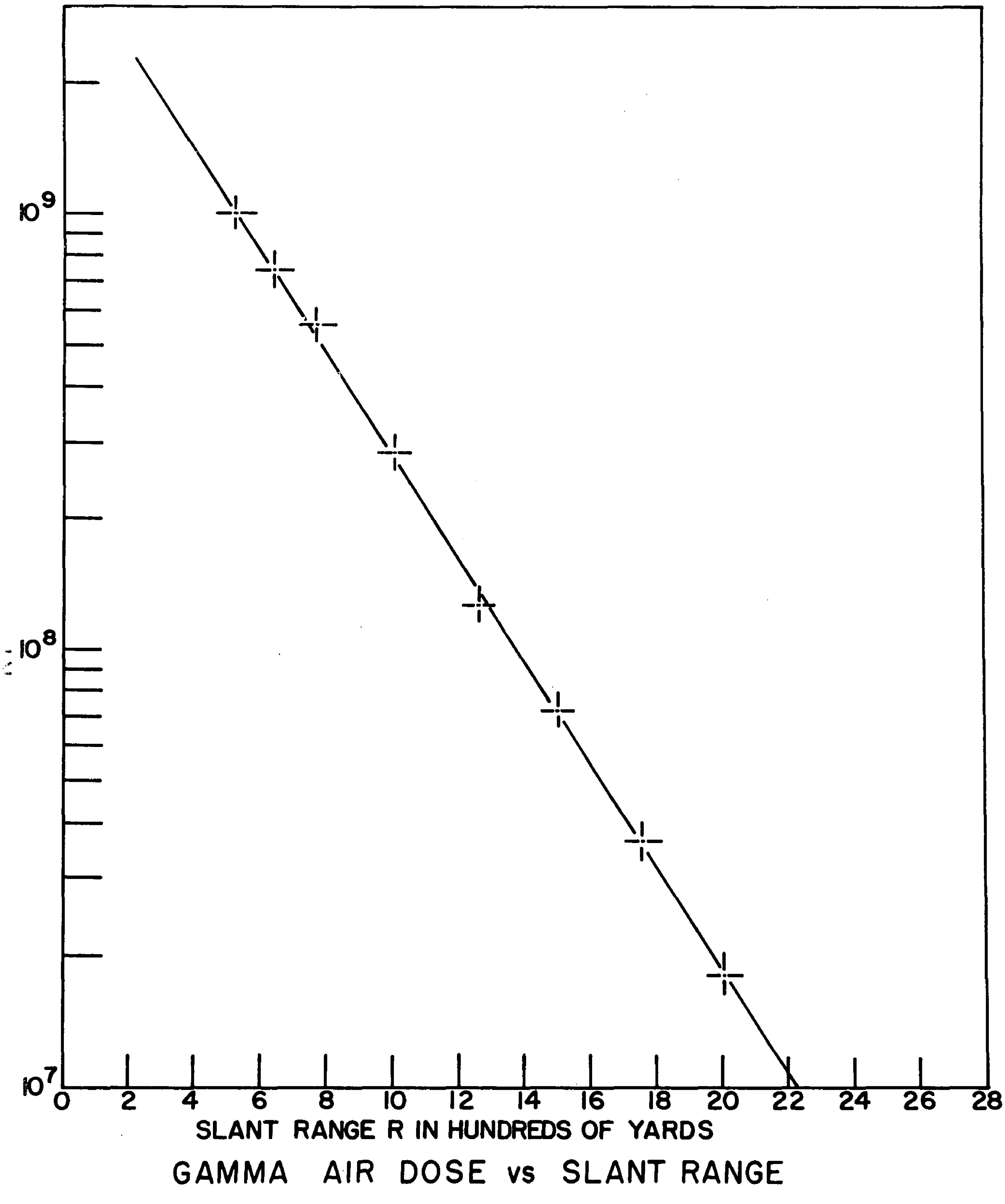
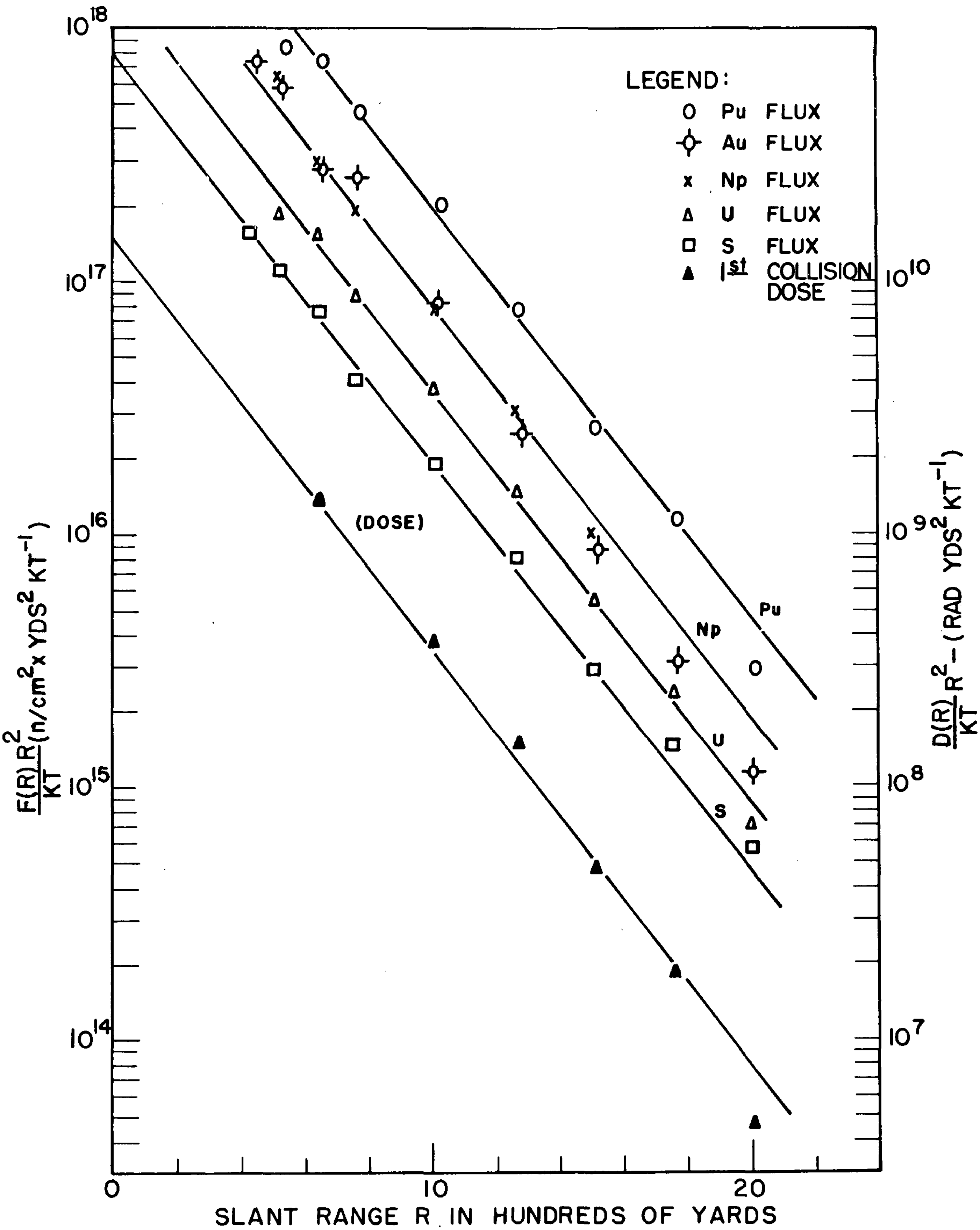


Fig. 1 - Gamma Air Dose as a Function of Slant Range for a Typical Nuclear Detonation



NEUTRON AIR DOSE & FLUX vs SLANT RANGE

Fig. 2 - Neutron Air Dose and Flux as a Function of Slant Range for a Typical Nuclear Detonation

The overall problem was divided into three parts: 1) the documentation of the location of the survivor at the instant the bomb exploded; 2) the establishment of the air-dose curves; 3) the shielding factors for the houses. By working with the ABCC, the solution of the first part of the problem reduced to a matter of time and required little research. The second part was further subdivided into two parts, the determination of the shape of the curves during weapons tests, and normalization of these curves to the radiation yield of the subject weapons. From the beginning of this investigation the problem of normalization was expected to be the most difficult.

A pilot study of neutron and gamma radiation dose distributions in Japanese houses was conducted during Operation Plumbbob at NTS in 1957. A larger and more fundamental study of the dose distributions in air was carried out also for several weapons during this operation.[8] Two replicas of a typical Japanese residence were constructed at NTS, Fig. 3. The only variations from the detailed specifications were omissions of thin glass and paper doors and windows; materials were imported from Japan. In addition, 120 "collimation" devices were constructed to permit measurement of the angular distribution of the radiation field incident on a point detector in an open field, Fig. 4. Seventy collimators were for gamma radiation measurements and fifty for neutron measurements.

Data from Plumbbob indicated that the radiation dose distribution in Japanese houses might be related, in general, to a few identifiable parameters such as house size, orientation, mutual shielding, proximity

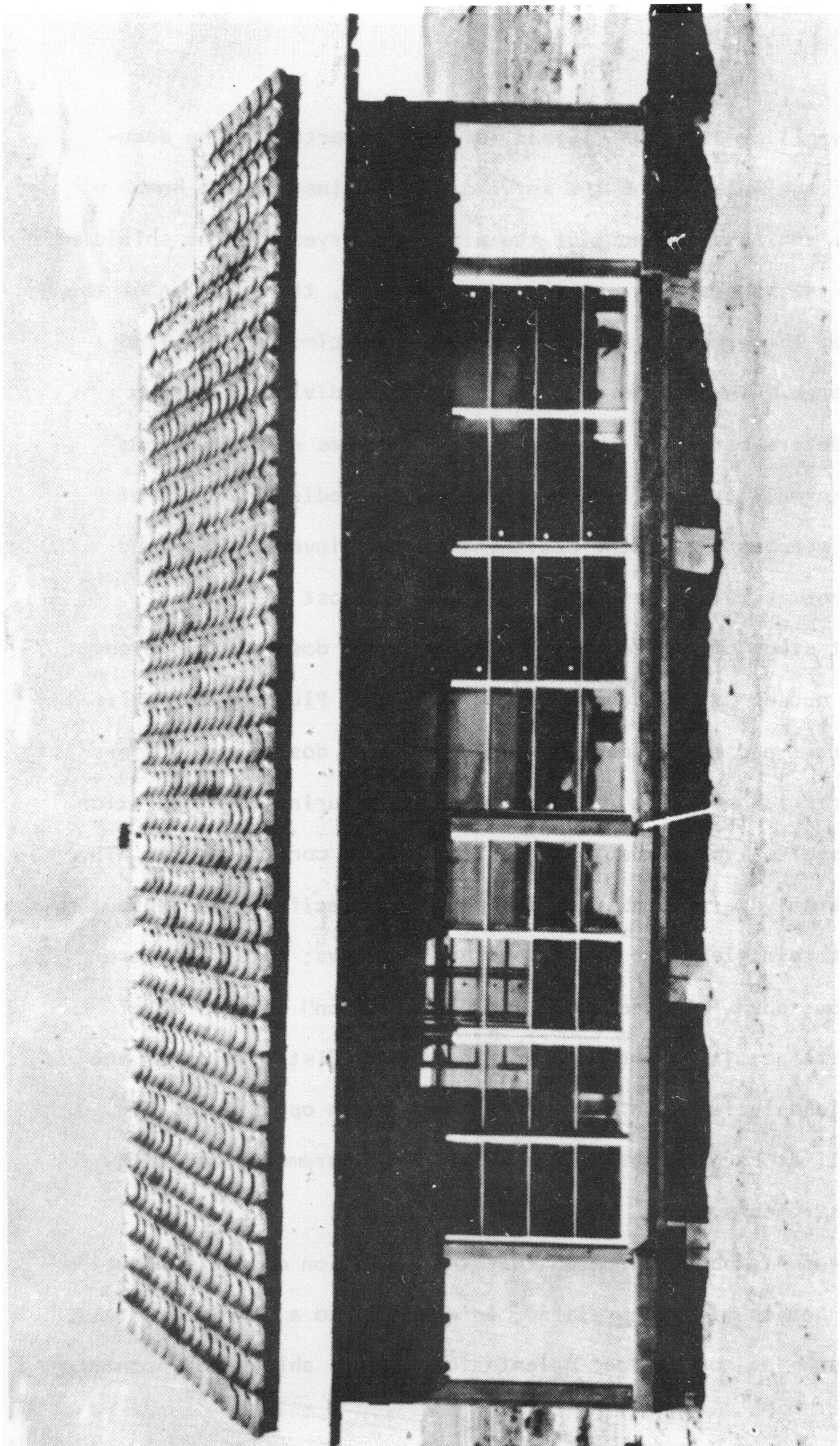
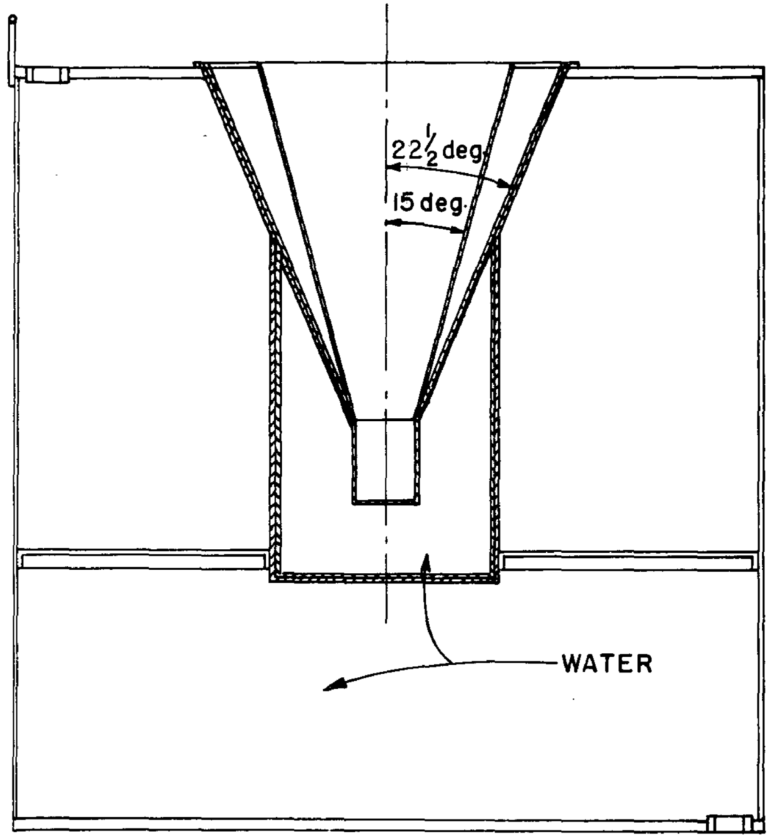
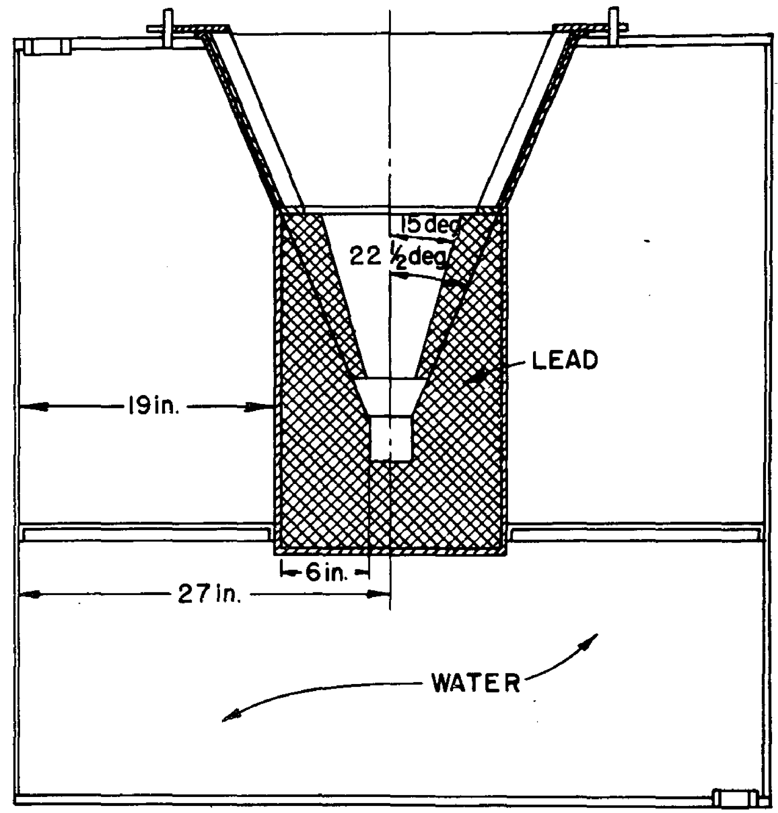


Fig. 3 - One of Two Japanese Houses Used During Dosimetry Studies During Operation Plumbbob



NEUTRON COLLIMATOR

Fig. 4A



GAMMA COLLIMATOR

Fig. 4B

Fig. 4 - Collimator Devices Used for Measuring the Angular Distribution of Radiation from Nuclear Weapons

of walls and windows, etc. The basic program extended the air-dose data and provided a description of the angular distribution of radiation, Figs. 5 and 6, especially for fast neutrons. The greatest uncertainties in the air-dose distribution involved the gamma radiation.

Upon completion of the analysis of data from Plumbbob, a summary of all dosimetry information applicable to the survivors was prepared and transmitted to the shielding group in ABCC. Designated T57D, this tentative dosimetry information served as a guide to establishment of techniques for determining dose values from the shielding "histories" of the exposed individuals; it also provided an estimate of dose which supplanted the use of distance as the correlative factor for observed responses. The "air-dose" curves, Figs. 7 and 8, were provided by York,[9] based on all weapons data available to him. The large uncertainties (probable error) in the curves are indicated by the dotted lines.

After Operation Plumbbob, laboratory studies of the shielding coefficients of Japanese and domestic building materials were conducted. Cement-asbestos board, commercially available in large sheets, was found to be suitable as a substitute for the mixture of clay, oyster shells, and sea-weed wall plaster and for the mud and tile roofs of Japanese houses for both neutrons and gamma rays. The wood framing used in Japan fitted well with the substitution of cement-asbestos board. Consequently, it was planned to use radiation analogs of Japanese houses for any further field experiments.

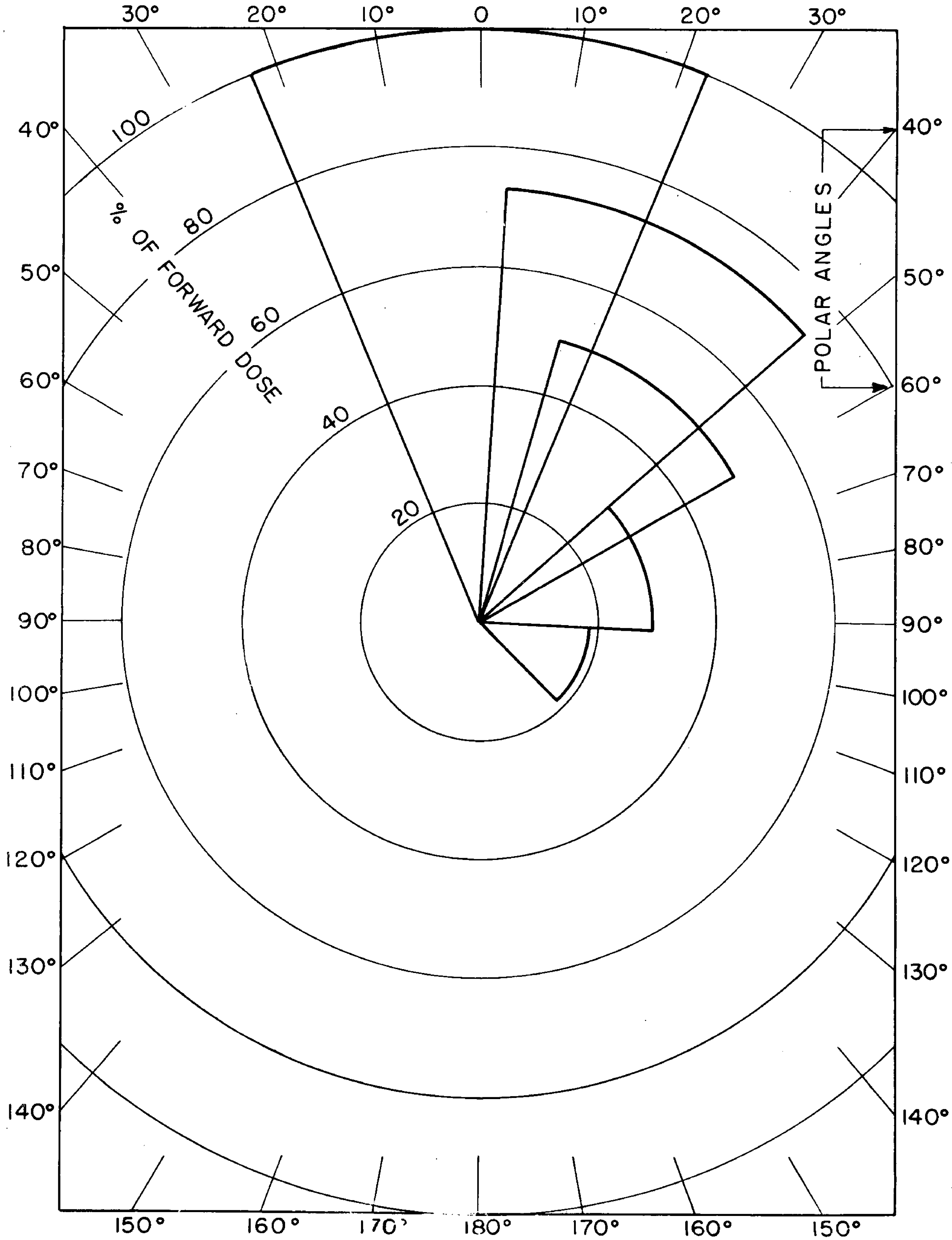


Fig. 5 - Angular Distribution of Neutron Dose at 1000 Yards from a Typical Nuclear Weapon of Nominal Size

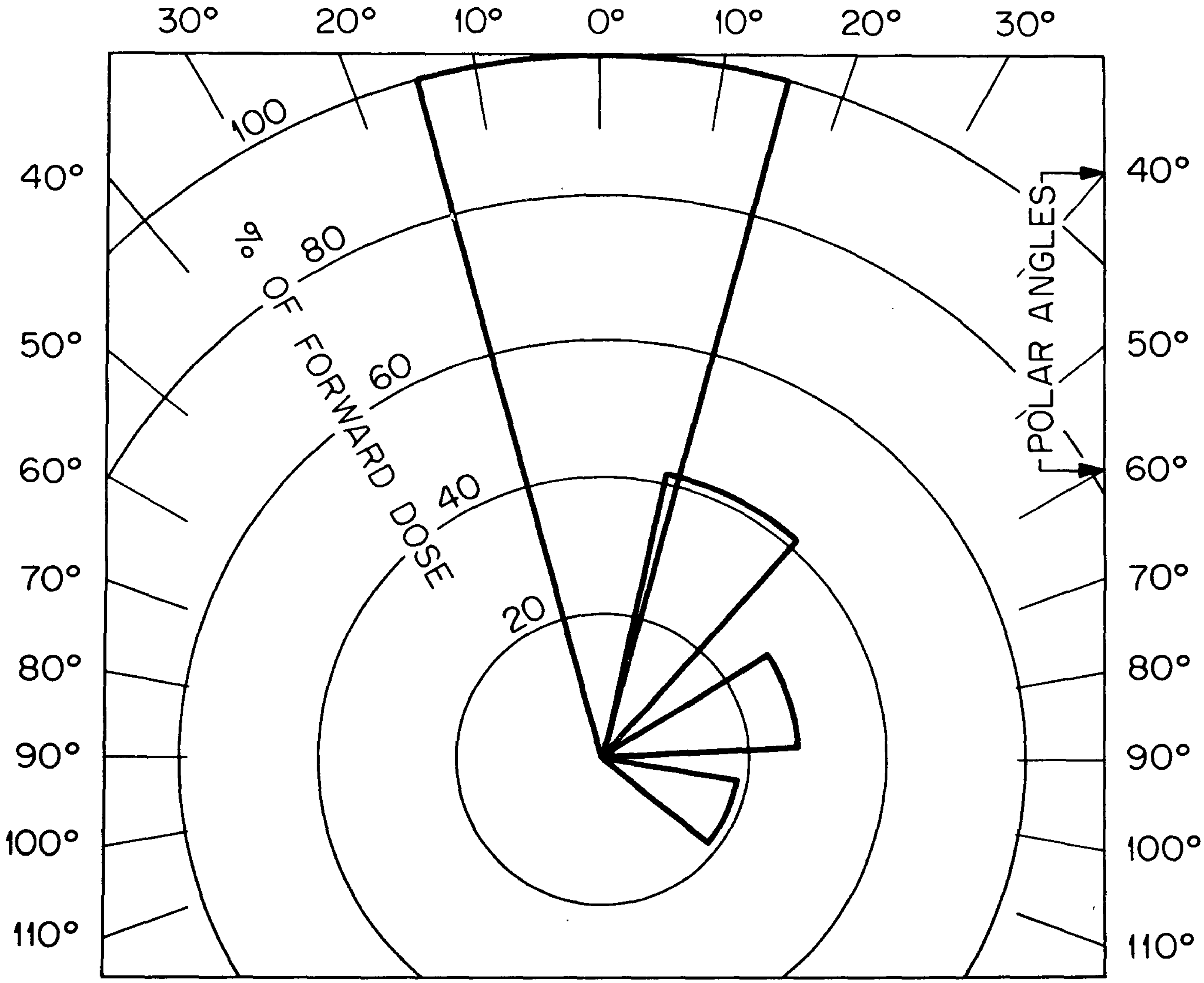


Fig. 6 - Angular Distribution of Gamma-Ray Dose at 1000 Yards from a Typical Weapon of Nominal Size

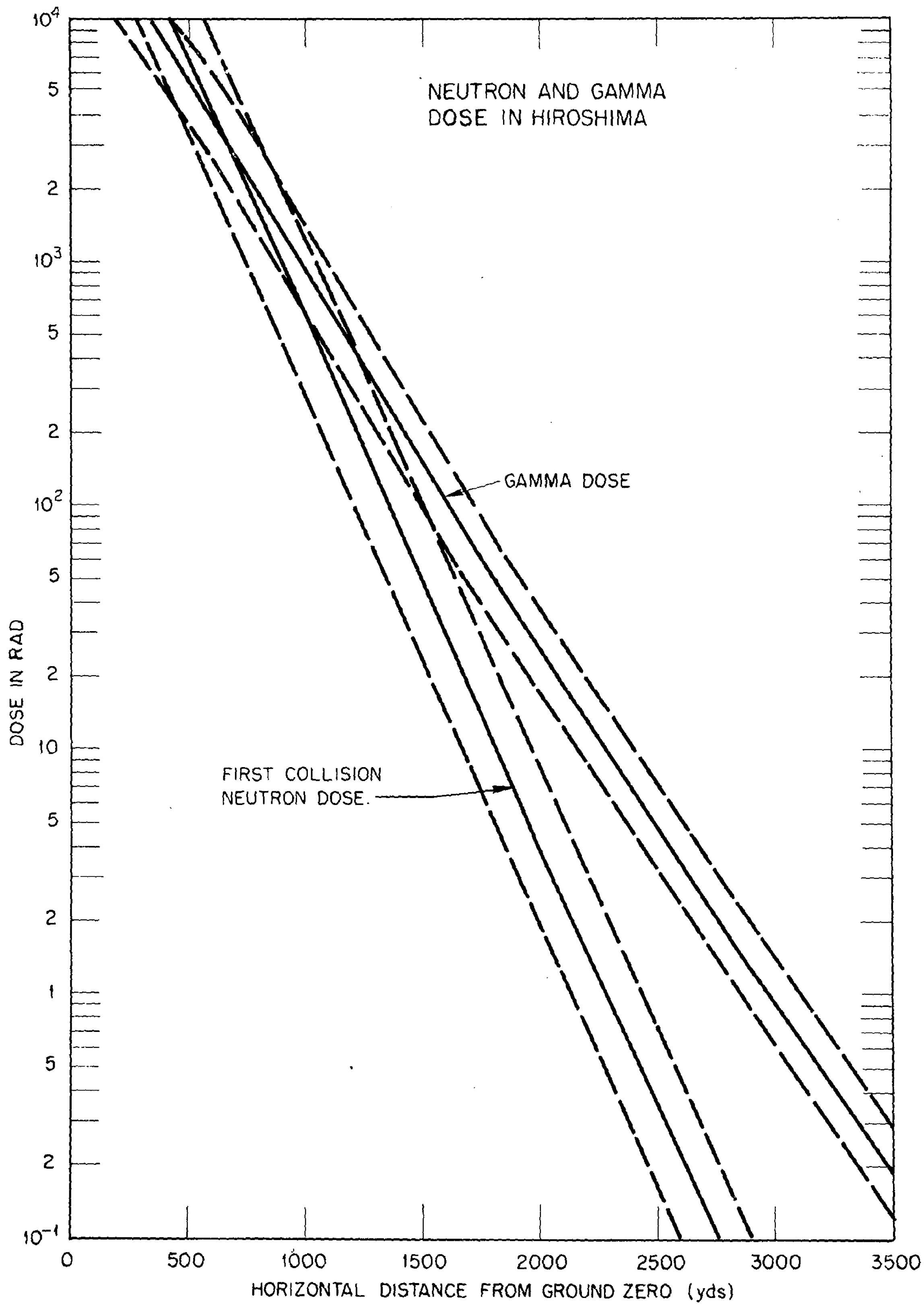


Fig. 7 - Radiation Dose as a Function of Horizontal Distance from Ground Zero in Hiroshima

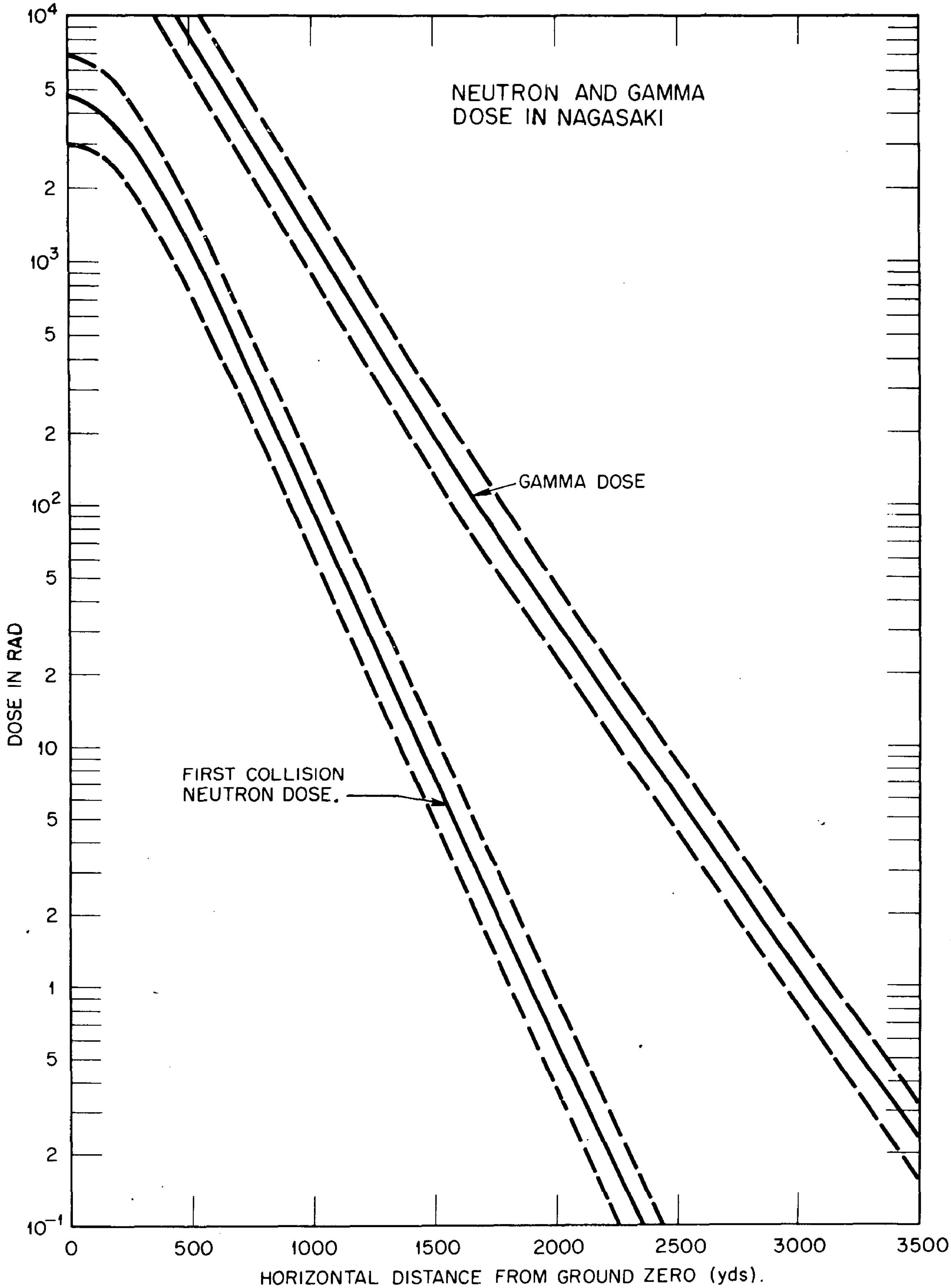


Fig. 8 - Radiation Dose as a Function of Horizontal Distance from Ground Zero in Nagasaki

Late in 1958 a weapons test series, Operation Hardtack II, was conducted at NTS, and further work was directed to the dose distributions in Japanese houses (radiation analogs constructed of cement-asbestos board in wood framing typical of Japan). Emphasis was placed on the determination of the dose distributions as a function of house size, orientation, and position relative to its neighbor. Seven houses were constructed and, due to the durability of the wall board and other fortuitous events, six were repaired and used three times; the seventh was used twice. One array of houses is shown in Fig. 9.

With all data available after Hardtack II,[10] it was possible to compute the neutron dose at any point in a Japanese house for a large number of typical configurations. The neutron data were generally satisfactory; some refinements in the angular distribution at small angles was needed, but the neutron program was in an advanced stage. However, there were apparent discrepancies in the gamma radiation data when they were compared to earlier data. These discrepancies were attributed, at the time, to the inadvertent substitution of lithium depleted in ^{6}Li in the thermal neutron shields used with the chemical dosimeters.

Consequently, it was decided to do a definitive study of the neutron and gamma radiation fields at large distances from a point fission source. The ORNL Health Physics Research Reactor (HPRR), Fig. 10, was suspended on a hoist car which was mounted on a 1527-ft high tower at NTS, Fig. 11. Designated Operation BREN, the experiments

Fig. 9 - Typical Array of Japanese Houses (Radiation Analogs) Used
During Operation Hardtack II

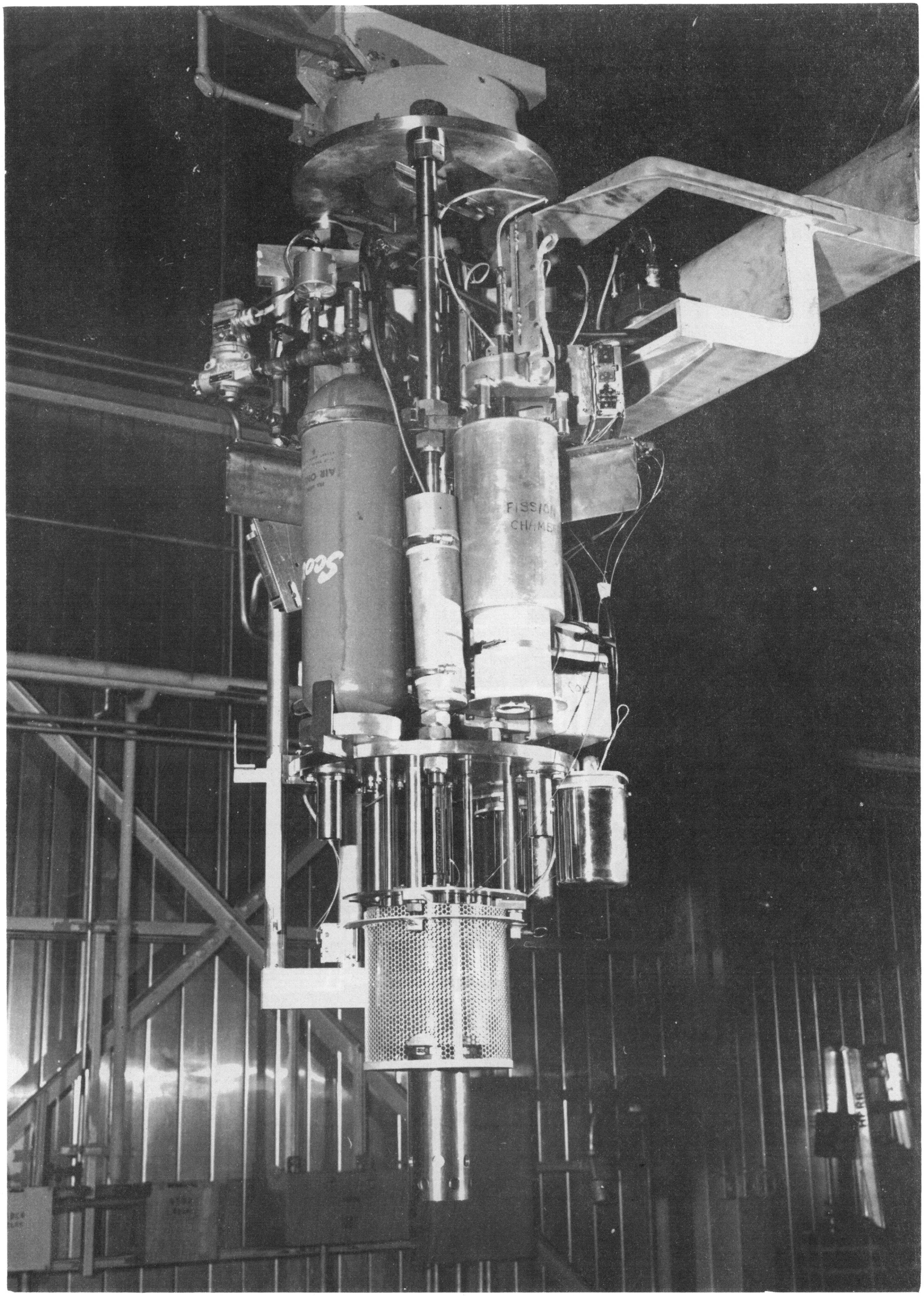


Fig. 10 - The Health Physics Research Reactor

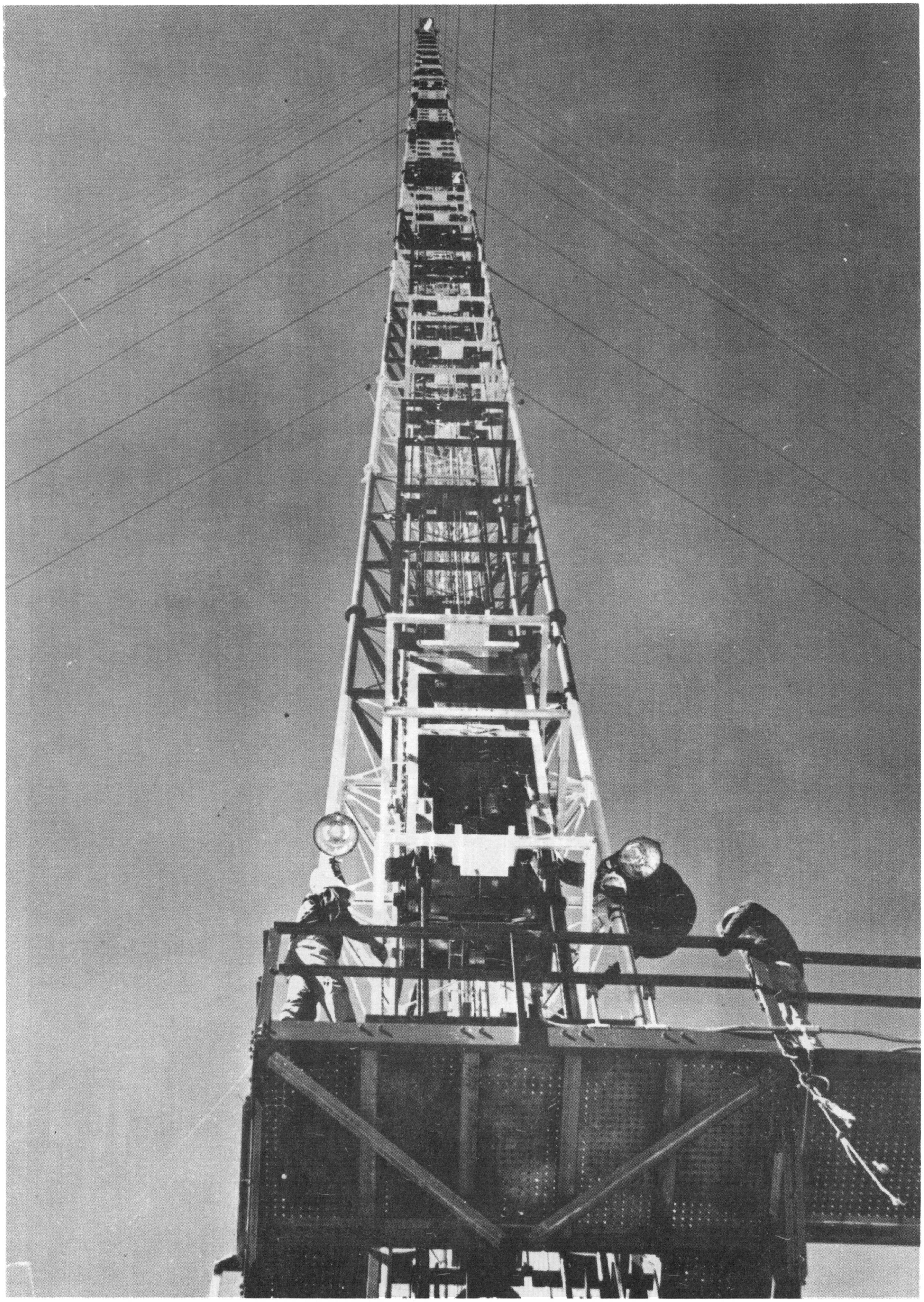


Fig. 11 - The Health Physics Research Reactor Mounted on Hoist Car on BREN Tower

were conducted during the spring and early summer of 1962.[11,12] Major objectives of Operation BREN included the energy, angular, and spatial distributions of neutrons and gamma radiation from the HPRR; also, a ^{60}Co source of a nominal 1200 curies was substituted for the reactor upon completion of the reactor studies. The measurements of spatial distributions of dose extended to radiation analogs of Japanese houses; the dose distributions were determined as a function of house size, orientation, and position relative to other houses. All measurements were made with sensitive laboratory-type instrumentation and only the spectral measurements for gamma rays from the fission source were considered to be marginal; with maximum reactor power (for continuous operation) and the most sensitive instruments, it appeared unlikely that the desired accuracy could be attained. Although considerable information concerning the spectrum was obtained, the number and distance range of these measurements were limited. However, all other phases were highly successful. The gamma dose distributions in the houses were found to be similar to those during Operation Hardtack, but they were consistent and reproducible. A small Japanese "house" and a transite "house" of identical size were found to yield identical distributions. These data, with those from later laboratory experiments, confirmed the hypothesis that neutron interactions with the major elements of the houses and buildup due to scattering of the high energy gamma rays (from neutron interactions in the air) resulted in the observed gamma distributions; the net "attenuation" of gamma radiation was found to be small and frequently there was a net increase in gamma radiation dose at points inside the house.

In addition to improved shielding information for houses, significant contributions were made to the description and understanding of the radiation fields from nuclear weapons and other intense radiation sources for large distances. Of special significance are the data on the effect of the air-ground interface.[13,14]

By early 1964, the final equations were developed for obtaining shielding factors for Japanese houses; i.e., technicians can use the following equations for computing shielding factors. For neutrons, the expression

$$\frac{\text{Shielded Dose}}{\text{Air Dose}} = A_1 e^{-G_1} + A_2 G_2 + A_3 G_3 + A_4 G_4 + A_5 G_5 + A_6 e^{-G_6} + A_7 e^{-G_7} + A_8 G_8 + A_9$$

yields the shielding factor to within $\pm$ 6% at the 50% confidence level. The constants A_i have all been determined and the geometry factors G_i are physical dimensions taken from the shielding "history" for the case of interest. For gamma radiation

$$\frac{\text{Shielded Dose}}{\text{Air Dose}} = A_1 + A_2 e^{-G_1} + A_3 e^{-G_2} + A_4 G_3 + A_5 G_4 + A_6 G_5 + A_7 G_6$$

is used; the 50% confidence limits are less than $\pm$ 6%. The constants A_i and the geometrical parameters G_i are different for each of the two equations. The confidence limits are based on a comparison with approximately 600 datum points from weapons tests and Operation BREN.

The remaining aspect of the problem is the normalization of the air-dose distributions to the radiation "yield" of the Hiroshima and Nagasaki bombs. An analysis of early post-bombing studies of neutron activation by Japanese scientists yielded no useful information; apparently samples were collected without sufficient regard for their precise location at the time of detonation. Later studies of steel samples were little better. In early 1963, a group at the Japanese National Institute of Radiological Sciences headed by T. Hashizumi commenced an activation study in collaboration with the Ichiban dosimetry group. In these studies only samples of steel which were several centimeters deep in concrete at the tops of buildings and which had not been disturbed are being analyzed. The HPRR is used in calibration studies. Similar studies are concerned with the radiation induced thermoluminescence in Japanese roof tiles.[15]

Ideally, the method of normalization would be the refiring of exact duplicates of the Japanese weapons under the same environmental conditions. However, as testing in the atmosphere is unlikely, it may be desirable to make radiation leakage measurements from underground tests. In addition, it is possible to calculate the yield of weapons, and a collaborative program between LASL and ORNL is directed to these calculations. However, the accuracy of these calculations is probably not better than about 30% to 50%. Consequently, all of these methods are being explored; all are independently useful for other problems.

In summary, the shielding factors for Japanese dwellings can now be computed and simple empirical formulae are being generated to simplify these computations. Spatial and angular distributions of dose are well defined, and spectral distributions are known, crudely. It now appears feasible to calculate the dose distributions in many of the more heavily shielded configurations. Some further study will be required for these cases. Normalization of the air-dose curves to the Hiroshima and Nagasaki weapons must yet be accomplished; at least one calculational and two experimental studies are underway, and success in at least two of these studies is expected by the end of 1964.

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CIVIL EFFECTS TEST OPERATIONS REPORT SERIES (CEX)

Through its Division of Biology and Medicine and Civil Effects Test Operations Office, the Atomic Energy Commission conducts certain technical tests, exercises, surveys, and research directed primarily toward practical applications of nuclear effects information and toward encouraging better technical, professional, and public understanding and utilization of the vast body of facts useful in the design of countermeasures against weapons effects. The activities carried out in these studies do not require nuclear detonations.

A complete listing of all the studies now underway is impossible in the space available here. However, the following is a list of all reports available from studies that have been completed. All reports listed are available from the Office of Technical Services, Department of Commerce, Washington 25, D. C., at the prices indicated.

CEX-57.1 ($0.75)	The Radiological Assessment and Recovery of Contaminated Areas, Carl F. Miller, September 1960.
CEX-58.1 ($2.75)	Experimental Evaluation of the Radiation Protection Afforded by Residential Structures Against Distributed Sources, J. A. Auxier, J. O. Buchanan, C. Eisenhauer, and H. E. Menker, January 1959.
CEX-58.2 ($0.75)	The Scattering of Thermal Radiation into Open Underground Shelters, T. P. Davis, N. D. Miller, T. S. Ely, J. A. Basso, and H. E. Pearse, October 1959.
CEX-58.7 ($0.50)	AEC Group Shelter, AEC Facilities Division, Holmes & Narver, Inc., June 1960.
CEX-58.8 ($1.00)	Comparative Nuclear Effects of Biomedical Interest, Clayton S. White, I. Gerald Bowen, Donald R. Richmond, and Robert L. Corsbie, January 1961.
CEX-58.9 ($1.25)	A Model Designed to Predict the Motion of Objects Translated by Classical Blast Waves, I. Gerald Bowen, Ray W. Albright, E. Royce Fletcher, and Clayton S. White, June 1961.
CEX-59.1 ($0.60)	An Experimental Evaluation of the Radiation Protection Afforded by a Large Modern Concrete Office Building, J. F. Batter, Jr., A. L. Kaplan, and E. T. Clarke, January 1960.
CEX-59.4 ($1.25)	Aerial Radiological Monitoring System. I. Theoretical Analysis, Design, and Operation of a Revised System, R. F. Merian, J. G. Lackey, and J. E. Hand, February 1961.
CEX-59.4 (Pt.II) ($1.50)	Aerial Radiological Monitoring System. Part II. Performance, Calibration, and Operational Check-out of the EG&G Arms-II Revised System, J. E. Hand, R. B. Guillou, and H. M. Borella, Oct. 1, 1962.
CEX-59.7C ($0.50)	Methods and Techniques of Fallout Studies Using a Particulate Simulant, William Lee and Henry Borella, February 1962.
CEX-59.13 ($0.50)	Experimental Evaluation of the Radiation Protection Afforded by Typical Oak Ridge Homes Against Distributed Sources, T. D. Strickler and J. A. Auxier, April 1960.
CEX-59.14 ($1.75)	Determinations of Aerodynamic-drag Parameters of Small Irregular Objects by Means of Drop Tests, E. P. Fletcher, R. W. Albright, V. C. Goldizen, and I. G. Bowen, October 1961.
CEX-60.1 ($1.75)	Evaluation of the Fallout Protection Afforded by Brookhaven National Laboratory Medical Research Center, H. Borella, Z. Burson, and J. Jacovitch, February 1961.
CEX-60.3 ($1.50)	Extended- and Point-source Radiometric Program, F. J. Davis and P. W. Reinhardt, August 1962.
CEX-60.6 ($1.00)	Experimental Evaluation of the Radiation Protection Provided by an Earth-covered Shelter, Z. Burson and H. Borella, February 1962.
CEX-61.1 (Prelim.)	Gamma Radiation at the Air-Ground Interface, Keran O'Brien and James E. McLaughlin, Jr., May 29, 1963.
CEX-61.4 ($2.25)	Experimental Evaluation of the Fallout-radiation Protection Provided by Selected Structures in the Los Angeles Area, Z. G. Burson, Feb. 26, 1963.
CEX-62.01 ($0.50)	Technical Concept—Operation Bren, J. A. Auxier, F. W. Sanders, F. F. Haywood, J. H. Thorngate, and J. S. Cheka, January 1962.
CEX-62.02 ($2.25)	Operation Plan and Hazards Report—Operation Bren, F. W. Sanders, F. F. Haywood, M. I. Lundin, L. W. Gilley, J. S. Cheka, and D. R. Ward, April 1962.
CEX-62.2 ($1.00)	Nuclear Bomb Effects Computer (Including Slide-rule Design and Curve Fits for Weapons Effects), E. Royce Fletcher, Ray W. Albright, Robert F. D. Perret, Mary E. Franklin, I. Gerald Bowen, and Clayton S. White, Feb. 15, 1963.
CEX-62.81 (Prelim.) ($.1.25)	Ground Roughness Effects on the Energy and Angular Distribution of Gamma Radiation from Fallout, C. M. Huddleston, Z. G. Burson, R. M. Kinkaid, and Q. G. Klinger, May 22, 1963.