HISTORICAL REVIEW

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On 6 August 1945, the first atomic bomb was dropped on Hiroshima, and three days later, on 9 August, the second A-bomb was dropped on Nagasaki. Immediately after the bombings, several small groups of Japanese scientists visited Hiroshima and Nagasaki to investigate the extent of the damage. The Science Research Council of Japan, now the Science Council of Japan, mobilized available scientists in early September 1945 to conduct a large-scale study of all aspects of the bombings. The results of the various investigations were eventually published by the Science Council of Japan in a book entitled, *Collection of the Reports on the Investigation of the Atomic Bomb Casualties.*[1] Several of these 1945 reports provide valuable data for the recent dose reassessment activities, namely the measurement of neutron-induced ^{32}P activity in sulfur by Yamasaki and Sugimoto, the determination of the hypocenters of the bombs by Kimura and Tajima, the meteorological data of Uda et al, the determination of the range of thermal radiation burns on roof tiles by Watanabe et al, and the measurement of radioactive fallout by Shinohara et al. In late September 1945, US Army, Navy, and Manhattan Project teams entered Japan and began working with the Japanese scientists.[2] The medical personnel from the various American and Japanese teams were combined on 12 October 1945 to form a US-Japan Joint Commission for studies of acute biological effects associated with exposure to atomic radiation. A comprehensive report was prepared by the Joint Commission,[3] and a recommendation was sent to the President of the United States urging that an investigation for potential late biological effects in the exposed survivors should be conducted (Figure 1).

In November 1946, President Harry S Truman approved a directive to the National Academy of Sciences to initiate a long-term study of the surviving populations in Hiroshima

DEPARTMENT OF THE NAVY
OFFICE OF THE SECRETARY
WASHINGTON

18 NOV 1946

RECEIVED

The President
The White House

Dear Mr. President:

At the earliest practicable date following the capitulation of Japan, scientific groups effected a survey of damage produced by the atomic bombs on Hiroshima and Nagasaki. Medical scientists studied the effect on personnel. Those observations were conducted under the auspices of the Army and Navy through the agencies of the Manhattan District and the Naval Technical Mission in Japan.

Preliminary surveys involve about 14,000 Japanese who were exposed to the radiation of atomic fission. It is considered that the group and others yet to be identified offer a unique opportunity for the study of the medical and biological effects of radiation which is of utmost importance to the United States. Such a study should continue for a span of time as yet undeterminable. However, the study is beyond the scope of military and naval affairs, involving as it does humanity in general, not only in war but in anticipated problems of peaceful industry and agriculture. In addition, demobilization and consequent loss of military scientific personnel engaged in this study prevent its continuation.

In order that the studies might be followed to their logical conclusion, a conference group of the Division of Medical Sciences, National Research Council, convened to discuss the problem. The group recommended that appropriate action be taken toward the evolution of a Presidential Directive to effect the study. The recommendation with which the Surgeon General of the Navy, the Vice Chief of Naval Operations, and the Chief of Naval Research Concur is as follows:

> "That the Presidential Directive instruct the National Academy of Sciences - National Research Council - to undertake a long range, continuing study of the biological and medical effects of the atomic bomb on man. That in this directive the council be authorized to enlist the aid of governmental agencies and personnel, and such civilian agencies and personnel as may be needed. Further, that those governmental agencies whose aid is requested by the Council be authorized and requested to provide the needed cooperation."

In view of the above, it is respectfully recommended that the National Academy of Sciences - National Research Council - be so directed.

Sincerely yours,

James Forrestal

Approved
Harry S. Truman
November 26, 1946

Figure 1. Directive to the National Academy of Sciences

and Nagasaki. The Academy established the Atomic Bomb Casualty Commission (ABCC) in 1947 with funding provided by the US Atomic Energy Commission (AEC), and investigation began shortly thereafter.[4] The Japanese National Institute of Health (JNIH) aided the investigations by establishing branch laboratories within ABCC at Hiroshima and Nagasaki. In April 1975, ABCC was officially dissolved and replaced by a binational organization known as the Radiation Effects Research Foundation (RERF). The Government of Japan, through the Ministry of Health and Welfare, and the United States Government, through the US Department of Energy (DOE), share equally in the funding of RERF.[5] The US funds are made available through the National Academy of Sciences-National Research Council (NAS-NRC) as contractor to DOE and previously to AEC.

The objectives of RERF are to conduct research and studies on the biological effects of radiation on man that will contribute to the maintenance of the health and welfare of the A-bomb survivors and to the health of all mankind. During the past 40 years, RERF and ABCC have published well over a thousand technical and scientific reports. These publications provide the most extensive and authoritative data available for estimating the overall risks of late radiation effects in man.

By the mid-1950s, several early ABCC studies had already reported an elevated incidence of cataracts and leukemia among survivors, especially in Hiroshima.[6–8] The need for accurate dosimetric data and the technology for obtaining it had both reached the point that an organized dosimetry study was judged necessary. Hence, the Ministry of Education in Japan and AEC in the US organized dosimetry research programs in their respective countries.

In 1956, the AEC assigned the task to the Oak Ridge National Laboratory (ORNL) in a project called ICHIBAN. One of the principal products of the ICHIBAN project was what is now referred to as the kerma in tissue, free-in-air (see Editor's Note), as a function of distance from the center of the explosions. In this case, the kerma reflects the absorption and scattering of radiation by intervening air and by the ground, but it does not include either the effects of shielding provided by surrounding structures or the absorption and scattering of radiation by an individual's body. With consultants from ORNL, ABCC determined map coordinates for most of the survivors then residing within the two cities and compiled detailed shielding data for those survivors located within 1600 m from the hypocenter in Hiroshima and within 2000 m from the hypocenter in Nagasaki. Most of the survivors in the two cities were exposed in residential wood-frame structures, and the highly modular and uniform construction of Japanese houses at that time made a definitive dosimetry study feasible. Hence, the shielding factors for typical Japanese houses were another principal product of the ICHIBAN project. Several Japanese-type houses were constructed at the Nevada Test Site (NTS) and used to make radiation shielding measurements at atmospheric weapon tests conducted prior to the Limited Test Ban Treaty of 1962. After 1962, the house-shielding measurements were continued using other neutron and gamma-ray sources mounted on a 500 m tower at NTS. These sources included a small unshielded reactor, a large ^{60}Co source, and a charged particle accelerator for producing neutrons. A summary of the ICHIBAN studies can be found in a recent book by J. A. Auxier.[9]

The first dose estimates for survivors were designated as Tentative 1957 Doses or T57D values.[10] These values were based on the house-shielding factors of Ritchie and Hurst[11] and the free-in-air kerma versus distance curves of York.[12] In 1965, a revised dosimetry system

was adopted by ABCC; it was based primarily on the house-shielding factors of Cheka et al[13] and the free-in-air kerma versus distance curves of Auxier et al.[14] These dose estimates were designated as Tentative 1965 Doses or T65D values, because ORNL scientists expected that the results would change with future work. The ORNL values for free-in-air kerma were found, however, to be in close agreement with results of independent Japanese studies by Ichikawa et al[15] at Kyoto University and Hashizume et al[16] at the National Institute of Radiological Sciences (NIRS) at Chiba. In the Kyoto University studies, the free-in-air kermas from gamma rays at various ground distances in Hiroshima and Nagasaki were measured by determining the thermoluminescence (TL) from the crystalline components in roof tiles. Because the roof tiles were used only on houses and small stores, and because these structures were destroyed near the hypocenter, the estimated ground distances corresponding to the TL measurements contained some rather large uncertainties.[16] The NIRS studies were based on gamma-ray kermas from TL measurements using decorative tiles and bricks and on neutron kermas from ^{60}Co measurements using steel reinforcing bars (rebars) from large buildings that had been repaired and used for a number of years following the bombings. Thus, the uncertainties in the estimated ground distances of the measurements were minimized, and the NIRS results seemed to confirm the ORNL values of free-in-air kerma for both neutrons and gamma rays.[17] As a result, the T65D system was used with a great deal of confidence for risk assessment throughout the 1970s.

An important step leading to the current reassessment of A-bomb radiation dosimetry was a presentation by H. H. Rossi in 1976 to the US National Council on Radiation Protection and Measurements (NCRP). The effect of attenuation of radiation by the body had been taken into account only recently,[18–20] and this made it possible to estimate the absorbed dose for critical organs of concern in the medical and epidemiological investigations conducted at ABCC and RERF. Rossi combined the results of the new calculations for the absorbed dose in active bone marrow[20] with the T65D estimates for survivors[17] and concluded that a radiation worker continually exposed to neutrons at the maximum permissible level recommended by the NCRP had a probability of developing leukemia that was several times greater than that of a person receiving the maximum permissible level of x or gamma rays. Therefore, Rossi recommended that the NCRP reduce its permissible dose limits for neutrons by an order of magnitude. The recommendation to NCRP was later repeated in a 1978 issue of Health Physics in an article by Rossi and Mays entitled *Leukemia Risk from Neutrons.*[21]

One immediate response of the NCRP to Rossi's talk was to set up a Task Group (Table 1), under the direction of H. O. Wyckoff, to investigate the accuracy of the T65D system. Among the major concerns of the Task Group were (1) the T65D kermas for neutrons and gamma rays were much lower per kiloton of bomb yield than published data from a variety of other weapons, and (2) the T65D kermas for gamma rays decreased at a much greater rate with distance from the hypocenter in Hiroshima than in Nagasaki. After considerable study, the Task Group concluded that the material available in the open literature was insufficient for a determination of the accuracy of the T65D system. Some documents needed in the review were classified because of their importance to national security. For this reason, the Task Group recommended that a person with the proper security clearance complete the review. DOE responded to the Task Group's recommendation by funding G. D. Kerr of ORNL in 1979. Fortunately, Kerr not only had access to classified data on the

Table 1. Members of the Task Group on A-Bomb Survivor Dosimetry of the National Council on Radiation Protection.

Dr. Harold O. Wyckoff (Chairman), International Commission on Radiation Units and Measurements.
Mr. Charles M. Eisenhauer, Physicist, Radiation Physics Division, Center for Radiation Research, National Bureau of Standards.
Dr. Payne S. Harris, retired, Santa Fe, NM.
Dr. William E. Ogle, Energy Systems, Inc.
Dr. Malcolm L. Randolph, Staff Scientist, Health and Safety Research Division, Oak Ridge National Laboratory (retired).
Dr. William C. Roesch, Staff Scientist, Pacific Northwest Laboratory (retired).
Dr. Lewis V. Spencer, Physicist Radiation Theory Group, Radiation Physics Division, National Bureau of Standards.
Dr. John B. Storer, former Director, Biology Division, Oak Ridge National Laboratory.

bombs dropped on Japan and on bombs used in weapons test, but also was aware of newer data that was relevant to the problem and other investigators were drawn into the review. Their assistance was provided at the request of NCRP through funding by both DOE and the US Defense Nuclear Agency (DNA).

In response to a DNA request in the mid-1970s, W. E. Preeg of the Los Alamos National Laboratory (LANL) calculated the radiation leakage from a variety of modern nuclear weapons. It was later suggested by C. P. Knowles of R & D Associates (RDA) that the Hiroshima and Nagasaki bombs be included in the calculations for the sake of completeness. In 1976, Preeg circulated a letter giving the data obtained in his radiation-leakage calculations for the two bombs dropped on Hiroshima and Nagasaki.[22] The letter included data from some additional calculations of neutron transport in an infinite air medium with the HEART computer code, which predicted much smaller neutron kermas in Hiroshima than the T65D estimates. Similar results were obtained in 1977 in more realistic air-over-ground calculations by Pace,[23] who used the DOT-3 computer code developed at ORNL, and by Kaul and Jarka,[24] who used the ATR-4 computer code developed at Science Applications International Corporation (SAIC). The ATR-4 calculations of Kaul and Jarka were reviewed by Kerr in 1978 for DNA[25] and his review stated:

> The T65D curves (for free-in-air kermas or so-called air-dose values) are in good agreement with air-dose values determined by Japanese scientists from the University of Kyoto and the National Institute of Radiological Sciences (NIRS) at Chiba, Japan. Their values are based on experimental measurements of neutron-induced ^{60}Co activity in steel and gamma-induced thermoluminescence in roof tiles and other decorative tiles from buildings that were not destroyed by the bombings. In comparison to the T65D curves, those of Kaul and Jarka for the Little Boy (Hiroshima) weapon give an air-dose value for neutrons that is a factor of two less and an air-dose value for gamma rays that is a factor of two greater at a ground distance of 1000 m. These differences are too important in the investigations of the effects of radiation on man by the RERF to be treated lightly. A

scholarly and forthright discussion is needed of the leakage and air-transport calculation and their associated uncertainties, but this is clearly outside the purpose and scope of their report.

The accuracy of the leakage and air-transport calculations was later reviewed for DNA by Marcum[26] at RDA and he made a number of suggestions for improving the calculations, especially those for gamma rays originating from radioactive decay of fission products in the fireballs of the explosions. At the time, Marcum was unaware of the results of the ORNL studies by Pace.[23] Pace's DOT-3 calculations predicted that the free-in-air kerma from neutrons in Hiroshima was about three times smaller than the T65D value at a ground distance of 1000 m. In 1979, Pace[27] showed that the moisture content of the air was an extremely important parameter in the air-transport calculations for neutrons from the Hiroshima bomb. Kaul and Jarka had used a dry NTS-type air in their calculations, whereas Pace had originally used a moist air composition based on known weather conditions in Hiroshima at the time of the bombing.[1] A study to refine the air-transport calculations for delayed gamma rays was started in 1980 by Scott[28] of SAIC, and it soon became clear that the T65D values in Hiroshima for both gamma rays and neutrons were not as accurate as previously assumed.[29]

Independently of Kerr and of the NCRP Task Group, a study of A-bomb radiation dosimetry was undertaken at Lawrence Livermore National Laboratory (LLNL). This study was initiated because the recommendation in the Rossi-Mays paper[21] was of concern to H. W. Patterson, who was Editor-in-Chief of Health Physics and also Head of the Hazard Control Department at LLNL. As a result, E. Mendelsohn was asked to make both air-transport and radiation-leakage calculations for the Hiroshima bomb using the TARTNP computer code developed at LLNL. Because of problems encountered in these calculations, especially the ones related to radiation leakage from the Hiroshima bomb, Mendelsohn contacted P. P. Whalen of LANL, who was aware of Preeg's earlier leakage calculations for the Hiroshima and Nagasaki bombs.[22] The LANL data were then applied in calculations using both the TARTNP code and the ORNL DOT-3 code that had been installed on LLNL computers and used by W. E. Loewe for other purposes. The reason for using DOT-3 in the calculations was that TARTNP did not work very well at large distances of 1000 m or more, where most A-bomb survivors were located at the time of the bombing. By using both TARTNP and DOT-3, and by comparing the results at small distances, Loewe and Mendelsohn gained a great deal of confidence in their calculated free-in-air kermas for neutrons.[30]

Air-transport calculations with the ORNL DOT-3 code require the use of broad energy-group sets of cross sections for both neutrons and gamma rays. One such set, developed by ORNL at the request of DNA for general use in modern weapon calculations, consists of 37 neutron groups and 21 gamm-ray groups.[31] It assumes a 300 K Maxwellian distribution in energy for thermal neutrons with energies less than 0.125 eV and a 1/E distribution for all higher energy neutrons. This set was used by Pace in his 1977 calculations for both Hiroshima and Nagasaki.[23] Pace's neutron kermas for Nagasaki were in close agreement with those obtained in 1980 by Loewe and Mendelsohn. The latter studies suggested, however, that the DNA cross-section set with its built-in assumption of a 1/E distribution of energies for fast neutrons did not work very well in Hiroshima. For example, Pace's 1977 calculations gave a neutron kerma in Hiroshima that was about three times smaller than the T65D value

Table 2. Members of the Working Group on the Reassessment of A-Bomb Dosimetry of the US Department of Energy.

Dr. Robert F. Christy (Chairman), Institute Professor of Theoretical Physics Emeritus, California Institute of Technology.
Mr. Gilbert C. Binninger, Staff Scientist, Science Applications International Corporation.
Dr. Daniel G. Cacuci, Section Head, Engineering Physics and Mathematics Division, Oak Ridge National Laboratory.
Dr. Stephen D. Egbert, Staff Scientist, Science Applications International Corporation.
Mr. Michael L. Gritzner, Staff Scientist, Science Applications International Corporation.
Dr. John H. Harley, retired, former Director, Environmental Measurements Laboratory, Department of Energy.
Dr. Edwin H. Haskell, Research Assistant Professor, and Director, Thermoluminescence Laboratory, University of Utah.
Mr. Dean C. Kaul, Manager, Radiation Physics Division, Science Applications International Corporation.
Dr. George D. Kerr, Staff Scientist, Health and Safety Research Division, Oak Ridge National Laboratory.
Dr. William E. Loewe, Senior Physicist, Lawrence Livermore National Laboratory.
Dr. John Malik, Staff Member, Los Alamos National Laboratory.
Mr. Jess Marcum, Consultant, R & D Associates.
Mr. Edgar Mendelsohn, Staff Physicist, Lawrence Livermore National Laboratory.
Mr. Joseph V. Pace, III, Staff Scientist, Computing and Telecommunications Division, Oak Ridge National Laboratory.
Mr. William H. Scott, Jr., Assistant Manager, Radiation Transport Division, Science Applications International Corporation.
Mr. Paul P. Whalen, Fellow, Los Alamos National Laboratory.
Dr. William A. Woolson, Assistant Vice-President, Science Applications International Corporation.
DOE Liaison Officer: Mr. Wayne M. Lowder, Environmental Measurements Laboratory, Department of Energy.

at a ground distance of 1000 m, whereas Loewe and Mendelsohn's 1980 calculation gave a neutron kerma about four and one-half times smaller than the T65D value at 1000 m in Hiroshima. An article by Loewe and Mendelsohn[32] in a 1981 issue of Health Physics challenged the validity of both the T65D system of survivor dosimetry[17] and the Rossi-Mays recommendation to the NCRP.[21]

Matters rapidly came to a head in the spring of 1981 when the NCRP cosponsored with the North American Late Effects Group a workshop (dedicated to the memory of George A. Sacher) on A-bomb survivor dosimetry that was held at the 29th annual meeting of the Radiation Research Society.[33] The attendant publicity in both the scientific and lay press brought the problem to the attention of interested scientists and of political representatives of the United States and Japanese Governments. In the fall of 1981, DOE convened another sym-

Table 3. Members of the Research Team on Atomic Bomb Radiation Dosimetry of the Japanese Ministry of Health and Welfare.

Dr. Tadashi Hashizume (Chairman), Professor, Department of Radiology, School of Veterinary Medicine, Azabu University, and former Chief, Radiation Protection Section, Department of Physics, National Institute of Radiological Sciences.
Mr. Shoichiro Fujita, Research Associate, Department of Statistics, Radiation Effects Research Foundation.
Dr. Masaharu Hoshi[a], Instructor, Department of Radiation Physics, Research Institute for Nuclear Medicine and Biology, Hiroshima University.
Dr. Yoshikazu Kumamoto, Senior Investigator, Cyclotron Section, Division of Technical Services, National Institute of Radiological Sciences.
Dr. Takashi Maruyama, Chief, Radiation Protection Section, Physics Division, National Institute of Radiological Sciences.
Dr. Shunzo Okajima, Consultant, Radiation Effects Research Foundation, and former Director, Atomic Disease Institute, Medical School, Nagasaki University.
Mr. Yoshio Okamoto[b], Chief, General Affairs and Accounting Sections, Radiation Effects Research Foundation, Nagasaki
Mr. Hiroaki Yamada[b], Chief, Master File Section, Radiation Effects Research Foundation, Hiroshima (deceased).

[a] Appointed in 1981 to fill the committee position held by Dr. Kenji Takeshita, Professor, Department of Radiobiology, Research Institute of Nuclear Medicine and Biology, Hiroshima University (deceased).

[b] Involved in the early shielding history studies of the Atomic Bomb Casualty Commission.

posium to review what was known and to determine what further work was needed.[34] The ORNL review by Kerr[29] suggested, for example, that Preeg's radiation-leakage calculations for the Hiroshima bomb were inadequate as his calculations were done quickly using computer codes available at LANL and one-dimensional (spherical) models of the two bombs. A one-dimensional model was adequate for the Nagasaki bomb which was a nearly spherical implosion device. The Hiroshima bomb, however, required a two-dimensional calculation. It was a cylindrical gun-assembly device, and the effects of its cylindrical design were noted in the 1945 sulfur-activation measurements by Yamasaki and Sugimoto.[1] The ORNL review by Kerr[29] also presented some additional results of Marcum's RDA studies which suggested that the shielding factors used to determine the gamma-ray kermas for survivors exposed inside Japanese houses were inadequate.

Following the DOE symposium in the fall of 1981 a Working Group on A-Bomb Dosimetry Reassessment was organized and R. F. Christy of the California Institute of Technology was appointed Chairman (Table 2). The members of this DOE Working Group were to conduct a reassessment of all dosimetry related factors including the bomb yields, source terms, air transport, house shielding, and organ doses. The Japanese Ministry of Health and Welfare, being cognizant of the importance of the radiation dosimetry for A-bomb survivors, also organized a research team in 1981 headed by T. Hashizume (Table 3), which initiated a determination of neutron-induced ^{152}Eu activity in stone and other building materials to

Table 4. Members of the Panel on Reassessment of A-Bomb Dosimetry of the US National Academy of Sciences.

Dr. Frederick Seitz (Chairman), President Emeritus, Rockefeller University, and former President, National Academy of Sciences.
Dr. Michael A. Bender, Senior Scientist, Medical Department, Brookhaven National Laboratory.
Dr. Victor P. Bond, former Associate Laboratory Director for Life and Environmental Sciences, Brookhaven National Laboratory.
Dr. Merril Eisenbud, Professor Emeritus, Institute of Environmental Medicine, New York University Medical Center.
Mr. Charles M. Eisenhauer, Physicist, Radiation Physics Division, Center for Radiation Research, National Bureau of Standards.
Dr. Mortimer L. Mendelsohn, Associate Director Biomedical and Environmental Research, Lawrence Livermore National Laboratory.
Dr. William C. Roesch[a], retired, former Staff Scientist, Pacific Northwest Laboratory.
Dr. James H. Schulman, Consultant, National Materials Advisory Board, National Research Council - National Academy of sciences.
Dr. Warren K. Sinclair, President, National Council on Radiation Protection and Measurements.
Dr. Lewis V. Spencer, retired, former Physicist, Radiation Theory Group, Radiation Physics Division, National Bureau of Standards.
Dr. Arthur C. Upton, Professor and Chairman, Institute of Environmental Medicine, New York University Medical Center.
Dr. Harold O. Wyckoff, Principal Scientific Counselor, International Commission on Radiation Units and Measurements.
Staff Officer: Dr. William H. Ellett, Medical Follow-up Agency Board on Radiation Effects Research, National Research Council - National Academy of Sciences.

[a]Resigned in September 1986 to become Editor of *Reassessment of Atomic Bomb Radiation Dosimetry in Hiroshima and Nagasaki. Final Report.*

supplement the earlier NIRS data on neutron-induced ^{60}Co activity in steel rebars, a new TL study using tile and brick samples located at larger ground distances to supplement the earlier TL data of NIRS and Kyoto University, a review of the shielding histories to obtain additional data on the orientation and posture of survivors, and of body dimensions of the Japanese in the period of the atomic bombings for use in the estimation of organ dose, etc. In addition, there were several research groups with similar objectives sponsored by the Japanese Ministry of Education.

Arrangements were completed in early 1983 for a US-Japan joint research program for reassessment of atomic bomb radiation dosimetry which was coordinated through RERF. NAS was asked to form a Panel on Reassessment of A-bomb Dosimetry (Table 4) to function as an oversight committee for the DOE Working Group. Frederick Seitz, President Emeritus of both NAS and Rockefeller University, was appointed to head the Panel. Two similar committees, the Review Committee to Evaluate the Radiation Dose from the Atomic Bomb

(Japanese Senior Dosimetry Committee) and the Japanese Dosimetry Working Group, were also established in 1983 under the chairmanship of Eizo Tajima, Professor Emeritus of St. Paul's University and Vice-Chairman of the Nuclear Safety Commission (Tables 5 and 6). The Japanese Working Group incorporated the research activities of the Hashizume team sponsored by the Ministry of Health and Welfare and several other research groups sponsored by the Ministry of Education. The function of the Japanese Senior Dosimetry Committee and NAS Panel was to insure that the research programs of the Working Groups had a firm scientific basis, that no essential elements were overlooked, and that the final results were formulated for specific application in the research programs of the RERF.

Table 5. Members of the Review Committee to Evaluate the Radiation Dose from the Atomic Bomb (Japanese Senior Dosimetry Committee).

Dr. Eizo Tajima (Chairman), Professor Emeritus, St. Paul's University, and Vice-Chairman, Nuclear Safety Commission.
Dr. Tadayoshi Doke, Professor, Science and Engineering Research Laboratory, Waseda University.
Dr. Tatsuji Hamada, Board Member, Japan Radioisotope Association.
Dr. Sohei Kondo, Professor, Atomic Energy Research Institute, Kinki University and former Professor, Department of Fundamental Biology, Medical School, Osaka University.
Dr. Toshiyuki Kumatori, Chairman, Radiation Effects Association, and former Director, National Institute of Radiological Sciences.
Dr. Nobuo Oda, Professor, Faculty of Science, Science University of Tokyo, and former Professor, Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology.
Dr. Masanobu Sakanoue, Professor, Low Level Radiation Laboratory, School of Science, Kanazawa University.
Dr. Itsuzo Shigematsu, Chairman, Radiation Effects Research Foundation.

Four US-Japan Joint Workshops for Reassessment of Atomic Bomb Radiation Dosimetry were held (1) at Nagasaki, Japan, 16 and 17 February 1983, (2) at Hiroshima, Japan, 8 and 9 November 1983, (3) at Pasadena, California, 12 to 14 March 1985, and (4) at Hiroshima, Japan, 15 to 17 March 1986. The proceedings of the first two workshops were published by RERF.[35,36] Special binational groups were appointed at the third workshop to prepare chapters on various topics for a final report on the new dosimetry. The final report was prepared from materials submitted by members of both the DOE and Japanese Working Groups. Chapters 1 to 9 describe the basis for the new dosimetry which is designated as Dosimetry System 1986 (DS86). The NAS Panel and Japanese Senior Dosimetry Committee served as reviewers in the preparation of the final report and approved the use of DS86 by RERF following the fourth workshop in March 1986.

Table 6. Members of the Japanese Dosimetry Working Group.

The Japanese dosimetry working group is chaired by Dr. Eizo Tajima and consists of members of the Japanese Senior Dosimetry Committee (Table 5), members of a Research Team headed by Dr. Tadashi Hashizume (Table 3), and other investigators.

Mr. Shoichiro Fujita, Research Associate, Department of Statistics, Radiation Effects Research Foundation.

Dr. Tadashi Hashizume, Professor, Department of Radiology, School of Veterinary Medicine, Azabu Univeristy, and former Chief, Radiation Protection Section, Department of Physics, National Institute of Radiological Sciences.

Dr. Masaharu Hoshi, Instructor, Department of Radiation Physics, Research Institute for Nuclear Medicine and Biology, Hiroshima University.

Dr. Yoneta Ichikawa, Professor, Department of Physics, Nara University of Education, and former Professor, Department of Nuclear Science, Kyoto University.

Dr. Keiji Kanda, Associate Professor, Research Reactor Institute, Kyoto University.

Dr. Hiroo Kato, Chief, Department of Epidemiology, Radiation Effects Research Foundation.

Dr. Toshiso Kosako, Associate Professor, Research Center for Nuclear Energy, Tokyo University.

Dr. Yoshikazu Kumamoto, Senior Investigator, Cyclotron Section, Division of Technical Services, National Institute of Radiological Sciences.

Dr. Takashi Maruyama, Chief, Radiation Protection Section, Physics Division, National Institute of Radiological Sciences.

Dr. Tsuneto Nagatomo, Assistant Professor, Department of Physics, Nara University of Education.

Dr. Shunzo Okajima, Consultant, Radiation Effects Research Foundation, and former Director, Atomic Disease Institute, Medical School, Nagasaki University.

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