DOE/EH-0268P

22

Twenty-second Annual Report

Radiation Exposures for DOE and DOE Contractor Employees - 1989

December 1992

Special Topic:
Assessment of Fetal Exposure

Prepared for:
U.S. Department of Energy

Assistant Secretary for
Environment, Safety and Health

Office of Health

DOE/EH-0286P

TWENTY-SECOND ANNUAL REPORT

RADIATION EXPOSURES FOR DOE AND DOE CONTRACTOR EMPLOYEES - 1989

M. H. Smith
P. A. Eschbach
R. Harty
W. H. Millet[a]
V. A. Scholes[a]

DOE Project Manager: S. G. Zobel
PNL Project Managers: J. M. Selby and K. L. Swinth

December 1992

Prepared for the U.S. Department of Energy
Assistant Secretary for
Environment, Safety, and Health
Office of Health
Under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

---

[a] Idaho National Engineering Laboratory
Idaho Falls, Idaho 83415

FOREWORD

This is the 22nd in a series of annual radiation exposure reports published by the Department of Energy (DOE) or its predecessors. This report summarizes the radiation exposures received at DOE and DOE contractor facilities in 1989. Radiation exposures to both employees and visitors are included. Trends in radiation exposures are evaluated by comparing the doses received in 1989 to those received in previous years. The significance of the doses is addressed by comparing them to the DOE limits and by correlating the doses to health risks based on risk estimates from expert groups.

This report is the second that is based on detailed exposure data for each individual monitored at a DOE facility. Prior to 1988, only summarized data from each facility were available. This report contains information on different types of radiation doses, including penetrating, shallow, and neutron doses. It also contains analysis of exposures by age, sex, and occupation of the exposed individuals. This report also continues the precedent established in the Twenty-First (1988) Annual Report by conducting a detailed, one-time, review and analysis of a particular topic of interest. The special topic for this report assesses potential fetal exposure at DOE facilities.

We believe this report will provide useful data to organizations or individuals involved in radiation protection activities. National and international organizations such as the National Council on Radiation Protection and Measurements, the International Commission on Radiological Protection, and the United Nations Scientific Committee on the Effects of Atomic Radiation have used DOE radiation exposure data in the past in formulating their recommendations and analyses. The information in these reports is also used by the DOE to identify areas of needed improvement to ensure continued commitment to the As Low As Reasonably Achievable (ALARA) philosophy of radiation protection.

Paul L. Ziemer, Ph.D.
Assistant Secretary
Environment, Safety and Health

Harry J. Pettengill, Ph.D.
Deputy Assistant Secretary
for Health

PREFACE

This report is one of a series of annual reports provided by the U.S. Department of Energy (DOE) summarizing occupational radiation exposures received by DOE and DOE contractor employees. These reports provide an overview of radiation exposures received each year and identify trends in exposures being experienced over the years.

In 1968, the U.S. Atomic Energy Commission (AEC) established a program for reporting certain occupational radiation exposure information to a central radiation records repository. Annual summary reports were published from 1969 through 1973 (WASH-1350-R1 through WASH-1350-R6); these included information on AEC contractor employees and visitors, as well as employees and visitors of companies in the private sector licensed by the AEC.

In January 1975, with the separation of the AEC into the Energy Research and Development Administration (ERDA) and the U.S. Nuclear Regulatory Commission (NRC), each agency assumed responsibility for collecting and maintaining occupational radiation exposure information reported by the facilities under its jurisdiction. Former AEC licensees reported to the NRC while contractors reported to ERDA. At the same time, a contract was established with Union Carbide Corporation at Oak Ridge, Tennessee, to computerize the reporting and processing of both the ERDA and NRC radiation exposure reporting systems. On October 1, 1977, DOE was formed and assumed the responsibilities of ERDA. Processing and programming of exposure information continued at Oak Ridge until October 1978, when management and further development of the DOE radiation exposure reporting system was assigned to the System Safety Development Center, EG&G Idaho, Inc.; the NRC system remained at Oak Ridge.

Radiation exposure data for ERDA and ERDA contractor employees and visitors for 1974 through 1976 were reported in ERDA 76/119, ERDA 77-29, and DOE/EV-0011/9. The DOE and DOE contractor radiation exposure data for 1977-1979 were presented in DOE/EV-0066/10, 11, and 12, respectively. A revised version of the 1979 report was issued as DOE/EP-0039. The data for 1980-1982 were presented in DOE/EP-0040, DOE/EP-0040/1, and DOE/EP-0040/2. The data for 1983-1988 were presented in DOE/PE-0072, DOE/EH-0011, DOE/EH-0036, DOE/EH-0069,

DOE/EH-0128, and DOE/EH-0171P, respectively. This report contains 1989 radiation exposure data for DOE and DOE contractor employees and visitors.

Previous reports for AEC/ERDA/DOE government and contractor employees and visitors may be obtained from the DOE Technical Information Center, P.O. Box 62, Oak Ridge, TN 37830.

SUMMARY

All U.S. Department of Energy (DOE) and DOE contractors are required by DOE Order 5484.1, Chapter IV, to submit occupational radiation exposure records to a central depository. In 1989, data were required to be submitted for all employees who were required to be monitored in accordance with DOE Order 5480.11 and for all visitors who had a positive exposure. The data required included the external penetrating whole-body dose equivalent, the shallow dose equivalent, and a summary of internal depositions of radioactive material above specified limits. Data regarding the exposed individuals included the individual's age, sex, and occupational category. This report is a summary of the external penetrating whole-body dose equivalents and shallow dose equivalents reported by DOE and DOE contractors for the calendar year 1989. Internal depositions of radioactive material are not discussed in this report since a significant portion of this data was unavailable. (See Section 2.3 for further explanation.)

A total of 90,882 DOE and DOE contractor employees were reported to have been monitored for whole-body ionizing radiation exposure during 1989. This represents 53.6% of all DOE and DOE contractor employees and is an increase (4.3%) from the number of monitored employees for 1988. In addition to the employees, 12,643 visitors were monitored. (For more information, see Table 4.1.)

Of all monitored employees reported, 63.3% received a dose equivalent that was less than measurable, 36.2% received a dose equivalent between measurable and 1 rem (10 mSv), and 0.5% received a dose equivalent greater than 1 rem (10 mSv). No employee received a dose equivalent greater than 3 rem (30 mSv). The dose equivalent received by 44.2% of the visitors to DOE facilities was less than measurable, 55.7% received a dose equivalent between measurable and 1 rem (10 mSv), and 0.1% received a dose equivalent greater than 1 rem (10 mSv). No visitor received a dose equivalent greater than 2 rem (20 mSv). (These data are detailed in Table 4.1.)

The collective dose equivalent for DOE and DOE contractor employees in 1989 was 3,073 person-rem (30.73 person-Sv), which represents a decrease of 16% from 1988. The collective dose equivalent for visitors was 303 person-rem (3.03 person-Sv), which represents an increase of 24%. The average dose equivalent for all monitored employees reported was 34 mrem (0.34 mSv), and the

average dose equivalent for all employees reported who received a measurable exposure was 92 mrem (0.92 mSv). The average dose equivalent for all monitored individuals (employees and visitors) reported was 33 mrem (0.33 mSv), and the average dose equivalent for all individuals reported who received a measurable exposure was 84 mrem (0.84 mSv). Activities at fuel reprocessing facilities resulted in the highest average dose equivalent of 138 mrem (1.38 mSv) for all monitored individuals reported. The lowest average dose equivalent (3 mrem) (0.03 mSv) was received at DOE offices. These averages are significantly less than the DOE 5 rem/year (50 mSv/year) radiation protection standard for whole-body exposures.

Of the ten occupational categories reported, production workers received both the highest collective dose equivalent (820 person-rem) (8.2 person-Sv) and the highest average dose equivalent per individual who received a measurable exposure (167 mrem) (1.67 mSv). Agricultural workers received both the lowest collective dose (1 person-rem) (0.01 person-Sv) and the lowest average dose equivalent (20 mrem) (0.20 mSv) per individual who received a measurable exposure. Service workers also received a low average dose equivalent (32 mrem) (0.32 mSv) per individual who received a measurable exposure.

For both males and females, the 5-year age group receiving the highest collective dose equivalent (694 person-rem) (6.94 person-Sv) was the 30-to-34 age group. This age group also had the highest average dose equivalent of 103 mrem (1.03 mSv) per individual who received a measurable exposure. The group receiving the lowest collective dose equivalent and average dose equivalent per individual who received a measurable exposure was the ≤ 19 age group.

The average dose for all males who received a measurable exposure was 88 mrem (0.88 mSv); for females, the average was 76 mrem (0.76 mSv). Males received a total of 2932 person-rem (29.32 person-Sv), while females received 388 person-rem (3.88 person-Sv). A total of 56 person-rem (0.56 person-Sv) was received by individuals for whom sex was not specified on the report forms.

Of the 3375 person-rem (33.75 person-Sv) received by DOE and DOE contractor employees and visitors at DOE facilities, 2739 person-rem (27.39 person-Sv) (81%) was attributable to beta-gamma exposures and 636 person-rem (6.36 person-Sv) (19%) was attributable to neutron exposures. In

addition to the penetrating dose equivalent (beta-gamma and neutron), DOE and DOE contractor employees and visitors received a collective shallow dose of 4639 person-rem (46.39 person-Sv).

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

The purpose of this report is to disseminate information regarding radiation exposures received at U.S. Department of Energy (DOE) and DOE contractor facilities. At these facilities, dose equivalents received by both workers and visitors are carefully monitored and recorded. The primary purpose of this practice is to ensure that the DOE occupational dose limits are not exceeded and that as low as reasonably achievable (ALARA) goals are met. A secondary purpose, however, is to provide information that can be used by other organizations and individuals who wish to collect and analyze such information. This information may be useful for estimating the effect of changing dose limits on operations at DOE facilities, determining the progress of DOE with respect to the ALARA principle, or, in combination with epidemiological information, assisting researchers in determining whether or not low doses of ionizing radiation are harmful.

This report contains eight main sections and four appendices. Section 2.0 presents relevant DOE operating requirements, including dose limits, ALARA, and reporting requirements. Section 3.0 presents brief descriptions of the various categories of DOE facilities and the sources of radiation exposure at each category of facility.

Section 4.0 presents a summary of the radiation doses received at DOE and DOE contractor facilities in 1989. The data are presented according to dose-equivalent interval, facility type, field organization, occupational category, age, sex, and type of exposure (external penetrating, shallow, internal, etc.). The section concludes with an evaluation of recent exposure trends at DOE and DOE contractor facilities.

Section 5.0 presents information regarding a study of fetal exposures at DOE and DOE contractor facilities. Section 6.0 presents reporting requirements for radiation exposure incidents at DOE and DOE contractor facilities. Section 7.0 presents a comparison of the doses received at DOE and DOE contractor facilities and the consequent risks relative to other risks that occur both in the workplace and as a part of everyday life. Section 8.0 lists the references cited in this report.

Four appendices are included in the report, all of which contain raw exposure data for DOE and DOE contractor employees and visitors. Appendix A presents the 1989 distribution of whole-body dose

equivalents by facility type for each DOE field organization. Appendix B presents the 1989 distribution of whole-body dose equivalents by contractor for each DOE field organization. Appendix C presents the 1989 distribution of whole-body dose equivalents for DOE government employees and visitors according to DOE field organization. Appendix D presents 1989 data on penetrating (whole-body) dose equivalents, including neutron and beta-gamma components, and shallow dose equivalents by various combinations of facility type, age, sex, and occupation.

Comments or suggestions that would improve the report or make it more useful should be sent to the U.S. Department of Energy, Assistant Secretary for Environment, Safety, and Health, Washington, D.C. 20585.

2.0 OPERATING REQUIREMENTS

One of the primary objectives of the DOE is to ensure that all its operations and those of DOE contractors are conducted safely. To help achieve this objective, the DOE has established radiation protection standards and program requirements to protect workers from ionizing radiation. The basic DOE standards are radiation dose limits, which establish maximum permissible doses to workers. In addition to the requirement that radiation doses to workers be maintained below the limits, it is DOE's policy that doses be maintained as far below the limits as is reasonably achievable.

2.1 DOSE LIMITS

In order to ensure that workers at DOE facilities are adequately protected from ionizing radiation, the DOE promulgates radiation protection standards for occupational workers. These standards include radiation dose limits to protect workers from both external radiation and internally deposited radionuclides. The current radiation dose limits were promulgated in DOE Order 5480.11, which became effective January 1, 1989. This order includes limits on dose equivalents to the whole body and to individual organs (Table 2.1). Personnel monitoring is required by DOE Order 5480.11 when the potential exists for an individual to receive an annual effective dose equivalent above 100 mrem (1 mSv), or an annual dose equivalent to an individual organ greater than 10% of the occupational radiation exposure limits shown in Table 2.1. Depending on the administrative policy of the field organization or contractor, monitoring may also be provided to some or all individuals, such as clerical workers, for whom the exposure potential is extremely low.

The current DOE radiation protection standards are based on the Environmental Protection Agency's (EPA's) revised guidance to federal agencies for protection against occupational radiation exposure (FR 1987). This guidance was a result of a review by EPA of the most recent recommendations of the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). The primary new feature of the guidance is that weighted internal doses are added to external doses to determine total effective dose equivalent. In the past, these were limited separately. The DOE became the first federal agency to implement the revised guidance when it promulgated its revised radiation protection standards (DOE Order 5480.11) for occupational workers on January 1, 1989.

TABLE 2.1. DOE Limiting Values for Assessed Dose from Exposure of Occupational Workers to Radiation (effective January 1, 1989)

Exposure Category	Limit
Total effective dose equivalent	5 rem/yr (effective dose equivalent)
Lens of eye	15 rem/yr (dose equivalent)
Extremity	50 rem/yr (dose equivalent)
Skin of the whole body	50 rem/yr (dose equivalent)
Other organ or tissue	50 rem/yr (dose equivalent)
Unborn child	0.5 rem/gestation period (dose equivalent)

2.2 ALARA PRINCIPLE

It has long been DOE's policy that radiation exposures should be maintained as far below the dose limits as is reasonably achievable. This policy is known as the ALARA principle of radiation protection, which maintains that radiation exposures should be maintained as low as reasonably achievable, economic and social factors being taken into account (ICRP 1977).

The ALARA principle is based on the hypothesis that even very low radiation doses carry some risk. As a result, it is not enough to maintain doses at or slightly below the limits; the lower the doses, the lower the risks. Because it is not possible to reduce all doses at DOE facilities to zero, economic and social factors must be considered to determine the optimal level of radiation doses. If doses are too high according to the ALARA principle, resources would be well spent to reduce them. At some point, the resources being spent to maintain low doses are exactly balanced by the risks avoided. Reducing doses below this point results in a misallocation of resources; the resources could be spent elsewhere and have a greater impact on health and safety.

To ensure that doses are maintained ALARA at DOE facilities, the DOE has mandated that ALARA plans and procedures be implemented and documented. To help ensure that facilities meet this requirement, the DOE has developed a manual of good practices for reducing exposures to ALARA levels (Munson et al. 1988). These include guidelines for administration of ALARA programs, techniques for performing ALARA calculations based on cost-benefit principles, guidelines for setting and evaluating ALARA goals, and methods for incorporating ALARA criteria into both radiological

design and operations. The establishment of ALARA as a required practice at DOE facilities demonstrates DOE's commitment to ensure minimum risk to workers from the operation of its facilities.

2.3 REPORTING REQUIREMENTS

In 1987, the DOE promulgated revised reporting requirements in DOE Order 5484.1 (DOE 1987). Formerly, contractors were required to report only the number of individuals who received an occupational whole-body exposure in one of 16 dose-equivalent ranges. However, contractors are required by the revised Order to report exposure data for individual employees and visitors. Data required include total effective dose equivalent, external penetrating dose equivalent (including neutron), internal effective dose equivalent, shallow dose equivalent, and extremity dose equivalent. Other data required include the individual's age, sex, employment status, and occupation, as well as the relevant organization and facility type.

Because the revised reporting requirements are still being implemented by individual facilities and contractors, the 1989 exposure data were not reported in a format consistent with the new requirements in all cases. Furthermore, not all sites were able to comply with the internal dose reporting requirements for calendar year 1989. Analysis and discussion of internal dose for 1989 will be presented in a subsequent annual report. In this report, data are presented based on the new reporting requirements, and explanations are provided for those cases when the data were incomplete.

3.0 FACILITY DESCRIPTIONS

DOE Order 5484.1 requires contractors to indicate for each reported individual the facility contributing the predominant portion of individual's effective dose equivalent. In cases when this cannot be distinguished, the facility indicated should represent the facility wherein the greatest portion of work service was performed.

The facility indicated must be one of eleven general facility categories: accelerator, fuel/uranium enrichment, fuel fabrication, fuel processing, maintenance and support (site-wide), reactor, general research, fusion research, waste processing/management, weapons fabrication and testing, and other. Because it is not always a straightforward procedure to determine the appropriate facility type for each individual, the assignment of an individual to a particular facility type is a policy decision of each contractor.

The facility descriptions that follow indicate the types of facilities included in each category. Also included are the types of work performed at the facilities and the sources of the majority of the radiation exposures.

3.1 ACCELERATOR

The DOE administers approximately a dozen laboratories that perform significant accelerator-based research. The accelerators range in size from small single-room electrostatic devices to a four-mile-circumference synchrotron, and their energies range from keV to TeV.

The differences in accelerator types, sizes, and energies result in differences in the radiation types and dose rates associated with the accelerator facilities. In general, radiation doses to employees at the facilities are attributable to neutrons and x-rays, as well as muons at some of the larger facilities. Exposure rates inside the primary shielding can range up to 200 mR/hour (52 μC/kg-hour) as a result of x-ray production near some machine components. Outside of the shielding, however, x-ray exposure rates are very low, and neutron dose rates are generally less than 5 mrem/hour (0.05 mSv/hour). Average annual doses at these facilities are slightly higher than the overall average for DOE; however, the collective dose is lower than the collective dose for most other DOE facility categories

because of the relatively small number of employees at accelerator facilities. Regarding internal exposures, tritium and short-lived airborne activation products exist at some accelerator facilities, although annual internal doses are generally quite low.

3.2 FUEL/URANIUM ENRICHMENT

Involvement by DOE in the nuclear fuel cycle generally begins with uranium enrichment operations and facilities (Rich et al. 1988). The current method of enrichment is isotopic separation using the gaseous diffusion process, which involves diffusing uranium through a porous membrane and using the different molecular weights of the different uranium isotopes to achieve separation.

Although current facility designs and physical controls result in low doses from internally deposited uranium, the primary radiological hazard is the potential for inhalation of airborne uranium (Rich et al. 1988). Because of the low specific activity of uranium, external dose rates are usually a few millirem per hour or less. Most of the external doses that are received are attributable to gamma exposures, although neutron exposures can occur, especially when work is performed near highly enriched uranium. Both the average and collective external doses at these facilities are among the lowest of any DOE facility category.

3.3 FUEL FABRICATION

Activities at fuel-fabrication facilities involve the physical conversion of uranium compounds to usable forms, usually rod-shaped metal. Radiation exposures to personnel at these facilities are attributable almost entirely to gamma and beta radiation. However, beta radiation is considered the primary external radiation hazard because of high beta dose rates (up to several hundred mrad per hour) at the surface of uranium rods (Rich et al. 1988). For example, physical modification of uranium metal by various metal-working operations, such as machining and lathing, requires protection against beta radiation exposures to the skin, eyes, and extremities. Average external doses at fuel-fabrication facilities are generally higher than at other types of DOE facilities; however, collective doses are relatively low because the number of employees is low. Internal doses from inhalation of uranium are kept very low.

3.4 FUEL PROCESSING

The DOE administers several facilities that reprocess spent reactor fuel. This process separates out the plutonium produced in the reactors for use in nuclear weapons. The process also separates the fission products, which are normally designated as radioactive waste products, and unspent uranium, which can be refabricated for further use as fuel.

The very high radioactivity of spent nuclear fuel (fission products) results in employees at fuel-processing facilities consistently having among the highest average doses of any DOE facility type. However, the collective dose at these facilities is less significant because of the small total number of employees. Penetrating doses are attributable primarily to gamma photons, although some neutron exposures do occur. Skin and extremity doses from handling of samples are also significant, although only a few employees typically receive skin doses greater than 5 rem (50 mSv) per year. Strict controls are in place at fuel-reprocessing facilities to prevent internal depositions; however, several measurable intakes typically occur per year. Plutonium isotopes represent the majority of the internal depositions, and annual effective dose equivalents from the depositions are typically less than 500 mrem (5 mSv).

3.5 MAINTENANCE AND SUPPORT

Most DOE sites have facilities dedicated to maintaining and supporting the site. In addition, some employees may be classified under this facility type if their main function is to provide site maintenance and support, even though they may not be located at a single facility dedicated to that purpose.

Because many maintenance and support activities at DOE sites do not involve work near sources of ionizing radiation, the average dose equivalent per monitored employee is typically among the lowest of any facility type. However, those employees who do perform work near radiation sources receive relatively high average annual doses, as is indicated by the relatively high average annual dose per employee who receives a measurable exposure. Also, collective doses are relatively high because there is a large number of these employees relative to the number classified under other facility types. The sources of ionizing radiation exposure are primarily gamma photons. However, variations in the

types of work performed and work locations result in exposures of all types, including exposures to beta particles, x-rays, neutrons, and airborne radioactivity.

3.6 REACTOR

The DOE and its predecessors have built and operated dozens of nuclear reactors since the mid-1940s. These facilities have included plutonium and tritium production reactors, prototype reactors for energy production, research reactors, reactors designed for special purposes such as production of medical radioisotopes, and reactors designed for the propulsion of naval vessels.

In 1989, many of the DOE reactors were not operating. As a result, personnel exposures at DOE reactor facilities were attributable primarily to gamma photons and beta particles from contaminated equipment and plant areas, spent reactor fuel, activated reactor components, and other areas containing fission or activation products encountered during plant maintenance and decommissioning operations. Neutron exposures do occur at operating reactors, although the resultant doses are a very small fraction of the collective penetrating doses. Gamma dose rates in some plant areas can be very high (up to several R per hour), requiring extensive protection measures. The average and collective external doses relative to other facility types are highly dependent on the status of reactor operations. Inhalation of airborne radioactive material is a concern in some plant areas. However, protective measures such as area ventilation or use of respiratory-protection equipment result in low internal doses.

3.7 RESEARCH, GENERAL

The DOE contractors perform research at many DOE facilities, including all of the national laboratories. Research is performed in general areas including biology, biochemistry, health physics, materials science, environmental science, epidemiology, and many others. Research is also performed in more specific areas such as global warming, hazardous waste disposal, energy conservation, and energy production, among others.

The wide variety of research being performed at DOE facilities results in a wide variety of radiological conditions at those facilities where ionizing radiation or radioactive materials are an

important part of the research. Depending on the research performed, personnel may be exposed to virtually any type of external radiation including beta particles, gamma photons, x-rays, and neutrons, as well as the potential for inhalation of radioactive material. Area dose rates and individual annual doses are also highly variable. Relative to other facility types, average annual individual doses are slightly above average at general research facilities. The collective dose equivalent is higher than at most other facility types because of the many individuals employed at general research facilities.

3.8 RESEARCH, FUSION

The DOE currently operates one major and several smaller facilities that participate in research on fusion energy. In general, both penetrating and shallow radiation doses are minimal at these facilities because the dose rates near the equipment are both low and intermittent. The external doses that do occur are attributable primarily to x-rays from energized equipment. Relative to other DOE facility types, average individual doses and collective doses are typically the lowest at fusion research facilities. Regarding internal exposures, airborne tritium is a concern at some fusion research facilities, although the current level of operation results in minimal doses.

3.9 WASTE PROCESSING/MANAGEMENT

Most DOE sites have facilities dedicated to the processing and disposal of radioactive waste. In general, the dose rates to employees when handling waste are very low because of the low specific activities or the effectiveness of shielding materials. As a result, very few employees at these facilities receive annual doses greater than 100 mrem (1 mSv). At two DOE sites, however, large-scale waste-processing facilities exist in order to properly dispose of radioactive waste products generated during the nuclear fuel cycle. At these facilities, radiation doses to some employees can be relatively high, sometimes exceeding 1 rem per year (10 mSv per year). Penetrating doses at waste processing facilities are mostly attributable to gamma photons; however, neutron exposures are significant at the large-scale facilities. Skin doses are generally not a significant problem. Overall average annual doses at waste-processing/management facilities are among the highest of any DOE facility type, which is attributable primarily to the two large-scale facilities. The annual collective doses are closer to the average of all facility types, however, because of the relatively small number of employees at this type of facility.

3.10 WEAPONS FABRICATION AND TESTING

The primary function of a facility in this category is to fabricate weapons-grade material for the production of nuclear weapons, or to conduct the testing of nuclear weapons. At the testing facilities, radiation doses received by personnel are generally minimal because of the strict controls over personnel access to testing areas, although extremity doses can be relatively high from handling neutron-activated materials. Radiation doses are more of a concern at facilities where weapons and weapons-grade nuclear material are handled. At these facilities, neutron radiation dose rates can be significant when processing relatively small quantities of ^{238}Pu or larger quantities of mixed plutonium isotopes (Faust et al. 1988). Penetrating doses from gamma photons and plutonium x-rays can also be significant in some situations, as can skin and extremity doses from plutonium x-rays. Overall, average individual annual doses at these facilities are slightly higher than the DOE average. The collective doses received by employees at these facilities are generally higher than the collective doses at other facility types because of the large number of individuals employed.

Also of significant concern at these facilities is inhalation of plutonium, where inhalation of very small amounts could result in doses exceeding limits. To prevent plutonium intakes, strict controls are in place including process containment, contamination control procedures, and air monitoring and bioassay programs (Faust et al. 1988). As a result, significant internal exposures are very rare at these facilities.

3.11 OTHER

Individuals placed in this facility type can be generally classified under three categories: 1) those who worked in a facility that did not match one of the ten facility types described above, 2) those who did not work for any appreciable time at any specific facility, such as transient workers, or 3) those for whom facility type was not indicated on the report forms. Examples of a facility type not included in the ten described above include construction and irradiation facilities. In general, employees classified under this facility type receive annual doses significantly less than the annual doses averaged over all DOE facilities. However, the wide variation in the type of work performed by these individuals results in a wide variation in the types and levels of exposures. Although

gamma photons are predominant, some individuals may be exposed to beta particles, x-rays, neutrons, or airborne radioactive material.

4.0 SUMMARY OF IONIZING RADIATION DOSES

Monitoring is required by DOE Order 5480.11 when the potential exists for an individual to receive an annual effective dose equivalent above 100 mrem (1 mSv), or an annual dose equivalent to individual organs above 10% of the exposure limits. Depending on the administrative policy of the contractor, monitoring may also be provided to individuals, such as clerical workers, for whom the exposure potential is extremely low.

On November 6, 1987, DOE promulgated revised reporting requirements in DOE Order 5484.1, which affected the reporting of occupational doses received during 1987 and beyond. Before 1987, DOE contractors were required to report only the number of individuals who received an occupational whole-body exposure in one of 16 dose-equivalent intervals ranging from "less than measurable" to "greater than 10 rem." Contractors are now required, however, to submit detailed exposure data for individual employees who were monitored and for visitors who received a measurable exposure. (Contractors are also required to provide a count of the total number of visitors monitored.) Data now required to be submitted for each individual include total effective dose equivalent, external penetrating dose equivalent (including neutron), shallow dose equivalent, and extremity dose equivalent. This report is a summary of the dose equivalents received by DOE and DOE contractor employees and visitors in 1989 as reported pursuant to DOE Order 5484.1.

One benefit of the new reporting requirements is that calculation of collective dose equivalents received by DOE and DOE contractor employees and visitors is more accurate than in the past. Prior to the 1987 reporting year, collective dose equivalents were calculated by multiplying the number of individuals who received dose equivalents in various dose-equivalent intervals by the midpoint of those intervals and then summing the products. For this report, however, this calculational method was not necessary because the actual doses received by individuals were reported by the contractors. This allowed the actual collective dose equivalents received by individuals to be determined. Analysis of the 1987, 1988, and 1989 data indicated that using the midpoints of the dose-equivalent ranges, rather than the actual dose equivalents reported, would have resulted in an overestimate of the collective dose equivalent received by all DOE and DOE contractor employees and visitors by 15.5% for 1987, 25.3% for 1988, and 31.7% for 1989. Therefore, it is likely that the collective dose equivalents reported for previous years were overestimated by approximately 24%.

Another important change resulting from the revised reporting requirements is that the specific employees for whom the results of monitoring are required to be reported have changed. Although both the former and current reporting requirements state that annual reports shall be submitted for all monitored DOE and DOE contractor workers, the current requirements define the term "monitored worker" whereas the former requirements did not. Monitored workers are defined by the current requirements as those employees who work with or near ionizing radiation or radioactive material and who are monitored in accordance with DOE Order 5480.11. Therefore, the term "monitored worker" is generally considered to be synonymous with the term "radiation worker." As a result, some contractors chose not to report data for individuals who were issued dosimeters but were not required to be monitored, especially those who received no measurable dose. This probably accounts for the significant decrease in the number of monitored employees reported for 1987, 1988, and 1989 compared to previous years (see Figure 4.1).

4.1 DISTRIBUTION BY DOSE INTERVAL

The number of employees and visitors who received a dose equivalent in each of 16 dose-equivalent ranges is presented in Table 4.1. No DOE or DOE contractor employee received a dose equivalent greater than 3 rem (30 mSv), which is significantly less than the DOE radiation protection standard of 5 rem (50 mSv). A total of 90,882 DOE and DOE contractor employees were reported to have been monitored for whole-body ionizing radiation exposure in 1989. This represents 53.6% of all DOE and DOE contractor employees. In addition to the employees, 12,643 visitors were monitored at DOE facilities. Visitors may include radiation workers from another DOE facility present on a temporary basis.

A comparison of the number of DOE and DOE contractor employees, the number of monitored employees reported, and the number of monitored employees reported who did not receive a measurable dose equivalent is presented for the years 1980-1989 in Figure 4.1. The figure also illustrates the average dose equivalent per employee who received a measurable exposure. The number of monitored employees reported for 1987, 1988, and 1989 decreased significantly from the number reported for previous years.

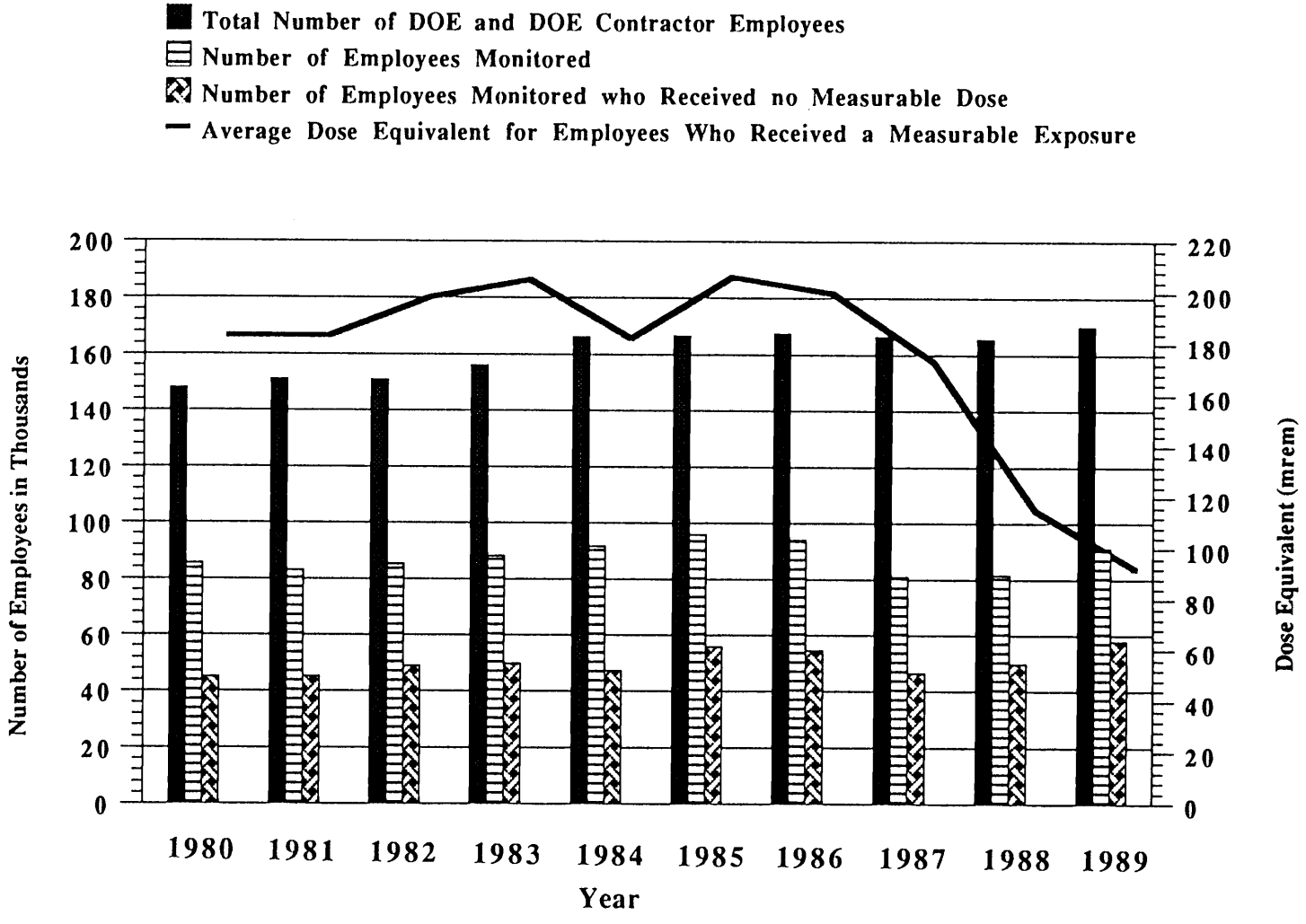

FIGURE 4.1. Comparison of Number of Employees, Number of Employees Monitored, and Number of Employees Monitored Who Received No Measurable Dose Equivalent, 1980-1989

TABLE 4.1. Distribution of Whole-Body Ionizing Radiation Doses for DOE/DOE Contractor Employees and Visitors by Dose-Equivalent Interval, 1989

Dose-Equivalent Interval (rem)	Number of Persons			Collective Person-rem		
	Employees	Visitors	Total	Employees	Visitors	Total
< Measurable	57,533	5,590	63,123	0	0	0
Measurable to 0.10	26,759	6,426	33,185	703	127	830
0.10 to 0.25	3,608	398	4,006	558	60	619
0.25 to 0.50	1,632	153	1,785	568	53	621
0.50 to 0.75	562	38	600	342	24	366
0.75 to 1.00	330	22	352	284	19	303
1 to 2	437	16	453	569	20	589
2 to 3	21	0	21	48	0	48
3 to 4	0	0	0	0	0	0
4 to 5	0	0	0	0	0	0
5 to 6	0	0	0	0	0	0
6 to 7	0	0	0	0	0	0
7 to 8	0	0	0	0	0	0
8 to 9	0	0	0	0	0	0
9 to 10	0	0	0	0	0	0
> 10	0	0	0	0	0	0
Total	90,882	12,643	103,525	3,073	303	3,375

Of the monitored employees reported for 1989, 63.3% received a dose equivalent that was less than measurable; 36.2% received a dose equivalent between measurable and 1 rem (10 mSv); and 0.5% received a dose equivalent greater than 1 rem (10 mSv) (Figure 4.2). For visitors to DOE facilities in 1989, the dose equivalent received by 44.2% was less than measurable; 55.6% received a dose equivalent between measurable and 1 rem (10 mSv); and 0.2% received a dose equivalent greater than 1 rem (10 mSv) (Figure 4.2). No visitor received a dose equivalent greater than 2 rem (20 mSv).

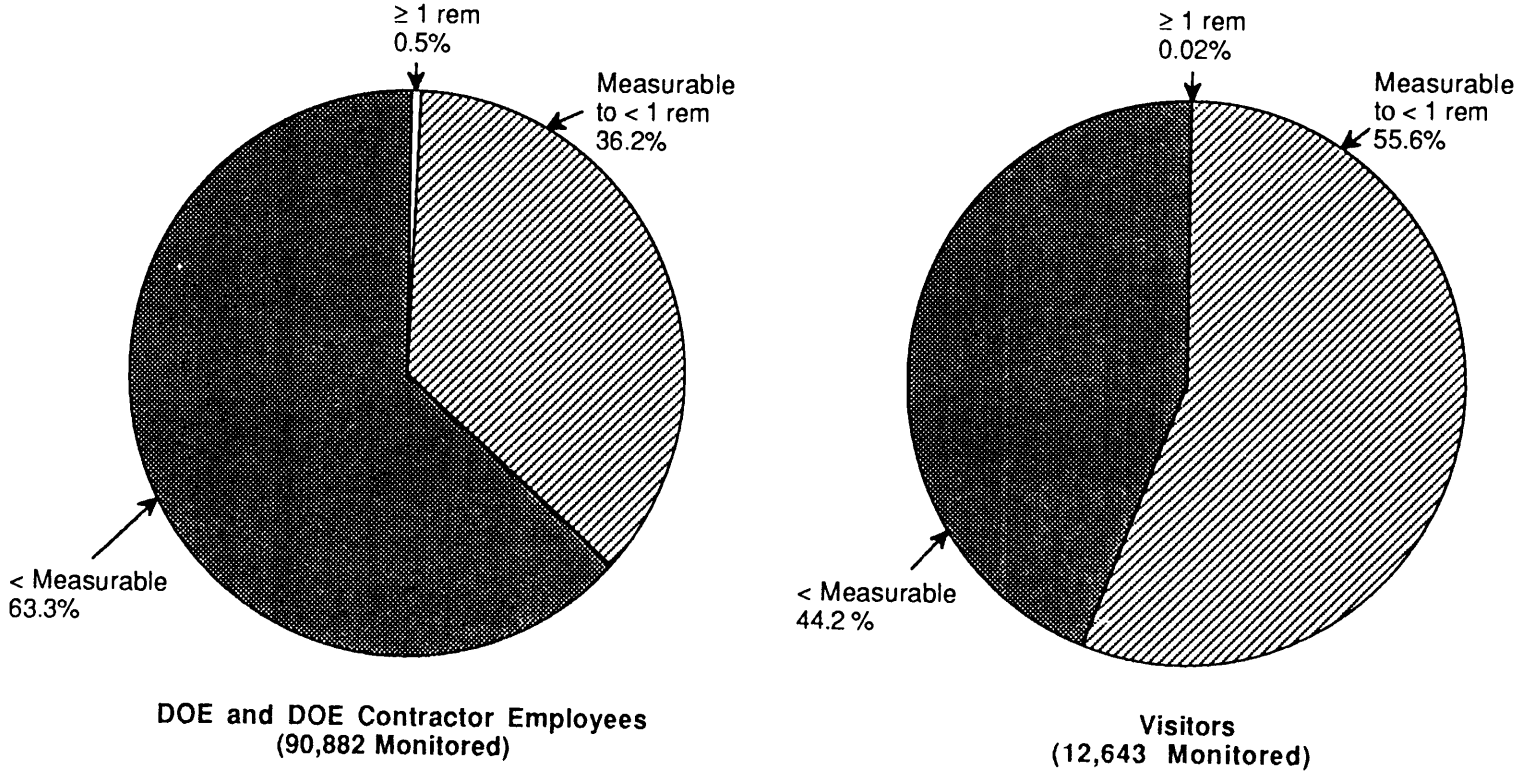

FIGURE 4.2. Percentage of Monitored Employees and Percentage of Monitored Visitors Who Received Dose Equivalents Less than Measurable, Measurable to 1 rem, or Greater than 1 rem, 1989

The collective whole-body dose equivalent was 3,073 person-rem (30.73 person-Sv) for all DOE and DOE contractor employees, and 303 person-rem (3.03 person-Sv) for visitors to DOE facilities, for a total DOE collective dose equivalent of 3,375 person-rem (33.75 person-Sv). The contribution of the individuals (employees and visitors) in each dose-equivalent interval to the collective dose equivalent is shown in Figure 4.3. Individuals whose exposure was between measurable and 1 rem (10 mSv) contributed the greatest portion (81.2%) of the total person-rem.

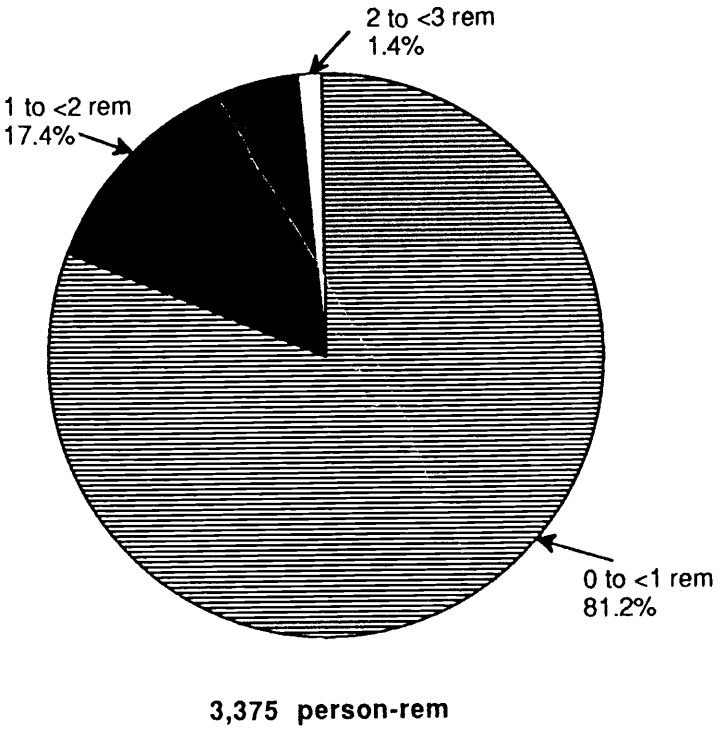

FIGURE 4.3. Contribution of Each Dose-Equivalent Interval to the Total Collective Dose Equivalent, 1989

The distribution of whole-body doses for DOE and DOE contractor employees for the years 1965-1989 is presented in Table 4.2. As indicated, the fraction of all monitored employees who received a dose equivalent greater than 1 rem (10 mSv) has declined dramatically since 1965, starting at about 5%, leveling off at about 2% from 1977 to 1987, and dropping to less than 1% in 1988 and 1989. This general downward trend in occupational radiation exposures can be observed in Figure 4.4, which shows the collective dose equivalent for employees from 1965 to 1989 who received a dose equivalent greater than 1 rem (10 mSv). The collective dose equivalent for employees who received an exposure less than 1 rem (10 mSv) was not included because, before 1974, less-than-measurable exposures were not distinguished from measurable exposures in the reporting system. This decrease in collective dose equivalent has been achieved even though some work was performed in older facilities that were not constructed using current design criteria. The trend reflects both changes in the nature of the work performed at DOE facilities and the required application of ALARA practices throughout all DOE operations. The most recent decrease may be attributable in part to reduced operations at some DOE facilities.

Analysis of occupational doses is commonly performed by fitting the data to a lognormal distribution (Brodsky et al. 1976; Brooks 1988). Figure 4.5 presents the 1989 data for DOE and DOE contractor employees on a lognormal probability plot. If the data in Figure 4.5 were truly distributed lognormally, the data points would form a straight line. The fact that the distributions curve upward indicates that the DOE occupational dose distributions are affected significantly by dose limits.

Figure 4.5 is useful for indicating the fraction of employees whose dose equivalents exceed various values as well as the fraction of the collective dose equivalent that is attributable to various ranges of individual dose equivalents. For example, the figure indicates that although less than 1% of monitored DOE and DOE contractor employees received a dose equivalent greater than 1 rem (10 mSv), approximately 20% of the employee collective dose equivalent was attributable to individual dose equivalents greater than 1 rem (10 mSv).

TABLE 4.2. Distribution of Whole-Body Ionizing Radiation Doses for DOE/DOE Contractor Employees, 1965-1989

	Number of Employees Receiving Radiation Doses in Each Dose-Equivalent Range (rem)														
Year	0-1[a] <Meas.	Meas.-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12	Monitored
1965	128,360		4,158	1,704	515	294	70	32	26	25	22	6	2		135,214
1966	131,522		3,706	1,630	593	313	88	47	24	6	2			1	137,932
1967	102,510		3,472	1,572	555	168	35	29	23	17	4	1			108,386
1968	103,206		2,799	1,408	425	144	3	1							107,986
1969	98,625		2,554	1,313	335	86	4					1			102,918
1970	92,185		2,698	1,329	279	158	5	4	2		1				96,661
1971	90,640		2,380	888	275	118	8	3				1		2	94,315
1972	86,077		2,130	929	219	95	8	2							89,460
1973	89,071		1,944	727	172	60	2	1							91,977
1974	43,184	32,500	1,667	688	149	40	4								78,232
1975	43,310	42,141	1,846	753	232	142				1					88,425
1976	40,083	47,886	1,679	475	70	6	1								90,200
1977	43,017	49,948	1,579	545	103	23			1	2				2	95,220
1978	44,898	55,296	1,323	439	53	11									102,020
1979	50,003	52,235	1,286	416	33	10	1							2	104,986
1980	45,054	38,895	1,113	387	16										85,465
1981	45,224	36,561	967	263	29	5									83,049
1982	48,968	34,949	1,010	313	56	28									85,324
1983	49,871	36,768	1,270	294	49	31									88,283
1984	47,327	42,696	1,226	312	31	11									91,603
1985	55,939	38,085	1,366	356	51	8				1					95,806
1986	54,581	37,774	1,298	349	35	1		1					1		94,040
1987	46,512	32,939	1,258	283	36										81,028
1988	49,833	31,260	502	34											81,629
1989	57,533	32,891	437	21											90,882

(a) Separation of data before 1974 is unavailable.

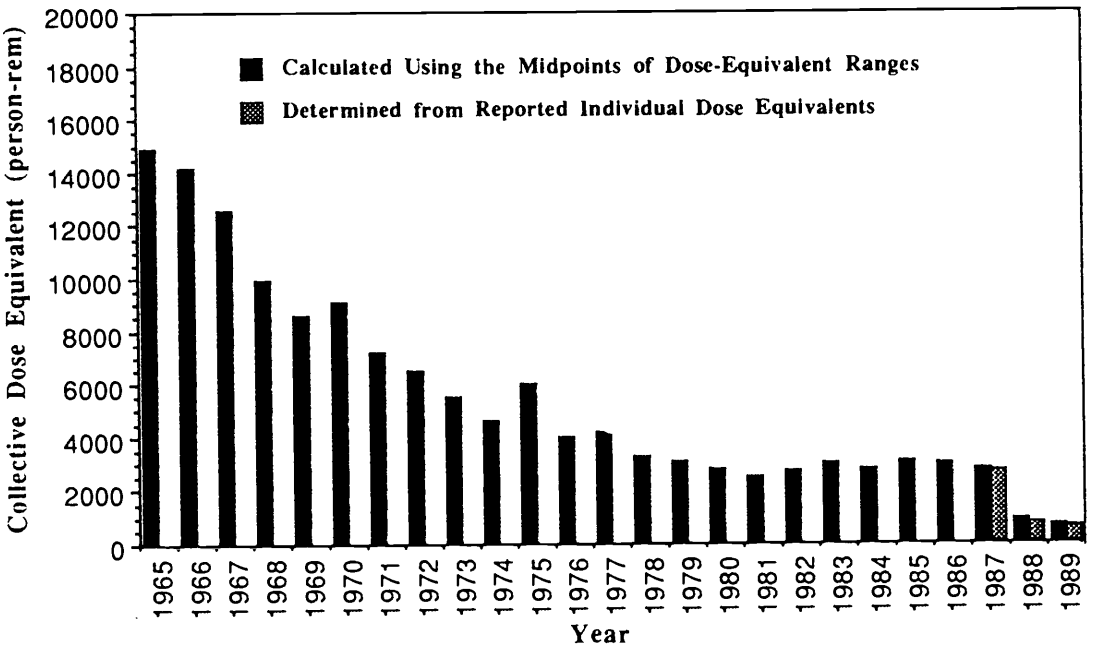

FIGURE 4.4. Total Collective Dose Equivalent for All DOE/DOE Contractor Employees Who Received a Dose Equivalent Greater than 1 rem, 1965-1989

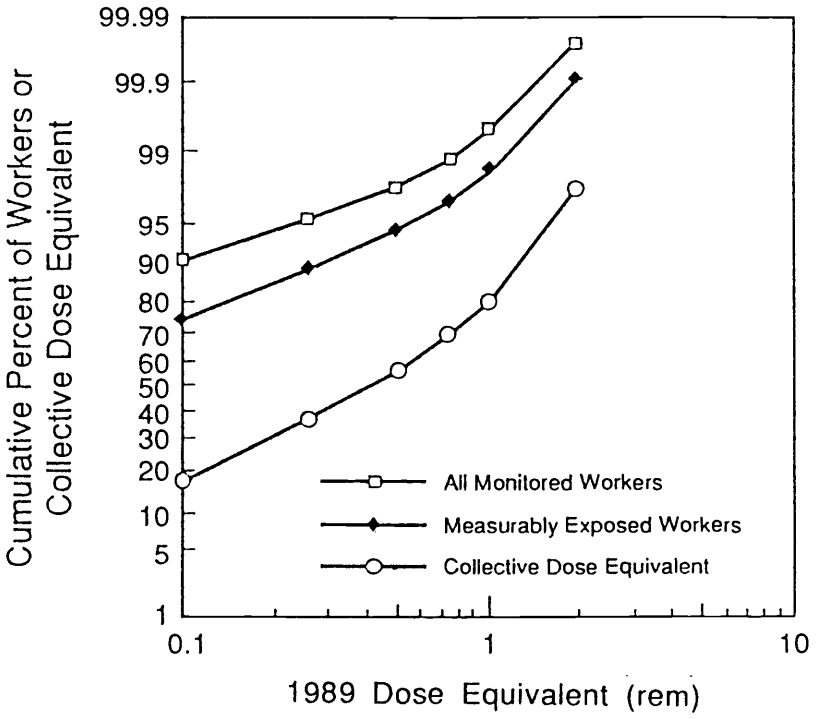

FIGURE 4.5. Lognormal Probability Plots of Annual Exposure for Potentially Exposed and Measurably Exposed DOE and DOE Contractor Employees, 1989

4.2 DISTRIBUTION BY FACILITY TYPE

The number of individuals (employees and visitors) and the distribution of the annual whole-body dose equivalents in each of 11 facility categories were reported to the central repository. The assignment of exposures to one of the 11 facility types (listed in DOE Order 5484.1) is a policy decision of each field organization. For this section of the report, visitors and DOE offices were also considered a facility type. The contribution of each facility type to the collective dose equivalent is shown in Figure 4.6. The largest percentage of the total collective dose equivalent (17.6%) was in the category "Maintenance and Support." The smallest contribution (0.1%) was from DOE offices. A summary of the data is presented in Table 4.3.

The average dose equivalent by facility type per individual monitored and per individual who received a measurable dose equivalent is shown in Table 4.4. The average dose equivalent per individual

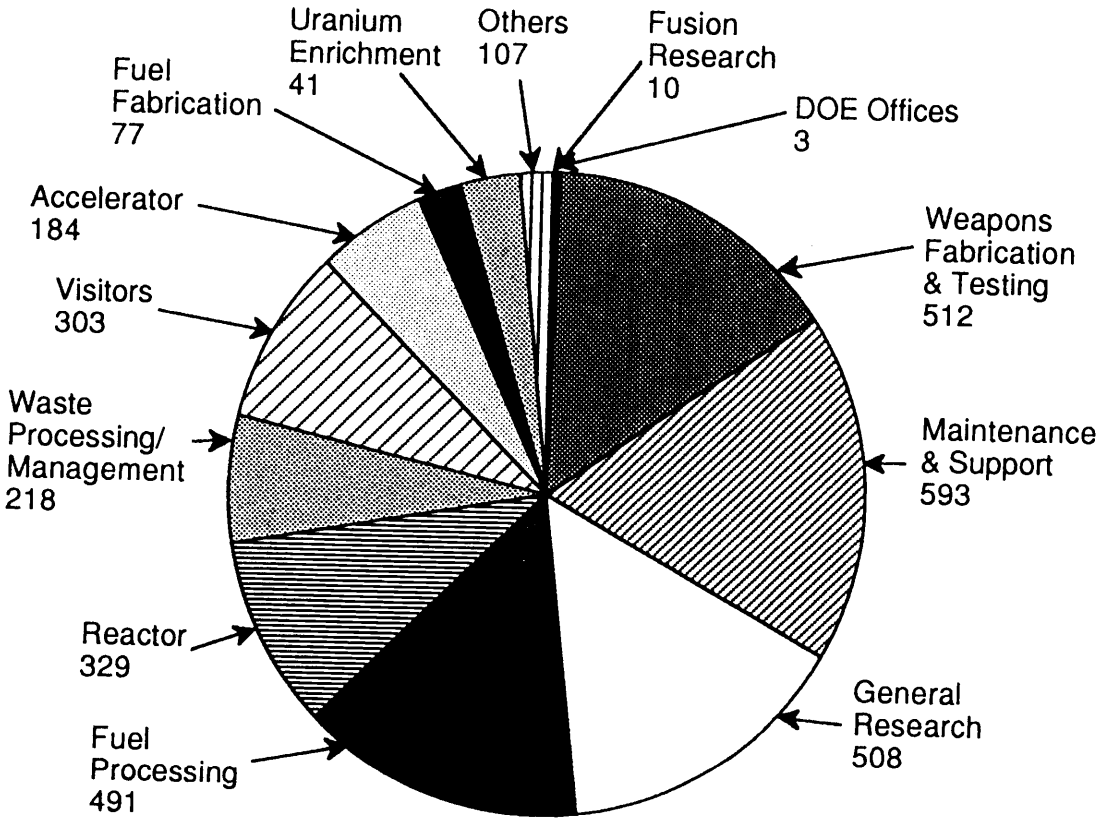

FIGURE 4.6. Contribution of Each Facility Type to the Total Collective Dose Equivalent, 1989 (Numbers indicate person-rem.)

TABLE 4.3. Distribution of Annual Whole-Body Radiation Doses for Monitored DOE/DOE Contractor Employees and Visitors by Facility Type, 1989[a]

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose-Equivalent Range (rem)															Total Persons	Total Person-rem
	≤ Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Accelerator	3,045	1,187	198	103	45	24	24	2									4,628	184
Fuel/Uran. Enrichment	3,744	1,417	59	11	1		1										5,233	41
Fuel Fabrication	1,276	925	124	54	9	4	4										2,396	77
Fuel Processing	1,655	1,034	330	214	82	75	158	2									3,550	491
Maint. and Support	15,127	6,557	909	371	100	38	37	4									23,143	593
Reactor	1,600	2,923	368	135	52	27	61	8									5,174	329
Research, General	10,767	4,152	578	249	81	60	88	3									15,978	508
Research, Fusion	1,203	253	10	1													1,467	10
Waste Proc./Management	2,552	1,637	259	143	60	22	17	1									4,691	218
Weapons Fab. & Test.	9,533	3,664	664	317	123	76	44										14,421	512
Other	6,191	2,867	106	34	9	4	3	1									9,215	107
Visitors	5,590	6,426	398	153	38	22	16										12,643	303
DOE Offices	840	143	3														986	3
Total Persons	63,123	33,185	4,006	1,785	600	352	453	21									103,525	
Total Person-rem		830	619	621	366	303	589	48										3,375

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

TABLE 4.4. Collective Dose-Equivalent for Monitored DOE/DOE Contractor Employees and Visitors by Facility Type, 1989

Facility Type	Number of Individuals	Number of Individuals with Measurable Doses	Collective Dose-Equivalent (person-rem)	Average Dose-Equivalent (mrem) per Individual	Dose-Equivalent (mrem) per Individual with Measurable Doses
Accelerator	4,628	1,583	184	40	116
Fuel/Uran. Enrichment	5,233	1,489	41	8	28
Fuel Fabrication	2,396	1,120	77	32	69
Fuel Processing	3,550	1,895	491	138	259
Maint. and Support	23,143	8,016	593	26	74
Reactor	5,174	3,574	329	64	92
Research, General	15,978	5,211	508	32	97
Research, Fusion	1,467	264	10	6	36
Waste Proc./Management	4,691	2,139	218	46	102
Weapons Fab. & Test.	14,421	4,888	512	36	105
Other	9,215	3,024	107	12	35
Visitors	12,643	7,053	303	24	43
DOE Offices	986	146	3	3	20
Total	103,525	40,402	3,375	33	84

monitored for all facilities was 33 mrem (0.33 mSv). The highest average dose equivalent per individual monitored (138 mrem) (1.38 mSv) was observed at fuel-processing facilities, and the lowest was observed at DOE offices (3 mrem) (0.03 mSv). The average dose equivalent per individual who received a measurable dose equivalent was 84 mrem (0.84 mSv). The highest average dose equivalent per individual who received a measurable dose equivalent (259 mrem) (2.59 mSv) was observed at fuel-processing facilities, and the lowest (20 mrem) (0.20 mSv) was observed at DOE offices.

4.3 DISTRIBUTION BY FIELD ORGANIZATION

For each field organization, the number of monitored individuals reported, the number of individuals who received a measurable dose equivalent, and the collective dose equivalent are shown in Table 4.5.

Differences in the collective dose equivalent at each field organization reflect differences in the number of employees at the facilities, the nature of the work performed, and the administrative policy concerning whether the dose distribution is reported for all monitored employees or only for those for whom monitoring is required. Table 4.6 provides an indication of the work performed at each field organization by showing the fraction of the collective dose equivalent at each field organization attributed to each facility type. Table 4.7 presents collective dose equivalents for each field organization from 1980 to 1989.

4.4 DISTRIBUTION BY OCCUPATION CATEGORY

DOE Order 5484.1 requires that for each monitored individual (employee and visitor) a three-digit occupation code be included indicating the generic occupation that best fits the individual's occupation title. The 44 three-digit codes pertain to DOE occupation codes summarizing all Standard Occupational Classification (SOC) codes from the Department of Commerce's SOC Manual of 1980. The DOE is considering a revised requirement to report occupations by the full four-digit SOC code. This would eliminate the need for an intermediate code, standardize occupational classifications, and provide research data at a greater level of detail.

TABLE 4.5. Collective Dose-Equivalent for Monitored DOE/DOE Contractor Employees and Visitors by Field Organization, 1989

Field Organization	Number of Monitored Individuals	Number of Individuals with Measurable Doses	Collective Dose-Equivalent (person-rem)	Average Dose-Equivalent (mrem) per Individual	Average Dose-Equivalent (mrem) per Individual with Measurable Doses
Albuquerque Operations	19,856	3,669	432	22	118
Chicago Operations	10,099	3,364	240	24	71
DOE Headquarters	254	16	0	1	10
Idaho Operations	6,194	2,020	336	54	166
Nevada Operations	2,138	65	6	3	100
Oak Ridge Operations	12,731	4,852	218	17	45
Pittsburgh N.R. Office	2,131	1,694	85	40	50
Richland Operations	8,566	5,590	619	72	111
Rocky Flats Operations	7,757	3,939	412	53	105
San Francisco Operations	10,535	905	82	8	90
Savannah River Operations	20,250	12,007	804	40	67
Schenectady N.R. Office	3,014	2,281	140	47	61
Total DOE	103,525	40,402	3,375	33	84

TABLE 4.6. Percent of Collective Dose-Equivalent for Monitored DOE/DOE Contractor Employees and Visitors Attributed to a Facility Type Within Each Field Organization, 1989

	Facility Type												
		Fuel			Maint&		Research		Waste	Weapon			DOE
Field Organization	Accel	Enrich	Fab	Proc	Support	Reactor	Genrl	Fusion	Proc	F&T	Other	Visit	Office
Albuquerque Operations	15.7				10.6	2.6	48.0	.1	.2	9.9	4.9	8.0	
Chicago Operations	34.5		.2		6.6	8.6	24.7	3.6	2.2		.4	19.2	
DOE Headquarters													100.0
Idaho Operations				64.8	1.7	12.0	5.6		1.5		9.0	5.5	
Nevada Operations					38.9					60.4		.8	
Oak Ridge Operations		16.9	16.6	1.1			18.7			30.6		16.0	
Pittsburgh N.R. Office						37.2	61.8				.6	.4	
Richland Operations			1.7	10.0	24.5	26.3	13.6		21.1		1.8	.5	.4
Rocky Flats Operations										94.3		5.7	
San Francisco Operations	40.2	5.1			19.2		17.0	.6		8.2	.1	9.5	
Savannah River Operations			3.8	26.0	44.2	4.6	3.0		9.4	.4	5.3	3.3	
Schenectady N.R. Office						18.1	4.8				.1	77.0	
Total DOE	5.4	1.2	2.3	14.6	17.6	9.7	15.0	.3	6.5	15.2	3.2	9.0	.1

TABLE 4.7. Collective Dose-Equivalent (person-rem) for Monitored DOE/DOE Contractor Employees and Visitors by Field Organization, 1980-1989[a]

Field Organization	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Albuquerque Operations[b]	873	1,147	1,112	1,190	1,423	1,344	979	483	556	432
Chicago Operations	918	758	587	623	615	502	408	348	310	240
Idaho Operations	593	302	363	353	441	420	620	318	253	336
Nevada Operations	50	36	29	25	24	34	65	8	13	6
Oak Ridge Operations	604	437	401	371	419	353	587	517	360	218
Pittsburgh N.R. Office	186	185	194	220	180	180	109	78	86	85
Richland Operations	2,256	2,093	2,272	2,458	2,399	2,548	2,321	2,477	654	619
Rocky Flats Operations[b]	827	877	1,173	1,142	1,315	1,556	1,407	880	654	412
San Francisco Operations	240	171	289	267	195	187	99	78	74	82
Savannah River Operations	1,391	1,401	1,310	1,293	1,283	1,394	1,498	945	887	804
Schenectady N.R. Office	79	76	147	217	130	165	167	220	81	140
Total	8,024	7,483	7,879	8,158	8,422	8,684	8,261	6,353	3,928	3,375

(a) The data may differ slightly from previous reports due to revisions received after publication.
(b) Effective 1/1/90, Rocky Flats Operations was designated as a separate DOE field organization. Accordingly, all current and historical radiation data associated with the Rocky Flats facilities have been extracted from Albuquerque Operations data and identified separately.

For this report, the 44 DOE occupational classifications were summarized into 11 general occupations to facilitate analysis:

- Management - managers and administrators, sales, support and clerical
- Scientists - scientists, engineers, health physicists, miscellaneous professionals, doctors and nurses
- Technicians - health technicians, engineering technicians, science technicians, radiation monitors/technicians, miscellaneous technicians
- Service - firefighters, security guards, food service employees, janitors, miscellaneous service
- Agriculture - groundskeepers, forest workers, miscellaneous agriculture
- Construction - mechanics/repairers, masons, carpenters, electricians, painters, pipe fitters, miners/drillers, miscellaneous repair/construction
- Production - machinists, sheet metal workers, operators - plant/system/utility, machine setup/operators, welders and solderers, miscellaneous precision/production
- Transport - truck drivers, bus drivers, pilots, equipment operators, miscellaneous transport
- Laborers - handlers/laborers/helpers
- Miscellaneous - military, miscellaneous
- Unknown - indicates that an occupation code was not specified on the form.

Table 4.8 lists the number of individuals monitored, the number of individuals monitored who received a measurable dose equivalent, and the average dose equivalents for each occupation category. The "Scientists" category accounted for both the most individuals monitored and the most individuals monitored who received a measurable exposure. Individuals in the "Production" category received the highest average dose equivalent per individual monitored (101 mrem) (1.01 mSv) and the highest average dose equivalent per individual monitored who received a measurable exposure (167 mrem) (1.67 mSv). Figure 4.7 illustrates the data in Table 4.8 including an indication of the sex distribution of the individuals. Figure 4.8 illustrates the collective dose equivalent values in Table 4.8 as a pie chart. Table 4.9 lists the number of individuals monitored according to occupation and facility type.

TABLE 4.8. Distribution of Whole-Body Ionizing Radiation Dose for DOE/DOE Contractor Employees and Visitors by Occupation, 1989

Occupation	Number of Individuals Monitored	Number of Individuals Monitored Who Received a Measurable Exposure	Collective Dose Equivalent (person-rem)	Average Dose Equivalent per Individual Monitored (mrem)	Average Dose Equivalent Per Individual Monitored Who Received a Measurable Exposure (mrem)
Unknown	18,871	5,739	481	25	84
Management	11,031	3,527	190	17	54
Scientists	26,437	8,401	402	15	48
Technicians	11,505	5,117	672	58	131
Service	6,281	2,584	84	13	33
Agriculture	102	25	0	0	0
Construction	12,571	3,996	554	44	139
Production	8,122	4,899	819	101	167
Transportation	2,575	718	41	16	57
Laborers	2,089	1,065	92	44	86
Miscellaneous	3,940	1,345	40	10	30

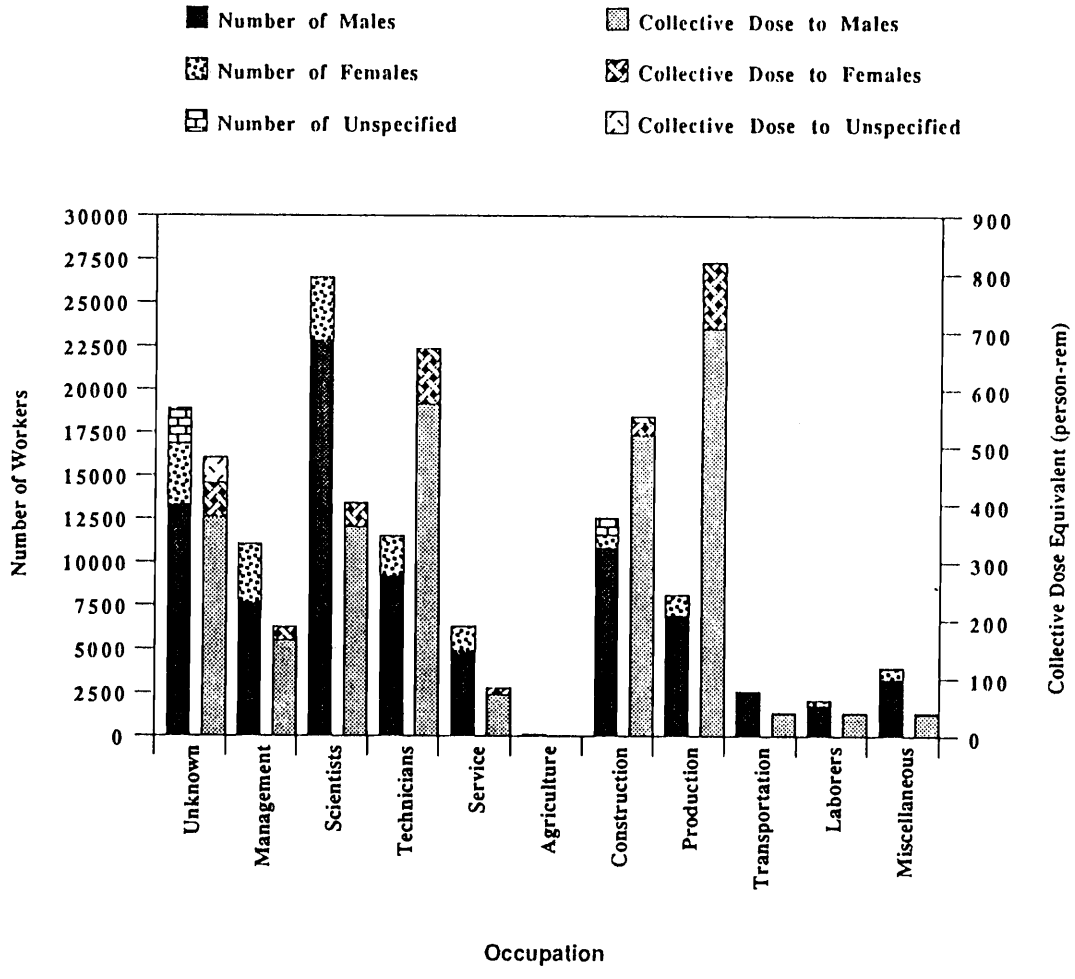

FIGURE 4.7. Penetrating Doses Received by DOE and DOE Contractor Employees and Visitors by Occupation, 1989

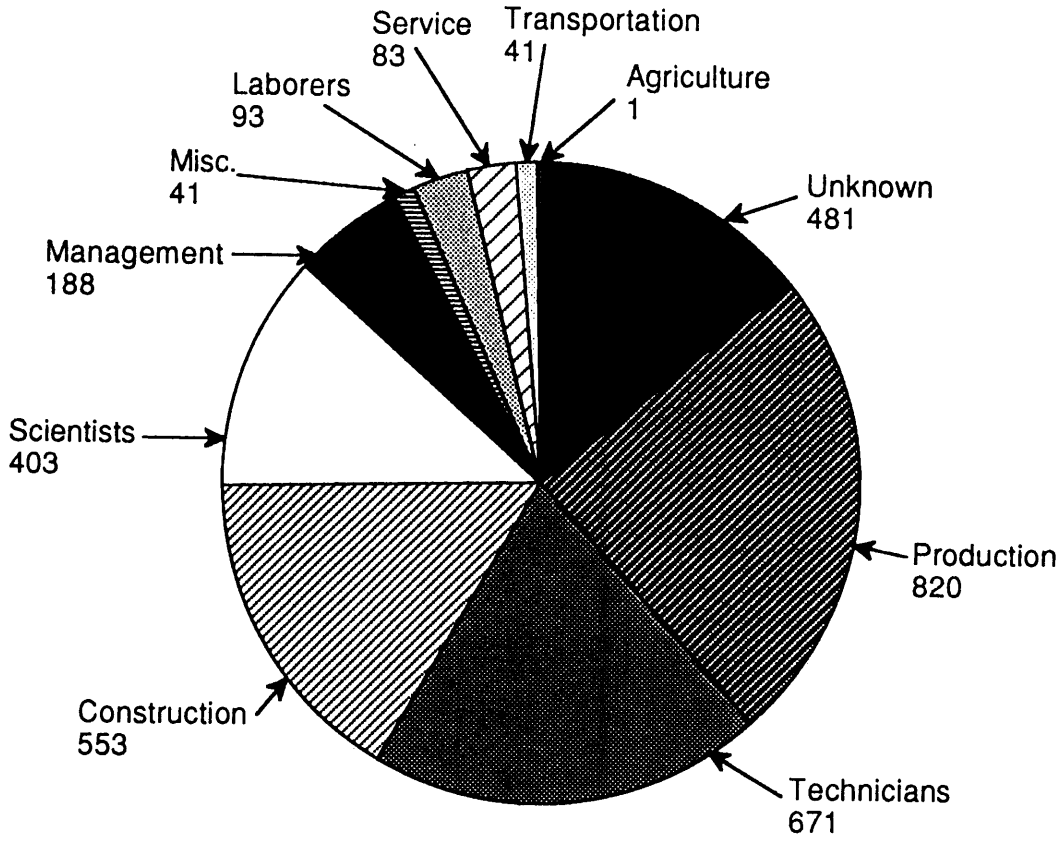

FIGURE 4.8. Contribution of Each Occupation Category to the Total Collective Dose Equivalent, 1989 (Numbers indicate person-rem.)

TABLE 4.9. Number of Monitored DOE/DOE Contractor Employees and Visitors by Occupation and Facility Type, 1989

Facility Type	Total Persons Monitored	Unknown	Management	Scientists	Technicians	Service	Agriculture	Construction	Production	Transportation	Laborers	Miscellaneous	Total Person-rem
Accelerator	5,429	1,296	197	1,966	1,461	192	16	128	104	38	1	30	200
Fuel/Uranium Enrichment	5,709	241	822	1,237	649	428	1	1,121	903	51	198	58	44
Fuel Fabrication	4,054	1,830	281	698	286	191	0	230	450	40	47	1	102
Fuel Processing	3,561	53	506	1,387	172	76	1	524	782	36	12	1	491
Maintenance and Support	25,142	5,333	3,050	3,524	1,718	1,572	34	7,091	1,095	847	926	12	618
Reactor	6,377	31	899	2,438	662	152	0	788	898	97	83	329	438
Research, General	16,547	3,847	1,179	6,038	2,469	559	8	450	350	61	100	1,486	515
Research, Fusion	1,527	148	123	654	309	55	0	128	50	0	64	56	10
Waste Proc/ Management	5,176	128	768	1,466	709	297	1	754	733	141	132	47	219
Weapons Fabrication and Testing	16,896	2,364	2,206	4,024	2,121	583	0	925	2465	141	218	1,849	543
Other	13,107	3,601	1,000	3,005	949	2,236	41	632	292	1,123	357	71	196
Total Persons Monitored	103,525	18,872	11,031	26,437	11,505	6,281	102	12,571	8,122	2,575	2,089	3,940	
Total Person-rem		481	188	403	671	83	0	553	820	41	93	41	3,375

The number of individuals monitored and collective dose equivalent by occupation and dose-equivalent range are illustrated in a three-dimensional format in Figure 4.9. The left half of the figure indicates the number of individuals monitored for any specified occupation and dose-equivalent range. For example, the heights of the bars indicate that most individuals monitored received either a less-than-measurable dose or a measurable dose less than 0.1 rem (1 mSv), and that more scientists and individuals of unknown occupation were monitored than were individuals of any other occupation. The exact number monitored is indicated by the numbers adjacent to the bars; for example, 398 technicians were monitored who received a dose equivalent between 0.25 and 0.50 rem (2.5 and 5.0 mSv). The right half of Figure 4.9 indicates the collective dose equivalent by occupation and dose-equivalent range. The figure demonstrates that technicians, construction workers, production workers, and individuals of unknown occupation received the majority of the collective dose equivalent received by DOE and DOE contractor employees. The numbers adjacent to the bars indicate the heights of the bars in person-rem. For example, the collective dose equivalent of the 398 technicians who received individual dose equivalents between 0.25 and 0.50 rem (2.5 and 5.0 mSv) was 137 person-rem (1.37 person-Sv).

4.5 DISTRIBUTION BY AGE AND SEX

The 1989 exposure data submitted per DOE Order 5484.1 included information on the age and sex of the exposed individuals (employees and visitors). Unfortunately, some records were submitted without the required information. For the analysis in this report, 10 age categories were defined: 19 and less, eight 5-year age groups beginning with the 20-24 age group, and ending with 65 and greater. In addition, individuals for whom age was not specified were arbitrarily placed into the 65-and-greater age group. Regarding sex of the exposed individuals, a separate category for unspecified sex was defined. It was clear from the data that if sex was not specified on the form, other information such as age, occupation, or facility type were likely to be unspecified or unknown as well. For example, of the 3,094 individuals for whom sex was not specified on the report form, 2,919 (94%) also were not identified by age. Similarly, the occupation was listed as unknown or was unspecified for 2,067 (67%) of the individuals for whom sex was unspecified.

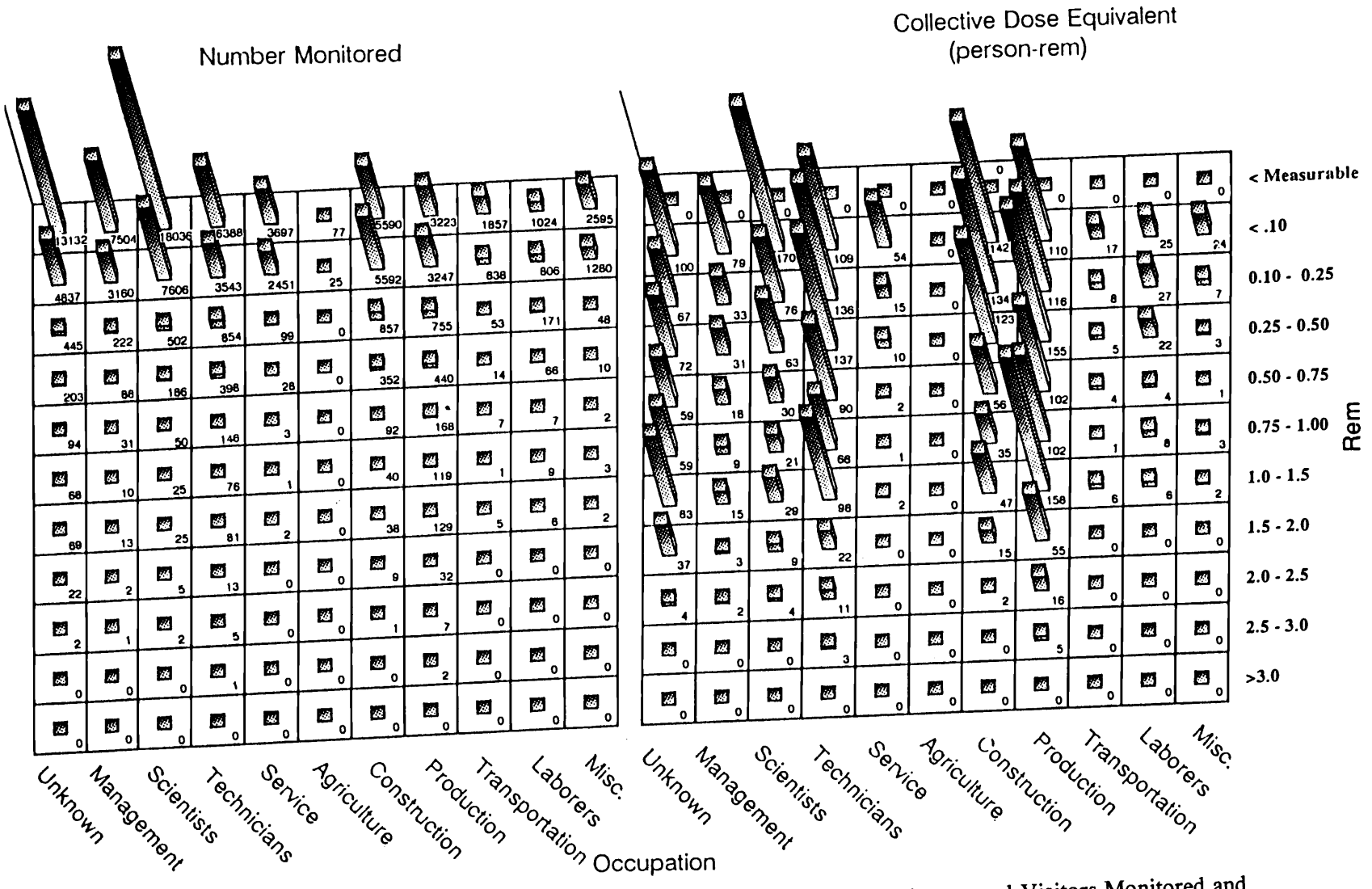

FIGURE 4.9. Three-dimensional Representation of Number of Employees and Visitors Monitored and Collective Dose Equivalent by Occupation and Dose-Equivalent Range, 1989

Table 4.10 lists the number of individuals who received various penetrating dose equivalents by age and sex. The age group having the most monitored individuals was the 30-34 group; the age group having the fewest was the 19-or-younger group. Table 4.11 presents similar data by collective dose equivalent rather than by number of monitored individuals. Again, the age group receiving the highest collective dose equivalent was the 30-34 age group; the lowest was the 19-or-younger group. Figure 4.10 illustrates the number of individuals by sex who received penetrating dose equivalents in various dose-equivalent ranges. Figure 4.11 illustrates the number of individuals by sex and age range who were monitored for ionizing radiation in 1989.

Table 4.12 lists the number of individuals monitored, the numbers of individuals monitored who received a measurable exposure, and the collective and average dose equivalents received by age range. The age groups receiving the highest average dose equivalent per individual monitored were the 25-29 and 30-34 age groups (43 mrem) (0.43 mSv); the age group receiving the lowest was the 19-or-younger group (8 mrem) (0.08 mSv). The age group receiving the highest average dose equivalent per individual who received a measurable exposure was the 30-34 age group (103 mrem) (1.03 mSv); the lowest was the 19-or-younger group (35 mrem) (0.35 mSv).

Table 4.13 presents similar data by sex rather than age. Males received approximately 88% of the collective dose equivalent received by individuals for whom sex was specified. Males also received higher average dose equivalents per individual monitored than did females (35 mrem versus 23 mrem) (0.35 mSv versus 0.23 mSv) as well as higher average dose equivalents per individual monitored who received a measurable exposure (88 mrem (0.88 mSv) versus 76 mrem (0.76 mSv)).

Because of the sensitivity of fetuses to ionizing radiation, which is greater than that of children or adults, it is important to evaluate the doses received by women of child-bearing age. Table 4.14 presents the number of women of child-bearing age (arbitrarily assumed to include women up to the age of 44) who received a measurable dose equivalent in 1989, by facility type. A total of 4,040 women of child-bearing age received a collective dose equivalent of 313 person-rem (3.13 person-Sv). The average individual dose equivalent for these women over all facilities was 77 mrem (0.77 mSv).

Figure 4.12 presents the number of individuals monitored and collective dose by age range and occupation in three-dimensional format. The figure indicates that many monitored individuals were

TABLE 4.10. Distribution of Penetrating Doses by Age, Sex, and Exposure Range for DOE and DOE Contractor Employees and Visitors, 1989

Age Range	Sex	<Meas.	Meas.-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1.0-2.0	2.0-3.0	>3.0	Total Monitored
≤19	M	269	3				1				343
	F	139	3								179
	U	7									8
20-24	M	1,924	1,136	168	62	17	10	10			3,327
	F	894	382	27	10	3	3				1,319
	U	1	1								2
25-29	M	4,786	3,232	482	238	69	47	76	4		8,934
	F	1,742	746	83	42	12	6	9			2,640
	U	10	3								13
30-34	M	7,329	4,363	682	318	128	65	88	5		12,978
	F	2,191	917	117	41	20	10	9	1		3,306
	U	2	6								8
35-39	M	7,678	4,467	603	287	95	58	80	5		13,273
	F	2,020	790	82	36	12	9	16			2,965
	U	5	8								13
40-44	M	7,221	3,865	509	220	75	46	56	3		11,995
	F	1,678	498	66	27	12	8	6			2,295
	U	3	1								4
45-49	M	6,121	2,855	327	147	45	29	26	2		9,552
	F	1,298	323	40	19	5	2	5			1,692
	U	2	2								4

TABLE 4.10. (continued)

Age Range	Sex	<Meas.	Meas.-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1.0-2.0	2.0-3.0	>3.0	Total Monitored
50-54	M	5,087	2,346	273	130	36	19	26			7,917
	F	843	234	19	6	3	2	4			1,111
	U	4	2								6
55-59	M	4,551	2,125	232	124	36	21	29	1		7,119
	F	594	152	2	7	2		2			759
	U	6	2								8
60-64	M	3,219	1,308	144	42	19	9	6			4,747
	F	340	74	6	3	1	2	2			428
	U	1	1								2
≥65 or	M	1,910	1,154	56	11	5	4	2			3,142
Unspecified	F	139	116	1	1		1				410
	U	957	1,968	81	14	5		1			3,026
Total	M	50,095	26,921	3,479	6,579	525	309	399	20	0	83,327
	F	12,030	4,269	446	192	70	43	53	1	0	14,104
	U	998	1,995	81	14	5	0	1	0	0	3,094

TABLE 4.11. Collective Dose Equivalent by Age, Sex, and Exposure Range, 1989

Age Range	Sex	Meas.-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1.0-2.0	2.0-3.0	>3.0	Total Person-rem	Average Dose Equivalent per Individual Who Received a Measurable Exposure (mrem)
≤19	M	1	0	0	0	1				1.1	41
	F	1	0							1	25
	U									0	
20-24	M	26	26	21	10	8	12			107	76
	F	9	4	3	2	2					44
	U									21	
										0	
25-29	M	86	75	82	43	41	100	9		436	105
	F	18	12	15	7	5	12				76
	U									68	
										0	
30-34	M	117	107	113	78	56	120	12		604	107
	F	23	19	14	12	9	12	2			81
	U									90	
										0	
35-39	M	117	94	100	57	51	103	11		535	96
	F	19	13	12	7	7	20				85
	U									80	
										0	
40-44	M	99	79	76	46	39	72	6		417	87
	F	13	10	9	7	7	9				88
	U									54	
										0	
45-49	M	74	50	50	27	25	34	5		265	77
	F	8	6	7	3	2	8				84
	U									33	
										0	

TABLE 4.11. (continued)

Age Range	Sex	Meas.-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1.0-2.0	2.0-3.0	>3.0	Total Person-rem	Average Dose Equivalent per Individual Who Received a Measurable Exposure (mrem)
50-54	M	59	41	45	22	17	32			217	77
	F	6	3	2	2	2	6			19	71
	U									0	
55-59	M	53	35	43	22	17	36	2		209	81
	F	4		2	1		2			10	61
	U									0	
60-64	M	33	23	15	11	8	7			97	63
	F	2	1	1	1	2	3			9	102
	U									0	
≥65 or	M	23	8	4	3	4	2			43	35
Unspec.	F	3				1				4	15
	U	36	11	5	3		1			55	27

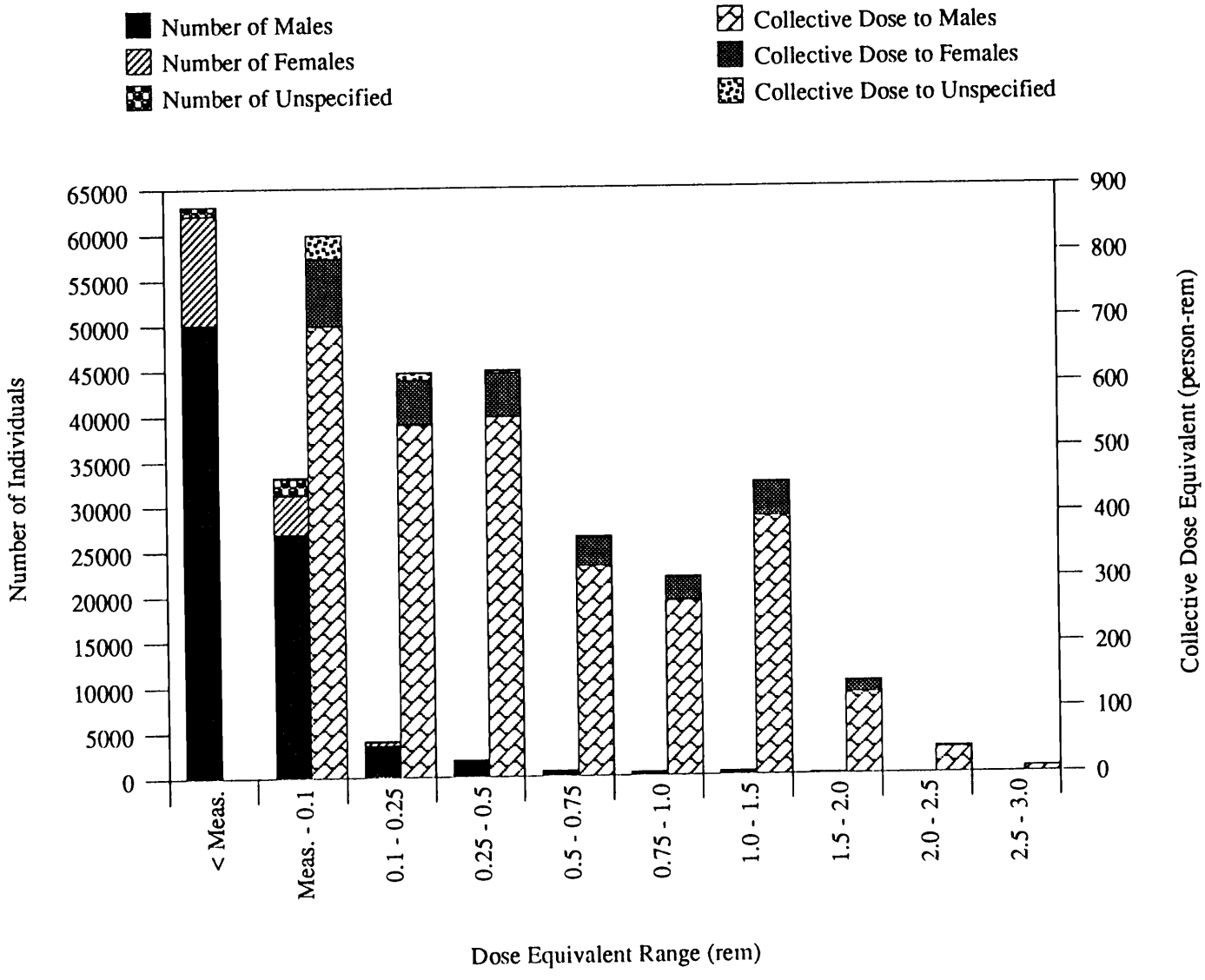

FIGURE 4.10. Distribution of Penetrating Dose Equivalents by Sex and Dose-Equivalent Range for DOE and DOE Contractor Employees and Visitors, 1989

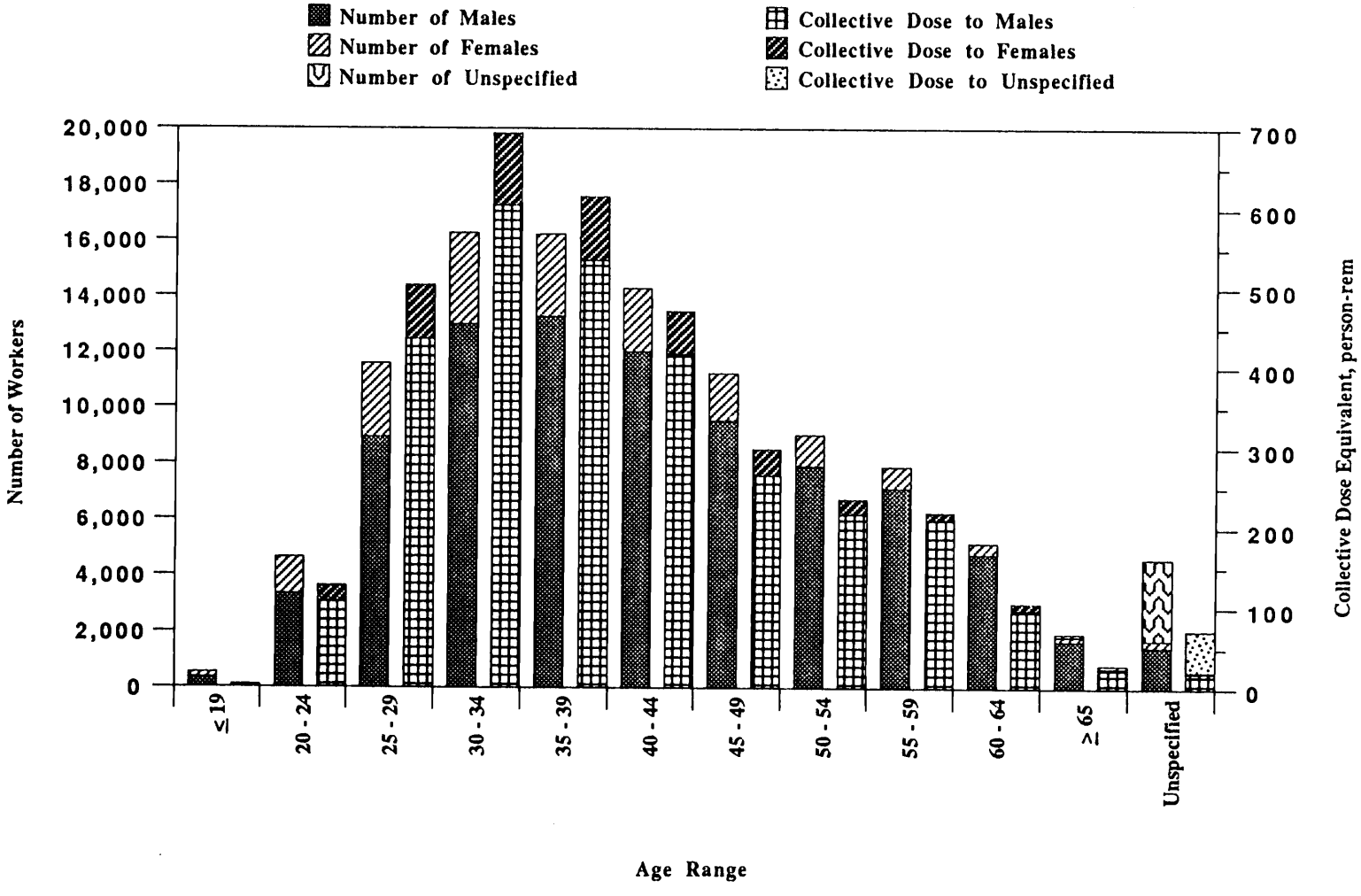

FIGURE 4.11. Number of Individuals (Employees and Visitors) Monitored and Collective Dose Equivalent by Age Range and Sex, 1989

TABLE 4.12. Number of Individuals Monitored and Average Penetrating Dose Equivalents by Age, 1989

Age Range	Number of Individuals Monitored	Number of Individuals Who Received a Measurable Exposure	Collective Dose Equivalent (person-rem)	Average Dose Equivalent per Individual Monitored (mrem)	Average Dose Equivalent per Individual Monitored Who Received a Measurable Exposure (mrem)
≤19	530	115	4	8	35
20-24	4,648	1,829	128	28	70
25-29	11,587	5,049	504	43	100
30-34	16,292	6,770	694	3	103
35-39	16,251	6,548	615	38	94
40-44	14,290	5,392	471	33	87
45-49	11,248	3,827	298	26	78
50-54	9,034	3,100	236	26	76
55-59	7,886	2,735	219	28	80
60-64	5,177	1,617	106	20	66
≥65 or Unspecified	6,578	3,572	102	16	29
Total	103,525	40,554	3,375		

TABLE 4.13. Number of Individuals Monitored and Average Penetrating Dose Equivalents by Sex, 1989

	Number of Individuals Monitored	Number of Individuals Who Received a Measurable Exposure	Collective Dose Equivalent (person-rem)	Average Dose Equivalent per Individual Monitored (mrem)	Average Dose Equivalent per Individual Monitored Who Received a Measurable Exposure (mrem)
Male	83,327	33,232	2,932	35	88
Female	17,104	5,074	388	23	76
Unspecified	3,094	2,096	56	18	28
Total	103,525	40,402	3,375	33	85

TABLE 4.14. Penetrating Doses Received by Female Employees and Visitors of Childbearing Age, 1989

Facility Type	Persons	Number of Females Receiving Measurable Doses in Each Age Group						Total Person-rem
		≤19	20-24	25-29	30-34	35-39	40-44	
Accelerator	102	3	8	28	30	23	10	10
Fuel/Uran Enrichment	159		6	21	56	52	24	4
Fuel Fabrication	185		11	39	61	40	34	13
Fuel Processing	277	1	32	67	87	59	31	50
Maint and Support	1,011	8	117	247	254	226	159	68
Reactor	327	2	34	90	87	61	53	27
Research, General	503	10	47	93	156	134	63	44
Research, Fusion	294		1	1	2	1		
Waste Proc/Management	294	1	28	67	83	69	46	22
Weapons Fab & Test	617	7	46	95	154	173	142	57
Other	560	8	95	150	145	107	55	19
Total Persons	4,040	40	425	898	1,115	945	617	
Total Person-rem		1	21	68	90	80	54	313

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

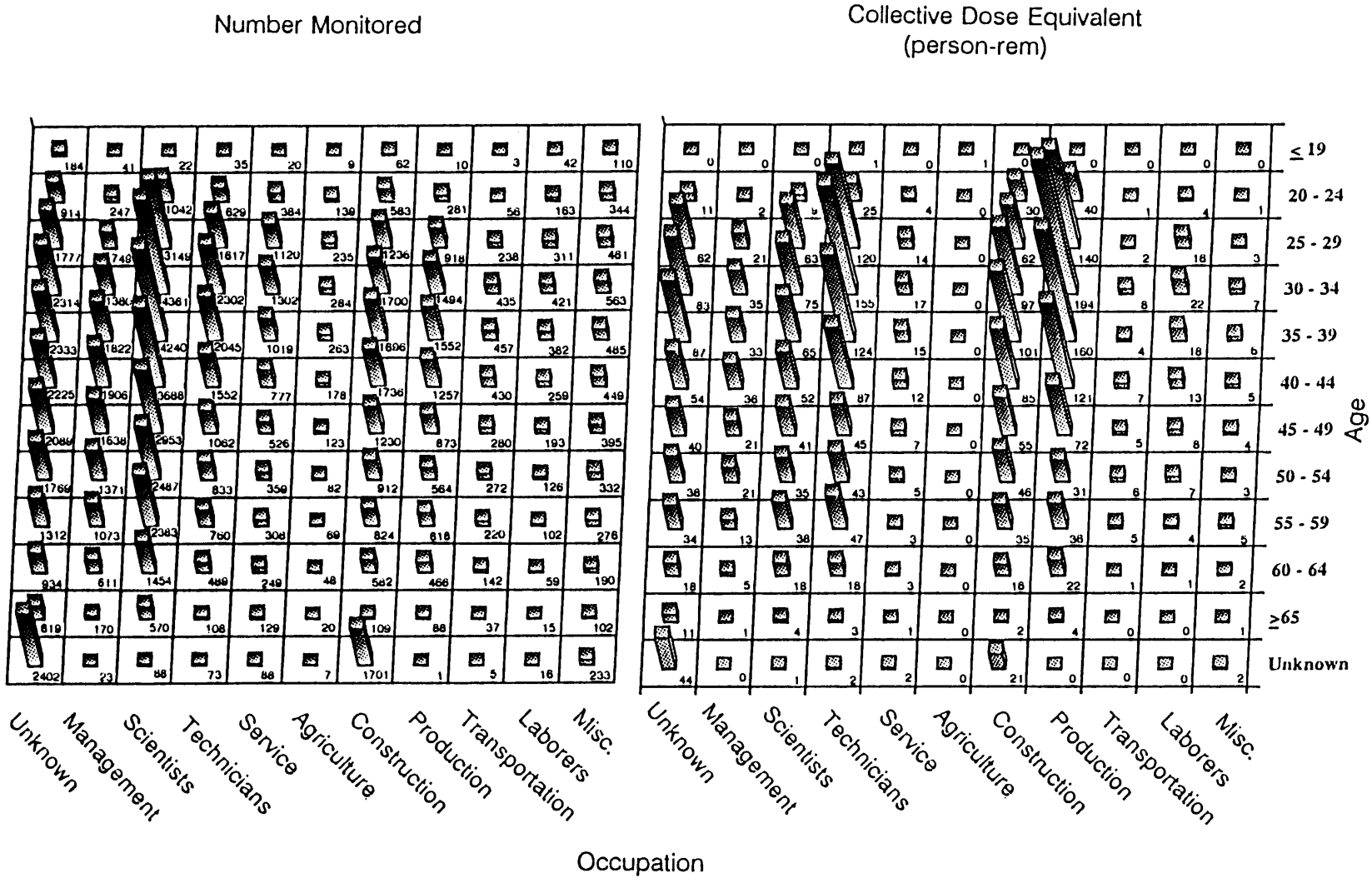

FIGURE 4.12. Three-dimensional Representation of Number of Individuals Monitored and Collective Dose Equivalent by Age Range and Occupation, 1989

either scientists or individuals for whom occupation was unspecified. Also, many monitored individuals were in the age range from 24 to 44. Production workers, construction workers, technicians, and workers of unspecified occupations in the age range 25-39 generally received the highest collective dose equivalents.

Figure 4.13 presents the age distributions of both the number of workers and collective dose equivalents for males and females. As indicated by the ages pertaining to the 50% mark on the figure, the median ages for monitored workers at DOE facilities were approximately 37 and 42 for females and males, respectively. The median ages for collective dose equivalent were approximately 36 and 38, respectively, indicating that, in general, younger workers receive slightly higher doses than do older workers.

4.6 DISTRIBUTION BY TYPE OF EXPOSURE

For calendar year 1989, DOE Order 5484.1 required that specific information on the types of radiation doses received by each worker be reported. Specifically, these included the total effective dose equivalent, the external penetrating dose equivalent (at a depth in tissue of 1.0 cm) including neutron exposure, the dose equivalent from neutron exposure only, the internal effective dose equivalent, the shallow dose equivalent, and the extremity dose equivalent. From these data, the external penetrating beta-gamma dose equivalent can be derived by subtracting the neutron dose equivalent from the external penetrating dose equivalent including neutron exposure. That is, the two contributors to external penetrating dose equivalent are beta-gamma radiation and neutron radiation.

Table 4.15 lists the various types of dose equivalents received by facility type. Of the total external penetrating dose equivalent of 3,375 person-rem (33.75 person-Sv) received, 2,739 person-rem (27.39 person-Sv) (81.1%) were attributable to beta-gamma radiation and 638 person-rem (6.38 person-Sv) (18.9%) were attributable to neutron radiation. Neutron radiation contributed the highest percentage (33.4%) of the total penetrating dose equivalent at general research facilities. The total shallow dose reported to have been received was 4637 person-rem (46.37 person-Sv). Relative to the total penetrating dose equivalent, the total shallow dose equivalent was greatest at fuel fabrication facilities, where the shallow dose equivalent exceeded the penetrating dose equivalent by a

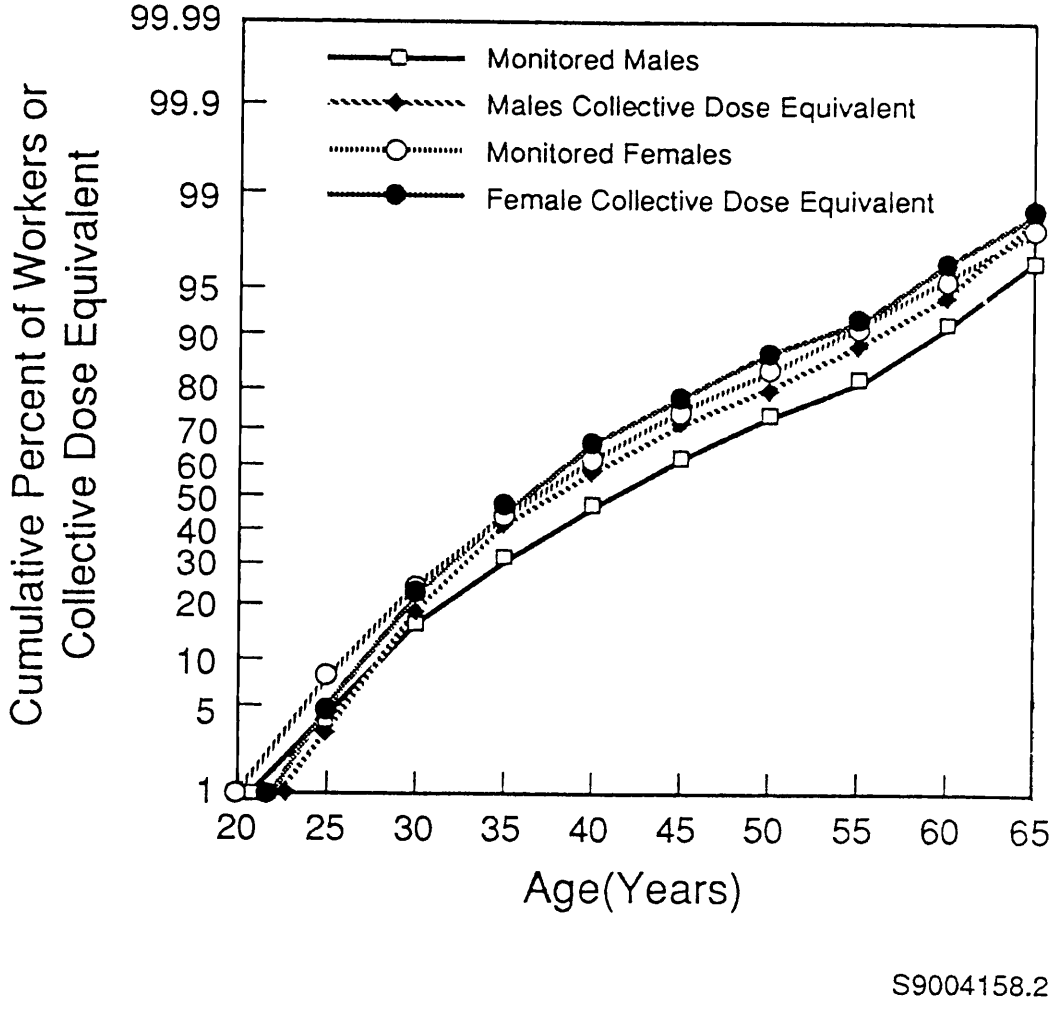

FIGURE 4.13. Age Distribution of Number of DOE and DOE Contractor Employees and Collective Dose Equivalent, 1989

TABLE 4.15. Dose Equivalent by Dose-Equivalent Type (person-rem)

Facility Type	Penetrating Total	Penetrating Beta-Gamma	Penetrating Neutron	Shallow
Accelerator	200	164	36	173
Fuel/Uran Enrich	44	43	2	88
Fuel Fab	102	101	1	190
Fuel Process.	491	415	76	730
Maintenance & Support	618	507	109	764
Reactor	438	432	6	510
Research, Gen.	515	345	173	471
Research, Fusion	10	10	0	9
Waste Process/Mgmt	219	154	64	345
Weapons Fab & Testing	543	399	142	1,122
Other	196	166	29	335
Total	3,375	2,739	638	4,637

factor of almost 4. However, because the critical organ regarding shallow dose equivalents is the skin and because the radiation risk coefficient for induction of fatal skin cancers is low (NCRP 1987a), the penetrating dose equivalents are of the most concern regarding health effects. The magnitude of the postulated health effects from radiation doses received at DOE facilities is discussed in Section 7 of this report.

Table 4.16 lists the reported cases of internal body depositions occurring since 1980 and identifies each by the first year known in which the dose equivalent exceeded 50% of the annual standard. Also listed are the radionuclide(s) involved, the organ showing the highest percent of the annual standard, and the number of individuals in each dose-equivalent range. Revisions to previously reported cases are included.

TABLE 4.16. Dose Distributions for Cases of Internal Body Depositions, 1980-1989

Year	Radionuclide	Critical Organ	Dose-Equivalent Interval (rem) 7.5-10	10-15	15-20	25-50	50-100	100-200
1980	^{238}Pu	Bone			2	2		
	^{234}U, ^{235}U, ^{238}U	Lung	1					
1981	^{238}Pu, ^{239}Pu, ^{240}Pu	Bone		1	1			
	^{238}Pu, ^{239}Pu, ^{240}Pu	Lung	1					
	^{234}U, ^{235}U, ^{238}U	Lung	3					
1982	^{238}Pu	Bone			3	1		
	^{238}Pu, ^{239}Pu, ^{240}Pu	Bone						1
1983	^{239}Pu, ^{240}Pu, ^{241}Am	Bone		1				
	^{234}U, ^{235}U	Lung	4					
1984	^{239}Pu, ^{241}Am	Lung					1	
1985	^{234}U, ^{235}U, ^{238}U	Lung	2					
	^{239}Pu, ^{241}Am	Lung	1					
1986	None							
1987	^{234}Pu	Liver	1	1				
1988	^{238}Pu, ^{239}Pu, ^{241}Am	Bone			1			
1989	None							

4.7 EVALUATION OF TRENDS

Doses received by DOE and DOE contractor employees have decreased dramatically over the last several years (see Table 4.7). For example, in 1985 the collective dose equivalent received by employees was 8,223 person-rem (82.23 person-Sv); in 1989, this value was 3,073 person-rem (3.073 person-Sv). Some of this decrease (~24% as indicated in section 4.3) is attributable to the fact that the 1985 value was estimated from the numbers of individuals reported to have received doses in various dose-equivalent ranges. However, the majority of the decrease is attributable to other factors.

The most evident example of the recent dramatic decrease in collective doses is at the Richland Field Organization. In 1987, the collective dose equivalent to employees at Richland was 2,477 person-rem (24.77 person-Sv); in 1989, this value dropped by over 75% to 619 person-rem (6.19 person-Sv).

This decrease was primarily the result of both changes in the type of work performed and facility closures. Decreases also occurred from 1987 to 1989 at the Oak Ridge (-58%) and Rocky Flats (-53%) field organizations. In addition, the Savannah River field organization experienced a 46% decrease in collective dose since 1986.

The 1989 data demonstrate that the significant decrease in collective dose equivalent is not attributable to fewer individuals being monitored, but to lower doses to those individuals who are monitored. Figure 4.14 illustrates the recent dramatic decrease in average annual dose equivalent per individual monitored who received a measurable exposure. Table 4.17 lists similar data for each facility type. Table 4.18 lists collective dose equivalent by facility type for the years 1980 through 1989.

One correlative effect of lower average individual dose equivalents is fewer employees who exceed various dose-equivalent levels. Figure 4.15 illustrates the number of employees who received dose equivalents greater than 0.5 rem (5 mSv), 1.0 rem (10 mSv), or 2.0 rem (20 mSv) from 1980 to 1989. As indicated in the figure, the numbers decreased significantly during the 1988-1989 time period. As a result, fewer employees are being exposed to doses that are significant fractions of the annual dose limit. This may be important if the annual dose limits are eventually lowered; this reduction is currently under consideration.

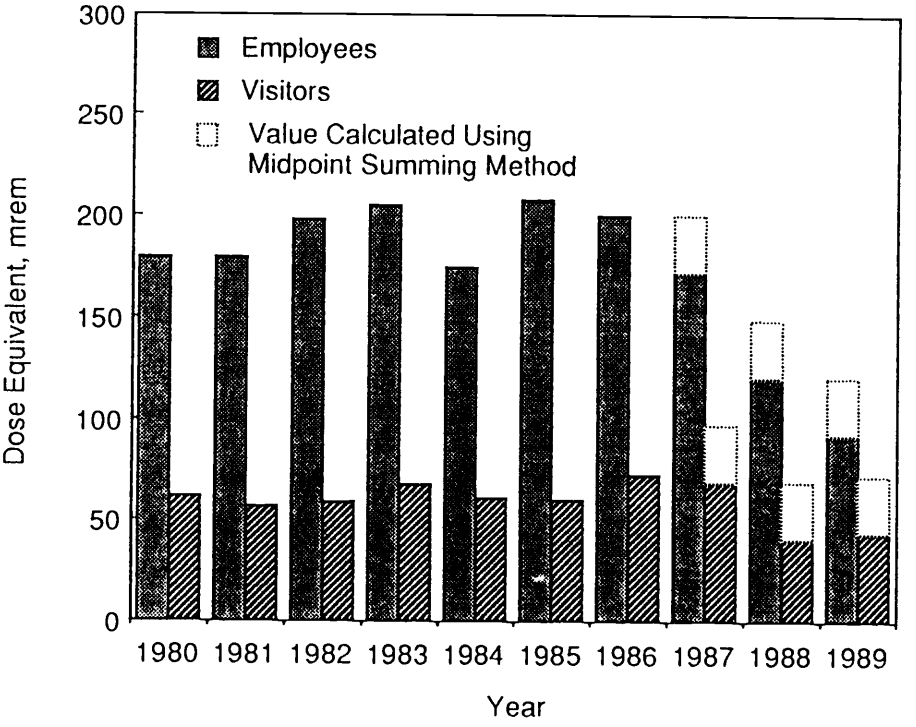

FIGURE 4.14. Average Dose Equivalent per Individual Who Received a Measurable Exposure, 1980-1989

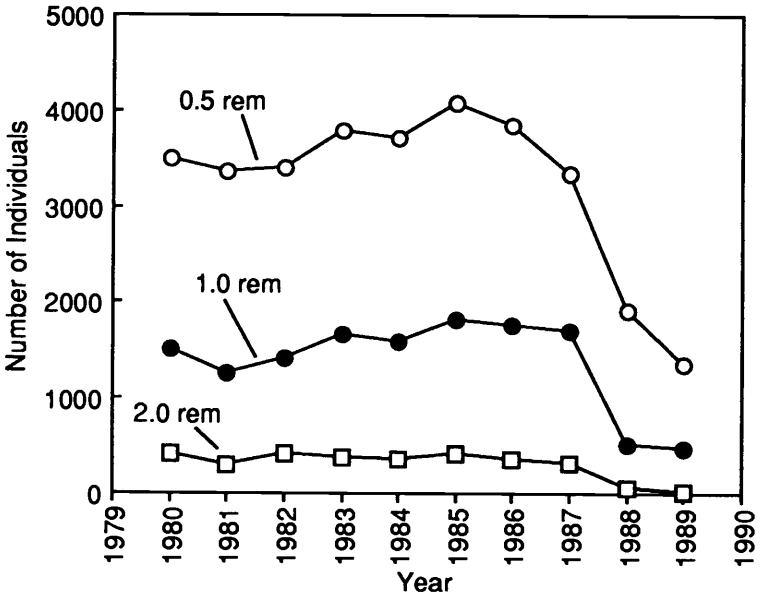

FIGURE 4.15. Number of Employees Who Received Dose Equivalents Greater than 0.5 rem, 1 rem, or 2 rem, 1980-1989

TABLE 4.17. Average Dose Equivalent Per Individual Who Received a Measurable Exposure by Facility Type, 1980-1989 (mrem)[a]

Year	Reactor	Fuel Fabrication	Fuel Processing	Uranium Enrichment	Weapons Fabrication and Testing	General Research	Accelerator	Other	Visitors	DOE Offices	All Facilities
1980	278	236	442	117	120	122	209	217	59	57	157
1981	270	246	412	74	129	140	228	202	57	59	156
1982	302	306	362	86	136	168	209	169	58	62	164
1983	313	322	298	79	149	169	219	202	66	57	190
1984	323	283	294	80	147	154	196	164	60	62	167
1985	323	226	318	63	170	193	175	188	59	63	182
1986	300	227	314	71	166	211	129	185	71	65	179
1987	239	155	267	37	183	150	98	173	69	30	159
1988	104	112	217	29	139	124	114	100	39	19	103
1989	92	68	259	28	105	97	116	69	43	21	84

(a) Beginning in 1987, three facility categories were added to those listed in the table: maintenance and support, fusion research, and waste processing/management. For this table, these facility categories are included in the "other" category for 1987-1989.

TABLE 4.18. Collective Dose Equivalent by Facility Type, 1980-1989 (person-rem)[a]

Year	Reactor	Fuel Fabrication	Fuel Processing	Uranium Enrichment	Weapons Fabrication and Testing	General Research	Accelerator	Other	Visitors	DOE Offices	All Facilities
1980	1,185	323	1,047	156	869	1,611	412	1,773	619	29	8,024
1981	1,270	267	592	62	982	1,535	348	1,813	571	38	7,483
1982	1,612	411	735	30	1,056	1,676	254	1,293	686	26	7,879
1983	1,781	434	726	31	1,399	1,662	273	1,522	300	30	8,158
1984	1,620	264	515	28	1,672	1,736	248	1,944	368	30	8,423
1985	1,716	265	574	26	1,851	1,484	262	2,025	461	20	8,684
1986	1,391	356	598	39	1,802	1,357	232	2,117	554	20	8,465
1987	1,007	271	426	41	1,028	769	169	2,260	373	8	6,353
1988	366	171	374	32	767	554	194	1,195	245	5	3,901
1989	329	77	491	41	512	508	184	928	303	3	3,375

(a) Beginning in 1987, three facility categories were added to those listed in the table: maintenance and support, fusion research, and waste processing/management. For this table, these facility categories are included in the "other" category for 1987-1989.

5.0 ASSESSMENT OF FETAL EXPOSURE AT DOE FACILITIES

The presence of female employees of childbearing age in the workplace is a source of concern to DOE because the embryo/fetus is biologically more radiosensitive than the worker. The extent of the problem is illustrated by comparing the range of doses currently received at DOE facilities with the current dose limits for radiation protection of the embryo/fetus.

5.1 CURRENT DOSE LIMITS FOR RADIATION PROTECTION OF THE EMBRYO/FETUS

DOE Order 5480.11 states in Section 9.b.(3) that

> "[t]he limiting value of annual dose equivalent received by the unborn child from the period of conception to birth (entire gestation period) as a result of occupational exposure of a female occupational worker, who has notified her employer in writing that she is pregnant, is 0.5 rem (5 mSv). Efforts should be made to avoid substantial variation above the uniform monthly exposure rate that would satisfy this limiting value. If the dose to the unborn child is determined to have already exceeded 0.5 rem (5 mSv) by the time a worker notifies her employer in writing of her pregnancy, the worker shall not be assigned to tasks where additional occupational exposure is likely."

The basis for the special limits on fetal dose is a combination of evidence that the embryo/fetus is more radiosensitive than adults at doses greater than occupational levels, and concerns that the embryo/fetus is more sensitive than the adult at occupational dose levels. The 1990 report of the National Research Council's Committee on the Biological Effects of Ionizing Radiation (BEIR V) indicates that the consequences of irradiation of a fetus during the period of major organogenesis may include teratogenic effects on various organs (including mental retardation) and cancer. It is apparent from the data that at certain periods of time following conception, the embryo/fetus is especially sensitive to certain radiation effects. For mental retardation, the effects are most evident within the first 3 months after conception (specifically during weeks 8-15). The first trimester of pregnancy

corresponds to the period during which the cells are dividing very rapidly and are beginning to differentiate.

Because of the heightened sensitivity of the embryo/fetus, other agencies have also recommended limits on the occupational dose to the embryo/fetus. The International Commission on Radiological Protection (ICRP) in Report 60 (ICRP 1990) recommends that once a pregnancy has been declared, the fetus should be protected by applying a supplementary equivalent dose limit to the surface of the women's abdomen of 200 mrem (2 mSv) during the remainder of the pregnancy, and by limiting intakes of radionuclides to about 1/20 of their annual limits of intake (ALI). The commission's policy is based on providing a standard of protection for the embryo/fetus that is comparable to that provided to members of the general public. No special occupational dose limits are specified for women in general, although ICRP Report 60 states that the basis for control of the occupational exposure of women who are not pregnant is essentially the same as that for men (2 rem (20 mSv) per year), averaged over defined periods of 5 years, with the further provision that the effective dose should not exceed 5 rem (50 mSv) in any single year.

The National Council on Radiation Protection and Measurements in Report No. 53 (NCRP 1977) and Report No. 91 (NCRP 1987) recommended a total dose equivalent limit of 0.5 rem (5 mSv) for the embryo/fetus. In Report 91, the NCRP specifies that once the pregnancy becomes known, exposure of the embryo/fetus shall be no greater than 0.05 rem (0.5 mSv) in any month. This excludes medical exposure.

5.2 DOSE RECEIVED BY FEMALE RADIATION WORKERS AT DOE FACILITIES

In order to determine the number of workers that could potentially be affected by the DOE's regulations for limiting dose to radiation workers who have declared their pregnancy, a review was conducted of the data reported in the Annual Exposure Report. The year 1987 was the first year that data in the Annual Exposure Report were listed separately for female and male radiation workers. Thus, the information that was reported by the DOE and DOE contractors and incorporated into the Annual Exposure Reports for 1987 and 1988 (Merwin et al. 1990) was used for this study. Data for the year 1989 were also available for this analysis. The data were examined to determine the total number of female radiation workers at DOE facilities, the age distribution of these women, the doses

received by these women, and the facility types in which the doses were obtained. The data were first examined for all female radiation workers and then re-examined for those workers of childbearing age who are considered to have the potential to become pregnant.

5.2.1 Populations of Radiation Workers

The total population of radiation workers in DOE facilities in 1989 is 103,525. This includes 3094 workers whose sex was not identified. Of the remaining 100,431 workers, 83,327 are male (83%) and 17,104 are female (17%). Figure 5.1 shows the total number of male, female and all radiation workers as a function of age. The same data are shown in Figure 5.2 as a frequency distribution for all workers, as well as for the male and female populations. The average age of male and female workers lies in the categories of 40-44 and 35-39 years old, respectively. Thus female workers tend to be younger than their male counterparts. The average age of all workers falls within the category 40-44 years old. An absolute average is not available due to the method of reporting workers' ages by ranges rather than actual numbers.

Considering the years 1987, 1988, and 1989, the population of female radiation workers can be considered to be fairly stable. The female population in 1987 was 15,165, in 1988 it was 14,529, and in 1989 it increased to 17,104. Figure 5.3 shows the distribution of the population of female radiation workers by age. The frequency distribution of this population, with respect to age, is given in Figure 5.4, which shows that it remains fairly constant with respect to age distribution.

Figure 5.5 shows the frequency distribution of the total person-rem received by each category of workers (males, females, and all workers) for the year 1989 as a function of workers' ages. For ages below 40 years the female population received a larger fraction of the person-rem dose than they did for ages above 40 years. This result is not unexpected since the female population was shown to be younger than the male population.

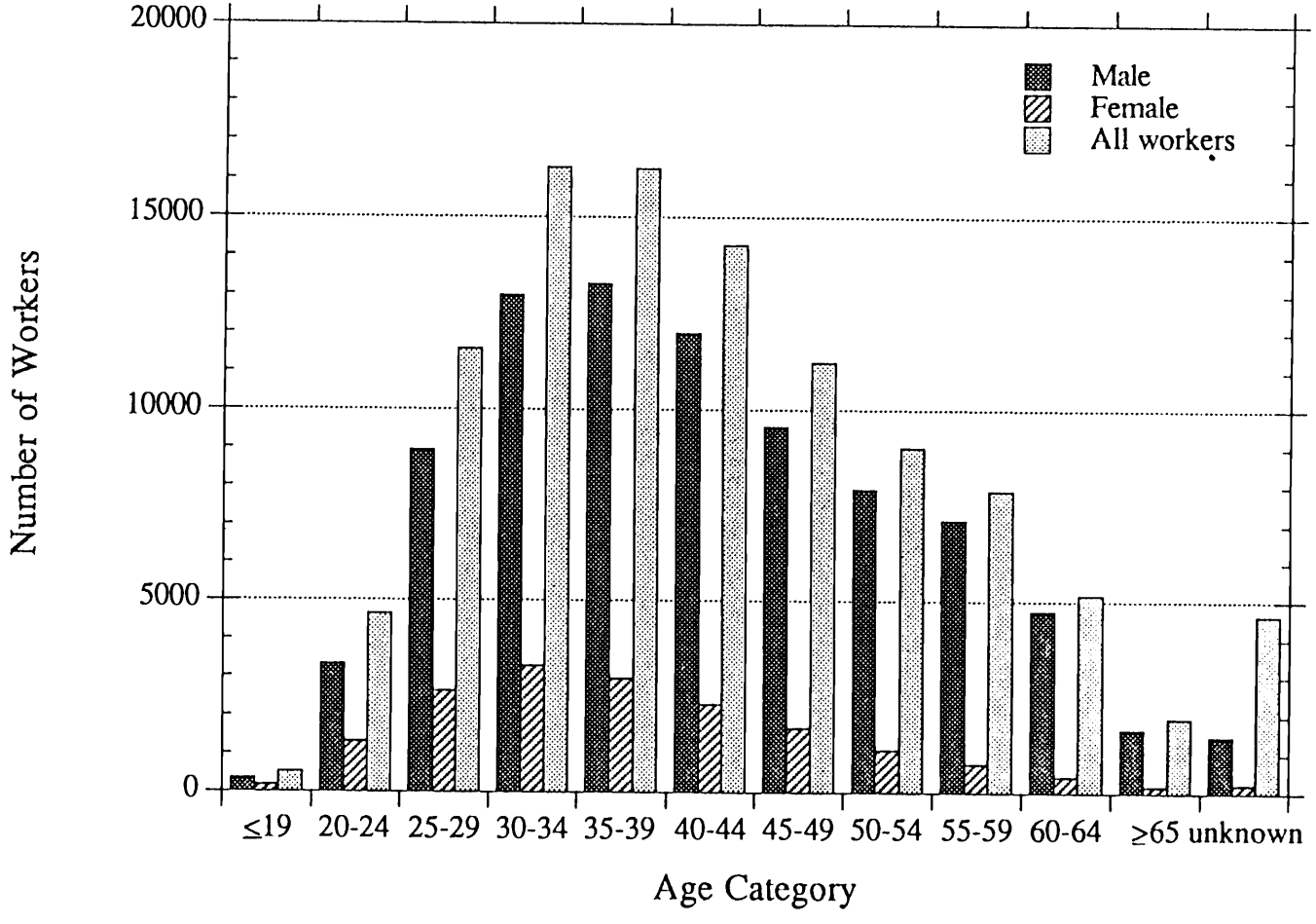

FIGURE 5.1. Distribution of Male, Female, and All Workers by Age for the Year 1989

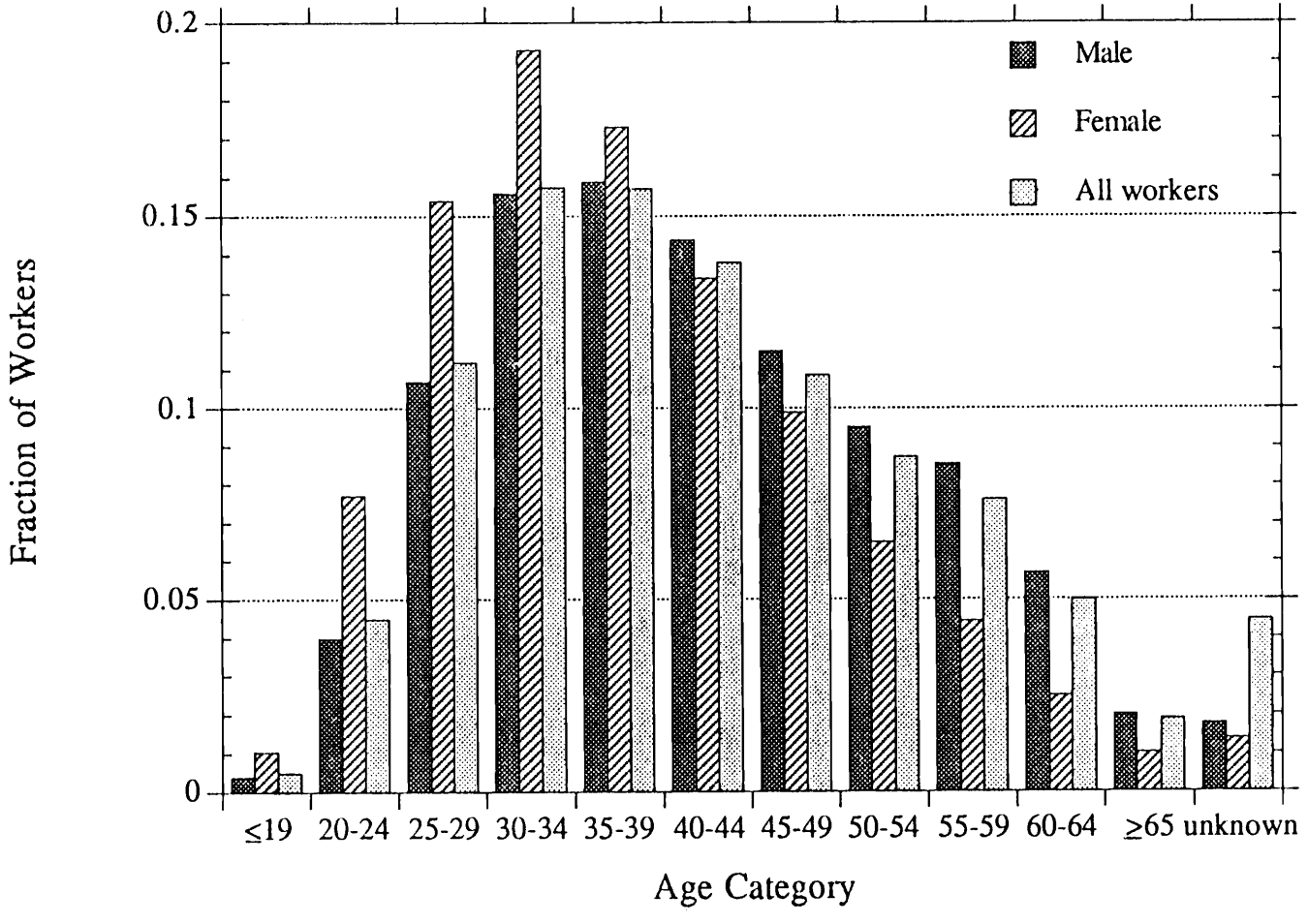

FIGURE 5.2. Frequency Distribution of Male, Female, and All Workers by Age for the Year 1989

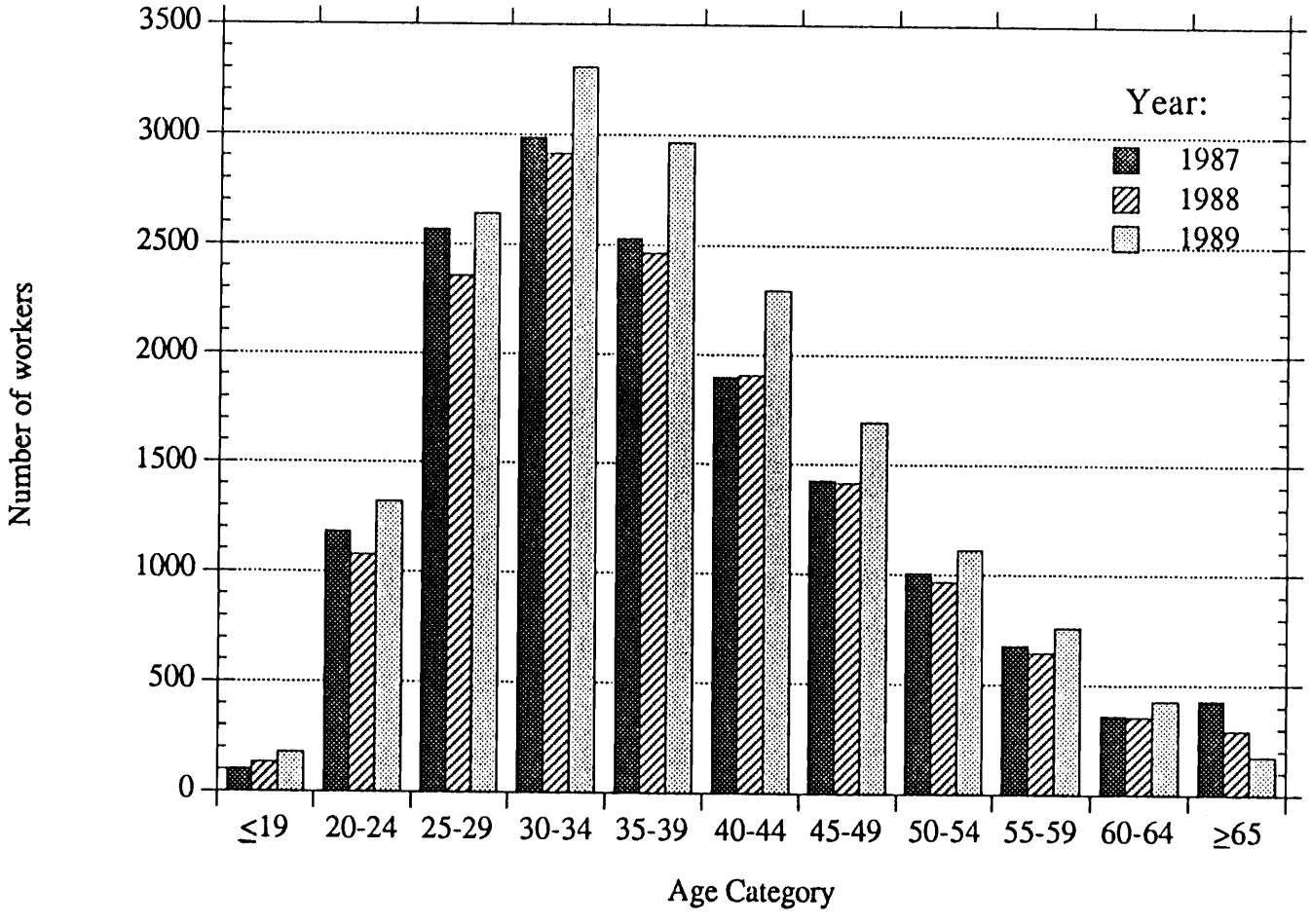

FIGURE 5.3. Distribution of Female Workers by Age Category for the Years 1987, 1988, and 1989

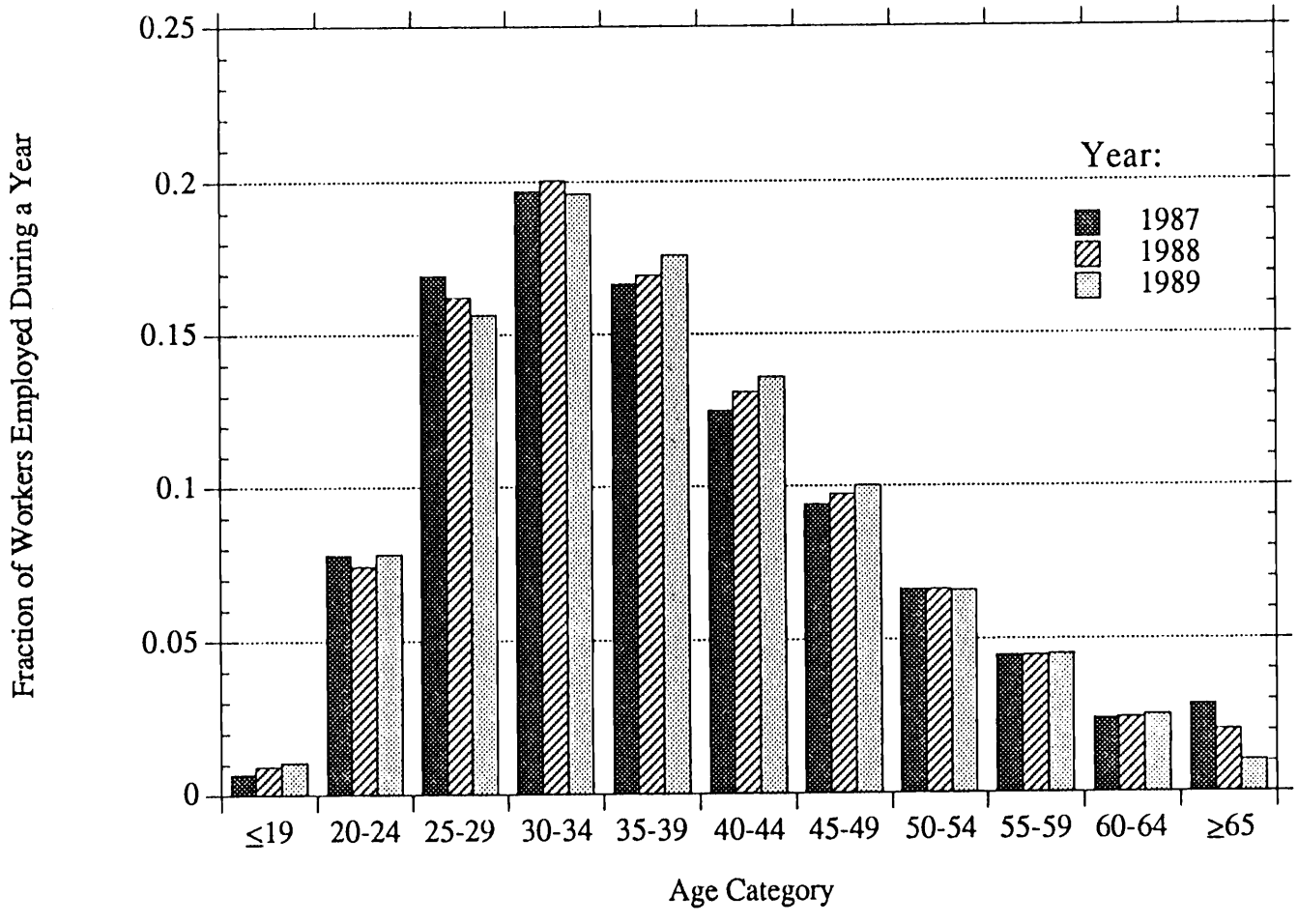

FIGURE 5.4. Frequency Distribution of Female Workers by Age Category for the Years 1987, 1988, and 1989

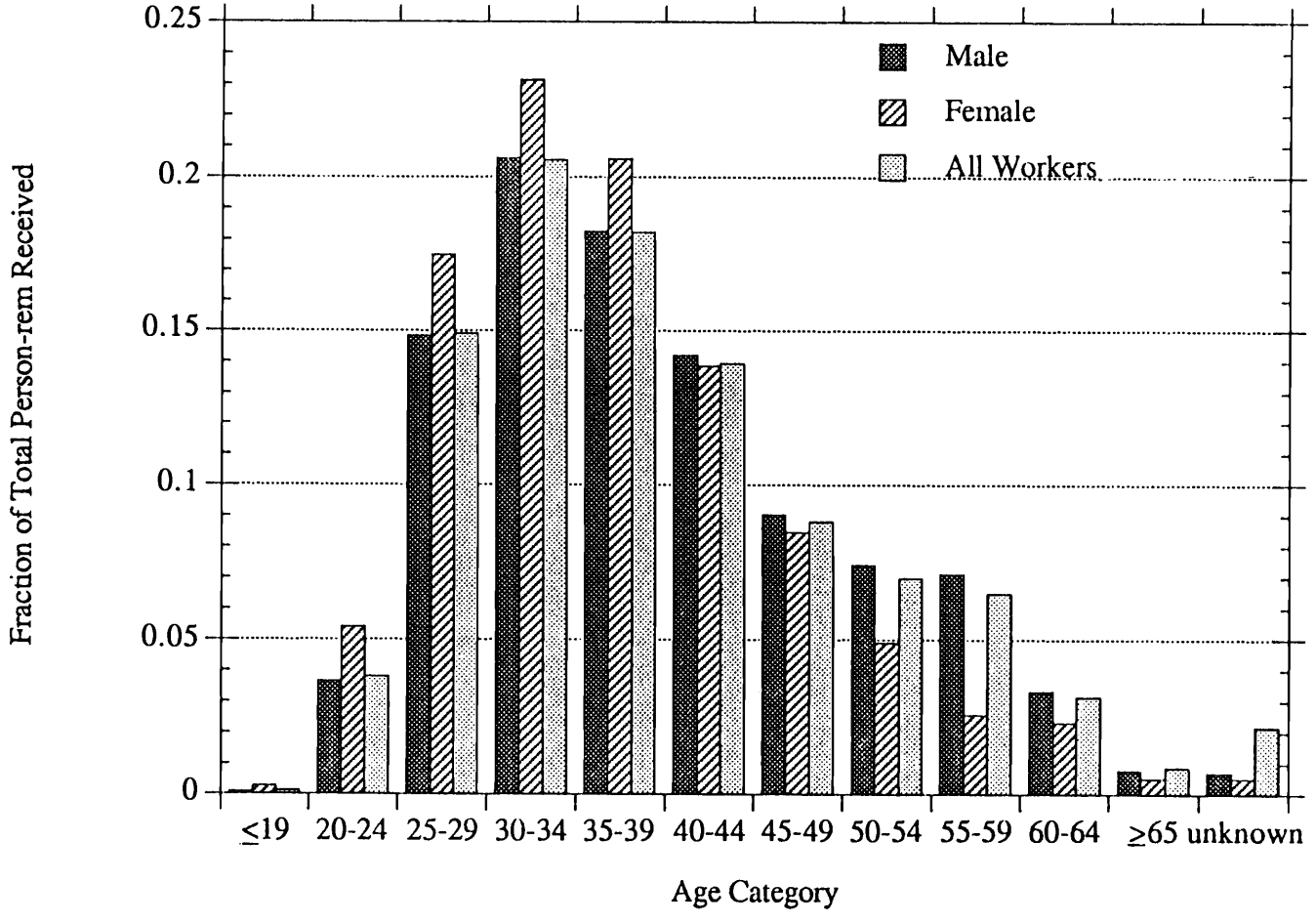

FIGURE 5.5. Frequency Distribution of Person-rem by Age for Male, Female, and All Workers for the Year 1989

It is important to compare the distribution of radiation dose to male and female workers. Figure 5.6 shows the frequency distribution of male, female, and all workers by dose category for the year 1989. The female population received lower doses than their male counterparts considering the female population as a whole. For the female population, more than 70% of the population received doses less than the measurable limit[a]; 30% received doses higher than the measurable limit; and less than 1% received doses higher than 0.5 rem (5 mSv). For the male population, the fraction receiving doses less than the measurable limit is 60%; 40% received doses higher than the measurable limit; and 1.5% received doses greater than 0.5 rem (5 mSv). Table 5.1 shows the corresponding number and percentage of workers receiving a dose in a given range.

The data from the Annual Exposure Reports were further examined based on facility type. Table 5.2 lists the different types of facilities considered in the Annual Exposure Reports.

Figures 5.7 and 5.8 show the distribution of the number of workers versus the dose category for different facility types for male and females, respectively. Qualitatively, all facility types show the same dose distribution, except for reactor facilities (No. 6) in which a smaller fraction of the work force received doses less than the measurable limit. In reactor facilities only 25% of the male population and 41% of the female population received doses lower than the measurable limit. However, the female population was still exposed to less radiation when compared with the male population.

(a) The measurable limit is based on the dosimeter used at the specific facility and thus will vary from facility to facility.

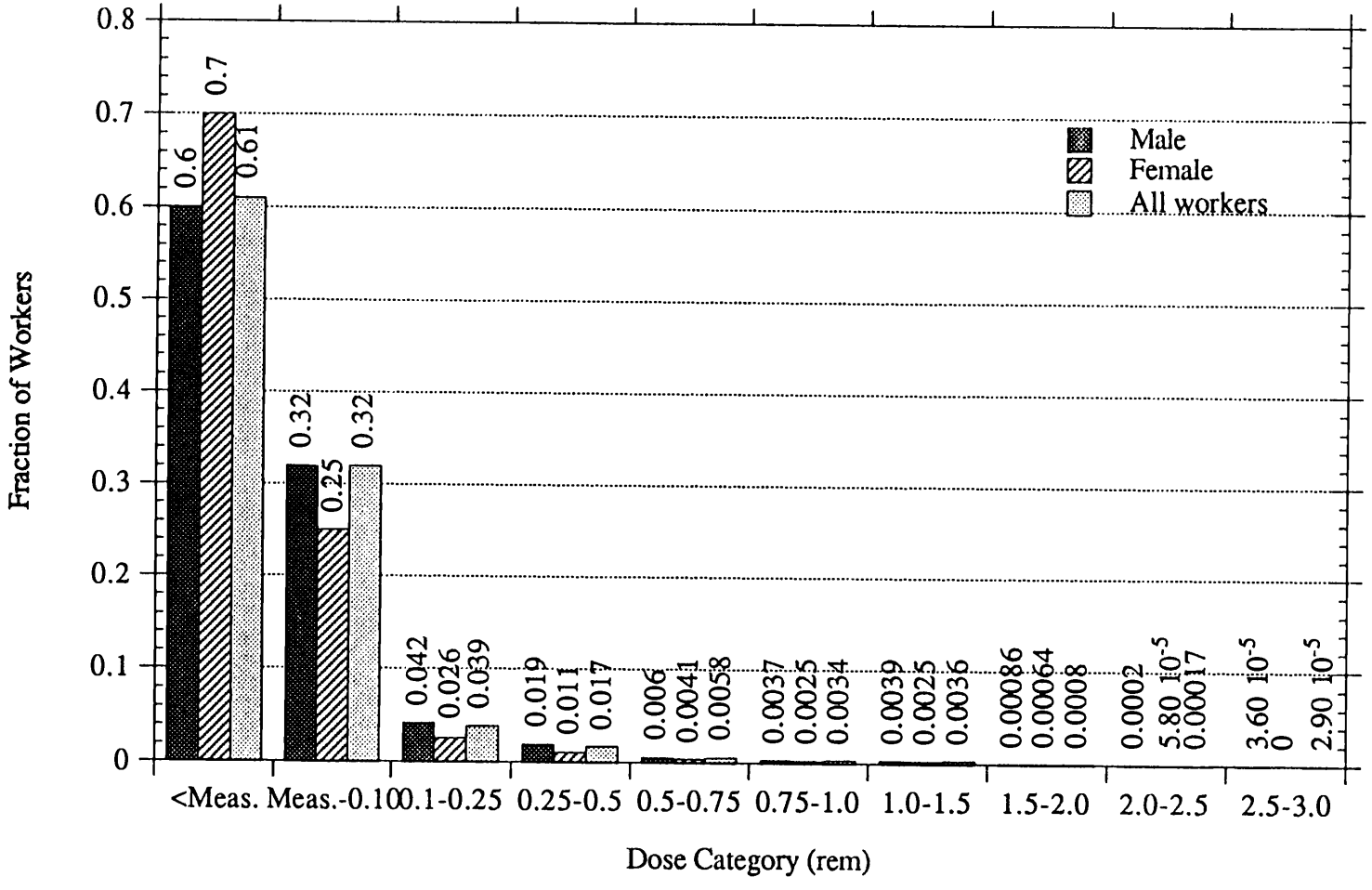

FIGURE 5.6. Frequency Distribution of Male, Female, and All Workers by Dose (rem) for the Year 1989

TABLE 5.1. Dose Distribution of Male, Female, and All Workers

	Male Workers		Female Workers		All Workers	
Dose (rem)	Number	%	Number	%	Number	%
< Meas.	50,095	60.12	12,030	70.33	63,123	60.97
Meas.-0.10	26,921	32.31	4,269	24.96	33,185	32.06
0.1 -0.25	3,479	4.18	446	2.61	4,006	3.87
0.25-0.5	1,579	1.89	192	1.12	1,785	1.72
0.5 -0.75	525	0.63	70	0.41	600	0.58
0.75-1.0	309	0.37	43	0.25	352	0.34
1.0 -1.5	327	0.39	42	0.25	370	0.36
1.5 -2.0	72	0.09	11	0.06	83	0.08
2.0 -2.5	17	0.02	1	0.01	18	0.02
2.5 -3.0	3	0.004	0	0	3	0.003

TABLE 5.2. Types of DOE Facilities

Identification	Facility Type
1	Accelerator
2	Fuel/Uranium Enrichment
3	Fuel Fabrication
4	Fuel Processing
5	Maintenance and Support
6	Reactor
7	Research, General
8	Research, Fusion
9	Waste Processing/Management
10	Weapons Fabrication and Testing
11	Other

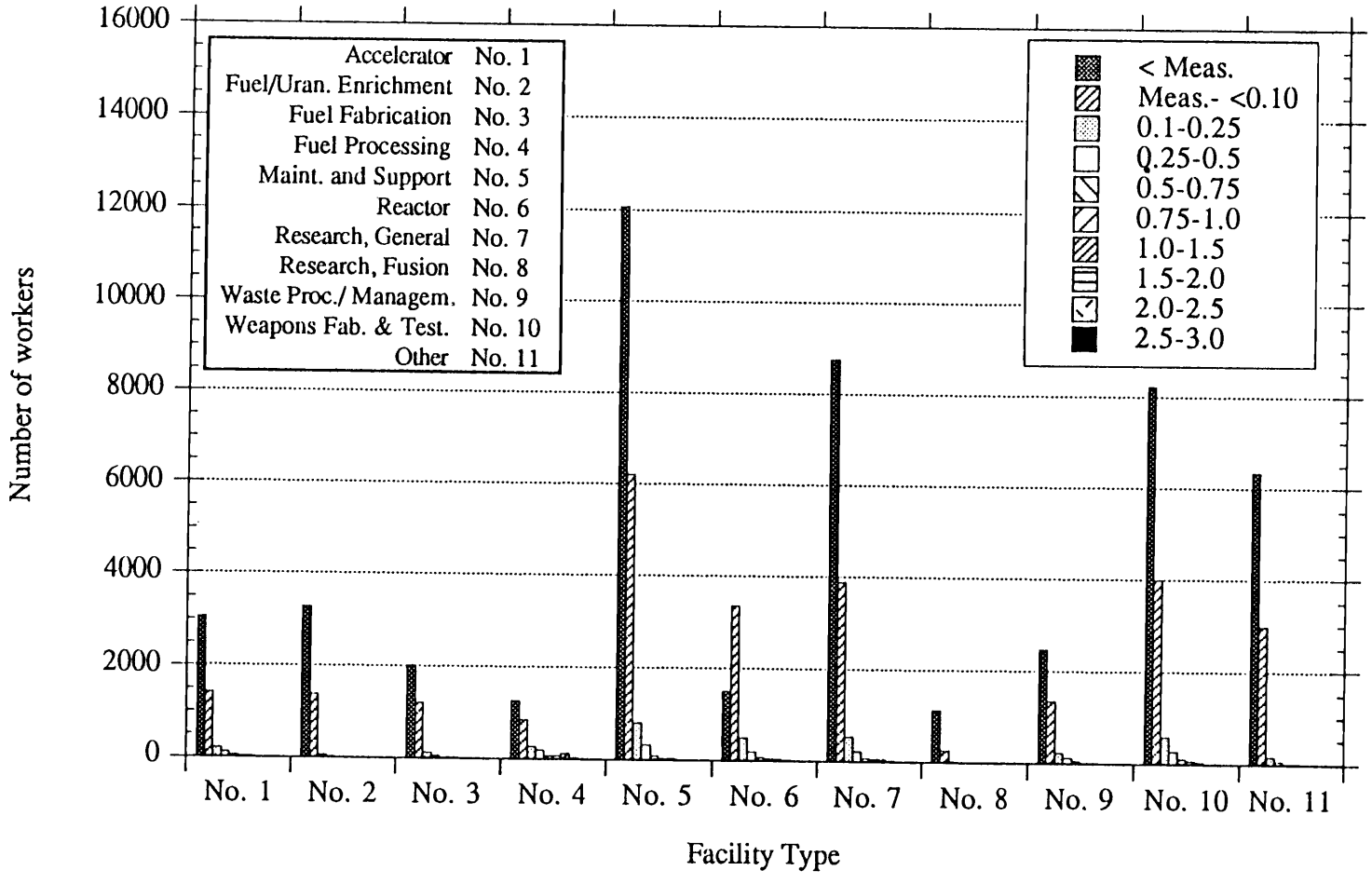

FIGURE 5.7. Distribution of Male Workers Receiving Radiation Doses by Facility Type for the Year 1989

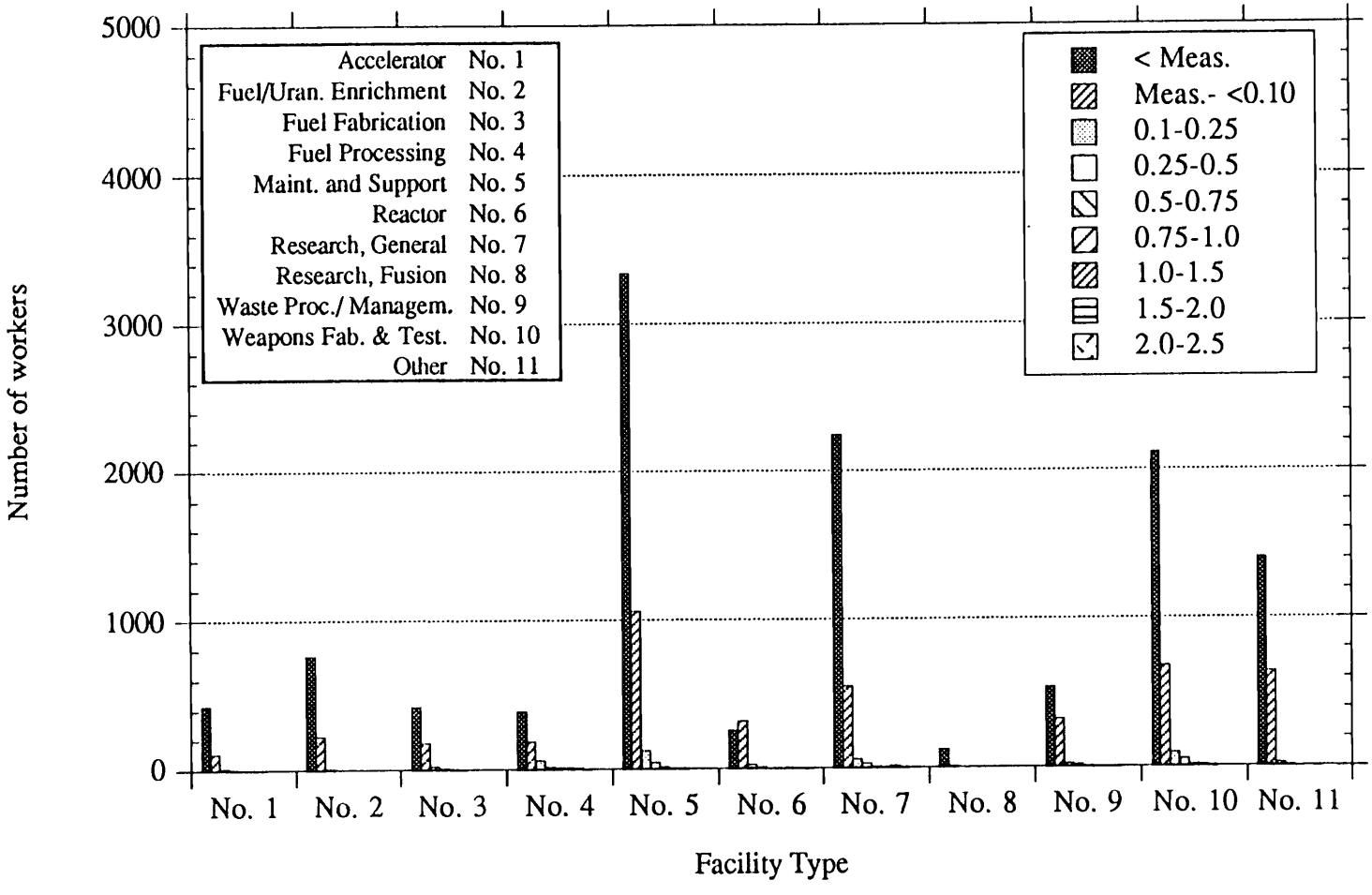

FIGURE 5.8. Distribution of Female Workers Receiving Radiation Doses by Facility Type for the Year 1989

5.2.2 Female Radiation Workers of Childbearing Age

Female radiation workers of childbearing age can be considered to be a subset of all female radiation workers. For this report, female workers in an age range of 18-44 years old were considered to be of childbearing age. For the year 1989, the total number of female radiation workers of childbearing age was 12,704, which is 12.5% of the total population of radiation workers and 75% of the total number of female radiation workers. Of this population of workers, 99% received doses below 0.5 rem (5 mSv) (the limiting value for annual dose equivalent to an unborn child as a result of occupational exposure of a female radiation worker who has declared her pregnancy). A total of 136 female radiation wokrers of childbearing age received doses greater than 0.5 rem (5 mSv). The highest annual dose received by a female radiation worker during 1989 was less than 2.5 rem (25 mSv). The number of female radiation workers has remained fairly stable over the years 1987, 1988 and 1989.

The distribution of this subset of the female radiation worker population as a function of age is shown in Figure 5.9. The average age of these females of childbearing age lies in the 30-34 years old age category, which is younger than the average age of the total population of female radiation workers (as given in Figure 5.2).

Figure 5.10 shows the frequency distribution of female radiation workers versus dose category for all facility types. As expected, 68% of female workers received doses below the measurable limit, and slightly greater than 1% received doses above 0.5 rem (5 mSv). These data are also given in Table 3.

Figure 5.11 shows the distribution of female radiation workers of childbearing age versus age and dose range. As can be seen in Figure 5.11 the dose distribution for different age categories follows the same qualitative pattern. Figure 5.11 shows that the population of female radiation workers of childbearing age is exposed to radiation homogeneously, independent of age. Thus, it can be concluded that Figure 5.10's distribution of female radiation workers of childbearing age versus dose is representative for all ages. The frequency distribution given in Figure 5.11 is based on all facility types. As discussed before, reactor facilities are an exception because the dose distribution does not follow the same pattern as for other facilities.

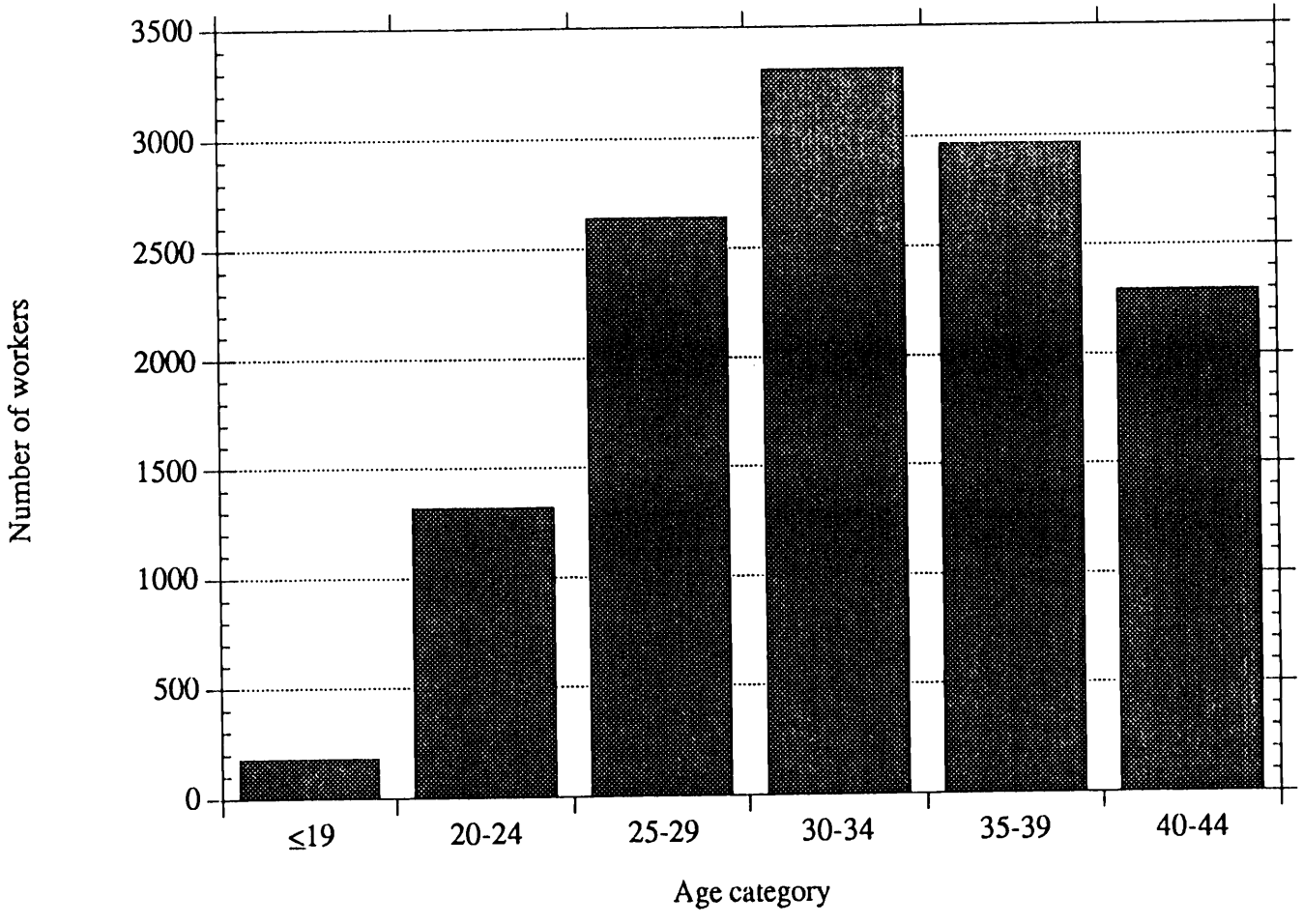

FIGURE 5.9. Distribution by Age of Female Workers of Childbearing Age (19-44) for the Year 1989

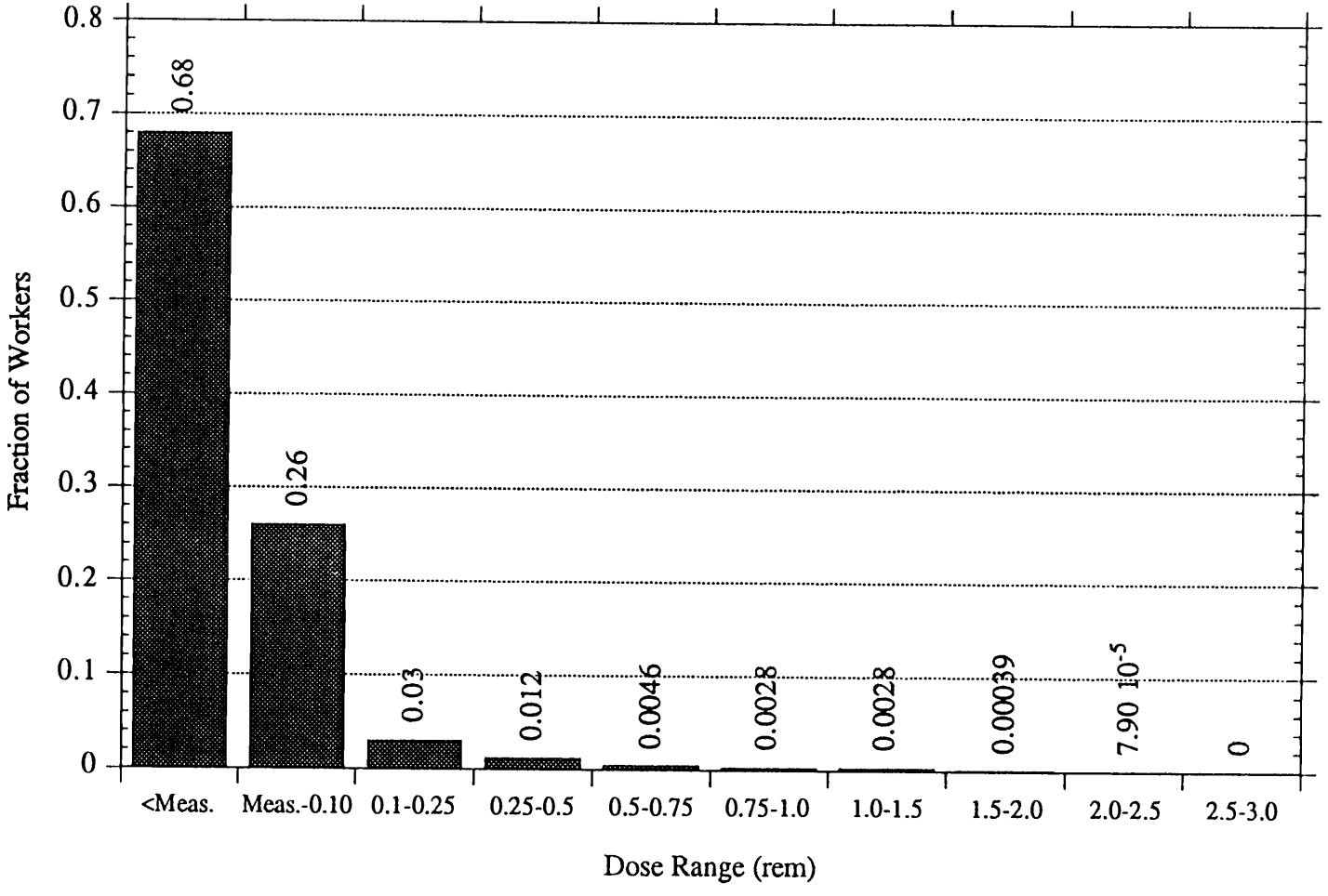

FIGURE 5.10. Frequency Distribution for Female Workers of Childbearing Age vs. Dose Range (rem) for the Year 1989

TABLE 5.3. Dose Frequency Distribution for Female Radiation Workers of Childbearing Age (1989)

Dose Range	Frequency	Workers
< Meas.	68.2%	8664
Meas.-0.10	26.53%	3370
0.1 -0.25	2.98%	378
0.25-0.5	1.23%	156
0.5 -0.75	0.46%	59
0.75-1.0	0.28%	36
1.0 -1.5	0.28%	35
1.5 -2.0	0.04%	5
2.0 -2.5	0.01%	1
2.5 -3.0	0.00%	0

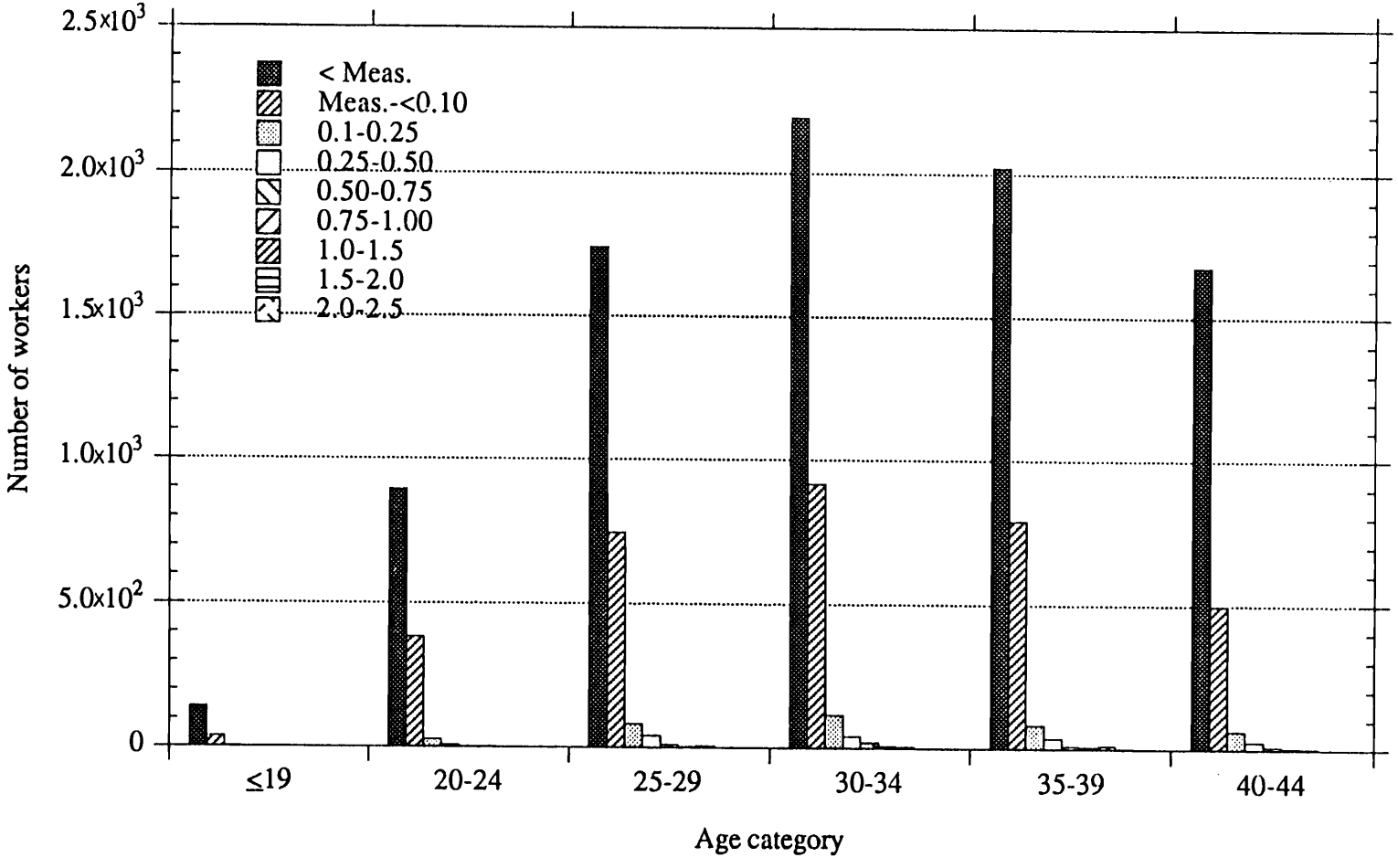

FIGURE 5.11. Distribution of Female Workers of Childbearing Age vs. Age and Dose Range for the Year 1989

5.3 CONCLUSION

During 1989, the number of female radiation workers of childbearing age (under the age of 45) employed at DOE facilities was 12,704. This represents 12.5% of the total population of radiation workers. Slightly less than 99% of the females of childbearing age received doses below 0.5 rem (5 mSv), and slightly more than 1% (a total of 136 female radiation workers) received doses greater than 0.5 rem (5 mSv). The highest annual dose received by a female radiation worker during 1989 was less than 2.5 rem (25 mSv).

6.0 REPORTABLE RADIATION EXPOSURE INCIDENTS

The DOE has established criteria for classifying, reporting, and investigating radiation exposure incidents in DOE Order 5484.1. Depending on the individual doses received, incidents involving exposure to radiation are classified as either Type A, Type B, or Type C occurrences. A Type A occurrence shall be reported to DOE Headquarters immediately, and an investigation of the incident shall be conducted by a DOE Headquarters or field organization board. A Type B occurrence shall be reported to DOE Headquarters within 72 hours, and an investigation of the incident shall be conducted by a DOE board appointed by the head of the field organization. A Type C incident shall be reported by memo, and an investigation shall be conducted by DOE contractor personnel when their operations are involved, or by DOE personnel when Federal operations are involved.

Table 6.1 lists the criteria for classifying incidents involving radiation exposures at DOE facilities. Descriptions of such incidents are normally reported to the System Safety Development Center (SSDC) following submittal of the investigation report. No such incidents were reported to have occurred in calendar year 1989.

TABLE 6.1. Dose Criteria for Classification of Incidents Involving Occupational Radiation Exposures

	Dose Criteria for Incident Type		
Type of Exposure	A[a]	B[b]	C[b]
Whole-body	25 rem	5 rem	3 rem
Skin of the whole-body	75 rem	15 rem	5 rem
Thyroid	N/A	15 rem	5 rem
Forearms	150 rem	30 rem	10 rem
Hands and feet	375 rem	75 rem	25 rem
Internal dose	5 times annual standard	In excess of annual standard	N/A

(a) Rem values pertain to a single exposure except for the value which pertains to a single or annual cumulated exposure.
(b) Rem values pertain to doses accumulated in one quarter.

7.0 COMPARISON OF DOSES TO RISKS

Crucial to assessing the safety of DOE operations with respect to occupational radiation exposure is an assessment of the risks from doses received by DOE and DOE contractor employees. In Section 4.0 of this report, summaries of the radiation doses received by DOE and DOE contractor employees were presented. Although the average doses were much lower than the DOE limits (indicating the impact of ALARA programs), comparison of employee doses to risks is necessary for determining the magnitude of health effects, if any, that may be expected to occur. This section compares the doses received by DOE and DOE contractor employees in 1989 to risks based on published radiation risk coefficients and compares the calculated risks to other risks incurred both inside and outside the workplace.

An important consideration in assessing the relative significance of the risk of radiation doses received at DOE facilities is the doses received from sources other than working at the facilities. Everyone receives radiation doses regularly from various sources, including terrestrial radiation from naturally radioactive elements in the soil, cosmic radiation from space, radon in the air, and naturally radioactive potassium in our bodies. Other sources of radiation to which many of us are exposed include radiation from medical and dental procedures, cigarette smoke, fallout from past nuclear testing, and various food and other consumer products. Typical radiation doses received from each of these sources are listed in Table 7.1. By comparison with the values in Tables 7.1, the average dose equivalent received by a DOE and DOE contractor employee who received a measurable occupational exposure during 1989 (92 mrem) (0.92 mSv) was less than the average dose equivalent received by an individual from non-work-related sources. No employee received a dose equivalent greater than the DOE occupational limit of 5 rem per year (50 mSv per year).

Although low doses of radiation have not been demonstrated to increase the incidence of cancer or other diseases, risk estimates have been estimated by extrapolating from known effects at high doses to hypothetical effects at low doses. Based primarily on data from survivors of the atomic bombings at Hiroshima and Nagasaki, risk estimates have been developed that express the risk of death from cancer per unit whole-body dose equivalent of ionizing radiation. According to several sources, data published in 1980 suggest that a population distributed over all ages and both sexes would experience approximately 1×10^{-4} cancer deaths per person per rem (NCRP 1987a, ICRP 1977,

TABLE 7.1. Radiation Doses Received by Individuals in the U.S. from Sources Other than Occupational Exposures (adapted from NCRP Publication 93 [NCRP 1987b])

Source	Average Annual Effective Dose Equivalent per Member of the U.S. Population (mrem)
Natural sources	
Radon	200
Cosmic	27
Terrestrial	28
In vivo	29
Nuclear Fuel Cycle	0.005
Consumer Products	
Domestic water supply	1 - 6
Building materials	3.6
Other	1 - 10
Medical	53
Total[(a)]	~360

(a) Value pertains to a nonsmoker. An additional 1300 mrem per year is estimated to be received by a typical smoker from inhalation of tobacco smoke.

NAS 1980, UNSCEAR 1977). However, as detailed in the BEIR III report (NAS 1980), risk coefficients vary considerably depending on the age and sex of the exposed individual. Furthermore, the calculated risk to an individual exposed to low levels of ionizing radiation depends highly on the models chosen to extrapolate from the Hiroshima and Nagasaki data, where excess deaths were observed only at relatively high doses delivered over a very short period of time.

More recently, both the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the Committee on the Biological Effects of Ionizing Radiations provided risk estimates based on a reassessment of the atomic bomb dosimetry as well as extended followups of the survivor data (UNSCEAR 1988, NAS 1990). In general, the associated risk estimates range from approximately 5×10^{-4} per rem to 1×10^{-3} per rem depending on the age, sex, and risk projection model used and based on acute exposures of at least 10 rem (100 mSv). For low doses and dose rates, both UNSCEAR and BEIR recognized the need to reduce these risk estimates by applying a dose rate effectiveness factor (DREF) of at least 2 these values.

Figure 7.1 shows the estimated incidence of fatal cancers and the total numbers of person-years of life lost based on the whole-body ionizing radiation doses received at DOE facilities in 1989. These hypothetical data are based on age- and sex-specific risk equations provided in the BEIR V report (NAS 1990) and life table calculations as described by Bunger, Cook, and Barrick (1981) and Merwin, Traub, and Faust (1990).

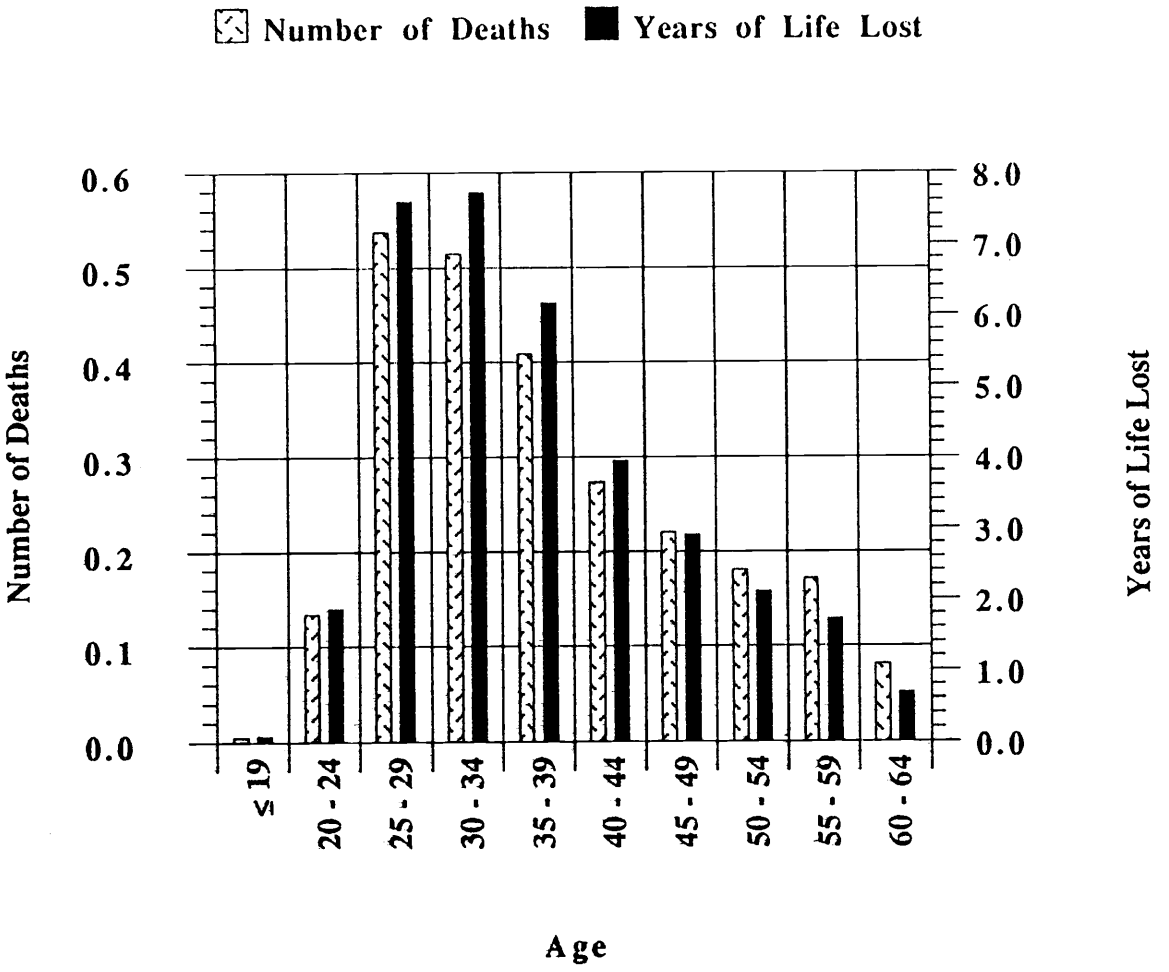

FIGURE 7.1. Estimated Maximum Number of Total Deaths and Years of Life Lost from Radiation Doses Received at DOE Facilities in 1989. (The values indicated are maximum estimates; the actual values may be zero. See text for explanation.)

The values were calculated directly from the BEIR V risk equations and the doses received by employees and visitors at DOE facilities in 1989. Applying a DREF to these values would be appropriate (NAS 1990; UNSCEAR 1988) and would reduce the values by factor of two or more. Furthermore, the BEIR V risk estimates were based on studies of individuals who received high doses. Consequently, the actual number of deaths and years of life lost from doses received at DOE facilities may be zero.

To put into perspective the calculated risks from ionizing radiation doses received at DOE facilities, it is important to review the risks associated with other activities. The primary purpose of this review is to indicate the effect of radiation doses received at DOE facilities on the health of workers relative to the effects of other hazards. Table 7.2 lists the estimated annual deaths per 100,000 persons in the U.S. population for various hazards.

As indicated in Table 7.2, reducing radiation doses at DOE facilities is only one way to improve the health of workers. Other effective methods may include anti-smoking campaigns, increased safety awareness, and the promotion of safe driving practices. Radiation doses received at DOE facilities do not significantly reduce the overall health or life expectancy of workers relative to the other risks encountered both in the workplace and as a part of everyday life.

TABLE 7.2. Estimated Annual Fatality Rates in the U.S. Attributable to Various Causes[a]

Cause	Annual Number of Deaths per 100,000 People or Workers
General Population	
All causes	874
Heart disease	323
Cancer, all types	193
Lung cancer	51
Leukemia	7
Other cancer types	135
Accidents, all types	39
Motor vehicle accidents	19
Other accidents	20
Other causes	319
Occupational	
Industrial injuries and illnesses	4.8[b]
Highway vehicles	1.6
Industrial vehicles or equipment	0.4
Falls	0.4
Heart attacks	0.3
Electrocutions	0.3
Caught between objects other than vehicles or equipment	0.3
Assaults	0.3
Aircraft crashes	0.2
Struck by objects other than vehicles or equipment	0.2
Explosions	0.2
Gas inhalation	0.1
Fires	0.1
Plant machinery operations	0.1
All other (including contact with carcinogenic or toxic substances, drowning, train accidents, and various occupational illnesses)	0.1
Estimated cancer fatalities from radiation doses received at DOE facilities	1.5[c]

(a) Sources: General population data for the year 1985 from NCHS (1988); occupational data (except cancer fatalities from DOE radiation doses) for the years 1986 and 1987 from DOL (1989).

(b) Ranges from a low of 1.9 per 100,000 in the services industry to a high of 24 per 100,000 in the mining industry.

(c) Based on age- and sex-specific risk equations provided in the BEIR V report (NAS 1990). These equations were based primarily on the Japanese A-bomb survivor data, which represented acute exposures. The BEIR V committee recognized the need to apply a dose rate effectiveness factor for chronic exposures, which would reduce the risk estimate provided in the table by a factor of at least two. Value indicates deaths per 100,000 DOE workers.

8.0 REFERENCES

Brodsky, A., R. P. Specht, B. G. Brooks, and W. S. Cool. 1976. "Log-Normal Distributions of Occupational Exposure in Medicine and Industry." In Proceedings of the Ninth Midyear Topical Symposium of the Health Physics Society, February 9-12, 1976, Denver, Colorado, pp. 373-379. Pergamon Press, New York.

Brooks, B. G. 1988. Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities, 1985: Eighteenth Annual Report. NUREG-0713, Vol. 7, U.S. Nuclear Regulatory Commission, Washington, D.C.

Bunger, B. M., J. R. Cook, and M. K. Barrick. 1981. "Life Table Methodology for Evaluating Radiation Risk: An Application Based on Occupational Exposures." Health Physics 40(4):439-455.

Faust, L. G., L. W. Brackenbush, K. R. Heid, W. N. Herrington, J. L. Kenoyer, L. F. Munson, L. H. Munson, J. M. Selby, K. L. Soldat, G. A. Stoetzel, and R. J. Traub. 1988. Health Physics Manual of Good Practices for Plutonium Facilities. PNL-6534, Pacific Northwest Laboratory, Richland, Washington.

Federal Register 52 FR 2822-2834. January 27, 1987. "Radiation Protection Guidance to Federal Agencies for Occupational Exposure. Recommendations Approved by the President." U.S. Environmental Protection Agency, Washington, D.C.

International Commission on Radiological Protection (ICRP). 1977. Recommendations of the International Commission on Radiological Protection. ICRP Publication 26. Pergamon Press, Oxford.

International Commission on Radiological Protection (ICRP). 1990. Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Pergamon Press, Oxford.

Merwin, S. E., R. J. Traub, and L. G. Faust. 1990. "The Next Step in Radiation Protection: Controlling Risk Rather than Dose." In Proceedings of the Twenty-third Midyear Topical Symposium of the Health Physics Society, February 5-8, 1990, Atlantic City, New Jersey, pp. 126-135. Pergamon Press, New York.

Munson, L. H., W. N. Herrington, D. P. Higby, R. L. Kathern, S. E. Merwin, and G. A. Stoetzel. 1988. Health Physics Manual of Good Practices for Reducing Radiation Exposure to Levels that are As Low As Reasonably Achievable (ALARA). PNL-6577, Pacific Northwest Laboratory, Richland, Washington.

National Academy of Sciences (NAS), Committee on the Biological Effects of Ionizing Radiations. 1980. The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980. National Academy of Sciences, Washington, D.C.

National Academy of Sciences (NAS), Committee on the Biological Effects of Ionizing Radiations. 1990. Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V. National Academy of Sciences, Washington, D.C.

National Center for Health Statistics (NCHS). 1988. Vital Statistics of the United States 1985. Volume II - Mortality. U.S. Department of Health and Human Services, Hyattsville, Maryland.

National Council on Radiation Protection and Measurements (NCRP). 1977. Review of NCRP Radiation Dose Limit for Embryo and Fetus in Occupationally-Exposed Women. NCRP Publication 53, NCRP, Bethesda, Maryland.

National Council on Radiation Protection and Measurements (NCRP). 1987a. Recommendations on Limits for Exposure to Ionizing Radiation. NCRP Publication 91, NCRP, Bethesda, Maryland.

National Council on Radiation Protection and Measurements (NCRP). 1987b. Ionizing Radiation Exposure of the Population of the United States. NCRP Publication 93, NCRP, Bethesda, Maryland.

Rich, B. L., S. L. Hinnefeld, C. R. Lagerquist, W. G. Mansfield, L. H. Munson, and E. R. Wagner. 1988. Health Physics Manual of Good Practices for Uranium Facilities. EGG-2530, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 1977. Sources and Effects of Ionizing Radiation. 1977 Report to the General Assembly. United Nations, New York.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 1988. Sources, Effects and Risks of Ionizing Radiation. 1988 Report to the General Assembly. United Nations, New York.

U.S. Department of Energy (DOE). 1986. Environment, Safety, and Health Program for Department of Energy Operations. DOE 5480.1B, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1987. Environmenal Protection, Safety, and Health Protection Information Reporting Requirements. DOE 5484.1, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1988. Radiation Protection for Occupational Workers. DOE 5480.11, U.S. Department of Energy, Washington, D.C.

U.S. Department of Labor (DOL). 1989. Occupational Injuries and Illnesses in the United States by Industry, 1987. Bulletin 2328, U.S. Department of Labor, Washington, D.C.

APPENDIX A

DISTRIBUTION OF ANNUAL WHOLE-BODY DOSES BY FACILITY FOR EACH FIELD ORGANIZATION, 1989

TABLE A.1
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Albuquerque Operations
1989

	Dose-Equivalent Ranges (rem)																	
Facility Type	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Total Persons	Total Person-rem
Accelerator	747	204	46	28	22	16	14										1,077	68
Maint. and Support	4,858	769	60	26	15		4										5,732	46
Reactor	124	34	7	10	2	1	3										181	11
Research, General	3,682	453	89	64	38	41	68	2									4,437	208
Research, Fusion	187	10															197	
Waste Proc./Management	789	30	1	1													821	1
Weapons Fab. & Test.	2,334	444	50	25	9	5	6										2,873	43
Other	2,395	400	24	12	4	2											2,837	21
Visitors	718	532	62	29	1	1											1,343	35
DOE Offices	353	5															358	
Total Persons	16,187	2,881	339	195	91	66	95	2									19,856	
Total Person-rem		66	55	69	57	57	124	4										432

TABLE A.2
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Chicago Operations
1989

Facility Type	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Accelerator	1,905	704	105	62	18	7	7										2,808	83
Fuel Fabrication	24	8	1														33	
Maint. and Support	576	157	21	8	1	1	1	1									766	16
Reactor	144	161	47	15	2		1										370	21
Research, General	2,534	372	89	44	17	4	2	1									3,063	59
Research, Fusion	649	222	10	1													882	9
Waste Proc./Management				1	3	1	2										7	5
Other	5	46	1														52	1
Visitors	815	1,120	79	13	3		1										2,031	46
DOE Offices	83	4															87	
Total Persons	6,735	2,794	353	144	44	13	14	2									10,099	
Total Person-rem		81	52	49	26	12	16	4										240

TABLE A.3
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Idaho Operations
1989

	Dose-Equivalent Ranges (rem)																	
Facility Type	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Total Persons	Total Person-rem
Fuel Processing	1,242	340	95	61	44	45	78	1									1,906	218
Maint. and Support	179	100	5		1		1										286	6
Reactor	513	178	79	28	5	8	2										813	40
Research, General	597	138	30	12	5	2	1										785	19
Waste Proc./Management	108	38	18	2	1												167	5
Other	1,503	423	45	12	3	1	1	1									1,989	30
Visitors	30	179	18	11	4	2	2										246	19
DOE Offices	2																2	
Total Persons	4,174	1,396	290	126	63	58	85	2									6,194	
Total Person-rem		41	48	44	40	50	109	4										336

TABLE A.4
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Nevada Operations
1989

Facility Type	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Maint. and Support	902	5	7	1	1												916	3
Weapons Fab. & Test.	1,170	37	9	3													1,219	4
Visitors	1	2															3	
Total Persons	2,073	44	16	4	1												2,138	
Total Person-rem		2	3	1	1													6

TABLE A.5
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Oak Ridge Operations
1989

	Dose-Equivalent Ranges (rem)																	
Facility Type	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Total Persons	Total Person-rem
Fuel/Uran. Enrichment	3,010	1,395	55	9													4,469	37
Fuel Fabrication	759	461	79	23	3												1,325	36
Fuel Processing	6	101															107	2
Research, General	689	241	108	33	2	2											1,075	41
Waste Proc./Management	146	7															153	
Weapons Fab. & Test.	1,293	1,210	134	18													2,655	67
Other	1																1	
Visitors	1,975	921	28	11	4	5	2										2,946	35
Total Persons	7,879	4,336	404	94	9	7	2										12,731	
Total Person-rem		113	59	32	6	6	3											218

TABLE A.6
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Pittsburgh Naval Reactors Office
1989

	Dose-Equivalent Ranges (rem)																	
Facility Type	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Total Persons	Total Person-rem
Reactor	51	444	33	18	11	5											562	32
Research, General	227	930	128	43	2												1,330	53
Other	26	19	2														47	1
Visitors	133	59															192	
Total Persons	437	1,452	163	61	13	5											2,131	
Total Person-rem		27	25	20	8	4												85

TABLE A.7
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Richland Operations
1989

	Dose-Equivalent Ranges (rem)																	
Facility Type	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Total Persons	Total Person-rem
Accelerator	2	6															8	
Fuel Fabrication	8	12	1	3	1	4	4										33	10
Fuel Processing	2	15	4	3	5	3	34	1									67	62
Maint. and Support	1,103	1,718	155	77	24	11	17	2									3,107	152
Reactor	219	367	71	48	32	13	55	8									813	163
Research, General	328	867	74	38	10	9	16										1,342	84
Waste Proc./Management	983	1,247	145	72	35	13	10	1									2,506	131
Other	257	184	9	4	2	1	2										459	11
Visitors		28	9	1													38	3
DOE Offices	74	116	3														193	3
Total Persons	2,976	4,560	471	246	109	54	138	12									8,566	
Total Person-rem		129	72	87	66	47	190	29										619

TABLE A.8
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Rocky Flats Operations
1989

	Dose-Equivalent Ranges (rem)																	
Facility Type	≤ Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Total Persons	Total Person-rem
Weapons Fab. & Test.	2,981	1,778	457	265	113	71	38										5,703	389
Visitors	837	1,190	20	4		1	2										2,054	23
Total Persons	3,818	2,968	477	269	113	72	40										7,757	
Total Person-rem		67	76	95	67	61	46											412

TABLE A.9
Distribution of Annual Whole-Body Radiation Doses by Facility Type
San Francisco Operations
1989

	Dose-Equivalent Ranges (rem)																	
Facility Type	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Total Persons	Total Person-rem
Accelerator	391	273	47	13	5	1	3	2									735	33
Fuel/Uran. Enrichment	734	22	4	2	1		1										764	4
Maint. and Support	4,260	61	10	4	4	1	3	1									4,344	16
Research, General	1,646	173	20	6	4		1										1,850	14
Research, Fusion	367	21															388	1
Waste Proc./Management	83	1															84	
Weapons Fab. & Test.	1,440	89	8	6	1												1,544	7
Other	562	6															568	
Visitors	57	85	16	8													166	8
DOE Offices	90	2															92	
Total Persons	9,630	733	105	39	15	2	8	3									10,535	
Total Person-rem		23	16	14	9	2	11	7										82

TABLE A.10
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Savannah River Operations
1989

	Dose-Equivalent Ranges (rem)																	
Facility Type	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Total Persons	Total Person-rem
Fuel Fabrication	485	444	43	28	5												1,005	31
Fuel Processing	405	578	231	150	33	27	46										1,470	209
Maint. and Support	3,249	3,747	651	255	54	25	11										7,992	356
Reactor	482	974	84	3													1,543	37
Research, General	583	586	31	9	3	2											1,214	24
Waste Proc./Management	443	314	95	67	21	8	5										953	76
Weapons Fab. & Test.	315	106	6														427	3
Other	1,437	1,783	25	6													3,251	43
Visitors	844	1,526	18	7													2,395	26
Total Persons	8,243	10,058	1,184	525	116	62	62										20,250	
Total Person-rem		240	182	181	70	53	78											804

TABLE A.11
Distribution of Annual Whole-Body Radiation Doses by Facility Type
Schenectady Naval Reactors Office
1989

Facility Type	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Reactor	67	765	47	13													892	25
Research, General	481	392	9														882	7
Other	5	6															11	
Visitors	180	784	148	69	26	13	9										1,229	108
Total Persons	733	1,947	204	82	26	13	9										3,014	
Total Person-rem		41	31	29	16	11	11											140

TABLE A.12
Distribution of Annual Whole-Body Radiation Doses by Facility Type
DOE Headquarters
1989

Facility Type	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
DOE Offices	238	16															254	
Total Persons	238	16															254	
Total Person-rem																		

APPENDIX B

DISTRIBUTION OF ANNUAL WHOLE-BODY DOSES TO DOE CONTRACTOR EMPLOYEES AND VISITORS FOR EACH FIELD ORGANIZATION, 1989

TABLE B.1
Distribution of Annual Whole-Body Radiation Doses by Contractor
Albuquerque Operations
1989

Contractor	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Albuquerque Office Subs																	
Employees	2	5	1	4												12	2
Visitors																	
Total	2	5	1	4												12	2
Allied-Signal, Inc. (Bendix Div.)																	
Employees	217	15														232	
Visitors	2	1														3	
Total	219	16														235	
EG&G Mound Applied Technologies																	
Employees	1,583	627	17	11	5	2	3									2,248	20
Visitors	447	43														490	
Total	2,030	670	17	11	5	2	3									2,738	21
G.E. - Pinellas																	
Employees	250	22	5													277	1
Visitors																	
Total	250	22	5													277	1
G.E. - Pinellas Subs																	
Employees																	
Visitors	3															3	
Total	3															3	
Inhalation Toxicology Research Inst.																	
Employees	291	18	1	2												312	1
Visitors																	
Total	291	18	1	2												312	1
Jacobs-Weston Team																	
Employees	49	3														52	
Visitors																	
Total	49	3														52	

TABLE B.1 (continued)
Distribution of Annual Whole-Body Radiation Doses by Contractor
Albuquerque Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Los Alamos National Laboratory																		
Employees	4,651	537	136	93	65	57	82	2									5,623	277
Visitors	31	175	55	27	1	1											290	25
Total	4,682	712	191	120	66	58	82	2									5,913	302
MK-Ferguson Co. - UMTRA																		
Employees	54	18	1														73	1
Visitors																		
Total	54	18	1														73	1
MK-Ferguson Subs - UMTRA (REM ONLY)																		
Employees	1,232	230	9														1,471	7
Visitors																		
Total	1,232	230	9														1,471	7
Mason & Hanger - Amarillo																		
Employees	1,206	95	39	23	6	5	6										1,380	34
Visitors	20	11	2														33	1
Total	1,226	106	41	23	6	5	6										1,413	34
Mason & Hanger - Los Alamos																		
Employees	388	14		1													403	1
Visitors																		
Total	388	14		1													403	1
Pan-Am World Services, Inc.																		
Employees	1,459	141	41	20	9												1,670	23
Visitors																		
Total	1,459	141	41	20	9												1,670	23
Ross Aviation, Inc.																		
Employees	86	9															95	
Visitors																		
Total	86	9															95	

TABLE B.1 (continued)
Distribution of Annual Whole-Body Radiation Doses by Contractor
Albuquerque Operations
1989

Contractor	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Sandia National Laboratory																		
Employees	2,589	527	26	12	5	1	4										3,164	29
Visitors	29	299	5	2													335	9
Total	2,618	826	31	14	5	1	4										3,499	38
Westinghouse & Subs (WIPP)																		
Employees	653	8															661	
Visitors	186	3															189	
Total	839	11															850	
Albuquerque Operations																		
Total	15,428	2,801	338	195	91	66	95	2									19,016	431

TABLE B.2
Distribution of Annual Whole-Body Radiation Doses by Contractor
Chicago Operations
1989

Contractor	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Ames Laboratory (Iowa State)																		
Employees	108																108	
Visitors																		
Total	108																108	
Argonne National Laboratory																		
Employees	2,288	388	102	40	16	4	2										2,840	60
Visitors	2	54	4														60	2
Total	2,290	442	106	40	16	4	2										2,900	61
Battelle Memorial Institute - Columbus																		
Employees	92	22	7	2	1	1	1										126	5
Visitors		1															1	
Total	92	23	7	2	1	1	1										127	5
Brookhaven National Laboratory																		
Employees	1,039	691	127	74	22	7	10	2									1,972	101
Visitors	327	819	64	8	3		1										1,222	35
Total	1,366	1,510	191	82	25	7	11	2									3,194	136
Chicago Office Subs																		
Employees	47	22	7	4	1												81	4
Visitors		3		1													4	
Total	47	25	7	5	1												85	4
Fermilab																		
Employees	1,319	277	19	9	1	1											1,626	14
Visitors	435	229	11	4													679	8
Total	1,754	506	30	13	1	1											2,305	23
Mass. Inst. of Tech.																		
Employees	270	64	5	2													341	3
Visitors																		
Total	270	64	5	2													341	3

TABLE B.2 (continued)
Distribution of Annual Whole-Body Radiation Doses by Contractor
Chicago Operations
1989

Contractor	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Princeton Plasma Physics Laboratory																		
Employees	622	197	7														826	7
Visitors	41	14															55	
Total	663	211	7														881	8
Solar Energy Research Institute																		
Employees	14	6															20	
Visitors																		
Total	14	6															20	
Chicago Operations																		
Total	6,604	2,787	353	144	44	13	14	2									9,961	240

TABLE B.3
Distribution of Annual Whole-Body Radiation Doses by Contractor
Idaho Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Chem-Nuclear Geotech																		
Employees	274	41	1														316	1
Visitors	1	21	1														23	
Total	275	62	2														339	2
EG&G Idaho, Inc.																		
Employees	1,334	418	120	39	10	7	3										1,931	61
Visitors	11	49		2													62	2
Total	1,345	467	120	41	10	7	3										1,993	62
Idaho Office Subs																		
Employees	5	1															6	
Visitors	3	20															23	1
Total	8	21															29	1
MK-Ferguson Company - ID																		
Employees	82	90	11	10	4	7	13										217	34
Visitors	3	29	9	7	4		2										54	10
Total	85	119	20	17	8	7	15										271	44
MK-Ferguson Subcontractors -ID																		
Employees	9	5	6		1	3	1										25	6
Visitors	11	45	7	2		2											67	5
Total	20	50	13	2	1	5	1										92	11
Protection Technology - INEL																		
Employees	278	121		1													400	3
Visitors																		
Total	278	121		1													400	3
Rockwell - INEL																		
Employees	371	118	14														503	6
Visitors		1															1	
Total	371	119	14														504	6

TABLE B.3 (continued)
Distribution of Annual Whole-Body Radiation Doses by Contractor
Idaho Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
West Valley Nuclear Services, Inc.																		
Employees	618	143	31	11	3	1	1	1									809	21
Visitors																		
Total	618	143	31	11	3	1	1	1									809	21
Westinghouse Idaho Nuclear Co.																		
Employees	1,021	237	87	54	41	38	65	1									1,544	186
Visitors	1	10	1														12	
Total	1,022	247	88	54	41	38	65	1									1,556	186
Idaho Operations																		
Total	4,022	1,349	288	126	63	58	85	2									5,993	335

TABLE B.4
Distribution of Annual Whole-Body Radiation Doses by Contractor
Nevada Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Computer Sciences Corporation																		
Employees	2																2	
Visitors																		
Total	2																2	
EG&G Amador Valley Operations																		
Employees	4																4	
Visitors																		
Total	4																4	
EG&G Kirtland																		
Employees	1																1	
Visitors																		
Total	1																1	
EG&G Las Vegas																		
Employees	196	1	1														198	
Visitors																		
Total	196	1	1														198	
EG&G Los Alamos																		
Employees	3																3	
Visitors																		
Total	3																3	
EG&G Santa Barbara																		
Employees	58	6															64	
Visitors																		
Total	58	6															64	

TABLE B.4 (continued)
Distribution of Annual Whole-Body Radiation Doses by Contractor
Nevada Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
EG&G Special Technologies Laboratories																		
Employees	4																4	
Visitors																		
Total	4																4	
EG&G Washington D.C.																		
Employees	4																4	
Visitors																		
Total	4																4	
Fenix & Scisson, Inc.																		
Employees	151	8	6	1	1												167	2
Visitors																		
Total	151	8	6	1	1												167	2
Holmes & Narver, Inc., ESD - OBSOLETE'89																		
Employees	82	3	1	1													87	1
Visitors																		
Total	82	3	1	1													87	1
Nevada Miscellaneous Contractors																		
Employees	73																73	
Visitors																		
Total	73																73	
Reynolds Elec. & Engr. Co.																		
Employees	1,182	22	8	2													1,214	3
Visitors	1	2															3	
Total	1,183	24	8	2													1,217	3

TABLE B.4 (continued)
Distribution of Annual Whole-Body Radiation Doses by Contractor
Nevada Operations
1989

Contractor	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Science Applications Internt'l Corp. -NV																	
Employees	37																37	
Visitors																		
Total	37																37	
Wackenhut Services, Inc. - NV																		
Employees	10																10	
Visitors																		
Total	10																10	
Nevada Operations Total	1,808	42	16	4	1												1,871	6

TABLE B.5
Distribution of Annual Whole-Body Radiation Doses by Contractor
Oak Ridge Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
M.M. Portsmouth Subcontractors																		
Employees	1																1	
Visitors	293	169	3														465	3
Total	294	169	3														466	3
Martin Marietta (ORGDP)																		
Employees	684	31	1														716	1
Visitors	3	7															10	
Total	687	38	1														726	1
Martin Marietta (ORNL)																		
Employees	580	226	107	33	2	2											950	40
Visitors	114	37	1														152	1
Total	694	263	108	33	2	2											1,102	41
Martin Marietta (Paducah)																		
Employees	1,109	112	21	1													1,243	7
Visitors		1															1	
Total	1,109	113	21	1													1,244	7
Martin Marietta (Portsmouth)																		
Employees	1,216	1,252	33	8													2,509	30
Visitors																		
Total	1,216	1,252	33	8													2,509	30
Martin Marietta (Y-12)																		
Employees	1,293	1,210	134	18													2,655	67
Visitors	135	205	3	1													344	5
Total	1,428	1,415	137	19													2,999	71
Morrison-Knudsen (decommissioning proj.)																		
Employees	110	7															117	
Visitors	186	13															199	
Total	296	20															316	

TABLE B.5 (continued)
Distribution of Annual Whole-Body Radiation Doses by Contractor
Oak Ridge Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Oak Ridge Assoc. Universities																		
Employees	110	15	1														126	1
Visitors		15		1													16	1
Total	110	30	1	1													142	1
Oak Ridge Office Subs																		
Employees	36																36	
Visitors	87	3															90	
Total	123	3															126	
RMI Company																		
Employees	6	101															107	2
Visitors		11															11	
Total	6	112															118	3
Westinghouse Materials Co. of Ohio																		
Employees	759	461	79	23	3												1,325	36
Visitors	1,157	460	21	9	4	5	2										1,325	25
Total	1,916	921	100	32	7	5	2										2,983	61
Oak Ridge Operations																		
Total	7,879	4,336	404	94	9	7	2										12,731	218

TABLE B.6
Distribution of Annual Whole-Body Radiation Doses by Contractor
Pittsburgh Naval Reactors Office
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.- <0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Westinghouse Electric (BAPL)																		
Employees	209	678	28	27	2												944	23
Visitors	98	53															151	
Total	307	731	28	27	2												1,095	24
Westinghouse Electric (NRF)																		
Employees	58	670	127	34	11	5											905	59
Visitors	35	6															41	
Total	93	676	127	34	11	5											946	60
Westinghouse Plant Apparatus Division																		
Employees	26	19	2														47	1
Visitors																		
Total	26	19	2														47	1
Pittsburgh N.R. Office																		
Total	426	1,426	157	61	13	5											2,088	84

TABLE B.7
Distribution of Annual Whole-Body Radiation Doses by Contractor
Richland Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Battelle Memorial Institute (PNL)																		
Employees	296	844	76	40	10	9	17										1,292	86
Visitors		4	1	1													6	1
Total	296	848	77	41	10	9	17										1,298	86
Hanford Environmental Health Foundation																		
Employees	23	27															50	1
Visitors																		
Total	23	27															50	1
Kaiser Engineers Hanford - Cost Const																		
Employees	284	544	89	56	22	9	9										1,013	85
Visitors		7	4														11	1
Total	284	551	93	56	22	9	9										1,024	86
Westinghouse Hanford Service Subs																		
Employees	32	86															118	2
Visitors		5															5	
Total	32	91															123	2
Westinghouse Hanford Services																		
Employees	2,267	2,915	294	149	77	36	112	12									5,862	440
Visitors		10	4														14	1
Total	2,267	2,925	298	149	77	36	112	12									5,876	441
Richland Operations																		
Total	2,902	4,442	468	246	109	54	138	12									8,371	616

TABLE B.8
Distribution of Annual Whole-Body Radiation Doses by Contractor
Rocky Flats Operations
1989

Contractor	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
EG&G Rocky Flats																		
Employees	2,976	1,776	456	265	113	71	38										5,695	389
Visitors	779	1,178	20	4		1	2										1,984	23
Total	3,755	2,954	476	269	113	72	40										7,679	412
Rocky Flats Operations Total	3,755	2,954	476	269	113	72	40										7,679	412

TABLE B.9
Distribution of Annual Whole-Body Radiation Doses by Contractor
San Francisco Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Energy Technology Engineering Center																		
Employees	6	2															8	
Visitors																		
Total	6	2															8	
LLNL Plant Services																		
Employees	437	7															444	
Visitors																		
Total	437	7															444	
LLNL Security																		
Employees	326	3															329	
Visitors																		
Total	326	3															329	
LLNL Subcontractors																		
Employees																		
Visitors	25	58	10	7													100	6
Total	25	58	10	7													100	6
Lawrence Berkeley Laboratory																		
Employees	27	292	25	8	1												353	14
Visitors		21	6	1													28	2
Total	27	313	31	9	1												381	16
Lawrence Livermore Nat'l Lab. - Nevada																		
Employees	85	5	2	2	1												95	2
Visitors	3																3	
Total	88	5	2	2	1												98	2
Lawrence Livermore National Laboratory																		
Employees	8,275	234	38	14	9	1	4	1									8,576	34
Visitors																		
Total	8,275	234	38	14	9	1	4	1									8,576	34

TABLE B.9 (continued)
Distribution of Annual Whole-Body Radiation Doses by Contractor
San Franciso Operations
1989

Contractor	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Los Angeles Lab of Biomedical & Envirmnt																		
Employees	65	18		2			3	2									90	10
Visitors	11	5															16	
Total	76	23		2			3	2									106	10
Rockwell International, Atomics Int'l																		
Employees		2		1			1										4	1
Visitors																		
Total		2		1			1										4	1
Stanford Linear Accelerator Center																		
Employees	222	69	23	4	4	1											323	11
Visitors																		
Total	222	69	23	4	4	1											323	11
U. of Cal./Davis, Radiobiology Lab -LEHR																		
Employees	13																13	
Visitors	18																18	
Total	31																31	
U. of Cal./SAN - Lab of Radiobiology																		
Employees	27	14	1														42	1
Visitors		1															1	
Total	27	15	1														43	1
San Francisco Operations																		
Total	9,540	731	105	39	15	2	8	3									10,443	82

TABLE B.10
Distribution of Annual Whole-Body Radiation Doses by Contractor
Savannah River Operations
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Westinghouse S.R. Subcontractors																		
Employees																		
Visitors	628	1,297	18	7													1,950	24
Total	628	1,297	18	7													1,950	24
Westinghouse Savannah River Co.																		
Employees	7,399	8,532	1,166	518	116	62	62										17,855	778
Visitors	216	229															445	3
Total	7,615	8,761	1,166	518	116	62	62										18,300	781
Savannah River Operations																		
Total	8,243	10,058	1,184	525	116	62	62										20,250	804

TABLE B.11
Distribution of Annual Whole-Body Radiation Doses by Contractor
Schenectady Naval Reactors Office
1989

Contractor	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
GE-KAPL - Kesselring																		
Employees	56	612	33	13													714	19
Visitors	97	709	144	69	26	13	9										1,067	107
Total	153	1,321	177	82	26	13	9										1,781	125
GE-KAPL - Knolls																		
Employees	472	387	9														868	7
Visitors	17	29															46	
Total	489	416	9														914	7
GE-KAPL - Knolls Subs																		
Employees	5	6															11	
Visitors	26	2															28	
Total	31	8															39	
GE-KAPL - Windsor																		
Employees	8	147	14														169	7
Visitors	40	44	4														88	1
Total	48	191	18														257	8
Schenectady N.R. Office																		
Total	721	1,936	204	82	26	13	9										2,991	140

APPENDIX C

DISTRIBUTION OF ANNUAL WHOLE-BODY DOSES FOR DOE GOVERNMENT EMPLOYEES AND VISITORS BY DOE FIELD ORGANIZATION, 1989

TABLE C.1
Distribution of Annual Whole-Body Radiation Doses for DOE Employees and Visitors by DOE Organization
1989

Organization	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Albuquerque Operations Office																		
Employees	576	67	1														644	1
Visitors																		
Total	576	67	1														644	1
Amarillo Area Office																		
Employees	46																46	
Visitors																		
Total	46																46	
Dayton Area Office																		
Employees	21	7															28	
Visitors																		
Total	21	7															28	
Kansas City Area Office																		
Employees	23	2															25	
Visitors																		
Total	23	2															25	
Los Alamos Area Office																		
Employees	45																45	
Visitors																		
Total	45																45	
Pinellas Area Office																		
Employees	5																5	
Visitors																		
Total	5																5	
UMTRA Project Office																		
Employees	10	1															11	
Visitors																		
Total	10	1															11	

TABLE C.1 (continued)
Distribution of Annual Whole-Body Radiation Doses for DOE Employees and Visitors by DOE Organization
1989

Organization	Dose-Equivalent Ranges (rem)																Total Persons	Total Person-rem
	≤ Meas.	Meas.- <0.10	0.10- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
WIPP Project Office																		
Employees	33	3															36	
Visitors																		
Total	33	3															36	
Albuquerque Operations																		
Total	759	80	1														840	1
Chicago Operations Office																		
Employees	23	2															25	
Visitors																		
Total	23	2															25	
Environmental Meas. Lab.																		
Employees	38	3															41	
Visitors																		
Total	38	3															41	
New Brunswick Laboratory																		
Employees	60	2															62	
Visitors	10																10	
Total	70	2															72	
Chicago Operations																		
Total	131	7															138	

TABLE C.1 (continued)
Distribution of Annual Whole-Body Radiation Doses for DOE Employees and Visitors by DOE Organization
1989

Organization	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
DOE Headquarters																		
Employees	238	16															254	
Visitors																		
Total	238	16															254	
DOE Headquarters Total	238	16															254	
Idaho Operations Office																		
Employees	152	43	2														197	1
Visitors		4															4	
Total	152	47	2														201	1
Idaho Operations Total	152	47	2														201	1
Nevada Operations Office																		
Employees	40	1															41	
Visitors																		
Total	40	1															41	
Defense Nuclear Agency - Kirtland AFB																		
Employees	186	1															187	
Visitors																		
Total	186	1															187	
Environmental Protection Agency (NERC)																		
Employees	39																39	
Visitors																		
Total	39																39	
Nevada Operations Total	265	2															267	

TABLE C.1 (continued)
Distribution of Annual Whole-Body Radiation Doses for DOE Employees and Visitors by DOE Organization
1989

Organization	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
Pittsburgh N.R. Office																		
Employees	11	26	6														43	1
Visitors																		
Total	11	26	6														43	1
Pittsburgh N.R. Office Total	11	26	6														43	1
Richland Operations Office																		
Employees	74	116	3														193	3
Visitors		2															2	
Total	74	118	3														195	3
Richland Operations Total	74	118	3														195	3
Rocky Flats Operations Office																		
Employees	5	2	1														8	
Visitors	58	12															70	
Total	63	14	1														78	
Rocky Flats Operations Total	63	14	1														78	

TABLE C.1 (continued)
Distribution of Annual Whole-Body Radiation Doses for DOE Employees and Visitors by DOE Organization
1989

Organization	Dose-Equivalent Ranges (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10		
San Francisco Operations Office																		
Employees	90	2															92	
Visitors																		
Total	90	2															92	
San Francisco Operations Total	90	2															92	
Schenectady N.R. Office																		
Employees	12	11															23	
Visitors																		
Total	12	11															23	
Schenectady N.R. Office Total	12	11															23	

APPENDIX D

1989 EXPOSURE DATA BY DOSE RANGE, EXPOSURE TYPE, FACILITY TYPE, AGE, SEX, AND OCCUPATION FOR DOE AND DOE CONTRACTOR EMPLOYEES AND VISITORS

Table D.1
Distribution of Penetrating Doses by Facility and Penetrating Dose Range[a]
1989 - Male

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	3,049	1,407	205	113	43	23	21	1	1	1						4,864	188
Fuel/Uran. Enrichment	3,277	1,369	51	11	1		1									4,710	36
Fuel Fabrication	2,013	1,203	124	52	9	8	6									3,415	88
Fuel Processing	1,264	854	270	197	69	63	122	25	1	1						2,866	438
Maint. and Support	12,068	6,215	802	330	85	32	29	4	4							19,569	529
Reactor	1,507	3,370	495	196	75	39	46	16	6	1						5,751	407
Research, General	8,748	3,896	531	221	71	53	50	21	3							13,594	448
Research, Fusion	1,124	261	10	2												1,397	10
Waste Proc./Management	2,476	1,342	238	124	53	21	11	2	1							4,268	189
Weapons Fab. & Test.	8,222	4,005	592	272	109	63	39	2								13,304	464
Other	6,347	2,999	161	61	10	7	2	1	1	—	—	—	—	—	—	9,589	133
Total Persons	50,095	26,291	3,479	1,579	525	309	327	72	17	3	0	0	0	0	0	83,327	
Total Person-rem	0	691	539	550	321	267	395	123	38	8	0	0	0	0	0		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.2
Distribution of Penetrating Doses by Facility Type and Penetrating Dose Range[a]
1989 - Female

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	430	108	13	5	3	1	2									562	12
Fuel/Uran. Enrichment	762	222	11													995	6
Fuel Fabrication	420	182	21	11	4	1										639	14
Fuel Processing	391	191	60	17	13	12	9	2								695	53
Maint. and Support	3,341	1,057	120	44	15	6	4									4,587	78
Reactor	260	319	25	9	3	1	5	3	1							626	31
Research, General	2,246	546	59	30	10	7	12	5								2,915	67
Research, Fusion	120	10														130	
Waste Proc./Management	535	321	21	19	7	1	3	1								908	30
Weapons Fab. & Test.	2,119	678	94	50	14	14	5									2,974	75
Other	1,406	635	22	7	1	—	2	—	—	—	—	—	—	—	—	2,073	22
Total Persons	12,030	4,269	446	192	70	43	52	11	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	68	67	42	36	42	16	2	0	0	0	0	0	0		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.3
Distribution of Penetrating Doses by Facility Type and Penetrating Dose Range[a]
1989 - Unknown Sex

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	2	1														3	
Fuel/Uran. Enrichment	1	3														4	
Maint. and Support	350	627	5	4												986	11
Research, General	23	15														38	
Weapons Fab. & Test.	168	449	1													618	4
Other	454	900	75	10	5	–	1	–	–	–	–	–	–	–	–	1,445	41
Total Persons	998	1,995	81	14	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	36	11	5	3	0	1	0	0	0	0	0	0	0	0		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.4
Distribution of Collective Penetrating Doses by Facility Type and Penetrating Dose Range[(a)]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)														Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator		42	31	38	26	20	24	2	2	3						4,864	188
Fuel/Uran. Enrichment		25	8	4	1	1	1									4,710	38
Fuel Fabrication		31	19	18	5	7	7									3,415	88
Fuel Processing		25	45	69	43	55	153	43	2	3						2,866	438
Maint. and Support		160	124	114	52	28	35	7	9							19,569	529
Reactor		86	74	68	46	34	55	27	14	3						5,751	407
Research, General		96	82	78	44	46	60	36	6							13,594	448
Research, Fusion		8	1	1												1,397	10
Waste Proc./Management		39	36	45	32	18	13	3	2							4,268	189
Weapons Fab. & Test.		111	91	94	66	54	45	3								13,304	464
Other		68	26	21	6	6	2	2	2							9,589	133
Total Persons	50,095	26,291	3,479	1,579	525	309	327	72	17	3	0	0	0	0	0	83,327	
Total Person-rem	0	691	539	550	321	267	395	123	38	8	0	0	0	0	0		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.5
Distribution of Collective Penetrating Doses by Facility Type and Penetrating Dose Range[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator		3	2	1	2	1	3									562	12
Fuel/Uran. Enrichment		4	2													995	6
Fuel Fabrication		4	3	4	2	1										639	14
Fuel Processing		5	9	6	8	10	11	3								695	53
Maint. and Support		26	18	15	9	5	5									4,587	78
Reactor		7	4	3	2	1	7	5	2							626	31
Research, General		13	9	10	6	6	15	8								2,915	67
Research, Fusion																130	
Waste Proc./Management		9	3	7	4	1	4	2								908	30
Weapons Fab. & Test.		17	15	18	8	11	6									2,974	75
Other	—	13	4	2	1	—	3	—	—	—	—	—	—	—	—	2,073	22
Total Persons	12,030	4,269	446	192	70	43	42	11	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	68	67	42	36	52	18	2	0	0	0	0	0	0		368

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.6
Distribution of Collective Penetrating Doses by Facility Type and Penetrating Dose Range[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator																3	
Fuel/Uran. Enrichment																4	
Maint. and Support		9	1	1												986	11
Research, General																38	
Weapons Fab. & Test.		3														618	4
Other	—	23	10	3	3	—	1	—	—	—	—	—	—	—	—	1,445	41
Total Persons	998	1,995	81	14	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	36	11	5	3	0	1	0	0	0	0	0	0	0	0		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.7
Distribution of Penetrating Doses by Age and Penetrating Dose Range[a]
1989 - Male

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	269	70	3			1										343	3
20 - 24	1,924	1,136	168	62	17	10	10									3,327	107
25 - 29	4,786	3,252	482	238	69	42	63	13	2	2						8,934	436
30 - 34	7,329	4,363	682	318	128	65	61	27	5							12,978	604
35 - 39	7,678	4,467	603	287	95	58	67	13	5							13,273	535
40 - 44	7,221	3,665	509	220	75	46	48	8	3							11,995	417
45 - 49	6,121	2,855	327	147	45	29	21	5	1	1						9,552	265
50 - 54	5,087	2,346	273	130	36	19	24	2								7,917	217
55 - 59	4,551	2,125	232	124	36	21	25	4	1							7,119	209
60 - 64	3,219	1,308	144	42	19	9	6									4,747	97
65 and greater	1,236	379	36	6	4	3	2									1,666	23
Unknown	674	775	20	5	1	1	—	—	—	—	—	—	—	—	—	1,476	20
Total Persons	50,095	26,921	3,479	1,579	525	309	327	72	17	3	0	0	0	0	0	83,327	
Total Person-rem	0	691	539	550	321	267	395	123	38	8	0	0	0	0	0		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.8
Distribution of Penetrating Doses by Age and Penetrating Dose Range[a]
1989 - Female

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	139	37	3													179	1
20 - 24	894	382	27	10	3	3										1,319	21
25 - 29	1,742	746	83	42	12	6	8	1								2,640	68
30 - 34	2,191	917	117	41	20	10	8	1	1							3,306	90
35 - 39	2,020	790	82	36	12	9	14	2								2,965	80
40 - 44	1,678	498	66	27	12	8	5	1								2,295	54
45 - 49	1,298	323	40	19	5	2	2	3								1,692	33
50 - 54	843	234	19	6	3	2	3	1								1,111	19
55 - 59	594	152	2	7	2		2									759	10
60 - 64	340	74	6	3	1	2		2								428	9
65 and greater	152	21	1			1										175	2
Unknown	139	95	—	1	—	—	—	—	—	—	—	—	—	—	—	235	2
Total Persons	12,030	4,269	446	192	70	43	42	11	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	68	67	42	36	52	18	2	0	0	0	0	0	0		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.9
Distribution of Penetrating Doses by Age and Penetrating Dose Range[a]
1989 - Unknown Sex

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	7	1														8	
20 - 24	1	1														2	
25 - 29	10	3														13	
30 - 34	2	6														8	
35 - 39	5	8														13	
40 - 44	3	1														4	
45 - 49	2	2														4	
50 - 54	4	2														6	
55 - 59	6	2														8	
60 - 64	1	1														2	
65 and greater	50	46	8	3												107	4
Unknown	907	1,922	73	11	5	—	1	—	—	—	—	—	—	—	—	2,919	51
Total Persons	998	1,995	81	14	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	36	11	5	3	0	1	0	0	0	0	0	0	0	0		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.10
Distribution of Collective Penetrating Doses by Age and Penetrating Dose Range[a]
1989 - Male

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)														Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less		1				1										343	3
20 - 24		28	26	21	10	8	12									3,327	107
25 - 29		86	75	82	43	41	78	22	4	5						8,934	436
30 - 34		117	107	113	78	56	74	46	12							12,978	604
35 - 39		117	94	100	58	51	81	22	11							13,273	535
40 - 44		99	79	76	46	39	58	14	6							11,995	417
45 - 49		74	50	50	27	25	25	9	2	3						9,552	265
50 - 54		59	41	45	22	17	29	3								7,917	217
55 - 59		53	35	43	22	17	30	6	2							7,119	209
60 - 64		33	23	15	11	8	7									4,747	97
65 and greater		9	5	2	2	3	2									1,666	23
Unknown		14	3	2	1	1										1,476	20
Total Persons	50,095	26,921	3,479	1,579	525	309	327	72	17	3	0	0	0	0	0	83,327	
Total Person-rem	0	691	539	550	321	267	395	123	38	8	0	0	0	0	0		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.11
Distribution of Collective Penetrating Doses by Age and Penetrating Dose Range[a]
1989 - Female

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less		1														179	1
20 - 24		9	4	3	2	2										1,319	21
25 - 29		18	12	15	7	5	10	2								2,640	68
30 - 34		23	19	14	12	9	10	2	2							3,306	90
35 - 39		19	13	12	7	7	17	3								2,965	80
40 - 44		13	10	9	7	7	7	2								2,295	54
45 - 49		8	6	7	3	2	3	5								1,692	33
50 - 54		6	3	2	2	2	4	2								1,111	19
55 - 59		4		2	1		2									759	10
60 - 64		2	1	1	1	2		3								428	9
65 and greater		1				1										175	2
Unknown		2	—	—	—	—	—	—	—	—	—	—	—	—	—	235	2
Total Persons	12,030	4,269	446	192	70	43	42	11	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	68	67	42	36	52	18	2	0	0	0	0	0	0		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.12
Distribution of Collective Penetrating Doses by Age and Penetrating Dose Range[a]
1989 - Unknown Sex

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	≤ Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less																8	
20 - 24																2	
25 - 29																13	
30 - 34																8	
35 - 39																13	
40 - 44																4	
45 - 49																4	
50 - 54																6	
55 - 59																8	
60 - 64																2	
65 and greater		2	1	1												107	4
Unknown	—	34	10	4	3	—	1	—	—	—	—	—	—	—	—	2,919	51
Total Persons	998	1,995	81	14	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	36	11	5	3	0	1	0	0	0	0	0	0	0	0		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.13
Distribution of Penetrating Doses by Occupation and Penetrating Doser Range[a]
1989 - Male

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	9,516	3,081	336	168	80	61	54	17	2							13,315	378
Management	4,773	2,565	195	78	28	9	12	2	1							7,663	164
Scientists	15,456	6,679	451	166	45	22	24	4	2							22,849	360
Technicians	5,057	2,809	726	341	126	64	71	11	5	1						9,211	574
Service	2,812	1,987	89	25	3	1	2									4,919	71
Agriculture	73	22														95	
Construction	4,895	4,614	804	336	90	39	38	9	1							10,826	520
Production	2,761	2,741	635	385	137	101	114	29	6	2						6,911	706
Transportation	1,789	609	53	14	7	1	5									2,478	40
Laborers	873	678	144	57	7	8	5									1,772	80
Miscellaneous	2,090	1,136	46	9	2	3	2	—	—	—	—	—	—	—	—	3,288	38
Total Persons	50,095	26,921	3,479	1,579	525	309	327	72	17	3	0	0	0	0	0	83,327	
Total Person-rem	0	691	539	550	321	267	395	123	38	8	0	0	0	0	0		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.14
Distribution of Penetrating Doses by Occupation and Penetrating Dose Range[a]
1989 - Female

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	2,993	404	33	25	9	7	14	5								3,490	59
Management	2,731	595	27	10	3	1	1									3,368	24
Scientists	2,577	926	51	20	5	3	1	1								3,584	43
Technicians	1,331	734	128	57	20	12	10	2								2,294	97
Service	885	464	10	3												1,362	12
Agriculture	4	3														7	
Construction	345	350	48	12	2	1										758	22
Production	462	506	120	55	31	18	15	3	1							1,211	114
Transportation	68	29														97	1
Laborers	151	128	27	9		1	1									317	13
Miscellaneous	483	130	2	1	—	—	—	—	—	—	—	—	—	—	—	616	3
Total Persons	12,030	4,269	446	192	70	43	42	11	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	68	67	42	36	52	18	2	0	0	0	0	0	0		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.15
Distribution of Penetrating Doses by Occupation and Penetrating Dose Range[a]
1989 - Unknown Sex

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	≥ 5		
Unknown	623	1,352	76	10	5		1									2,067	44
Scientists	3	1														4	
Construction	350	628	5	4												987	11
Miscellaneous	22	14	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	998	1,995	81	14	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	36	11	5	3	0	1	0	0	0	0	0	0	0	0		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.16
Distribution of Collective Penetrating Doses by Occupation and Penetrating Dose Range[a]
1989 - Male

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		67	52	60	50	53	64	29	4							13,315	378
Management		66	29	27	16	8	14	3	2							7,663	164
Scientists		151	68	56	27	19	28	7	4							22,849	360
Technicians		87	116	118	78	56	86	19	11	3						9,211	574
Service		44	13	9	2	1	2									4,919	71
Agriculture																95	
Construction		124	126	118	55	34	47	15	2							10,826	520
Production		93	98	135	84	87	140	50	14	5						6,911	706
Transportation		16	8	5	4	1	6									2,478	40
Laborers		21	23	19	4	7	5									1,772	80
Miscellaneous		22	7	3	1	3	2									3,288	38
Total Persons	50,095	26,921	3,479	1,579	525	309	327	72	17	3	0	0	0	0	0	83,327	
Total Persons-rem	0	691	539	550	321	267	395	123	38	8	0	0	0	0	0		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.17
Distribution of Collective Penetrating Doses by Occupation and Penetrating Dose Range[a]
1989 - Female

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	≥ 5		
Unknown		7	5	9	6	6	18	8								3,490	59
Management		13	4	4	2	1	1									3,368	24
Scientists		19	8	7	3	2	1	2								3,584	43
Technicians		22	20	19	12	10	12	3								2,294	97
Service		10	2	1												1,362	12
Agriculture																7	
Construction		9	7	4	1	1										758	22
Production		17	18	20	18	15	18	5	2							1,211	114
Transportation		1														97	1
Laborers		4	4	3		1	1									317	13
Miscellaneous	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	616	3
Total Persons	12,030	4,269	446	192	70	43	42	11	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	68	67	42	36	52	18	2	0	0	0	0	0	0		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.18
Distribution of Collective Penetrating Doses by Occupation and Penetrating Dose Range[a]
1989 - Unknown Sex

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		26	10	3	3		1									2,067	44
Scientists																4	
Construction		9	1	1												987	11
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	998	1,995	81	14	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	36	11	5	3	0	1	0	0	0	0	0	0	0	0		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.19
Distribution of Persons Receiving Penetrating Doses by Age and Facility Type[a]
1989 - Male

Facility Type	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator	28	237	575	762	673	683	569	495	405	226	153	58	4,864	154
Fuel/Uran. Enrichment	4	62	242	593	933	892	581	413	424	424	84	58	4,710	38
Fuel Fabrication	19	209	516	633	579	442	316	240	249	163	43	6	3,415	88
Fuel Processing	1	159	364	565	499	429	268	193	217	151	19	1	2,866	438
Maint. and Support	105	816	2,173	3,067	3,055	2,625	2,164	1,799	1,653	1,094	368	650	19,569	529
Reactor		251	860	990	988	869	551	460	448	283	41	10	5,751	407
Research, General	120	599	1,182	1,868	2,106	1,809	1,665	1,410	1,353	900	426	156	13,594	448
Research, Fusion	1	32	118	187	237	203	168	148	132	106	56	9	1,397	10
Waste Proc./Management	10	214	601	777	720	626	435	362	280	176	55	12	4,268	189
Weapons Fab. & Test.	16	239	993	1,877	1,990	2,055	1,848	1,670	1,412	880	214	110	13,304	464
Other	39	509	1,310	1,659	1,493	1,362	987	727	546	344	207	406	9,589	133
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	107	436	604	535	417	265	217	209	97	23	20		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.20
Distribution of Persons Receiving Penetrating Doses by Age and Facility Type[a]
1989 - Female

Facility Type	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator	14	44	104	109	89	67	52	44	15	9	9	6	562	12
Fuel/Uran. Enrichment	9	51	108	208	189	134	92	81	64	40	10	9	995	6
Fuel Fabrication	2	42	120	139	115	96	43	35	27	17	3		639	14
Fuel Processing	2	68	131	171	127	82	63	30	14	3	4		695	53
Maint. and Support	29	312	709	852	792	661	503	290	202	98	44	95	4,587	78
Reactor	3	53	144	143	102	88	36	22	19	13		3	626	31
Research, General	81	287	419	559	491	326	255	197	136	92	37	35	2,915	67
Research, Fusion	1	8	12	20	21	27	19	4	9	5	3	1	130	
Waste Proc./Management	7	85	172	177	171	116	85	46	28	18	3		908	30
Weapons Fab. & Test.	11	133	342	536	539	474	369	249	184	104	26	7	2,974	75
Other	20	236	379	392	329	224	175	113	61	29	36	79	2,073	22
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	21	68	90	80	54	33	19	10	9	2	2		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.21
Distribution of Persons Receiving Penetrating Doses by Age and Facility Type[a]
1989 - Unknown Sex

Facility Type	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator									2			1	3	
Fuel/Uran. Enrichment												4	4	
Maint. and Support								1				985	986	11
Research, General	6	1	2	3	2	1		1		1		21	38	
Weapons Fab. & Test.	1		6	4	8	1	2	1	1			594	618	4
Other	1	1	5	1	3	2	2	3	5	1	107	1,314	1,445	41
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	4	51		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.22
Distribution of Collective Penetrating Doses by Age and Facility Type[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator		4	22	32	33	31	19	20	18	7	1	1	4,864	188
Fuel/Uran. Enrichment			4	7	8	7	4	2	3	2			4,710	38
Fuel Fabrication	1	3	17	19	12	14	7	5	6	3	1		3,415	88
Fuel Processing		26	83	117	84	56	38	15	15	4			2,866	438
Maint. and Support	1	32	81	108	88	72	47	41	32	13	3	9	19,569	529
Reactor		14	70	79	81	66	28	29	25	13	1	1	5,751	407
Research, General		7	46	82	95	53	43	41	49	22	7	3	13,594	448
Research, Fusion			1	2	2	1	1	1	1	1		1	1,397	10
Waste Proc./Management		9	42	41	37	25	11	7	14	3			4,268	189
Weapons Fab. & Test.		1	45	91	78	75	55	44	40	26	6	2	13,304	464
Other		9	25	25	17	17	13	11	7	3	3	3	9,589	133
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	107	436	604	535	417	265	217	209	97	23	20		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.23
Distribution of Collective Penetrating Doses by Age and Facility Type[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator			3	3	4		1						562	12
Fuel/Uran. Enrichment			1	2	1	1	1						995	6
Fuel Fabrication			2	4	2	4		1	1				639	14
Fuel Processing		5	11	18	13	3	3						695	53
Maint. and Support		7	18	21	13	7	6	2	1			1	4,587	78
Reactor		1	5	6	5	10	1			2			626	31
Research, General		2	11	11	16	4	5	9	3	5	1		2,915	67
Research, Fusion													130	
Waste Proc./Management		2	5	7	4	4	5	1	1				908	30
Weapons Fab. & Test.		1	7	14	17	17	9	4	3	1			2,974	75
Other	—	3	5	4	4	3	1	1	—	—	—	—	2,073	22
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	21	68	90	80	54	33	19	10	9	2	2		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.24
Distribution of Collective Penetrating Doses by Age and Facility Type[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator													3	
Fuel/Uran. Enrichment													4	
Maint. and Support												11	986	11
Research, General													38	
Weapons Fab. & Test.												2	618	3
Other	—	—	—	—	—	—	—	—	—	—	4	37	1,445	41
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	4	51		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.25
Distribution of Persons Receiving Penetrating Doses by Age and Occupation[a]
1989 - Male

Occupation	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	117	661	1,330	1,795	1,789	1,726	1,674	1,437	1,130	804	438	414	13,315	378
Management	16	55	336	849	1,226	1,378	1,177	1,084	860	525	138	19	7,663	164
Scientists	16	770	2,405	3,502	3,610	3,292	2,673	2,324	2,240	1,396	550	71	22,849	360
Technicians	20	410	1,231	1,768	1,605	1,249	893	731	702	436	103	63	9,211	574
Service	12	250	895	1,037	774	613	412	285	248	202	110	81	4,919	71
Agriculture	1	5	10	19	18	14	9	8	9	1	1		95	
Construction	57	510	1,093	1,542	1,770	1,659	1,194	892	798	570	109	632	10,826	520
Production	4	228	765	1,231	1,307	1,055	743	490	565	438	84	1	6,911	706
Transportation	3	53	227	408	443	412	269	268	217	141	33	4	2,478	40
Laborers	31	143	267	363	324	204	158	104	95	56	14	13	1,772	80
Miscellaneous	66	242	375	464	407	393	350	294	255	178	86	178	3,288	38
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	107	436	604	535	417	265	217	209	97	23	20		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.26
Distribution of Persons Receiving Penetrating Doses by Age and Occupation[a]
1989 - Female

Occupation	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	65	252	436	514	533	496	411	328	176	129	74	76	3,490	59
Management	25	192	413	531	596	528	461	287	213	86	32	4	3,368	24
Scientists	6	272	744	859	630	396	280	163	142	58	20	14	3,584	43
Technicians	15	219	386	534	440	303	169	102	58	53	5	10	2,294	97
Service	8	134	225	265	245	164	114	74	60	47	19	7	1,362	12
Agriculture			1	1	2	1		1	1				7	
Construction	5	73	143	158	126	77	36	19	25	12		84	758	22
Production	6	53	153	263	245	202	130	74	53	28	4		1,211	114
Transportation		3	11	27	14	18	11	4	3	1	4	1	97	1
Laborers	11	20	44	58	58	55	35	22	7	3	1	3	317	13
Miscellaneous	38	101	84	96	76	55	45	37	21	11	16	36	616	3
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	21	68	90	80	54	33	14	10	9	6	2		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.27
Distribution of Persons Receiving Penetrating Doses by Age and Occupation[a]
1989 - Unknown Sex

Occupation	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	2	1	11	5	11	3	4	4	6	1	107	1,912	2,067	44
Scientists									1			3	4	
Construction									1	1		985	987	11
Miscellaneous	6	1	2	3	2	1	—	1	—	1	—	19	36	—
Total Persons	8	2	13	8	13	4	4	5	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	4	51		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.28
Distribution of Collective Penetrating Doses by Age and Occupation[a]
1989 - Male

Occupation	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown		9	53	76	70	49	37	30	32	13	6	4	13,315	378
Management		1	17	31	28	32	18	19	12	5	1		7,663	164
Scientists		7	53	62	59	46	39	34	36	18	4	1	22,849	360
Technicians	1	19	100	129	105	75	38	40	45	17	3	2	9,211	574
Service		3	12	14	13	11	6	4	2	3	1	2	4,919	71
Agriculture													95	
Construction	1	28	57	92	97	84	53	46	35	16	2	9	10,826	520
Production		35	124	166	139	98	59	28	33	20	4		6,911	706
Transportation		1	2	8	4	7	5	6	5	1			2,478	40
Laborers		4	15	19	14	11	7	6	4	1			1,772	80
Miscellaneous	—	1	3	6	6	5	4	3	4	2	1	2	3,288	38
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	107	436	604	535	417	265	217	209	97	23	20		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.29
Distribution of Collective Penetrating Doses by Age and Occupation[a]
1989 - Female

Occupation	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown		2	9	7	17	5	3	8	2	5	1		3,490	59
Management		1	4	4	5	4	3	2	1				3,368	24
Scientists		2	10	13	6	6	2	1	2				3,584	43
Technicians		6	20	26	19	12	7	3	2	1			2,294	97
Service		1	2	3	2	1	1	1	1				1,362	12
Agriculture													7	
Construction		2	5	5	4	1	2					1	758	22
Production		5	16	28	21	23	13	3	3	2			1,211	114
Transportation													97	1
Laborers			1	3	4	2	1	1					317	13
Miscellaneous	—	—	—	1	—	—	—	—	1	—	—	—	616	3
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	21	68	90	80	54	33	19	10	9	2	2		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.30
Distribution of Collective Penetrating Doses by Age and Occupation[a]
1989 - Unknown Sex

Occupation	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown											4	40	2,067	44
Scientists													4	
Construction												11	987	11
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	4	51		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.31
Distribution of Persons Receiving Penetrating Doses by Occupation and Facility Type[a]
1989 - Male

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	1,124	134	1,789	1,370	147	15	123	98	38	1	25	4,864	188
Fuel/Uran. Enrichment	128	530	1,075	485	343	1	1,082	807	48	167	44	4,710	38
Fuel Fabrication	1,711	239	502	177	170		211	336	38	30	1	3,415	88
Fuel Processing	51	338	1,170	128	47	1	482	594	34	20	1	2,866	438
Maint. and Support	4,130	1,904	2,895	1,146	1,255	34	5,629	1,005	803	759	9	19,569	529
Reactor	27	739	2,267	596	128		743	768	94	77	312	5,751	407
Research, General	2,944	851	5,288	1,946	468	6	442	312	59	87	1,191	13,594	448
Research, Fusion	120	101	609	286	50		126	50		3	52	1,397	10
Waste Proc./Management	98	581	1,296	544	154	1	721	566	136	130	41	4,268	189
Weapons Fab. & Test.	1,249	1,527	3,446	1,783	478		839	2,116	136	178	1,552	13,304	464
Other	1,733	719	2,512	750	1,679	37	428	259	1,092	320	60	9,589	133
Total Persons	13,315	7,663	22,849	9,211	4,919	95	10,826	6,911	2,478	1,772	3,288	83,327	
Total Person-rem	378	164	360	574	71	0	520	706	40	80	38		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.32
Distribution of Persons Receiving Penetrating Doses by Occupation and Facility Type[a]
1989 - Female

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	172	63	175	91	45	1	4	6			5	562	12
Fuel/Uran. Enrichment	109	292	162	164	85		39	96	3	31	14	995	6
Fuel Fabrication	119	42	196	109	21		19	114	2	17		639	14
Fuel Processing	2	168	217	44	29		42	188	2	3		695	53
Maint. and Support	1,203	1,146	629	572	257		476	90	44	167	3	4,587	78
Reactor	4	160	171	66	24		45	130	3	6	17	626	31
Research, General	903	328	748	523	91	2	8	38	2	13	259	2,915	67
Research, Fusion	28	22	45	23	5		2			1	4	130	
Waste Proc./Management	30	187	170	165	143		33	167	5	2	6	908	30
Weapons Fab. & Test.	497	679	578	338	105		86	349	5	40	297	2,974	75
Other	423	281	493	199	557	4	4	33	31	37	11	2,073	22
Total Persons	3,490	3,368	3,584	2,294	1,362	7	758	1,211	97	317	616	17,104	
Total Person-rem	59	24	43	97	12	0	22	116	1	13	3		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.33
Distribution of Persons Receiving Penetrating Doses by Occupation and Facility Type[a]
1989 - Unknown Sex

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator			2				1					3	
Fuel/Uran. Enrichment	4											4	
Maint. and Support							986					986	11
Research, General			2								36	38	
Weapons Fab. & Test.	618											618	4
Other	1,445	—	—	—	—	—	—	—	—	—	—	1,445	41
Total Persons	2,067	0	4	0	0	0	987	0	0	0	36	3,094	
Total Person-rem	44	0	0	0	0	0	11	0	0	0	0		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.34
Distribution of Collective Penetrating Doses by Occupation and Facility Type[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	83	2	29	61			2	4	4			4,864	188
Fuel/Uran. Enrichment		1	3	5	3		8	12		6		4,710	38
Fuel Fabrication	26	6	5	10	16		3	19	2	1		3,415	88
Fuel Processing	1	16	57	46	2		91	214	7	5		2,866	438
Maint. and Support	38	26	26	94	18		236	36	12	42		19,569	529
Reactor	1	37	50	87	2		94	114	3	11	8	5,751	407
Research, General	169	14	77	131	5		22	15	1	6	8	13,594	448
Research, Fusion			3	3	1		1	1				1,397	10
Waste Proc./Management		13	34	26	1		34	76	4	1		4,268	189
Weapons Fab. & Test.	13	43	49	97	5		23	208	1	1	20	13,304	464
Other	45	7	27	15	18		7	7	3	2		9,589	133
Total Persons	13,315	7,663	22,849	9,211	4,919	95	10,826	6,911	2,478	1,772	3,288	83,327	
Total Person-rem	378	164	360	574	71	0	520	706	40	80	38		2,932

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.35
Distribution of Collective Penetrating Doses by Occupation and Facility Type[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	6		3	3								562	12
Fuel/Uran. Enrichment		1	1	1	1			2		1		995	6
Fuel Fabrication	1							9				639	14
Fuel Processing		1	6	4			2	38				695	53
Maint. and Support	7	7	5	35	2		16	3	1	6		4,587	78
Reactor		1	3	10			1	14		1		626	31
Research, General	41	2	7	14	1		1	1		1	1	2,915	67
Research, Fusion												130	
Waste Proc./Management		3	2	6			1	16				908	30
Weapons Fab. & Test.	2	9	9	18	2		1	31		2	2	2,974	75
Other	5	1	4	4	5	—	—	1	—	—	—	2,073	22
Total Persons	3,490	3,368	3,584	2,294	1,362	7	758	1,211	97	317	616	17,104	
Total Person-rem	59	24	43	97	12	0	22	114	1	13	3		388

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.36
Distribution of Collective Penetrating Doses by Occupation and Facility Type[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator												3	
Fuel/Uran. Enrichment												4	
Maint. and Support							11					986	11
Research, General												38	
Weapons Fab. & Test.	4											618	4
Other	41	—	—	—	—	—	—	—	—	—	—	1,445	41
Total Persons	2,067	0	4	0	0	0	987	0	0	0	36	3,094	
Total Person-rem	44	0	0	0	0	0	11	0	0	0	0		56

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.37
Distribution of Neutron Doses by Facility Type and Neutron Dose Range[a]
1989 - Male

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	4,491	263	77	30	3											4,864	34
Fuel/Uran. Enrichment	4,690	14	5		1											4,710	2
Fuel Fabrication	3,403	9	1	2												3,415	1
Fuel Processing	2,640	87	60	35	20	16	8									2,866	62
Maint. and Support	18,469	854	159	59	20	2	4	1	1							19,569	91
Reactor	5,603	134	11	2		1										5,751	6
Research, General	12,729	674	89	53	51	28	27	3								13,594	142
Research, Fusion	1,390	7														1,397	
Waste Proc./Management	3,852	279	68	48	14	5	2									4,268	52
Weapons Fab. & Test.	11,799	1,116	256	109	23	1										13,304	121
Other	9,260	249	61	14	35	—	—	—	—	—	—	—	—	—	—	9,589	24
Total Persons	78,326	3,626	767	352	137	53	41	4	1	0	0	0	0	0	0	83,327	
Total Person-rem	0	108	124	120	84	45	48	7	2	0	0	0	0	0	0		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.38
Distribution of Neutron Doses by Facility Type and Neutron Dose Range[a]
1989 - Female

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	540	16	2	4												562	2
Fuel/Uran. Enrichment	995															995	
Fuel Fabrication	638	1														639	
Fuel Processing	633	26	12	17	4	3										695	14
Maint. and Support	4,433	106	21	19	6	2										4,587	18
Reactor	617	8	1													626	
Research, General	2,784	76	17	12	8	9	7									2,915	31
Research, Fusion	120															130	
Waste Proc./Management	818	63	10	11	3	2	1									908	12
Weapons Fab. & Test.	2,748	157	47	19	3											2,974	20
Other	2,035	28	9	1	—	—	—	—	—	—	—	—	—	—	—	2,073	2
Total Persons	16,371	483	119	83	24	16	8	0	0	0	0	0	0	0	0	17,104	
Total Person-rem	0	15	19	28	15	14	10	0	0	0	0	0	0	0	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.39
Distribution of Neutron Doses by Facility Type and Neutron Dose Range[a]
1989 - Unknown Sex

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	3															3	
Fuel/Uran. Enrichment	4															4	
Maint. and Support	983	3														986	
Research, General	33	5														38	
Weapons Fab. & Test.	429	189														618	1
Other	1,383	56	5	1	–	–	–	–	–	–	–	–	–	–	–	1,445	3
Total Persons	2,835	253	5	1	0	0	0	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.40
Distribution of Collective Neutron Doses by Facility Type and Neutron Dose Range[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator		10	12	10	2											4,864	34
Fuel/Uran. Enrichment			1		1											4,710	2
Fuel Fabrication			1													3,415	1
Fuel Processing	3	10	13	13	14	8										2,866	62
Maint. and Support	25	25	20	12	2	4	2	2								19,569	91
Reactor	3	2	1		1											5,751	6
Research, General	16	14	19	32	24	32	5									13,594	142
Research, Fusion																1,397	
Waste Proc./Management	9	11	17	8	4	3										4,268	52
Weapons Fab. & Test.	31	41	35	13	1											13,304	121
Other	—	7	9	4	3	—	—	—	—	—	—	—	—	—	—	9,589	24
Total Persons	78,326	3,626	787	352	137	53	41	4	1	0	0	0	0	0	0	83,327	
Total Person-rem	0	106	124	120	84	45	48	7	2	0	0	0	0	0	0		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.41
Distribution of Collective Neutron Doses by Facility Type and Neutron Dose Range[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator		1		1												562	2
Fuel/Uran. Enrichment																995	
Fuel Fabrication																639	
Fuel Processing		1	2	6	3	3										695	14
Maint. and Support		3	3	7	3	2										4,587	18
Reactor																626	
Research, General		2	3	4	5	8	8									2,915	31
Research, Fusion																130	
Waste Proc./Management		2	2	4	2	2	1									908	12
Weapons Fab. & Test.		5	8	6	2											2,974	20
Other	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	2,073	2
Total Persons	16,371	483	119	83	24	16	8	0	0	0	0	0	0	0	0	17,104	
Total Person-rem	0	15	19	28	15	14	10	0	0	0	0	0	0	0	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.42
Distribution of Collective Neutron Doses by Facility Type and Neutron Dose Range[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator																3	
Fuel/Uran. Enrichment																4	
Maint. and Support																986	
Research, General																38	
Weapons Fab. & Test.		1														618	1
Other	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	1,445	3
Total Persons	2,835	253	5	1	0	0	0	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.43
Distribution of Neutron Doses by Age and Neutron Dose Range[a]
1989 - Male

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	338	5														343	
20 - 24	3,182	95	27	11	5	4	2	1								3,327	22
25 - 29	8,344	364	120	54	28	14	8	2								8,934	91
30 - 34	12,049	619	172	85	31	9	12		1							12,978	118
35 - 39	12,436	604	120	66	27	13	7									13,273	94
40 - 44	11,301	521	99	47	19	6	2									11,995	65
45 - 49	8,947	477	83	30	9	4	2									9,552	47
50 - 54	7,399	415	77	17	6	1	2									7,917	36
55 - 59	6,764	255	56	29	7	1	6	1								7,119	41
60 - 64	4,515	191	25	11	4	1										4,747	16
65 and greater	1,595	60	8	2	1											1,666	4
Unknown	1,456	20	—	—	—	—	—	—	—	—	—	—	—	—	—	1,476	1
Total Persons	78,326	3,626	787	352	137	53	41	4	1	0	0	0	0	0	0	83,327	
Total Person-rem	0	106	124	120	84	45	48	7	2	0	0	0	0	0	0		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.44
Distribution of Neutron Doses by Age and Neutron Dose Range[a]
1989 - Female

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	175	4														179	
20 - 24	1,283	20	10	5	1											1,319	4
25 - 29	2,520	77	15	22	2	3	1									2,640	18
30 - 34	3,134	111	29	20	8	8										3,306	24
35 - 39	2,817	89	33	16	4	4	2									2,965	22
40 - 44	2,196	71	16	9	2	1										2,295	10
45 - 49	1,624	47	10	7	2		2									1,692	9
50 - 54	1,059	39	5	3	2	1	2									1,111	7
55 - 59	744	12		1		2										759	2
60 - 64	415	8	1		3		1									428	3
65 and greater	171	3				1										175	1
Unknown	233	2	—	—	—	—	—	—	—	—	—	—	—	—	—	235	—
Total Persons	16,371	483	119	83	24	16	8	0	0	0	0	0	0	0	0	17,104	
Total Person-rem	0	15	19	28	15	14	10	0	0	0	0	0	0	0	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.45
Distribution of Neutron Doses by Age and Neutron Dose Range[a]
1989 - Unknown Sex

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	8															8	
20 - 24	1	1														2	
25 - 29	11	2														13	
30 - 34	6	2														8	
35 - 39	13															13	
40 - 44	4															4	
45 - 49	4															4	
50 - 54	6															6	
55 - 59	8															8	
60 - 64	2															2	
65 and greater	94	11	1	1												107	1
Unknown	2,678	237	4	—	—	—	—	—	—	—	—	—	—	—	—	2,919	3
Total Persons	2,835	253	5	1	0	0	0	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.46
Distribution of Collective Neutron Doses by Age and Neutron Dose Range[a]
1989 - Male

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less																343	
20 - 24		3	4	4	3	4	2	2								3,327	22
25 - 29		12	19	19	17	12	9	3								8,934	91
30 - 34		19	27	29	19	8	14		2							12,978	118
35 - 39		18	18	22	16	11	9									13,273	94
40 - 44		14	16	16	12	5	2									11,995	65
45 - 49		13	13	9	6	3	3									9,552	47
50 - 54		11	13	6	4	1	2									7,917	36
55 - 59		8	9	10	4	1	7	2								7,119	41
60 - 64		5	4	4	2	1										4,747	16
65 and greater		2	1	1	1											1,666	4
Unknown			1													1,476	1
Total Persons	78,326	3,626	787	352	137	53	41	4	1	0	0	0	0	0	0	83,327	
Total Person-rem	0	106	124	120	84	45	48	7	2	0	0	0	0	0	0		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.47
Distribution of Collective Neutron Doses by Age and Neutron Dose Range[a]
1989 - Female

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less																179	
20 - 24			2	2	1											1,319	4
25 - 29		2	3	8	1	3	1									2,640	18
30 - 34		4	5	7	5	4										3,306	24
35 - 39		2	5	6	2	3	2									2,965	22
40 - 44		3	2	3	1	1										2,295	10
45 - 49		1	2	2	1		3									1,692	9
50 - 54		1	1	1	1	1	2									1,111	7
55 - 59						2										759	2
60 - 64					2		1									428	3
65 and greater						1										175	1
Unknown																235	
Total Persons	16,371	483	119	83	24	16	8	0	0	0	0	0	0	0	0	17,104	
Total Person-rem	0	15	19	28	15	14	10	0	0	0	0	0	0	0	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.48
Distribution of Collective Neutron Doses by Age and Neutron Dose Range[a]
1989 - Unknown Sex

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less																8	
20 - 24																2	
25 - 29																13	
30 - 34																8	
35 - 39																13	
40 - 44																4	
45 - 49																4	
50 - 54																6	
55 - 59																8	
60 - 64																2	
65 and greater																107	1
Unknown	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	2,919	3
Total Persons	2,835	253	5	1	0	0	0	0	0	0	0	0	0	0		3,094	
Total Person-rem	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.49
Distribution of Neutron Doses by Occupation and Neutron Dose Range[a]
1989 - Male

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	11,998	894	204	102	57	28	30	2								13,315	190
Management	7,192	388	61	16	6											7,663	28
Scientists	22,098	632	92	20	6	1										22,849	42
Technicians	8,400	622	136	31	15	4	1	1	1							9,211	69
Service	4,736	167	15	1												4,919	7
Agriculture	95															95	
Construction	10,352	347	91	33	3											10,826	37
Production	6,171	368	151	141	50	20	10									6,911	146
Transportation	2,441	24	11	2												2,478	3
Laborers	1,706	42	18	6												1,772	6
Miscellaneous	3,137	142	8	—	—	—	—	1	—	—	—	—	—	—	—	3,288	6
Total Persons	78,326	3,727	787	352	137	53	41	4	1	0	0	0	0	0	0	83,327	
Total Person-rem	0	106	124	120	84	45	48	7	2	0	0	0	0	0	0		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.50
Distribution of Neutron Doses by Occupation and Neutron Dose Range[a]
1989 - Female

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	3,316	102	27	18	10	10	7									3,490	36
Management	3,282	69	10	6	1											3,368	6
Scientists	3,502	61	17	2	1	1										3,584	6
Technicians	2,125	119	26	18	4	1	1									2,294	19
Service	1,331	29	1	1												1,362	1
Agriculture	7															7	
Construction	738	16	3	1												758	1
Production	1,068	65	29	37	8	4										1,211	28
Transportation	97															97	
Laborers	300	11	6													317	1
Miscellaneous	605	11	—	—	—	—	—	—	—	—	—	—	—	—	—	616	
Total Persons	16,371	483	119	83	24	16	8	0	0	0	0	0	0	0	0	17,104	
Total Person-rem	0	15	19	28	15	14	10	0	0	0	0	0	0	0	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.51
Distribution of Neutron Doses by Occupation and Neutron Dose Range[a]
1989 - Unknown Sex

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	1,816	245	5	1												2,067	4
Scientists	4															4	
Construction	984	3														987	
Miscellaneous	31	5	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	2,835	253	5	1	0	0	0	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.52
Distribution of Collective Neutron Doses by Occupation and Neutron Dose Range[a]
1989 - Male

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		24	33	36	35	24	36	3								13,315	190
Management		10	10	5	3											7,663	28
Scientists		17	14	6	4	1										22,849	42
Technicians		21	20	10	9	3	1	2	2							9,211	69
Service		5	2													4,919	7
Agriculture																95	
Construction		11	14	11	2											10,826	37
Production		13	26	49	31	17	11									6,911	146
Transportation		1	2	1												2,478	3
Laborers		1	3	2												1,772	6
Miscellaneous		3	1					2								3,288	6
Total Persons	78,326	3,626	787	352	137	53	41	4	1	0	0	0	0	0	0	83,327	
Total Person-rem	0	106	124	120	84	45	48	7	2	0	0	0	0	0	0		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.53
Distribution of Collective Neutron Doses by Occupation and Neutron Dose Range[a]
1989 - Female

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		2	4	6	6	9	8									3,490	36
Management		2	2	2	1											3,368	6
Scientists		2	3	1	1	1										3,584	6
Technicians		4	5	6	2	1	1									2,294	19
Service		1														1,362	1
Agriculture																7	
Construction		1														758	1
Production		3	5	13	5	3										1,211	28
Transportation																97	
Laborers			1													317	1
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	616	616
Total Persons	16,371	483	119	83	24	16	8	0	0	0	0	0	0	0	0	17,104	
Total Person-rem	0	15	19	28	15	14	10	0	0	0	0	0	0	0	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.54
Distribution of Collective Neutron Doses by Occupation and Neutron Dose Range[a]
1989 - Unknown Sex

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		3	1													2,067	4
Scientists																4	
Construction																987	
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	2,835	253	5	1	0	0	0	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.55
Distribution of Persons Receiving Neutron Doses by Age and Facility Type[a]
1989 - Male

Facility Type	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator	28	237	575	762	673	683	569	495	405	226	153	58	4,864	34
Fuel/Uran. Enrichment	4	62	242	593	933	892	581	413	424	424	84	58	4,710	2
Fuel Fabrication	19	209	516	633	579	442	316	240	249	163	43	6	3,415	1
Fuel Processing	1	159	364	565	499	429	268	193	217	151	19	1	2,866	62
Maint. and Support	105	816	2,173	3,067	3,055	2,625	2,164	1,799	1,653	1,094	368	650	19,569	91
Reactor		251	860	990	988	869	551	460	448	283	41	10	5,751	6
Research, General	120	599	1,182	1,868	2,106	1,809	1,665	1,410	1,353	900	426	156	13,594	142
Research, Fusion	1	32	118	187	237	203	168	148	132	106	56	9	1,397	
Waste Proc./Management	10	214	601	777	720	626	435	362	280	176	55	12	4,268	52
Weapons Fab. & Test.	16	239	993	1,877	1,990	2,055	1,848	1,670	1,412	880	214	110	13,304	121
Other	39	509	1,310	1,659	1,493	1,362	987	727	546	344	207	406	9,589	24
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	0	22	91	118	94	65	47	36	41	16	4	1		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.56
Distribution of Persons Receiving Neutron Doses by Age and Facility Type[a]
1989 - Female

Facility Type	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator	14	44	104	109	89	67	52	44	15	9	9	6	562	2
Fuel/Uran. Enrichment	9	51	108	208	189	134	92	81	64	40	10	9	995	
Fuel Fabrication	2	42	120	139	115	96	43	35	27	17	3		639	
Fuel Processing	2	68	131	171	127	82	63	30	14	3	4		695	14
Maint. and Support	29	312	709	852	792	661	503	290	202	98	44	95	4,587	18
Reactor	3	53	144	143	102	88	36	22	19	13		3	626	
Research, General	81	287	419	559	491	326	255	197	136	92	37	35	2,915	31
Research, Fusion	1	8	12	20	21	27	19	4	9	5	3	1	130	
Waste Proc./Management	7	85	172	177	171	116	85	46	28	18	3		908	12
Weapons Fab. & Test.	11	133	342	536	539	474	369	249	184	104	26	7	2,974	20
Other	20	236	379	392	329	224	175	113	61	29	36	79	2,073	2
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	0	4	18	24	22	10	9	7	2	3	1	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.57
Distribution of Persons Receiving Neutron Doses by Age and Facility Type[a]
1989 - Unknown Sex

Facility Type	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator									2			1	3	
Fuel/Uran. Enrichment												4	4	
Maint. and Support								1				985	986	0
Research, General	6	1	2	3	2	1		1		1		21	38	
Weapons Fab. & Test.	1		6	4	8	1	2	1	1			594	618	1
Other	1	1	5	1	3	2	2	3	5	1	107	1,314	1,445	3
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	1	3		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.58
Distribution of Collective Neutron Doses by Age and Facility Type[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator			4	5	7	5	4	5	3	1			4,864	34
Fuel/Uran. Enrichment			1										4,710	2
Fuel Fabrication			1										3,415	1
Fuel Processing		10	17	17	9	5	2		2				2,866	82
Maint. and Support		4	16	20	14	11	8	9	6	2	1		19,569	91
Reactor		1	1	1	1	1							5,751	6
Research, General		4	20	33	28	15	13	7	16	5	1		13,594	142
Research, Fusion													1,397	
Waste Proc./Management		1	13	10	12	7	3	3	3	1			4,268	52
Weapons Fab. & Test.			16	28	21	19	14	9	9	5	1		13,304	121
Other		3	4	4	3	2	2	2	1	1			9,589	24
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	0	22	91	118	94	65	47	36	41	16	4	1		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.59
Distribution of Collective Neutron Doses by Age and Facility Type[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator					1								562	2
Fuel/Uran. Enrichment													995	
Fuel Fabrication													639	
Fuel Processing		1	4	6	2	1	1						695	14
Maint. and Support		2	4	6	3	2	1	1					4,587	18
Reactor													626	
Research, General		1	5	4	9	1	2	5	1	3	1		2,915	31
Research, Fusion													130	
Waste Proc./Management			1	3	1	2	3	1	1				908	12
Weapons Fab. & Test.			3	4	5	5	3	1					2,974	20
Other	—	1	—	1	—	—	—	—	—	—	—	—	2,073	2
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	0	4	18	24	22	10	9	7	2	3	1	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.60
Distribution of Collective Neutron Doses by Age and Facility Type[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator													3	
Fuel/Uran. Enrichment													4	
Maint. and Support													986	
Research, General													38	
Weapons Fab. & Test.												1	618	1
Other	—	—	—	—	—	—	—	—	—	—	1	2	1,445	3
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	1	3		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.61
Distribution of Persons Receiving Neutron Doses by Age and Occupation[a]
1989 - Male

Occupation	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	117	661	1,330	1,795	1,789	1,726	1,674	1,437	1,130	804	438	414	13,315	190
Management	16	55	336	849	1,226	1,378	1,177	1,084	860	525	138	19	7,663	28
Scientists	16	770	2,405	3,502	3,610	3,292	2,673	2,324	2,240	1,396	550	71	22,849	42
Technicians	20	410	1,231	1,768	1,605	1,249	893	731	702	436	103	63	9,211	69
Service	12	250	895	1,037	774	613	412	285	248	202	110	81	4,919	7
Agriculture	1	5	10	19	18	14	9	8	9	1	1		95	
Construction	57	510	1,093	1,542	1,770	1,659	1,194	892	798	570	109	632	10,826	37
Production	4	228	765	1,231	1,307	1,055	743	490	565	438	84	1	6,911	146
Transportation	3	53	227	408	443	412	269	268	217	141	33	4	2,478	3
Laborers	31	143	267	363	324	204	158	104	95	56	14	13	1,772	6
Miscellaneous	66	242	375	464	407	393	350	294	255	178	86	178	3,288	6
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	0	22	91	118	94	65	47	36	41	16	4	1		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.62
Distribution of Persons Receiving Neutron Doses by Age and Occupation[a]
1989 - Female

Occupation	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	65	252	436	514	533	496	411	328	176	129	74	76	3,490	36
Management	25	192	413	531	596	528	461	287	213	86	32	4	3,368	6
Scientists	6	272	744	859	630	396	280	163	142	58	20	14	3,584	6
Technicians	15	219	386	534	440	303	169	102	58	53	5	10	2,294	19
Service	8	134	225	265	245	164	114	74	60	47	19	7	1,362	1
Agriculture			1	1	2	1		1	1				7	
Construction	5	73	143	158	126	77	36	19	25	12		84	758	1
Production	6	53	153	263	245	202	130	74	53	28	4		1,211	28
Transportation		3	11	27	14	18	11	4	3	1	4	1	97	1
Laborers	11	20	44	58	58	55	35	22	7	3	1	3	317	1
Miscellaneous	38	101	84	96	76	55	45	37	21	11	16	36	616	
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	0	4	18	24	22	10	9	7	2	3	1	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.63
Distribution of Persons Receiving Neutron doses by Age and Occupation[a]
1989 - Unknown Sex

Occupation	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	2	1	11	5	11	3	4	4	6	1	107	1,912	2,067	4
Scientists									1			3	4	0
Construction								1	1			985	987	
Miscellaneous	6	1	2	3	2	1	—	1	—	1	—	19	36	—
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	1	3		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.64
Distribution of Collective Neutron Doses by Age and Occupation[a]
1989 - Male

Occupation	Collective Dose (person-rem) Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown		4	26	42	37	23	19	15	17	6	2		13,315	190
Management			4	7	4	3	4	4	2	1			7,663	28
Scientists			7	7	5	5	6	5	5	2	1		22,849	42
Technicians		4	12	17	10	8	4	5	7	2			9,211	69
Service			2	1	2	1							4,919	7
Agriculture													95	
Construction		1	5	6	7	7	3	3	3	1			10,826	37
Production		10	32	35	29	18	10	3	6	3			6,911	146
Transportation							1	1	1				2,478	3
Laborers			2	2	1			1					1,772	6
Miscellaneous		2	1	1			1		1				3,288	6
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	0	22	91	118	94	65	47	36	41	16	4	1		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.65
Distribution of Collective Neutron Doses by Age and Occupation[a]
1989 - Female

Occupation	Collective Dose (person-rem) Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown		1	6	4	10	2	2	5	1	3	1		3,490	36
Management			1	1	1	1	1						3,368	6
Scientists			1	3	1	1							3,584	6
Technicians		1	3	5	3	2	2	1					2,294	19
Service													1,362	1
Agriculture													7	
Construction			1										758	1
Production		1	6	9	5	3	3		1				1,211	28
Transportation													97	
Laborers				1									317	1
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	616	—
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	0	4	18	24	22	10	9	7	2	3	1	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.66
Distribution of Collective Neutron Doses by Age and Occupation[a]
1989 - Unknown Sex

Occupation	Collective Dose (person-rem) Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown											1	3	2,067	4
Scientists													4	
Construction													987	
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	1	3		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.67
Distribution of Persons Receiving Neutron Doses by Occupation and Facility Type[a]
1989 - Male

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	1,124	134	1,789	1,370	147	15	123	98	38	1	25	4,864	34
Fuel/Uran. Enrichment	128	530	1,075	485	343	1	1,082	807	48	167	44	4,710	2
Fuel Fabrication	1,711	239	502	177	170		211	336	38	30	1	3,415	1
Fuel Processing	51	338	1,170	128	47	1	482	594	34	20	1	2,866	62
Maint. and Support	4,130	1,904	2,895	1,146	1,255	34	5,629	1,005	803	759	9	19,569	91
Reactor	27	739	2,267	596	128		743	768	94	77	312	5,751	6
Research, General	2,944	851	5,288	1,946	468	6	442	312	59	87	1,191	13,594	142
Research, Fusion	120	101	609	286	50		126	50		3	52	1,397	
Waste Proc./Management	98	581	1,296	544	154	1	721	566	136	130	41	4,268	52
Weapons Fab. & Test.	1,249	1,527	3,446	1,783	478		839	2,116	136	178	1,552	13,304	121
Other	1,733	719	2,512	750	1,679	37	428	259	1,092	320	60	9,589	24
Total Persons	13,315	7,663	22,849	9,211	4,919	95	10,826	6,911	2,478	1,772	3,288	83,327	
Total Person-rem	190	28	42	69	7	0	37	146	3	6	6		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.68
Distribution of Persons Receiving Neutron Doses by Occupation and Facility Type[a]
1989 - Female

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	172	63	175	91	45	1	4	6			5	562	2
Fuel/Uran. Enrichment	109	292	162	164	85		39	96	3	31	14	995	
Fuel Fabrication	119	42	196	109	21		19	114	2	17		639	
Fuel Processing	2	168	217	44	29		42	188	2	3		695	14
Maint. and Support	1,203	1,146	629	572	257		476	90	44	167	3	4,587	18
Reactor	4	160	171	66	24		45	130	3	6	17	626	
Research, General	903	328	748	523	91	2	8	38	2	13	259	2,915	31
Research, Fusion	28	22	45	23	5		2			1	4	130	
Waste Proc./Management	30	187	170	165	143		33	167	5	2	6	908	12
Weapons Fab. & Test.	497	679	578	338	105		86	349	5	40	297	2,974	20
Other	423	281	493	199	557	4	4	33	31	37	11	2,073	19
Total Persons	3,490	3,368	3,584	2,294	1,362	7	758	1,211	97	317	616	17,104	
Total Person-rem	36	6	6	19	1	0	1	28	0	1	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.69
Distribution of Persons Receiving Neutron Doses by Occupation and Facility Type[a]
1989 - Unknown Sex

Facility Type	Number of Persons Receiving Radiation Doses in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator			2				1					3	
Fuel/Uran. Enrichment	4											4	
Maint. and Support							986					986	
Research, General			2								36	38	
Weapons Fab. & Test.	618											618	1
Other	1,445	—	—	—	—	—	—	—	—	—	—	1,445	3
Total Persons	2,067	0	4	0	0	0	987	0	0	0	36	3,094	
Total Person-rem	4	0	0	0	0	0	0	0	0	0	0		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.70
Distribution of Collective Neutron Doses by Occupation and Facility Type[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	25		1	3				1	3			4,864	34
Fuel/Uran. Enrichment				2								4,710	2
Fuel Fabrication												3,415	1
Fuel Processing			6				5	50				2,866	62
Maint. and Support	24	4	4	21	7		19	7		5		19,569	91
Reactor		1	1	1			1	1				5,751	6
Research, General	118	1	10	9							3	13,594	142
Research, Fusion												1,397	
Waste Proc./Management		6	5	7			6	27				4,268	52
Weapons Fab. & Test.	3	14	14	23			4	58		1	3	13,304	121
Other	19	2	1	1	—	—	—	—	—	—	—	9,589	26
Total Persons	13,315	7,663	22,849	9,211	4,919	95	10,826	6,911	2,478	1,772	3,288	83,327	
Total Person-rem	190	28	42	69	7	0	37	146	3	6	6		535

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.71
Distribution of Collective Neutron Doses by Occupation and Facility Type[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	2											562	2
Fuel/Uran. Enrichment												995	
Fuel Fabrication												639	
Fuel Processing			1				1	12				695	14
Maint. and Support	2	1	1	11	1		1	1		1		4,587	18
Reactor												626	
Research, General	29			1								2,915	31
Research, Fusion												130	
Waste Proc./Management		2		3				7				908	12
Weapons Fab. & Test.	1	2	3	5				8		1		2,974	20
Other	2	—	—	—	—	—	—	—	—	—	—	2,073	2
Total Persons	3,490	3,368	3,584	2,294	1,362	7	758	1,211	97	317	616	17,104	
Total Person-rem	36	6	6	19	1	0	1	28	0	1	0		100

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.72
Distribution of Collective Neutron Doses by Occupation and Facility Type
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator												3	
Fuel/Uran. Enrichment												4	
Maint. and Support												986	
Research, General												38	
Weapons Fab. & Test.	1											618	1
Other	3	—	—	—	—	—	—	—	—	—	—	1,445	3
Total Persons	2,067	0	4	0	0	0	987	0	0	0	36	3,094	
Total Person-rem	4	0	0	0	0	0	11	0	0	0	0		4

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.73
Distribution of Beta-Gamma Doses by Facility Type and Beta-Gamma Dose Range[a]
1989 - Male

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	≥ 5		
Accelerator	3,203	1,319	180	90	43	17	9	1	1	1						4,864	154
Fuel/Uran. Enrichment	3,284	1,364	50	12												4,710	37
Fuel Fabrication	2,016	1,201	126	49	9	8	6									3,415	87
Fuel Processing	1,265	886	295	196	69	46	85	22	1	1						2,866	376
Maint. and Support	12,421	6,074	711	255	60	23	22	2	1							19,569	437
Reactor	1,534	3,360	486	190	74	40	44	16	6	1						5,751	401
Research, General	9,048	3,772	480	213	40	19	17	4	1							13,594	308
Research, Fusion	1,127	258	10	2												1,397	10
Waste Proc./Management	2,604	1,313	220	82	30	11	7	1								4,268	137
Weapons Fab. & Test.	8,401	4,038	560	187	82	28	8									13,304	342
Other	6,503	2,905	134	34	7	3	1	1	1	—	—	—	—	—	—	9,589	109
Total Persons	51,406	26,490	3,252	1,310	414	195	199	47	11	3	0	0	0	0	0	83,327	
Total Person-rem	0	668	501	453	252	168	243	81	25	8	0	0	0	0	0		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.74
Distribution of Beta-Gamma Doses by Facility Type and Beta-Gamma Dose Range[a]
1989 - Female

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	444	98	12	3	3		2									562	10
Fuel/Uran. Enrichment	762	222	11													995	6
Fuel Fabrication	420	182	21	11	4	1										639	14
Fuel Processing	393	206	57	18	10	6	4	1								695	39
Maint. and Support	3,383	1,039	122	39	2		2									4,587	59
Reactor	262	318	24	9	3	1	5	3	1							626	31
Research, General	2,271	555	52	25	10	1	1									2,915	37
Research, Fusion	120	10														130	
Waste Proc./Management	567	304	23	12	1	1										908	17
Weapons Fab. & Test.	2,137	696	89	34	15	3										2,974	54
Other	1,422	628	16	4	1	—	2	—	—	—	—	—	—	—	—	2,073	19
Total Persons	12,181	4,258	427	155	49	13	16	4	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	64	52	29	11	21	7	2	0	0	0	0	0	0		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.75
Distribution of Beta-Gamma Doses by Facility Type and Beta-Gamma Dose Range[a]
1989 - Unknown Sex

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	2	1														3	
Fuel/Uran. Enrichment	1	3														4	
Maint. and Support	352	625	5	4												986	11
Research, General	28	10														38	
Weapons Fab. & Test.	315	302	1													618	3
Other	462	905	64	8	5	–	1	–	–	–	–	–	–	–	–	1,445	38
Total Persons	1,160	1,846	70	12	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	34	9	4	3	0	1	0	0	0	0	0	0	0	0		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.76
Distribution of Collective Beta-Gamma Doses by Facility Type and Beta-Gamma Dose Range[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	39	27	31	26	15	11	2	2	3							4,864	154
Fuel/Uran. Enrichment	25	8	4													4,710	37
Fuel Fabrication	31	20	17	5	7	7										3,415	87
Fuel Processing	26	49	69	43	40	106	39	2	3							2,866	376
Maint. and Support	152	109	88	37	20	26	3	2								19,569	437
Reactor	85	73	66	46	34	53	27	14	3							5,751	401
Research, General	91	75	73	24	17	20	7	2								13,594	308
Research, Fusion	8	1	1													1,397	10
Waste Proc./Management	36	33	30	18	9	8	2									4,268	137
Weapons Fab. & Test.	113	84	63	50	23	10										13,304	342
Other	64	21	12	4	3	1	2	2	—	—	—	—	—	—	—	9,589	109
Total Persons	51,406	26,490	3,252	1,310	414	195	199	47	11	3	0	0	0	0	0	83,327	
Total Person-rem	0	668	501	453	252	168	243	81	25	8	0	0	0	0	0		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.77
Distribution of Collective Beta-Gamma Doses by Facility Type and Beta-Gamma Dose Range[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator		3	2	1	2	3										562	10
Fuel/Uran. Enrichment		4	2													995	6
Fuel Fabrication		4	3	4	2	1										639	14
Fuel Processing		6	9	6	6	5	6	2								695	39
Maint. and Support		26	18	12	1	2										4,587	59
Reactor		7	4	3	2	1	7	5	2							626	31
Research, General		13	8	8	6	1	1									2,915	37
Research, Fusion																	130
Waste Proc./Management		8	4	4	1	1										908	17
Weapons Fab. & Test.		18	13	12	9	2										2,974	54
Other	—	13	2	1	1	—	3	—	—	—	—	—	—	—	—	2,073	19
Total Persons	12,181	4,258	427	155	49	13	16	4	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	64	52	29	11	21	7	2	0	0	0	0	0	0		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.78
Distribution of Collective Beta-Gamma Doses by Facility Type and Beta-Gamma Dose Range[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator																3	
Fuel/Uran. Enrichment																4	
Maint. and Support		9	1	1												986	11
Research, General																38	
Weapons Fab. & Test.		3														618	3
Other	—	22	8	3	3	—	1	—	—	—	—	—	—	—	—	1,445	38
Total Persons	1,160	1,846	70	12	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	34	9	4	3	0	1	0	0	0	0	0	0	0	0		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.79
Distribution of Beta-Gamma Doses by Age and Beta-Gamma Dose Range[a]
1989 - Male

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	273	67	2			1										343	3
20 - 24	1,954	1,144	148	61	16	2	2									3,327	86
25 - 29	4,926	3,215	472	196	53	24	37	8	1	2						8,934	345
30 - 34	7,545	4,328	643	265	98	40	40	15	4							12,978	485
35 - 39	7,892	4,400	569	234	80	45	41	10	2							13,273	441
40 - 44	7,401	3,806	466	192	62	28	29	8	3							11,995	351
45 - 49	6,302	2,752	313	116	36	12	15	4	1	1						9,552	218
50 - 54	5,243	2,274	240	100	24	18	17	1								7,91	181
55 - 59	4,636	2,101	219	101	35	12	14	1								7,119	168
60 - 64	3,286	1,271	137	34	8	8	3									4,747	81
65 and greater	1,265	364	25	6	1	4	1									1,666	20
Unknown	683	768	18	5	1	1	—	—	—	—	—	—	—	—	—	1,476	20
Total Persons	51,406	26,490	3,252	1,310	414	195	199	47	11	3	0	0	0	0	0	83,327	
Total Person-rem	0	668	501	453	252	168	243	81	25	8	0	0	0	0	0		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.80
Distribution of Beta-Gamma Doses by Age and Beta-Gamma Dose Range[a]
1989 - Female

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	143	33	3													179	1
20 - 24	902	384	21	9	2	1										1,319	17
25 - 29	1,765	747	83	33	8		4									2,640	50
30 - 34	2,220	925	112	33	9	3	3		1							3,306	66
35 - 39	2,055	786	73	31	8	7	4	1								2,965	58
40 - 44	1,694	499	66	20	9	1	5	1								2,295	44
45 - 49	1,311	319	43	12	5	1		1								1,692	24
50 - 54	859	223	19	6	4											1,111	12
55 - 59	596	153		7	3											759	8
60 - 64	343	73	7	3	1			1								428	6
65 and greater	153	22														175	1
Unknown	140	94	—	1	—	—	—	—	—	—	—	—	—	—	—	235	2
Total Persons	12,181	4,258	427	155	49	13	16	4	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	64	52	29	11	21	7	2	0	0	0	0	0	0		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.81
Distribution of Beta-Gamma Doses by Age and Beta-Gamma Dose Range[a]
1989 - Unknown Sex

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	7	1														8	
20 - 24	2															2	
25 - 29	12	1														13	
30 - 34	4	4														8	
35 - 39	5	8														13	
40 - 44	3	1														4	
45 - 49	2	2														4	
50 - 54	4	2														6	
55 - 59	6	2														8	
60 - 64	1	1														2	
65 and greater	51	47	7	2												107	3
Unknown	1,063	1,777	63	10	5	—	1	—	—	—	—	—	—	—	—	2,919	48
Total Persons	1,160	1,846	70	12	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	34	9	4	3	0	1	0	0	0	0	0	0	0	0		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.82
Distribution of Collective Beta-Gamma Doses by Age and Beta-Gamma Dose Range[a]
1989 - Male

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less		1				1										343	3
20 - 24		27	24	21	10	2	2									3,327	86
25 - 29		86	72	67	33	21	45	13	2	5						8,934	345
30 - 34		115	99	94	59	34	49	26	9							12,978	485
35 - 39		113	88	80	49	38	50	17	5							13,273	441
40 - 44		96	72	67	37	23	36	14	6							11,995	351
45 - 49		69	48	39	22	10	18	7	2	3						9,552	218
50 - 54		56	37	34	15	16	21	2								7,917	181
55 - 59		51	33	35	21	10	16	2								7,119	168
60 - 64		31	22	12	5	7	4									4,747	81
65 and greater		8	4	2	1	4	1									1,666	20
Unknown		14	3	2	1	1										1,476	20
Total Persons	51,406	26,490	3,252	1,310	414	195	199	47	11	3	0	0	0	0	0	83,327	
Total Person-rem	0	668	501	453	252	168	243	81	25	8	0	0	0	0	0		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.83
Distribution of Collective Beta-Gamma Doses by Age and Beta-Gamma Dose Range[a]
1989 - Female

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less		1														179	1
20 - 24		9	3	3	1	1										1,319	17
25 - 29		18	12	10	5		5									2,640	50
30 - 34		23	17	11	6	2	4		2							3,306	66
35 - 39		19	11	10	5	6	5	2								2,965	58
40 - 44		13	10	7	6	1	7	2								2,295	44
45 - 49		8	6	4	3	1		2								1,692	24
50 - 54		5	3	2	2											1,111	12
55 - 59		4		2	2											759	8
60 - 64		2	1	1	1			2								428	6
65 and greater		1														175	1
Unknown	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	235	2
Total Persons	12,181	4,258	427	155	49	13	16	4	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	64	52	29	11	21	7	2	0	0	0	0	0	0		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.84
Distribution of Collective Beta-Gamma Doses by Age and Beta-Gamma Dose Range[a]
1989 - Unknown Sex

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less																8	
20 - 24																2	
25 - 29																13	
30 - 34																8	
35 - 39																13	
40 - 44																4	
45 - 49																4	
50 - 54																6	
55 - 59																8	
60 - 64																2	
65 and greater		1	1	1												107	3
Unknown	—	32	8	3	3	—	1	—	—	—	—	—	—	—	—	2,919	48
Total Persons	1,160	1,846	70	12	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	34	9	4	3	0	1	0	0	0	0	0	0	0	0		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.85
Distribution of Beta-Gamma Doses by Occupation and Beta-Gamma Dose Range[a]
1989 - Male

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	10,234	2,649	243	105	55	20	9									13,315	189
Management	4,913	2,486	176	52	19	4	10	2	1							7,663	137
Scientists	15,656	6,580	395	143	37	17	15	4	2							22,849	317
Technicians	5,131	2,866	683	310	90	59	59	10	2	1						9,211	505
Service	2,866	1,961	63	23	3	1	2									4,919	64
Agriculture	73	22														95	
Construction	4,930	4,693	768	268	85	36	36	9	1							10,826	483
Production	2,797	2,828	697	343	113	46	58	22	5	2						6,911	560
Transportation	1,793	609	56	11	3	1	5									2,478	37
Laborers	876	695	136	47	7	7	4									1,772	74
Miscellaneous	2,137	1,101	35	8	2	4	1	—	—	—	—	—	—	—	—	3,288	34
Total Persons	51,406	26,490	3,252	1,310	414	195	199	47	11	3	0	0	0	0	0	83,327	
Total Person-rem	0	668	501	453	252	168	243	81	25	8	0	0	0	0	0		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.86
Distribution of Beta-Gamma Doses by Occupation and Beta-Gamma Dose Range[a]
1989 - Female

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	3,057	386	20	16	9		2									3,490	23
Management	2,762	575	25	4	2											3,368	18
Scientists	2,592	923	46	17	4	1	1									3,584	36
Technicians	1,345	744	137	44	11	4	8	1								2,294	78
Service	897	455	8	2												1,362	11
Agriculture	4	3														7	
Construction	346	357	41	12	1	1										758	20
Production	469	526	127	53	22	6	4	3	1							1,211	86
Transportation	68	29														97	1
Laborers	151	136	22	6		1	1									317	11
Miscellaneous	490	124	1	1	—	—	—	—	—	—	—	—	—	—	—	616	3
Total Persons	12,181	4,258	427	155	49	13	16	4	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	64	52	29	11	21	7	2	0	0	0	0	0	0		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.87
Distribution of Beta-Gamma Dose by Occupation and Beta-Gamma Dose Range[a]
1989 - Unknown Sex

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	778	1,210	65	8	5		1									2,067	41
Scientists	3	1														4	
Construction	352	626	5	4												987	11
Miscellaneous	27	9	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	1,160	1,846	70	12	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	34	9	4	3	0	1	0	0	0	0	0	0	0	0		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.88
Distribution of Collective Beta-Gamma Doses by Occupation and Beta-Gamma Dose Range[a]
1989 - Male

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)														Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		54	37	36	34	17	10									13,315	189
Management		61	26	18	11	3	11	3	2							7,663	137
Scientists		144	59	49	22	15	18	7	4							22,849	317
Technicians		88	107	107	55	51	73	17	4	3						9,211	505
Service		41	10	8	2	1	2									4,919	64
Agriculture																95	
Construction		125	119	94	52	31	45	15	2							10,826	483
Production		96	109	120	69	39	72	39	12	5						6,911	560
Transportation		16	8	4	2	1	6									2,478	37
Laborers		22	22	15	4	6	4									1,772	74
Miscellaneous	—	20	5	3	1	3	1	—	—	—	—	—	—	—	—	3,288	34
Total Persons	51,406	26,490	3,252	1,310	414	195	199	47	11	3	0	0	0	0	0	83,327	
Total Person-rem	0	668	501	453	252	168	243	81	25	8	0	0	0	0	0		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.89
Distribution of Collective Beta-Gamma Doses by Occupation and Beta-Gamma Dose Range[a]
1989 - Female

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		7	3	5	5		3									3,490	23
Management		12	4	1	1											3,368	18
Scientists		19	7	5	3	1	1									3,584	36
Technicians		22	21	14	7	3	10	2								2,294	78
Service		9	1	1												1,362	11
Agriculture																7	
Construction		9	6	4	1	1										758	20
Production		18	19	19	13	5	5	5	2							1,211	86
Transportation		1														97	1
Laborers		4	3	2		1	1									317	11
Miscellaneous	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	616	3
Total Persons	12,181	4,258	427	155	49	13	16	4	1	0	0	0	0	0	0	17,104	
Total Person-rem	0	103	64	52	29	11	21	7	2	0	0	0	0	0	0		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.90
Distribution of Collective Beta-Gamma Doses by Occupation and Beta-Gamma Dose Ranges[a]
1989 - Unknown Sex

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		25	9	3	3		1									2,067	41
Scientists																4	
Construction		9	1	1												987	11
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	1,160	1,846	70	12	5	0	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	34	9	4	3	0	1	0	0	0	0	0	0	0	0		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.91
Distribution of Persons Receiving Beta-Gamma Doses by Age and Facility Type[a]
1989 - Male

Facility Type	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator	28	237	575	762	673	683	569	495	405	226	153	58	4,864	154
Fuel/Uran. Enrichment	4	62	242	593	933	892	581	413	424	424	84	58	4,710	37
Fuel Fabrication	19	209	516	633	579	442	316	240	249	163	43	6	3,415	87
Fuel Processing	1	159	364	565	499	429	268	193	217	151	19	1	2,866	376
Maint. and Support	105	816	2,173	3,06	3,055	2,625	2,164	1,799	1,653	1,094	368	650	19,569	437
Reactor	251	860	990	988	869	551	460	448	283	41	10	5,751	401	
Research, General	120	599	1,182	1,868	2,106	1,809	1,665	1,410	1,353	900	426	156	13,594	308
Research, Fusion	1	32	118	187	237	203	168	148	132	106	56	9	1,397	10
Waste Proc./Management	10	214	601	777	720	626	435	362	280	176	55	12	4,268	137
Weapons Fab. & Test.	16	239	993	1,877	1,990	2,055	1,848	1,670	1,412	880	214	110	13,304	342
Other	39	509	1,310	1,659	1,493	1,362	987	727	546	344	207	406	9,589	109
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	86	345	485	441	351	218	181	168	81	20	20		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.92
Distribution of Persons Receiving Beta-Gamma Doses by Age and Facility Type[a]
1989 - Female

Facility Type	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator	14	44	104	109	89	67	52	44	15	9	9	6	562	10
Fuel/Uran. Enrichment	9	51	108	208	189	134	92	81	64	40	10	9	995	6
Fuel Fabrication	2	42	120	139	115	96	43	35	27	17	3		639	14
Fuel Processing	2	68	131	171	127	82	63	30	14	3	4		695	39
Maint. and Support	29	312	709	852	792	661	503	290	202	98	44	95	4,587	59
Reactor	3	53	144	143	102	88	36	22	19	13		3	626	31
Research, General	81	287	419	559	491	326	255	197	136	92	37	35	2,915	37
Research, Fusion	1	8	12	20	21	27	19	4	9	5	3	1	130	
Waste Proc./Management	7	85	172	177	171	116	85	46	28	18	3		908	17
Weapons Fab. & Test.	11	133	342	536	539	474	369	249	184	104	26	7	2,974	54
Other	20	236	379	392	329	224	175	113	61	29	36	79	2,073	19
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	17	50	66	58	44	24	12	8	6	1	2		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.93
Distribution of Persons Receiving Beta-Gamma Doses by Age and Facility Type[a]
1989 - Unknown Sex

Facility Type	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator									2			1	3	
Fuel/Uran. Enrichment												4	4	
Maint. and Support								1				985	986	11
Research, General	6	1	2	3	2	1		1		1		21	38	
Weapons Fab. & Test.	1		6	4	8	1	2	1	1			594	618	3
Other	1	1	5	1	3	2	2	3	5	1	107	1,314	1,445	38
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	3	48		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.94
Distribution of Collective Beta-Gamma Doses by Age and Facility Type[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator		4	18	27	26	26	16	16	14	6	1	1	4,864	154
Fuel/Uran. Enrichment			3	7	8	6	4	2	3	2			4,710	37
Fuel Fabrication	1	3	16	19	12	14	7	5	6	3	1		3,415	87
Fuel Processing		17	66	100	76	51	36	14	13	3			2,866	376
Maint. and Support	1	29	65	88	74	61	39	32	27	10	2	9	19,569	437
Reactor		13	69	78	80	65	27	29	24	13	1	1	5,751	401
Research, General		6	26	50	67	38	29	35	33	17	6	2	13,594	308
Research, Fusion			1	2	2	1	1	1	1	1		1	1,397	10
Waste Proc./Management		8	30	31	25	19	8	4	10	2			4,268	137
Weapons Fab. & Test.		1	30	63	57	56	41	35	31	20	6	2	13,304	342
Other		6	21	21	14	14	10	8	6	2	3	3	9,589	109
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	86	345	485	441	351	218	181	168	81	20	20		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.95
Distribution of Collective Beta-Gamma Doses by Age and Facility Type[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator			3	2	3		1						562	10
Fuel/Uran. Enrichment			1	2	1	1	1						995	6
Fuel Fabrication			2	4	2	4		1	1				639	14
Fuel Processing		4	7	12	11	2	3						695	39
Maint. and Support		6	14	15	10	6	5	1	1			1	4,587	59
Reactor		1	5	6	5	10	1			2			626	31
Research, General		2	6	8	7	3	3	4	2	2			2,915	37
Research, Fusion													130	
Waste Proc./Management		1	4	4	3	2	2	1	1				908	17
Weapons Fab. & Test.		1	5	10	12	13	7	3	3	1			2,974	54
Other	—	2	5	4	4	3	1	1	—	—	—	—	2,073	19
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	17	50	66	58	44	24	12	8	6	1	2		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.96
Distribution of Collective Beta-Gamma Doses by Age and Facility Type[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator													3	
Fuel/Uran. Enrichment													4	
Maint. and Support												11	986	11
Research, General													38	
Weapons Fab. & Test.												2	618	3
Other	—	—	—	—	—	—	—	—	—	—	3	35	1,445	38
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	3	48		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.97
Distribution of Persons Receiving Beta-Gamma Doses by Age and Occupation[a]
1989 - Male

Occupation	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	117	661	1,330	1,795	1,789	1,726	1,674	1,437	1,130	804	438	414	13,315	189
Management	16	55	336	849	1,226	1,378	1,177	1,084	860	525	138	19	7,663	137
Scientists	16	770	2,405	3,502	3,610	3,292	2,673	2,324	2,240	1,396	550	71	22,849	317
Technicians	20	410	1,231	1,768	1,605	1,249	893	731	702	436	103	63	9,211	505
Service	12	250	895	1,037	774	613	412	285	248	202	110	81	4,919	64
Agriculture	1	5	10	19	18	14	9	8	9	1	1		95	
Construction	57	510	1,093	1,542	1,770	1,659	1,194	892	798	570	109	632	10,826	483
Production	4	228	765	1,231	1,307	1,055	743	490	565	438	84	1	6,911	560
Transportation	3	53	227	408	443	412	269	268	217	141	33	4	2,478	37
Laborers	31	143	267	363	324	204	158	104	95	56	14	13	1,772	74
Miscellaneous	66	242	375	464	407	393	350	294	255	178	86	178	3,288	34
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	86	345	485	441	351	218	181	168	81	20	20		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.98
Distribution of Persons Receiving Beta-Gamma Doses by Age and Occupation
1989 - Female

Occupation	Number of Persons Monitored for Radiation Doses in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	65	252	436	514	533	496	411	328	176	129	74	76	3,490	23
Management	25	192	413	531	596	528	461	287	213	86	32	4	3,368	18
Scientists	6	272	744	859	630	396	280	163	142	58	20	14	3,584	36
Technicians	15	219	386	534	440	303	169	102	58	53	5	10	2,294	78
Service	8	134	225	265	245	164	114	74	60	47	19	7	1,362	11
Agriculture			1	1	2	1		1	1				7	
Construction	5	73	143	158	126	77	36	19	25	12		84	758	20
Production	6	53	153	263	245	202	130	74	53	28	4		1,211	86
Transportation		3	11	27	14	18	11	4	3	1	4	1	97	1
Laborers	11	20	44	58	58	55	35	22	7	3	1	3	317	11
Miscellaneous	38	101	84	96	76	55	45	37	21	11	16	36	616	3
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	17	50	66	58	44	24	12	8	6	1	2		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.99
Distribution of Persons Receiving Beta-Gamma Doses by Age and Occupation
1989 - Unknown Sex

Occupation	Number of Persons Receiving Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	2	1	11	5	11	3	4	4	6	1	107	1,912	2,067	41
Scientists									1			3	4	
Construction								1	1			985	987	11
Miscellaneous	6	1	2	3	2	1	—	1	—	1	—	19	36	—
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	3	48		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.100
Distribution of Collective Beta-Gamma Doses by Age and Occupation[a]
1989 - Male

Occupation	Collective Dose (person-rem) in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown		5	27	34	33	26	18	15	15	7	4	4	13,315	189
Management		1	13	24	24	29	14	15	10	5	1		7,663	137
Scientists		7	46	56	54	41	33	30	31	16	4	1	22,849	317
Technicians	1	15	88	112	95	67	34	35	39	14	3	2	9,211	505
Service		2	10	13	11	10	5	4	2	3	1	2	4,919	64
Agriculture													95	
Construction	1	27	52	86	90	77	51	43	32	15	2	9	10,826	483
Production		24	92	131	110	80	49	26	28	17	3		6,911	560
Transportation		1	2	8	4	7	4	5	4	1			2,478	37
Laborers		3	13	17	13	10	6	5	4	1			1,772	74
Miscellaneous	—	1	2	5	5	4	3	3	3	2	1	2	3,288	34
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	86	345	485	441	351	218	181	168	81	20	20		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.101
Distribution of Collective Beta-Gamma Doses by Age and Occupation[a]
1989 - Female

Occupation	Collective Dose (person-rem) in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown		1	3	3	7	2	1	3	1	2			3,490	23
Management		1	2	3	4	3	2	1	1				3,368	18
Scientists		2	9	10	5	5	2	1	2				3,584	36
Technicians		5	17	21	16	10	5	2	1	1			2,294	78
Service		1	2	3	1	1	1	1	1				1,362	11
Agriculture													7	
Construction		2	5	4	4	1	2					1	758	20
Production		4	11	18	16	20	10	2	2	2			1,211	86
Transportation													97	1
Laborers			1	2	4	2	1						317	11
Miscellaneous	—	—	—	1	—	—	—	—	1	—	—	—	616	3
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	17	50	66	58	44	24	12	8	6	1	2		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.102
Distribution of Collective Beta-Gamma Doses by Age and Occupation[a]
1989 - Unknown Sex

Occupation	Collective Dose (person-rem) in Each Dose Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown											3	37	2,067	41
Scientists													4	
Construction												11	987	11
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	3	4		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.103
Distribution of Persons Receiving Beta-Gamma Doses by Occupation and Facility Type[a]
1989 - Male

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupational Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	1,124	134	1,789	1,370	147	15	123	98	38	1	25	4,864	154
Fuel/Uran. Enrichment	128	530	1,075	485	343	1	1,082	807	48	167	44	4,710	37
Fuel Fabrication	1,711	239	502	177	170		211	336	38	30	1	3,415	87
Fuel Processing	51	338	1,170	128	47	1	482	594	34	20	1	2,866	376
Maint. and Support	4,130	1,904	2,895	1,146	1,255	34	5,629	1,005	803	759	9	19,569	437
Reactor	27	739	2,267	596	128		743	768	94	77	312	5,751	401
Research, General	2,944	851	5,288	1,946	468	6	442	312	59	87	1,191	13,594	308
Research, Fusion	120	101	609	286	50		126	50		3	52	1,397	10
Waste Proc./Management	98	581	1,296	544	154	1	721	566	136	130	41	4,268	137
Weapons Fab. & Test.	1,249	1,527	3,446	1,783	478		839	2,116	136	178	1,552	13,304	342
Other	1,733	719	2,512	750	1,679	37	428	259	1,092	320	60	9,589	109
Total Persons	13,315	7,663	22,849	9,211	4,919	95	10,826	6,911	2,478	1,772	3,288	83,327	
Total Person-rem	189	137	317	505	64	0	483	560	37	74	34		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.104
Distribution of Persons Receiving Beta-Gamma Doses by Occupation and Facility Type[a]
1989 - Female

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupational Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	172	63	175	91	45	1	4	6			5	562	10
Fuel/Uran. Enrichment	109	292	162	164	85		39	96	3	31	14	995	6
Fuel Fabrication	119	42	196	109	21		19	114	2	17		639	14
Fuel Processing	2	168	217	44	29		42	188	2	3		695	39
Maint. and Support	1,203	1,146	629	572	257		476	90	44	167	3	4,587	59
Reactor	4	160	171	66	24		45	130	3	6	17	626	31
Research, General	903	328	748	523	91	2	8	38	2	13	259	2,915	37
Research, Fusion	28	22	45	23	5		2			1	4	130	
Waste Proc./Management	30	187	170	165	143		33	167	5	2	6	908	17
Weapons Fab. & Test.	497	679	578	338	105		86	349	5	40	297	2,974	54
Other	423	281	493	199	557	4	4	33	31	37	11	2,073	19
Total Persons	3,490	3,368	3,584	2,294	1,362	7	758	1,211	97	317	616	17,104	
Total Person-rem	23	18	36	78	11	0	20	86	1	11	3		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.105
Distribution of Persons Receiving Beta-Gamma Doses by Occupation and Facility Type[a]
1989 - Unknown Sex

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupational Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator			2				1					3	
Fuel/Uran. Enrichment	4											4	
Maint. and Support							986					986	11
Research, General			2								36	38	
Weapons Fab. & Test.	618											618	3
Other	1,445	—	—	—	—	—	—	—	—	—	—	1,445	38
Total Persons	2,067	0	4	0	0	0	987	0	0	0	36	3,094	
Total Person-rem	41	0	0	0	0	0	11	0	0	0	0		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.106
Distribution of Collective Beta-Gamma Doses by Occupation and Facility Type[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	58	2	28	57			2	3	4			4,864	154
Fuel/Uran. Enrichment		1	2	4	3		8	12		6		4,710	37
Fuel Fabrication	26	5	5	10	16		3	18	2	1		3,415	87
Fuel Processing	1	16	51	46	2		85	163	7	5		2,866	376
Maint. and Support	14	22	23	73	12		216	29	12	38		19,569	437
Reactor	1	35	49	85	2		93	113	3	11	8	5,751	401
Research, General	51	13	67	122	4		22	15	1	6	7	13,594	308
Research, Fusion			3	3	1		1	1				1,397	10
Waste Proc./Management		7	29	19			28	49	4	1		4,268	137
Weapons Fab. & Test.	10	29	35	74	5		19	150	1	4	17	13,304	324
Other	26	5	26	13	18		7	7	3	2		9,589	109
Total Persons	13,315	7,663	22,849	9,211	4,919	95	10,826	6,911	2,478	1,772	3,288	83,327	
Total Person-rem	189	137	317	505	64	0	483	560	37	74	34		2,399

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.107
Distribution of Collective Beta-Gamma Doses by Occupation and Facility Type[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	4		3	3								562	10
Fuel/Uran. Enrichment		1	1	1	1			2		1		995	6
Fuel Fabrication	1		1	1	1			9				639	14
Fuel Processing		1	5	4			1	26		2		695	39
Maint. and Support	1	5	4	24	2		15	2	1	5		4,587	59
Reactor		1	3	10			1	14	1	1		626	31
Research, General	12	2	7	12	1		1	1		1	1	2,915	37
Research, Fusion												130	
Waste Proc./Management		1	2	4			1	9				908	17
Weapons Fab. & Test.	1	7	6	14	1		1	22		1	2	2,974	54
Other	3	1	4	4	5	—	—	1	—	—	—	2,073	19
Total Persons	3,490	3,368	3,584	2,294	1,362	7	758	1,211	97	317	616	17,104	
Total Person-rem	23	18	36	78	11	0	20	86	1	11	3		288

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.108
Distribution of Collective Beta-DGamma Doses by Occupation and Facility Type[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator												3	
Fuel/Uran. Enrichment												4	
Maint. and Support							11					986	11
Research, General												38	
Weapons Fab. & Test.	3											618	3
Other	38	—	—	—	—	—	—	—	—	—	—	1,445	38
Total Persons	2,067	0	4	0	0	0	987	0	0	0	36	3,094	
Total Person-rem	41	0	0	0	0	0	11	0	0	0	0		52

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.109
Distribution of Shallow Doses by Facility Type and Shallow Dose Range[a]
1989 - Male

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	3.300	1,232	167	86	44	20	9	2	1	1	1			1		4,864	161
Fuel/Uran. Enrichment	2,856	1,708	116	25	4		1									4,710	76
Fuel Fabrication	1,773	1,349	167	52	22	22	11	6	8	4	1					3,415	168
Fuel Processing	1,083	920	257	181	119	63	121	79	23	10	3	2	3		2	2,866	673
Maint. and Support	10,784	7,277	980	340	108	33	35	7	4						1	19,569	643
Reactor	1,223	3,556	551	210	85	44	49	21	5	6	1					5,751	471
Research, General	8,483	4,124	584	248	77	30	32	8	6	1	1					13,594	425
Research, Fusion	1,150	238	8	1												1,397	9
Waste Proc./Management	2,237	1,562	260	109	48	22	17	6	4	2		1				4,268	218
Weapons Fab. & Test.	7,139	3,965	1,145	539	243	135	94	27	11	4	1	1				13,304	971
Other	5,753	3,433	247	85	21	15	18	7	4	2	2	2				9,589	244
Total Persons	45,781	29,364	4,482	1,876	771	384	387	163	66	30	10	6	3	1	3	83,327	
Total Person-rem	0	844	696	651	467	331	467	283	146	81	32	23	13	5	21		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.110
Distribution of Shallow Doses by Facility Type and Shallow Dose Range[a]
1989 - Female

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	447	94	12	4	3		1		1							562	12
Fuel/Uran. Enrichment	686	287	19	3												995	12
Fuel Fabrication	358	234	23	14	7	2		1								639	22
Fuel Processing	350	219	61	34	14	10	2	5								695	57
Maint. and Support	3,022	1,318	172	58	12	2	2					1				4,587	99
Reactor	215	349	37	10	4	1	5	3	1	1						626	39
Research, General	2,185	624	65	27	11	2	1									2,915	46
Research, Fusion	122	8														130	
Waste Proc./Management	490	361	38	13	3	2			1							908	27
Weapons Fab. & Test.	1,869	761	198	82	30	19	8	4		1	2					2,974	141
Other	1,226	781	39	14	2	3	5	2			1				2,073	49	2
Total Persons	10,970	5,036	664	259	86	41	24	15	3	2	3	1	0	0	0	17,104	
Total Person-rem	0	145	102	89	51	36	29	26	7	5	10	4	0	0	0		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.111
Distribution of Shallow Doses by Facility Type and Shallow Dose Range[a]
1989 - Unknown Sex

Facility Type	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator	2	1														3	
Fuel/Uran. Enrichment	1	3														4	
Maint. and Support	2	957	21	6												986	22
Research, General	28	10														38	
Weapons Fab. & Test.	54	547	16	1												618	10
Other	401	956	65	16	5	1	1	—	—	—	—	—	—	—	—	1,445	42
Total Persons	488	2,474	102	23	5	1	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	50	14	7	3	1	1	0	0	0	0	0	0	0	0		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.112
Distribution of Collective Shallow Doses by Facility Type and Shallow Dose Range[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)														Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator		35	25	29	27	17	11	3	2	3	3			5		4,864	161
Fuel/Uran. Enrichment		47	17	8	2		1									4,710	76
Fuel Fabrication		37	26	18	13	19	14	10	17	11	3					3,415	168
Fuel Processing		29	42	65	73	55	149	138	52	27	9	8	13		13	2,866	673
Maint. and Support		211	151	116	66	28	42	12	9						8	19,569	643
Reactor		100	84	73	52	38	59	35	11	16	3					5,751	471
Research, General		107	91	85	46	26	37	14	13	3	3					13,594	425
Research, Fusion		7	1													1,397	9
Waste Proc./Management		46	40	37	28	19	20	11	9	6		4				4,268	218
Weapons Fab. & Test.		133	184	190	147	117	111	47	25	11	3	4				13,304	971
Other		92	36	28	13	13	22	12	9	5	6	8				9,589	24
Total Persons	45,781	29,364	4,482	1,876	771	384	387	163	66	30	10	6	3	1	3	83,327	
Total Person-rem	0	844	696	651	467	331	467	283	146	81	32	23	13	5	21		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.113
Distribution of Collective Shallow Doses by Facility Type and Shallow Dose Range[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)														Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator		3	2	1	2		1		2							562	12
Fuel/Uran. Enrichment		8	3	1												995	12
Fuel Fabrication		6	3	5	4	2		2								639	22
Fuel Processing		7	10	12	8	9	2	8								695	57
Maint. and Support		39	26	19	7	2	2					4				4,587	99
Reactor		9	6	3	3	1	7	5	2	3						626	39
Research, General		17	10	9	7	2	1									2,915	46
Research, Fusion																130	
Waste Proc./Management		10	6	4	2	2			2							908	27
Weapons Fab. & Test.		24	30	28	17	16	9	7		3	6					2,974	141
Other		21	6	5	1	3	6	3			3					2,073	49
Total Persons	10,970	5,036	664	259	86	41	24	15	3	2	3	1	0	0	0	17,104	
Total Person-rem	0	145	102	89	51	36	29	26	7	5	10	4	0	0	0		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.114
Distribution of Collective Shallow Doses by Facility Type and Shallow Dose Range[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Accelerator																3	
Fuel/Uran. Enrichment																4	
Maint. and Support		18	3	2												986	22
Research, General																38	
Weapons Fab. & Test.		8	2													618	10
Other	—	24	9	5	3	1	1	—	—	—	—	—	—	—	—	1,445	42
Total Persons	488	2,474	102	23	5	1	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	50	14	7	3	1	1	0	0	0	0	0	0	0	0		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.115
Distribution of Shallow Doses by Age and Shallow Dose Range[a]
1989 - Male

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	269	67	6			1										343	3
20 - 24	1,775	1,224	187	84	38	7	7	1	2	1			1			3,327	142
25 - 29	4,380	3,477	572	254	100	42	64	30	10	4		1				8,934	547
30 - 34	6,706	4,673	842	356	166	80	80	45	14	8	3	2	2		1	12,978	826
35 - 39	6,902	4,890	793	336	142	74	77	34	13	6	2	2		1	1	13,273	753
40 - 44	6,577	4,182	698	269	108	64	56	22	11	5	3					11,995	595
45 - 49	5,692	3.059	444	197	76	30	37	8	4	4					1	9,552	385
50 - 54	4,793	2,488	335	176	57	25	27	9	6		1					7,917	304
55 - 59	4,148	2,381	318	141	55	39	27	5	4			1				7,119	283
60 - 64	2,899	1,521	216	49	24	19	8	6	2	2	1					6,747	160
65 and greater	1,185	418	45	8	4	2	2	2								1,666	31
Unknown	455	984	26	6	1	1	2	1	—	—	—	—	—	—	—	1,476	31
Total Persons	45,781	29,364	4,482	1,876	771	384	387	163	66	30	10	6	3	1	3	83,327	
Total Person-rem	0	844	696	651	467	331	467	283	146	81	32	23	13	5	21		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.116
Distribution of Shallow Doses by Age and Shallow Dose Range[a]
1989 - Female

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	140	36	3													179	1
20 - 24	815	450	35	12	4	2	1									1,319	28
25 - 29	1,573	872	124	44	18	4	4		1							2,640	81
30 - 34	1,952	1,089	174	49	26	10	2	2	1	1						3,306	113
35 - 39	1,831	920	120	58	10	11	8	5		1		1				2,965	106
40 - 44	1,537	589	96	45	10	7	6	2	1		2					2,295	78
45 - 49	1,205	390	55	26	7	4	2	3								1,692	44
50 - 54	801	260	29	10	6	2	1	2								1,111	25
55 - 59	553	180	13	9	4											759	12
60 - 64	317	91	11	5	1	1		1			1					428	12
65 and greater	151	21	3													174	1
Unknown	95	138	1	1	—	—	—	—	—	—	—	—	—	—	—	235	3
Total Persons	10,970	5,036	664	259	86	41	24	15	3	2	3	1	0	0	0	17,104	
Total Person-rem	0	145	102	89	51	36	29	26	7	5	10	4	0	0	0		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.117
Distribution of Shallow doses by Age and Shallow Dose Range[a]
1989 - Unknown Sex

Age Category	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less	6	2														8	
20 - 24	2															2	
25 - 29	8	4		1												13	1
30 - 34	4	3	1													8	
35 - 39	4	9														13	
40 - 44	3	1														4	
45 - 49	2	2														4	
50 - 54	2	4														6	
55 - 59	6	2														8	
60 - 64	1	1														2	
65 and greater	51	45	6	4	1											107	4
Unknown	399	2,401	95	18	4	1	1	—	—	—	—	—	—	—	—	2,919	70
Total Persons	488	2,474	102	23	5	1	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	50	14	7	3	1	1	0	0	0	0	0	0	0	0		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.118
Distribution of Collective Shallow Doses by Age and Shallow Dose Range[a]
1989 - Male

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)														Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less		1	1				1									343	3
20 - 24		35	28	29	23	6	9	2	5	3				4		3,327	142
25 - 29		105	90	88	61	36	78	52	22	11		4				8,934	547
30 - 34		139	133	126	101	69	96	78	31	21	9	8	9		6	12,978	826
35 - 39		144	123	115	85	63	93	59	29	16	6	8		5	7	3,273	753
40 - 44		119	108	95	65	55	67	38	24	14	10					11,995	595
45 - 49		90	68	68	46	26	45	14	9	11					8	9,552	385
50 - 54		70	53	61	34	22	31	15	14		3					7,917	304
55 - 59		67	48	48	33	33	33	9	9			4				7,119	283
60 - 64		43	34	17	15	17	10	10	4	5	3					4,747	160
65 and greater		11	7	3	3	2	2	3								1,666	31
Known		20	4	2	1	1	3	2								1,476	31
Total Persons	45,781	29,364	4,482	1,876	771	384	387	163	66	30	10	6	3	1	3	83,327	
Total Person-rem	0	844	696	651	467	331	467	283	146	81	32	23	13	5	21		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.119
Distribution of Collective Shallow Doses by Age and Shallow Dose Range[a]
1989 - Female

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)														Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less		1	1													179	1
20 - 24		13	5	4	2	2	1									1,319	28
25 - 29		25	19	15	11	4	5		2							2,640	81
30 - 34		33	27	17	15	9	2	3	2	3						3,306	113
35 - 39		27	18	20	6	10	10	9		3		4				2,965	106
40 - 44		16	15	16	6	6	7	4	2		7					2,295	78
45 - 49		12	8	9	4	4	2	5								1,692	44
50 - 54		8	4	4	3	2	1	3								1,111	25
55 - 59		5	2	3	2											759	12
60 - 64		2	2	2	1	1		2			3					428	12
65 and greater		1														175	1
Unknown		—	—	—	—	—	—	—	—	—	—	—	—	—	—	235	3
Total Persons	10,970	5,036	664	259	86	41	24	15	3	2	3	1	0	0	0	17,104	
Total Person-rem	0	145	102	89	51	36	29	26	7	5	10	4	0	0	0		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.120
Distribution of Collective Shallow doses by Age and Shallow Dose Range[a]
1989 - Unknown Sex

Age Category	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
19 and less																8	
20 - 24																2	
25 - 29																13	1
30 - 34																8	
35 - 39																13	
40 - 44																4	
45 - 49																4	
50 - 54																6	
55 - 59																8	
60 - 64																2	
65 and greater		1	1	1	1											107	4
Known	—	47	13	5	2	1	1	—	—	—	—	—	—	—	—	2,919	70
Total Persons	488	2,474	102	23	5	1	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	50	14	7	3	1	1	0	0	0	0	0	0	0	0		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.121
Distribution of Shallow Doses by Occupation and Shallow Dose Range[a]
1989 - Male

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	9,575	3,159	293	149	80	37	17	3	2							13,315	276
Management	4,536	2,678	271	103	43	13	13	3	2			1				7,663	216
Scientists	14,019	7,856	589	202	71	41	35	16	10	5	2		1		2	22,849	570
Technicians	4,721	2,888	804	429	152	70	85	38	15	5	1	2		1		9,211	759
Service	2,494	2,261	97	28	8	9	7	5	5	4	1					4,919	137
Agriculture	67	28														95	1
Construction	3,725	5,363	1,097	341	121	66	51	33	16	6	2	2	2		1	10,826	789
Production	2,179	2,575	975	524	277	133	159	63	16	7	2	1				6,911	1,087
Transportation	1,685	678	84	14	3	4	7	2		1						2,478	58
Laborers	771	706	196	67	13	6	10			2	1					1,772	112
Miscellaneous	2,009	1,172	76	19	3	5	3				1					3,288	55
Total Persons	45,781	29,364	4,482	1,876	771	384	387	163	66	30	10	6	3	1	3	83,327	
Total Person-rem	0	844	696	651	467	331	467	283	146	81	32	23	13	5	21		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.122
Distribution of Shallow doses by Occupation and Shallow Dose Range[a]
1989 - Female

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	2,946	485	29	17	10	1	1	1								3,490	30
Management	2,568	726	53	13	3	4	1									3,368	37
Scientists	2,334	1,132	68	32	12	4			1			1				3,584	68
Technicians	1.169	815	187	72	22	11	12	3		1	2					2,294	135
Service	766	567	22	5	1	1										1,362	22
Agriculture	3	4														7	
Construction	211	457	68	17	3	2										758	33
Production	329	538	189	83	33	17	9	10	2		1					1,211	149
Transportation	55	37	5													97	2
Laborers	121	139	35	17	1	1	1	1		1						317	22
Miscellaneous	468	136	8	3	1	—	—	—	—	—	—	—	—	—	—	616	5
Total Persons	10,970	5,036	664	259	86	41	24	15	3	2	3	1	0	0	0	17,104	
Total Person-rem	0	145	102	89	51	36	29	26	7	5	10	4	0	0	0		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.123
Distribution of Shallow Doses by Occupation and Shallow dose Range[a]
1989 - Unknown Sex

Occupation	Number of Persons Receiving Radiation Doses in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown	456	1,506	81	17	5	1	1									2,,067	53
Scientists	3	1														4	
Construction	2	958	21	6												987	23
Miscellaneous	27	9	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	488	2,474	102	23	5	1	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	50	14	7	3	1	1	0	0	0	0	0	0	0	0		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.124
Distribution of Collective Shallow Doses by Occupation and Shallow Dose Range[a]
1989 - Male

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		68	45	52	49	32	20	5	4							13,315	276
Management		73	40	37	26	11	15	5	4			4				7,663	216
Scientists		204	87	68	43	36	41	28	23	14	6		4		15	22,849	570
Technicians		96	132	147	92	61	103	67	33	13	3	8		5		9,211	759
Service		59	14	10	5	8	9	9	11	11	3					4,919	137
Agriculture		1														95	1
Construction		172	170	118	73	56	62	58	35	16	6	8	8		6	10,826	789
Production		97	155	186	167	115	193	109	36	19	6	4				6,911	1,087
Transportation		23	12	4	2	3	8	3		3						2,478	58
Laborers		26	30	22	8	5	12			6	3					1,772	112
Miscellaneous	25	11	6	2	4	3	—	—	—	—	3	—	—	—	—	3,288	55
Total Persons	45,781	29,364	4,482	1,876	771	384	387	163	66	30	10	6	3	1	3	83,327	
Total Person-rem	0	844	696	651	467	331	467	283	146	81	32	23	13	5	21		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.125
Distribution of Collective Shallow Doses by Occupation and Shallow Dose Range[a]
1989 - Female

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		10	5	6	6	1	1	2								3,490	30
Management		18	8	4	2	3	1									3,368	37
Scientists		30	10	10	7	3		2				4				3,584	68
Technicians		29	30	25	13	10	15	5		3	6					2,294	135
Service		15	3	2	1	1										1,362	22
Agriculture																7	
Construction		14	10	5	2	2										758	33
Production		20	29	30	19	15	11	17	5		3					1,211	149
Transportation		2	1													97	2
Laborers		5	5	5	1	1	1	2		3						317	22
Miscellaneous		3	1	1	1											616	5
Total Persons	10,970	5,036	664	259	86	41	24	15	3	2	3	1	0	0	0	17,104	
Total Person-rem	0	145	102	89	51	36	29	26	7	5	10	4	0	0	0		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.126
Distribution of Collective Shallow Doses by Occupation and Shallow Dose Range[a]
1989 - Unknown Sex

Occupation	Collective Dose (person-rem) in Each Dose Range (rem)															Total Persons	Total Person-rem
	< Meas.	Meas.-<0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	> 5		
Unknown		32	11	5	3	1	1									2,067	53
Scientists																4	
Construction		18	3	2												987	23
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	488	2,474	102	23	5	1	1	0	0	0	0	0	0	0	0	3,094	
Total Person-rem	0	50	14	7	3	1	1	0	0	0	0	0	0	0	0		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.127
Distribution of Persons Receiving Shallow Doses by Age and Facility Type[a]
1989 - Male

Facility Type	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator	28	237	575	762	673	683	569	495	405	226	153	58	4,864	161
Fuel/Uran. Enrichment	4	62	242	593	933	892	581	413	424	424	84	58	4,710	76
Fuel Fabrication	19	209	516	633	579	442	316	240	249	163	43	6	3,415	168
Fuel Processing	1	159	364	565	499	429	268	193	217	151	19	1	2,866	673
Maint. and Support	105	816	2,173	3,067	3,055	2,625	2,164	1,799	1,653	1,094	368	650	19,569	643
Reactor		251	860	990	988	869	551	460	448	283	41	10	5,751	471
Research, General	120	599	1,182	1,868	2,106	1,809	1,665	1,410	1,353	900	426	156	13,594	425
Research, Fusion	1	32	118	187	237	203	168	148	132	106	56	9	1,397	9
Waste Proc./Management	10	214	601	777	720	626	435	362	280	176	55	12	4,268	218
Weapons Fab. & Test.	16	239	993	1,877	1,990	2,055	1,848	1,670	1,412	880	214	110	13,304	971
Other	39	509	1,310	1,659	1,493	1,362	987	727	546	344	207	406	9,589	244
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	142	547	826	753	595	385	304	283	160	31	31		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.128
Distribution of Persons Receiving Shallow Doses by Age and Facility Type[a]
1989 - Female

Facility Type	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator	14	44	104	109	89	67	52	44	15	9	9	6	562	12
Fuel/Uran. Enrichment	9	51	108	208	189	134	92	81	64	40	10	9	995	12
Fuel Fabrication	2	42	120	139	115	96	43	35	27	17	3		639	22
Fuel Processing	2	68	131	171	127	82	63	30	14	3	4		695	57
Maint. and Support	29	312	709	852	792	661	503	290	202	98	44	95	4,587	99
Reactor	3	53	144	143	102	88	36	22	19	13		3	626	39
Research, General	81	287	419	559	491	326	255	197	136	92	37	35	2,915	46
Research, Fusion	1	8	12	20	21	27	19	4	9	5	3	1	130	
Waste Proc./Management	7	85	172	177	171	116	85	46	28	18	3		908	27
Weapons Fab. & Test.	11	133	342	536	539	474	369	249	184	104	26	7	2,974	141
Other	20	236	379	392	329	224	175	113	61	29	36	79	2,073	49
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	28	81	113	106	78	44	25	12	12	1	3		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.129
Distribution of Persons Receiving Shallow Doses by Age and Facility Type[a]
1989 - Unknown Sex

Facility Type	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator									2			1	3	
Fuel/Uran. Enrichment												4	4	
Maint. and Support												985	986	22
Research, General	6	1	2	3	2	1		1		1		21	38	
Weapons Fab. & Test.	1		6	4	8	1	2	1	1			594	618	10
Other	1	1	5	1	3	2	2	3	5	1	107	1,314	1,445	42
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	4	70		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.130
Distribution of Collective Shallow Doses by Age and Facility Type[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator		5	19	27	31	25	16	15	14	7	1	1	4,864	161
Fuel/Uran. Enrichment		1	6	13	16	14	9	5	6	4	1		4,710	76
Fuel Fabrication	1	4	20	30	29	35	13	10	14	10	1		3,415	168
Fuel Processing		37	129	184	136	79	53	24	14	7			2,866	673
Maint. and Support	2	44	96	127	104	85	62	45	40	16	4	18	19,569	643
Reactor		18	77	90	92	81	32	33	30	16	1	1	5,751	471
Research, General		7	32	66	89	53	44	45	48	29	9	3	13,594	425
Research, Fusion			1	2	1	1	1	1	1	1		1	1,397	9
Waste Proc./Management		12	44	47	46	29	13	6	18	3			4,268	218
Weapons Fab. & Test.		3	73	181	176	160	119	105	80	61	10	3	13,304	971
Other		10	48	60	32	32	22	16	9	5	4	6	9,589	244
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	142	547	826	753	595	385	304	283	160	31	31		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.131
Distribution of Collective Shallow Doses by Age and Facility Type[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator			4	2	3		1						562	12
Fuel/Uran. Enrichment			1	3	3	2	1	1	1				995	12
Fuel Fabrication			4	5	3	6	1	2	1				639	22
Fuel Processing		5	10	18	16	4	4						695	57
Maint. and Support		9	22	24	20	9	8	2	2			2	4,587	98
Reactor		1	6	8	9	11	1			2			626	39
Research, General		2	8	10	9	4	3	5	2	2			2,915	46
Research, Fusion													130	
Waste Proc./Management		2	5	5	5	5	3	1	1				908	27
Weapons Fab. & Test.		2	12	27	29	29	18	11	5	7			2,974	141
Other		6	9	9	10	8	4	1	1			1	2,073	49
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	28	81	113	106	78	44	25	12	12	1	3		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.132
Distribution of Collective Shallow Doses by Age and Facility Type[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Accelerator													3	
Fuel/Uran. Enrichment													4	
Maint. and Support												22	986	22
Research, General													38	
Weapons Fab. & Test.												10	618	10
Other	—	—	—	—	—	—	—	—	—	—	4	38	1,445	42
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	0	0	0	0	0	0	0	0	4	70		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.133
Distribution of Persons Receiving Shallow Doses by Age and Occupation[a]
1989 - Male

Occupation	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	117	661	1,330	1,795	1,789	1,726	1,674	1,437	1,130	804	438	414	13,315	276
Management	16	55	336	849	1,226	1,378	1,177	1,084	860	525	138	19	7,663	216
Scientists	16	770	2,405	3,502	3,610	3,292	2,673	2,324	2,240	1,396	550	71	22,849	570
Technicians	20	410	1,231	1,768	1,605	1,249	893	731	702	436	103	63	9,211	759
Service	12	250	895	1,037	774	613	412	285	248	202	110	81	4,919	137
Agriculture	1	5	10	19	18	14	9	8	9	1	1		95	1
Construction	57	510	1,093	1,542	1,770	1,659	1,194	892	798	570	109	632	10,826	789
Production	4	228	765	1,231	1,307	1,055	743	490	565	438	84	1	6,911	1,087
Transportation	3	53	227	408	443	412	269	268	217	141	33	4	2,478	58
Laborers	31	143	267	363	324	204	158	104	95	56	14	13	1,772	112
Miscellaneous	66	242	375	464	407	393	350	294	255	178	86	178	3,288	55
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	142	547	826	753	595	365	304	283	260	31	31		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.134
Distribution of Persons Receiving Shallow Doses by Age and Occupation[a]
1989 - Female

Occupation	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	65	252	436	514	533	496	411	328	176	129	74	76	3,490	30
Management	25	192	413	531	596	528	461	287	213	86	32	4	3,368	37
Scientists	6	272	744	859	630	396	280	163	142	58	20	14	3,584	68
Technicians	15	219	386	534	440	303	169	102	58	53	5	10	2,294	135
Service	8	134	225	265	245	164	114	74	60	47	19	7	1,362	22
Agriculture			1	1	2	1		1	1				7	
Construction	5	73	143	158	126	77	36	19	25	12		84	758	33
Production	6	53	153	263	245	202	130	74	53	28	4		1,211	149
Transportation		3	11	27	14	18	11	4	3	1	4	1	97	2
Laborers	11	20	44	58	58	55	35	22	7	3	1	3	317	22
Miscellaneous	38	101	84	96	76	55	45	37	21	11	16	36	616	5
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	28	81	113	106	78	44	25	12	12	1	3		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.135
Distribution of Persons Receiving Shallow Doses by Age and Occupation[a]
1989 - Unknown Sex

Occupation	Number of Persons Monitored for Radiation Doses in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown	2	1	11	5	11	3	4	4	6	1	107	1,912	2,067	53
Scientists									1			3	4	
Construction								1	1			985	987	23
Miscellaneous	6	1	2	3	2	1	—	1	—	1	—	19	36	—
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	1	0	0	0	0	0	0	0	4	70		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.136
Distribution of Collective Shallow Doses by Age and Occupation[a]
1989 - Male

Occupation	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown		6	32	45	46	37	28	26	24	18	6	6	13,315	276
Management		1	17	36	40	41	24	27	18	9	2		7,663	216
Scientists		15	76	105	103	77	58	45	54	30	7	1	22,849	370
Technicians	1	21	128	179	145	101	52	48	55	22	4	2	9,211	759
Service		5	17	27	25	28	12	7	5	9	1	2	4,919	137
Agriculture													95	1
Construction	2	48	98	151	143	112	82	63	47	22	4	17	10,826	789
Production		37	154	235	216	160	108	69	65	38	5		6,911	1,087
Transportation		1	5	13	7	12	6	6	5	2			2,478	58
Laborers		7	17	25	19	19	9	8	5	2			1,772	112
Miscellaneous		1	4	9	8	9	5	4	5	7	2	2	3,288	55
Total Persons	343	3,327	8,934	12,978	13,273	11,995	9,552	7,917	7,119	4,747	1,666	1,476	83,327	
Total Person-rem	3	142	547	826	753	595	385	304	283	160	31	31		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.137
Distribution of Collective Shallow doses by Age and Occupation[a]
1989 - Female

Occupation	Collective Dose (person-rem) in Each Age Range											Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown		1	4	5	8	4	1	4	1	2			3,490	30
Management		2	5	6	9	4	4	3	2	2			3,368	37
Scientists		4	16	18	14	8	3	2	2				3,584	68
Technicians		8	26	36	27	19	9	3	1	5		1	2,294	135
Service		2	5	5	3	2	2	1	1				1,362	22
Agriculture													7	
Construction		3	7	7	6	3	3	1	1			2	758	33
Production		5	17	30	30	34	19	8	4	3			1,211	149
Transportation				1									97	2
Laborers		1	2	4	9	2	3	1					317	22
Miscellaneous	—	1	1	1	—	1	—	1	1	—	—	—	616	5
Total Persons	179	1,319	2,640	3,306	2,965	2,295	1,692	1,111	759	428	175	235	17,104	
Total Person-rem	1	28	81	113	106	78	44	25	12	12	1	3		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.138
Distribution of Collective Shallow Doses by Age and Occupation
1989 - Unknown Sex

Occupation	Collective Dose (person-rem) in Each Age Range												Total Persons	Total Person-rem
	≤ 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	≥ 65	Unknown		
Unknown			1								4	47	2,067	52
Scientists													4	
Construction												22	987	23
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	36	—
Total Persons	8	2	13	8	13	4	4	6	8	2	107	2,919	3,094	
Total Person-rem	0	0	1	0	0	0	0	0	0	0	4	70		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.139
Distribution of Persons Receiving Shallow Doses by Occupation and Facility Type[a]
1989 - Male

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	1,124	134	1,789	1,370	147	15	123	98	38	1	25	4,864	161
Fuel/Uran. Enrichment	128	530	1,075	485	343	1	1,082	807	48	167	44	4,710	76
Fuel Fabrication	1,711	239	502	177	170		211	336	38	30	1	3,415	168
Fuel Processing	51	338	1,170	128	47	1	482	594	34	20	1	2,866	673
Maint. and Support	4,130	1,904	2,895	1,146	1,255	34	5,629	1,005	803	759	9	19,569	643
Reactor	27	739	2,267	596	128		743	768	94	77	312	5,751	471
Research, General	2,944	851	5,288	1,946	468	6	442	312	59	87	1,191	13,594	425
Research, Fusion	120	101	609	286	50		126	50		3	52	1,397	9
Waste Proc./Management	98	581	1,296	544	154	1	721	566	136	130	41	4,268	218
Weapons Fab. & Test.	1,249	1,527	3,446	1,783	478		839	2,116	136	178	1,552	13,304	971
Other	1,733	719	2,512	750	1,679	37	428	259	1,092	320	60	9,589	244
Total Persons	13,315	7,663	22,849	9,211	4,919	95	10,826	6,911	2,478	1,772	3,288	83,327	
Total Person-rem	276	216	570	759	127	1	769	1.087	58	112	55		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.140
Distribution of Persons Receiving Shallow Doses by Occupation and Facility Type[a]
1989 - Female

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	172	63	175	91	45	1	4	6			5	562	12
Fuel/Uran. Enrichment	109	292	162	164	85		39	96	3	31	14	995	12
Fuel Fabrication	119	42	196	109	21		19	114	2	17		639	22
Fuel Processing	2	168	217	44	29		42	188	2	3		695	57
Maint. and Support	1,203	1,146	629	572	257		476	90	44	167	3	4,587	99
Reactor	4	160	171	66	24		45	130	3	6	17	626	39
Research, General	903	328	748	523	91	2	8	38	2	13	259	2,915	46
Research, Fusion	28	22	45	23	5		2			1	4	130	
Waste Proc./Management	30	187	170	165	143		33	167	5	2	6	908	27
Weapons Fab. & Test.	497	679	578	338	105		86	349	5	40	297	2,974	141
Other	423	281	493	199	557	4	4	33	31	37	11	2,073	49
Total Persons	3,490	3,368	3,584	2,294	1,362	7	758	1,211	97	317	616	17,104	
Total Person-rem	30	37	68	135	22	0	33	149	2	22	5		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.141
Distribution of Persons Receiving Shallow Doses by Occupation and Facility Type[a]
1989 - Unknown Sex

Facility Type	Number of Persons Monitored for Radiation Doses in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator			2				1					3	
Fuel/Uran. Enrichment	4											4	
Maint. and Support							986					986	22
Research, General			2								36	38	
Weapons Fab. & Test.	618											618	10
Other	1,445	—	—	—	—	—	—	—	—	—	—	1,445	42
Total Persons	2,067	0	4	0	0	0	987	0	0	0	36	3,094	
Total Person-rem	53	0	0	0	0	0	23	0	0	0	0		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.142
Distribution of Collective Shallow Doses by Occupation and Facility Type[a]
1989 - Male

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	61	1	29	63			1	2	4			4,864	161
Fuel/Uran. Enrichment		4	6	9	5		19	23		10		4,710	76
Fuel Fabrication	32	10	11	12	60		9	32	2	1		3,415	168
Fuel Processing	2	20	119	62	2		194	252	16	6		2,866	673
Maint. and Support	24	28	51	110	15		304	39	20	52		19,569	643
Reactor	1	38	71	92	3		109	125	3	20	9	5,751	471
Research, General	62	21	98	163	6		31	23	1	7	12	13,594	425
Research, Fusion			2	3	1		1	1				1,397	9
Waste Proc./Management		6	51	26	1		51	74	5	1		4,268	218
Weapons Fab. & Test.	50	78	83	145	9		56	503	2	11	33	13,304	971
Other	43	7	49	74	37		13	14	4	3		9,589	244
Total Persons	13,315	7,663	22,849	9,211	4,919	95	10,826	6,911	2,478	1,772	3,288	83,327	
Total Person-rem	276	216	570	759	137	1	789	1,087	58	112	55		4,059

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.143
Distribution of Collective Shallow Doses by Occupation and Facility Type[a]
1989 - Female

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator	5		4	2								562	12
Fuel/Uran. Enrichment		2	1	2	1		1	3		2		995	12
Fuel Fabrication	1		3	2	2		1	13				639	22
Fuel Processing		1	9	6			2	37		3		695	57
Maint. and Support	2	9	11	41	3		21	3	1	8		4,587	99
Reactor		1	5	11			2	17		4		626	39
Research, General	14	2	9	17	1		1	1		1	1	2,915	49
Research, Fusion												130	
Waste Proc./Management		1	3	5			2	15				908	27
Weapons Fab. & Test.	3	19	15	31	2		4	58		5	4	2,974	141
Other	5	2	8	18	12	—	—	2	1	—	—	2,073	49
Total Persons	3,490	3,368	3,584	2,294	1,362	7	758	1,211	97	317	616	17,104	
Total Person-rem	30	37	68	135	22	0	33	149	2	22	5		504

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

Table D.144
Distribution of Collective Shallow Doses by Occupation and Facility Type[a]
1989 - Unknown Sex

Facility Type	Collective Dose (person-rem) in Each Occupation Category											Total Persons	Total Person-rem
	Unknown	Management	Science	Technician	Service	Agriculture	Construction	Production	Transport	Laborer	Misc.		
Accelerator												3	
Fuel/Uran. Enrichment												4	
Maint. and Support							22					986	22
Research, General												38	
Weapons Fab. & Test.	10											618	10
Other	42	—	—	—	—	—	—	—	—	—	—	1,445	42
Total Persons	2,067	0	4	0	0	0	987	0	0	0	36	3,094	
Total Person-rem	53	0	0	0	0	0	23	0	0	0	0		76

(a) Throughout this report there may be minor variations in collective dose-equivalent values because of rounding.

UNITED STATES
DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20545

EH-411