DOE/EH-0688

DOE Occupational Radiation Exposure

2003 Report

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DEPARTMENT OF ENERGY • UNITED STATES OF AMERICA •

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DOE Occupational Radiation Exposure

2003 Report

The U.S. Department of Energy
Assistant Secretary for Environment, Safety and Health
Office of Corporate Performance Assessment

Foreword

The goal of the U.S. Department of Energy (DOE) is to conduct it's operations, including radiological operations, to ensure the safety and health of all DOE employees, contractors, and subcontractors. The DOE strives to maintain radiation exposures to its workers below administrative control levels and DOE limits and to further reduce these exposures to levels that are "As Low As Reasonably Achievable" (ALARA).

The Rule 10 CFR 835 702 (a) and (b) requires annual individual radiation exposure records for all monitored DOE employees, contractors, subcontractors and members of the public to be reported to the Radiation Exposure Monitoring Systems (REMS) Repository according to procedures provided in DOE Order 231.1A and DOE M 231.1-1A (Chapter 3 and Appendix G). The *2003 DOE Occupational Radiation Exposure Report* provides a summary and analysis of the occupational radiation exposure received by individuals associated with DOE activities and annually reported to REMS.

A brief discussion of the analysis of the occupational exposure data at DOE for 2003 is provided in the Executive Summary

This report is intended to be a valuable tool for managing radiological safety programs and resources. The process of data collection, analysis, and report generation is streamlined to provide a current assessment of the performance of the Department with respect to radiological operations. The key to the timeliness of this report is the correct and prompt reporting of employee radiation exposure data by the sites. Your feedback and comments are important to us to make this report meet your needs.

John S. Shaw
Acting Assistant Secretary
Environment, Safety and Health

Frank B. Russo
Deputy Assistant Secretary
Office of Corporate Performance Assessment

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10 CFR 835	Title 10 Code of Federal Regulation Part 835 "Occupational Radiation Protection," December 14, 1993
10 CFR 835, Amendment	Issued on November 4, 1998
ACL	Administrative Control Level
AEDE	Annual Effective Dose Equivalent
AEC	Atomic Energy Commission
ALAP	As Low As Practicable
ALARA	As Low As Reasonably Achievable
ANL-E	Argonne National Laboratory - East
ANL-W	Argonne National Laboratory - West
ANSI	American National Standards Institute
ANSI N13.30-1996	ANSI Note on Performance Criteria for Radioassay
BGD	Below Ground Ducts
BGRR	Brookhaven Graphite Research Reactor
BHI	Bechtel Hanford, Inc.
BNFL	British Nuclear Fuels Limited
BNL	Brookhaven National Laboratory
CAP	Corrective Action Plan
CDE	Committed Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CEDR	Comprehensive Epidemiologic Data Resource
CPC	Chemical Process Cell
D&D	Decontamination and Decommissioning
DDE	Deep Dose Equivalent
DOE	Department of Energy
DOE HQ	DOE Headquarters
DOE M 231.1-1	Manual for Environment, Safety and Health Reporting, September 10, 1995
DOE Notice 441.1	Radiological Protection for DOE Activities, September 29, 1995
DOE Order 5480.11	Radiation Protection for Occupational Workers, December 1988
DOE Order 5484.1	Environmental Protection, Safety and Health Protection Information Reporting Requirements, February 24, 1981, Change 7, October 17, 1990
DOELAP	DOE Laboratory Accreditation Program
DSB	Duct Service Building
EDE	Effective Dose Equivalent
EDT	Emergency Dump Tank
EH-32	DOE Office of Corporate Performance Assessment
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ES&H	Environment, Safety and Health
ETTP	East Tennessee Technology Park (formerly K-25)
EUO	Enriched Uranium Operations
Fermilab	Fermi National Accelerator Laboratory
FHI	Fluor Hanford, Inc.
FRT	Filter Removal Tool
GPC	General Purpose Cell
HEC	Head End Cells
HLW	High-Level Waste
ICRP	International Commission on Radiological Protection
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
ISMS	Integrated Safety Management System
LANL	Los Alamos National Laboratory
LASO	Los Alamos Site Office
LBNL	Lawrence Berkeley National Laboratory
LDE	Lens (of the eye) Dose Equivalent

TABLE OF ACRONYMS (continued)

LEHR	Laboratory for Energy-related Health Research
LLNL	Lawrence Livermore National Laboratory
LLPIT	Lessons Learned Process Improvement Team
NCRP	National Council on Radiation Protection and Measurements
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
NTS	Nevada Test Site
ORNL	Oak Ridge National Laboratory
ORPS	Occurrence Reporting and Processing System
OSHA	Occupational Safety & Health Administration
OSL	Optically Stimulated Luminescent Dosimeters
PBS	Polymeric Barrier System™
PFP	Plutonium Finishing Plant
PGDP	Paducah Gaseous Diffusion Plant
PMC	Process Mechanical Cell
PNNL	Pacific Northwest National Laboratory
PORTS	Portsmouth Gaseous Diffusion Plant
PP	Pantex Plant
PPC	Product Purification Cell
PPE	Personal Protective Equipment
PR	Product Receiver
PSEs	Planned Special Exposures
RadCon	Radiological Control Manual, June 1992
RCO	Radiological Control Operations
RCS	Radiological Control Standard
RCT	Radiological Control Technician
REMS	Radiation Exposure Monitoring System
RFETS	Rocky Flats Environmental Technology Site
RW	Radiological Workers
RWP	Radiological Work Permit
SARF	Supercompactor and Repackaging Facility
SCBA	Self Contained Breathing Apparatus
SDE	Shallow Dose Equivalent
SDE-ME	Shallow Dose Equivalent to the Maximally Exposed Extremity
SDE-WB	Shallow Dose Equivalent to the Skin of the Whole Body
SLAC	Stanford Linear Accelerator Center
SNF	Spent Nuclear Fuel
SNL	Sandia National Laboratory
SOC	Standard Occupational Classification
SRR	Scrap Removal Room
SRS	Savannah River Site
TEDE	Total Effective Dose Equivalent
TLD	Thermoluminescent Dosimeters
TLND	Thermoluminescent Neutron Dosimeter
TODE	Total Organ Dose Equivalent
TRA	Test Reactor Area
TRU	Transuranic
UHP	Ultra High Pressure
UMTRA	Uranium Mill Tailings Remedial Action
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant
WRAP	Waste Receiving and Processing
WVDP	West Valley Demonstration Project
WVNS	West Valley Nuclear Services, Inc.
WVNSCO	West Valley Nuclear Services Company
Y-12 Plant	Y-12 National Security Complex

Executive Summary

The U.S. Department of Energy (DOE) Office of Corporate Performance Assessment (EH-3) publishes the annual *DOE Occupational Radiation Exposure Report*. This report is intended to be a valuable tool for DOE and DOE contractor managers and workers in managing radiological safety programs and to assist them in prioritizing resources. We appreciate the efforts and contributions from the various stakeholders within and outside DOE to make the report most useful.

This report includes occupational radiation exposure information for all monitored DOE employees, contractors, subcontractors, and members of the public. DOE is defined to include the National Nuclear Security Administration sites. The exposure information is analyzed in terms of aggregate data, dose to individuals, and dose by site. For the purposes of examining trends, data for the past 5 years are included in the analysis.

As shown in *Exhibit ES-1*, between years 2002 and 2003, the DOE collective Total Effective Dose Equivalent (TEDE) increased by 6% from 1,360 person-rem (13,600 person-mSv) to 1,445 person-rem (14,450 person-mSv) primarily due to increased doses at four of the six DOE sites with the highest radiation dose. The average dose to workers with measurable dose increased by 4% from 0.080 rem (0.80 mSv) in 2002 to 0.083 rem (0.83 mSv) in 2003, as shown in *Exhibit ES-2*, because of the 10% increase in the collective dose and a 3% increase in the number of workers with measurable dose. The number of individuals with measurable dose increased from 17,051 in 2002 to 17,484 in 2003. The percentage of monitored individuals receiving measurable dose remained the same for the past 3 years at 17%. There were two exposures in excess of the DOE 5 rem (50 mSv) annual TEDE limit and one exposure in excess of the DOE Administrative Control Level (ACL) of 2 rem (20 mSv) TEDE. The two individuals who received exposures in excess of the 5 rem (50 mSv) annual TEDE limit resulted from plutonium intakes at Los Alamos National Laboratory (LANL) (8.170 rem and 10.197 rem).

Eighty percent of the collective TEDE for the DOE complex was accrued at six DOE sites in 2003. These six sites are (in descending order of collective dose for 2003) Hanford, Savannah River, Los Alamos, Rocky Flats, Oak Ridge, and Idaho. Sites reporting under the category of weapons fabrication and testing account for the highest collective dose. Even though these sites are now primarily involved in nuclear materials stabilization and waste management, they report under this facility type. For the past 3 years, technicians and production staff have received the highest collective dose of any specified labor category.

Exhibit ES-1:
Collective TEDE Dose (person-rem), 1999-2003.

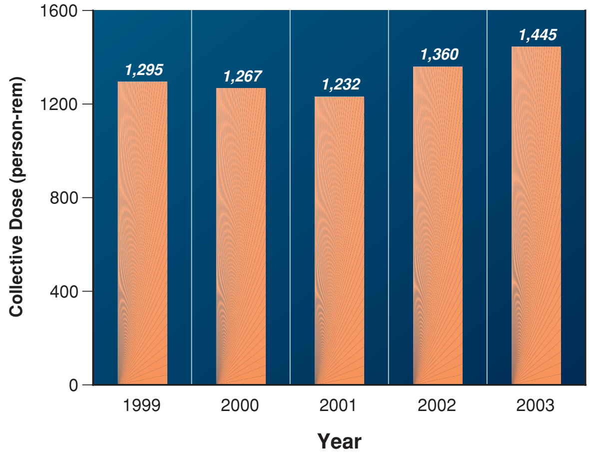
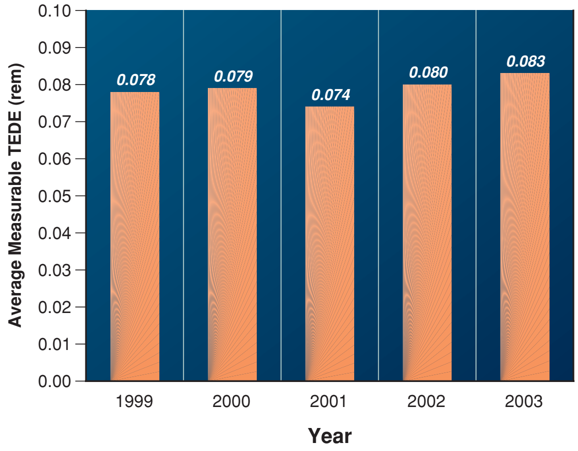


Exhibit ES-2:
Average Measurable TEDE (rem), 1999-2003.

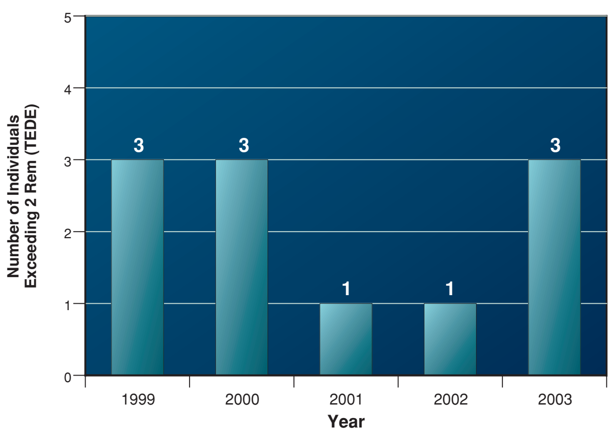


The change in operational status of DOE facilities has had the largest impact on radiation exposure over the past 5 years due to the shift in mission from production to cleanup activities and the shutdown of certain facilities. For 2003, this resulted in an increase in the collective dose as sites handled more radioactive materials for processing, storage, or shipping. Reports submitted by four of the sites that experienced increases in the collective dose indicate that the increases were due to thermal stabilization and repackaging of plutonium-bearing materials, processing of spent fuels, and accelerated cleanup of tank farms at Hanford, resumption of processing of radioactive material, special programs, and accelerated facility closure and waste processing activities at Savannah River, and work activities associated with the building 9204-4 Cleanup Project and the TVA Off-Specification Fuel repackaging project at Oak Ridge, and the processing of more materials containing americium, an upgrade to the material storage vault, and the decontamination and decommissioning of the Omega West reactor at LANL.

A statistical analysis was performed to determine the trend in collective dose over the past 5 years. The analysis indicates that while the collective TEDE, neutron, and extremity dose increased between 2002 to 2003, it does not represent a statistically significant change in the dose received by individual workers at DOE. Further tests revealed fewer individuals received neutron doses above 0.500 rem (5 mSv). This may be the result of a positive change in accordance with ALARA (Note: keeping individual doses below a value alone is not necessarily ALARA).

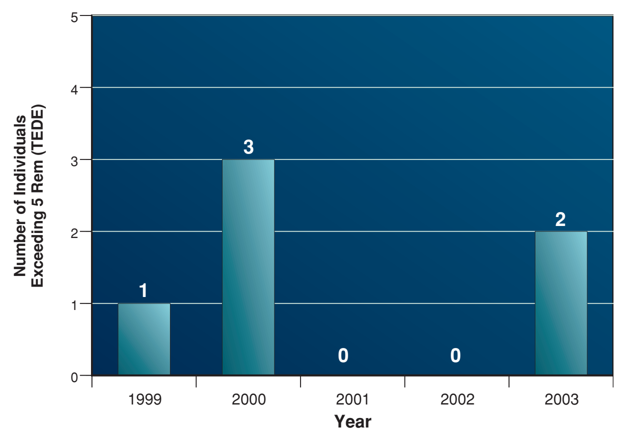
Over the past 5 years, few occupational doses in excess of the 2 rem (20 mSv) ACL and 5 rem (50 mSv) TEDE regulatory limit have occurred at DOE facilities, as shown in *Exhibits ES-3* and *ES-4*. All but two of the doses in excess of 2 rem (20 mSv) in the past 5 years were due entirely to internal dose. Three individuals received doses in excess of 2 rem (20 mSv) in 2003. Two of these individuals received a dose in excess of the 5 rem (50 mSv) TEDE limit in 2003 from plutonium intakes at LANL.

Exhibit ES-3:
Number of Individuals Exceeding 2 Rem TEDE, 1999-2003.



Note: Number of individuals exceeding 2 rem TEDE includes those individuals that also exceeded 5 rem TEDE shown in Exhibit ES-4.

Exhibit ES-4:
Number of Individuals Exceeding 5 Rem TEDE, 1999-2003.



The collective internal dose (CEDE) increased by 38% between 2002 and 2003. Due to the increase in the collective CEDE and an increase in the number of internal depositions, the average measurable CEDE increased by 32% from 0.028 rem (0.28 mSv) in 2002 to a value of 0.037 rem (0.37 mSv) in 2003. The 38% increase in the collective CEDE in 2003 was due to a nearly four-fold increase in internal dose from plutonium. The main contributor to this increase was the two exposures in excess of 5 rem (50mSv) at LANL (see Section 3.3.1). Mound and Rocky Flats also reported increases in internal dose from plutonium from 2002 to 2003.

A transient worker, or transient, is defined as an individual monitored at more than one DOE site in a year. The results of this analysis on the transient workforce at DOE show that the number of transient workers monitored has decreased by 6% from 2,848 in 2002 to 2,665 in 2003 and still remains a very low percentage (2.6%) of the monitored workforce at DOE. The collective dose for these transients increased by 54% from 36.5 person-rem (365 mSv) in 2002 to 56.1 person-rem (561 mSv) in 2003. As a result, the average measurable dose to transients increased by 41% from 0.066 rem (0.66 mSv) in 2002 to 0.093 rem (0.93 mSv) in 2003. The average measurable dose to transient workers is 0.093 rem (0.93 mSv) which is 12% higher than the 0.083 rem (0.83mSv) value for the overall DOE workforce in 2003. This is the first year since the transient data have been analyzed where the average measurable dose of transients exceeded the value for the overall DOE workforce.

To access this report and other information on occupational radiation exposure at DOE, visit the Radiation Exposure Monitoring System (REMS) web site at:

http://www.eh.doe.gov/rems/

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Section One

1

Introduction

Introduction

The *U.S. Department of Energy (DOE) Occupational Radiation Exposure Report, 2003* reports occupational radiation exposures incurred by individuals at DOE facilities during the calendar year 2003. This report includes occupational radiation exposure information for all DOE employees, contractors, subcontractors, and members of the public. The 99 DOE organizations submitting radiation exposure reports for 2003 have been grouped into 27 geographic sites across the complex (see Appendix Exhibit B-1c). This information is analyzed and trended over time to provide a measure of DOE's performance in protecting its workers from radiation.

1.1 Report Organization

This report is organized into the five sections and appendices listed below. Supporting technical information, tables of data, and additional items identified by users as useful are provided in the appendices.

1.2 Report Availability

Requests for additional copies of this report, access to the data files, or individual dose records used to compile this report should be directed to:

Ms. Nirmala Rao
DOE REMS Project Manager
EH-32, 270 Corporate Square Building
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, D.C. 20585-0270
E-mail: nimi.rao@hq.doe.gov

A discussion of the various methods of accessing DOE occupational radiation exposure information is presented in Appendix E. Visit the DOE Radiation Exposure web site for information concerning occupational radiation exposure in the DOE complex at:

`http://www.eh.doe.gov/rems/`

Section One	Provides a description of the content and organization of this report.
Section Two	Provides a discussion of the radiation protection and dose reporting requirements and their impacts on data interpretation. Additional information on dose calculation methodologies, personnel monitoring methods and reporting thresholds, regulatory dose limits, and ALARA is included.
Section Three	Presents the occupational radiation dose data from monitored individuals at DOE facilities for 2003. The data are analyzed to show trends over the past 5 years.
Section Four	Includes examples of successful ALARA projects within the DOE complex.
Section Five	Presents conclusions based on the analysis contained in this report.
Appendices	Lists reporting codes and organizations, a detailed breakdown of the data analyzed in this report, limitations of the data, and ways to access the REMS data.

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Standards and Requirements

One of DOE's primary objectives is to provide a safe and healthy workplace for all employees and contractors. To meet this objective, DOE's Office of Health establishes comprehensive and integrated programs for the protection of workers from hazards in the workplace, including ionizing radiation. The basic DOE standards are radiation dose limits, which establish maximum permissible doses to workers and members of the public. In addition to the requirement that radiation doses not exceed the limits, contractors are required to maintain exposures as low as reasonably achievable (ALARA).

This section discusses radiation protection standards and requirements in effect for the year 2003. Requirements leading up to this time period are also included to facilitate a better understanding of changes that have occurred in the recording and reporting of occupational dose.

2.1 Radiation Protection Requirements

DOE radiation protection standards are based on federal guidance for protection against occupational radiation exposure promulgated by the U.S. Environmental Protection Agency (EPA) in 1987. [1] These standards are provided to ensure that DOE workers are adequately protected from exposure to ionizing radiation. This guidance, initially implemented by DOE in 1989, is based on the 1977 recommendations of the International Commission on Radiological Protection (ICRP) [2] and the 1987 recommendations of the National Council on Radiation Protection and Measurements (NCRP). [3] This guidance recommended that internal organ dose (resulting from the intake of radionuclides) be added to the external whole body dose to determine the Total Effective Dose Equivalent (TEDE). Prior to this, the whole body dose and internal organ dose were each limited separately. The present DOE dose limits based on the TEDE were established from this guidance.

DOE became the first federal agency to implement the EPA guidance when it promulgated DOE Order 5480.11, "Radiation Protection for Occupational Workers," in December 1988. [4] DOE Order 5480.11 was in effect from 1989 to 1995.

In June 1992, the "DOE Radiological Control (RadCon) Manual" [5] was issued and became effective in 1993. The "RadCon Manual" was the result of a Secretarial initiative to improve and standardize radiological protection practices throughout DOE and to achieve the goal of making DOE the pacesetter for radiological health and safety. The "RadCon Manual" is a comprehensive guidance document written for workers, line managers, and senior management. The "RadCon Manual" states DOE's views on the best practices currently available in the area of radiological control. The "RadCon Manual" was revised in 1994 in response to comments from the field and to enhance consistency with the requirements in 10 CFR 835 "Occupational Radiation Protection." [6] In July 1999, the "RadCon Manual" was formally reissued as the Radiological Control Standard (RCS). [7] The RCS incorporates changes resulting from the amendment to 10 CFR 835 issued on November 4, 1998.

The 10 CFR 835 rule became effective on January 13, 1994, and required full compliance by January 1, 1996. In general, 10 CFR 835 codified existing radiation protection requirements in DOE Order 5480.11. The rule provides nuclear safety requirements that, if violated, provide a basis for the assessment of civil and criminal penalties under the Price-Anderson Amendments Act of 1988, Public Law 100-408, August 20, 1988 [8] as implemented by 10 CFR 820 "Procedural Rules for DOE Nuclear Activities," August 17, 1993. [9]

One and one-half years after the promulgation of 10 CFR 835, DOE Order 5480.11 was canceled and the "RadCon Manual" was made non-mandatory guidance with issuance of DOE Notice 441.1, "Radiological Protection for DOE Activities," [10] (applicable to defense nuclear facilities). This notice was issued to establish radiological protection program requirements that, combined with 10 CFR 835 and its associated non-mandatory implementation guidance, formed the basis for a comprehensive radiological protection program. DOE N 441.1 continued in effect until June 1, 2000, when compliance with the amendment to 10 CFR 835 (issued November 4, 1998) was achieved by DOE sites.

During 1994 and 1995, DOE undertook an initiative to reduce the burden of unnecessary, repetitive, or conflicting requirements on DOE contractors. As a result, DOE Order 5484.1 [11] requirements for reporting radiation exposure records were split into two directives; DOE Order 231.1, "Environment, Safety, and Health Reporting" [12], which required the reporting of occupational radiation exposure records, and DOE Manual 231.1-1, "Environment, Safety, and Health Reporting Manual" [13], which specified the format and content of the required reports. Both became effective September 30, 1995.

Most sites reported radiation monitoring results under DOE Order 231.1 and Manual 231.1-1 for 1996. Each site implemented the change in requirements as operating contracts were issued or renegotiated. DOE Order 231.1 underwent two subsequent revisions (Change 1 in 1995 and Change 2 in 1996) and was reissued as DOE Order 231.1A [14] in August of 2003. DOE Manual 231.1-1 underwent similar revisions (Change 1 in 1996 and Change 2 in 2000) and was reissued as DOE Manual 231.1-1A and approved on March 19, 2004. [15]

2.1.1 Monitoring Requirements

10 CFR 835.402(a) requires that, for external monitoring, personnel dosimetry be provided to general employees likely to receive an effective dose equivalent to the whole body greater than 0.1 rem (1 mSv) in a year or an effective dose equivalent to the skin or extremities, lens of the eye, or any organ or tissue greater than 10% of the corresponding annual limits. Monitoring for internal radiation exposure is also required when the general employee is likely to receive 0.1 rem (1 mSv) or more Committed Effective Dose Equivalent (CEDE) in a year. Monitoring for minors and members of the public is required if the TEDE is likely to exceed 50% of the annual limit of 0.1 rem (1 mSv) TEDE. Monitoring of declared pregnant workers is required if the TEDE to the embryo/fetus is likely to exceed 10% of the limit of 0.5 rem (5 mSv) TEDE during the gestation period.

Monitoring for external exposures is also required for any individual entering a high or very high radiation area.

2.1.1.1 External Monitoring

External or personnel dosimeters are used to measure ionizing radiation from sources external to the individual. The choice of dosimeter is based on the type and energy of radiation that the individual is likely to encounter in the workplace. External monitoring devices include thermoluminescent dosimeters (TLDs), optically stimulated luminescent dosimeters (OSLs), pocket ionization chambers, electronic dosimeters, personnel nuclear accident dosimeters, bubble dosimeters, plastic dosimeters, and combinations of the above.

Beginning in 1986, the DOE Laboratory Accreditation Program (DOELAP) formalized accuracy and precision performance standards for external dosimeters used for dose of record and quality assurance/quality control requirements for external dosimetry programs at facilities within the DOE complex. All DOE facilities requiring accreditation were DOELAP-accredited by the fall of 1995.

External dosimeters have a lower limit of detection of approximately 0.005 to 0.030 rem (0.05 to 0.30 mSv) per monitoring period. The differences are attributable to the particular type of dosimeter used and the types of radiation monitored. Monitoring periods are usually quarterly for individuals receiving less than 0.300 rem/year (3 mSv/year) and monthly for individuals who may receive higher doses or who enter higher radiation areas.

2.1.1.2 Internal Monitoring

Bioassay monitoring includes in-vitro (outside the body) and in-vivo (inside the body) sampling. In-vitro assays include urine and fecal samples, nose swipes, saliva samples, and hair samples. In-vivo assays include whole body counting, thyroid counting, lung counting, and wound counting.

Monitoring intervals for internal dosimetry depend on the radionuclides being monitored and their concentrations in the work environment. Routine monitoring intervals may be monthly, quarterly, or annually, whereas special monitoring intervals following an incident may be daily or weekly. Detection thresholds for internal dosimetry are highly dependent on the monitoring methods, the monitoring intervals, the radionuclides in question, and their chemical form. Follow-up measurements and analysis may take many months to confirm preliminary findings. DOELAP has developed a Radiobioassay Accreditation Program in conjunction with the publication of American National Standards Institute (ANSI) N13.30-1996, "Performance Criteria for Radiobioassay." Implementation of the program began in November 1998 with issuance of the amendments to 10 CFR 835.402.(d), with full compliance achieved in January 2004.

2.2 Radiation Dose Limits

Radiation dose limits are codified in 10 CFR 835.202, 206, 207, 208 and are summarized in *Exhibit 2-1*. While some of these sections have been revised, the limits remain the same.

Under 835.204, Planned Special Exposures (PSEs) may be authorized under certain conditions allowing an individual to receive exposures in excess of the dose limits shown in *Exhibit 2-1*. With the appropriate prior authorization, the annual dose limit for an individual may be increased by an additional 5 rems (50 mSv) TEDE above the routine dose limit as long as the individual does not exceed a cumulative lifetime TEDE of 25 rems (250 mSv) from other PSEs and doses above the limits. PSE doses are required to be recorded separately and are only intended to be used in exceptional situations where dose reduction alternatives are unavailable or impractical. No PSEs have occurred since the requirement became effective.

Exhibit 2-1:
DOE Dose Limits from 10 CFR 835

Personnel Category	Section of 10 CFR 835	Type of Exposure	Acronym	Annual Limit
General Employees	§835.202	Total Effective Dose Equivalent	TEDE	5 rems
		Deep Dose Equivalent + Committed Dose Equivalent to any organ or tissue (except lens of the eye). This is often referred to as the Total Organ Dose Equivalent	DDE+CDE (TODE)	50 rems
		Lens (of the eye) Dose Equivalent	LDE	15 rems
		Shallow Dose Equivalent to the skin of the whole body or to any extremity	SDE-WB and SDE-ME	50 rems
Declared Pregnant Worker *	§835.206	Total Effective Dose Equivalent	TEDE	0.5 rem per gestation period
Minors	§835.207	Total Effective Dose Equivalent	TEDE	0.1 rem
Members of the Public in a Controlled Area	§835.208	Total Effective Dose Equivalent	TEDE	0.1 rem

* Limit applies to the embryo/fetus

2.2.1 Administrative Control Levels

Administrative Control Levels (ACLs) were initially established in the "RadCon Manual" and retained in the RCS. ACLs are established below the regulatory dose limits to administratively control and help reduce individual and collective radiation dose. ACLs are multi-tiered, with increasing levels of authority needed to approve a higher level of exposure.

The RCS recommends a DOE ACL of 2 rem (20 mSv) per year, per person, for all DOE activities. Prior to allowing an individual to exceed this level, approval from the appropriate Secretarial Officer or designee should be received. In addition, contractors are encouraged to establish an annual facility ACL. This control level is established by the contractor senior site executive and is based upon an evaluation of historical and projected radiation exposures, workload, and mission. The RCS suggests an annual facility ACL of 0.5 rem (5 mSv) or less; however, the RCS also states that a control level greater than 1.5 rem (15 mSv) is, in most cases, not sufficiently challenging. Approval by the contractor senior site executive must be received prior to an individual exceeding the facility ACL. In addition to the annual ACL, the RCS recommends the establishment of a lifetime ACL of "N" rem, where N is the age of the person in years. Special control levels are also recommended to be established for personnel who have lifetime doses exceeding N rem.

2.2.2 ALARA Principle

Until the 1970s, the fundamental radiation protection principle was to limit occupational radiation dose to quantities less than the regulatory limits and to be concerned mainly with high dose and high-dose rate exposures. During the 1970s, there was a fundamental shift within the radiation protection community to be concerned with low dose and low-dose rate exposures because it could be inferred from the linear no-threshold dose response hypothesis that there was an increased level of risk associated with any radiation exposure. The As Low As Practicable (ALAP) concept was initiated and became part of numerous guidance documents and radiation protection good practices. ALAP was eventually replaced by ALARA. DOE Order 5480.11 and 10 CFR 835 require that each DOE facility have an ALARA Program as part of its overall Radiation Protection Program.

The ALARA methodology considers both individual and group doses and generally involves a cost/benefit analysis. The analysis considers social, technical, economic, practical, and public policy aspects of the overall goal of dose reduction. Because it is not feasible to reduce all doses at DOE facilities to zero, ALARA cost/benefit analysis must be used to optimize levels of radiation dose reduction. According to the ALARA principle, resources spent to reduce dose need to be balanced against 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 mandated, in DOE Order 5480.11 and subsequently in 10 CFR 835, that ALARA plans and procedures be implemented and documented. To help facilities meet this requirement, DOE developed a manual of good practices for reducing exposures to ALARA levels.[16] This document includes 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 minimize the risk to workers from the operation of its facilities.

2.3 Reporting Requirements

In 1987, DOE promulgated revised reporting requirements in DOE Order 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements." Previously, contractors were required to report only the number of individuals who received an occupational whole body dose in one of 16 dose equivalent ranges. The revised Order required the reporting of the results of radiation exposure monitoring for each employee and member of the public. Required dose data reporting includes the TEDE, internal dose equivalent, Shallow Dose Equivalent (SDE) to the skin and extremities, and Deep Dose Equivalent (DDE). Other reported data include the individual's age, sex, monitoring status, and occupation, as well as the reporting organization and facility type.

On August 19, 2003, DOE approved and issued the revised DOE Order 231.1A. The DOE Manual 231.1-1A, which details the format and content of reporting radiation exposure records to the DOE, was approved on March 19, 2004. The revisions affect the content and reporting of radiation exposure records that will be reported to the DOE Radiation Exposure Monitoring System (REMS) repository in 2006. Readers should take note of these revisions for the potential future impact on the recording and reporting of occupational exposure to the REMS repository.

2.4 Change in Internal Dose Methodology

Prior to 1989, intakes of radionuclides into the body were not reported as dose, but as body burden in units of activity of systemic burden, such as the percent of the maximum permissible body burden. The implementation of DOE Order 5480.11 in 1989 specified that the intakes of radionuclides be converted to internal dose and evaluated against the dose limits using the Annual Effective Dose Equivalent (AEDE) methodology. AEDE as well as CEDE were required for reports to employees.

With the implementation of the "RadCon Manual" in 1993, the required methodology used to determine compliance within the dose limits and report internal dose was changed from the AEDE to the 50-year CEDE. The change was made to provide consistency with scientific recommendations, facilitate the transfer of workers between DOE and Nuclear Regulatory Commission (NRC)-regulated facilities, and simplify record keeping by recording all dose in the year of intake. The CEDE methodology is now codified in 10 CFR 835.

When analyzing TEDE data prior to 1993, readers should note that the method of calculating internal dose changed from AEDE to CEDE between 1992 and 1993.

This report primarily analyzes dose information for the past 5 years, from 1999 to 2003. During these years, the CEDE methodology was used to calculate internal dose; therefore, the change in methodology from AEDE to CEDE between 1992 and 1993 does not affect the analysis contained in this report. When analyzing TEDE data prior to 1993, readers should keep in mind the change in methodology.

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Section Three

Occupational Radiation Dose at DOE

3

Occupational Radiation Dose at DOE

3.1 Analysis of the Data

Analysis and explanation of observed trends in occupational radiation dose data reveal opportunities to improve safety and demonstrate performance. Several indicators were identified from the data submitted to the central data repository, which can be used to evaluate the occupational radiation exposures received at DOE facilities. In addition, the key indicators are analyzed to identify and correlate parameters having an impact on radiation dose at DOE.

Key indicators for the analysis of aggregate data are: number of records for monitored individuals and individuals with measurable dose, collective dose, average measurable dose, and the dose distribution. Analysis of individual dose data includes an examination of doses exceeding DOE regulatory limits and doses exceeding the 2 rem (20 mSv) DOE ACL. Analysis of site data includes comparisons by site, labor category, facility type, and occurrence report information. Additional information is provided concerning activities at sites contributing to the collective dose. To determine the significance of trends, statistical analysis was performed on the data.

3.2 Analysis of Aggregate Data

3.2.1 Number of Records for Monitored Individuals

The number of records for monitored individuals represents the size of the DOE worker population provided with radiation dose monitoring. The number represents the sum of all records for monitored individuals, including all DOE employees, contractors, subcontractors, and members of the public. The number of monitored individuals is determined from the number of monitoring records submitted by each site. Because individuals may have more than one monitoring record, they may be counted more than once. The number of records for monitored individuals is an indication of the size of a dosimetry program, but it is not necessarily an indicator of the size of the exposed workforce. This is because of the conservative practice at some DOE facilities of providing radiation dose monitoring to individuals for reasons other than the potential for exposure to radiation and/or radioactive materials exceeding the monitoring thresholds. Many individuals are monitored for reasons such as security, administrative convenience, and legal liability. Some sites offer monitoring for any individual who requests monitoring, independent of the potential for exposure. For this reason, the number of records for workers who receive a measurable dose best represents the exposed workforce.

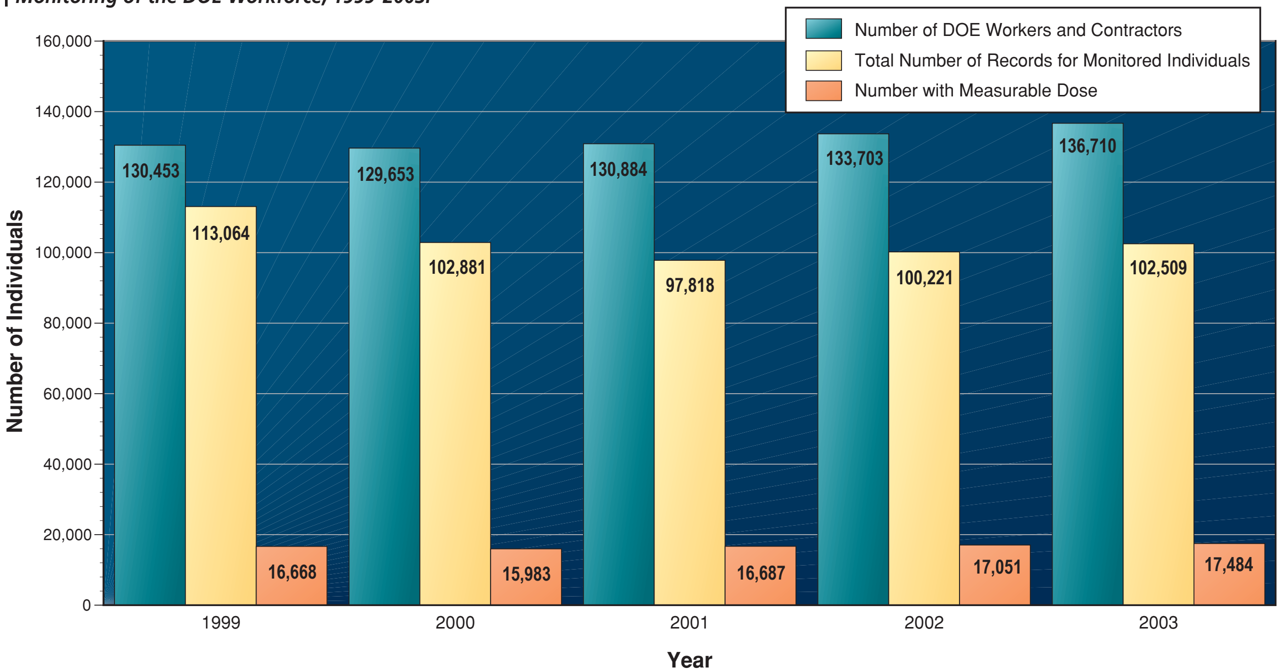
3.2.2 Number of Records for Individuals with Measurable Dose

DOE uses the number of individuals receiving measurable dose to represent the exposed workforce size. The number of individuals with measurable dose includes any individuals with reported TEDE greater than zero.

Exhibit 3-1 shows the number of DOE workers and contractors, the total number of records for monitored individuals, and the number with measurable dose for the past 5 years. Compared to 2002, the same percentage (75%) of the DOE workforce was monitored for radiation in 2003, and the same percentage (17%) of monitored individuals received a measurable dose. The total number of records of individuals monitored for radiation has decreased over the past 5 years, but increased over the past 3 years by 5% from 97,818 in 2001 to 102,509 in 2003. The percentage of the DOE workforce monitored for radiation exposure has decreased by 12% from 87% in 1999 to 75% in 2003. However, most (84%) of the monitored individuals over the past 5 years did not receive

For 2001-2003, the same percentage (75%) of the DOE workforce was monitored for radiation dose, and the same percentage of monitored individuals received a measurable dose (17%).

Exhibit 3-1:
Monitoring of the DOE Workforce, 1999-2003.



any measurable radiation dose. An average of 16% of monitored individuals (13% of the DOE workforce) received a measurable dose during the past 5 years. The percentage of monitored workers receiving measurable dose has remained fairly constant for the past 5 years: 15% in 1999 and 17% in 2003. The overall DOE workforce has increased by 2% from 133,703 in 2002 to 136,710 in 2003.

Fourteen of the 27 reporting sites (see Appendix *Exhibit B-1c*) experienced decreases in the number of workers with measurable dose from 2002 to 2003. The largest decrease in total number of workers with measurable dose occurred at Rocky Flats.The largest increases in the number of workers receiving measurable dose occurred at Los Alamos National Laboratory (LANL) and Savannah River. A discussion of activities at the six highest-dose facilities is included in Section 3.5.

The number of workers with measurable dose increased from 17,051 in 2002 to 17,484 in 2003.

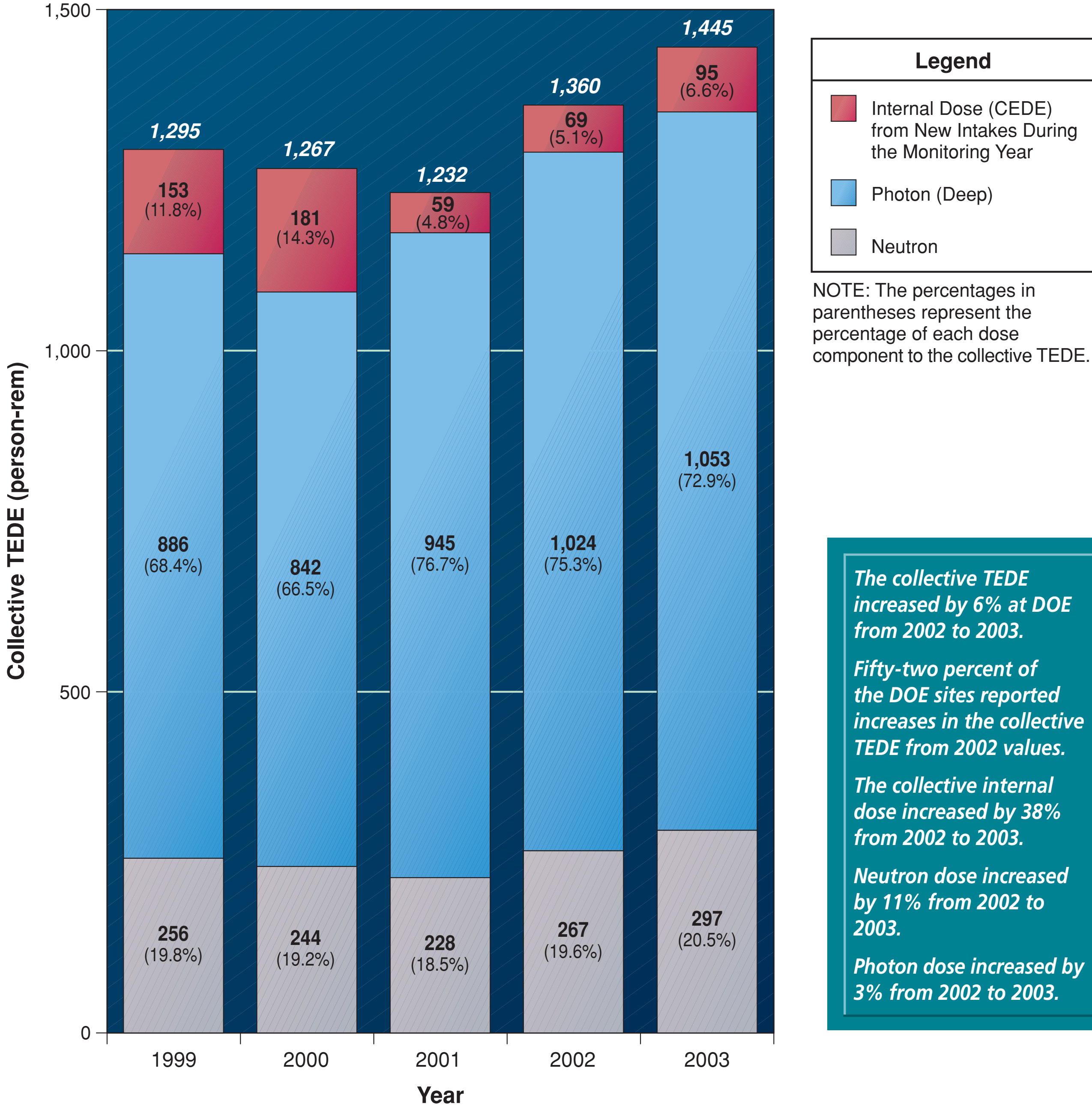
The percentage of monitored workers receiving measurable dose remained the same, at 17%, in 2003.

3.2.3 Collective Dose

The collective dose is the sum of the dose received by all individuals with measurable dose and is measured in units of person-rem (person-Sv). The collective dose is an indicator of the overall radiation exposure at DOE facilities and includes the dose to all DOE employees, contractors, subcontractors, and members of the public. DOE monitors the collective dose as one measure of the overall performance of radiation protection programs to keep individual exposures and collective exposures ALARA.

As shown in *Exhibit 3-2*, the collective TEDE increased at DOE by 6% from 1,360 person-rem (13.60 person-Sv) in 2002 to 1,445 person-rem (14.45 person-Sv) in 2003. Fifty-two percent of the DOE sites (14 out of 27 sites) reported increases in the collective TEDE from the 2002 values. Four out of six of the highest dose sites reported increases in the collective TEDE. The six highest dose sites are (in descending order of collective dose for 2003) Hanford, Savannah River, Los Alamos, Rocky Flats, Oak Ridge, and Idaho. These sites attributed the increase in dose to thermal stabilization and repackaging of plutonium-bearing materials,

Exhibit 3-2:
Components of TEDE, 1999-2003.



NOTE: The percentages in parentheses represent the percentage of each dose component to the collective TEDE.

The collective TEDE increased by 6% at DOE from 2002 to 2003.

Fifty-two percent of the DOE sites reported increases in the collective TEDE from 2002 values.

The collective internal dose increased by 38% from 2002 to 2003.

Neutron dose increased by 11% from 2002 to 2003.

Photon dose increased by 3% from 2002 to 2003.

Photon dose (deep) - the component of external dose from gamma or x-ray electromagnetic radiation. (Also includes energetic betas.)

Neutron dose - the component of external dose from neutrons ejected from the nucleus of an atom during nuclear reactions.

Internal dose - radiation dose resulting from radioactive material taken into the body.

processing of spent fuels, and accelerated cleanup of tank farms at Hanford, resumption of processing of radioactive material, special programs, and accelerated facility closure and waste processing activities at Savannah River, and work activities associated with the building 9204-4 Cleanup Project and the TVA Off-Specification Fuel repackaging project at Oak Ridge, and the processing of more materials containing americium, an upgrade to the material storage vault, and the decontamination and decommissioning of the Omega West reactor at LANL. A discussion of the activities leading to this increase is included in Section 3.5.

A statistical analysis was performed to analyze the trend in collective dose over the past 5 years. The analysis examines the logarithmic mean of the TEDE, neutron, and extremity dose in comparison with prior years. The analysis revealed no significant changes to the logarithmic mean TEDE, neutron, or extremity dose between 2002 and 2003. This indicates that while the collective TEDE, neutron, and extremity dose increased between 2002 to 2003, it does not represent a statistically significant change in the dose received by individual workers at DOE. Further tests revealed a statistically significant downward shift in the neutron dose distribution, indicating that fewer individuals received doses above 0.500 rem (5 mSv). See Section 3.5 for more information on activities contributing to the collective dose and Section 4 for a discussion of notable ALARA activities.

It is important to note that the collective TEDE includes the components of external dose and internal dose. *Exhibit 3-2* shows the types of radiation and their contribution to the collective TEDE. Internal dose, photon, and neutron components are shown.

It should be noted that the internal dose shown in *Exhibit 3-2* for 1999 through 2003 is based on the 50-year CEDE methodology. The internal dose component increased by 38% from 69 person-rem (690 person-mSv) in 2002 to 95 person-rem (950 person-mSv) in 2003, although it remains lower than the values for 1999 through 2000. There were three individuals who received a TEDE dose above 2 rem (20 mSv) in 2003. All three occurred at LANL. Two of these individuals received internal dose from plutonium, and the third received an external dose. The collective internal dose can vary from year to year due to the relatively small number of intakes of radioactive material and the fact that they often involve long-lived radionuclides, such as plutonium, which can result in relatively large committed doses. Due to the infrequent nature of these intakes, care should be taken when attempting to identify trends from the internal dose records.

The external deep dose (comprised of photon, energetic beta, and neutron dose) is shown in *Exhibit 3-2* in order to see the contribution of external dose to the collective TEDE. The collective photon dose increased by 3% from 1,024 person-rem (10.24 person-Sv) in 2002 to 1,053 person-rem (10.53 person-Sv) in 2003. Three of the sites that reported the largest increases in the photon dose attributed the increase to activities involving the processing of more materials containing americium, an upgrade to the material storage vault, and the decontamination and decommissioning of the Omega West reactor at LANL, the resumption of processing radioactive material, special programs, and accelerated facility closure and waste processing activities at Savannah River, and the building 9204-4 Cleanup Project and the TVA Off-Specification Fuel repackaging project at Oak Ridge. See Section 3.5 for more information on activities at these sites.

The neutron component of the TEDE increased by 11% from 267 person-rem (2.67 person-Sv) in 2002 to 297 person-rem (2.97 person-Sv) in 2003. This is primarily due to an 18% increase in the neutron dose at LANL. LANL contributed 30% of the neutron dose during 2003. LANL and Rocky Flats process plutonium in gloveboxes, which can result in a neutron dose from the alpha/neutron reaction and from spontaneous fission of the plutonium. The collective neutron dose for 2003 by site is shown in Appendix *Exhibit B-5*. External deep dose (DDE) and TEDE for prior years (1974 through 2003) can be found in Appendix *Exhibit B-3*.

3.2.4 Average Measurable Dose

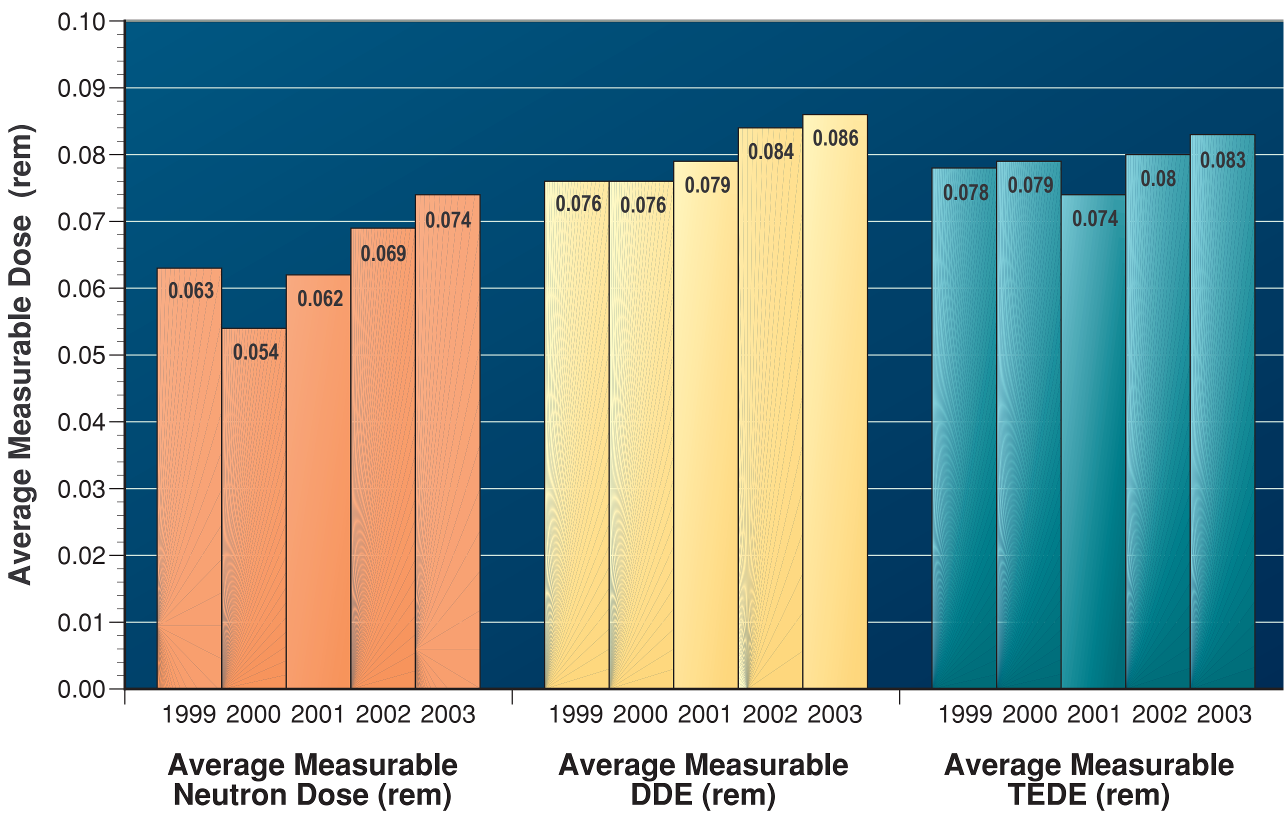
The average measurable dose to DOE workers presented in this report for TEDE, DDE, neutron, extremity, and CEDE is determined by dividing the collective dose for each dose type by the number of individuals with measurable dose for each dose type. This is one of the key indicators of the overall level of radiation dose received by DOE workers.

The average measurable neutron, DDE, and TEDE is shown in *Exhibit 3-3*. The average measurable neutron dose increased by 7% from 0.069 rem (0.69 mSv) in 2002 to 0.074 rem (0.74 mSv) in 2003, primarily due to increases in neutron dose at LANL. The average measurable neutron dose increased by 17% from 0.063 rem (0.63 mSv) in 1999 to 0.074 rem (0.74 mSv) in 2003. The average measurable DDE increased by 2% from 0.084 rem (0.84 mSv) in 2002 to 0.086 rem (0.86 mSv) in 2003 and increased by 13% from 0.076 rem (0.76 mSv) in 1999 to 0.086 rem (0.86 mSv) in 2003. The collective TEDE increased, as well as the number with measurable dose, resulting in a 4% increase in the average measurable TEDE from 0.080 rem (0.80 mSv) in 2002 to 0.083 rem (0.83 mSv) in 2003. The average measurable TEDE increased by 6% from 0.078 rem (0.78 mSv) in 1999 to 0.083 rem (0.83 mSv) in 2003. The average measurable neutron, DDE, and TEDE values are provided for trending purposes, not for comparison between them.

While the collective dose and average measurable dose serve as measures of the magnitude of the dose accrued by DOE workers, they do not indicate the distribution of doses among the worker population.

The average measurable neutron dose increased by 7% and the average measurable DDE increased by 2%, while the average measurable TEDE increased by 4% from 2002 to 2003.

Exhibit 3-3:
Average Measurable Neutron, DDE, and TEDE, 1999-2003.



3.2.5 Dose Distribution

Exposure data are commonly analyzed in terms of dose intervals to depict the dose distribution among the worker population. *Exhibit 3-4* shows the number of individuals in each of 18 different dose ranges. The dose ranges are presented for the TEDE and DDE. The DDE is shown separately to allow for analysis of the external dose, independent of changes in internal dose, and includes the photon and neutron dose. The number of individuals receiving doses above 0.1 rem (1 mSv) is also included to show the number of individuals with doses above the monitoring threshold specified in 10 CFR 835.402(a) and (c).

Exhibit 3-4 shows that few individuals receive doses in the higher ranges, that the vast majority of doses are at low levels, and that the collective TEDE dose decreased from 1999 to 2000, but has increased over the past 3 years from 2001 to 2003.

Another way to examine the dose distribution is to analyze the percentage of the dose received above a certain dose value as compared to the total collective dose.

The United Nations' *Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, Volume I* [17] recommends the calculation of a parameter "SR" (previously referred to as CR) to aid in the examination of the distribution of radiation exposure among workers. SR is defined to be the ratio of the annual collective dose incurred by workers whose annual doses exceed 1.5 rem (15 mSv) to the total annual collective dose. The UNSCEAR report notes that a dose level of 1.5 rem (15 mSv) may not be useful where doses are consistently lower than this level, and they recommend that research organizations report SR values lower than 1.5 rem

Exhibit 3-4:
Distribution of Dose by Dose Range, 1999-2003.

	Dose Ranges (rem)	1999		2000		2001		2002		2003	
		TEDE	DDE	TEDE	DDE	TEDE	DDE	TEDE	DDE	TEDE	DDE
Number of Individuals in Each Dose Range*	Less than Measurable	96,396	98,125	86,898	88,621	81,131	82,950	83,170	84,874	85,025	86,756
	Measurable < 0.1	13,561	12,137	13,020	11,498	13,559	11,881	13,500	11,994	13,865	12,352
	0.10 - 0.25	1,898	1,763	1,873	1,722	1,891	1,782	2,202	2,042	2,205	2,025
	0.25 - 0.5	770	684	727	690	840	820	919	893	910	880
	0.5 - 0.75	238	206	211	203	259	250	269	259	287	284
	0.75 - 1.0	118	87	91	93	89	88	95	94	117	118
	1 - 2	80	62	58	54	48	47	65	64	97	93
	2 - 3	1				1		1	1	1	1
	3 - 4	1									
	4 - 5										
	5 - 6										
	6 - 7	1									
	7 - 8										
	8 - 9									1	
	9 - 10			1							
	10 - 11									1	
	11 - 12			1							
	> 12			1							
Total Number of Records for Monitored Individuals		113,064	113,064	102,881	102,881	97,818	97,818	100,221	100,221	102,509	102,509
Number with Measurable Dose		16,668	14,939	15,983	14,260	16,687	14,868	17,051	15,347	17,484	15,753
Number with Dose >0.1rem		3,107	2,802	2,963	2,762	3,128	2,987	3,551	3,353	3,619	3,401
% of Individuals with Measurable Dose		15%	13%	16%	14%	17%	15%	17%	15%	17%	15%
Collective Dose (person-rem)		1,295	1,142	1,267	1,086	1,232	1,173	1,360	1,291	1,445	1,350
Average Measurable Dose (rem)		0.078	0.076	0.079	0.076	0.074	0.079	0.080	0.084	0.083	0.086

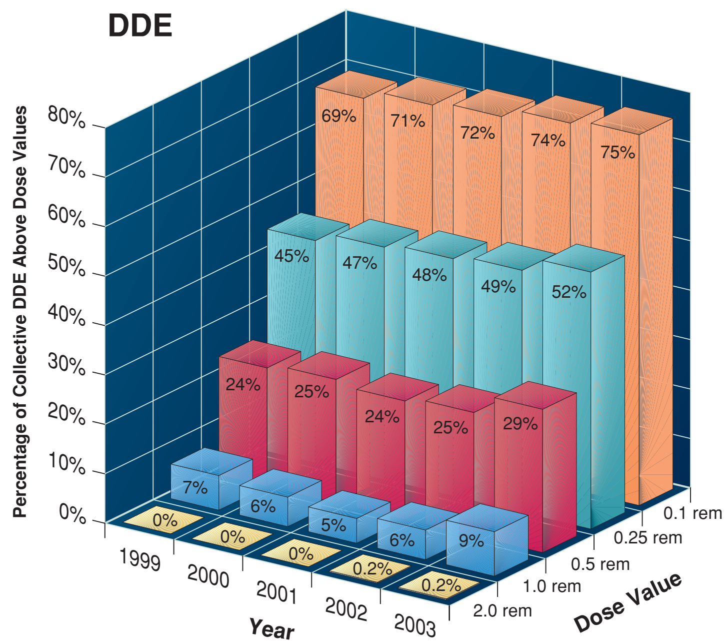
* Individuals with doses equal to the dose value separating the dose ranges are included in the next higher dose range.

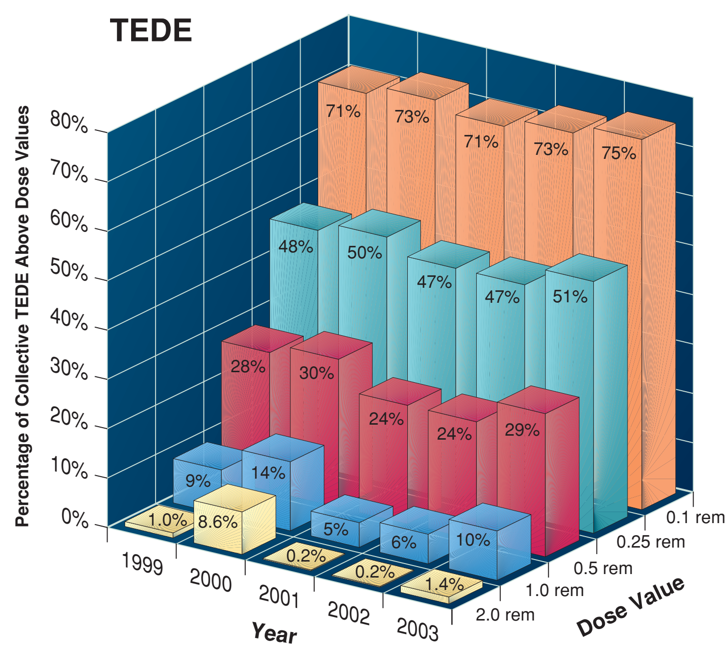
(15 mSv) where appropriate. For this reason, the DOE calculates and tracks the SR ratio at dose levels of 0.100 rem (1 mSv), 0.250 rem (2.5 mSv), 0.500 rem (5 mSv), 1.0 rem (10 mSv), and 2.0 rem (20 mSv). The SR values in this report were calculated by summing the TEDE to each individual who received a TEDE greater than, or equal to, the specified dose level divided by the total collective TEDE. This ratio is presented as a percentage rather than a decimal fraction.

Using this method of plotting the data, an ideal distribution would show only a small percentage of the collective dose delivered to individuals in the higher dose ranges. In addition, this method can be used to show the trend in the percentage of the collective dose above a certain dose range over time. For example, a significantly decreasing trend from year to year may indicate the effectiveness of ALARA programs to reduce doses to individuals or may indicate an overall reduction in activities involving radiation exposure over time. An increasing trend over time may indicate deficiencies in the implementation of ALARA practices or an increase in production or cleanup activities resulting in radiation exposure.

Exhibit 3-5 shows the dose distribution given by percentage of collective TEDE and DDE above each of five dose values, from 0.1 rem (1 mSv) to 2 rem (20 mSv). This graph facilitates the examination of two properties described above which may be used as indications of effective ALARA programs at DOE: (1) a relatively small percentage of the collective dose accrued in the high dose ranges, and (2) a decreasing trend over time of the percentage of the collective dose accrued in the higher dose ranges. *Exhibit 3-5* also shows that each successively higher dose range is responsible for a lower percentage of the collective dose. The values for the external dose (DDE) have fluctuated within a 5% margin for each dose range over the past 5 years. The values for TEDE in each dose range increased from 1999 to 2000, decreased significantly in 2001, and have increased from 2002 to 2003. The increases from 1999 to 2000 were due to the increase in internal doses that exceeded the DOE limits. In 2000, three individuals received a TEDE above 5.0 rem (50 mSv), which contributed to 8.6% of the

Exhibit 3-5:
Percentage of Collective Dose above Dose Values During 1999-2003.





collective TEDE for the year, the highest percentage above 2 rem (20 mSv) since 1990. For 2003, two individuals received doses in excess of 5.0 rem (50 mSv). This resulted in an increase for the percentages in each dose range. In contrast, no individuals exceeded the DOE limits in 2001 and 2002. See Section 3.3 for more information on exposures in excess of the DOE limit.

The neutron and extremity dose distributions are shown in *Exhibits 3-6* and *3-7*. The neutron dose is a component of the total DDE. Exposure to neutron radiation is much less common at DOE than photon dose. In 2003, 3,987 individuals received measurable neutron dose, which is 23% of the individuals with measurable TEDE, and 4% of the total monitored individuals. The collective neutron dose in 2003 represents 21% of the collective TEDE. All neutron doses were below 2 rem (20 mSv) for the past 5 years. The collective neutron dose increased by 11% from 267 person-rem (2.67 person-Sv) in 2002 to 297 person-rem (2.97 person-Sv) in 2003. The average measurable neutron dose increased by 7% from 0.069 rem (0.69 mSv) in 2002 to 0.074 rem (0.74 mSv) in 2003. Statistical analysis reveals that the logarithmic mean neutron dose did not change significantly from 2002 to 2003. This indicates that while the collective neutron dose increased between 2002 to 2003, it does not represent a statistically significant change in the dose received by individual workers at DOE. Further tests revealed a statistically significant downward shift in the neutron dose distribution, indicating that fewer individuals received doses above 0.500 rem (5 mSv). This reflects a positive change in accordance with ALARA to reduce neutron dose to individuals at higher annual dose levels. The neutron dose distribution for 2003 by site is shown in Appendix *Exhibit B-5*.

Exhibit 3-7 shows the distribution of extremity dose over the past 5 years. "Extremities" are defined as the hands and arms below the elbow, and the feet and legs below the knee. 10 CFR 835.402(a)(1)(ii) requires monitoring for an SDE to the extremities of 5 rem (50 mSv) or more in a year. As shown in *Exhibit 3-7*, less than 1% of individuals with measurable extremity dose have received doses above the 5 rem (50 mSv) monitoring threshold over the past 5 years.

Exhibit 3-6:
Neutron Dose Distribution, 1999-2003.

Year	No Meas. Dose	Meas. <0.100	0.10-0.25	0.25-0.50	0.5 - 0.75	0.75-1.0	1.0-2.0	>2.0	Total Monitored*	Number of Individuals with Meas. Neutron Dose	Collective Neutron DDE (person-rem)	Average Meas. Neutron DDE (rem)
1999	109,007	3,329	559	129	27	7	6		**113,064** ◀	4,057	256.075	0.063
2000	98,353	3,809	554	144	17	4			102,881	**4,528** ◀	243.802	0.054
2001	94,135	3,051	454	136	38	3	1		97,818	3,683	228.494	0.062
2002	96,343	3,082	607	122	50	11	6		100,221	3,878	267.029	0.069
2003	98,522	3,129	568	228	38	12	12		102,509	3,987	**296.874** ◀	**0.074** ◀

Note: Arrowed values indicate the greatest value in each column.

* Represents the total number of records reported. The number of individuals monitored for neutron radiation is not known because there is no distinction made between zero dose and not monitored.

Exhibit 3-7:
Extremity Dose Distribution, 1999-2003.

Year	No Meas. Dose	Meas. <0.1	0.1-1.0	1-5	5-10	10-20	20-30	30-40	>40	Total Monitored*	Number with Measurable Dose	Number Above Monitoring Threshold (5 rem)**	Collective Extremity Dose (person-rem)	Average Measurable Extremity Dose (rem)
1999	99,776	8,759	3,649	750	95	30	2			**113,064** ◄	**13,285** ◄	127	3,988.6	0.300
2000	91,329	7,279	3,322	818	88	37	8			102,881	11,552	133	4,309.5	0.373
2001	85,353	8,364	3,282	682	109	27		1		97,818	12,465	137	3,839.0	0.308
2002	87,921	7,902	3,461	777	115	39	5		1	100,221	12,300	160	4,466.1	0.363
2003	90,400	7,726	3,445	761	108	56	13			102,509	12,109	**177** ◄	**4,736.1** ◄	**0.391** ◄

Note: Arrowed values indicate the greatest value in each column.

* Represents the total number of records reported. The number of individuals monitored for extremity radiation is not known because there is no distinction made between zero dose and not monitored.

** DOE annual limit for extremities is 50 rem. 10 CFR 835.402(a)(1)(ii) requires extremity monitoring for a shallow dose equivalent to the extremity of 5 rem or more in 1 year.

Forty-six percent, the highest percentage of the extremity exposures above 5 rem (50 mSv) in 2003 occurred at Hanford, where operations involving the manipulation of radioactive materials are more common. Ninety-three percent of individuals with measurable extremity dose were monitored at four sites: Savannah River, Hanford, Rocky Flats, and Los Alamos. The number of individuals receiving a measurable extremity dose decreased by 2% from 12,300 in 2002 to 12,109 in 2003, and the average extremity dose increased by 8% from 0.363 rem (3.63 mSv) in 2002 to 0.391 rem (3.91 mSv) in 2003. The DOE annual limit for extremity dose is 50 rem (500 mSv). The higher dose limit is due to the lack of blood-forming organs in the extremities; therefore, extremity dose involves less health risk to the individual. The highest extremity dose in 2003 was 24.3 rem (243 mSv) received by an individual at Hanford. Statistical analysis reveals that the logarithmic mean extremity dose did not change significantly from 2002 to 2003. This indicates that while the collective extremity dose increased between 2002 to 2003, it does not represent a statistically significant change in the dose received by individual workers at DOE. The extremity dose distribution by site for 2003 is shown in Appendix *Exhibit B-22*.

3.3 Analysis of Individual Dose Data

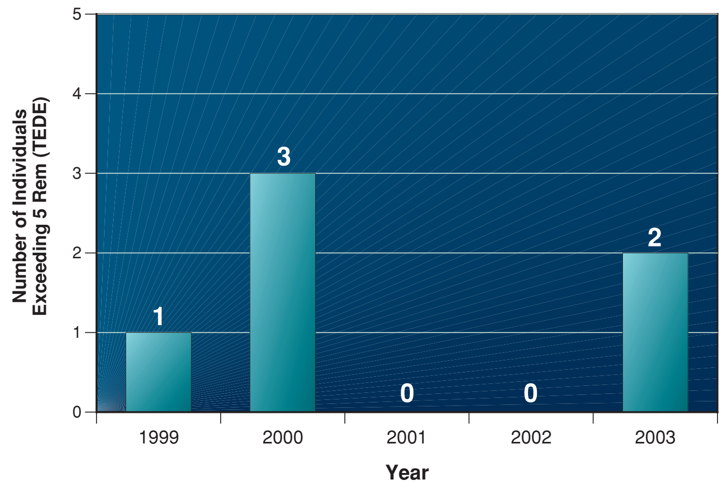
The above analysis is based on aggregate data for DOE. From an individual worker perspective, as well as a regulatory perspective, it is important to closely examine the doses received by individuals in the elevated dose ranges to thoroughly understand the circumstances leading to these doses in the workplace and to better manage and avoid these doses in the future. The following analysis focuses on doses received by individuals that were in excess of the DOE limit (5 rem TEDE) or (50 mSv) and the DOE recommended ACL (2 rem TEDE) or (20 mSv).

3.3.1 Doses in Excess of DOE Limits

Exhibit 3-8 shows the number of doses in excess of the TEDE regulatory limit (5 rem) or (50 mSv) from 1999 through 2003. Further information concerning the individual doses, radionuclides involved, and sites where the doses in excess of the 5 rem (50 mSv) TEDE limit have occurred during the past 5 years is shown in *Exhibit 3-9*.

In 2003, two individuals received internal doses that resulted in a TEDE in excess of the 5 rem (50 mSv) TEDE limit. Both individuals had intakes of Plutonium 238 that occurred at LANL. The two employees were performing inventories of items on shelves in a high radiation area. The employees had completed two shelves, self monitoring after each, and no contamination was detected. While inventorying the third shelf, a continuous air monitor in the room alarmed. The two employees immediately exited the room, monitored themselves and upon finding contamination, summoned the responsible radiological control technician (RCT) for assistance. The two employees received clothing and skin contamination, and contamination was also found on the anti-c clothing of the RCT performing the

Exhibit 3-8:
Number of Individuals Exceeding 5 Rem (TEDE), 1999-2003.



In 2003 there were two individuals reported who received doses in excess of the 5 rem (50 mSv) TEDE limit.

Exhibit 3-9:
Doses in Excess of DOE Limits, 1999-2003.

Year	TEDE (rem)	DDE (rem)	CEDE (rem)	SDE Extremity (rem)	Intake Nuclides	Facility Types	Site
1999	6.964	0.245	6.719		Pu-238, Pu-239, Pu-241, Am-241	Weapons Fabrication and Testing	Savannah River
2000 *	9.692	0.322	9.370		Pu-238, Pu-239, Pu-240	Research, General	LANL
	11.745	0.245	11.500		Pu-238, Pu-239, Pu-240	Research, General	LANL
	87.156	0.156	87.000		Pu-238, Pu-239, Pu-240	Maintenance and Support	LANL
2001	None Reported						
2002	0.080	0.080	-	111		Research, General	LLNL
2003	8.170	0.949	7.221	1.302	Pu-238	Other	LANL
	10.197	0.609	9.588	0.834	Pu-238	Waste Processing	LANL

***** *These three doses were all a result of the same occurrence.*

whole-body survey. All three of the employees were placed on diagnostic bioassay. Initial nasal swipes indicated that the exposure could be in excess of 10 rem CEDE. The TEDE reported to DOE for two of the individuals was 8.170 rem and 10.197 rem as a result of the intake of plutonium.

There was a Type B investigation of this incident that determined the direct cause of the accident was the release of airborne contamination from a degraded package containing cellulose material and Pu-238 residues. A Corrective Action Plan (CAP) to address the Type B Board's Judgement of Needs will be developed and implemented. The CAP will be submitted for approval and corrective actions will be tracked to completion and documented.

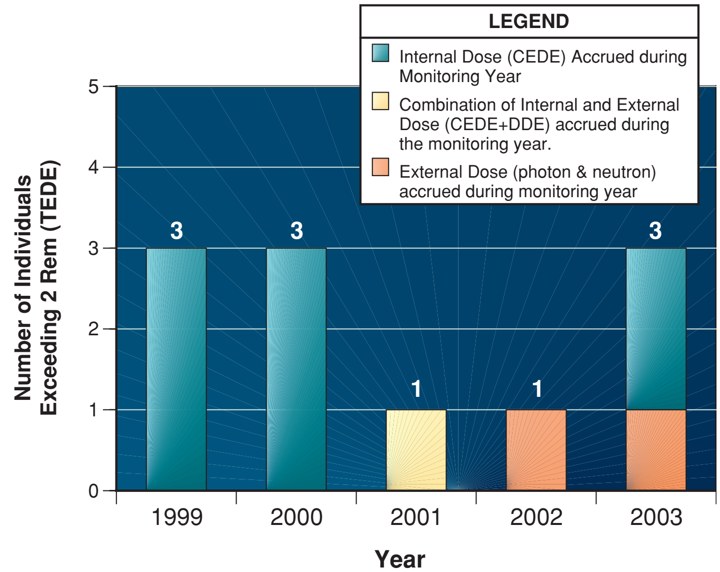
For more information, see the occurrence report ALO-LA-LANL-TA55-2003-0017. The investigation report is available at https://reports.eh.doe.gov/csa/accidents/typeb/typeb.html (authorization required).

3.3.2 Doses in Excess of Administrative Control Level

The RCS [7] recommends a 2 rem (20 mSv) ACL for TEDE, which should not be exceeded without prior DOE approval. The RCS recommends that each DOE site establish its own, more restrictive ACL that would require contractor management approval to be exceeded. The number of individuals receiving doses in excess of the 2 rem (20 mSv) ACL is a measure of the effectiveness of DOE's radiation protection program.

As shown in *Exhibit 3-10*, three individuals received a TEDE above 2 rem (20 mSv) during 2003. Two of the three were also in excess of 5 rem (50 mSv) as described in the previous section. All three individuals received doses in excess of 2 rem (20 mSv) at LANL. The third individual was reported to have received 2.4 rem (24 mSv) TEDE, which included 1.731 rem (17.31 mSv) from neutrons. Neutron dose is more common at LANL due to the nature of the work involving plutonium at this facility. The dose was anticipated and formally approved by the LANL ALARA Steering Committee prior to incurring the dose; therefore, no occurrence report was required for this event.

Exhibit 3-10:
Number of Doses in Excess of the DOE 2 Rem ACL, 1999-2003.

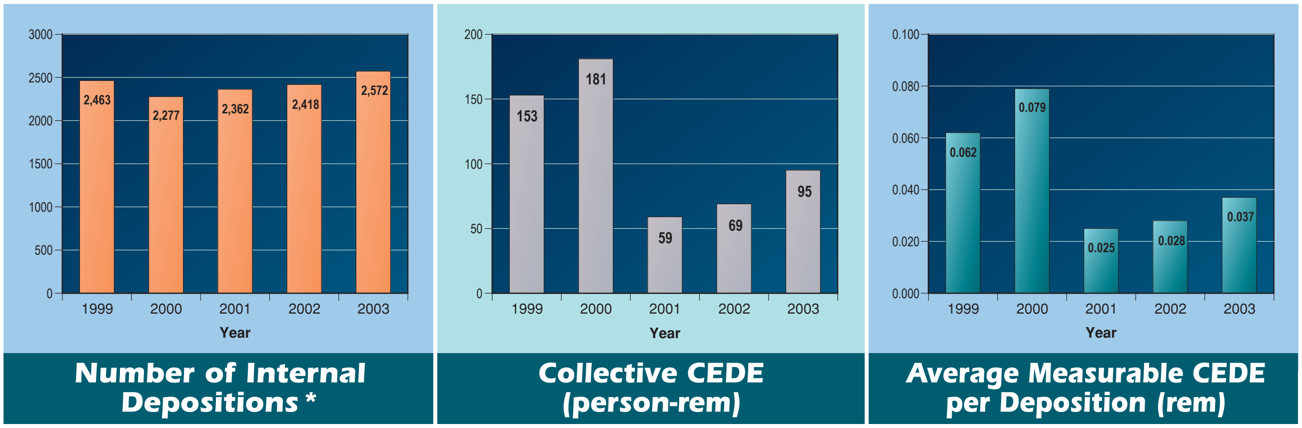


3.3.3 Internal Depositions of Radioactive Material

As shown in *Exhibit 3-9*, some of the highest doses to individuals have been the result of intakes of radioactive material. For this reason, DOE emphasizes the need to avoid intakes and tracks the number of intakes as a performance measure.

The number of internal depositions of radioactive material (otherwise known as worker intakes), collective CEDE, and average measurable CEDE for 1999-2003 are shown in *Exhibit 3-11*. The number of internal depositions increased by 6% from 2,418 in 2002 to 2,572 in 2003, while the collective CEDE increased by 38%. Due to the increase in the collective CEDE and the increase in the number of internal depositions, the average measurable CEDE increased by 32% from 0.028 rem (0.28 mSv) in 2002 to 0.037 rem (0.37 mSv) in 2003.

Exhibit 3-11:
Number of Internal Depositions, Collective CEDE, and Average Measurable CEDE (Graph), 1999-2003.



* The number of internal depositions represents the number of internal dose records reported for each individual. Individuals may have multiple intakes in a year and, therefore, may be counted more than once.

The number of internal depositions of radioactive material for 2001 through 2003 is also shown in *Exhibit 3-12*. The internal depositions were categorized into eight radionuclide groups. Intakes involving multiple nuclides are listed as "mixed". Nuclides where fewer than 10 individuals had intakes each year over the 3-year period are grouped together as "other." Only those records with internal dose greater than zero are included in this analysis. It should be noted that the different nuclides have different radiological properties, resulting in varying minimum levels of detection and reporting.

The 38% increase in the collective CEDE from 69 person-rem (690 person-mSv) in 2002 to 95 person-rem (950 person-mSv) in 2003 was due to a nearly four-fold increase in internal dose from plutonium. The main contributor to this increase was the two exposures in excess of 5 rem (50 mSv) at LANL (see Section 3.3.1). Mound and Rocky Flats also reported increases in internal dose from plutonium from 2002 to 2003. Internal dose from other radionuclides decreased or essentially remained the same from 2002 to 2003.

Exhibit 3-12:
Number of Internal Depositions, Collective CEDE, and Average Measurable CEDE by Nuclides (Data), 2001-2003.

Nuclide	Number of Internal Depositions*			Collective CEDE (person-rem)			Average Measurable CEDE per Deposition (rem)		
Year	**2001**	**2002**	**2003**	**2001**	**2002**	**2003**	**2001**	**2002**	**2003**
Hydrogen-3 (Tritium)	315	270	271	1.189	1.351	1.232	0.004	0.005	0.005
Radon-222	2	15	19	0.076	2.115	0.568	0.038	**0.141**◄	0.030
Thorium	23	67	83	0.204	0.836	0.930	0.009	0.012	0.011
Uranium	**1,838**◄	**1,664**◄	**1,607**◄	**47.078**◄	**55.962**◄	**54.946**◄	0.026	0.034	0.034
Plutonium	137	298	492	8.258	6.868	33.524	0.060	0.023	**0.068**◄
Americium-241	28	65	78	1.777	1.226	3.109	**0.063**◄	0.019	0.040
Other	13	26	11	0.146	0.091	0.069	0.011	0.004	0.006
Mixed	6	13	11	0.226	0.241	0.124	0.038	0.019	0.011
Totals	**2,362**	**2,418**	**2,572**	**58.954**	**68.690**	**94.502**	**0.025**	**0.028**	**0.037**

Note: Arrowed values indicate the greatest value in each column.
* The number of internal depositions represents the number of internal dose records reported for each individual.

During the past 5 years, there have been several intakes from plutonium or uranium in excess of 2 rem (20 mSv) each year, with some of the doses in excess of 5 rem (50 mSv) (see *Exhibit 3-9*). While the number of internal depositions above 2 rem (20 mSv) has been few, they have contributed significantly to the collective internal dose for the years 1999 and 2000. No such intakes were reported for 2001 and 2002, and the reduction in the collective CEDE reflects this fact. For 2003, two intakes resulted in doses in excess of 5 rem (50 mSv) which resulted in a significant increase in collective CEDE.

The highest collective CEDE and number of depositions in 2003 are due to uranium intakes. Almost all of the collective dose from uranium (99%) occurred at the Oak Ridge Y-12 facility during the continued operation and management of Enriched Uranium Operations (EUO) facilities at the site. The highest average measurable CEDE in 2003 is from plutonium, primarily due to the two high doses at LANL, but increases in the collective CEDE from plutonium at Mound and Rocky Flats also contributed.

Because relatively few workers receive measurable internal dose, fluctuations in the number of workers and collective CEDE can occur from year to year.

Exhibit 3-13 shows the distribution of the internal dose from 1999 to 2003. The total number of individuals with intakes in each dose range is the sum of all records of intake in the subject dose range. The internal dose does not include doses from prior intakes (legacy AEDE dose). Individuals with multiple intakes during the year may be counted more than once. Doses below 0.020 rem (0.20 mSv) are shown as a separate dose range to show the large number of doses in this low-dose range. There were two internal doses above 2 rem (20 mSv) in 2003 and these two individuals received doses in excess of 5 rem (50 mSv).

Exhibit 3-13:
Internal Dose Distribution from Intakes, 1999-2003.

Number of individuals* with internal dose in each dose range (rem).

Year	Meas. <0.020	0.020-0.100	0.100-0.250	0.250-0.500	0.500-0.750	0.750-1.000	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	>5.0	Total No. of Indiv.*	Total Collective Internal Dose CEDE (person-rem)
1999	1,726	443	137	78	32	26	19		1		1	2,463	152.868
2000	1,472	625	136	34	5	2					3	2,277	180.580
2001	1,673	574	90	19	4		2					2,362	58.954
2002	1,534	734	131	16	3							2,418	68.690
2003	1,622	763	163	18	3		1				2	2,572	94.502

Note: Individuals with doses equal to the dose value separating the dose ranges are included in the next higher dose range.
* Individuals may have multiple intakes in a year and, therefore, may be counted more than once.

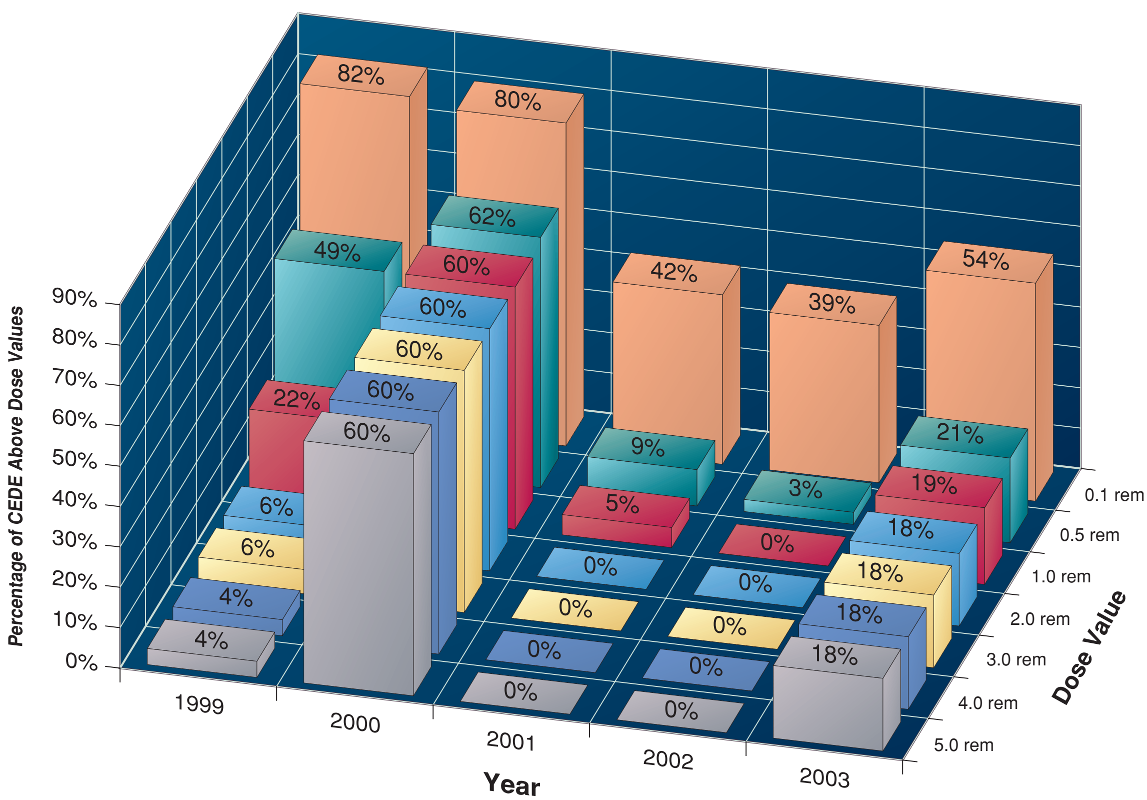
The internal dose records indicate that the majority of the intakes reported are at very low doses. In 2003, 63% of the internal dose records were for doses below 0.020 rem (0.20 mSv). Over the 5-year period, internal doses from intakes accounted for 11% of the collective TEDE, and 8% of the individuals who received internal dose were above the monitoring threshold specified (100 mrem or 1 mSv) in 10 CFR 835.402(c).

The internal dose records indicate that the majority of the intakes reported are at very low doses.

Over the 5-year period, internal doses accounted for only 11% of the collective TEDE.

The internal dose distribution can also be shown in terms of the percentage of the collective dose delivered above certain dose levels. *Exhibit 3-14* shows this information for the CEDE for each year from 1999 to 2003. While the fluctuations in internal dose prohibit definitive trend analysis, it is evident from the graph that from 1999 to 2000, there was an increase in the percentages above 2 rem (20 mSv), which was due to the individuals who exceeded the DOE annual limits. In 2000, the percentages above 2 rem (20 mSv) were dominated by the three doses in excess of the DOE annual limit that occurred at LANL. For 2001 and 2002, the percentage of internal dose above each dose range decreased dramatically because of the lack of any internal doses above 2 rem (20 mSv). In 2003, there were two internal doses above 5 rem (50 mSv), which increased the percentages for each dose range by about 18%. The distribution of internal dose by site and nuclide for 2003 is presented in Appendix *Exhibit B-21*.

Exhibit 3-14:
Distribution of Collective CEDE vs. Dose Value, 1999-2003.



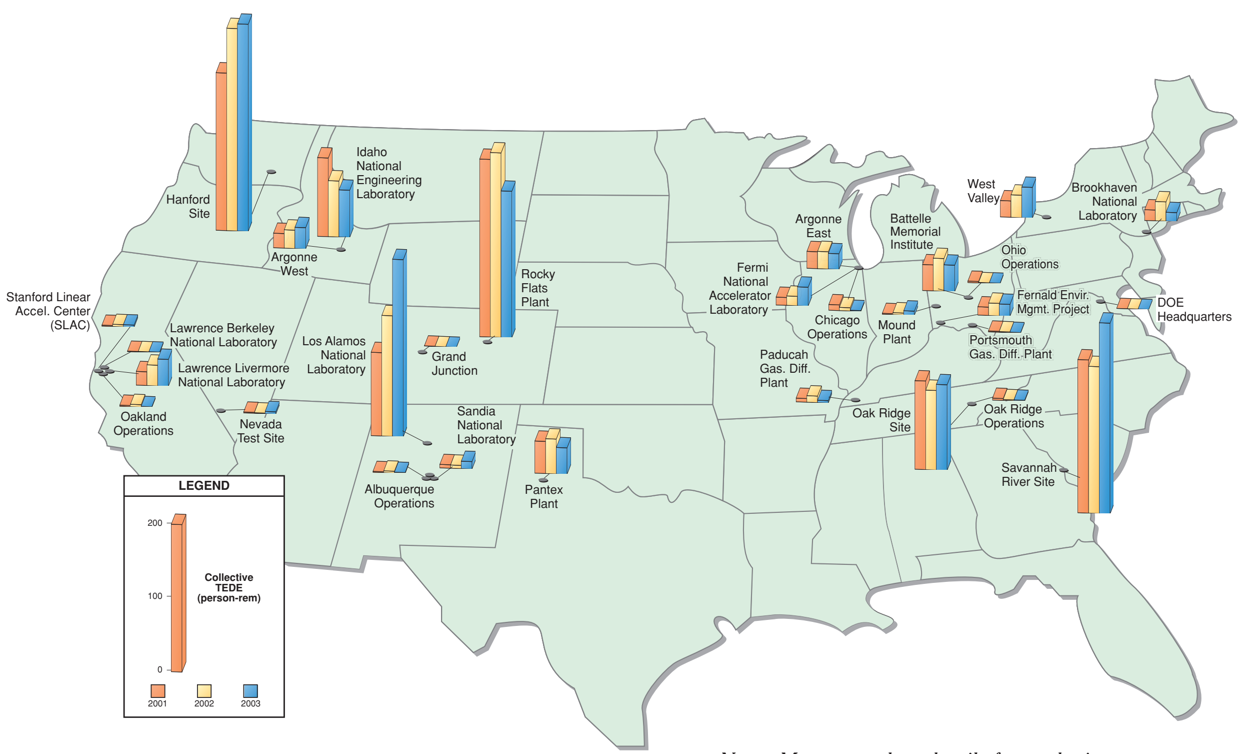
When examining trends involving internal dose, several factors should be considered. Some of the largest changes in the number of reported intakes over the years resulted from changes in internal dosimetry practices. Periodically, sites may implement new technology or change monitoring practices or procedures, which may involve increasing the sensitivity of the detection equipment, thereby increasing the number of individuals with measurable internal doses. Conversely, sites may determine that internal monitoring is no longer required due to historically low levels of internal dose or a decreased potential for intake. There are relatively few intakes each year, and the CEDE method of calculating internal dose can result in large internal doses from the intake of long-lived nuclides. This can result in variability of the internal dose data from year to year.

3.4 Analysis of Site Data

3.4.1 Collective TEDE by Site and Operations/Field Offices

The collective TEDE for 2001 through 2003 for the major DOE sites and Operations/Field Offices is shown in *Exhibit 3-15*. A list of the collective TEDE and number of individuals with measurable TEDE for the DOE Sites and Operations/Field Offices is shown in *Exhibit 3-16*. Operations/Field Office dose is shown separately from the site dose wherever it is reported separately (see Appendix Exhibit A-2). Other small sites and facilities that do not contribute significantly to the collective dose are included within the numbers shown for "Ops. and Other Facilities." The collective TEDE increased by 6% from 1,360 person-rem (13.60 person-Sv) in 2002 to 1,445 person-rem (14.45 person-Sv) in 2003, with six of the highest dose sites (Hanford, Savannah River, Los Alamos, Rocky Flats, Oak Ridge, and Idaho) contributing 80% of the total DOE collective TEDE.

Exhibit 3-15:
Collective TEDE by Site for 2001-2003.



Note: More complete details for each site, Operations/Field Office, and reporting organization can be found in Appendix B.

Exhibit 3-16:
Collective TEDE and Number of Individuals with Measurable TEDE by Site, 2001-2003.

Operations/ Field Office	Site	2001 Collective TEDE (person-rem)	2001 Number with Meas. TEDE	2002 Collective TEDE (person-rem)	2002 Number with Meas. TEDE	2003 Collective TEDE (person-rem)	2003 Number with Meas. TEDE
Albuquerque	Ops. and Other Facilities	1.2	95	2.5	118	1.3	107
	Los Alamos National Lab. (LANL)	112.9	1,330	163.5	1,696	240.0	2,047
	Pantex Plant (PP)	43.6	293	47.3	292	35.9	290
	Sandia National Lab. (SNL)	4.7	99	4.5	109	10.2	250
	Grand Junction *	0.1	2				
Chicago	Ops. and Other Facilities	7.8	162	4.5	182	1.2	153
	Argonne Nat'l. Lab. - East (ANL-E)	23.0	187	23.6	233	21.4	231
	Argonne Nat'l. Lab. - West (ANL-W)	19.8	258	24.9	278	28.8	277
	Brookhaven Nat'l. Lab.(BNL)	14.6	387	26.2	439	12.2	306
	Fermi Nat'l. Accelerator Lab.(FERMI)	10.7	368	12.8	389	25.7	612
DOE HQ	DOE Headquarters	0.0	5	0.0	0		
	DOE North Korea Project *	1.0	8				
	Russian Federation Project						
Idaho	Idaho Site	106.6	1,088	76.0	1,089	64.0	1,141
Nevada	Nevada Test Site (NTS)	1.3	32	0.9	30	3.2	69
Oakland	Ops. and Other Facilities	1.6	134	3.2	81	0.9	64
	Lawrence Berkeley Nat'l. Lab. (LBNL)	0.7	21	0.9	33	1.0	20
	Lawrence Livermore Nat'l. Lab. (LLNL)	18.6	153	28.0	163	36.4	202
	Stanford Linear Accelerator Center (SLAC)	1.4	35	3.1	79	3.1	109
Oak Ridge	Ops. and Other Facilities	2.6	144	1.4	103	1.3	98
	Oak Ridge Site	120.0	2,576	107.8	2,304	116.0	2,389
	Paducah Gaseous Diff. Plant (PGDP)	5.0	122	8.8	232	3.2	38
	Portsmouth Gaseous Diff. Plant (PORTS)	1.2	35	1.0	37	0.6	26
Ohio	Ops. and Other Facilities	2.0	89	0.6	49	0.7	47
	Battelle Memorial Institute - Columbus	35.2	84	44.4	103	35.9	100
	Fernald Environmental Management Project	11.4	355	17.0	572	16.2	631
	Mound Plant	1.2	97	2.7	198	5.8	237
	West Valley	22.2	233	30.5	239	41.7	207
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	**240.7** ◄	2,436	250.0	2,175	198.6	1,761
Richland	Hanford Site	213.6	2,219	**274.4** ◄	2,611	**280.8** ◄	2,626
Savannah River	Savannah River Site (SRS)	207.6	**3,640** ◄	199.1	**3,217** ◄	258.6	**3,446** ◄
Totals		**1,232.4**	**16,687**	**1,359.6**	**17,051**	**1,444.6**	**17,484**

*No longer in operation; therefore, not required to report.

Note: Arrowed values indicate the greatest value in each column.

Exhibit 3-17:
Number with Measurable Dose, Collective TEDE, and Average Measurable TEDE by Labor Category, 2001-2003.

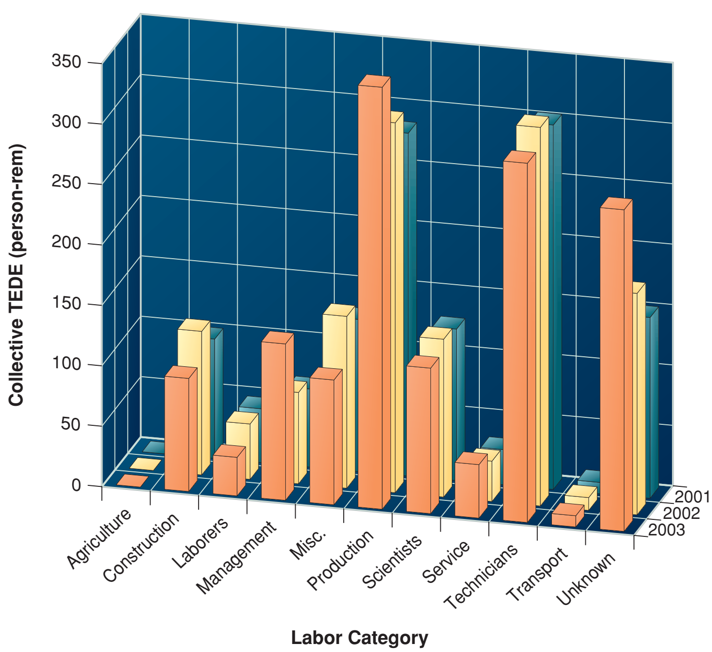
Labor Category	Number with Meas. Dose			Collective TEDE (person-rem)			Average Meas. TEDE (rem)		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
Agriculture	0	1	0	0.0	0.0	0.0	0.0	0.012	0.0
Construction	1,825	1,949	1,865	98.7	118.8	93.5	0.054	0.061	0.050
Laborers	434	605	530	44.6	45.8	31.9	0.103	0.076	0.060
Management	1,368	1,392	2,095	64.7	75.6	129.4	0.047	0.054	0.062
Misc.	1,667	1,527	1,170	125.9	142.2	103.2	0.076	0.093	0.088
Production	2,296	2,419	2,431	283.7	306.1	**349.1** ◄	**0.124** ◄	**0.127** ◄	**0.144** ◄
Scientists	**2,978** ◄	2,908	2,699	125.3	130.6	120.4	0.042	0.045	0.045
Service	710	631	830	29.2	33.4	44.2	0.041	0.053	0.053
Technicians	2,865	**2,956** ◄	2,758	**301.5** ◄	**313.3** ◄	297.3	0.105	0.106	0.108
Transport	183	245	247	9.3	10.6	9.3	0.051	0.043	0.038
Unknown	2,361	2,418	**2,859** ◄	149.6	183.2	266.1	0.063	0.076	0.093
Totals	**16,687**	**17,051**	**17,484**	**1,232.4**	**1,359.6**	**1,444.6**	**0.074**	**0.080**	**0.083**

Note: Arrowed values indicate the greatest value in each column.

3.4.2 Dose by Labor Category

DOE occupational exposures are tracked by labor category at each site to facilitate identification of exposure trends, which assists management in prioritizing ALARA activities. Worker occupation codes are reported in accordance with DOE M 231.1-1 and are grouped into major labor categories in this report. The collective TEDE for each labor category for 2001 through 2003 is shown in *Exhibits 3-17* and *3-18*. Technicians and production staff have the highest collective TEDE and average measurable TEDE for the past 3 years because they generally handle more radioactive sources than individuals in the other labor categories. In 2003, 51% of the technician dose was attributed to radiation protection technicians, and 76% of the dose to production personnel is attributed to plant operators.

Exhibit 3-18:
Graph of Collective TEDE by Labor Category, 2001-2003.



In 2003, the "unknown" category had the highest number of individuals with measurable TEDE. Ninety percent of the dose in the "unknown" category for 2003 is attributed to LANL. Currently, the LANL computer system does not maintain the data necessary to report occupation codes in accordance with DOE M 231.1-1. Other sites also report individuals with an occupation code of "unknown." Typically, these workers are subcontractors or temporary workers. Information concerning these workers tends to be limited.

An examination of internal dose from intake by labor category from 2001 to 2003 is presented in Appendix *Exhibit B-19*. In addition, Appendix *Exhibit B-20* shows the TEDE distribution by labor category and occupation for 2003.

3.4.3 Dose by Facility Type

DOE occupational exposures are tracked by facility type at each site to better understand the nature of exposure trends and to assist management in prioritizing ALARA activities. The contributions of certain facility types to the DOE collective TEDE is shown in *Exhibits 3-19* and *3-20*. The collective dose for each facility type at each major site of each DOE Operations/Field Office from 2001 to 2003 is shown in Appendix *Exhibit B-7*. An examination of internal dose from intake by facility type and nuclide for 2001 to 2003 is presented in Appendix *Exhibit B-17*.

The collective TEDE for 2001 through 2003 was highest at weapons fabrication and testing facilities. Fifty-two percent of this dose was accrued at Rocky Flats in 2003, with 22% at Savannah River and 16% at the Oak Ridge Y-12 facility. It should be noted that, although weapons fabrication and testing facilities account for the highest collective dose, Rocky Flats and Savannah River account for the majority of this dose, and these sites are now primarily involved in nuclear materials stabilization and waste management. See Section 3.5 for information concerning the current activities at these sites.

Exhibit 3-19:
Graph of Collective TEDE by Facility Type, 2001-2003.

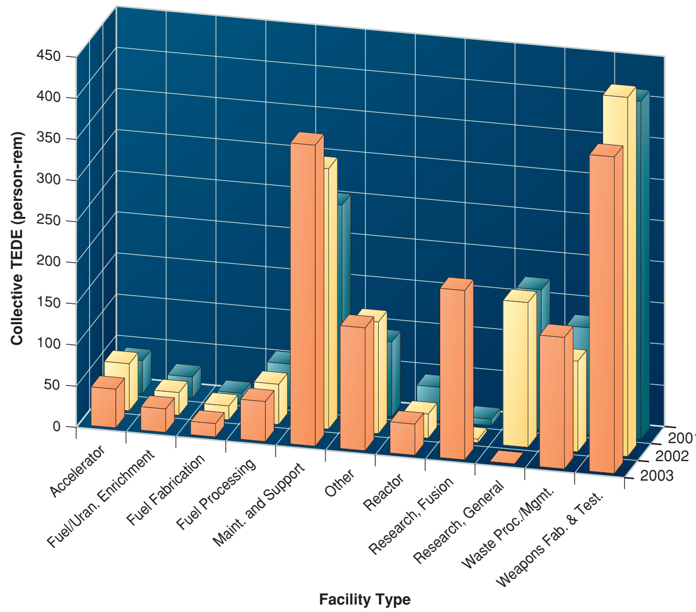


Exhibit 3-20:
Number with Measurable Dose, Collective TEDE, and Average Measurable TEDE by Facility Type, 2001-2003.

Facility Type	Number with Meas. Dose			Collective TEDE (person-rem)			Average Meas. TEDE (rem)		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
Accelerator	976	1,087	1,118	40.1	57.2	47.0	0.041	0.053	0.042
Fuel/Uranium Enrichment	846	744	713	25.8	27.7	28.5	0.031	0.037	0.040
Fuel Fabrication	355	572	631	11.4	17.0	16.2	0.032	0.030	0.026
Fuel Processing	1,155	1,137	1,080	52.5	48.9	48.6	0.045	0.043	0.045
Maintenance and Support	2,389	2,825	3,141	251.6	316.6	365.8	**0.105◄**	**0.112◄**	**0.116◄**
Other	1,401	1,576	1,646	90.8	135.8	149.3	0.065	0.086	0.091
Reactor	560	470	522	40.9	29.3	37.9	0.073	0.062	0.073
Research, Fusion	116	153	2,413	7.8	4.3	205.8	0.067	0.028	0.085
Research, General	2,227	2,172	118	170.6	175.9	0.7	0.077	0.081	0.006
Waste Processing/Mgmt.	1,938	1,875	2,114	129.9	110.3	159.9	0.067	0.059	0.076
Weapons Fab. and Testing	**4,724◄**	**4,440◄**	**3,988◄**	**411.1◄**	**436.6◄**	**384.9◄**	0.087	0.098	0.097
Totals	**16,687**	**17,051**	**17,484**	**1,232.4**	**1,359.6**	**1,444.6**	**0.074**	**0.080**	**0.083**

Note: Arrowed values indicate the greatest value in each column.

3.4.4 Radiation Protection Occurrence Reports

Sites are required to report certain unusual or off-normal occurrences involving radiation under DOE Order 231.1A. These reports are submitted to Occurrence Reporting and Processing System (ORPS) in accordance with the reporting criteria of DOE M 231.1-2. Two of the occurrence categories are directly related to occupational exposure and are required to be reported under Group 6 as "Subgroup C" and "Subgroup D" occurrences. Subgroup C reports *radiation exposure* occurrences, and Subgroup D reports *personnel contamination* occurrences. DOE Manual 231.1-2 became effective in August 2003 and replaced DOE Manual 232.1-1A. The new manual contains several changes in the reporting requirements for occurrence reports. The occurrence reporting requirements for DOE M 231.1-2 are summarized in *Exhibit 3-21*.

The number of reports submitted to ORPS is usually indicative of breaches or lapses in radiation protection practices resulting in unanticipated radiation exposure or contamination of personnel or clothing. Significant increases or decreases in the number of occurrences reported may reflect trends in radiation exposures, the effectiveness of DOE radiation protection programs, or changes to the reporting procedure or thresholds. However, changes in the number of radiation exposure and confirmation occurrences reported from year to year may reflect statistical variability rather than any performance trend.

It is important to note that reports are submitted to ORPS for an occurrence or event. In some cases, one event could result in the contamination or exposure of multiple individuals. In ORPS, this is counted as one occurrence, even though multiple individuals were exposed. In addition, one report may involve the roll up of similar or multiple occurrences. For the analysis included in this report, only the number of occurrences is considered. Also, it should be noted that some occurrences are reported based on an initial estimate of exposure, but may be recategorized later pending the receipt of the final determined exposure.

Exhibit 3-21:
Criteria for Radiation Exposure and Personnel Contamination Occurrence Reporting.

Subgroup	Category Under Previous Manual 232.1-1A	Significance Category	Manual 231.1-2 Criteria
Radiation Exposure Subgroup C	Unusual	1	Determination of a dose that exceeds the limits specified in 10 CFR Part 835, Subpart C, Occupational Radiation Protection or DOE O 5400.5, Chapter II, Item 1 [i.e., 100 mrem Total Effective Dose Equivalent (TEDE) for offsite exposures to a member of the public].
	Off-Normal	2	Any unmonitored exposure that exceeds the values for providing personnel dosimeters and bioassays as stated in 10 CFR 835.402(a) or 10 CFR 835.402(c).
		3	Any single occupational exposure that exceeds an expected exposure or dosimetry result by: (1) 500 mrem Committed Effective Dose Equivalent (CEDE), or (2) the greater of 10 percent or 100-mrem effective dose equivalent due to external exposure.
		3	Determination of an estimated annual dose that exceeds 10 mrem Total Effective Dose Equivalent (TEDE) for offsite exposures to a member of the public from air pathways only.
Personnel Contamination Subgroup D	Unusual	2	Any occurrence requiring offsite medical assistance for contaminated personnel, including transporting a person to an offsite medical facility or bringing offsite medical personnel onsite to perform treatment or decontamination.
	Off-Normal	2	Identification of personnel or clothing contamination offsite due to DOE operations that exceeds the values for total contamination found in 10 CFR Part 835, Appendix D. For tritium use the values for removable contamination found in 10 CFR Part 835, Appendix D.
	(New)	4	Any onsite contamination of personnel or clothing (excluding site-provided protective clothing) that exceeds 10 times the values for total contamination identified in 10 CFR Part 835, Appendix D. The contamination level must be based on direct measurement and not averaged over any area. This criterion does not apply to tritium contamination.

The number of occurrences reported under Personnel Radiological Protection is broken into two subcategories: *Radiation Exposure,* and *Personnel Contamination.* Results for those two subcategories are presented in *Exhibits 3-22* and *3-24*.

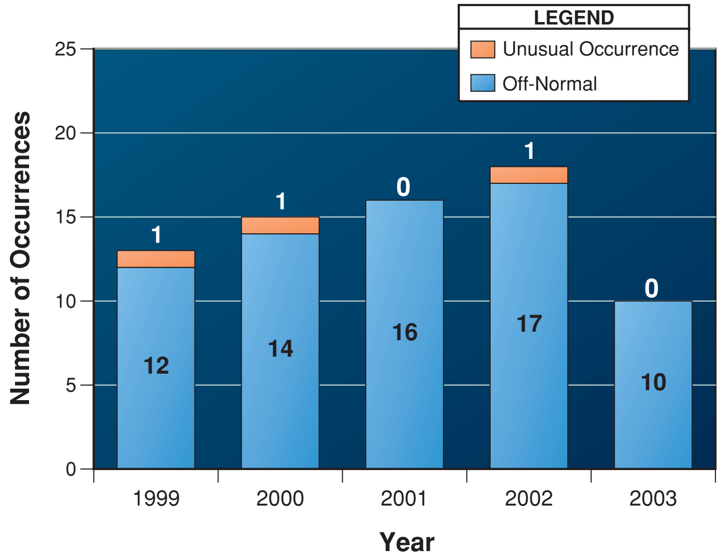
3.4.4.1 Radiation Exposure Occurrences

Two criteria for reporting *Radiation Exposure* occurrences are when individuals are exposed to radiation above anticipated levels, or when the resulting exposure exceeds 100 mrem (0.1 rem) (1 mSv) external (whole-body, skin, or extremity) or internal. The number of *radiation exposure* occurrences decreased by 44% from 18 in 2002 to 10 in 2003 as shown in *Exhibit 3-22*. The number of people involved in *radiation exposure* occurrences reported in 2003 (14 people) was 44% less than those in 2002 (25 people).

> ***The number of radiation exposure occurrences decreased by 44% from 2002 to 2003.***

One of the internal exposures reported in 2003 occurred in 2000 and another one occurred in 2002. In one case (see Occurrence Report ALO-LA-LANL-CMR-2003-002), an internal dose was discovered during a routine bioassay program for an individual working in an administrative area. The employee had not been involved in a radiological incident and a thorough investigation was performed including: (1) extensive radiological surveys of the employee's office resulting in no detectable activity; and (2) review of bioassay results for co-workers during the same time period that revealed no uptake.Thus, there was no evidence that an intake actually occurred. During the same time period, at the analysis lab, a number of high-priority samples containing plutonium were being processed and an unexplained increase in the number of blanks measuring above minimum detectable activity occurred. Although it could not be verified, it was determined that cross-contamination in the analysis was the likely cause. An intake of 0.5 rem CEDE for Pu-238 was assigned to the employee for CY 2000. In the other case (see RFO-KHLL-SOLIDWST-2003-0012), routine bioassay results were positive for plutonium for one individual following a continuous air monitor alarm incident. Six of seven follow-up bioassay samples over a 4-month period confirmed contamination. An internal dose of 660 mrem was assigned to the individual for CY 2002.

Exhibit 3-22:
Number of Radiation Exposure Occurrences, 1999-2003.



There were zero Unusual Events recorded for radiation exposure occurrences in 2003 compared to one in 2002.

In one *radiation exposure* occurrence for 2003 (see Occurrence Report RL-PHMC-PFP-2003-0015), a failed glovebox glove resulted in two workers receiving an intake of americium and plutonium resulting in a dose in excess of 100 mrem CEDE. Nasals smears indicated contamination and after nose blows, results were less than detectable. A chest count for one worker detected americium-241 and medical treatment (DTPA) was administered.

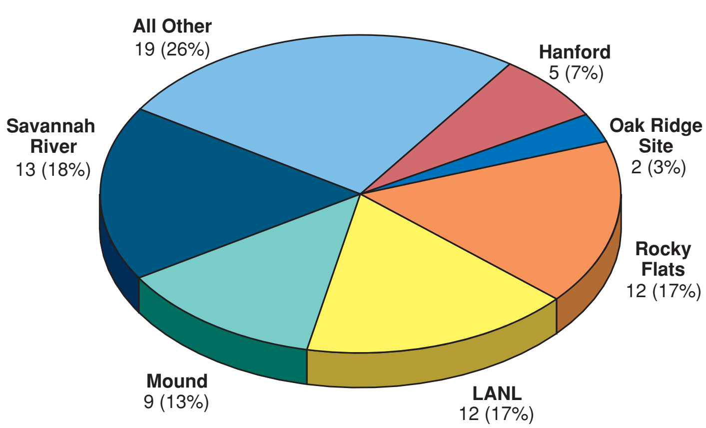
In another case, a small spill occurred in a room with 15 employees (see Occurrence Report ALO-LA-LANL-TA55-2003-002). All 15 employees submitted nasal smears resulting in no detectable contamination. Bioassay samples were also submitted and one employee received an intake of plutonium resulting in a dose of 219 mrem CEDE.

In another case (see Occurrence Report RFO-KHLL-371OPS-2003-0009), an employee was repositioning an intake hose when it slipped out of his hand resulting in a release of airborne contamination (plutonium). After submitting bioassay samples, three of the six employees present at the time were determined to have received contamination that resulted in CEDE doses of 330 mrem, 0 mrem, and 52 mrem.

None of the 72 *radiation exposure* occurrence reports submitted to the ORPS between 1999 and 2003 involved exposure to minors, members of the public, or pregnant workers.

Exhibit 3-23 shows the breakdown of occurrences for radiation exposure by site for the 5-year period 1999-2003. Seventy-four percent of the 2003 *radiation exposure* occurrences were reported by six sites: Savannah River, Rocky Flats, Oak Ridge, Los Alamos, Mound, and Hanford. During 2003, Hanford and Rocky Flats had increases in reported occurrences, Savannah River and Mound experienced decreases, and Los Alamos and Oak Ridge recorded the same number as 2002.

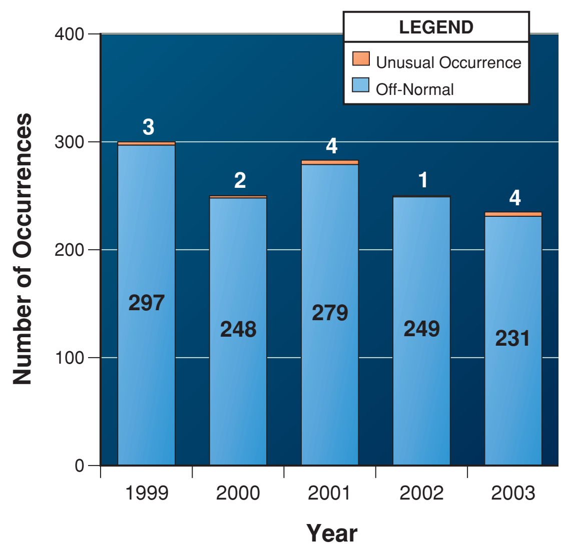
Exhibit 3-23:
Radiation Exposure Occurrences by Site, 1999-2003.



3.4.4.2 Personnel Contamination Occurrences

Personnel contamination occurrences are reported whenever personnel, clothing, or personal items are contaminated above threshold levels, generally five times the unconditional release limits. The number of *personnel contamination* occurrences reported decreased 6% from 250 in 2002 to 235 in 2003. The number of *personnel contamination* occurrences reported has decreased by 22% from 300 in 1999 to 235 in 2003 (see *Exhibit 3-24*). Four *personnel contamination* occurrences in 2003 were classified as an Unusual Event compared to one in 2002. The first Unusual Event (Occurrence Report ORO-BJC-X10ENVRES-2003-0016) occurred when two employees wore contaminated personal clothing home. Although the field trailer and vehicles used by the employees had surface contamination, no contamination was found in either of their homes or personal vehicles. The second Unusual Event (Occurrence Report ORO-BWXT-Y12SITE-2003-0017) was a uranium fire inside a glovebox. The event was considered an Operational Emergency; therefore, everyone in the building was evacuated and sheltered in place. Two employees received clothing and shoe

Exhibit 3-24:
Number of Personnel Contamination Occurrences, 1999-2003.



The number of Personnel Contamination occurrences reported decreased by 6% between 2002 and 2003.

contamination and one other received skin and hair contamination. The third Unusual Event (Occurrence Report RFO-KHLL-371OPS-2003-0011) also involved a glovebox fire. Workers used 8-10 fire extinguishers to put out the fire, but it re-ignited. Fire fighters were called in and four fire fighters received skin contamination. It was determined that contamination was spread from the fire fighter's gear to exposed skin during the doffing process. The fire fighters were wearing "bunker gear" instead of the traditional anti-C clothing making doffing more difficult. The use of respirators prevented the fire fighters from receiving any radiological material intake or significant dose. Finally, the fourth Unusual Event (Occurrence Report RFO-KHLL-PUFAB-2003-0012) occurred when a release resulted in contamination in several areas of a building. Precautionary nasal/mouth smears were administered for 36 individuals working without respiratory protection in areas nearby, and for six individuals wearing respirators in the immediate area. The six in the immediate area received contamination on their anti-C clothing and/or boots. However, due to excellent doffing techniques, there was no skin contamination. Bioassay samples indicated 12 individuals received internal radiological uptakes; however, none exceeded the administrative control level of 750 mrem per year.

In one case (ALO-LA-LANL-TA55-2003-0017) reported as a personnel contamination occurrence, two employees received an internal dose from plutonium. The two employees were performing inventories of items on shelves in a high-radiation area. The employees had completed two shelves, self monitoring after each, and no contamination was detected. While inventorying the third shelf, a continuous air monitor in the room alarmed. The two employees immediately exited the room, monitored themselves and upon finding contamination summoned the responsible RCT for assistance. The two employees received clothing and skin contamination and contamination was also found on the anti-c clothing of the RCT performing the whole-body survey. All three employees were placed on diagnostic bioassay. Initial nasal swipes indicated that the exposure could be in excess of 10 rem CEDE. The TEDE reported to DOE for two of the individuals was 8.170 rem and 10.197 rem as a result of the intake of plutonium (see Section 3.3.1).

There was a Type B investigation of this incident that determined the direct cause of the accident was the release of airborne contamination from a degraded package containing cellulose material and Pu-238 residues. A CAP to address the Type B Board's Judgement of Needs will be developed and implemented. The CAP will be submitted to Los Alamos Site Office (LASO) for approval and corrective actions will be tracked to completion and documented.

It should be noted that the totals for *Exhibits 3-24, 3-25*, and *3-26* are not equivalent because some occurrences involve more than one affected area, and some occurrences involve more than one individual. *Exhibit 3-24* presents the total number of occurrences. *Exhibit 3-25* presents the number of personnel contaminations by affected area and may count occurrences more than once if there is more than one affected area involved in the occurrence. *Exhibit 3-26* shows the number of individuals by affected area. Individuals may be counted more than once if they have more than one affected area.

Exhibit 3-25:
Personnel Contaminations by Affected Area, 1999-2003.

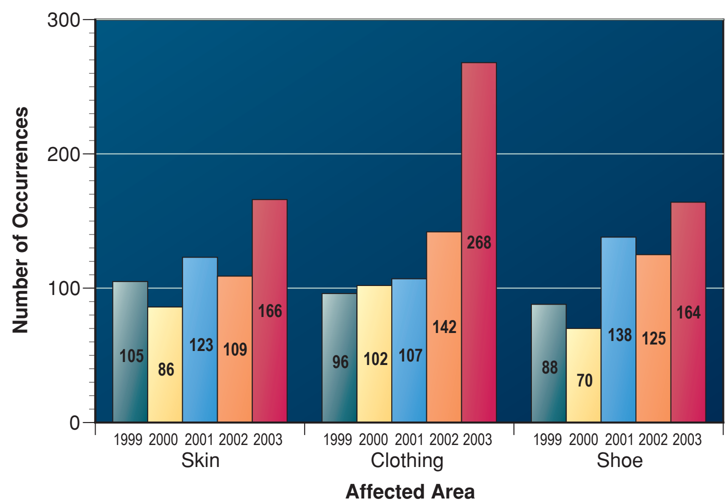


Exhibit 3-26:
Number of Individuals Contaminated by Affected Area in 2003.

Affected Area	Individuals Contaminated
Skin contamination only	91
Clothing (or other personal item) only	172
Shoes only	115
Skin and Clothing	57
Skin and Shoes	10
Clothing and Shoes	31
Skin, Clothing, and Shoes	8

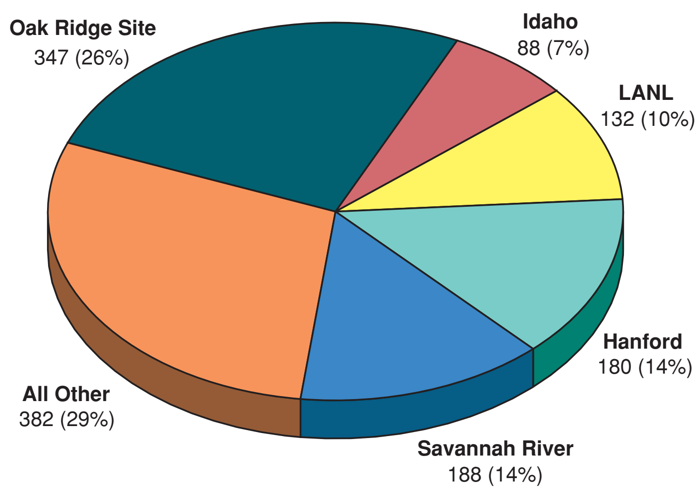
Exhibit 3-25 compares the *personnel contamination* occurrences by the affected area. The combination of skin, clothing, and shoes decreased from 2002 to 2003 while all other areas of *personnel contamination* increased. Hand contaminations made up approximately 35% of the skin contamination incidents with right hand contamination slightly more than left. One case (RFO-KHLL-370OPS-2003-004) recorded hand and face contamination. After performing glovebox operations and before exiting the area, an employee self monitored anti-c gloves and detected no contamination. The employee went on break, returned to work in a different area, and upon exiting the area discovered contamination on his hands, face, and ink pen. Radiological surveys were performed in all areas the employee entered during break. Contamination was found only on the newspaper the employee had been reading. It was determined that due to inadequate self-monitoring of personal items, the contaminated "ink pen" transferred contamination to the hands, face, and newspaper.

Although 235 *personnel contamination* occurrences were reported in 2003 (a 6% decline from 2002), 297 individuals were contaminated on the skin, clothing, and/or shoes as shown in *Exhibit 3-26*, which represents a 4% decline from the 309 individuals in 2002.

The combination of skin and clothing (and many of the skin, clothing, and shoe) contamination usually involved situations where the contamination on the outer protective clothing was inadvertently transferred to the skin. Three modes of contamination are common among these occurrences. The first is personnel error in "doffing" or removing protective clothing resulting in transferring contamination to exposed skin. The second involves the transference or "wicking" of contaminated liquid through the protective clothing to the skin. This can occur as a result of kneeling in or leaning against wet spots or from sweat-soaked clothing. The third common cause of skin contamination occurrences is from residual contamination remaining on the protective clothing after laundering. All of these problems have been reported in past years and the frequency of their occurrence has not changed significantly.

Exhibit 3-27 shows the *personnel contamination* occurrences for 1999-2003. The overall number of *personnel contamination* occurrences continued on a downward trend with two of the top five sights experiencing a decrease and the other three experiencing a slight increase from the previous year.

Exhibit 3-27:
Personnel Contamination Occurrences by Site, 1999-2003.



3.4.4.3 Occurrence Cause

Exhibits 3-28 and *3-29* provide a breakdown of *radiation exposure* occurrences and *personnel contamination* occurrences by their root cause. For the ORPS, the "root-cause" is defined as that which, if corrected, would prevent recurrences. Only four significant root causes are considered here (management problem, personnel error, equipment/material, and unknown source of radiation); other causes are included in the category entitled "All Other."

In 2003, three of the root cause categories ("Management Problem," "Personnel Error," and "Unknown Source of Radiation") cited two occurrences each making up six (60%) of the *radiation exposure* occurrences reported. The number of radiation occurrences of "Equipment or Material" failure increased from zero in 2002 to one (10%) in 2003. The "All-Other" category made up 30% of the root causes and had the largest increase from one occurrence in 2002 to three in 2003.

For *personnel contamination* occurrences, three categories reported increases in the "root cause" from 2002 to 2003. The largest increase occurred in "Equipment/Material" with an increase of 167% over 2002. The other areas that saw increases were "Management Problem" with a 15% increase and "All Other" with a 14% increase over the previous year. "All Other" includes the categories Design Problems, Procedure Inadequacy, Training Deficiency, and None (no root cause reported). The remaining "root cause" categories declined. "Personnel Error" had the largest decrease of 39% less than 2002. "Unknown Source of Radiation" decreased 33% from 2002 to 2003 and includes unknown sources, as well as known sources from "legacy" contamination.

Further information concerning ORPS can be obtained by contacting Eugenia Boyle of EH-32, or the ORPS web page at:

http://www.eh.doe.gov/paa/orps.html

Exhibit 3-28:
Radiation Exposure Occurrences by Root Cause, 2001-2003.

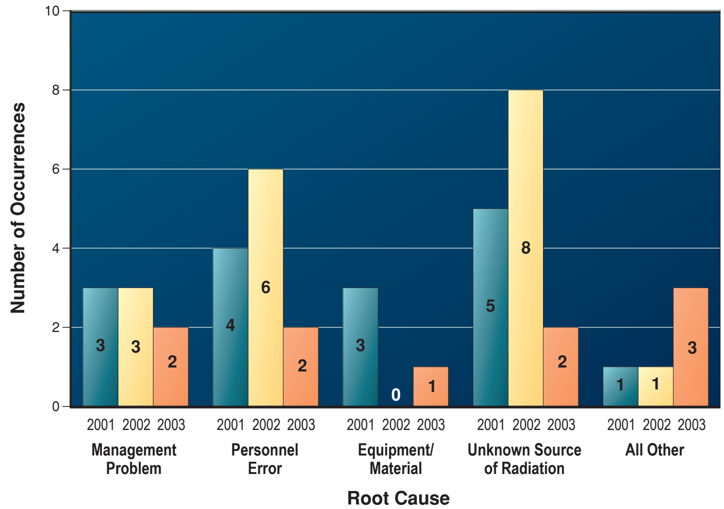
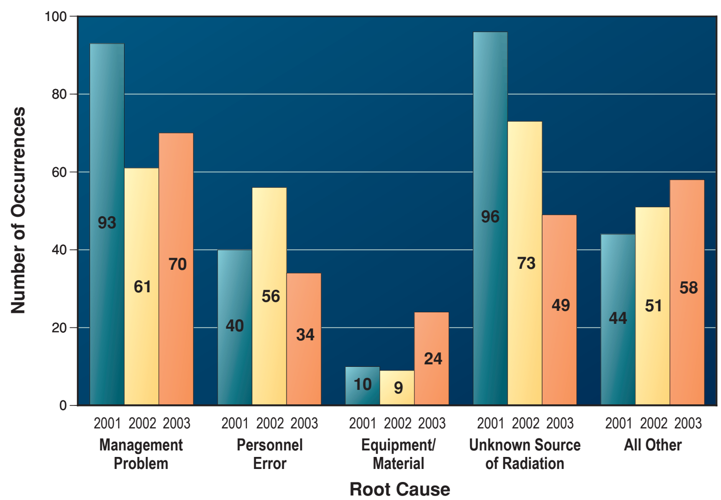


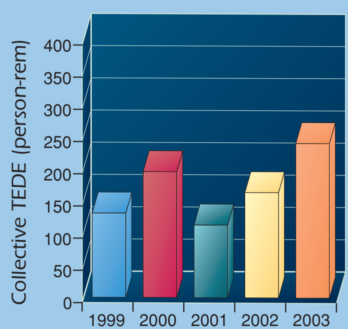
Exhibit 3-29:
Personnel Contamination Occurrences by Root Cause, 2001-2003.



3.5 Activities Significantly Contributing to Collective Dose in 2003

In an effort to identify the reasons for changes in the collective dose at DOE, several of the larger sites were contacted to provide information on activities that significantly contributed to the collective dose for 2003. These sites (Hanford, Savannah River, Los Alamos, Rocky Flats, Oak Ridge, and Idaho) were the top six sites in their contribution to the collective TEDE for 2003 and comprised 80% of the total DOE dose. Four of the six sites reported increases in the collective TEDE, which resulted in a 6% increase in the DOE collective dose from 1,360 person-rem (13.60 person-Sv) in 2002 to 1,445 person-rem (14.45 person-Sv) in 2003. The six sites are shown in *Exhibit 3-30*, including a description of activities that contributed to the collective TEDE for 2003.

Exhibit 3-30:
Activities Significantly Contributing to Collective TEDE in 2003 for Six Sites.

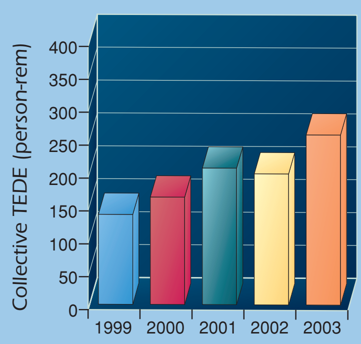
<table>
<tr><th rowspan="2">Los Alamos National Lab.</th><th colspan="3">Percent Change</th><th rowspan="2">Description of Activities at the Site</th></tr>
<tr><th>2002 - 2003 (last yr.)</th><th>2001 - 2003 (3 yr.)</th><th>Since 1999 (5 yr.)</th></tr>
<tr><td>
</td><td>↑ 47%</td><td>↑ 113%</td><td>↑ 83%</td><td>The collective TEDE at LANL increased by 47% from 2002 to 2003.

Work at the TA-55 Plutonium Facility continues to account for the majority of occupational dose incurred at Los Alamos. Such dose is related to the large population of workers and the nature of exposures from routine work with large quantities of actinide materials. Also, this dose is received both by programmatic workers responsible for the materials, and by workers in support functions, such as waste management, materials control and accountability, radiological control technicians, and craft workers. Activities at TA-55 differed from 2002 to 2003 in several ways. While pit manufacturing was not as active, two organizations processed more materials with higher concentrations of americium leading to an increase in the collective dose of approximately 10.6 person-rem. Pu-238 work was initially anticipated to increase significantly, including another large fuel production campaign and bringing a new process on line, but the August 5, 2003 contamination event greatly reduced their work level for the remainder of the calendar year. The RCT and support services subcontractor collective dose increased commensurate with support of programmatic work, help in recovery from the August 5 event, and a significant effort to upgrade the material storage vault (with an increment of ~3 person-rem for that job alone).

There was an unusual dose increment in 2003 as a result of a dedicated effort to decontaminate and decommission the Omega West reactor. This activity entailed removal of reactor containment and other legacy activated materials and resulted in a collective dose of over 32 person-rem. This dose was anticipated, managed, and maintained ALARA during this activity. This was a one-time activity for that facility. Radiological work continued at several other nuclear and radiological facilities across LANL (including the LANSCE linear accelerator, several tritium facilities, the critical assembly facility, and the Chemistry and Metallurgy Research facility), collectively contributing approximately 17 person-rem.</td></tr>
</table>

Exhibit 3-30:
Activities Significantly Contributing to Collective TEDE in 2003 for Six Sites (continued).

Savannah River Site

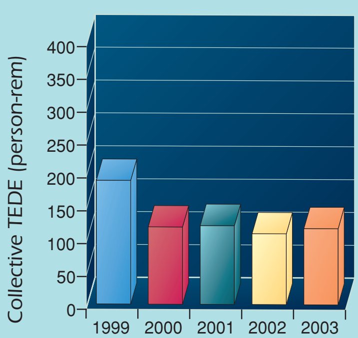


Percent Change: 2002-2003 (last yr.)	Percent Change: 2001-2003 (3 yr.)	Percent Change: Since 1999 (5 yr.)
↑ 30%	↑ 25%	↑ 89%

Description of Activities at the Site

The collective TEDE at Savannah River increased by 30% from 2002 to 2003. Radiation exposures have risen since 2001 due to resumption of processing of radioactive material, such as legacy reactor fuels and targets, and special programs and accelerated facility closure and waste processing activities. Examples of the work performed in 2003 included the receipt and storage of excess plutonium from RFETS, movement of spent nuclear fuel from the Receiving Basin for Offsite Fuels to the L-Area fuel storage facility, replacement of the failed Defense Waste Processing Facility melter, accelerated retrieval and preparation of transuranic waste for shipment to Waste Isolation Pilot Plant (WIPP), remediation of contaminated environmental sites and facilities, and stabilization and packaging of excess special nuclear materials.

Oak Ridge Site



Percent Change: 2002-2003 (last yr.)	Percent Change: 2001-2003 (3 yr.)	Percent Change: Since 1999 (5 yr.)
↑ 8%	3% ↓	38% ↓

Description of Activities at the Site

The collective TEDE at the Oak Ridge Site increased 8% from 2002 to 2003. The Oak Ridge Site includes the Oak Ridge National Laboratory (ORNL), Y-12 National Security Complex (Y-12 Plant), and East Tennessee Technology Park (ETTP, formerly known as K-25).

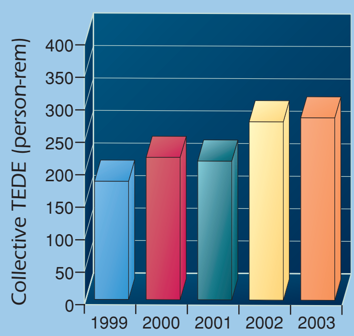
ORNL: The reported TEDE for ORNL during 2003 is slightly higher (6.3% increase) than the 2002 reported TEDE. This increase can be attributed to an occurrence that took place at ORNL involving spilled low-level waste, which resulted in internal exposures to two individuals. (See occurrence report ORO–ORNL-X10NUCLEAR-2003-0024.)

Y-12: The 2003 collective external deep dose equivalent for the Y-12 Complex increased by 50% from 9.8 person-rem in 2002, to 14.7 person-rem in 2003. The increase in deep dose was primarily due to work activities associated with two special projects. These projects were the building 9204-4 Cleanup Project and the Tennessee Valley Authority Off-Specification Fuel repackaging project.

The collective TEDE remained essentially the same from 2002 to 2003, while the total persons monitored increased by 9% from 4,906 to 5,369. The collective CEDE decreased 10% from 53.0 person-rem in 2002 to 47.8 person-rem in 2003. Airborne radioactivity contributed to 173 workers receiving internal doses in excess of 100 mrem.

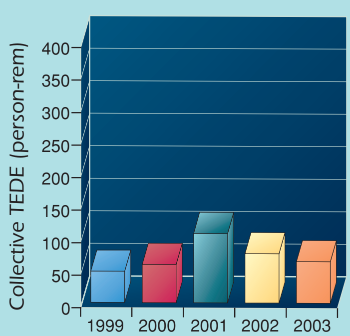
Exhibit 3-30:
Activities Significantly Contributing to Collective TEDE in 2003 for Six Sites (continued).

Hanford



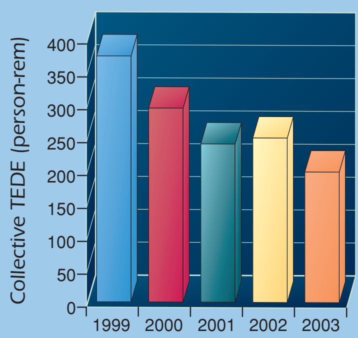
Percent Change 2002 - 2003 (last yr.)	Percent Change 2001 - 2003 (3 yr.)	Percent Change Since 1999 (5 yr.)	Description of Activities at the Site
↑ 2%	↑ 31%	↑ 35%	The collective TEDE at Hanford increased by 2% from 2002 to 2003. The largest contributors to the collective TEDE at Hanford were thermal stabilization and repackaging of plutonium-bearing materials at the Plutonium Finishing Plant (PFP) (46.6%), processing of spent fuels in K-Basins for interim dry storage at the Canister Storage Building (18.7%) and accelerated cleanup of tank farms by the Office of River Protection contractors (12.3%). Other contributors to the dose include Pacific Northwest National Laboratory (PNNL) activities (7.1%), radioactive waste management (4.8%) and D&D activities (4.1%). For the Office of River Protection (ORP), the collective TEDE for ORP contractors increased 46%, from 25.4 rem in 2002 to 37.0 rem in 2003. Extremity dose increased 57%. These increases in dose were due to performing more hours of field work with greater dose potential, as the ORP focus changed from tank waste maintenance to tank waste recovery. Previously abandoned equipment is being removed, size-reduced, and prepared for disposal to support final tank closure. ORP acquisition of 222-S Analytical Services in 2003 resulted in 5% of the total dose for ORP work. The collective TEDE for Richland Operations Office did not change significantly. However, the distribution of dose among facilities changed as some projects were accelerated and other projects were completed. Neutron doses increased 45% and extremity dose increased 18%. These increases were due to accelerated plutonium stabilization activities at the plutonium finishing plant. PFP processed in 2003 nearly 5-1/2 times the number of items processed in 2002. The collective CEDE increased 500%, from 0.268 rem in 2002 to 1.617 in 2003. The major contributor to CEDE was a result of a breach in a glovebox at PFP (see Occurrence Report Number RL–PHMC-PFP-2003-0015).

Idaho



Percent Change 2002 - 2003 (last yr.)	Percent Change 2001 - 2003 (3 yr.)	Percent Change Since 1999 (5 yr.)	Description of Activities at the Site
16% ↓	40% ↓	↑ 33%	The collective TEDE at the Idaho National Engineering and Environmental Laboratory decreased by 16% from 2002 to 2003. Radiation exposure to INEEL employees (excluding ANL-W and BNFL employees) is primarily the result of radiological work conducted in support of two major activities: Idaho Completion Project (ICP) and Reactor Operations. The primary ICP activities involving radiation exposure included spent nuclear fuel work at Test Area North (TAN) and Idaho Nuclear Technology and Engineering Center (INTEC), cleaning and sampling of the tank farm vessels at INTEC, eliminating mixed low-level waste backlog at INTEC, and D&D activities at TAN-616 Waste Evaporator Building. The remaining activities involving significant radiation exposure were the operation of the Advanced Test Reactor and the Hot Cells at the Test Reactor Area. The decrease in collective dose was primarily due to the completion of the shipments of waste to the WIPP and spent fuel repackaging and transfer work in 2002. These activities did not contribute to the INEEL exposure in 2003.

Exhibit 3-30:
Activities Significantly Contributing to Collective TEDE in 2003 for Six Sites (continued).

Rocky Flats	**Percent Change** 2002 - 2003 (last yr.)	2001 - 2003 (3 yr.)	Since 1999 (5 yr.)	**Description of Activities at the Site**
	21% ⬇	17% ⬇	47% ⬇	The collective TEDE at Rocky Flats decreased by 21% from 2002 to 2003. The activities for calendar year 2003 included processing and shipment of the last of the plutonium residues, packaging and shipment of low-level waste, and the Decontamination and Decommissioning (D&D) of the four major plutonium facilities on site, as well as D&D of numerous uranium and administrative facilities. The collective dose decreased primarily due to a reduction of radioactive source material on site due to the repackaging and shipment of these materials for off-site disposal or storage. Reported internal dose increased 144% (2.3 person-rem to 5.6 person-rem) from 2002, primarily due to enhanced air monitoring and a conservative approach in the method of accounting for internal dose when workers are wearing supplied air and in Level B suits. Previously, workers wearing this PPE were not assigned any internal dose unless there was an incident (e.g., a wound or damaged PPE) that required a bioassay. Now, workers in supplied air and Level B suits are assigned an intake based on the airborne contamination level and time in the area, and the stated Protection Factor of the supplied air respirator. This approach resulted in an additional 2.9 person-rem CEDE assigned in 2003. Overall, the enhanced air monitoring process has improved the monitoring of potential low-level intakes, and the increased data analysis is resulting in a better understanding of the work environment.

3.6 Transient Individuals

Transient individuals, or transients, are defined as individuals who are monitored at more than one DOE site during the calendar year. For the purposes of this report, a DOE site is defined as a geographic location. The DOE sites are listed in Appendix Exhibit A-2 by operations office. During the year, some individuals perform work at multiple sites and, therefore, have more than one monitoring record reported to the repository. In addition, some individuals transfer from one site to another during the year. This section presents information on transient individuals to determine the extent to which individuals travel from site to site and to examine the dose received by these individuals.

Exhibit 3-31 shows the distribution and total number of transient individuals from 1999 to 2003. Over the past 5 years, on an average, transient individuals have accounted for 3.2% of the total number of records for monitored individuals at DOE and received, on an average, 2.7% of the collective dose. As shown in *Exhibits 3-32* and *3-33,* the number of transients with measurable dose increased by 9% from 550 in 2002 to 602 in 2003. The collective dose for transients increased by 54% from 36.5 person-rem (365 person-mSv) in 2002 to 56.1 person-rem (561 person-mSv) in 2003. The average measurable TEDE increased by 41% from 0.066 rem (0.66 mSv) in 2002 to 0.093 rem (0.93 mSv) in 2003. The average measurable TEDE for transients in 2003 was 12% higher than the average measurable TEDE (0.083 rem) for all monitored DOE workers. This is the first year since the transient data has been analyzed that the average measurable TEDE to transients is higher than the value for all DOE workers. As shown in *Exhibit 3-34,* LANL was the site with the largest collective dose to transient workers from 1999 to 2003. LANL has the largest percentage of dose to transients because workers at TA-55 (who generally receive elevated doses due to the nature of their work) tend to perform temporary work at sites such as Nevada Test Site (NTS), Rocky Flats, and Pantex, as part of their routine duties. In addition, the collective TEDE at LANL increased by 47% from 163.5 person-rem (1635 person-mSv) 2002 to 240.0 person-rem (2400 person-mSv) 2003, which contributed to the 115% increase in the collective TEDE to transient workers at LANL.

Exhibit 3-31:
Dose Distribution of Transient Workers, 1999-2003.

	Dose Ranges (TEDE in rem)	1999	2000	2001	2002	2003
Transients	Less than Measurable Dose	3,876	2,537	2,696	2,298	2,063
	Measurable < 0.1	638	466	439	470	492
	0.10 - 0.25	50	37	31	50	59
	0.25 - 0.5	21	14	13	12	23
	0.5 - 0.75	6	4	1	11	9
	0.75 - 1.0	6		1	5	7
	1.0 - 2.0			2	2	12
	Total Number of Individuals Monitored *	4,597	3,058	3,183	2,848	2,665
	Number with Measurable Dose	721	521	487	550	602
	% with Measurable Dose	16%	17%	15%	19%	23%
	Collective TEDE (person rem)	39.521	23.632	25.138	36.477	56.141
	Average Measurable TEDE (rem)	0.055	0.045	0.052	0.066	0.093
All DOE	Total Number of Records for Monitored Individuals	113,064	102,881	97,818	100,221	102,509
	Number with Meas. Dose	16,668	15,983	16,687	17,051	17,484
	% of Total Monitored who are Transient	4.1%	3.0%	3.2%	2.8%	2.6%
	% of the Number with Measurable Dose Who are Transient	4.3%	3.3%	2.9%	3.2%	3.4%

* Total number of individuals represents the number of individuals monitored and not the number of records.

Exhibit 3-32:
Individuals Monitored at More Than One Site (Transients) During the Year, 1999-2003.

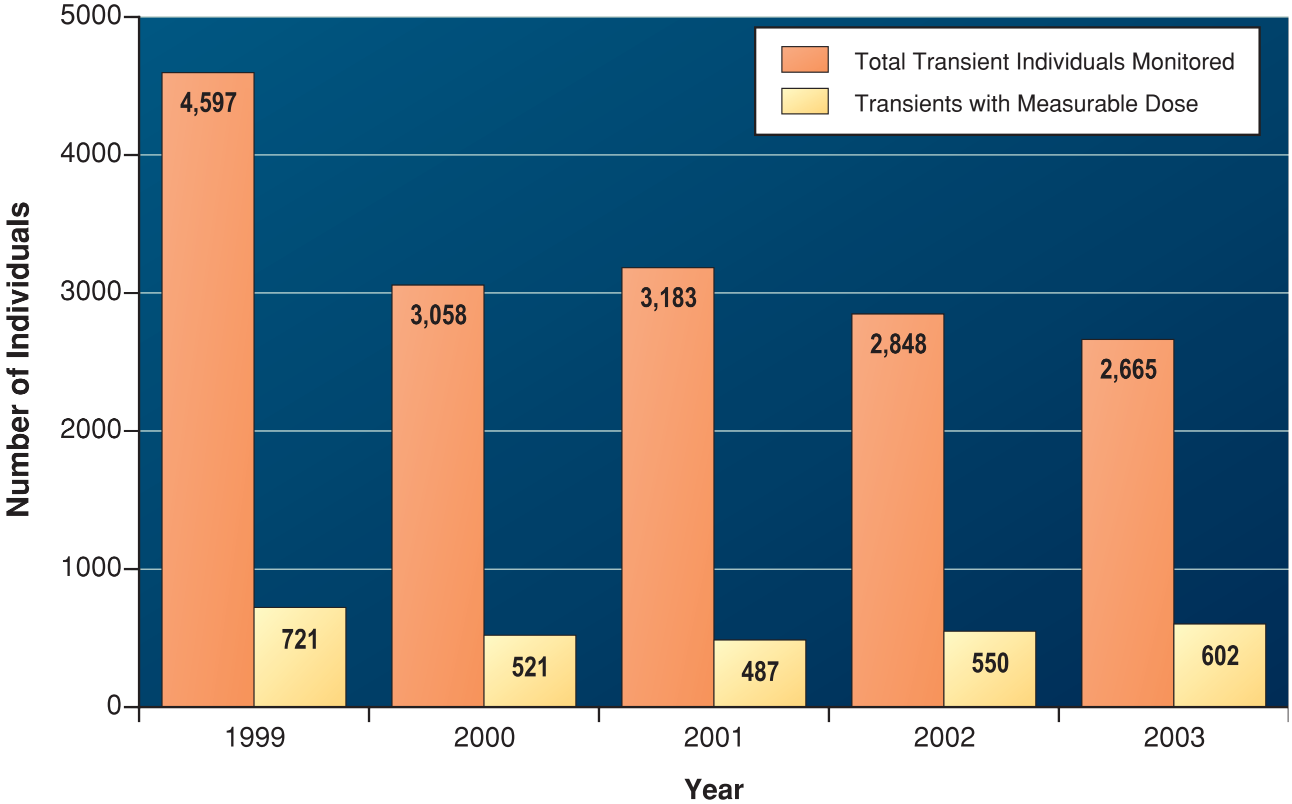
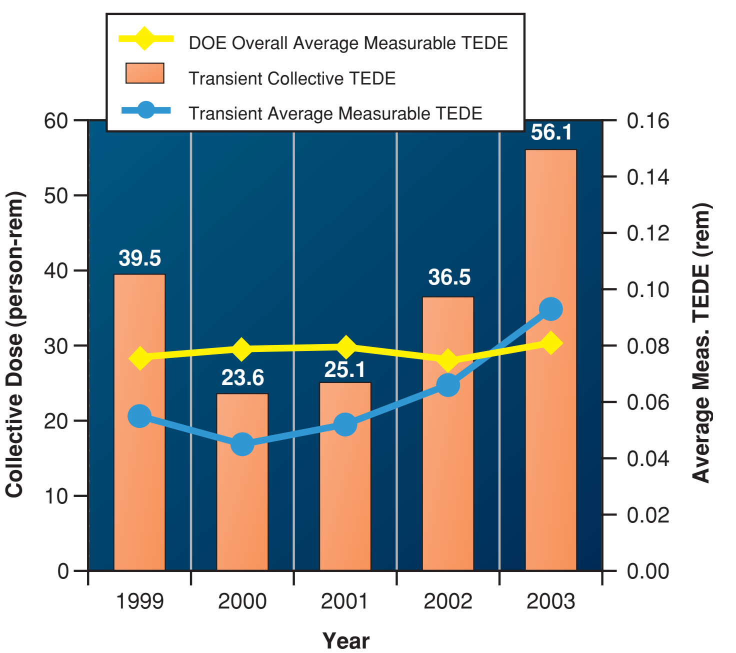


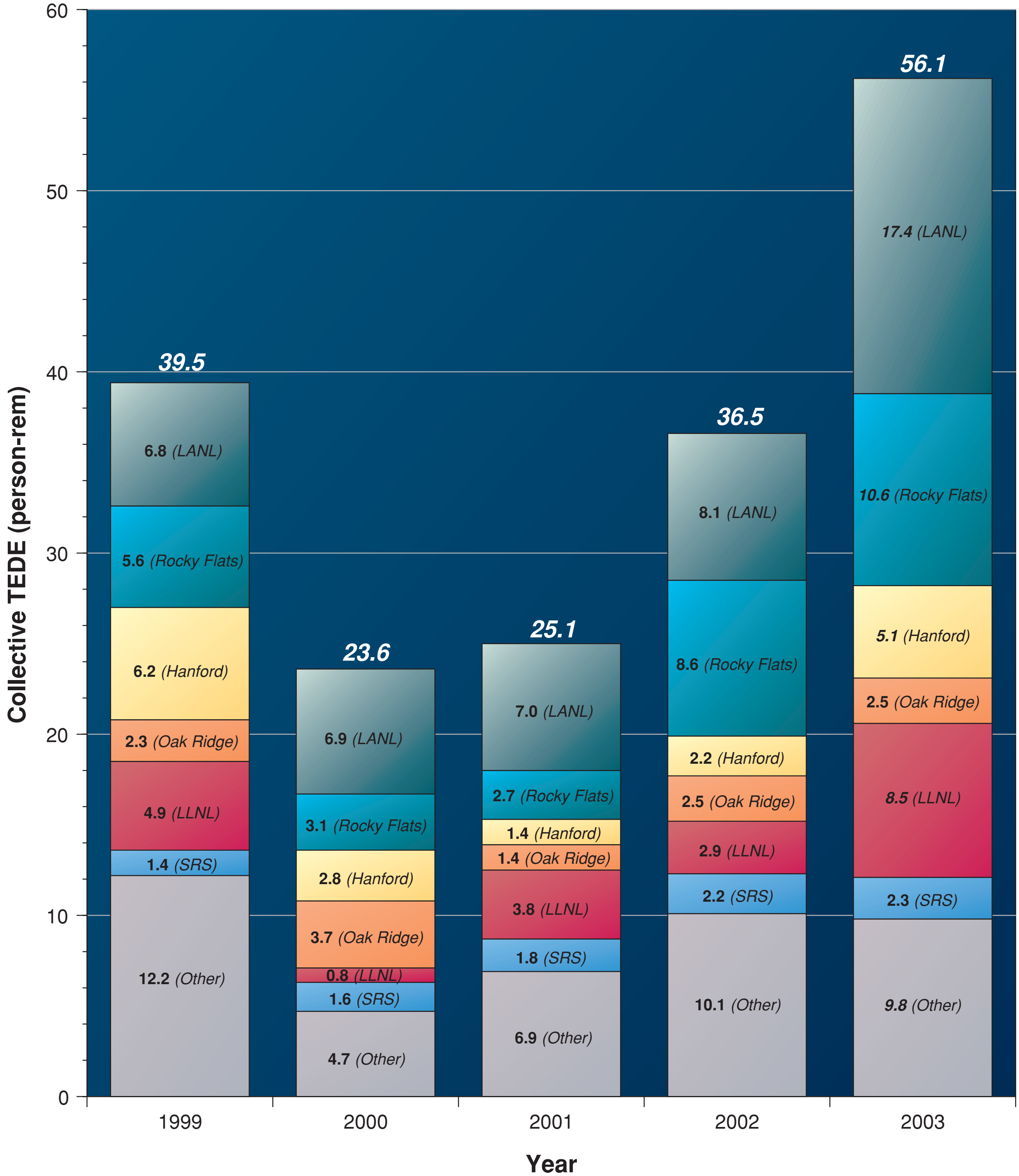
Exhibit 3-33:
Collective and Average Measurable Dose to Transient Individuals, 1999-2003.



One group of individuals who routinely travel from site to site is DOE employees from Headquarters or the Field Offices who visit or inspect multiple sites during the year. For 2003, this group accounts for 12% of the monitored transient individuals but only 1% of the collective dose to transients.

In 2003, 12% of the transient individuals were monitored at three or more sites. DOE Headquarters and Field Office personnel are included among these individuals. In 2003, 14% of the individuals monitored at three or more sites were DOE Headquarters or Field Office employees, and 15% of the individuals monitored at four or more facilities were DOE Headquarters or Field Office employees. The maximum number of sites visited by one monitored individual during 2003 was six.

Exhibit 3-34:
Collective TEDE to Transient Workers by Site, 1999-2003.



LANL has a larger percentage of dose to transients because workers at TA-55 (who generally receive elevated doses) tend to perform temporary work at sites such as NTS, Rocky Flats, and Pantex, as part of their routine duties.

Section 3.7 Historical Data Collection

In Section 3.7 of the 2000 and 2001 annual reports on occupational exposure, information was presented on historical data that have been collected to date from a request by the DOE Office of Environment, Safety and Health to the DOE sites to voluntarily provide historical exposure records. No additional sites have reported historical data during the year 2003.

Sites that have not yet reported historical dose records are encouraged to contact Ms. Nirmala Rao at DOE to obtain further information on reporting these records. This is a voluntary request to report historical data (records prior to 1987) that are available in electronic form in whatever format that is most convenient for the site to report. The data will be stored as reported in the REMS and wherever possible, data will be extracted and loaded into the REMS database for analysis and retrieval. For detailed analysis, read Section 3.7 of the 2000 report.

Sites that have voluntarily reported historical data are:

- Fernald
- Hanford
- Idaho
- Kansas City Plant
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Nevada Test Site
- Oak Ridge K-25 Site
- Pantex
- Portsmouth
- Rocky Flats
- Sandia National Laboratory
- Savannah River Site

Section Four

ALARA Activities at DOE

4

ALARA Activities at DOE

This section on ALARA activities is a vehicle to document successes and to point all DOE sites to those programs whose managers have confronted radiation protection issues and used innovative techniques to solve problems common to most DOE sites. DOE program and site offices and contractors who are interested in benchmarks of success and continuous improvement in the context of Integrated Safety Management and quality are encouraged to provide input to be included in future reports.

4.1 ALARA Activities at the Hanford Site

4.1.1 Fluor Hanford, Inc. Implements ALARA During Open Air Demolition of 233S Plutonium Concentration Facility

The 233S Plutonium Concentration Facility (shown in *Exhibit 4-1*) was a part of the plutonium production processing facilities at the Hanford Site. Plutonium solutions from the 202-S REDOX building were transferred to the 233S facility, where the plutonium solution was concentrated and loaded into Product Receiver (PR) cans for transport to the Plutonium Finishing Plant for further processing. In 1962, operations at the 233S facility were expanded to include a Neptunium concentration and loadout process as well as an ion-exchange plutonium purification process.

Exhibit 4-1:
233S Prior to Demolition.

Photo Courtesy of Hanford.

A plutonium spill in 1956 and a fire in 1963 resulted in the spread of gross levels of contamination within the process areas of the facility and lesser amounts of contamination in the non-process areas including the exterior roof of the facility. The 233S building was a reinforced concrete structure 37 feet high, 86 feet long and 43 feet wide, with 8-inch thick walls and 6-inch thick floors.

In a previous contract, Bechtel Hanford, Inc. removed the process equipment and performed some stabilization of the contamination. Non-process areas were decontaminated to below 2,000 dpm/100cm^2 alpha. However, the process hood and viewing room remained at 50,000 – to more than 20,000,000 dpm/100 cm^2 alpha. Resuspension of contamination caused airborne radioactivity levels between 10 and 100 DAC, requiring all entries to be made in Powered Air Purifying Respirators.

The challenge for Fluor Hanford, Inc. (FHI) was to economically demolish a highly contaminated plutonium facility while maintaining exposures to internal and external radiation ALARA, protecting the workers, public, and the environment. To meet this challenge, FHI developed and implemented methods of controlling airborne radioactivity generation while demolishing the building in the open air in lieu of fully decontaminating the building prior to demolition.

The highly contaminated areas were partially decontaminated by hydrolasing. VAC TRAX® Hydrolase System was used to reduce external and internal dose to workers and prepare the building for open air demolition. The VAC TRAX® is a remote-operated, track driven, rotating high-pressure water jetting tool that directs Ultra High Pressure (UHP) water to remove material coverings from a variety of surfaces. The VAC TRAX® is capable of light scabbling or deep scarification of concrete surfaces, allowing for deeper cleaning. Additionally, the VAC TRAX® is fully encapsulated. Water and debris are vacuumed to a Waste Barrel Containment System. After hydrolasing, area dose rates were significantly reduced. Contact exposure levels in the northeast corner of the process hood were reduced from > 2,000 mrem/hr to approximately 300 mrem/hr and general area dose rates were reduced to < 5 mrem/hr in most areas.

To further reduce the dose rates, a 12-inch layer of grout was applied to the process hood and viewing room floors. Following grouting, dose rates were in the μrem/hr range. The lowering of the background allowed more accurate characterization to be performed, which allowed the majority of the process hood / viewing room walls to be designated for low-level waste. Grouting also further reduced airborne contamination levels within the facility.

Polymetric Barrier System™ (PBS) was used to fix the remaining contamination on surfaces of the interior of the building prior to demolition. PBS is a non-toxic, water-based system and is easily applied in the field to form a strong, impermeable barrier between hazardous materials and the environment.

Demolition of 233S was performed in two phases. Low- and medium-risk portions of the building were demolished using mechanical shears (see *Exhibits 4-2* and *4-3*). The high-risk portion of the building (the process hood) was demolished using wall saws (see *Exhibits 4-4*, *4-5*, and *4-6*). Fog cannons were used to control potential airborne radioactivity during the shearing operations and the mechanical shears had a fogging system built in as well (see *Exhibits 4-7* and *4-8*). Fixatives were incorporated into the fog cannon and mechanical shear fogging systems. For the wall saw operations, gutters were placed on the inside of the facility along the wall saw cut lines (*Exhibit 4-9*) to collect contaminated liquid and particles to prevent release during the cutting operations.

These techniques each contributed to the successful completion of open air demolition of the 233S Plutonium Concentration Facility.

Exhibit 4-2:
The Mechanical Shears Quickly Cut Up Reinforced Concrete Walls, Metal Sheet Walls, and Ventilation Ducting.

Photo Courtesy of Hanford.

Exhibit 4-3:
Debris From the Shearing Operation is Scooped Up and Transported to the Environmental Restoration Disposal Facility.

Photo Courtesy of Hanford.

Exhibit 4-4:
Wall Saw is Mounted on the Installed Track. The Concrete Roof was Cut Into Four Sections and Removed First.

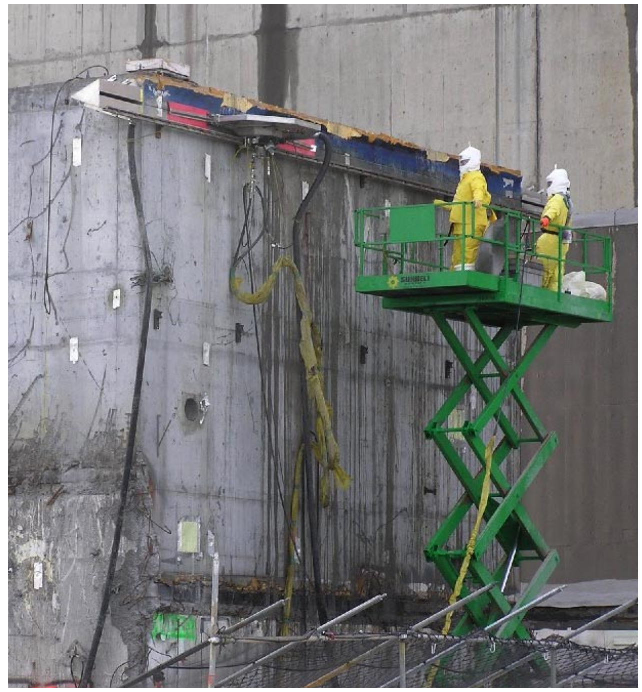


Photo Courtesy of Hanford.

Exhibit 4-5:
Once the Roof was Removed, the Contractor Began Removing Sections of Wall.

Photo Courtesy of Hanford.

Exhibit 4-6:
A Closeup of the Wall-Mounted Saw as it Cuts Through the Wall of the Process Hood Portion of 233S Plutonium Concentration Facility.

Photo Courtesy of Hanford.

Exhibit 4-7:
Fog Cannon Operating During Shearing of the Low- and Medium-Risk Areas. Two Cannons were Staged to Provide Continuous Fogging During Shearing.

Photo Courtesy of Hanford.

Exhibit 4-8:
The Mechanical Shear Also had a Fogger Attached. Water with Fixative Controls the Release of Airborne Radioactivity During Shearing Operations.

Photo Courtesy of Hanford.

Exhibit 4-9:
Gutters were Installed on the Interior of the Building Where the Wall Saw Cuts were to be Made to Collect Water and Debris During the Cutting Operation and Control Release of Airborne Radioactivity.

Photo Courtesy of Hanford.

4.1.2 Bechtel Hanford, Inc. Uses Rust Doctor® Fixative to Reduce Airborne Radioactivity During Demolition of 1304N Emergency Dump Tank

The 1304N Emergency Dump Tank (EDT) was extensively corroded with gross quantities of flighty red rust on the inner steel surfaces of the tank. Pre-demolition surveys of the steel revealed removable contamination levels in excess of 500,000 dpm/100cm^2 beta-gamma and approximately 3,500 dpm/100cm^2 alpha. To effectively demolish and remove the tank structure, it was necessary to fix the contamination so that airborne radioactivity levels would not pose a significant threat to workers or the environment during demolition activities. A fixative satisfying the following criteria was needed:

- Fixes the radioactive rust to below 100,000 dpm/100cm^2 beta-gamma and 400 dpm/100cm^2 alpha removable contamination
- Environmentally friendly disposition with waste material
- Chemically compatible with the steel tank
- Feasible application requirements
- Reasonable availability and cost-effectiveness

After evaluating available options, Rust Doctor® rust converter and fixative was selected. The Rust Doctor® changes the red flighty rust to black magnetite that re-adheres to the tank surface (see *Exhibit 4-10*). The latex component provides a primer coat that (in its intended use) could be painted with a top coat.

Physically removable rust material was significantly reduced and in some cases eliminated entirely. A survey taken from a small section removed from the tank wall indicated removable contamination levels were reduced to approximately 8,000 dpm/100cm^2 beta-gamma and <100 dpm/100cm^2 alpha. Direct contamination levels were significantly higher. This indicated that the contamination was indeed fixed to the surfaces of the tank via the latex-based matrix that was associated with the fixative (see *Exhibit 4-11*). Air samples collected during demolition verified the fixative controlled potential generation of airborne radioactivity.

Exhibit 4-10:
Inside Surface of the Tank. Rust Doctor® Turned the Red Rust to Black. The Coverage Is Apparent.

Photo Courtesy of Hanford.

Exhibit 4-11:
The Spray Rig was a Counterweighted Arm About 28 Feet in Length Extending from the Center Shaft Toward the Wall of the Tank. Approximately 100 Gallons of Rust Doctor® were used to Fix the Contamination in the Tank. The Top of the Spray Rig Can be Seen Leaning Up Against the Wall in the Left of the Photo.

Photo Courtesy of Hanford.

4.1.3 CH2M HILL Hanford Group, Inc. Saved 6.5 Person-Rem Using Cast Antimonial Lead Shielding During Sluice and Retrieval of Saltcake from S-112 Tank

CH2M HILL has begun the process of removing radioactive sludge from some of the Hanford underground single-shelled tanks in preparation for tank closures. Tank S-112 Saltcake Waste Retrieval Technology Demonstration Project used high-pressure spray nozzles to break up the saltcake waste forms in the single-shelled tank and then pumped it into a double-shelled tank.

The S-112 retrieval team had a problem: How do you shield 500 feet of transfer line in the S-Farm complex? The traditional solution was to dig a trench, place the pipe in the trench, and cover the trench with steel plating. A trench already existed for another temporary line that was being used to remove liquids from the tank in an operation called saltwell pumping. Using the existing trench would have required temporary shutdown of the saltwell pumping operation, causing a significant delay in that project and additional dose to workers installing the new line next to the previously active transfer line.

Exhibit 4-12:
Nuclear Lead Company Antimonial-lead Shielding was Placed Over a Temporary Above-ground Radioactive Waste Transfer Line. This Line is Adjacent to Another Temporary Transfer Line that was Buried in a Trench and Covered with Steel Plates. The New Method Saved 6.5 Person-rem and Significant Labor Costs.

Photo Courtesy of Hanford.

The retrieval team went to the Hanford ALARA Center of Technology to look for an alternative. At the ALARA Center, the team found a sample of antimonial lead shielding made by Nuclear Lead Company of Oak Ridge, Tennessee. The shielding, containing 3 percent antimony, is stronger than regular lead shielding, holds it shape, but retains all the required shielding properties (see *Exhibit 4-12*).

Deciding to use the shielding was the easy part. Making the idea practical by designing interlocking shielding that could accommodate the curves of transfer lines and the uneven terrain in the tank farms took the engineering support of COGEMA. A dog house design was developed and the shielding was custom cast by Nuclear Lead Company at their Oak Ridge plant. Each shielding block, designed to sit over the top of the transfer line, is 24 inches long, weighs 270 pounds, and contains a lifting lug for installing and removing the shielding using a crane. Installation began in August on tank S-112 and later in the fall on S-102.

For the initial application of the antimonial lead "dog house" style shielding, CH2M HILL saved 6.5 person-rem for the project. Most of the savings is attributed to not having to bury, and then dig up, the transfer line following use. The antimonial lead shielding is also more effective than steel in reducing the gamma dose rates resulting in lower doses during operation. The shield blocks are easily installed and removed, resulting in considerable cost/schedule savings as well as dose savings. This shielding is also being applied to other tank waste retrieval projects and will be applied to future work evolutions for additional savings.

4.2 ALARA Activities at the West Valley Demonstration Project

The West Valley Demonstration Project (WVDP) is the site of a former commercial nuclear fuel reprocessing plant. The WVDP Act, passed by Congress in 1980, directed DOE to solidify the liquid waste left from reprocessing activities, clean and close the facilities used, and dispose of low-level and TRU wastes left from project operations. The Project is unique in that the site property is owned by New York State.

Following the successful vitrification of liquid high-level radioactive waste in 2002, cleanup efforts are now focused on decontamination and dismantlement of some of the cells in the former nuclear fuel reprocessing plant. Three of these cells are the Product Purification Cell-South (PPC-S) and two Head End Cells (HECs).

4.2.1 Project Description of PPC-S

During former reprocessing operations, recovered uranium and plutonium were purified in the multi-level PPC. The cell measures 21 feet wide by 16 feet long by 57 feet high and is divided into two sections by a 1-foot-thick concrete shield wall. The PPC-North section was used primarily to purify uranium and was decontaminated in the 1980s. The smaller south section was used primarily to purify plutonium.

Decontamination of PPC-S was performed to significantly reduce the level of radiological hazard and risk associated with contaminated piping, valves, tanks, vessels, support structures, and components that were used during the product purification process (see *Exhibit 4-13*).

4.2.1.1 Radiological Concerns

The main challenges associated with removing 28 separate vessels and more than 3,000 linear feet of piping in the cell included:

- high alpha contamination levels at >50 million disintegrations per minute (dpm)
- a silo-like cell configuration (57 feet tall, 16 feet long and only 5 feet wide)
- lack of remote equipment capabilities or ability to readily install such equipment
- difficult access
- the residual fissile material potentially remaining in the cell's pipes and vessels

Smear samples confirmed alpha contamination exceeding 50 million dpm. The cell's general area exposure rate at the ground level varied from 5 to 35 mR/hour gamma, with the majority of radiation coming from the floor. General area exposure rates at the upper regions of the cell were 1 to 2 mR/hour gamma.

Exhibit 4-13:
Removal of Slab Tank in PPC-S.

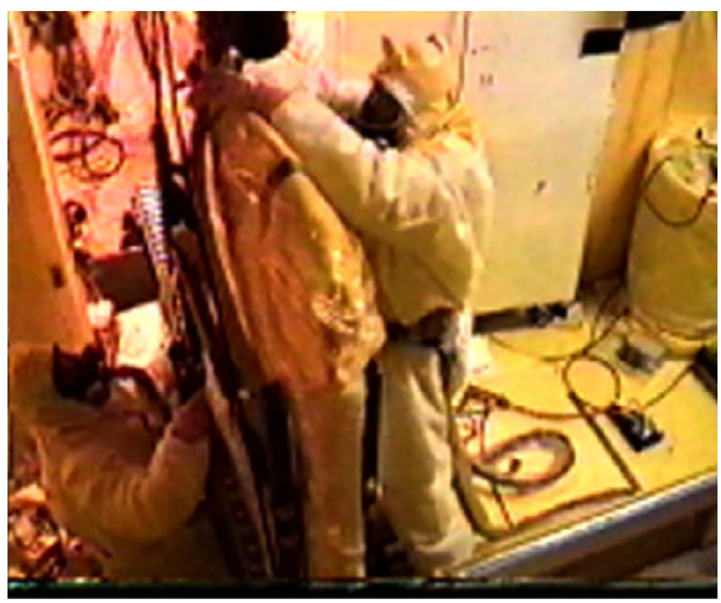


Photo Courtesy of WVDP.

4.2.1.2 Implementation of Innovative ALARA Techniques

Project engineers designed a doorway in the cell's 3-foot-thick concrete shield wall to provide the shortest path for in-cell equipment removal and to allow for installation of multiple containment barriers. The team also modified ventilation flowpaths into and out of the PPC-S to increase the number of air changes in the cell and to reduce the potential for spreading contamination during cell entries. Additionally, operators applied a strippable fixative coating to the in-cell surfaces.

The containment design, ventilation modification, and use of fixatives established safe conditions for workers. Radiological protection was also provided by selecting highly protective Personal Protective Equipment (PPE). Each operator wore two inner layers of anti-contamination clothing, an air-fed cooling vest, and a supplied air respirator and hood. Over this PPE, operators wore an air-fed vinyl suit and hood or bubble suit. To protect the bubble suit from being torn, cloth coveralls were worn over the top of the bubble suit. Each operator was equipped with a two-way radio for communication (transmitter and earpiece).

To ensure the safe handling of residual liquids inside piping and vessels, more than 100 sampling points were identified and a telltale (a custom-machined, stainless-steel block valve assembly) was installed on each point. The telltale assemblies were used to vent and drain the lines, and draw samples to determine the fissile content of the liquid. Approximately 17 gallons of liquid were removed from in-cell piping during the decontamination effort. All components 2 inches in diameter or larger were visually inspected to identify the presence of bulk solids. A total of 129 telltales were performed on pipe ranging in size from 2 inches to 1.5 inches in diameter.

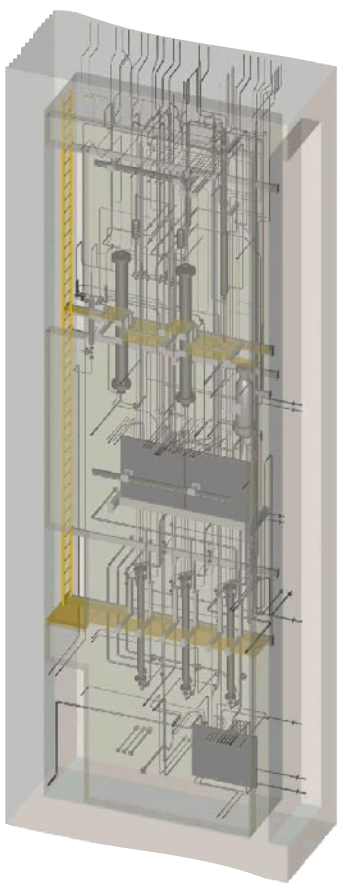
Project engineers conducted benchmarking at several DOE facilities that have handled and packaged Pu-contaminated wastes and established a method for determining fissile content that is recommended by the NRC. The team used an NaI (Tl) scintillation detector to screen piping. They also developed limits for packaging assayed piping, and prepared a strategy to stage the piping that facilitated batch accumulation and transfer during removal.

Specific criticality analyses were performed on each process vessel to ensure safe handling as the vessel was removed from the cell. Waste containers used to package the equipment were transported directly to separate criticality control zones to provide a safe staging area for the vessels until final characterization data needed to complete packaging were available.

Removal work was structured to clear the PPC-S of contaminated components beginning at the lowest level and progressing upward. Operators identified process and utility piping lines using line number tags and color coding to correspond with the system pipe (i.e., Pu, U, or utility piping). As entries were conducted, project engineers guided crew members using two-way communication and small-diameter video cameras. After confirming the correct identification of line numbers, workers vented and sampled the lines. More than 3,000 feet of piping were removed from the cell following the sampling evolution.

The team used a mast climber rather than conventional scaffolding to remove equipment and piping from the cell. The mast climber is a compact, single-mast and single-platform unit that was specifically designed for use in narrow, restricted spaces (see schematic drawing at *Exhibit 4-14*). The length and width of the unit were adjusted to fit the PPC-S cell dimensions. The unit made it possible for operators to continue to work safely and efficiently as they moved higher into the cell. Prior to using the mast climber in the cell, team members installed it in a nonradioactive facility as part of mock-up training and to ensure that the work incorporated ALARA and industrial safety principles.

Exhibit 4-14:
Schematic Drawing of PPC-S.



Drawing Courtesy of WVDP.

With only a 16-foot-long and 5-foot-wide area to work in, creative maneuvering was required to rig larger, heavier components and lower them down through the cell for removal. Contaminated equipment was rigged, detached from its structural supports, and layered in Herculite® prior to being lowered down through the cell. The largest vessels were as tall as 13 feet and weighed up to 1,000 pounds.

Field work on the PPC-S project began in July 2002 and the cell was partially decontaminated and dismantled by August 2003. An estimated 2,300 curies of radioactivity, the majority of which was contained in process piping and vessels, were removed from the cell. Work crews made approximately 240 entries into the cell and logged more than 47,000 hours with no OSHA-recordable injuries or illnesses, no uptakes of radioactive material, no unplanned exposures greater than administrative control levels, and no airborne events exceeding permissible levels. The final radiological survey showed contamination levels on the walls were generally less than 10,000 dpm/cm^2 alpha, on the floor generally less than 30,000 dpm/cm^2 alpha, and exposure rates ranged from 0.5 to 25 mR/hour.

4.2.1.3 Estimated Dose Avoided

The ALARA budget for the PPC-S project was 8.77 rem. The project team received an actual dose (based on daily direct-reading dosimeters) of 6.98 rem total. For more information on this project, contact Ken Schneider at 716-942-4671.

4.2.2 Project Description of HECs and Radiological Concerns

The HECs consist of two main cells: the Process Mechanical Cell (PMC) and General Purpose Cell (GPC). The cells are heavily contaminated with spent fuel and mixed-fission/activation products from former spent nuclear fuel reprocessing operations. At the start of the decontamination effort, radiation levels in the cells ranged from general area exposure rates of 100 R/hour to hot spots of 2,000 R/hour, with alpha and beta/gamma removable contamination levels on the order of billions of disintegrations per minute. The 2002 DOE Occupational Radiation Exposure ALARA report provided information on initial cleanup of these cells and described shield window refurbishment, shield door repair, and replacement of remote handling equipment.

Decontamination work continues in the HECs with the packaging and removal of contaminated components from the two cells. Loose debris in the HECs include scrap from fuel and waste handling, fuel assembly hardware, leached fuel hulls, fine particles, and other materials. To maintain radiation exposure of workers on this project below ALARA limits, operations are being performed remotely (as shown in *Exhibit 4-15*).

Exhibit 4-15:
Remote Packaging of Waste from the HECs.

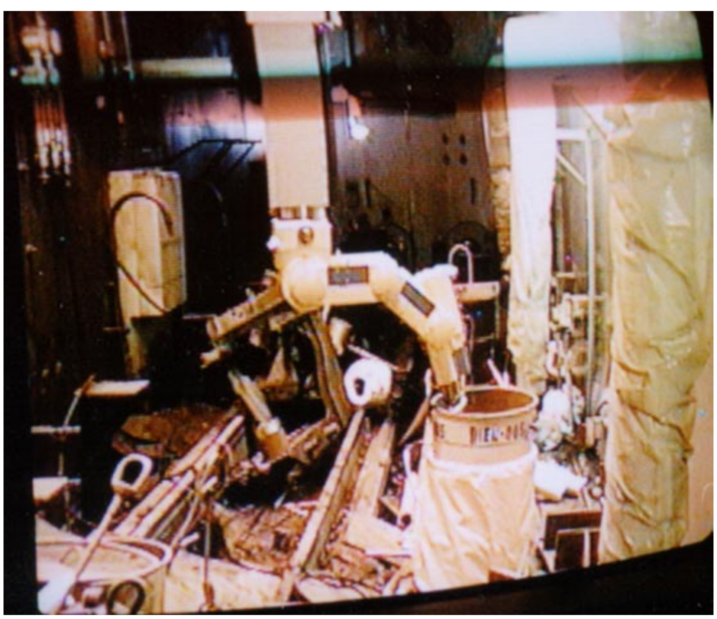


Photo Courtesy of WVDP.

4.2.2.1 Implementation of Innovative ALARA Techniques

The WVDP developed waste packaging plans for the HECs based on the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC). The former spent nuclear fuel reprocessing operations conducted on the site of the WVDP were considered commercial and were not included in the legislation that created the WIPP. However, in the absence of any other disposal facility capable of accepting WVDP TRU waste, the WVDP is using the WIPP WAC for HEC and other project waste. Two key factors were considered in project planning to ensure that the WIPP WAC were met: information on the chemical, physical, and radiological composition of the debris was critical, and WIPP WAC-compliant containers were to be used.

An innovative in-situ gamma spectroscopy unit was deployed in the HECs to aid in identifying gamma-emitting radionuclides in debris and equipment, and targeting specific areas for sampling. Thirty-gallon containers were selected for packaging debris, based on the size constraints of the HECs and to allow for the greatest degree of flexibility for packaging into final disposal containers. The containers can be placed readily into the proposed TRU waste canister or other containers.

Combustible materials were removed first from the HECs to reduce the potential for an in-cell fire. Materials including wood, plastics, and rubber were packaged and size-reduced using shears or bolt cutters that were modified for remote use. A variety of tooling was developed to handle the wide range of material inside the cells. They included off-the-shelf hand tools that could be easily modified for use with remote handling devices such as manipulators or robotic arms.

WVDP operators used bench-top band saws lowered into the cells from a crane hook to cut up waste debris. Hand-held band saws were used to cut broken manipulators left inside the cell. As cell cleanup efforts progressed, the dose rates of the packages began to increase. Initially, drums were loaded with general combustible waste that produced low exposure rates (<500 mR/hour) and could have been packaged using hands-on methods. Engineers developed methods to minimize contamination spread by covering waste packages with a remotely removable covering. To remove the package from the contaminated area, the covering was removed while the drum was suspended in the air, and the drum was quickly transferred to a clean area. These inner drums were removed from areas where contamination levels are in the billions of counts per minute with minimal cross-contamination occurring on the outside of the packages.

Additional efforts to facilitate the overall dose reduction ALARA strategy were implemented in the Scrap Removal Room (SRR) adjacent to the HECs. The SRR was redesigned to permit drums to be brought out of the HECs in a lower background radiation level area. Engineering developed a method to remotely weigh and take dose readings on inner drums and then place them in shielded containers. A 55-gallon drum with prepositioned radiation probes on it served as the remote measurement device. It was mounted on a standard floor scale. Waste drums were lifted from the GPC through a hatchway where their contamination covers were removed. The waste drums were placed in the drum counter and their weight and exposure readings were transmitted to an indicator panel outside the cell. Finally, the drum was placed in a shielded container without exposing operators to the unshielded radiation field. In the final step, workers entered a low-exposure, low-contamination zone to bolt the outer lids on drums to permit their removal from the area.

The WVDP also explored other areas to help reduce exposure to workers while handling HEC waste. The Chemical Process Cell (CPC) had been cleaned out and racks installed in support of the high-level waste (HLW) vitrification project. When the vitrification process was completed and all of the available rack space had not been used, WVDP engineers reestablished the flow path between the GPC and the CPC to allow for temporary waste storage of higher-dose waste drums. This process allowed remote storage of the waste drums and ensured worker safety during the storage of TRU waste drums until the disposal path for this waste is determined.

For ease in removing some components from their mounts, impact wrenches were attached with manipulator-friendly handles on the base of the wrenches and telerobotic manipulator quick-disconnects for the air lines. An off-the-shelf saw with counter rotating cutoff saw blades was also adapted for remote use, as was an off-the-shelf, battery-operated, automobile rescue tool modified for in-cell use. The rescue tool was used to quickly cut through various loose piping and rods (see *Exhibit 4-16*). When larger items required size reduction, the project team developed more aggressive remote cutting methods using generic cutoff saws with 9-inch and 14-inch blades, as well as hand-held circular saws.

Exhibit 4-16:
Automobile Rescue Tool Being Used to Cut Through Pipes and Rods.

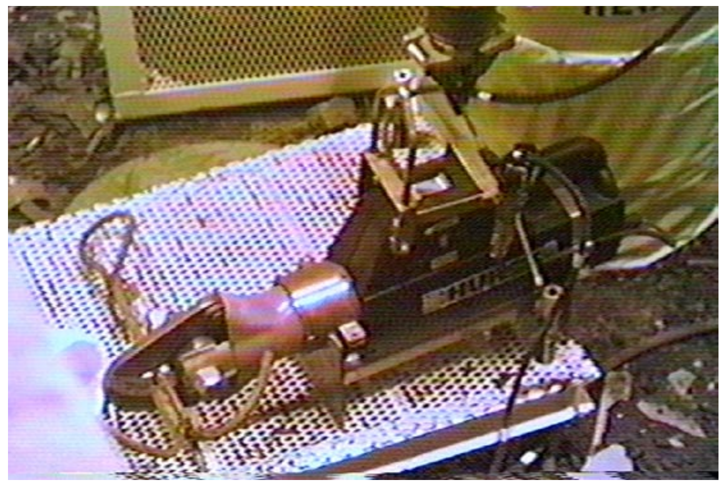


Photo Courtesy of WVDP.

Remote visual access and lighting were issues throughout the project. Several innovative designs were developed to create acceptable means to allow for acceptable views and visual access to areas being worked. Traditional radiation-hardened cameras proved to be expensive, and spare parts were difficult to find. The project team developed a technique to install cameras that were not radiation hardened through penetrations to the cells. The cameras were pushed into the cells to get the required views, then drawn back into the walls when not in use to shield them from high cell radiation fields. Inexpensive Aspy cameras were also used to view areas being worked by the robotic arms. These cameras gave very sharp pictures and lasted for days to weeks at a time.

Cleanup of the HECs is continuing in 2004; however, an ALARA budget of 6.258 rem was allotted for the project during 2003. Due to the use of innovative ALARA dose reduction techniques, the dose received (based on daily direct-reading dosimeters) for this project in 2003 was 1.287 rem. For more information about the HECs project, contact Scott Chase at 716-942-2184.

4.3 ALARA Activities at Brookhaven National Laboratory

4.3.1 Removal of the Brookhaven Graphite Research Reactor Below Ground Duct Outlet Air Filters

4.3.1.1 History and Description of the Brookhaven Graphite Research Reactor

The Brookhaven Graphite Research Reactor (BGRR) at Brookhaven National Laboratory (BNL) (*Exhibit 4-17*) was the first reactor built for the sole purpose of providing neutrons for research. Construction on the BGRR was completed in August 1950, and initial criticality of the reactor was achieved the same month. During its years of operation, it was one of the principal research reactors in the United States. The science mission of the BGRR concluded in 1963, and all operations ceased when operation of the reactor was terminated and deactivation of the facility was initiated. In March 1972, the last fuel element was removed from the reactor and shipment of the fuel to the Savannah River Site was completed shortly thereafter. The BGRR complex was described as being in a "safe shutdown" condition by the U.S. Atomic Energy Commission and became a "surplus facility" within the DOE complex.

Exhibit 4-17:
Brookhaven Graphite Research Reactor at Brookhaven National Laboratory.

Photo Courtesy of BNL.

The BGRR was a heterogeneous, enriched uranium-fueled graphite moderated and reflected, thermal neutron, air-cooled research reactor. The reactor consisted of a graphite cube, penetrated in the north-south direction by an array of parallel cylindricals, which held the cladded fuel elements. The graphite cube was built in two halves, separated by a vertical gap running east-west. Filtered cooling air was drawn into this gap and flowed through the individual channels, removing heat from the fuel elements and graphite. Hot air was collected in the plenum chambers at the north and south ends of the graphite cube and then flowed out of the building through two (north and south) underground concrete ducts. The air was filtered and cooled, and then drawn through fans and discharged into the stack.

Each of the north and south Below Ground Ducts (BGDs) had one filter bank (*Exhibit 4-18*). The filter banks each contained a total of 320 filter elements, which were arranged in eight cells that formed a four "V" configuration. Each filter cell was five elements across and eight elements high. The concrete BGDs that housed the filter banks are approximately 20 feet wide and 18 feet high. Each concrete duct contains a primary steel liner.

Exhibit 4-18:
Filter Bank.

Photo Courtesy of BNL.

Outlet air samples were taken as part of the BGRR characterization study. Due to the well-defined contamination associated with the filters located within the BGDs, and the poor condition of the equipment itself, the removal of the filters was determined necessary to prevent potential future contamination of the environment.

4.3.1.2 Radiological Condition of the BGD Outlet Air Filters

There were two filter banks; one located in the north BGD and a second located in the south BGD. The south filter bank contained approximately twice the activity as the north filter bank. The source of the filter activity was due to numerous fuel element failures.

Typical south filter bank contact gamma exposure rates ranged from 500 mR/h to 900 mR/h. Gamma exposure rates 6 feet from the filters indicated 100 mR/h (contact beta dose rates were measured up to 1.8 Rad/h).

The principal radionuclides of concern and inventory in the south filter bank were ^{90}Sr (7.09 Curies), ^{137}Cs (16.2 Curies), ^{238}U (1.36E-3 Curies), ^{238}Pu (3.32E-3 Curies), $^{239/240}$Pu (1.24E-01 Curies), ^{241}Pu (1.39E-01 Curies), and ^{241}Am (3.79E-02 Curies).

4.3.1.3 Filter Removal Method

A key concept during the planning and engineering for removal of the filters was to use custom-designed and -built remote-controlled equipment: a Brokk machine for removing the filters, a hammer mill for shredding the filters, and a vacuum/separator/system, which carried the shredded filters directly from the BGD to the waste burial container.

A Duct Service Building (DSB) was constructed to house the vacuum/separator/system and waste container (*Exhibit 4-19*). A ventilation system was installed that maintained the BGD at negative pressure with respect to the DSB and that also kept the DSB negative with respect to the outside environment. Shielding was installed around the waste container inside the DSB. Dry runs and mock-ups were performed on all new systems.

Exhibit 4-19:
Separator Inside Duct Service Building.

Photo Courtesy of BNL.

Prior to removal, a fixative was applied to the filter elements (*Exhibit 4-20*). This fixative significantly mitigated the radioactivity that was available for resuspension in air and also allowed the use of air-purifying respirators for personnel access into the BGD rather than the more limiting self-contained breathing apparatus (SCBA). The filter elements were then removed with a specially designed Filter Removal Tool (FRT) that was attached to a diesel powered, remote-controlled manipulator (Brokk 330D). The FRT removed the filter elements and placed them into a hammer mill shredder (*Exhibit 4-21*). The shredder rendered the filter media into nominal 1-inch cubes that were then carried through a vacuum hose to a waste liner. The Brokk manipulator was controlled remotely from a video control console (*Exhibit 4-22*).

Exhibit 4-21:
Brokk Machine Loading Filter Element Into Hammer Mill.

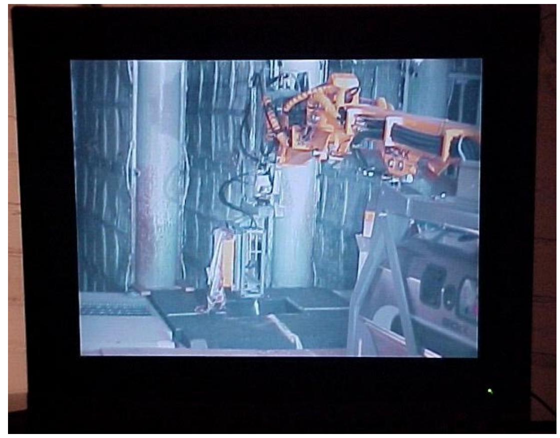


Photo Courtesy of BNL.

Exhibit 4-20:
Application of Fixative.

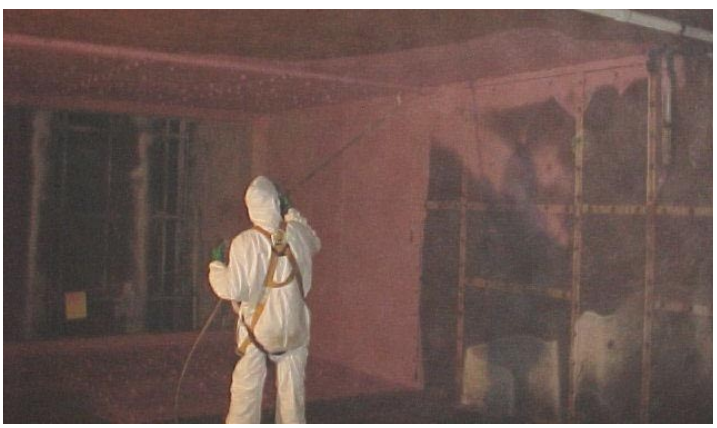


Photo Courtesy of BNL.

Exhibit 4-22:
Remote Video Display Terminal.

Photo Courtesy of BNL.

The use of the remotely controlled Brokk manipulator reduced the number of personnel entries into the confined space, thereby minimizing personnel exposure to the industrial and radiological hazards associated with removal of the filters. The Brokk manipulator performed this work in a high-radiation, high-contamination area (contamination levels in excess of 1.0E+6 disintegrations per minute per 100 square centimeters were routinely identified). The work, which involved two shifts per day over a 3-month period, was performed without a single personnel contamination or any loss of control of radioactive material. Removal of all the filters required 643 Brokk operating hours.

4.3.1.4 Collective Dose

The collective dose for removal of the 640 filter elements was 2.4 person-rem. The dose for performing the work without the Brokk Manipulator was estimated to exceed 20 person-rem (the average BNL annual site dose over the last several years) and would have resulted in exposures that approached administrative control levels for most of the BGRR field workers. The savings in external and internal dose and minimization of personnel exposure to other BGD industrial hazards justified the purchase and use of the Brokk Manipulator, which continues to be used in removing the BGD primary liner.

Point of contact: Thomas Jernigan, Project Engineer, 631-344-8244.

4.4 Hanford ALARA Center of Excellence

The Hanford ALARA Center of Excellence is committed to providing a centralized resource for others to gain insight into practical applications of the ALARA approach and to serve as a clearinghouse of ALARA information.

DOE's Hanford Site (586 square miles located in southeastern Washington State) was established during World War II as part of the Manhattan Project and played a pivotal role in the nation's defense for more than 50 years.

Currently, the Hanford Site is engaged in the world's largest environmental cleanup effort with many challenges to be resolved in the face of overlapping technical, regulatory, and cultural interests. The cleanup effort focuses on three outcomes: restoring the Columbia River corridor for other uses, transitioning the central plateau to long-term waste treatment and storage, and preparing for the future.

Over the years, the center has gathered a great deal of information in the application of the ALARA approach to daily operations. In 1996, DOE established the ALARA Center of Technology to provide a common resource for Hanford workers in the practical aspects of ALARA.

The Hanford ALARA Center is centrally located on the Hanford site to provide an informational resource to workers in the application of the ALARA approach in daily operations. While the focus of the ALARA Center has been at the Hanford site, ALARA Center staff routinely exchange information and ideas with others throughout the DOE complex for the benefit of all. Access the Center's web site for more information:

http://www.hanford.gov/alara/index.cfm

4.5 Submitting ALARA Success Stories for Future Annual Reports

Individual success stories should be submitted in writing to the DOE Office of Corporate Performance Assessment. The submittal should describe the process in sufficient detail to provide a basic understanding of the project, the radiological concerns, and the activities initiated to reduce dose.

The submittal should address the following:

- Mission statement
- Project description
- Radiological concerns
- Information on how the process implemented ALARA techniques in an innovative or unique manner
- Estimated dose avoided
- Project staff involved
- Approximate cost of the ALARA effort
- Impact on work processes, in person-hours if possible (may be negative or positive)
- Figures and/or photos of the project or equipment (electronic images if available)
- Point-of-contact for follow-up by interested professionals.

4.6 Lessons Learned Process

The Department of Energy has a mature lessons learned process that was initially developed in 1994. The current DOE Lessons Learned process is described in DOE Technical Standard, DOE-STD-7501-99. The purpose of the DOE Lessons Learned process is to facilitate the identification, documentation, sharing, and utilization of lessons learned from a review of actual operating experiences throughout the DOE complex. This is accomplished by lessons sharing between DOE sites through a common Corporate Database. A recent review of the Lessons Learned process has led to a redesign of the process to add a more corporate component to the process. This new corporate component, modeled after the Institute for Nuclear Power Operations (INPO) Significant Event Evaluation and Information Network (SEE-IN) program, has introduced an additional corporate role in the review of DOE Site performance and crosscutting operating experience and has started to provide additional Lessons Learned information to the DOE community, in addition to that already provided by DOE Field Sites.

The collected information is currently located on an Internet web site as part of the Environmental Safety & Health (ES&H) web page. This system allows for shared access to lessons learned across the DOE complex. The information available on the system complements existing reporting systems presently used within DOE. DOE is taking this approach to enhance those existing systems by providing a method to quickly share information among the field elements. Also, this approach goes beyond the typical occurrence reporting to identify good lessons learned. DOE uses the web site to openly disseminate such information so that not only DOE but also other entities will have a source of information to improve the health and safety aspects of operations at and within their facilities. Additional benefits include enhancing the workplace environment and reducing the number of accidents and injuries.

The web site contains several items that are related to health physics. Items range from off-normal occurrences to procedural and training issues. Documentation of occurrences includes the description of events, root-cause analysis, and corrective measures. Several of the larger sites have systems that are connected through this system. DOE organizations are encouraged to participate in this valuable effort.

The Web site address for DOE Corporate Operating Experience Review Lessons Learned web page is:

http://www.eh.doe.gov/ll

The specific web site address may be subject to change. ES&H information services can be accessed through the main Office of Environment, Safety, and Health web page at:

http://www.eh.doe.gov

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Section Five
Conclusions

5.1 Conclusions

The collective dose at DOE facilities has experienced a dramatic (83%) decrease since 1986. The main reasons for this large decrease were the shutdown of facilities within the weapons complex and the end of the Cold War era, which shifted the DOE mission from weapons production to shutdown, stabilization, and D&D activities. The DOE weapons production sites have continued to contribute the majority of the collective dose over these years. Sites reporting under the category of weapons fabrication and testing account for the highest collective dose. Even though these sites are now primarily involved in nuclear materials stabilization and waste management, they still report under this facility type. As facilities are shut down or undergo transition from operation to stabilization or D&D, there are significant changes in the opportunities for worker radiation exposure.

The collective TEDE increased 6% from1,360 person-rem (13.60 person-Sv) in 2002 to 1,445 person-rem (14.45 person-Sv) in 2003 due to increases in the collective dose at four of the six highest dose sites. These six sites accounted for 80% of the collective dose at DOE in 2003. Four of these sites attributed the increase in dose to thermal stabilization and repackaging of plutonium-bearing materials, processing of spent fuels, and accelerated cleanup of tank farms at Hanford, resumption of processing of radioactive material, special programs, and accelerated facility closure and waste processing activities at Savannah River, and work activities associated with the building 9204-4 Cleanup Project and the TVA Off-Specification Fuel repackaging project at Oak Ridge, and the processing of more materials containing americium, an upgrade to the material storage vault, and the decontamination and decommissioning of the Omega West reactor at LANL. A statistical analysis was performed to determine the trend in collective dose over the past 5 years. The analysis indicates that while the collective TEDE, neutron, and extremity dose increased between 2002 to 2003, it does not represent a statistically significant change in the dose received by individual workers at DOE. Further tests revealed fewer individuals received neutron doses above 0.500 rem (5 mSv).

The collective internal dose (CEDE) increased by 38% from 69 person-rem (690 person-mSv) in 2002 to 95 person-rem (950 person-mSv) in 2003. The increase was primarily due to a nearly four-fold increase in internal dose from plutonium. The main contributor to this increase was the two exposures in excess of 5 rem (50 mSv) at LANL (see Section 3.3.1). Mound and Rocky Flats also reported increases in internal dose from plutonium from 2002 to 2003. Internal dose from other radionuclides decreased or essentially remained the same from 2002 to 2003. Due to several factors, such as changes in internal dosimetry practices, monitoring and reporting procedures, changes in the dosimetry equipment, and the relatively small number of internal doses, care should be taken in examining trends in internal dose.

An analysis was performed on the transient workforce at DOE. A transient individual, or transient, is defined as an individual monitored at more than one DOE site in a year. The results of this analysis show that the number of transient workers monitored decreased from 2,848 in 2002 to 2,665 in 2003. The collective dose for these transients increased by 54% from 36.5 person-rem (365 person-mSv) in 2002 to 56.1 person-rem (561 person-mSv) in 2003, resulting in a 41% increase in the average measurable dose.

The detailed nature of the data available has made it possible to investigate distribution and trends in data and to identify and correlate parameters having an effect on occupational radiation exposure at DOE sites. A summary of the findings for 2003 is shown in *Exhibit 5-1*.

Exhibit 5-1:
2003 Radiation Exposure Fact Sheet.

- The collective TEDE increased by 6% (from 1,360 person-rem to 1,445 person-rem) (13,600 person-mSv to 14,450 person-mSv) from 2002 to 2003.
- The six highest dose sites (in descending order of collective dose: Hanford, Savannah River, Los Alamos, Rocky Flats, Oak Ridge, and Idaho) accounted for 80% of the collective dose at DOE in 2003.
- Increases in collective dose at four of the top six sites were attributed to a thermal stabilization and repackaging of plutonium-bearing materials, processing of spent fuels, and accelerated cleanup of tank farms at Hanford, resumption of processing of radioactive material, special programs, and accelerated facility closure and waste processing activities at Savannah River, and work activities associated with the building 9204-4 Cleanup Project and the TVA Off-Specification Fuel repackaging project at Oak Ridge, and the processing of more materials containing americium, an upgrade to the material storage vault, and the decontamination and decommissioning of the Omega West reactor at LANL.
- A statistical analysis was performed to determine the trend in collective dose over the past 5 years. The analysis indicates that while the collective TEDE, neutron, and extremity dose increased between 2002 to 2003, it does not represent a statistically significant change in the dose received by individual workers at DOE. Further tests revealed fewer individuals received neutron doses above 0.500 rem (5 mSv). This reflects a positive change in accordance with ALARA to reduce neutron dose to individuals at higher annual dose levels.
- The collective internal dose (CEDE) increased by 38% from 69 person-rem (690 person-mSv) in 2002 to 95 person-rem (950 person-mSv) in 2003. The increase was primarily due to a nearly four-fold increase in internal dose from plutonium.
- The number of transient workers monitored at DOE decreased from 2,848 in 2002 to 2,665 in 2003. However, the average measurable dose to transient workers increased by 41%.

Glossary

Administrative Control Level (ACL)
A dose level that is established below the DOE dose limit in order to administratively control exposures. ACLs are multi-tiered with increasing levels of authority required to approve a higher level of exposure.

ALARA
Acronym for "As Low As Reasonably Achievable," which is the approach to radiation protection to manage and control exposures (both individual and collective) to the workforce and the general public to as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit but a process with the objective of attaining doses as far below the applicable limits as is reasonably achievable.

Annual Effective Dose Equivalent (AEDE)
The summation for all tissues and organs of the products of the dose equivalent calculated to be received by each tissue or organ during the specified year from all internal depositions multiplied by the appropriate weighting factor. Annual effective dose equivalent is expressed in units of rem.

Average Measurable Dose
Dose obtained by dividing the collective dose by the number of individuals who received a measurable dose. This is the average most commonly used in this and other reports when examining trends and comparing doses received by workers because it reflects the exclusion of those individuals receiving a less than measurable dose. Average measurable dose is calculated for TEDE, DDE, neutron dose, extremity dose, and other types of doses.

Collective Dose
The sum of the total annual effective dose equivalent or total effective dose equivalent values for all individuals in a specified population. Collective dose is expressed in units of person–rem.

Committed Dose Equivalent (CDE) (H_T,50)
The dose equivalent calculated to be received by a tissue or organ over a 50–year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed dose equivalent is expressed in units of rem.

Committed Effective Dose Equivalent (CEDE) (H_E,50)
The sum of the committed dose equivalents to various tissues in the body (H_T,50), each multiplied by the appropriate weighting factor (w_T)—i.e., $H_E,50 = \sum w_T H_T,50$. Committed effective dose equivalent is expressed in units of rem.

CR
CR is defined by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) as the ratio of the annual collective dose delivered at individual doses exceeding 1.5 rem (15 mSv) to the collective dose. UNSCEAR now uses SR_{15} to denote this ratio where the subscript indicates the dose value (in mSv) used to calculate the ratio.

Deep Dose Equivalent (DDE)
The dose equivalent derived from external radiation at a depth of 1 cm in tissue.

DOE Site
A geographic location operated under the authority of the Department of Energy (DOE). The DOE sites considered in this report are listed in Appendix A by Operations Office.

Effective Dose Equivalent (H_E)
The summation of the products of the dose equivalent received by specified tissues of the body (H_T) and the appropriate weighting factor (w_T)—i.e., $H_E = \sum w_T H_T$. It includes the dose from radiation sources internal and/or external to the body. The effective dose equivalent is expressed in units of rem.

Exposure
As used in this report, *exposure* refers to individuals subjected to, or in the presence of, radioactive materials which may or may not result in occupational radiation dose.

Kruskall-Wallis Test
Uses a test statistic based on rank sums to determine whether two populations are significantly different.

Lens of the Eye Dose Equivalent (LDE)
The radiation dose for the lens of the eye is taken as the external equivalent at a tissue depth of 0.3 cm.

Logarithmic Mean
The mean calculated from log-transformed values.

Members of the Public
Individuals who are not occupationally exposed to radiation or radioactive material. This includes visitors and visiting dignitaries.

Minimum Detectable Activity (MDA)
The smallest quantity of radioactive material or level of radiation that can be distinguished from background with a specified degree of confidence. Often used synonymously with minimum detection level or lower limit of detection.

Non-parametric Procedures
Statistical tests that do not depend on a specific parent distribution.

Normal Log-transformed Data
Data that fit a normal distribution after being transformed to logarithms.

Number of Individuals with Measurable Dose
The subset of all monitored individuals who receive a measurable dose (greater than limit of detection for the monitoring system). Many personnel are monitored as a matter of prudence and may not receive a measurable dose. For this reason, the number of individuals with measurable dose is presented in this report as a more accurate indicator of the exposed workforce. The number of individuals represents the number of dose records reported. Some individuals may be counted more than once if multiple dose records are reported for the individual during the year.

Occupational Dose
An individual's ionizing radiation dose (external and internal) as a result of that individual's work assignment. Occupational dose does not include doses received as a medical patient or doses resulting from background radiation or participation as a subject in medical research programs.

Pairwise T-tests
This test compares all possible pairs of means and uses a T-test to determine whether differences are significant.

Shallow Dose Equivalent (SDE)
The dose equivalent deriving from external radiation at a depth of 0.007 cm in tissue.

SR

SR is defined by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) as the ratio of the annual collective dose delivered at individual doses exceeding a specified dose value to the collective dose. UNSCEAR uses a subscript to denote the dose value (in mSv) used in the calculation of the ratio. Therefore SR_{15} would be the ratio of the annual collective dose delivered at individual doses exceeding 1.5 rem (15 mSv) to the collective dose.

Statistical Normal Distribution

A distribution that is symmetric and can be described completely by the mean and variance. This property is required for many statistical tests.

Total Effective Dose Equivalent (TEDE)

The sum of the effective dose equivalent for external exposures and the committed effective dose equivalent for internal exposures. Deep dose equivalent to the whole body is typically used as effective dose equivalent for external exposures. The internal dose component of TEDE changed from the Annual Effective Dose Equivalent (AEDE) to the Committed Effective Dose Equivalent (CEDE) in 1993.

Total Number of Records for Monitored Individuals

All individuals who are monitored and reported to the DOE Headquarters database system. This includes DOE employees, contractors, subcontractors, and members of the public monitored during a visit to a DOE site. The number of individuals represents the number of dose records reported. Some individuals may be counted more than once if multiple dose records are reported for the individual during the year.

Transient Individual

An individual who is monitored at more than one DOE site during the calendar year.

T-test

A statistical test for comparing means from two populations based on the value of t, where

$$t = \frac{\overline{y}_1 - \overline{y}_2}{S_{\overline{y}_1 - \overline{y}_2}}$$

and $\overline{y}_1$ = sample mean, population 1

$\overline{y}_2$ = sample mean, population 2

$S_{\overline{y}_1 - \overline{y}_2}$ = standard deviation appropriate to the difference between the two means.

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References

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2. ICRP (International Commission on Radiological Protection), 1977. "Recommendations of the International Commission on Radiological Protection," ICRP Publication 26, Annals of the ICRP, Vol. 1, No. 3 (Pergamon Press, New York).

3. NCRP (National Council on Radiation Protection and Measurements), 1987. "Recommendations on Limits for Exposure to Ionizing Radiation," NCRP 91; superceded by NCRP Report No. 116.

4. DOE (U.S. Department of Energy), December 21, 1988, Order 5480.11, "Radiation Protection for Occupational Workers, " Change 3, June 17, 1992.

5. DOE 1994. *Radiological Control Manual.* Revision 1, DOE/EH-0256T, Assistant Secretary for Environment, Safety and Health, April.

6. 10 CFR Part 835. "Occupational Radiation Protection." Final Rule; DOE *Federal Register,* November 4, 1998.

7. DOE-STD-1098-99, "Radiological Control Standard," July 1999.

8. The Price-Anderson Amendments Act of 1988, Public Law 100-408, August 20, 1988.

9. 10 CFR 820. "Procedural Rules for DOE Nuclear Activities," August 17,1993.

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11. DOE Order 5484.1, "Environmental Protection Safety, and Health Protection Information Reporting Requirements," February 24, 1981, Change 7, October 17, 1990.

12. DOE Order 231.1-1, "Environment, Safety and Health Reporting, " September 30, 1995. Revised October 26, 1995. Revised November 7, 1996.

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14. DOE Order 231.1A, "Environment, Safety and Health Reporting, " August 19, 2003.

15. DOE M 231.1-1A, "Environment, Safety and Health Reporting Manual, " Approved March 19, 2004.

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Appendix A

DOE Reporting Sites and Reporting Codes

A

DOE Reporting Sites and Reporting Codes

A.1 Labor Categories and Occupation Codes

The following is a list of the Occupation Codes that are reported with each individual's dose record to the DOE Radiation Exposure Monitoring System (REMS) in accordance with DOE M 231.1-1 [13]. Occupation Codes are grouped into Labor Categories for the purposes of analysis and summary in this report. The occupation codes are listed in DOE M 231.1-1, Appendix G, Table 2, and represent a subset of the occupations listed in the Department of Commerce's Standard Occupational Classification (SOC) Manual (1980).

Exhibit A-1.
Labor Categories and Occupation Codes.

Labor Category	Occupation Code	Occupation Name
Agriculture	0562	Groundskeepers
	0570	Forest Workers
	0580	Misc. Agriculture
Construction	0610	Mechanics/Repairers
	0641	Masons
	0642	Carpenters
	0643	Electricians
	0644	Painters
	0645	Pipe Fitter
	0650	Miners/Drillers
	0660	Misc. Repair/Construction
Laborers	0850	Handlers/Laborers/Helpers
Management	0110	Manager - Administrator
	0400	Sales
	0450	Admin. Support and Clerical
Misc.	0910	Military
	0990	Miscellaneous
Production	0681	Machinists
	0682	Sheet Metal Workers
	0690	Operators, Plant/System/Utility
	0710	Machine Setup/Operators
	0771	Welders and Solderers
	0780	Misc. Precision/Production
Scientists	0160	Engineer
	0170	Scientist
	0184	Health Physicist
	0200	Misc. Professional
	0260	Doctors and Nurses
Service	0512	Firefighters
	0513	Security Guards
	0521	Food Service Employees
	0524	Janitors
	0525	Misc. Service
Technicians	0350	Technicians
	0360	Health Technicians
	0370	Engineering Technicians
	0380	Science Technicians
	0383	Radiation Monitors/Techs.
	0390	Misc. Technicians
Transport	0820	Truck Drivers
	0821	Bus Drivers
	0825	Pilots
	0830	Equipment Operators
	0840	Misc. Transport
Unknown	0001	Unknown

A.2 Organizations Reporting to DOE REMS, 1999-2003

Twenty-seven sites reported occupational exposure data in 2003. The following is a list of all organizations reporting to the DOE REMS from 1999 to 2003. The list provides the Operations Field Office and Site groupings used in this report as well as the organization reporting code and name.

Exhibit A-2.
Organizations Reporting to DOE REMS, 1999-2003.

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'99	'00	'01	'02	'03
Albuquerque	Ops. and Other Facilities	501001	Albuquerque Operations Office	●	●	●	●	
		502009	Albuquerque Transportation Division	●	●	●		
		530001	Kansas City Area Office	●	●	●	●	●
		531002	Honeywell Federal Manufacturing Tech.	●	●	●	●	●
		590001	Waste Isolation Pilot Project (WIPP)	●	●	●	●	●
		593004	Carlsbad Area Miscellaneous Contractors	●	●	●	●	●
		2806003	National Renewable Energy Lab (NREL) - GO	●	●	●	●	●
	Grand Junction	560605	MACTEC - ERS	●	●	●		
		560704	WASTREN	●	●	●		
	Los Alamos National Lab. (LANL)	540001	Los Alamos Area Office	●	●	●	●	●
		544003	Los Alamos National Laboratory	●	●	●	●	●
		544809	Protection Technologies Los Alamos	●	●	●	●	●
		544904	Johnson Controls, Inc.	●	●	●	●	●
	Pantex Plant (PP)	510001	Amarillo Area Office	●	●	●	●	●
		514004	Battelle - Pantex	●				
		515002	BWXT - Amarillo	●	●	●	●	●
		515006	BWXT - Amarillo - Subcontractors			●	●	●
		515009	BWXT - Amarillo - Security Forces	●	●	●	●	
	Sandia National Lab. (SNL)	570001	Kirtland Area Office		●	●	●	
		578003	Sandia National Laboratory	●	●	●	●	●
Chicago	Ops. and Other Facilities	1000503	Ames Laboratory (Iowa State)	●	●	●	●	●
		1001501	Chicago Operations Office	●	●	●	●	●
		1001606	Chicago Office Subs	●	●		●	●
		1002001	Environmental Meas. Lab. - Research	●	●	●	●	
		1004031	New Brunswick Laboratory - Research	●	●	●	●	●
		1005003	Princeton Plasma Physics Laboratory	●	●	●	●	●
	Argonne Nat'l Lab. - East (ANL-E)	1000703	Argonne National Laboratory - East	●	●	●	●	●
	Argonne Nat'l Lab. - West (ANL-W)	1000713	Argonne National Laboratory - West	●	●	●	●	●
	Brookhaven Nat'l Lab. (BNL)	1001003	Brookhaven National Laboratory	●	●	●	●	●
	Fermi Nat'l. Accelerator Lab.(FERMI)	1002503	Fermilab	●	●	●	●	●
DOE HQ	DOE Headquarters	1504001	DOE Headquarters	●	●	●	●	
	N. Korea Project	8009001	DOE North Korea Project			●		
		8011001	Russian Federation Project				●	
	Kazakhstan	8010001	DOE Kazakhstan Project	●		●		
Idaho	Idaho Site	3004001	Idaho Field Office	●	●	●	●	●
		3004402	BNFL - Idaho				●	●
		3005004	Bechtel BWXT Idaho, LLC - Services	●	●	●	●	●
		3005016	Bechtel BWXT Idaho, LLC - Subs - Construction	●	●	●	●	●
		3060605	Stoller Corporation					●
		3060616	Stoller Corporation Subs					●
		3060634	Stoller Service Subs - Grand Junction				●	

Exhibit A-2.
Organizations Reporting to DOE REMS, 1999-2003 (continued).

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'99	'00	'01	'02	'03
Nevada	Nevada Test Site (NTS)	3500000	Nevada Operations	●	●	●	●	●
		3501204	Bechtel Nevada - Las Vegas					●
		3501405	Bechtel Nevada - NTS	●	●	●	●	●
		3501416	Bechtel Nevada - NTS Subcontractors	●	●	●	●	●
		3501503	Bechtel Nevada - Special Technologies Labs	●	●			
		3501604	Bechtel Nevada - Washington Aerial Meas.			●	●	●
		3507501	Nevada Field Office	●				
		3507514	Nevada Miscellaneous Contractors	●	●	●	●	●
		3507531	Defense Nuclear Agency - Kirtland AFB	●				
		3508004	Nye County Sheriff	●	●	●	●	●
		3508703	Science Applications Int'l. Corp. - NV	●	●	●	●	
		3509009	Wackenhut Services, Inc. - NV	●	●	●	●	●
Oak Ridge	Ops. and Other Facilities	4004203	Oak Ridge Inst. for Science & Educ. (ORISE)	●	●	●	●	●
		4004501	Oak Ridge Field Office	●	●	●	●	●
		4009006	Morrison-Knudsen (WSSRAP)	●	●	●		
		4009503	Thomas Jefferson National Accel. Facility	●	●	●	●	●
		4542005	RMI Company	●				
	Oak Ridge Site	4004602	UT-Battelle: Foster Wheeler					●
		4005505	LMES/MK - Ferguson Subcontractors	●				
		4006002	Bechtel-Jacobs Co., LLC – ETTP	●	●	●	●	●
		4006302	British Nuclear Fuels Limited (BNFL) (ETTP)	●	●	●	●	●
		4006406	Decontamination & Recovery Services - ETTP	●	●	●		
		4006503	UT-Battelle - ORNL	●	●	●	●	●
		4006510	Bechtel Jacobs - ORNL		●	●	●	●
		4007509	Wackenhut Services		●	●	●	●
		4008002	BWXT Y-12, LLC	●	●	●		
		4008010	Bechtel-Jacobs - Y-12		●	●	●	●
		4018102	BWXT, Y-12			●	●	●
	Paducah Gas. Diff. Plant (PGDP)	4007002	Bechtel-Jacobs Co., LLC – Paducah	●	●	●	●	●
	Portsmouth Gas. Diff. Plant (PORTS)	4002502	Bechtel-Jacobs (Portsmouth)	●	●	●	●	●
Oakland	Ops. and Other Facilities	8001003	Boeing, Rocketdyne - ETEC	●	●	●	●	
		8001023	Rocketdyne - Boeing					●
		8006103	U. of Cal./Davis, Radiobiology Lab. - LEHR	●	●	●	●	●
		8007001	Oakland Field Office					●
	Lawrence Berkeley Nat'l. Lab. (LBNL)	8003003	Lawrence Berkeley National Laboratory	●	●	●	●	●
	Lawrence Livermore Nat'l. Lab. (LLNL)	8004003	Lawrence Livermore National Laboratory	●	●	●	●	●
		8004004	LLNL Subcontractors			●	●	●
		8005003	LLNL - Nevada				●	●
	Stanford Linear Acc. Center (SLAC)	8008003	Stanford Linear Accelerator Center	●	●	●	●	●
		8009005	Separation Process Research Unit			●		

Exhibit A-2.
Organizations Reporting to DOE REMS, 1999-2003 (continued).

Operations/ Field Office		Organization Code	Organization Name	Year Reported *				
				'99	'00	'01	'02	'03
Ohio	Ops. and Other Facilities	4500001	Ohio Field Office	●	●	●	●	●
		4510001	Miamisburg Envir. Mgmt. Project Office	●	●	●	●	●
		4510006	MEMP Office Subs	●	●	●	●	●
		4517003	Battelle Memorial Institute - Columbus	●	●	●	●	●
	Fernald Environmental	4521001	Fernald Envir. Mgmt. Project Office	●	●	●	●	●
		4521004	FEMP Office Service Subcontractors	●	●	●	●	●
		4523702	Flour Fernald - FEMP	●	●	●	●	●
		4523704	Flour Fernald Service Vendors	●	●	●	●	●
		4523706	Flour Fernald Subcontractors	●	●	●	●	●
	Mound Plant	4516002	CH2M Hill-Mound, Inc.	●	●	●	●	●
		4516004	CH2M Hill-Mound, Inc. - Subcontractors	●	●	●	●	●
		4516009	CH2M Hill-Mound, Inc. - Security Forces	●	●	●	●	●
	West Valley Project	4530001	West Valley Area Office			●		
		4539004	West Valley Nuclear Services, Inc. (WVNS)	●	●	●	●	●
		4542005	RMI Environmental Services		●	●	●	●
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	7700001	Rocky Flats Office	●	●	●	●	●
		7700007	Rocky Flats Office Subs					
		7707002	Rocky Flats Prime Contractors	●	●	●	●	●
		7707004	Rocky Flats Subcontractors	●	●	●	●	●
Richland	Hanford Site	4700805	Bechtel National, Inc. - WTP			●	●	●
		4701001	Office of River Protection					●
		4707104	CH2M Hill Hanford Group		●	●	●	●
		7500503	Battelle Memorial Institute (PNL)	●	●	●	●	●
		7500605	Environmental Restoration Contr. (ERC)				●	●
		7500705	Bechtel Power Co.	●	●	●		
		7502504	Hanford Environmental Health Foundation	●	●	●	●	●
		7503005	Kaiser Engineers Hanford - Cost Const.	●				
		7505004	Fluor Daniel - Hanford	●	●	●	●	●
		7505005	Fluor Daniel Northwest	●	●	●	●	●
		7505006	Fluor Daniel Northwest Services	●	●	●	●	●
		7505012	Babcock Wilcox Hanford	●	●	●		
		7505013	Babcock Wilcox Protection, Inc.	●				
		7505024	Rust Services Hanford	●	●	●	●	●
		7505025	Rust Federal Services Northwest	●	●	●	●	●
		7505034	Duke Engineering Services Hanford	●	●	●	●	●
		7505035	Duke Engineering & Services Northwest, Inc.	●	●	●		
		7505044	NUMATEC Hanford	●	●	●	●	●
		7505054	Lockheed Martin Hanford	●				

Exhibit A-2.
Organizations Reporting to DOE REMS, 1999-2003 (continued).

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'99	'00	'01	'02	'03
Richland	Hanford Site	7505055	Lockheed Martin Info Tech (LMIT)	●	●	●	●	●
		7505064	Dyncorp Hanford	●	●	●		
		7505075	SGN Eurisys Services Corp.	●	●	●	●	●
		7505099	Hanford Security	●	●	●	●	●
		7506001	Richland Field Office	●	●	●	●	●
		7509104	Verizon/Qwest	●	●	●	●	●
Savannah River	Savannah River Site (SRS)	8500505	Bechtel Construction - SR	●	●	●	●	●
		8501002	Westinghouse Savannah River Co.	●	●	●	●	●
		8501014	Westinghouse S.R. Subcontractors	●	●	●	●	●
		8505001	S.R. Forest Station			●		
		8505501	Savannah River Field Office	●	●	●	●	●
		8507004	Miscellaneous DOE Contractors - SR	●	●	●	●	●
		8507504	Southern Bell Tel. & Tel.			●	●	
		8509003	Univ. of Georgia Ecology Laboratories	●	●	●	●	●
		8509509	Wackenhut Services, Inc. - SR	●	●	●	●	●
Not included in this report (see Appendix D)								
Pittsburgh Naval Reactor Office	Pittsburgh Naval Reactor Office	6007001	Pittsburgh N.R. Office					
		6007504	Bechtel Plant Apparatus Division					
		6008003	Westinghouse Electric (BAPL)					
		6009003	Westinghouse Electric (NRF)					
Schenectady Naval Reactor Office	Schenectady Naval Reactor Office	6009014	Newport News Reactor Services					
		9004003	LM-KAPL - Kesselring					
		9004005	Gen. Dynam. - Kesselring - Electric Boat					
		9005003	LM-KAPL - Knolls					
		9005004	LM-KAPL - Knolls Subs					
		9007003	LM-KAPL - Windsor					
		9007005	LM-KAPL - Windsor - Electric Boat					
		9009001	Schenectady N.R. Office					

* Those organizations no longer reporting radiation exposure information have either ceased operations requiring the monitoring and reporting of radiation records, are no longer under contract or subcontract at the DOE facility, or have changed organization codes or the name of the organization.

A.3 Facility Type Codes

The following is the list of Facility Type Codes reported to REMS in accordance with DOE M 231.1-1 [13]. A facility type code is reported with each individual's dose record and indicates the facility type where the majority of the individual's dose was accrued during the monitoring year.

Exhibit A-3.
Facility Type Codes.

Facility Type Code	Description
10	Accelerator
21	Fuel/Uranium Enrichment
22	Fuel Fabrication
23	Fuel Processing
40	Maintenance and Support (Site-Wide)
50	Reactor
61	Research, General
62	Research, Fusion
70	Waste Processing/Mgmt.
80	Weapons Fab. and Testing
99	Other

See complete Facility Type descriptions shown in Appendix C.

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Appendix B

Additional Data

B

Additional Data

Exhibit B-1a: Operations Office/Site Dose Data - 2001

Operations/ Field Office	Site	2001 Collective TEDE (person-rem)	Percent Change from 2000	Number with Meas. Dose	Percent Change from 2000	Avg. Meas. TEDE (rem)	Percent Change from 2000	Percentage of Coll. TEDE above 0.500 rem	Percent Change from 2000
Albuquerque	Ops. and Other Facilities	1.2	**347%** ▲	95	**150%** ▲	0.013	79% ▲	0%	0%
	Los Alamos National Lab. (LANL)	112.9	-42% ▼	1,330	-3% ▼	0.085	-41% ▼	31%	-34% ▼
	Pantex Plant (PP)	43.6	25% ▲	293	6% ▲	0.149	18% ▲	32%	2% ▲
	Sandia National Lab. (SNL)	4.7	-38% ▼	99	-6% ▼	0.048	-34% ▼	0%	-9% ▼
	Grand Junction	0.1	9% ▲	2	-67% ▼	0.038	226% ▲	0%	0%
Chicago	Ops. and Other Facilities	7.8	119% ▲	162	50% ▲	0.048	46% ▲	0%	0%
	Argonne National Lab. - East (ANL-E)	23.0	34% ▲	187	2% ▲	0.123	31% ▲	47%	10% ▲
	Argonne National Lab. - West (ANL-W)	19.8	-5% ▼	258	10% ▲	0.077	-14% ▼	0%	-5% ▼
	Brookhaven National Lab. (BNL)	14.6	-35% ▼	387	-10% ▼	0.038	-27% ▼	0%	-5% ▼
	Fermi Nat'l. Accelerator Lab. (FERMI)	10.7	-14% ▼	368	-9% ▼	0.029	-5% ▼	0%	-4% ▼
DOE HQ	DOE Headquarters (includes DNFSB)	0.0	-56% ▼	5	-55% ▼	0.006	-3% ▼	0%	0%
	North Korea Project	1.0		8		0.130			
	Kazakhstan								
Idaho	Idaho Site	106.6	81% ▲	1,088	37% ▲	0.098	32% ▲	19%	-2% ▼
Nevada	Nevada Test Site (NTS)	1.3	-18% ▼	32	33% ▲	0.041	-39% ▼	0%	0%
Oakland	Ops. and Other Facilities	1.6	72% ▲	134	1% ▲	0.012	70% ▲	0%	0%
	Lawrence Berkeley National Lab. (LBNL)	0.7	-39% ▼	21	-52% ▼	0.032	28% ▲	0%	0%
	Lawrence Livermore National Lab. (LLNL)	18.6	46% ▲	153	6% ▲	0.121	38% ▲	50%	**20%** ▲
	Stanford Linear Accelerator Center (SLAC)	1.4	-75% ▼	35	-93% ▼	0.039	**250%** ▲	0%	0%
Oak Ridge	Ops. and Other Facilities	2.6	38% ▲	144	15% ▲	0.018	20% ▲	0%	0%
	Oak Ridge Site	120.0	2% ▲	2,576	13% ▲	0.047	-10% ▼	11%	3% ▲
	Paducah Gaseous Diff. Plant (PGDP)	5.0	2% ▲	122	94% ▲	0.041	-48% ▼	0%	0%
	Portsmouth Gaseous Diff. Plant (PORTS)	1.2	-23% ▼	35	-20% ▼	0.034	-3% ▼	0%	0%
Ohio	Ops. and Other Facilities	2.0	6% ▲	89	-41% ▼	0.023	79% ▲	0%	0%
	Battelle Memorial Institute - Columbus	35.2	12% ▲	84	-20% ▼	**0.419**	40% ▲	**82%**	15% ▲
	Fernald Environmental Mgmt. Project	11.4	-24% ▼	355	-16% ▼	0.032	-10% ▼	0%	0%
	Mound Plant	1.2	11% ▲	97	-21% ▼	0.013	41% ▲	0%	0%
	West Valley Project	22.2	34% ▲	233	-5% ▼	0.095	42% ▲	2%	2% ▲
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	**240.7**	-19% ▼	2,436	5% ▲	0.099	-22% ▼	23%	-12% ▼
Richland	Hanford Site	213.6	-2% ▼	2,219	15% ▲	0.096	-15% ▼	32%	-4% ▼
Savannah River	Savannah River Site (SRS)	207.6	27% ▲	**3,640**	8% ▲	0.057	18% ▲	16%	11% ▲
Totals		**1,232.4**	**-3%** ▼	**16,687**	**4%** ▲	**0.074**	**-7%** ▼	**0%**	**-30%** ▼

Note: Boxed values indicate the greatest value in each column.

The collective dose decreased by 3% from 2000 to 2001. LANL and Rocky Flats were primary contributors to this decrease. The decrease at LANL was mainly due to a decrease in internal dose when compared to the three individuals that exceeded the annual DOE limit in 2000.

Exhibit B-1b: Operations Office/Site Dose Data - 2002

Operations/ Field Office	Site	2002 Collective TEDE (person-rem)	Percent Change from 2001	Number with Meas. Dose	Percent Change from 2001	Avg. Meas. TEDE (rem)	Percent Change from 2001	Percentage of Coll. TEDE above 0.500 rem	Percent Change from 2001
Albuquerque	Ops. and Other Facilities	2.5	101% ▲	118	24% ▲	0.021	62% ▲	0%	0%
	Los Alamos National Lab. (LANL)	163.5	45% ▲	1,696	28% ▲	0.096	14% ▲	35%	4% ▲
	Pantex Plant (PP)	47.3	9% ▲	292	0%	0.162	9% ▲	32%	0%
	Sandia National Lab. (SNL)	4.5	-4% ▼	109	10% ▲	0.042	-13% ▼	0%	0%
	Grand Junction*								
Chicago	Ops. and Other Facilities	4.5	-42% ▼	182	12% ▲	0.025	-48% ▼	12%	12% ▲
	Argonne National Lab. - East (ANL-E)	23.6	2% ▲	233	25% ▲	0.101	-18% ▼	39%	-8% ▼
	Argonne National Lab. - West (ANL-W)	24.9	26% ▲	278	8% ▲	0.090	17% ▲	8%	8% ▲
	Brookhaven National Lab. (BNL)	26.2	79% ▲	439	13% ▲	0.060	58% ▲	20%	20% ▲
	Fermi Nat'l. Accelerator Lab. (FERMI)	12.8	20% ▲	389	6% ▲	0.033	14% ▲	0%	0%
DOE HQ	DOE Headquarters (includes DNFSB)	0.0		0		0.0		0%	0%
	Russian Federation Project	0.0		0		0.0		0%	0%
Idaho	Idaho Site	76.0	-29% ▼	1,089	0%	0.070	-29% ▼	4%	-15% ▼
Nevada	Nevada Test Site (NTS)	0.9	-30% ▼	30	-6% ▼	0.031	-25% ▼	0%	0%
Oakland	Ops. and Other Facilities	3.2	103% ▲	81	-40% ▼	0.040	**236%** ▲	19%	19% ▲
	Lawrence Berkeley National Lab. (LBNL)	0.9	31% ▲	33	57% ▲	0.027	-16% ▼	0%	0%
	Lawrence Livermore National Lab. (LLNL)	28.0	51% ▲	163	7% ▲	0.172	41% ▲	60%	11% ▲
	Stanford Linear Accelerator Center (SLAC)	3.1	**125%** ▲	79	**126%** ▲	0.039	0%	0%	0%
Oak Ridge	Ops. and Other Facilities	1.4	-48% ▼	103	-28% ▼	0.013	-27% ▼	0%	0%
	Oak Ridge Site	107.8	-10% ▼	2,304	-11% ▼	0.047	0%	4%	-7% ▼
	Paducah Gaseous Diff. Plant (PGDP)	8.8	75% ▲	232	90% ▲	0.038	-8% ▼	0%	0%
	Portsmouth Gaseous Diff. Plant (PORTS)	1.0	-18% ▼	37	6% ▲	0.026	-23% ▼	0%	0%
Ohio	Ops. and Other Facilities	0.6	-71% ▼	49	-45% ▼	0.012	-48% ▼	0%	0%
	Battelle Memorial Institute - Columbus	44.4	26% ▲	103	23% ▲	**0.431**	3% ▲	**80%**	-3% ▼
	Fernald Environmental Mgmt. Project	17.0	50% ▲	572	61% ▲	0.030	-7% ▼	0%	0%
	Mound Plant	2.7	120% ▲	198	104% ▲	0.014	8% ▲	0%	0%
	West Valley Project	30.5	38% ▲	239	3% ▲	0.128	34% ▲	24%	**21%** ▲
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	250.0	4% ▲	2,175	-11% ▼	0.115	16% ▲	24%	1% ▲
Richland	Hanford Site	**274.4**	28% ▲	2,611	18% ▲	0.105	9% ▲	29%	-3% ▼
Savannah River	Savannah River Site (SRS)	199.1	-4% ▼	**3,217**	-12% ▼	0.062	9% ▲	15%	-1% ▼
Totals		**1,359.6**	**10%** ▲	**17,051**	**2%** ▲	**0.080**	**8%** ▲	**24%**	**24%** ▲

Note: Boxed values indicate the greatest value in each column.

*No longer in operation, therefore not required to report.

The collective dose increased by 10% from 2001 to 2002. Primary contributors to the increase include LANL (up 45%) and Hanford (up 28%). Increases at these sites were attributed to increased processing of spent nuclear fuel in K-Basins at Hanford and increased work on pit manufacturing, Pu-238 fuel and heat source work, nuclear material processing, nuclear materials science, pit disassembly, and associated support at LANL.

Exhibit B-1c: Operations Office/Site Dose Data - 2003

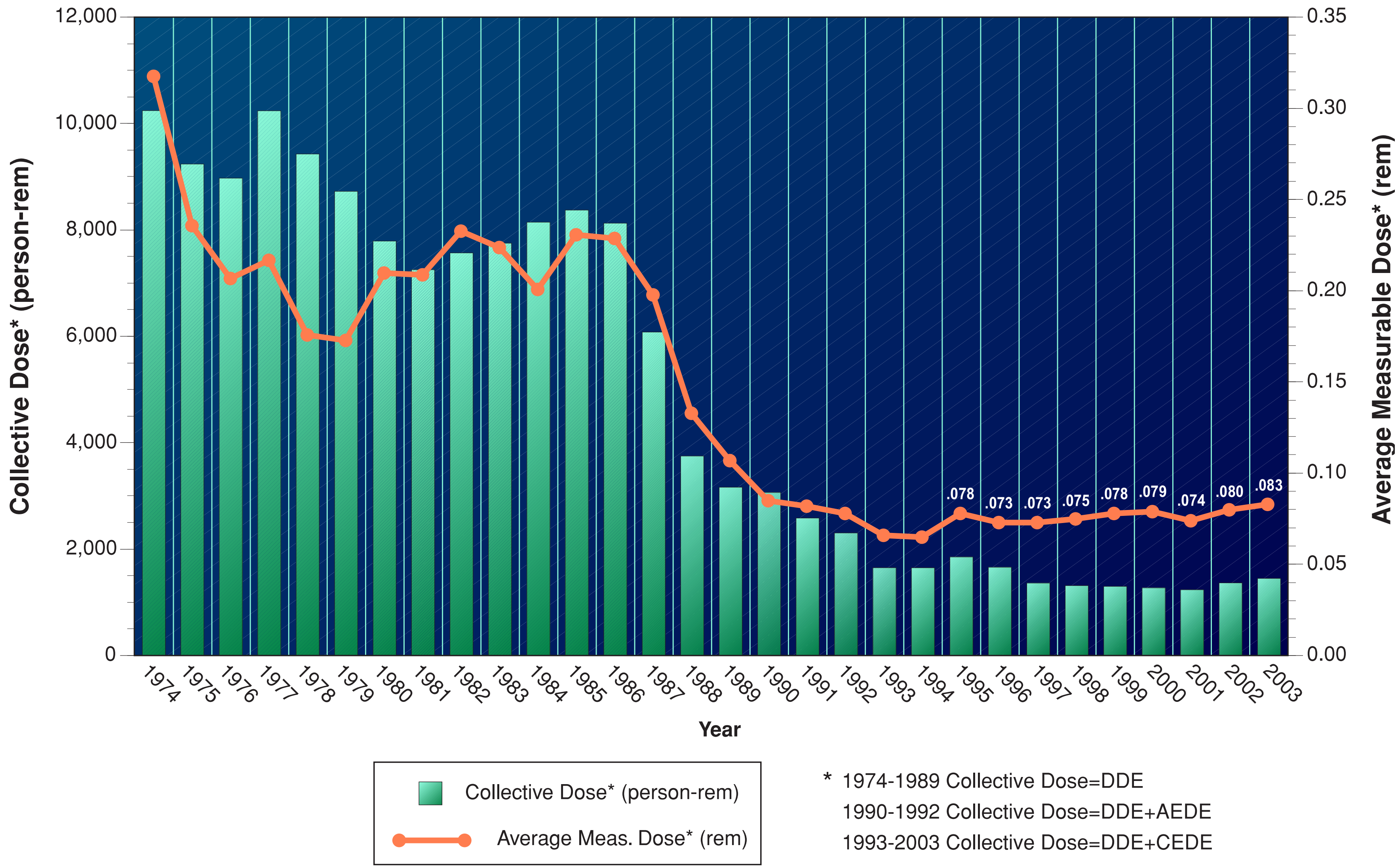
		2003							
Operations/ Field Office	**Site**	Collective TEDE (person-rem)	Percent Change from 2002	Number with Meas. Dose	Percent Change from 2002	Avg. Meas. TEDE (rem)	Percent Change from 2002	Percentage of Coll. TEDE above 0.500 rem	Percent Change from 2002
Albuquerque	Ops. and Other Facilities	1.3	-47% ▼	107	-9% ▼	0.012	-42% ▼	0%	%
	Los Alamos National Lab. (LANL)	240.0	47% ▲	2,047	21% ▲	0.117	22% ▲	49%	14% ▲
	Pantex Plant (PP)	35.9	-24% ▼	290	-1% ▼	0.124	-24% ▼	26%	-6% ▼
	Sandia National Lab. (SNL)	10.2	125% ▲	250	129% ▲	0.041	-2% ▼	0%	0%
	Grand Junction *								
Chicago	Ops. and Other Facilities	1.2	-73% ▼	153	-16% ▼	0.008	-68% ▼	0%	-12% ▼
	Argonne National Lab. - East (ANL-E)	21.4	-9% ▼	231	-1% ▼	0.093	-8% ▼	8%	-31% ▼
	Argonne National Lab. - West (ANL-W)	28.8	15% ▲	277	0%	0.104	16% ▲	22%	14% ▲
	Brookhaven National Lab. (BNL)	12.2	-54% ▼	306	-30% ▼	0.040	-33% ▼	5%	-15% ▼
	Fermi Nat'l. Accelerator Lab. (FERMI)	25.7	101% ▲	612	57% ▲	0.042	28% ▲	7%	7% ▲
DOE HQ	DOE Headquarters (includes DNFSB)								
	North Korea Project								
Idaho	Idaho Site	64.0	-16% ▼	1,141	5% ▲	0.056	20% ▲	3%	-1% ▼
Nevada	Nevada Test Site (NTS)	3.2	**251%** ▲	69	**130%** ▲	0.047	53% ▲	0%	0%
Oakland	Ops. and Other Facilities	0.9	-72% ▼	64	-21% ▼	0.014	65% ▲	0%	-19% ▼
	Lawrence Berkeley National Lab. (LBNL)	1.0	16% ▲	20	-39% ▼	0.052	91% ▲	0%	0%
	Lawrence Livermore National Lab. (LLNL)	36.4	30% ▲	202	24% ▲	0.180	5% ▲	69%	9% ▲
	Stanford Linear Accelerator Center (SLAC)	3.1	2% ▲	109	38% ▲	0.029	-26% ▼	0%	0%
Oak Ridge	Ops. and Other Facilities	1.3	-8% ▼	98	-5% ▼	0.013	-3% ▼	0%	0%
	Oak Ridge Site	116.0	8% ▲	2,389	4% ▲	0.049	4% ▲	6%	2% ▲
	Paducah Gaseous Diff. Plant (PGDP)	3.2	-64% ▼	38	-84% ▼	0.084	**122%** ▲	0%	0%
	Portsmouth Gaseous Diff. Plant (PORTS)	0.6	-39% ▼	26	-30% ▼	0.023	-13% ▼	0%	0%
Ohio	Ops. and Other Facilities	0.7	27% ▲	47	-4% ▼	0.016	33% ▲	0%	0%
	Battelle Memorial Institute - Columbus	35.9	-19% ▼	100	-3% ▼	**0.359**	-17% ▼	**73%**	-6% ▼
	Fernald Environmental Mgmt. Project	16.2	-5% ▼	631	10% ▲	0.026	-14% ▼	0%	0%
	Mound Plant	5.8	112% ▲	237	20% ▲	0.025	77% ▲	0%	0%
	West Valley Project	41.7	37% ▲	207	-13% ▼	0.202	58% ▲	64%	**41%** ▲
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	198.6	-21% ▼	1,761	-19% ▼	0.113	-2% ▼	27%	3% ▲
Richland	Hanford Site	**280.8**	2% ▲	2,626	1% ▲	0.107	2% ▲	37%	8% ▲
Savannah River	Savannah River Site (SRS)	258.6	30% ▲	**3,446**	7% ▲	0.075	21% ▲	16%	1% ▲
Totals		**1,444.6**	**6%** ▲	**17,484**	**3%** ▲	**0.083**	**4%** ▲	**29%**	**5%** ▲

Note: Boxed values indicate the greatest value in each column.

*No longer in operation, therefore not required to report.

The collective TEDE increased by 6% from 2002 to 2003. This is the third year in a row that it has increased. The largest contributors to the increase were LANL and Savannah River. Battelle Memorial Institute in Columbus continues to have the highest average measurable TEDE of any site, with a value over four times the value for all of DOE.

Exhibit B-2a: Collective Dose and Average Measurable Dose 1974-2003



* 1974-1989 Collective Dose=DDE
1990-1992 Collective Dose=DDE+AEDE
1993-2003 Collective Dose=DDE+CEDE

Exhibit B-2b: Number with Measurable Dose and Average Measurable Dose 1974-2003

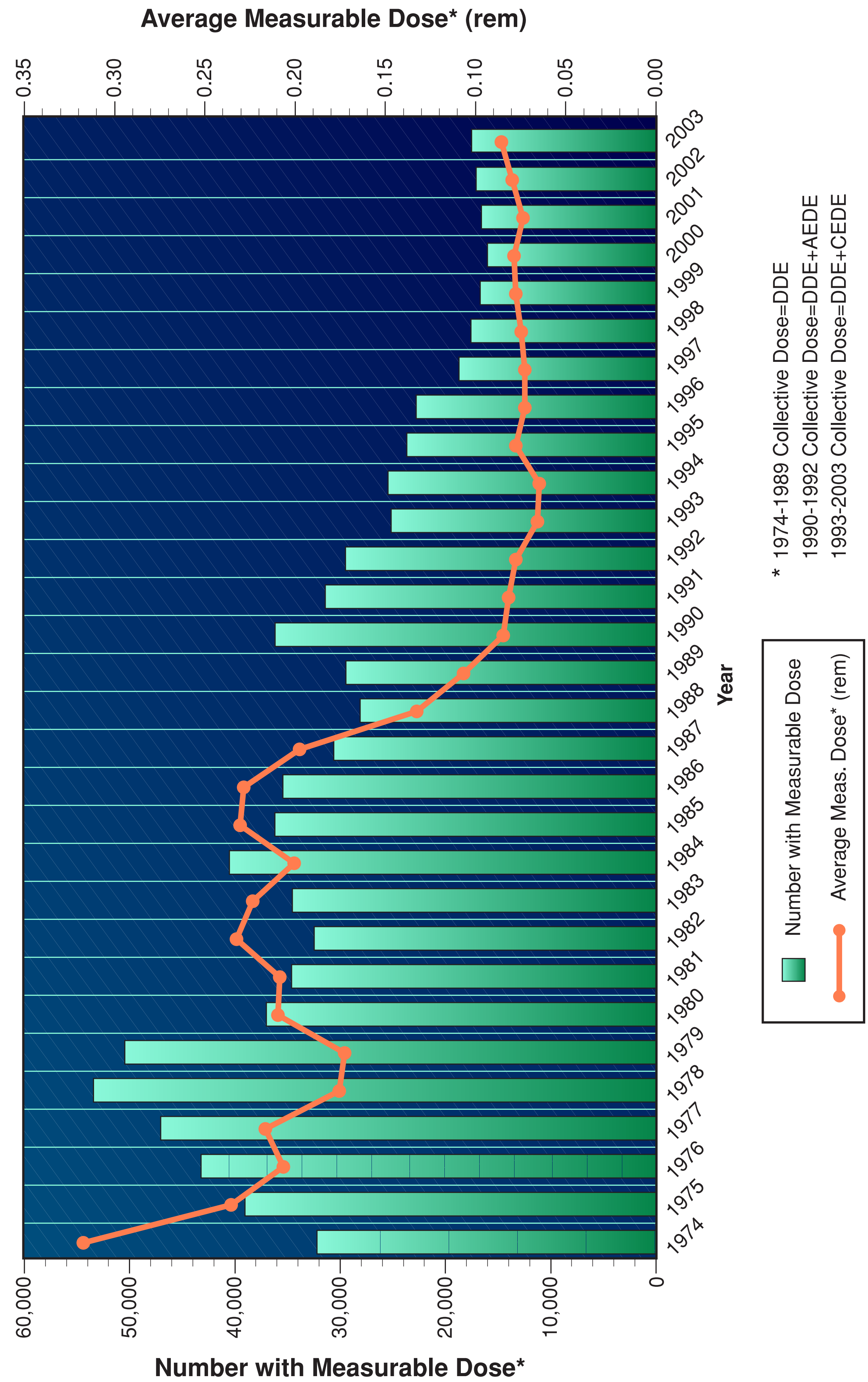


Exhibit B-3: Distribution of Deep Dose Equivalent (DDE) 1974-2003 and Total Effective Dose Equivalent (TEDE) 1990-2003

Deep Dose Equivalent (DDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Year	Less than 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	Total Monitored	No. with Meas. DDE	Coll. DDE (person-rem)	Avg. Meas. DDE
1974	37,060	29,735	1,531	652	149	40	4								69,171	32,111	**10,202** ◄	**0.318** ◄
1975	41,390	36,795	1,437	541	122	28				1					80,314	38,924	9,202	0.236
1976	38,408	41,321	1,296	387	70	6	1								81,489	43,081	8,938	0.207
1977	41,572	44,730	1,499	540	103	23			1	2				2	88,472	46,900	10,199	0.217
1978	43,317	51,444	1,311	439	53	11									96,575	**53,258** ◄	9,390	0.176
1979	48,529	48,553	1,281	416	33	10	1							2	98,825	50,296	8,691	0.173
1980	43,663	35,385	1,113	387	16										80,564	36,901	7,760	0.210
1981	43,775	33,251	967	263	29	5									78,290	34,515	7,223	0.209
1982	47,420	30,988	990	313	56	28									79,795	32,375	7,538	0.233
1983	48,340	32,842	1,225	294	49	31									82,781	34,441	7,720	0.224
1984	46,056	38,821	1,223	312	31	11									86,454	40,398	8,113	0.201
1985	54,582	34,317	1,362	356	51	8				1					90,677	36,095	8,340	0.231
1986	53,586	33,671	1,279	349	35	1		1					1		88,923	35,337	8,095	0.229
1987	45,241	28,995	1,210	283	36										75,765	30,524	6,056	0.198
1988	48,704	27,492	502	34											76,732	28,028	3,735	0.133
1989	56,363	28,925	428	21											85,737	29,374	3,151	0.107
1990	76,798	31,110	140	17											108,065	31,267	2,230	0.071
1991	92,526	27,149	95												119,770	27,244	1,762	0.065
1992	98,900	24,769	42												123,711	24,811	1,504	0.061
1993	103,905	23,050	86			1									127,042	23,137	1,534	0.066
1994	92,245	24,189	77												116,511	24,266	1,600	0.066
1995	104,793	22,330	153												**127,276** ◄	22,483	1,809	0.080
1996	101,529	21,720	74	1											123,324	21,795	1,598	0.073
1997	89,805	17,331	45												107,181	17,376	1,285	0.074
1998	92,803	15,669	36												108,508	15,705	1,219	0.078
1999	98,125	14,877	62												113,064	14,939	1,142	0.076
2000	88,621	14,206	54												102,881	14,260	1,086	0.076
2001	82,950	14,821	47												97,818	14,868	1,173	0.079
2002	84,874	15,282	64	1											100,221	15,347	1,291	0.084
2003	86,756	15,659	93	1											102,509	15,753	1,350	0.086

Total Effective Dose Equivalent (TEDE)*

Year	Less than 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	Total Monitored	No. with Meas. TEDE	Coll. TEDE (person-rem)	Avg. Meas. TEDE
1990	71,991	35,780	226	47	8	8	1	2		1				1	108,065	**36,074** ◄	**3,052** ◄	**0.085** ◄
1991	88,444	31,086	193	25	9	8		2		1				2	119,770	31,326	2,574	0.082
1992	94,297	29,240	132	22	9	6		2	1		1			1	123,711	29,414	2,295	0.078
1993	101,947	25,002	87			2				1	1			2	127,042	25,095	1,644	0.066
1994	91,121	25,310	79		1										116,511	25,390	1,643	0.065
1995	103,663	23,454	157		1	1									**127,276** ◄	23,613	1,845	0.078
1996	100,599	22,641	80	2	1								1		123,324	22,725	1,652	0.073
1997	88,502	18,627	48	1	2	1									107,181	18,675	1,356	0.073
1998	90,964	17,501	41	1				1							108,508	17,544	1,309	0.075
1999	96,396	16,585	80	1	1			1							113,064	16,668	1,295	0.078
2000	86,898	15,922	58								1		1	1	102,881	15,983	1,267	0.079
2001	81,131	16,638	48	2											97,818	16,687	1,232	0.074
2002	83,170	16,985	65	1											100,221	17,051	1,360	0.080
2003	85,025	17,384	97	1						1		1			102,509	17,484	1,445	0.083

* 1990-1992 TEDE=DDE+AEDE 1993-2003 TEDE=DDE+CEDE Note: Arrowed values indicate the greatest value in each column.

Exhibit B-4: Internal Dose by Operations/Site, 2001-2003

Operations/ Field Office	Site	No. of Individuals with New Intakes*			Collective CEDE Dose from Intake (person-rem)			Average CEDE (rem)		
		2001	2002	2003	2001	2002	2003	2001	2002	2003
Albuquerque	LANL	97	111	179	2.948	3.200	20.131	0.030	0.029	**0.112** ◄
	Pantex	25	30	56	0.669	0.304	0.621	0.027	0.010	0.011
	Sandia National Lab	1	0	5	0.005	0	0.012	0.005	0	0.002
	Grand Junction	2	0	0	0.076	0	0	0.038	0	0
Chicago	Ops. and Other Facilities	12	8	0	0.038	0.028	0	0.003	0.004	0
	ANL-E	16	17	45	0.523	0.591	2.414	0.033	0.035	0.054
	ANL-W	0	2	0	0	0.013	0	0	0.007	0
	BNL	30	18	4	0.223	0.302	0.033	0.007	0.017	0.008
Idaho	Idaho Site	5	22	24	0.083	2.141	0.666	0.017	**0.097** ◄	0.028
Oakland	LBNL	7	9	0	0.124	0.165	0	0.018	0.018	0
	LLNL	0	2	7	0	0.007	0.037	0	0.004	0.005
Oak Ridge	Oak Ridge Site	**1,779** ◄	**1,559** ◄	**1,518** ◄	**46.193** ◄	**54.653** ◄	**56.090** ◄	0.026	0.035	0.037
	Paducah	2	10	3	0.041	0.104	0.026	0.021	0.010	0.009
	Portsmouth	2	4	0	0.013	0.026	0	0.007	0.007	0
Ohio	OH	31	28	8	0.302	0.188	0.062	0.010	0.007	0.008
	BMI - Columbus	43	35	28	0.228	0.083	0.093	0.005	0.002	0.003
	Fernald	20	24	39	0.093	0.162	0.209	0.005	0.007	0.005
	Mound Plant	77	276	357	0.538	2.161	5.777	0.007	0.008	0.016
	WVNS	0	38	9	0	1.088	0.390	0	0.029	0.043
Rocky Flats	Rocky Flats	47	99	134	3.327	2.902	5.698	**0.071** ◄	0.029	0.043
Richland	Hanford Site	23	24	25	0.919	0.263	1.617	0.040	0.011	0.065
Savannah River	Savannah River Site	143	102	131	2.611	0.309	0.626	0.018	0.003	0.005
Totals		**2,362**	**2,418**	**2,572**	**58.954**	**68.690**	**94.502**	**0.025**	**0.028**	**0.037**

Facilities with no new intakes reported during the past 3 years: Albuquerque Ops., Oak Ridge Ops., DOE-HQ, Fermi Lab, NTS, Oakland Ops., and SLAC.

* Only includes intakes that occurred during the monitoring year. Individuals may be counted more than once.

Note: Arrowed values indicate the greatest value in each column.

The collective CEDE increased by 38% from 2002 to 2003. The increase was due to a nearly four-fold increase in internal dose from plutonium. The main contributor to this increase was the two exposures in excess of 5 rem (50 mSv) at LANL (see Section 3.3.1). Mound and Rocky Flats also reported increases in internal dose from plutonium from 2002 to 2003.

Exhibit B-5: Neutron Dose Distribution by Operations/Site, 2003

Operations	Site	No Meas. Dose	Meas. <0.1	0.1-0.25	0.25-0.5	0.5-0.75	0.75-1.0	1-2	>2	Total Monitored*	No. of Individuals with Meas. Dose	% of Individuals with Meas. Dose	Collective Neutron Dose (person-rem)	Average Meas. Neutron Dose (rem)
Albuquerque	Albuquerque	754								754				
	Los Alamos National Lab. (LANL)	9,275	1,148	174	51	9	4	9		10,670	**1,395** ◄	**13%** ◄	**90.312** ◄	0.065
	Pantex Plant (PP)	5,181	87	13	2					5,283	102	2%	5.137	0.050
	Sandia National Lab. (SNL)	3,024								3,024				
Chicago	Chicago Operations	596	20							616	20	3%	0.099	0.005
	Argonne Nat'l. Lab. - East (ANL-E)	2,262	100	8						2,370	108	5%	3.700	0.034
	Argonne Nat'l. Lab. - West (ANL-W)	657	23	2						682	25	4%	1.087	0.043
	Brookhaven Nat'l. Lab. (BNL)	4,107	28							4,135	28	1%	0.293	0.010
	Fermi Nat'l. Accelerator Lab. (FERMI)	1,879								1,879				
DOE HQ	DOE Headquarters													
	Russian Federation Project													
Idaho	Idaho Site	4,608	70	4						4,682	74	2%	2.491	0.034
Nevada	Nevada Test Site (NTS)	5,696	35	1						5,732	36	1%	1.411	0.039
Oakland	Oakland Operations	351								351				
	Lawrence Berkeley National Lab. (LBNL)	1,381	3							1,384	3	0%	0.038	0.013
	Lawrence Livermore National Lab. (LLNL)	9,690	64	11	10	4				9,779	89	1%	9.218	0.104
	Stanford Linear Accelerator Center (SLAC)	3,013	10							3,023	10	0%	0.150	0.015
Oak Ridge	Oak Ridge Operations	1,499								1,499				
	Oak Ridge Site	16,200	115	15	7					**16,337** ◄	137	1%	8.417	0.061
	Paducah Gaseous Diff. Plant (PGDP)	1,069	25	3						1,097	28	3%	1.229	0.044
	Portsmouth Gaseous Diff. Plant (PORTS)	540	1							541	1	0%	0.010	0.010
Ohio	Ohio Field Office	219								219				
	Battelle Memorial Institute - Columbus	455								455				
	Fernald Environmental Mgmt. Project	2,820								2,820				
	Mound Plant	694	1							695	1	0%	0.001	0.001
	West Valley	666								666				
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	4,208	343	87	47	11				4,696	488	10%	50.506	0.103
Richland	Hanford Site	9,598	799	98	54	6	6	3		10,564	966	9%	62.737	0.065
Savannah River	Savannah River Site (SRS)	8,080	257	152	57	8	2			8,556	476	6%	60.038	**0.126** ◄
	Totals	**98,522**	**3,129**	**568**	**228**	**38**	**12**	**12**	**0**	**102,509**	**3,987**	**4%**	**296.874**	**0.074**

* Represents the total number of monitoring records. The number of individuals specifically monitored for neutron radiation cannot be determined.
Note: Arrowed values indicate the greatest value in each column.

LANL, Hanford, Savannah River, and Rocky Flats combined contributed to 89% of the collective neutron dose in 2003. Workers at these sites receive neutron dose from the handling of plutonium in gloveboxes. LANL contributed the largest percentage (30%).

Exhibit B-6a: Distribution of TEDE by Facility Type - 2001

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Facility Type	Less than 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	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Accelerator	10,472	882	67	22	3	2						11,448	9%	976	40.147	0.041
Fuel/Uran. Enrich.	4,038	782	46	17	1							4,884	17%	846	25.845	0.031
Fuel Fabrication	1,824	330	24	1								2,179	16%	355	11.355	0.032
Fuel Processing	2,594	1,020	112	21	2							3,749	31%	1,155	52.461	0.045
Maint. and Support	11,679	1,800	275	175	83	41	15					14,068	17%	2,389	251.554	**0.105** ◄
Other	12,163	1,156	153	72	15	4	1					13,564	10%	1,401	90.807	0.065
Reactor	1,023	461	55	26	13	3	2					1,583	**35%** ◄	560	40.873	0.073
Research, General	21,821	1,809	253	110	32	8	14	1				**24,048** ◄	9%	2,227	170.584	0.077
Research, Fusion	455	94	11	10	1							571	20%	116	7.803	0.067
Waste Proc./Mgmt.	3,849	1,554	276	94	14							5,787	33%	1,938	129.898	0.067
Weapons Fab. & Test	11,213	3,671	619	292	95	31	16					15,937	30%	**4,724** ◄	**411.063** ◄	0.087
Totals	**81,131**	**13,559**	**1,891**	**840**	**259**	**89**	**48**	**1**	**0**	**0**	**0**	**97,818**	**17%**	**16,687**	**1,232.390**	**0.074**

Note: *Arrowed values indicate the greatest value in each column.*

Weapons Fabrication and Testing remains the facility type with the highest collective dose. Maintenance and Support facilities received the highest average measurable TEDE since individuals reported under this facility type tend to perform maintenance and support work at multiple facility types involving work with radiological materials.

Exhibit B-6b: Distribution of TEDE by Facility Type - 2002

Total Effective Dose Equivalent (TEDE)
Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Facility Type	Less than Meas.	Meas. 0-0.10	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	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Accelerator	9,679	945	91	43	4	4						10,766	10%	1,087	57.220	0.053
Fuel/Uran. Enrich.	4,436	677	57	8	2							5,180	14%	744	27.683	0.037
Fuel Fabrication	1,648	540	30	2								2,220	26%	572	16.982	0.030
Fuel Processing	2,555	1,023	97	17								3,692	31%	1,137	48.881	0.043
Maint. and Support	12,301	2,051	415	204	82	48	25					15,126	19%	2,825	316.582	0.112
Other	11,711	1,230	198	98	33	8	8	1				13,287	12%	1,576	29.295	0.019
Reactor	1,109	385	62	19	3	1						1,579	30%	470	135.818	**0.289** ◄
Research, General	22,946	1,735	267	112	32	8	18					**25,118** ◄	9%	2,172	175.900	0.081
Research, Fusion	361	137	15	1								514	30%	153	4.299	0.028
Waste Proc./Mgmt.	3,802	1,561	223	89	1	1						5,677	**33%** ◄	1,875	110.320	0.059
Weapons Fab. & Test	12,622	3,216	747	326	112	25	14					17,062	26%	**4,440** ◄	**436.597** ◄	0.098
Totals	**83,170**	**13,500**	**2,202**	**919**	**269**	**95**	**65**	**1**				**100,221**	**17%**	**17,051**	**1,359.577**	**0.080**

Note: Arrowed values indicate the greatest value in each column.

Weapons Fabrication and Testing remains the facility type with the highest collective dose. Maintenance and Support facilities received the highest average measurable TEDE since individuals reported under this facility type tend to perform maintenance and support work at multiple facility types involving work with radiological materials.

Exhibit B-6c: Distribution of TEDE by Facility Type - 2003

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Facility Type	Less than Meas.	Meas. 0-0.10	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	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Accelerator	9,260	1,004	86	25	3							10,378	11%	1,118	47.038	0.042
Fuel/Uran. Enrich.	5,040	648	50	10	5							5,753	12%	713	28.548	0.040
Fuel Fabrication	2,189	610	17	4								2,820	22%	631	16.192	0.026
Fuel Processing	2,328	947	114	18	1							3,408	32%	1,080	48.556	0.045
Maint. and Support	13,341	2,328	415	210	85	43	59	1				16,482	19%	3,141	365.825	**0.116** ◄
Other	10,436	1,345	156	60	48	26	10				1	12,082	14%	1,646	149.294	0.091
Reactor	1,048	390	95	36	1							1,570	33%	522	37.864	0.073
Research, General	24,446	1,901	296	146	37	19	14					**26,859** ◄	9%	2,413	205.769	0.085
Research, Fusion	322	118										440	27%	118	0.740	0.006
Waste Proc./Mgmt.	3,559	1,648	330	117	18						1	5,673	**37%** ◄	2,114	159.917	0.076
Weapons Fab. & Test	13,056	2,926	646	284	89	29	14					17,044	23%	**3,988** ◄	**384.888** ◄	0.097
Totals	**85,025**	**13,865**	**2,205**	**910**	**287**	**117**	**97**	**1**			**2**	**102,509**	**17%**	**17,484**	**1,444.631**	**0.083**

Note: Arrowed values indicate the greatest value in each column.

Weapons Fabrication and Testing remains the facility type with the highest collective dose and the number of individuals with measurable dose. It should be noted that Rocky Flats and Savannah River account for the majority (77%) of the dose reported under this facility type even though these sites are no longer actively involved in the activity. Maintenance and Support facilities received the highest average measurable TEDE since individuals reported under this facility type tend to perform maintenance and support work at multiple facility types involving work with radiological materials.

Exhibit B-7a: Collective TEDE by Operations/Site and Facility Type - 2001

DOE Operations	Site	Accelerator	Fuel/Uranium Enrichment	Fuel Fabrication	Fuel Processing	Maintenance and Support	Reactor	Research, General	Research, Fusion	Waste Processing/ Management	Weapons Fab. and Testing	Other	Totals
Albuquerque	Ops. and Other Facilities									1.1		0.1	**1.2**
	Los Alamos National Lab. (LANL)	**11.3** ◄				34.6	0.0	37.1	0.4	0.9		28.6	**112.9**
	Pantex Plant (PP)										43.6		**43.6**
	Sandia National Lab. (SNL)	0.1				0.4	2.3	0.7		0.1	0.6	0.6	**4.7**
	Grand Junction											0.1	**0.1**
Chicago	Ops. and Other Facilities	0.0						0.3	**7.4** ◄			0.0	**7.8**
	Argonne Nat'l. Lab. - East (ANL-E)	6.3				0.3		13.1		3.3		0.0	**23.0**
	Argonne Nat'l. Lab. - West (ANL-W)						0.0	19.6		0.2			**19.8**
	Brookhaven Nat'l. Lab. (BNL)	8.1				1.2	0.5	2.9		1.5		0.4	**14.6**
	Fermi Nat'l. Accelerator Lab. (FERMI)	10.7											**10.7**
DOE HQ	DOE Headquarters											0.0	**0.0**
	North Korea											1.0	**1.0**
Idaho	Idaho Site				13.9	7.3	**33.3** ◄	4.0		44.0		4.0	**106.6**
Nevada	Nevada Test Site (NTS)					1.3							**1.3**
Oakland	Ops. and Other Facilities							1.6					**1.6**
	Lawrence Berkeley National Lab. (LBNL)	0.1						0.6					**0.7**
	Lawrence Livermore National Lab. (LLNL)							18.6					**18.6**
	Stanford Linear Accelerator Center (SLAC)	1.4											**1.4**
Oak Ridge	Ops. and Other Facilities	2.3						0.3					**2.6**
	Oak Ridge Site		**19.6** ◄					**47.2** ◄			53.2	0.0	**120.0**
	Paducah Gaseous Diff. Plant (PGDP)		5.0										**5.0**
	Portsmouth Gaseous Diff. Plant (PORTS)		1.2										**1.2**
Ohio	Ops. and Other Facilities											2.0	**2.0**
	Fernald Environmental Mgmt. Project			**11.4** ◄									**11.4**
	Mound Plant					0.8					0.5		**1.2**
	West Valley											22.2	**22.2**
	Battelle Memorial Institute - Columbus					35.2							**35.2**
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)										**240.7** ◄		**240.7** ◄
Richland	Hanford Site					**154.3** ◄		11.1		17.3		**31.0** ◄	**213.6**
Savannah River	Savannah River Site (SRS)				**38.5** ◄	16.3	4.7	13.3		**61.6** ◄	72.5	0.7	**207.6**
	Totals	**40.1**	**25.8**	**11.4**	**52.5**	**251.6**	**40.9**	**168.8**	**7.8**	**129.9**	**411.0**	**91.6**	**1,232.4**

Note: Arrowed values indicate the greatest value in each column.

Rocky Flats contributed 59% of the dose attributed to the Weapons Fabrication and Testing facility type, although the site is primarily involved in materials stabilization and waste management. Hanford contributed 61% of the Site-wide Maintenance and Support dose and is involved in thermal stabilization and repackaging of plutonium-bearing materials at the Plutonium Finishing Plant and processing of spent nuclear fuel.

Exhibit B-7b: Collective TEDE by Operations/Site and Facility Type - 2002

DOE Operations	Site	Accelerator	Fuel/Uranium Enrichment	Fuel Fabrication	Fuel Processing	Maintenance and Support	Reactor	Research, General	Research, Fusion	Waste Processing/ Management	Weapons Fab. and Testing	Other	Totals
Albuquerque	Ops. and Other Facilities									2.3	0.0	0.1	**2.5**
	Los Alamos National Lab. (LANL)	14.0				48.9	0.0	**43.4** ◄	0.6	1.9	0.0	**54.8** ◄	**163.5**
	Pantex Plant (PP)										47.3		**47.3**
	Sandia National Lab. (SNL)	0.3				0.2	2.1	0.8		0.1	0.6	0.4	**4.5**
Chicago	Ops. and Other Facilities							0.2	**3.7** ◄			0.6	**4.5**
	Argonne Nat'l. Lab. - East (ANL-E)	7.5				0.1		12.7		3.3			**23.6**
	Argonne Nat'l. Lab. - West (ANL-W)						0.0	24.9					**24.9**
	Brookhaven Nat'l. Lab. (BNL)	**18.4** ◄				2.4	0.4	2.6		1.6		0.8	**26.2**
	Fermi Nat'l. Accelerator Lab. (FERMI)	12.8											**12.8**
DOE HQ	DOE Headquarters												**0.0**
	Russian Federation Project												**0.0**
Idaho	Idaho Site				19.0	12.3	**22.8** ◄	6.0		13.4		2.6	**76.0**
Nevada	Nevada Test Site (NTS)					0.9							**0.9**
Oakland	Ops. and Other Facilities							3.2					**3.2**
	Lawrence Berkeley National Lab. (LBNL)	0.1						0.8					**0.9**
	Lawrence Livermore National Lab. (LLNL)							28.0					**28.0**
	Stanford Linear Accelerator Center (SLAC)	3.1											**3.1**
Oak Ridge	Ops. and Other Facilities	1.1						0.3					**1.4**
	Oak Ridge Site		**17.9** ◄					27.0			62.8		**107.8**
	Paducah Gaseous Diff. Plant (PGDP)		8.8										**8.8**
	Portsmouth Gaseous Diff. Plant (PORTS)		1.0										**1.0**
Ohio	Ops. and Other Facilities					0.0					0.0	0.6	**0.6**
	Battelle Memorial Institute - Columbus					44.4							**44.4**
	Fernald Environmental Mgmt. Project			**17.0** ◄									**17.0**
	Mound Plant					1.9					0.9		**2.7**
	West Valley					0.0						30.5	**30.5**
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)										**250.0** ◄		**250.0**
Richland	Hanford Site					**193.6** ◄		12.4		23.9		44.4	**274.4** ◄
Savannah River	Savannah River Site (SRS)				**29.8** ◄	11.9	4.0	13.5		**63.9** ◄	75.0	1.0	**199.1**
	Totals	**57.2**	**27.7**	**17.0**	**48.9**	**316.6**	**29.3**	**175.9**	**4.3**	**110.3**	**436.6**	**135.8**	**1,359.6**

Note: Arrowed values indicate the greatest value in each column.

Rocky Flats contributes 57% of the dose attributed to the Weapons Fabrication and Testing facility type, although the site is primarily involved in materials stabilization and waste management. Hanford contributes 61% of the Site-wide Maintenance and Support dose and is involved in stabilization and repackaging of plutonium-bearing materials and processing of spent nuclear fuel.

Exhibit B-7c: Collective TEDE by Operations/Site and Facility Type - 2003

DOE Operations	Site	Accelerator	Fuel/Uranium Enrichment	Fuel Fabrication	Fuel Processing	Maintenance and Support	Reactor	Research, General	Research, Fusion	Waste Processing/ Management	Weapons Fab. and Testing	Other	Totals
Albuquerque	Ops. and Other Facilities									1.1	0.2		**1.3**
	Los Alamos National Lab. (LANL)	11.3				86.4		**46.1◄**	0.1	13.5		**82.7◄**	**240.0**
	Pantex Plant (PP)										35.9		**35.9**
	Sandia National Lab. (SNL)	1.7				1.0	2.7	1.2	0.1	1.3	0.8	1.5	**10.2**
Chicago	Ops. and Other Facilities	0.0						0.6	**0.6◄**				**1.2**
	Argonne Nat'l. Lab. - East (ANL-E)							21.4					**21.4**
	Argonne Nat'l. Lab. - West (ANL-W)					0.0		28.7					**28.8**
	Brookhaven Nat'l. Lab. (BNL)	4.1				1.7	0.4	3.1		2.2		0.7	**12.2**
	Fermi Nat'l. Accelerator Lab. (FERMI)	**25.7◄**											**25.7**
DOE HQ	DOE Headquarters												
	Russian Federation Project												
Idaho	Idaho Site				16.9	7.8	**24.5◄**	5.8		7.9		1.3	**64.0**
Nevada	Nevada Test Site (NTS)					3.2							**3.2**
Oakland	Ops. and Other Facilities							0.9					**0.9**
	Lawrence Berkeley National Lab. (LBNL)	0.1						1.0					**1.0**
	Lawrence Livermore National Lab. (LLNL)							36.4					**36.4**
	Stanford Linear Accelerator Center (SLAC)	3.1											**3.1**
Oak Ridge	Ops. and Other Facilities	1.0						0.3					**1.3**
	Oak Ridge Site		**24.8◄**					28.7			62.5		**116.0**
	Paducah Gaseous Diff. Plant (PGDP)		3.2										**3.2**
	Portsmouth Gaseous Diff. Plant (PORTS)		0.6										**0.6**
Ohio	Ops. and Other Facilities										0.0	0.7	**0.7**
	Battelle Memorial Institute - Columbus					35.9							**35.9**
	Fernald Environmental Mgmt. Project			**16.2◄**									**16.2**
	Mound Plant					4.0					1.8	0.0	**5.8**
	West Valley											41.7	**41.7**
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)										**198.6◄**		**198.6**
Richland	Hanford Site					**211.6◄**		14.7		34.1		20.4	**280.8◄**
Savannah River	Savannah River Site (SRS)				**31.7◄**	14.3	10.3	17.0		**99.9◄**	85.1	0.2	**258.6**
	Totals	**47.0**	**28.5**	**16.2**	**48.6**	**365.8**	**37.9**	**205.8**	**0.7**	**159.9**	**384.9**	**149.3**	**1,444.6**

Note: Arrowed values indicate the greatest value in each column.

Rocky Flats contributed 52% of the dose attributed to the Weapons Fabrication and Testing facility type in 2003, although the site is primarily involved in materials stabilization and waste management. Hanford contributed 58% of the Site-wide Maintenance and Support dose and is involved in thermal stabilization and repackaging of plutonium-bearing materials, processing of spent fuels, and accelerated cleanup of tank farms.

Exhibit B-8: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Accelerator Facilities, 2003

ACCELERATORS

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
AL	Los Alamos National Laboratory	496	150	25	13					684	27%	188	11.314	**0.060** ◄
AL	Sandia National Laboratory	379	24	4	2					409	7%	30	1.699	0.057
CH	Fermilab	1,267	556	43	10	3				1,879	33%	**612** ◄	**25.670** ◄	0.042
CH	Brookhaven National Laboratory	2,400	123	10						2,533	5%	133	4.124	0.031
OAK	Stanford Linear Accelerator Center	2,914	106	3						**3,023** ◄	4%	109	3.127	0.029
OR	Thomas Jefferson Natl. Accel. Facil.	1,367	38	1						1,406	3%	39	0.992	0.025
OAK	Lawrence Berkeley Laboratory	425	3							428	1%	3	0.072	0.024
CH	Chicago Operations Office	6	4							10	**40%** ◄	4	0.040	0.010
AL	Johnson Controls, Inc.	2								2	0%		0.000	0.000
OR	Oak Ridge Field Office	4								4	0%		0.000	0.000
	Totals	**9,260**	**1,004**	**86**	**25**	**3**	**0**	**0**	**0**	**10,378**	**11%**	**1,118**	**47.038**	**0.042**

Note: Arrowed values indicate the greatest value in each column.

In 2003, Fermilab and LANL contributed 79% of the collective dose for this facility type. The collective dose for this facility type decreased by 18% primarily due to the 78% decrease in collective dose at BNL from 2002 to 2003.

Exhibit B-9: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Fuel Facilities, 2003

FUEL FACILITIES

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
ENRICHMENT														
OR	Bechtel Jacobs - Paducah	1,059	26	7	5					1,097	3%	38	3.192	**0.084◄**
OR	Bechtel Jacobs - ORNL	880	172	19	4	5				1,080	19%	200	**13.718◄**	0.069
OR	Bechtel Jacobs - ETTP	1,200	29	1						1,230	2%	30	0.750	0.025
OR	British Nuclear Fuels Ltd. - (BNFL) - ETTP	1,065	386	23	1					**1,475◄**	**28%◄**	**410◄**	10.161	0.025
OR	Bechtel Jacobs - Portsmouth	515	26							541	5%	26	0.592	0.023
OR	Bechtel Jacobs - Y-12	230	9							239	4%	9	0.135	0.015
OR	Wackenhut Services	91								91	0%	0	0.000	0.000
	Totals	**5,040**	**648**	**50**	**10**	**5**	**0**	**0**	**0**	**5,753**	**12%**	**713**	**28.548**	**0.040**
FABRICATION														
OH	Fluor Fernald - FEMP	1,045	273	9	4					1,331	21%	286	7.578	**0.026◄**
OH	Fluor Fernald Const Subcontractors	1,106	337	8						**1,451◄**	**24%◄**	**345◄**	**8.614◄**	0.025
OH	Femp Office Service Subcontractors	11								11	0%	0	0	0
OH	Fernald Env Mgmt Proj Office	22								22	0%	0	0	0
OH	Fluor Fernald Service Vendors	5								5	0%	0	0	0
	Totals	**2,189**	**610**	**17**	**4**	**0**	**0**	**0**	**0**	**2,820**	**22%**	**631**	**16.192**	**0.026**

Note: Arrowed values indicate the greatest value in each column.

The parameters for Fuel Enrichment and Fuel Fabrication remain essentially unchanged for the past 3 years. Oak Ridge facilities (including Paducah and Portsmouth that report through Oak Ridge Operations) account for all of the Enrichment dose, and Fernald accounts for all of the dose reported under Fabrication.

Exhibit B-9: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Fuel Facilities, 2003 (Continued)

FUEL FACILITIES	Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)												
Ops. Office	**Site/Contractor**	**Less than Meas.**	**Meas. 0-0.1**	**0.10-0.25**	**0.25-0.50**	**0.50-0.75**	**0.75-1.00**	**1.00-2.00**	**>2**	**Total Monitored**	**Percent of Monitored with Meas. TEDE**	**No. with Meas. TEDE**	**Collective TEDE (person-rem)**	**Avg. Meas. TEDE (rem)**
PROCESSING														
ID	Bechtel BWXT Idaho - Services	722	230	43	6					1,001	28%	279	16.168	**0.058**◄
SR	Westinghouse Savannah River Co.	1,177	581	63	7	1				**1,829**◄	36%	**652**◄	**26.756**◄	0.041
SR	Bechtel Construction - SR	188	104	6	5					303	**38%**◄	115	4.712	0.041
ID	Bechtel BWXT Idaho - Construction	98	17	2						117	16%	19	0.682	0.036
SR	Wackenhut Services, Inc. - SR	102	8							110	7%	8	0.140	0.018
SR	Savannah River Field Office	18	3							21	14%	3	0.050	0.017
SR	Westinghouse S.R. Subcontractors	20	4							24	17%	4	0.048	0.012
AL	Johnson Controls, Inc.	2								2	0%	0	0.000	0.000
AL	Los Alamos National Laboratory	1								1	0%	0	0.000	0.000
	Totals	**2,328**	**947**	**114**	**18**	**1**	**0**	**0**	**0**	**3,408**	**32%**	**1,080**	**48.556**	**0.045**

Note: Arrowed values indicate the greatest value in each column.

Savannah River contributed 55% of the collective dose for this category, and Idaho contributed 33%.

Exhibit B-10: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Maintenance and Support, 2003

MAINTENANCE AND SUPPORT

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less Than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	>4.00	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
OH	Battelle Memorial Institute - Columbus	355	41	7	18	18	12	4				455	22%	100	35.875	**0.359** ◄
AL	Los Alamos National Laboratory	972	178	51	39	16	8	17				1,281	24%	309	66.144	0.214
RL	Fluor Hanford, Inc.,	1,976	1,015	223	134	44	23	38				3,453	43%	**1,477** ◄	**204.028** ◄	0.138
AL	Johnson Controls, Inc.	1,213	160	39	11	4			1			1,428	15%	215	18.657	0.087
RL	Fluor Northwest Services	32	31	13	1							77	58%	45	3.476	0.077
SR	Bechtel Construction - SR	40	39	5	2							86	53%	46	2.644	0.057
SR	Westinghouse Savannah River Co.	228	170	44	1							443	49%	215	11.554	0.054
NV	Bechtel Nevada - NTS	4,628	47	7								**4,682** ◄	1%	54	2.767	0.051
RL	Protection Technology Hanford	86	16	4								106	19%	20	0.892	0.045
ID	Bechtel BWXT Idaho - Services	302	155	7	3	3						470	36%	168	7.461	0.044
RL	CH2M Hill Hanford Group Inc.	116	47	2	1							166	30%	50	2.068	0.041
RL	Cogema Engineering Corporation	6	2									8	25%	2	0.073	0.037
RL	Duke Engineering & Services Hanford	6	4									10	40%	4	0.135	0.034
RL	Numatec Hanford, Inc.	33	2									35	6%	2	0.067	0.034
OH	BWX Technologies, Inc. - Subcontractors	113	83	6								202	44%	89	2.932	0.033
CH	Brookhaven National Laboratory	699	50	4								753	7%	54	1.708	0.032
NV	Bechtel Nevada - Las Vegas	220	13									233	6%	13	0.405	0.031
CH	Argonne National Laboratory - West		1									1	**100%** ◄	1	0.029	0.029
AL	Los Alamos Area Office	46	7									53	13%	7	0.196	0.028
AL	Sandia National Laboratory	565	33	3								601	6%	36	0.983	0.027
RL	Fluor Federal Services	38	20									58	34%	20	0.521	0.026
SR	Wackenhut Services, Inc. - SR	5	1									6	17%	1	0.026	0.026
NV	Nevada Operations	463	2									465	0%	2	0.043	0.022
ID	Bechtel BWXT Idaho - Construction	19	15									34	44%	15	0.310	0.021

Note: Arrowed values indicate the greatest value in each column.

Exhibit B-10: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Maintenance and Support, 2003 (Continued)

MAINTENANCE AND SUPPORT

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	>4.00	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
SR	Univ. of Georgia Ecology Laboratory	6	1									7	14%	1	0.020	0.020
RL	Duratek Federal Services Of Hanford	45	10									55	18%	10	0.180	0.018
RL	Duratek Federal Services, Inc.	12	3									15	20%	3	0.052	0.017
SR	Westinghouse S.R. Subcontractors	4	4									8	50%	4	0.065	0.016
AL	Protection Technologies Los Alamos	470	94									564	17%	94	1.383	0.015
OH	BWX Technologies, Inc.	196	79									275	29%	79	1.068	0.014
RL	Lockheed Martin Services, Inc.	17	4									21	19%	4	0.051	0.013
RL	Battelle - PNNL	27	1									28	4%	1	0.012	0.012
NV	B.N. - NTS Subcontractors	26										26	0%		0.000	0.000
RL	Bechtel Hanford	15										15	0%		0.000	0.000
NV	B.N. - Washington Aerial Meas.	46										46	0%		0.000	0.000
ID	BNFL - Idaho	1										1	0%		0.000	0.000
HH	BWX Technologies, Inc. -Security Forces	28										28	0%		0.000	0.000
RL	DOE - Richland Field Office	10										10	0%		0.000	0.000
OH	Memp Office Subs	3										3	0%		0.000	0.000
OH	Miamisburg Env Mgmt Proj Office	10										10	0%		0.000	0.000
SR	Miscellaneous DOE Contractors - SR	1										1	0%		0.000	0.000
NV	Nevada Miscellaneous Contractors	23										23	0%		0.000	0.000
NV	Nye County Sheriff	5										5	0%		0.000	0.000
Oh	Ohio Field Office	8										8	0%		0.000	0.000
SR	Savannah River Field Office	10										10	0%		0.000	0.000
Nv	Wackenhut Services, Inc. - NV	217										217	0%		0.000	0.000
	Totals	**13,341**	**2,328**	**415**	**210**	**85**	**43**	**59**	**1**	**0**	**0**	**16,482**	**19%**	**3,141**	**365.825**	**0.116**

Note: Arrowed values indicate the greatest value in each column.

The collective dose for Maintenance and Support increased by 16% from 2002 to 2003. Fluor Daniel at Hanford has reported the largest collective dose for this facility type for the past 7 years. Battelle Memorial Institute (BMI) in Columbus, Ohio, has the highest average measurable dose in this category for the past 6 years. BMI-Columbus is involved in decontamination and remediation of facilities formerly dedicated to nuclear research and development for DOE.

Exhibit B-11: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Reactor Facilities, 2003

REACTOR FACILITIES

Ops. Office	Site/Contractor	Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)								Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
		Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2					
ID	Bechtel BWXT Idaho - Services	224	126	64	27	1				442	49%	**218** ◄	**23.654** ◄	**0.109** ◄
AL	Sandia National Laboratory	60	18	7	3					88	32%	28	2.710	0.097
ID	Bechtel BWXT Idaho - Construction	6	13		1					20	**70%** ◄	14	0.803	0.057
SR	Westinghouse Savannah River Co.	454	127	23	5					**609** ◄	25%	155	8.485	0.055
CH	Brookhaven National Laboratory	79	11	1						91	13%	12	0.389	0.032
SR	Savannah River Field Office	21	4							25	16%	4	0.119	0.030
SR	Bechtel Construction - SR	91	40							131	31%	40	0.924	0.023
SR	Wackenhut Services, Inc. - SR	100	51							151	34%	51	0.780	0.015
CH	Argonne National Laboratory - West	1								1	0%		0.000	0.000
RL	Battelle - PNNL	1								1	0%		0.000	0.000
RL	Bechtel Hanford	1								1	0%		0.000	0.000
CH	Chicago Operations Office	2								2	0%		0.000	0.000
AL	Los Alamos National Laboratory	5								5	0%		0.000	0.000
SR	Westinghouse S.R. Subcontractors	3								3	0%		0.000	0.000
	Totals	**1,048**	**390**	**95**	**36**	**1**				**1,570**	**33%**	**522**	**37.864**	**0.073**

Note: Arrowed values indicate the greatest value in each column.

The collective dose for Reactor facilities increased by 29% from 2002 to 2003. Bechtel BWXT Idaho Services continues to report the majority (62%) of the collective dose for this facility type in 2003. Westinghouse Savannah River Company contributed to 68% of the increase in collective dose in 2003.

Exhibit B-12: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, General, 2003

RESEARCH, GENERAL

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	>4.00	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
OAK	Lawrence Livermore Nat'l Lab.	8,481	144	21	8	11	6	9				**8,680** ◄	2%	199	36.309	**0.182** ◄
RL	Battelle PNNL	546	106	18	6	5	4					685	20%	139	14.706	0.106
CH	Argonne National Laboratory West	404	197	44	27	4	4					680	41%	276	28.732	0.104
AL	Los Alamos National Laboratory	1,395	331	57	37	9	5	4				1,838	24%	**443** ◄	**46.067** ◄	0.104
CH	Argonne National Laboratory East	2,139	159	51	18	3						2,370	10%	231	21.379	0.093
OR	UT Battelle: ORNL	6,181	296	52	22	4		1				6,556	6%	375	28.591	0.076
SR	Westinghouse Savannah River Co.	565	229	33	19	1						847	33%	282	16.711	0.059
OAK	Lawrence Berkeley Laboratory	939	14	2	1							956	2%	17	0.965	0.057
AL	Sandia National Laboratory	386	26	1	1							414	7%	28	1.204	0.043
CH	Brookhaven National Laboratory	521	64	6	2							593	12%	72	3.062	0.043
OAK	Oakland Field Office	173	1									174	1%	1	0.042	0.042
Id	Bechtel BWXT Idaho Services	761	122	8	5							896	15%	135	5.347	0.040
Id	Bechtel BWXT Idaho Construction	48	11	1								60	20%	12	0.405	0.034
OAK	Lawrence Livermore Natl Lab. Nevada	390	1									391	0%	1	0.030	0.030
CH	New Brunswick Laboratory Research	31	2									33	6%	2	0.045	0.023
CH	Ames Laboratory (Iowa State)	117	21									138	15%	21	0.448	0.021
SR	Wackenhut Services, Inc. SR	29	4									33	12%	4	0.069	0.017
OAK	LLNL Subcontractors	705	2									707	0%	2	0.028	0.014
OAK	Rocketdyne Boeing	113	61	2								176	36%	63	0.860	0.014

Note: Arrowed values indicate the greatest value in each column.

Exhibit B-12: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, General, 2003 (Continued)

RESEARCH, GENERAL

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	>4.00	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
OAK	LLNL Subcontractors	705	2									707	0%	2	0.028	0.014
OAK	Rocketdyne - Boeing	113	61	2								176	36%	63	0.860	0.014
SR	Bechtel Construction - SR	41	10									51	20%	10	0.124	0.012
OR	UT-Battelle: Foster Wheeler	214	10									224	4%	10	0.121	0.012
CH	Chicago Operations Office	49	2									51	4%	2	0.024	0.012
SR	Westinghouse S.R. Subcontractors	27	7									34	21%	7	0.077	0.011
OR	Wackenhut Services	65	2									67	3%	2	0.021	0.011
SR	Univ. of Georgia Ecology Laboratory	22	2									24	8%	2	0.019	0.010
AL	Protection Technologies Los Alamos	7	1									8	13%	1	0.009	0.009
CH	Chicago Office Subs	14	13									27	48%	13	0.065	0.005
SR	Savannah River Field Office	24	4									28	14%	4	0.020	0.005
OR	Oak Ridge Inst. for Sci. & Educ. (ORISE)	30	59									89	**66%** ◄	59	0.289	0.005
RL	Bechtel Hanford	1										1	0%	0	0	0
RL	Fluor Northwest Services	1										1	0%	0	0	0
AL	Johnson Controls, Inc.	7										7	0%	0	0	0
AL	Los Alamos Area Office	2										2	0%	0	0	0
AL	Nat'l. Renewable Energy Lab (NREL)-GO	18										18	0%	0	0	0
	Total	**24,446**	**1,901**	**296**	**146**	**37**	**19**	**14**	**0**	**0**	**0**	**26,859**	**9%**	**2,413**	**205.769**	**0.085**

Note: Arrowed values indicate the greatest value in each column.

The collective dose for General Research increased by 17% from 2002 to 2003. LANL was the largest contributor to the collective dose (22%).

Exhibit B-13: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, Fusion, 2003

RESEARCH, FUSION

		Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)												
Ops. Office	**Site/Contractor**	**Less than Meas.**	**Meas. 0-0.1**	**0.10-0.25**	**0.25-0.50**	**0.50-0.75**	**0.75-1.00**	**1.00-2.00**	**>2**	**Total Monitored**	**Percent of Monitored with Meas. TEDE**	**No. with Meas. TEDE**	**Collective TEDE (person-rem)**	**Avg. Meas. TEDE (rem)**
AL	Sandia National Laboratory	40	2							42	5%	2	0.097	**0.049** ◄
AL	Los Alamos National Laboratory	38	5							43	12%	5	0.050	0.010
CH	Princeton Plasma Physics Laboratory	237	111							**348** ◄	**32%** ◄	**111** ◄	**0.593** ◄	0.005
CH	Chicago Operations Office	7								7	0%	0	0	0
	Totals	**322**	**118**	**0**	**0**	**0**	**0**	**0**	**0**	**440**	**27%**	**118**	**0.740**	**0.006**

Note: Arrowed values indicate the greatest value in each column.

With only four organizations reporting in this category, doses can fluctuate from year to year. Princeton Plasma Physics Lab reports the majority of the dose in this category every year, and reported very little dose in 2003.

Exhibit B-14: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Waste Processing, 2003

WASTE PROCESSING

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
AL	Johnson Controls, Inc.					1				1	**100%** ◄	1	0.698	**0.698** ◄
AL	Los Alamos National Laboratory	62	13	4	3	1			1	84	26%	22	12.757	0.580
RL	CH2M Hill Hanford Group, Inc.	831	257	63	40	3				1,194	30%	363	34.037	0.094
SR	Westinghouse Savannah River Co.	1,132	778	211	62	12				**2,195** ◄	48%	**1,063** ◄	**83.188** ◄	0.078
CH	Brookhaven National Laboratory	97	19	8	1					125	22%	28	2.160	0.077
AL	Sandia National Laboratory	100	18	3						121	17%	21	1.267	0.060
SR	Bechtel Construction SR	187	220	29	11	1				448	58%	261	15.362	0.059
RL	Fluor Hanford, Inc.,	1	2							3	67%	2	0.083	0.042
ID	BNFL Idaho	212	122	1						335	37%	123	4.497	0.037
ID	Bechtel BWXT Idaho Services	213	78	9						300	29%	87	3.180	0.037
SR	Westinghouse S.R. Subcontractors	41	25	1						67	39%	26	0.909	0.035
RL	Cogema Engineering Corporation		1							1	**100%** ◄	1	0.021	0.021

Note: Arrowed values indicate the greatest value in each column.

Exhibit B-14: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Waste Processing, 2003 (Continued)

WASTE PROCESSING

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
SR	Savannah River Field Office	29	20	1						50	42%	21	0.362	0.017
AL	Carlsbad Area Misc. Contractors	540	76							616	12%	76	1.147	0.015
SR	Miscellaneous DOE Contractors SR	4	3							7	43%	3	0.041	0.014
ID	Bechtel BWXT Idaho Construction	65	16							81	20%	16	0.208	0.013
RL	Battelle PNNL	1								1	0%	0	0	0
RL	Bechtel Hanford	2								2	0%	0	0	0
RL	Bechtel National Corporation	1								1	0%	0	0	0
AL	Los Alamos Area Office	1								1	0%	0	0	0
RL	Protection Technology Hanford	1								1	0%	0	0	0
SR	Wackenhut Services, Inc. SR	3								3	0%	0	0	0
AL	Waste Isolation Pilot Project (WIPP)	36								36	0%	0	0	0
	Totals	**3,559**	**1,648**	**330**	**117**	**18**	**0**	**0**	**1**	**5,673**	**37%**	**2,114**	**159.917**	**0.076**

Note: Arrowed values indicate the greatest value in each column.

Westinghouse Savannah River Co. (WSRC) was the largest contributor (52%) to the collective dose in 2003. The collective dose at WSRC increased by 60% from 2002 to 2003. WSRC attributed the increase to a resumption of processing of radioactive material, special programs, and accelerated facility closure and waste processing activities.

Exhibit B-15: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Weapons Fabrication, 2003

WEAPONS FABRICATION

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	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	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
SR	Westinghouse Savannah River Co.	219	144	28	59	22	9	9			490	55%	271	65.253	**0.241** ◄
RFO	Rocky Flats Prime Contractors	1,007	698	236	147	52	15	5			2,160	53%	1,153	**163.064** ◄	0.141
SR	Wackenhut Services, Inc. - SR	54	35	81	2						172	**69%** ◄	118	14.782	0.125
AL	BWXT - Amarillo	4,871	178	69	29	9	4				5,160	6%	289	35.884	0.124
SR	Bechtel Construction - SR	29	26	19	2						76	62%	47	5.030	0.107
RFO	Rocky Flats Subcontractors	1,724	478	53	24	6	1				2,286	25%	562	34.552	0.061
OR	BWXT, Y-12	4,016	1,177	155	21						**5,369** ◄	25%	**1,353** ◄	62.495	0.046
OH	BWX Technologies, Inc. - Subcont.	52	32	3							87	40%	35	1.272	0.036
AL	BWXT- Amarillo - Subcontractors	47	1								48	2%	1	0.024	0.024
RFO	Rocky Flats Office	204	46								250	18%	46	1.023	0.022
AL	Sandia National Laboratory	598	42	1							641	7%	43	0.781	0.018
OH	BWX Technologies, Inc.	59	32	1							92	36%	33	0.526	0.016
SR	Westinghouse S.R. Subcontractors	9	1								10	10%	1	0.009	0.009
SR	Savannah River Field Office	23	4								27	15%	4	0.032	0.008
AL	Honeywell, Federal Mfg. & Techno.	48	29								77	38%	29	0.154	0.005
AL	Kansas City Area Office	5	2								7	29%	2	0.006	0.003
OH	Miamisburg Env. Mgmt. Proj. Office	6	1								7	14%	1	0.001	0.001
AL	Amarillo Area Office	75									75	0%		0	0
AL	Los Alamos National Laboratory	8									8	0%		0	0
OH	MEMP Office Subs	1									1	0%		0	0
OH	Ohio Field Office	1									1	0%		0	0
	Totals	**13,056**	**2,926**	**646**	**284**	**89**	**29**	**14**	**0**	**0**	**17,044**	**23%**	**3,988**	**384.888**	**0.097**

Note: Arrowed values indicate the greatest value in each column.

Rocky Flats Contractors and Subcontractors combined contributed to 51% of the dose in this category in 2003. It should be noted that Rocky Flats and Savannah River are no longer active in Weapons Fabrication and Testing and are now involved in nuclear materials stabilization and waste management.

Exhibit B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 2003

OTHER

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	>4	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
OH	West Valley Nuclear Services, Inc.	459	122	31	17	21	16					666	31%	207	41.737	**0.202**◄
AL	Los Alamos National Laboratory	3,793	587	72	35	25	10	10			1	**4,533**◄	16%	**740**◄	**81.598**◄	0.110
CH	Brookhaven National Laboratory	33	6			1						40	18%	7	0.740	0.106
AL	Johnson Controls, Inc.	48	4	1	1							54	11%	6	0.573	0.096
RL	Duratek Federal Services of Hanford	45	1	2								48	6%	3	0.274	0.091
RL	Office of River Protection	76	3	2								81	6%	5	0.401	0.080
RL	Battelle - PNNL	1,274	59	13	5	1						1,352	6%	78	5.689	0.073
RL	Fluor Northwest Services	88	48	14	1							151	42%	63	3.707	0.059
RL	Protection Technology Hanford	18	23	4								45	60%	27	1.329	0.049
RL	Cogema Engineering Corporation	55	15									70	21%	15	0.575	0.038
RL	Bechtel Hanford	666	69	4								739	10%	73	2.693	0.037
AL	Protection Technologies Los Alamos	46	12	2								60	23%	14	0.499	0.036
ID	Stoller Svc Subs - Grand Junction	6	22	1								29	79%	23	0.670	0.029
RL	Fluor Hanford, Inc.,	580	82	3	1							666	13%	86	2.342	0.027
ID	Bechtel BWXT Idaho - Construction	35	1									36	3%	1	0.027	0.027
RL	Fluor Federal Services	149	44	2								195	24%	46	1.242	0.027

Note: *Arrowed values indicate the greatest value in each column.*

Exhibit B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 2003 (Continued)

OTHER

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	>4	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
RL	CH2M Hill Hanford Group, Inc.	214	31									245	13%	31	0.818	0.026
RL	Duratek Federal Services, Inc.	54	7									61	11%	7	0.177	0.025
RL	DOE-Richland Field Office	841	41	3								885	5%	44	1.073	0.024
AL	Sandia National Laboratory	646	60	2								708	9%	62	1.483	0.024
ID	Idaho Field Office	17	2									19	11%	2	0.046	0.023
ID	Bechtel BWXT Idaho - Services	812	29									841	3%	29	0.516	0.018
OH	RMI Environmental Services	142	45									187	24%	45	0.736	0.016
OH	BWX Technologies, Inc. - Subcont.	7	1									8	13%	1	0.016	0.016
RL	Verizon/Qwest	15	3									18	17%	3	0.041	0.014
SR	Westinghouse Savannah River Co.	152	18									170	11%	18	0.207	0.012
OH	Miamisburg Env. Mgmt. Proj. Office		1									1	**100%** ◄	1	0.010	0.010
SR	Bechtel Construction - SR	11	3									14	21%	3	0.029	0.010
RL	Lockheed Martin Services, Inc.	17	2									19	11%	2	0.018	0.009
AL	Los Alamos Area Office	9	2									11	18%	2	0.017	0.009
SR	Westinghouse S.R. Subcontractors	17	1									18	6%	1	0.006	0.006
SR	Savannah River Field Office	4	1									5	20%	1	0.005	0.005

Note: Arrowed values indicate the greatest value in each column.

Exhibit B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 2003 (Continued)

OTHER

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	>4	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
RL	Bechtel National Corporation	1										1	0%	0	0	0
NV	Bechtel Nevada - NTS	35										35	0%	0	0	0
OH	BWX Technologies, Inc.	3										3	0%	0	0	0
RL	Duke Engrg. & Services Hanford	1										1	0%	0	0	0
RL	Hanford Environ. Health Foundation	31										31	0%	0	0	0
OAK	Lawrence Livermore National Lab.	1										1	0%	0	0	0
SR	Miscellaneous DOE Contractors - SR	2										2	0%	0	0	0
RL	NUMATEC Hanford, Inc.	7										7	0%	0	0	0
OH	Ohio Field Office	1										1	0%	0	0	0
OAK	U. Of Cal./Davis, Radiobiology Lab-LEHR	1										1	0%	0	0	0
OR	UT-Battelle: ORNL	6										6	0%	0	0	0
SR	Wackenhut Services, Inc. - SR	18										18	0%	0	0	0
	Totals	**10,436**	**1,345**	**156**	**60**	**48**	**26**	**10**	**0**	**0**	**1**	**12,082**	**14%**	**1,646**	**149.294**	**0.091**

Note: Arrowed values indicate the greatest value in each column.

The collective dose to "Other" facilities increased by 10% from 2002 to 2003, primarily due to a 50% increase at LANL.

Exhibit B-17: Internal Dose by Facility Type and Nuclide, 2001-2003

Facility Type	Nuclide*	No. of Individuals with New Intakes**			Collective CEDE (person-rem)			Average CEDE (rem)		
		2001	2002	2003	2001	2002	2003	2001	2002	2003
Accelerator	Americium		1			0.002			0.002	
	Hydrogen-3	5	3	3	0.074	0.057	0.023	0.015	0.019	0.008
	Plutonium			1			0.006			0.006
	Uranium	2	3	3	0.014	0.031	0.013	0.007	0.01	0.004
	Total	7	7	7	0.088	0.090	0.042	0.013	0.013	0.006
Fuel Fabrication	Thorium	10	16	18	0.046	0.110	0.074	0.005	0.007	0.004
	Uranium	10	8	21	0.047	0.052	0.135	0.005	0.007	0.006
	Total	20	24	39	0.093	0.162	0.209	0.005	0.007	0.005
Fuel Processing	Americium	4		1	1.543		0.014	**0.386** ◄		0.014
	Hydrogen-3	79	77	102	0.238	0.208	0.286	0.003	0.003	0.003
	Plutonium	3	5	5	0.286	0.082	0.110	0.095	0.016	0.022
	Total	86	82	108	2.067	0.290	0.410	0.024	0.004	0.004
Fuel/Uranium Enrichment	Americium		3	1		0.027	0.006		0.009	0.006
	Other	3	3	1	0.103	0.041	0.006	0.034	0.014	0.006
	Thorium	1	3	2	0.002	0.017	0.021	0.002	0.006	0.011
	Plutonium		1	2		0.009	0.004		0.009	0.002
	Uranium	397	222	372	1.712	1.677	6.618	0.004	0.008	0.018
	Total	401	232	378	1.817	1.771	6.655	0.005	0.008	0.018
Maintenance and Support	Americium	8	23	36	0.069	0.117	1.509	0.009	0.005	0.042
	Hydrogen-3	58	88	66	0.135	0.313	0.422	0.002	0.004	0.006
	Mixed and Other		29	9		0.224	0.048		0.008	0.005
	Plutonium	55	108	203	0.674	0.961	4.122	0.012	0.009	0.020
	Radon-222		3			0.173			0.058	
	Thorium	2	23	13	0.058	0.485	0.240	0.029	0.021	0.018
	Uranium	14	28	18	0.102	0.176	0.070	0.007	0.006	0.004
	Total	137	302	345	1.038	2.449	6.411	0.008	0.008	0.019
Other	Americium	2	15	4	0.032	0.715	0.309	0.016	0.048	0.077
	Hydrogen-3	27	21	24	0.111	0.147	0.065	0.004	0.007	0.003
	Mixed and Other	2		1	0.002		0.002	0.001		0.002
	Plutonium	8	39	33	0.772	0.760	7.841	0.097	0.019	0.238
	Radon-222	2	12	19	0.076	1.942	0.568	0.038	**0.162** ◄	0.030
	Uranium	42	30	22	0.413	0.225	0.106	0.010	0.008	0.005
	Total	83	117	103	1.406	3.789	8.891	0.017	0.032	0.086
Reactor	Hydrogen-3	43	17	10	0.101	0.025	0.014	0.002	0.001	0.001
	Plutonium		1			0.022			0.022	
	Total	43	18	10	0.101	0.047	0.014	0.002	0.003	0.001
Research, Fusion	Hydrogen-3	14	10	1	0.051	0.061	0.008	0.004	0.006	0.008
	Total	14	10	1	0.051	0.061	0.008	0.004	0.006	0.008
Research, General	Americium	1	3	20	0.002	0.098	1.078	0.002	0.033	0.054
	Hydrogen-3	60	24	21	0.383	0.329	0.139	0.006	0.014	0.007
	Mixed and Other	10	4	1	0.043	0.017	0.002	0.004	0.004	0.002
	Plutonium	10	10	58	2.399	1.614	4.624		0.161	0.080
	Uranium	25	26	19	0.172	0.711	0.070	0.007	0.027	0.004
	Total	106	67	119	2.999	2.769	5.913	0.028	0.041	0.050
Waste Processing	Americium	12	13	1	0.130	0.257	0.021	0.011	0.020	0.021
	Hydrogen-3	9		7	0.026		0.023	0.003		0.003
	Mixed and Other	1		9	0.003		0.134	0.003		0.015
	Plutonium	12	9	5	0.615	0.299	9.818	0.051	0.033	**1.964** ◄
	Thorium	1			0.005			0.005		
	Uranium		1	2		0.016	0.003		0.016	0.002
	Total	35	23	24	0.779	0.572	9.999	0.022	0.025	0.417
Weapons Fab. and Testing	Americium	1	7	15	0.001	0.010	0.172	0.001	0.001	0.011
	Hydrogen-3	20	30	37	0.070	0.211	0.252	0.004	0.007	0.007
	Mixed and Other	3	3	1	0.221	0.050	0.001	0.074	0.017	0.001
	Plutonium	9	125	185	0.093	3.121	6.999	0.010	0.025	0.038
	Thorium	49	25	50	3.512	0.224	0.595	0.072	0.009	0.012
	Uranium	**1,348** ◄	**1,346** ◄	**1,150** ◄	**44.618** ◄	**53.074** ◄	**47.931** ◄	0.033	0.039	0.042
	Total	1,430	1,536	1,438	48.515	56.690	55.950	0.034	0.037	0.039
	Totals	**2,362**	**2,418**	**2,572**	**58.954**	**68.690**	**94.502**	**0.025**	**0.028**	**0.037**

* Intakes grouped by nuclide. Intakes involving multiple nuclides were grouped into "mixed."
Nuclides where fewer than 10 individuals had intakes were grouped as "other."
** Individuals may be counted more than once.
Note: Arrowed values indicate the greatest value in each column.

The collective CEDE increased by 38% due to a nearly four-fold increase in internal dose from plutonium. The main contributor to this increase was the two exposures in excess of 5 rem (50 mSv) at LANL. Mound and Rocky Flats also reported increases in internal dose from plutonium from 2002 to 2003.

Exhibit B-18a: Distribution of TEDE by Labor Category - 2001

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Labor Category	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	>4	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Agriculture	44											44	0%	0	0	0
Construction	3,823	1,569	164	76	12	3	1					5,648	32%	1,825	98.676	0.054
Laborers	731	304	68	55	7							1,165	37%	434	44.593	0.103
Management	7,956	1,200	135	22	10		1					9,324	15%	1,368	64.666	0.047
Miscellaneous	4,932	1,340	199	88	28	11	1					6,599	25%	1,667	125.918	0.076
Production	2,666	1,601	345	208	86	38	18					4,962	**46%** ◄	2,296	283.679	**0.124** ◄
Scientists	23,850	2,735	169	47	11	8	8					26,828	11%	**2,978** ◄	125.279	0.042
Service	3,556	658	33	15	3	1						4,266	17%	710	29.181	0.041
Technicians	7,214	1,994	558	218	59	21	15					10,079	28%	2,865	**301.460** ◄	0.105
Transport	904	165	7	9	2							1,087	17%	183	9.337	0.051
Unknown	25,455	1,993	213	102	41	7	4	1				**27,816** ◄	8%	2,361	149.601	0.063
Totals	**81,131**	**13,559**	**1,891**	**840**	**259**	**89**	**48**	**1**	**0**	**0**	**0**	**97,818**	**17%**	**16,687**	**1,232.390**	**0.074**

Note: Arrowed values indicate the greatest value in each column.

As in prior years, Production and Technician personnel received the highest collective dose of any labor category and accounted for 47% of the collective dose at DOE for 2001.

Exhibit B-18b: Distribution of TEDE by Labor Category - 2002

Total Effective Dose Equivalent (TEDE)
Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Labor Category	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	>4	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Agriculture	95	1										96	1%	1	0.012	0.012
Construction	4,278	1,616	247	68	11	6	1					6,227	31%	1,949	118.805	0.061
Laborers	1,070	462	98	36	9							1,675	36%	605	45.835	0.076
Management	8,083	1,199	132	49	8	4						9,475	15%	1,392	75.608	0.054
Miscellaneous	4,478	1,155	201	123	42	3	3					6,005	25%	1,527	142.222	0.093
Production	2,744	1,681	378	211	90	37	22					5,163	**47%** ◄	2,419	306.094	**0.127** ◄
Scientists	23,493	2,656	150	70	19	8	5					26,401	11%	2,908	130.564	0.045
Service	3,945	499	114	17	1							4,576	14%	631	33.386	0.053
Technicians	7,554	2,025	622	219	48	24	18					10,510	28%	**2,956** ◄	**313.335** ◄	0.106
Transport	1,038	214	23	8								1,283	19%	245	10.558	0.043
Unknown	26,392	1,992	237	118	41	13	16	1				**28,810** ◄	8%	2,418	183.158	0.076
Totals	**83,170**	**13,500**	**2,202**	**919**	**269**	**95**	**65**	**1**	**0**	**0**	**0**	**100,221**	**17%**	**17,051**	**1,359.577**	**0.080**

Note: Arrowed values indicate the greatest value in each column.

Similar to prior years, Production and Technician personnel received the highest collective dose of any labor category and accounted for 46% of the collective dose at DOE for 2002.

Exhibit B-18c: Distribution of TEDE by Labor Category - 2003

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Labor Category	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	>4	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Agriculture	99											99	0%	0	0	0
Construction	4,488	1,631	162	60	11	1						6,353	29%	1,865	93.518	0.050
Laborers	1,329	428	83	15	4							1,859	29%	530	31.930	0.060
Management	9,064	1,732	258	83	16	1	5					11,159	19%	2,095	129.434	0.062
Miscellaneous	3,503	914	135	82	29	7	3					4,673	25%	1,170	103.246	0.088
Production	2,794	1,645	363	237	83	60	43					5,225	**47%** ◄	2,431	**349.143** ◄	**0.144** ◄
Scientists	21,974	2,409	206	65	16	3						24,673	11%	2,699	120.438	0.045
Service	4,074	670	142	13	4		1					4,904	17%	830	44.240	0.053
Technicians	7,581	1,902	546	209	65	22	14					10,339	27%	2,758	297.298	0.108
Transport	1,182	229	12	6								1,429	17%	247	9.304	0.038
Unknown	28,937	2,305	298	140	59	23	31	1			2	**31,796** ◄	9%	**2,859** ◄	266.080	0.093
Totals	**85,025**	**13,865**	**2,205**	**910**	**287**	**117**	**97**	**1**	**0**	**0**	**2**	**102,509**	**17%**	**17,484**	**1,444.631**	**0.083**

Note: Arrowed values indicate the greatest value in each column.

As in prior years, Production and Technician personnel received the highest collective dose of any labor category and accounted for 45% of the collective dose at DOE for 2003.

Exhibit B-19: Internal Dose by Labor Category, 2001-2003

Labor Category	Number of Individuals with New Intakes*			Collective CEDE (person-rem)			Average CEDE (rem)		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
Construction	502	396	450	7.905	8.059	9.601	0.016	0.020	0.021
Laborers	36	62	62	2.751	3.885	3.151	**0.076** ◄	**0.063** ◄	**0.051** ◄
Management	216	216	162	7.242	7.270	6.157	0.034	0.034	0.038
Miscellaneous	61	80	102	1.104	2.812	3.944	0.018	0.035	0.039
Production	**551** ◄	**564** ◄	599	**17.219** ◄	**23.327** ◄	26.336	0.031	0.041	0.044
Scientists	263	239	193	5.310	5.259	4.945	0.020	0.022	0.026
Service	27	33	44	0.643	0.545	1.884	0.024	0.017	0.043
Technicians	295	293	299	8.781	8.053	8.342	0.030	0.027	0.028
Transport	3	8	5	0.024	0.026	0.024	0.008	0.003	0.005
Unknown	408	527	**656** ◄	7.975	9.454	**30.118** ◄	0.020	0.018	0.046
Totals	**2,362**	**2,418**	**2,572**	**58.954**	**68.690**	**94.502**	**0.025**	**0.028**	**0.037**

* Only included intakes that occurred during the monitoring year. Individuals may be counted more than once.

Note: Arrowed values indicate the greatest value in each column.

In 2003, the labor category with the highest collective dose was the "Unknown" category. There were 2 individuals that received doses in excess of the 5 rem annual TEDE as a result of intakes from plutonium at LANL. These 2 individuals account for 61% of the dose reported in this labor category in 2003. LANL does not record or report the occupation code for their personnel, and therefore these doses are included in the "Unknown" labor category.

Exhibit B-20: Dose Distribution by Labor Category and Occupation - 2003

Labor Category	Occupation	Less Than Meas.	Meas. <0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1-2	2-3	3-4	4-5	>5	Total Monitored	Percent with Meas.	No. with Meas.	Collective TEDE	Average Meas. TEDE
Agriculture	Groundskeepers	88											88	0%			
	Misc. Agriculture	11											11	0%			
Construction	Carpenters	314	123	9	2								448	30%	134	6.137	0.046
	Electricians	1,256	490	39	1	1	1						1,788	30%	532	19.634	0.037
	Masons	33	8										41	20%	8	0.072	0.009
	Mechanics/Repairers	665	213	24	11	2							915	27%	250	13.489	0.054
	Miners/Drillers	77	11										88	13%	11	0.149	0.014
	Misc. Repair/Construction	1,424	473	28	20	6							1,951	27%	527	26.819	0.051
	Painters	143	45	3	2								193	26%	50	1.817	0.036
	Pipe Fitter	576	268	59	24	2							929	38%	353	25.401	0.072
Laborers	Handlers/Laborers/Helpers	1,329	428	83	15	4							1,859	29%	530	31.930	0.060
Management	Admin. Supt. & Clerical Sec.	2,866	433	130	44	9							3,482	18%	616	54.490	0.088
	Manager - Administrator	6,191	1,299	128	39	7	1	5					7,670	19%	1,479	74.944	0.051
	Sales	7											7	0%			
Misc.	Military	1											1	0%			
	Miscellaneous	3,502	914	135	82	29	7	3					4,672	25%	1,170	103.246	0.088
Production	Machine Setup/Operators	147	197	39	8								391	**62%** ◄	244	16.507	0.068
	Machinists	278	36	4	2		2	1					323	14%	45	5.274	0.117
	Misc. Precision/Production	713	265	63	48	20	10	1					1,120	36%	407	56.082	0.138
	Operators, Plant/System/Util.	1,411	1,052	247	173	63	48	41					3,035	54%	1,624	265.389	**0.163** ◄
	Sheet Metal Workers	168	70	6	5								249	33%	81	4.285	0.053
	Welders and Solderers	77	25	4	1								107	28%	30	1.606	0.054
Scientists	Doctors and Nurses	126	8	1									135	7%	9	0.232	0.026
	Engineer	8,280	1,114	79	22	4	1						9,500	13%	1,220	46.593	0.038
	Health Physicist	388	115	10	2	1							516	25%	128	5.437	0.042
	Misc. Professional	4,672	679	59	16	5	2						5,433	14%	761	34.225	0.045
	Scientist	8,508	493	57	25	6							9,089	6%	581	33.951	0.058
Service	Firefighters	436	58	2									496	12%	60	1.262	0.021
	Food Service Employees	13	4										17	24%	4	0.130	0.033
	Janitors	689	51	12	4	1							757	9%	68	4.943	0.073
	Misc. Service	842	240	40	5	3							1,130	25%	288	15.697	0.055
	Security Guards	2,094	317	88	4			1					2,504	16%	410	22.208	0.054
Technicians	Engineering Technicians	2,308	207	36	9	5	1	3					2,569	10%	261	22.697	0.087
	Health Technicians	128	27	15	5			1					176	27%	48	5.804	0.121
	Misc. Technicians	2,349	363	95	49	11	5	4					2,876	18%	527	58.959	0.112
	Radiation Monitors/Techs.	1,397	913	282	122	36	6	5					2,761	49%	1,364	152.885	0.112
	Science Technicians	681	140	30	9	5	4	1					870	22%	189	20.134	0.107
	Technicians	718	252	88	15	8	6						1,087	34%	369	36.819	0.100
Transport	Bus Drivers	11	3										14	21%	3	0.064	0.021
	Equipment Operators	345	109	11	6								471	27%	126	6.485	0.051
	Misc. Transport	423	50	1									474	11%	51	1.057	0.021
	Pilots	1											1	0%			
	Truck Drivers	402	67										469	14%	67	1.698	0.025
Unknown	Unknown	28,937	2,305	298	140	59	23	31	1			2	**31,796** ◄	9%	**2,859** ◄	**266.080** ◄	0.093
Totals		**85,025**	**13,865**	**2,205**	**910**	**287**	**117**	**97**	**1**	**0**	**0**	**2**	**102,509**	**17%**	**17,484**	**1,444.631**	**0.083**

Note: Arrowed values indicate the greatest value in each column.

There was a 45% increase in the collective dose for the "Unknown" labor category from 2002 to 2003. This increase was due primarily to the 47% increase in the collective dose at LANL. LANL does not record or report the occupation code for their personnel so the dose from this site is all reported under the "Unknown" labor category.

Exhibit B-21: Internal Dose Distribution by Site and Nuclide - 2003

Operations/ Field Office	Site	Nuclide	Number of Individuals Receiving Doses in Each Dose Range: Meas. -0.02	0.02-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	>5.0	Total Individuals with Meas. CEDE	Collective CEDE (person-rem)	Average CEDE (rem)
Albuquerque	Los Alamos National Lab (LANL)	Americium		1										1	0.051	0.051
		Hydrogen-3	45	3										48	0.261	0.005
		Other	4											4	0.007	0.002
		Plutonium	48	17	6		1						2	74	19.622	0.265
		Uranium	51	1										52	0.190	0.004
	Pantex Plant	Thorium	37	9										46	0.546	0.012
		Uranium	9	1										10	0.075	0.008
	Sandia National Lab. (SNL)	Plutonium	3											3	0.009	0.003
		Uranium	2											2	0.003	0.002
Chicago	Argonne Nat'l. Lab.-East (ANL-E)	Americium	10	8										18	0.409	0.023
		Hydrogen-3	2											2	0.007	0.004
		Plutonium	4	16	4	1								25	1.998	0.080
	Brookhaven National Lab. (BNL)	Hydrogen-3	2											2	0.014	0.007
		Other	2											2	0.019	0.010
Idaho	Idaho Site	Americium	1											1	0.014	0.014
		Plutonium	2	2										4	0.084	0.021
		Radon-222	11	7	1									19	0.568	0.030
Oakland	Lawrence Livermore Nat'l. Lab. (LLNL)	Hydrogen-3	7											7	0.037	0.005
Oak Ridge	Oak Ridge Site	Americium	1		1		1							3	0.673	0.224
		Hydrogen-3	2											2	0.004	0.002
		Plutonium	2	1	2		1							6	0.967	0.161
		Thorium	1											1	0.007	0.007
		Uranium	824	540	126	16								**1,506** ◄	**54.439** ◄	0.036
	Paducah	Americium	1											1	0.006	0.006
		Other	1											1	0.006	0.006
		Thorium	1											1	0.014	0.014
Ohio	Ops. and Other Facilities	Hydrogen-3	1											1	0.001	0.001
		Uranium	6	1										7	0.061	0.009
	Battelle Memorial Inst.-Columbus	Americium	1											1	0.002	0.002
		Plutonium	27											27	0.091	0.003
	Fernald Environ. Mgmt. Project	Thorium	18											18	0.074	0.004
		Uranium	19	2										21	0.135	0.006
	Mound Plant	Americium	44	3										47	0.285	0.006
		Hydrogen-3	77	4										81	0.573	0.007
		Other	3											3	0.003	0.001
		Plutonium	125	67	8									200	4.584	0.023
		Thorium	9	8										17	0.289	0.017
		Uranium	9											9	0.043	0.005
	West Valley Nuclear Services, Inc.	Americium		2	1									3	0.258	0.086
	(WVNS)	Plutonium	4	2										6	0.132	0.022
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	Plutonium	60	61	12	1								134	5.698	0.043
Richland	Hanford Site	Americium		1	1				1					3	1.411	**0.470** ◄
		Mixed	9	2										11	0.124	0.011
		Plutonium	10	1										11	0.082	0.007
Savannah River	Savannah River Site (SRS)	Hydrogen-3	127	1										128	0.335	0.003
		Other		1										1	0.034	0.034
		Plutonium		1	1									2	0.257	0.129
Totals			**1,622**	**763**	**163**	**18**	**3**	**0**	**1**	**0**	**0**	**0**	**2**	**2,572**	**94.502**	**0.037**

Note: Arrowed values indicate the greatest value in each column.

The collective CEDE increased by 38% from 2002 to 2003. The increase was primarily due to a nearly four-fold increase in internal dose from plutonium. The main contributor to this increase was the two exposures in excess of 5 rem (50 mSv) at LANL. Mound and Rocky Flats also reported increases in internal dose from plutonium from 2002 to 2003. The Oak Ridge Y-12 site was the primary contributor to the dose reported for uranium intakes. The dose reported for uranium intakes decreased by less than 1% from 2002 to 2003.

Exhibit B-22: Extremity Dose Distribution by Operations/Site - 2003

Operations	Site	No Meas. Dose	Meas. –0.1	0.1-1	1-5	5-10	10-20	20-30	>30	Total Monitored*	No. with Meas.	No. Above Monitoring Threshold. (5 rem)**	Collective Extremity Dose (person-rem)	Average Meas. Extremity Dose (rem)
Albuquerque	Albuquerque	605	144	5						754	149		4.153	0.028
	Los Alamos National Lab. (LANL)	9,924	249	353	121	14	8	1		10,670	746	23	621.799	0.834
	Pantex Plant (PP)	5,117	41	96	24	5				5,283	166	5	119.667	0.721
	Sandia National Lab. (SNL)	2,979	12	29	4					3,024	45		19.684	0.437
Chicago	Chicago Operations	590	24	2						616	26		1.210	0.047
	Argonne Nat'l. Lab. - East (ANL-E)	2,270	50	42	8					2,370	100		29.370	0.294
	Argonne Nat'l. Lab. - West (ANL-W)	394	192	80	13	3				682	288	3	78.943	0.274
	Brookhaven National Lab. (BNL)	3,901	176	52	4	1	1			4,135	234	2	46.646	0.199
	Fermi Nat'l. Accelerator Lab. (FERMI)	1,872	2	5						1,879	7		1.780	0.254
DOE HQ	DOE Headquarters													
Idaho	Idaho Site	3,489	937	252	4					4,682	1,193		98.159	0.082
Nevada	Nevada Test Site (NTS)	5,717	10	5						5,732	15		2.572	0.171
Oakland	Oakland Operations	351								351				
	Lawrence Berkeley National Lab. (LBNL)	1,347	26	7	3	1				1,384	37	1	13.088	0.354
	Lawrence Livermore Nat'l. Lab. (LLNL)	9,705	18	23	31	1	1			9,779	74	2	98.216	**1.327** ◄
	Stanford Linear Accelerator Center (SLAC)	3,023								3,023				
Ohio	Ohio Field Office	219								219				
	Battelle Memorial Institute - Columbus	354	39	49	13					455	101		46.346	0.459
	Fernald Environmental Mgmt. Project	2,814	2	4						2,820	6		0.706	0.118
	Mound Plant	695								695				
	West Valley	403	161	93	9					666	263		57.420	0.218
Oak Ridge	Oak Ridge Operations	1,499								1,499				
	Oak Ridge Site	16,163	33	114	27					**16,337** ◄	174		106.798	0.614
	Paducah Gaseous Diff. Plant (PGDP)	1,092	5							1,097	5		0.152	0.030
	Portsmouth Gaseous Diff. Plant (PORTS)	541								541				
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	2,853	1,201	480	131	31				4,696	1,843	31	691.168	0.375
Richland	Hanford Site	7,332	2093	896	162	29	40	12		10,564	3,232	**81** ◄	**1,709.212** ◄	0.529
Savannah River	Savannah River Site (SRS)	5,151	2311	858	207	23	6			8,556	**3,405** ◄	29	988.983	0.290
	Totals	**90,400**	**7,726**	**3,445**	**761**	**108**	**56**	**13**	**0**	**102,509**	**12,109**	**177**	**4,736.072**	**0.391**

* Represents the total number of monitoring records. The number of individuals provided extremity monitoring cannot be determined.

** All extremity doses above 5 rem were for the upper extremities (hands and forearms). DOE annual limit for extremities is 50 rem. 10 CFR 835.402(a)(1)(ii) requires extremity monitoring for a shallow dose equivalent to the skin or extremity of 5 rem or more in a year.

Note: Arrowed values indicate the greatest value in each column.

The Oak Ridge Site reports the largest number of individuals monitored for extremity dose. Hanford, Savannah River, and Rocky Flats report the majority (72%) of the collective dose to extremities. Extremity dose at these facilities is most often associated with the handling of radioactive material in gloveboxes. Of the monitored individuals that received measurable extremity dose, only 1% received a dose above the monitoring threshold of 5 rem.

Facility Type Code Descriptions

DOE M 231.1-1 [13] requires contractors to indicate for each reported individual the facility contributing the predominant portion of that individual's effective dose equivalent. In cases when this cannot be distinguished, the facility type indicated should represent the facility type wherein the greatest portion of work service was performed.

The facility type indicated must be one of 11 general facility categories shown in *Exhibit C-1*. 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 judgment by 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.

Exhibit C-1:
Facility Type Codes.

Facility Type Code	Description
10	Accelerator
21	Fuel/Uranium Enrichment
22	Fuel Fabrication
23	Fuel Processing
40	Maintenance and Support (Site-Wide)
50	Reactor
61	Research, General
62	Research, Fusion
70	Waste Processing/Mgmt.
80	Weapons Fab. and Testing
99	Other

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 4-mile circumference synchrotron, and their energies range from keV to TeV.

In general, radiation doses received by occupational workers at accelerator facilities are largely attributable to the beta/gamma radiation emitted from the activated structural and mechanical components. The nature of the radiation fields and the magnitude of dose rates inside the primary shielding vary considerably depending upon the operational parameters of the machine, the types of particles accelerated, and the energies achieved. Doses received by personnel who enter the accelerator enclosures are dependent upon these factors. In many cases dependent upon the radiological conditions, personnel are prevented from entering the accelerator enclosures when the beam is operational. Outside of the shielding, exposure rates due to prompt radiation from the accelerator are typically very low. Average annual doses of exposed personnel at these facilities are comparable to the overall average for DOE. However, the collective dose is lower than the collective dose for most other DOE facilities' categories because of the relatively small number of employees at accelerator facilities who work on or around the activated components. Regarding internal exposures, tritium and short-lived airborne activation products exist at some accelerator facilities, although annual internal doses are generally quite low.

Fuel/Uranium Enrichment

The DOE involvement in the nuclear fuel cycle generally begins with uranium enrichment operations and facilities. 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 atomic weights of the 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 and transuranics from recycled uranium. 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.

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. For example, physical modification of uranium metal by various metalworking operations, such as machining and lathing operations, requires protection against beta radiation exposures to the skin, eyes, and extremities.

Fuel Processing

The DOE administers several facilities that reprocess spent reactor fuel. These facilities separate the plutonium produced in reactors. They also separate the fission products and uranium;the fission products are normally designated as radioactive waste products, while the uranium can be refabricated for further use as fuel.

Penetrating doses are attributable primarily to gamma photons, although some neutron exposures do occur. Skin and extremity doses can result from handling samples. 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.

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.

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.

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.

By 1992, 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 resulting 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 rems per hour), requiring extensive protective measures.

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.

The spectrum of research involving ionizing radiation or radioactive materials being performed at DOE facilities results in a wide variety of radiological conditions. 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. In addition, there is the potential for inhalation of radioactive material. Area dose rates and individual annual doses are highly variable.

Research, Fusion

DOE currently operates both major and small 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.

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 0.1 rem (1 mSv). At two DOE sites, however, large-scale waste processing facilities exist to properly dispose of radioactive waste products generated during the nuclear fuel cycle. At these facilities, radiation doses to some employees can be elevated, sometimes exceeding 1 rem/year (10 mSv/year). Penetrating doses at waste processing facilities are attributable primarily to gamma photons; however, neutron exposures also occur at the large-scale facilities.

Weapons Fabrication and Testing

The primary function of a facility in this category is to fabricate weapons-grade material for the production or testing of nuclear weapons. At these facilities, workers can receive neutron radiation dose when processing plutonium isotopes, as well as penetrating dose from gamma photons and plutonium x-rays, and skin and extremity dose from plutonium x-rays. An additional pathway for radiation exposure at these facilities is the inhalation of plutonium, where the inhalation of material can result in some of the highest individual doses based on the calculation of the 50-year committed effective dose equivalent. To prevent plutonium intakes, strict controls are in place, including process containment, contamination control procedures, and air monitoring and bioassay programs.

No DOE facilities currently are involved in weapons testing. Several of the sites reporting under this category are no longer actively involved in weapons fabrication and testing, but are in the process of stabilization and waste management.

Other

Individuals included 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 types described above include construction and irradiation facilities. Although exposures to gamma photons are predominant, some individuals may be exposed to beta particles, x-rays, neutrons, or airborne radioactive material.

Appendix D

Limitations of Data

The following is a description of the limitations of the data currently available in the DOE Radiation Exposure Monitoring System (REMS). While these limitations have been taken into consideration in the analysis presented in this report, readers should be alert to these limitations and consider their implications when drawing conclusions from these data.

Individual Dose Records vs Dose Distribution

Prior to 1987, exposure data were reported from each facility in terms of a statistical dose distribution wherein the number of individuals receiving a dose within specific dose ranges was reported. The collective dose was then calculated from the distribution by multiplying the number of individuals in each dose range by the midpoint value of the dose range. Starting in 1987, reports of individual exposures were collected that recorded the specific dose for each monitored individual. The collective dose can be accurately determined by summing the total dose for each individual. The dose distribution reporting method prior to 1987 resulted in up to a 20% overestimation of collective dose. The reason is that the distribution of doses within a range is usually skewed toward the lower end of the range. If the midpoint of the range is multiplied by the number of people in the range, the product overestimates the collective dose. This overestimation only affects the data prior to 1987 presented in Appendix Exhibits B-2a, B-2b, and B-3.

The dose distributions presented in this report are based on the individual dose records reported to REMS. Individuals may be counted more than once as some sites report multiple dose records for an individual who visits the site more than once, or the individual may visit more than one site during the year. (See Section 3.6.)

Monitoring Practices

Radiation monitoring practices vary from site to site and are based on the radiation hazards and work practices at each site. Sites use different dosimeters and have different policies to determine which workers are monitored. All sites have achieved compliance with the DOE Laboratory Accreditation Program (DOELAP), which standardizes the quality of dosimetry measurements. The number of monitored individuals can significantly impact the site's collective dose. Some sites supply dosimeters to virtually all workers. While this tends to increase the number of monitored workers with no dose, it also can add an increased number of very low dose workers to the total number of workers with measurable dose, thereby lowering the site's average measurable dose. Even at low doses, these workers increase the site's collective dose. In contrast, other sites only monitor workers who exceed the monitoring requirement threshold (as specified in 10 CFR 835.402). This tends to reduce the number of monitored workers and reports only those workers receiving doses above the monitoring threshold. This can decrease the site's collective dose while increasing the average measurable dose.

AEDE vs CEDE

Prior to 1989, intakes of radionuclides into the body were not reported as dose, but as body burden in units of activity of systemic burden. The implementation of DOE Order 5480.11 in 1989 specified that the intakes of radionuclides be converted to internal dose and reported using the Annual Effective Dose Equivalent (AEDE) methodology. The AEDE methodology requires the calculation of the summation of dose for all tissues and organs multiplied by the appropriate weighting factor for a specified year. Note that per 5480.11, AEDE included components of internal and external dose. Therefore, the AEDE was analogous to the TEDE. However, 5480.11 does not define TEDE.

With the implementation of the RadCon Manual in 1993, the required methodology used to calculate and report internal dose was changed from the AEDE to the 50-year CEDE. The CEDE represents the dose equivalent delivered to all organs and tissues over the next 50 years and the 50-year CEDE is reported to REMS and assigned to the individual in the year of intake. The change was made to provide consistency with scientific recommendations, facilitate the transfer of workers between DOE- and NRC-regulated facilities, and simplify recordkeeping by recording all dose in the year of intake. The CEDE methodology is now codified in 10 CFR 835. From 1993 to the present, the TEDE is defined as the summation of the Deep Dose Equivalent (DDE) to the whole body and the CEDE.

This report primarily analyzes dose information for the past 5 years, from 1999 to 2003. During these years, the CEDE methodology was used to calculate internal dose; therefore, the change in methodology from AEDE to CEDE between 1992 and 1993 does not affect the analysis contained in this report. Readers should keep in mind the change in methodology if analyzing TEDE data prior to 1993 in Exhibits B-2a, B-2b, and B-3.

Occupation Codes

Each individual's dose record includes the occupation code for the individual while he worked at the DOE site during the monitoring year. Occupational codes typically represent the occupation the individual held at the end of the calendar year and may not represent the occupation where the majority of dose was received if the individual held multiple occupations during the year. The occupation codes are very broad categorizations and are grouped into nine general categories. Each year a percentage (over 30%) of the occupations is listed as unknown, or as miscellaneous. The definitions of each of the labor categories are subject to interpretation by the reporting organization and/or the individual's employer.

Facility Type

The facility type is also recorded with each dose record for the monitoring year. It is intended to reflect the type of facility where the individual received most of their occupational radiation exposure during the monitoring year. While the facility types are clearly defined (see Appendices A and C), the reporting organizations often have difficulty tracking which facility type contributed to the majority of the individual's exposure. Certain individuals tend to work in the proximity of several different facility types throughout the monitoring year and are often included in the "Maintenance and Support (Site-wide)" facility type. The facility type for temporary contract workers and members of the public is often not reported and is defaulted to "unknown."

In addition to these uncertainties, the phase of operation of the facility types is not currently reported. A facility type of "accelerator" may be reported when, in fact, the accelerator has not been in operation for a considerable time and may be in the process of stabilization, decommissioning, or decontamination. In addition, several sites have commented that they have difficulty assigning the facility type, because many of the facilities are no longer operational. For example, some sites commented that a reactor that is being decommissioned is no longer considered a "reactor" facility type. Other sites continue to categorize a facility based on the original intent or design of the facility, regardless of its current status.

DOE Headquarters will be reviewing the Facility Type codification scheme and modifying the reporting requirements to standardize the use of facility type classifications and improve the quality of the data and the data analysis. DOE will also pursue the usefulness of collecting data on the operational phase of facilities with end-users of this report.

Organization Code

Facilities report data to the central repository based on an "organization code." This code identifies the Operations or Field Office, the reporting facility, and the contractor or subcontractor that is reporting the exposure information. The organization code changes over time as DOE Offices are reorganized. In some cases, new Operations or Field Offices are created. In other cases, a Field Office may change organizations and begin reporting with another Field Office.

Occurrence Reports

Occurrence reports involving radiation exposure and personnel contamination events are additional indicators of the effectiveness of radiation protection efforts at DOE. These events will continue to be analyzed and presented in this report.

Additional Data Requirements

To provide analysis of the activities at DOE sites with respect to radiation exposure (see Section 3.5), it is necessary to augment the information reported to the REMS database. For the past 5 years, DOE Headquarters has requested additional information from the six sites with the highest collective dose. This information includes a summary of activities, project descriptions, and ALARA planning documentation. DOE Headquarters will continue to request this information in subsequent years. It is recommended that sites submit this information with their annual records.

Naval Reactor Facilities

The exposure information for the Schenectady and Pittsburgh Naval Reactor facilities is not included in this report. Readers should note that the dose information for the overall DOE complex presented in this report may differ from other reports or sources of information because of the exclusion of these data.

Exposure information for Naval Reactor programs can be found in the most recent version of the following series of reports (where XX represents the report year):

- NT-XX-2 – "Occupational Radiation Exposure from U.S. Naval Nuclear Plants and Their Support Facilities,"
- NT-XX-3 – "Occupational Radiation Exposure from U.S. Naval Reactors' Department of Energy Facilities."

Updates to the Data

The data in the REMS database are subject to correction and update on a continual basis. Data for prior years are subject to correction as well as the data for the most recent year included in this report. The most common reason for correction to a dose record is because of a final dose determination of an internal dose after the original dose record was submitted to REMS. This delay is due to the time needed to assess the bioassay results and determine the dose from long-lived radionuclides. It is recommended that sites review their dose record update and reporting process, specifically for internal dose determination, and consider the addition of a mechanism whereby they report dose updates to REMS in a timely fashion when updates occur. Corrections will be reflected in subsequent annual reports. For the most up-to-date status of radiation exposure information, contact:

Ms. Nirmala Rao
REMS Project Manager
U.S. Department of Energy
Office of Corporate Performance Assessment
(EH-32)
Germantown, MD 20874
nimi.rao@hq.doe.gov

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Appendix E

Access to Radiation Exposure Information

E

Radiation Exposure Monitoring System

The data used to compile this report were obtained from the DOE Radiation Exposure Monitoring System (REMS), which serves as the central repository of radiation exposure information for DOE Headquarters. The database consists of individual monitoring records of occupational exposure for DOE workers from 1987 to the present. REMS also contains career exposure records for individuals who terminated employment between 1969 and 1986, and additional historical records voluntarily submitted to REMS from the sites that participated in the epidemiologic surveillance pilot project. Over 3 million exposure records are contained in the REMS central repository. In 1995, REMS underwent an extensive redesign effort in combination with the efforts involved in revising the annual report. One of the main goals of the redesign effort was to allow researchers better access to the REMS data. However, there is considerable diversity in the goals and needs of these researchers. For this reason, a multi-faceted approach has been developed to allow researchers flexibility in accessing the REMS data.

Exhibit E-1 lists the various ways of accessing the DOE radiation exposure information contained in REMS. A description is given for each access method, as well as requirements for access. To obtain further information, a contact name and phone number are provided.

The data contained in the REMS system are subject to periodic update. Data for the current or previous years may be updated as corrections or additions are submitted by the sites. For this reason, the data presented in published reports may not agree with the current data in the REMS database. These updates typically have a relatively small impact on the data and should not affect the general conclusions and analysis of the data presented in this report.

REMS Web Page

As noted in *Exhibit E-1*, a web page has been established to disseminate radiation exposure information at DOE. The web site contains the latest published annual report on occupational exposure, information on reporting exposure data to DOE, points of contact for requesting information from REMS, DOE Orders and Standards related to radiation exposure, and links to other related sites. The site contains a web-based data query tool that allows users to obtain specific data reported to REMS from 1987 to the most recent year available. The data can be selected and grouped by year, site, organizati on, facility type, labor category, occupation, and monitoring status. The web page query tool allows access to summary information for over 1.9 million monitoring records.

Visit the REMS web page at:

`http://www.eh.doe.gov/rems/`

Comprehensive Epidemiologic Data Resource

Of interest to researchers in radiation exposure are the health effects associated with worker exposure to radiation. While the health effects from occupational exposure are not treated in this report, it has been extensively researched by DOE. The Comprehensive Epidemiologic Data Resource (CEDR) serves as a central resource for radiation health effects studies at the DOE.

Epidemiologic studies on health effects of radiation exposures have been supported by the DOE for more than 30 years. The results of these studies, which initially focused on the evaluation of mortality among workers employed in the nuclear weapons complex, have been published in scientific literature. However, the data collected during the conduct of the studies were not widely shared. CEDR has now been established as a public-use database to broaden independent access and use of these data. At its introduction in 1993, CEDR included primarily occupational studies of the DOE workforce, including demographic, employment, exposure, and mortality follow-up information on more than 420,000 workers. The program's holdings have been expanded to include data from both occupational and historical community health studies, such as those examining the impact of fallout from atmospheric nuclear weapons testing, community dose reconstructions, and data from the decades of follow-up on atomic bomb survivors.

CEDR accomplishes this by a hierarchical structure that accommodates analysis and working files generated during a study, as well as files of documentation that are critical for understanding the data. CEDR provides easy access to its holdings through the Internet or phone and mail interchanges, and provides an extensive catalog of its holdings. CEDR has become a unique resource comprising the majority of data that exist on the health risks of occupational radiation exposure.

For further information about CEDR, access the CEDR internet web page at:

http://cedr.lbl.gov

Or the CEDR Program Manager may be contacted at:

barbara.brooks@hq.doe.gov

Exhibit E-1: Methods of Accessing REMS Information

REMS Information Access Method	Information Available	Eligibility Requirements	Software Requirements	To Get Access
Hardcopy Annual Report	Analysis and data for annual occupational exposure information, primarily for the past 5 years. Tables and graphs present data and trends for the most commonly asked questions concerning exposure information at DOE facilities.	None.	None.	Contact EH-32* to request that you be added to the Annual Report mailing list.
Web Page	• Annual reports from 1992 to the most recent report. • Information on reporting exposure data to DOE. • How to request information from REMS. • A query tool for extracting summary data from REMS. • DOE Orders and Standards on radiation exposure. • Links to other related sites.	None.	Internet access. Web browser client software.	Connect to http://www.eh.doe.gov/rems/
Access to REMS Database	Individual annualized dose records submitted to REMS from 1987 to the present. In addition, dose records are available for individuals who terminated employment at a DOE facility from 1969 to 1986.	Records are subject to the privacy Act of 1974. Records are only available to researchers within DOE or other governmental agency upon approval by the REMS Project Manager in accordance with System of Records #35. Contact the REMS Project Manager* for further information on accessing individual dose records in REMS.	Internet access (TCP/IP). Oracle SQLNet and encryption software (provided). Database access tool for querying data that can connect to an Oracle database.	Contact EH-32* to request access.

* EH-32 contact Ms. Nirmala Rao, DOE REMS Project Manager, EH-32, 270 Corporate Square Building, U.S. Department of Energy, 1000 Independence Avenue, SW, Washington, D.C. 20585-0270
Phone: (301) 903-2297, Fax: (301) 903-1257, E-mail: nimi.rao@hq.doe.gov

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Prepared by:
Science Applications International Corporation
301 Laboratory Road • Oak Ridge, TN 37830