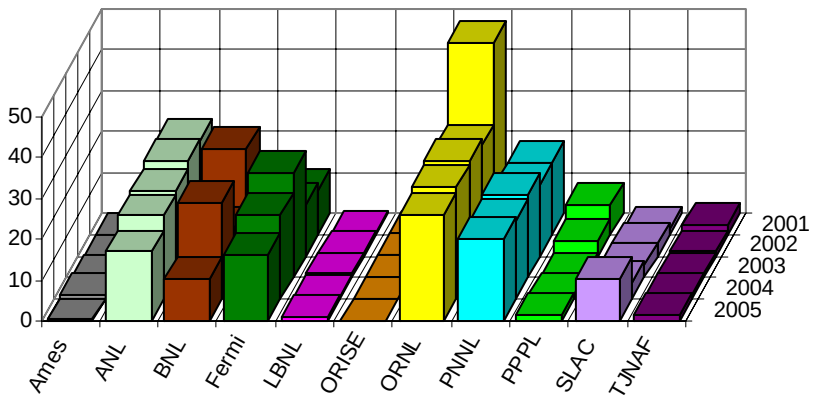
# Radiological Control Profile for the Office of Science Laboratories 2001-2005

**Collective Dose at SC Laboratories (Person-Rem)**




Office of Laboratory Policy and Infrastructure (SC-31)
Office of Science
U.S. Department of Energy

**This page intentionally left blank.**

## Executive Summary

Looking back at the trend over the past five years, the collective dose from all Office of Science (SC) laboratories has dropped by about 17 percent overall, from 125 person-rem in 2001 to 104 person-rem in 2005. By comparison, the collective dose at all Department of Energy (DOE) laboratories dropped by about 20 percent in the same period, from 1,232 to 989 person-rem.

During 2005, the collective occupational radiation dose for all SC laboratories dropped by about 13 percent to 104 person-rem, down from 120 person-rem in 2004. A large part of the drop in collective dose at SC laboratories was at Brookhaven National Laboratory (BNL), which dropped from 23.7 person-rem in 2004 to 10.2 person-rem in 2005. The decrease at BNL is mostly attributable to completion of remediation activities, especially the Brookhaven Graphite Research Reactor (BGRR) Project to remove below ground duct work. The collective dose also dropped significantly at Fermilab, from 20.6 person-rem in 2004 to 16.1 person-rem in 2005. The principal activities at Fermilab that resulted in occupational radiation exposures were associated with repairs and maintenance necessary for maintaining accelerator performance.

The largest increase in collective dose was at Stanford Linear Accelerator Center (SLAC), up from 3.9 person-rem in 2004 to 10.4 person-rem in 2005. This represents an increase by a factor of 2.5, which was directly attributable to a corresponding increase in maintenance activities conducted inside Radiological Control Areas where activated accelerator components are present.

In 2005, there were no workers with an annual dose exceeding 1,000 millirem. In 2004, there were two workers in this category, both at the Alpha Gamma Hot Cell Facility (AGHCF) at Argonne National Laboratory (ANL).

Most workers who were monitored for radiation exposure at SC laboratories received no measurable dose at all. Of those who did, approximately 88 percent received less than 100 millirem per year (the threshold for when a dosimeter must be issued). More than 99 percent of those with a measurable dose received an annual dose under 500 millirem, which is one-tenth of the DOE annual limit of 5,000 millirem (5 rem).

Reportable occurrences for personnel contamination, loss of control of radioactive material, spread of contamination or unplanned radiation exposures do not show any clear trend, although they generally correspond to the amount of work performed. Off-site doses to members of the public from releases of radionuclides to the environment are all well within regulatory limits. Some SC laboratories have issues with legacy contamination in groundwater and soils from historical releases of radionuclides, but there are no issues of non-compliance with applicable standards for protection of the public.

## Introduction

This is a current assessment of the performance of SC laboratories with respect to radiological control. It provides a five-year retrospective look at occupational radiation exposures and radionuclide releases to the environment at all SC laboratories, including results for all DOE employees, contractors, subcontractors, and visitors. The scope of the report includes occupational doses for all workers at each facility and is not limited to just those funded by SC.

The occupational exposure data in this report is taken from the DOE Radiation Exposure Monitoring System (REMS), which serves as the central repository of radiation exposure information for DOE Headquarters. The REMS data is available on the web at http://www.eh.doe.gov/rems/rems/ri.htm and is also published annually in the *DOE Occupational Radiation Exposure Report*. Information on radionuclide releases to the environment was taken from the Annual Site Environmental Reports.

## Excellence in Radiological Control

The Department strives to maintain radiation exposures to its workers and the public below administrative control levels and regulatory limits and to further reduce these exposures to levels that are "As Low As Reasonably Achievable" (ALARA). The ALARA methodology considers both individual and group doses and involves a cost/benefit analysis that considers social, technical, economic, practical, and public policy aspects of the overall goal of dose reduction.

To evaluate how well ALARA is being implemented for workers at SC laboratories, it is necessary to look at several different measures of occupational dose. The analysis in this report considers the collective dose for all monitored individuals, the average dose, the total number of individuals who are monitored for dose, and the number of those who actually receive a measurable dose.

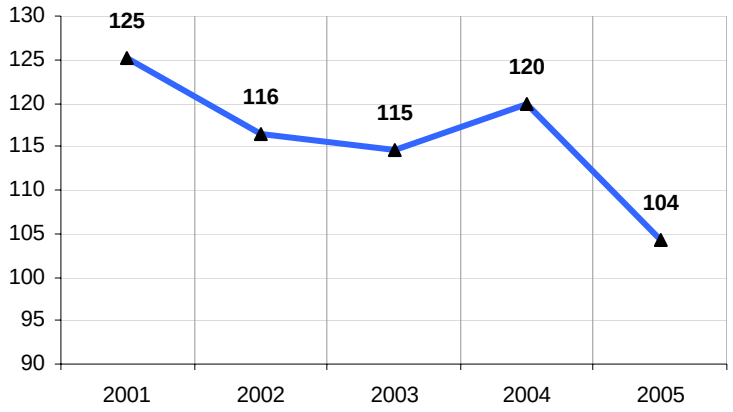
One characteristic of a good ALARA program is that the majority of worker dose should be at relatively low levels, with only a small percentage of workers receiving doses approaching administrative control levels. For this reason, this report also includes a frequency distribution for the total number of exposed workers at selected ranges of dose.

Another characteristic of a robust radiological safety program is that, for a constant workload, both individual and group doses should drop over time, as experience and lessons learned combine to improve radiological work practices. This analysis provides a five-year retrospective of occupational and environmental radiation exposures to evaluate where reductions have occurred. It is important to note that an increase in dose does not necessarily indicate a problem if it can be attributed to increased work activity rather than a decrease in radiation control practices.

## Collective Occupational Dose

Looking back at the trend over the past five years, the collective dose from all SC laboratories has dropped by about 17 percent overall, from 125 person-rem in 2001 to 104 person-rem in 2005 (See Figure 1.) By comparison, the collective dose at all DOE sites dropped by about 20 percent in the same period, from 1,232 to 989 person-rem.

**Figure 1: Collective Dose from all SC laboratories (Person-Rem)**

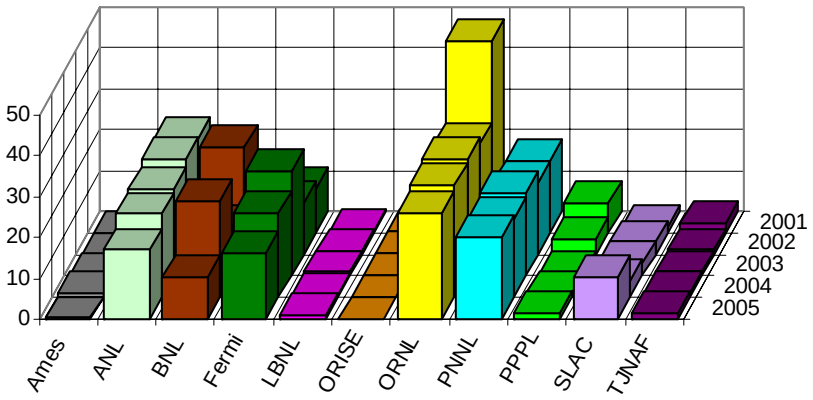



During 2005, the collective occupational radiation dose for all SC laboratories dropped by about 13 percent to 104 person-rem, down from 120 person-rem in 2004. A large part of the drop in collective dose at SC laboratories was at BNL, which dropped from 23.7 person-rem in 2004 to 10.2 person-rem in 2005. The decrease at BNL is mostly attributable to completion of remediation activities, especially the BGRR Project to remove below ground duct work.

The collective dose also dropped significantly at Fermilab, from 20.6 person-rem in 2004 to 16.1 person-rem in 2005. The principal activities at Fermilab that resulted in occupational radiation exposures were associated with repairs and maintenance necessary for maintaining accelerator performance. Nearly all of the collective dose to personnel was due to exposures to items activated by the accelerator beams. The repair and maintenance work included extensive pre-job planning to keep doses ALARA, implementation of specific ALARA activities during radiological work, and post-job analyses. For example, during the dismantling and removal of the MP and ME beamlines located in the Meson Detector Building, a customized steel and lead blanket shield was used to protect personnel working inside the beam cavity of the SM12 Magnet, which reduced collective doses by an estimated eighty percent. Also, a 12 hour cool-down time was instituted for the replacement of the Anti-Proton Prevault Enclosure Beam Pipe and Torroid, which reduced the collective dose from an estimated 1.46 person-rem to an actual dose of 0.096 person-rem.

The largest increase in collective dose was at SLAC, up from 3.9 person-rem in 2004 to 10.4 person-rem in 2005 (See Figure 2.) This represents an increase by a factor of 2.5, which was directly attributable to a corresponding increase in maintenance activities conducted inside Radiological Control Areas where activated accelerator components are present.

**Figure 2: Collective Dose at SC Laboratories (Person-Rem)**




| Year | Ames | ANL | BNL | Fermi | LBNL | ORISE | ORNL | PNNL | PPPL | SLAC | TJNAF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 0.174 | 23.033 | 14.627 | 10.650 | 0.682 | 0.327 | 47.039 | 17.639 | 7.420 | 1.368 | 2.317 |
| 2002 | 0.076 | 23.560 | 26.244 | 12.790 | 0.895 | 0.274 | 27.046 | 17.690 | 3.707 | 3.075 | 1.113 |
| 2003 | 0.448 | 21.379 | 12.183 | 25.670 | 1.037 | 0.289 | 28.591 | 20.407 | 0.552 | 3.127 | 0.992 |
| 2004 | 1.152 | 20.514 | 23.678 | 20.570 | 0.739 | 0.249 | 27.675 | 19.340 | 0.972 | 3.916 | 1.074 |
| 2005 | 0.339 | 16.984 | 10.216 | 16.130 | 1.180 | 0.253 | 26.122 | 20.073 | 1.164 | 10.370 | 1.519 |

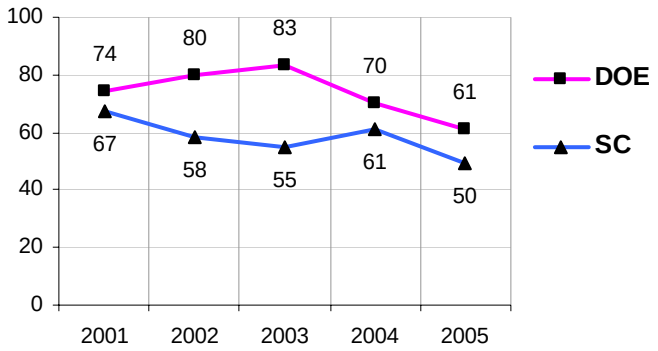
In 2005, the collective dose at Pacific Northwest National Laboratory (PNNL) was 20 person-rem, up very slightly from 19 person-rem the previous year. More than 80 percent of the collective dose is from operations at the Radiochemical Processing Laboratory (RPL). The dose from the RPL correlates primarily to projects that support Hanford Site cleanup, the RPL Inventory Reduction Initiative, the Prostate Seed Development Project, and decontamination and evaluation of nuclear power reactor control rod drive mechanisms. The PNNL collective dose was below anticipated levels, primarily due to highly effective implementation of ALARA controls supporting the Waste Inventory Reduction Initiative within the RPL.

The collective dose at ANL was approximately 17 person-rem in 2005, down from 21 person-rem the previous year. There were no workers with an annual dose exceeding 750 millirem. A major dose contributor in 2005 was the Intense Pulsed Neutron Source (IPNS). The dose was accrued primarily during periods of maintenance on the accelerator. In past years the Alpha Gamma Hot Cell Facility (AGHCF) has been the principal dose contributor. Less programmatic work was done at nuclear facilities such as AGHCF during the last half of 2005 as a result of efforts to address nuclear safety issues identified by the DOE Office of Assessment.

## Average Measurable Occupational Dose

The average measurable dose for all SC facilities has ranged between 50 to 67 millirem during the last five years. By comparison, the average measurable dose for all DOE sites has ranged between 61 to 83 millirem (See Figure 3.)

**Figure 3: Average Measurable Dose - DOE and SC compared (mrem/yr)**




The average measurable dose is calculated by dividing the collective dose by the total number of individuals with a measurable dose. While the average measurable dose is one useful indicator for dose to workers (and visitors) at SC laboratories, it can be misunderstood if taken out of context. For example, the average measurable dose can drop if there is an overall increase in the number of workers who receive very low levels of measurable dose. This may give a mistaken impression that doses are dropping, when in fact they are rising.

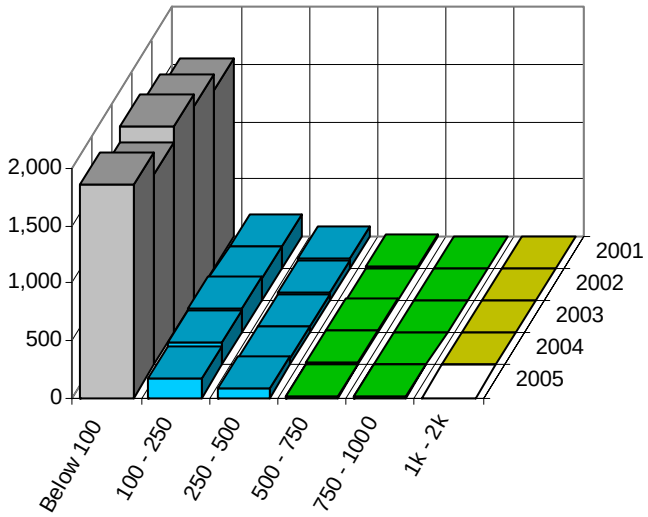
Also, since the average is calculated by dividing by the total number of workers with a measurable dose, the average may not be very sensitive to increases in dose to small numbers of workers, which may also be of concern.

In order to provide a more complete picture of radiation exposures, the following section presents exposure data as a frequency distribution showing the number of workers at selected intervals of annual dose with trends over the past five years.

## Occupational Dose Distribution

Of all SC laboratory workers who receive a measurable dose, the majority received an annual dose of less than 100 millirem, which is the DOE threshold for requiring dosimetry (See Figure 4.) For the last five years, at least 80 percent of all workers at SC laboratories fell into this category.

**Figure 4: Dose Distribution for SC Laboratories: Total Number of Workers in Each Dose Range**




**Dose Range (millirem/year)**

| Year | Below 100 | 100 - 250 | 250 - 500 | 500 - 750 | 750 - 1000 | 1k - 2k |
|---|---|---|---|---|---|---|
| 2001 | 1,549 | 191 | 88 | 19 | 5 | 7 |
| 2002 | 1,698 | 201 | 73 | 12 | 6 | 6 |
| 2003 | 1,801 | 212 | 65 | 17 | 4 | 1 |
| 2004 | 1,662 | 204 | 64 | 17 | 14 | 2 |
| 2005 | 1,855 | 164 | 72 | 12 | 3 | 0 |

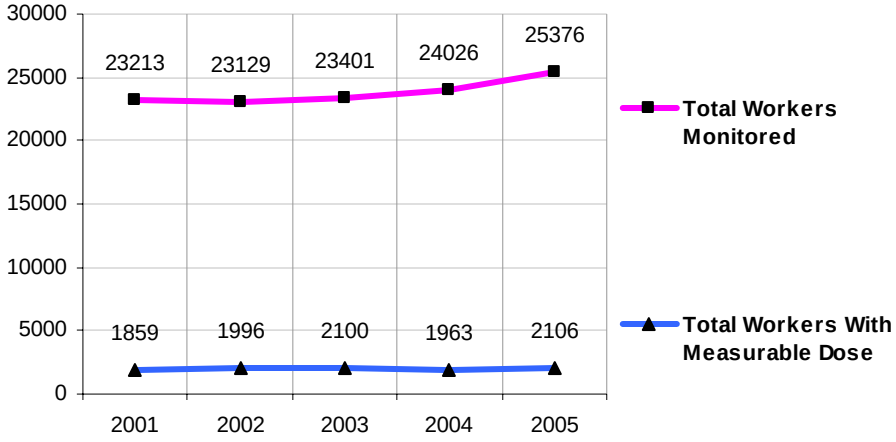
Also, for this same time period, more than 99 percent of all workers had a dose of less than 500 millirem per year, which is one-tenth of the annual limit of 5,000 millirem in 10 CFR 835, *Occupational Radiation Protection.*

In 2005, there were no workers with an annual dose exceeding 1,000 millirem. In 2004, there were two workers in this category, both at the AGHCF at ANL

## Number of Monitored Workers

The total number of monitored workers at all SC laboratories has increased slightly, from 23,213 in 2001 to 25,376 in 2005 (See Figure 5.) However, only a fraction of those monitored actually received a measurable dose. The number of workers with a measurable dose increased slightly from 1,859 in 2001 to 2,106 in 2005.

**Figure 5: Number of Monitored Workers at SC Laboratories**



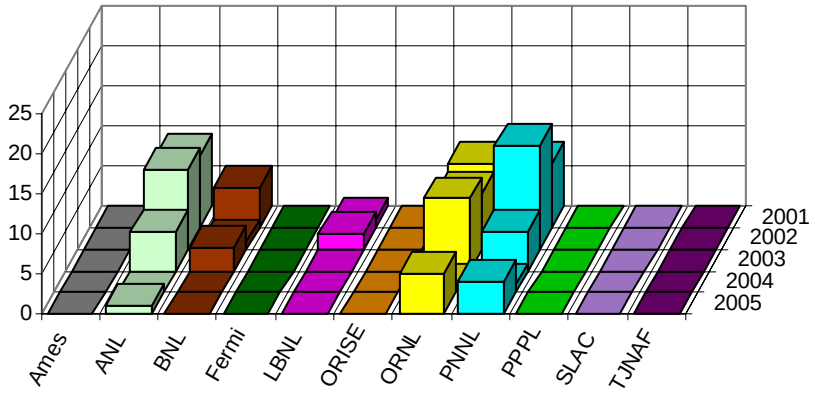

Personnel dosimetry is required for DOE workers who are likely to receive a dose greater than 100 millirem per year. Also, visitors are monitored at half that limit (50 millirem per year) if they are members of the public and not employees.

In practice, most sites prudently provide dosimetry in excess of this requirement, for reasons of administrative convenience, legal liability, and security. While the total number of monitored workers gives a good indication of the overall scope of the dosimetry program, it is not necessarily a good indicator of the actual exposed work force.

## Personnel Contamination

There were 10 reported occurrences of personnel contamination in 2005. Over the past five years, there were 98 occurrences, as compared to 844 for all of DOE. These occurrences were predominately at the multi-program laboratories (See Figure 6.) These occurrences do not show any clear trend, although they generally correspond to the amount of work performed.

**Figure 6: Occurrences at SC Laboratories for Personnel Contamination**



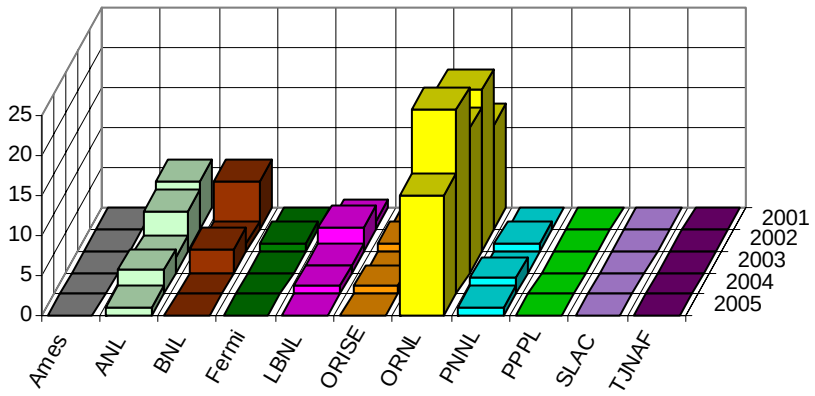

| Year | Ames | ANL | BNL | Fermi | LBNL | ORISE | ORNL | PNNL | PPPL | SLAC | TJNAF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 0 | 9 | 5 | 0 | 1 | 0 | 8 | 8 | 0 | 0 | 0 |
| 2002 | 0 | 10 | 1 | 0 | 2 | 0 | 7 | 13 | 0 | 0 | 0 |
| 2003 | 0 | 5 | 3 | 0 | 0 | 0 | 9 | 5 | 0 | 0 | 0 |
| 2004 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 2005 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | 4 | 0 | 0 | 0 |

Although occurrences of personnel contamination do not cause any significant dose, they are tracked as a performance indicator for conduct of operations. An increase in the number of personnel contaminations may indicate a degradation in radiological control practices, if not otherwise attributable to a change in work activities. The threshold for reporting personnel contamination occurrences was raised in mid-2003, which generally decreased the total number reported, as compared to previous years.

## Loss of Control of Radioactive Material & Spread of Contamination

In 2005, there were 17 reported occurrences for loss of control of radioactive material and spread of contamination. Over the past five years, there were 129 occurrences, as compared to 834 for all of DOE. These occurrences were predominately at ORNL (See Figure 7), which are mostly due to the legacy contamination found during movement of personnel from old buildings to newer facilities.

**Figure 7: Occurrences at SC Laboratories for Loss of Control of Radioactive Material & Spread of Contamination**




| Year | Ames | ANL | BNL | Fermi | LBNL | ORISE | ORNL | PNNL | PPPL | SLAC | TJNAF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 0 | 6 | 6 | 0 | 1 | 0 | 13 | 0 | 0 | 0 | 0 |
| 2002 | 0 | 5 | 1 | 1 | 3 | 1 | 20 | 1 | 0 | 0 | 0 |
| 2003 | 0 | 2 | 3 | 0 | 1 | 0 | 18 | 0 | 0 | 0 | 0 |
| 2004 | 0 | 3 | 0 | 0 | 1 | 1 | 23 | 2 | 0 | 0 | 0 |
| 2005 | 0 | 1 | 0 | 0 | 0 | 0 | 15 | 1 | 0 | 0 | 0 |

Like personnel contamination, these occurrences do not cause any significant dose, but are used as a performance indicator for conduct of operations. The threshold for reporting these contamination occurrences was raised in mid-2003, which generally decreased the total number reported, as compared to previous years.

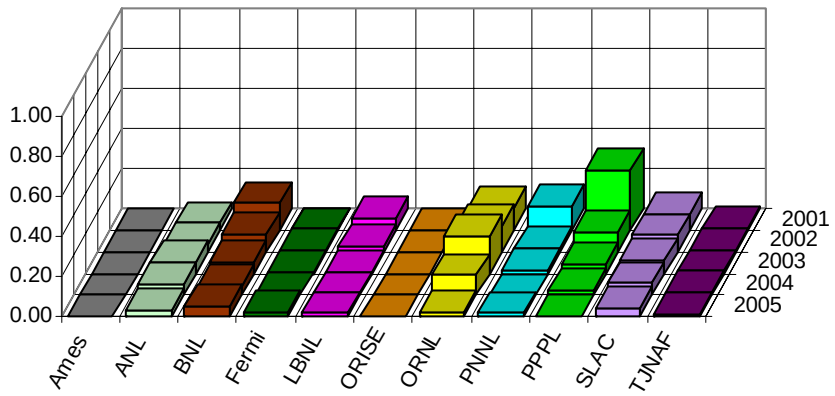
## Unplanned Radiation Exposures

There were no occurrences of unplanned radiation exposures at SC laboratories in 2005. During the past five years, there were only two of these types of occurrences at SC laboratories, as compared to 62 for all of DOE.

## Environmental Releases of Radionuclides

All DOE facilities are required to demonstrate to the Environmental Protection Agency (EPA) that radionuclides released to air do not cause a dose greater than 10 millirem per year to any member of the public. This standard is found in the National Emission Standards for Hazardous Air Pollutants (NESHAPS) standard 40 CFR 61, Subpart H. This dose of 10 millirem per year is too small to measure because of the much higher natural background radiation (around 300 millirem per year) and must be calculated annually, using EPA-approved computer codes.

**Figure 8: NESHAPS dose at SC Laboratories (mrem/yr)**




| Year | Ames | ANL | BNL | Fermi | LBNL | ORISE | ORNL | PNNL | PPPL | SLAC | TJNAF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 0.000 | 0.036 | 0.137 | 0.006 | 0.060 | 0.000 | 0.110 | 0.120 | 0.300 | 0.080 | 0.011 |
| 2002 | 0.000 | 0.039 | 0.086 | 0.008 | 0.030 | 0.000 | 0.130 | 0.023 | 0.100 | 0.085 | 0.007 |
| 2003 | 0.000 | 0.057 | 0.060 | 0.007 | 0.010 | 0.000 | 0.189 | 0.021 | 0.047 | 0.070 | 0.013 |
| 2004 | 0.000 | 0.054 | 0.044 | 0.008 | 0.010 | 0.000 | 0.100 | 0.000 | 0.029 | 0.060 | 0.019 |
| 2005 | 0.000 | 0.034 | 0.053 | 0.022 | 0.019 | 0.000 | 0.020 | 0.017 | 0.007 | 0.040 | 0.014 |

Over the past five years, the dose to the maximally exposed individual has remained substantially less than one millirem per year at all SC laboratories (See Figure 8.) In 2005, the largest dose was at BNL (0.053 millirem, or 0.5 percent of the limit).

In addition to complying with the NESHAPS standard for releases to air, DOE facilities must also comply with the DOE dose limit of 100 millirem per year for members of the public from all pathways (DOE O 5400.5, *Radiation Protection of the Public and the Environment*). Important pathways which are evaluated include releases to both groundwater and surface waters (e.g., drinking water, eating fish, swimming, wading, and shoreline use). Some SC laboratories have outdoor radiological soil contamination from legacy releases which can contribute to the water pathways if the radionuclides migrate from the soil.

Ames Laboratory has not reported any radionuclide releases to groundwater or surface water, or any legacy contamination in soil.

At ANL, the only significant location where radionuclides attributable to operations (primarily tritium and strontium-90) have been found is off-site water in Sawmill Creek, below the wastewater outfall. Although this water is not used for drinking purposes, radionuclide concentrations are regularly monitored and are well below regulatory limits for drinking water.

There are several groundwater tritium plumes at BNL where concentrations exceed the 20,000 picocuries per liter (pCi/L) drinking water standard. One is associated with a leak from the spent fuel pool at the inactive High Flux Beam Reactor (HFBR), and one is associated with activated soil shielding at the former accelerator facility experiment, known as g-2. The portion of the HFBR tritium plume with concentrations exceeding 20,000 pCi/L extends from the HFBR approximately 2,700 feet to the south. The g-2 tritium plume extends from the experiment area, approximately 1,800 feet to the southeast. Activated soils containing tritium and sodium-22 have been created near a number of BNL's accelerator facilities as the result of secondary particles (primarily neutrons) produced at beam targets, beam stops, and beam line collimators. Tritium (and lesser amounts of sodium-22) has leached into the groundwater in several of these areas where rainwater had infiltrated into the activated soils. Procedures are in place to evaluate the potential for soil activation impacts on groundwater quality. In areas where significant soil activation can occur, engineered and operational controls are put in place to limit the extent of soil activation and prevent rainwater infiltration. Only groundwater at g-2 has tritium concentrations that exceeds the drinking water standard. There are also several strontium-90 plumes where concentrations exceed the 8 pCi/L drinking water standard. Two are associated with the Waste Concentration Facility and the Brookhaven Graphite Research Reactor (BGRR), which is no longer in operation. Strontium-90 is also routinely detected in groundwater in the former Animal/Chemical Pits/Glass Holes area. The tritium and strontium-90 plumes are expected to attenuate (via natural decay and dispersion in the aquifer) to concentrations below drinking water standards entirely onsite. Furthermore, there would be no radiological dose risk from drinking water because most residents adjacent to BNL site get their water from Suffolk County Water Authority. Additionally, routine monitoring of BNL's on-site drinking water supply wells has shown that the tritium and strontium-90 contamination is not impacting the wells. The total annual dose from all pathways to the maximally exposed individual remains substantially below regulatory limits.

In November 2005, environmental monitoring at Fermilab detected a low level of tritium in Indian Creek at the southwest corner of the Fermilab site. This was the first time in the history of Fermilab that radionuclides were detected in the surface waters leaving the site. The highest measured level was 3pCi/ml, which is only slightly above the detectable level and 600 times lower than the Federal surface water standard of 2,000 pCi/ml. Fermilab has eliminated leaks from the Main Injector ponds that are likely to have been the source. These concentrations continue to be maintained as low as reasonably achievable and are presently less than a detection limit of 1 pCi/ml. While this level of tritium is very low and of no real consequence, Fermilab is working proactively and transparently to keep the public informed on the issue.

Lawrence Berkeley National Laboratory (LBNL) does not release any tritium to groundwater offsite. Although tritium has been found in groundwater onsite, it does not contribute to the public dose because there is no exposure pathway.

Oak Ridge Institute for Science and Education (ORISE) has not reported any radionuclide releases to groundwater or surface water or any legacy contamination in soil.

There are large areas of outdoor radiological soil contamination at Oak Ridge National Laboratory from legacy releases. The majority of these releases are from legacy waste disposal and aging underground process waste lines. The major radionuclides are strontium-90 and cesium-137. Waterborne radionuclide concentrations are regularly monitored, and the maximum possible individual dose remains well below regulatory limits for all pathways combined (e.g., drinking water, eating fish, swimming, wading, and shoreline use).

There have not been any known releases of radionuclides to groundwater or surface waters from PNNL that resulted in a significant off-site dose to members of the public. The Hanford Site has legacy soil and groundwater contamination, some of which is located at or near PNNL facilities. However, this contamination is primarily the result of historical Hanford weapons production activities, not PNNL activities.

There had been a substantial tritium inventory at Princeton Plasma Physics Laboratory (PPPL) from 1994-97 for fusion research on the Tokamak Fusion Test Reactor (TFTR). In August 1995, PPPL began to monitor tritium levels in on-site groundwater more comprehensively; all measurements have been well below the EPA drinking water standard and have continued to decrease since the dismantlement of TFTR was completed in 2002.

Tritium exists in low concentrations in a few, localized groundwater wells at the SLAC. There is no indication that the tritium is migrating offsite, based on routine monitoring of groundwater wells. Consequently, the tritium in groundwater poses negligible dose potential to affected workers, the public, and environment. Both groundwater and wastewater are routinely monitored at SLAC and tritium concentrations remain well within regulatory limits.

Groundwater samples have been monitored at the Thomas Jefferson National Accelerator Facility 1987, and no accelerator-produced activity has been detected.

## Laboratory Profile Sheets

The following section is one-page synopses for each of the SC laboratories, briefly discussing their radiological operations and a summary of the occupational radiation exposures for the past five years. Contractual performance measures for radiological control are also noted, including both dose and contamination control, as applicable.

The dose distribution tables are highlighted in color for easier reading and to help facilitate comparison of one laboratory with another. The highlight colors are the same as those used in Figure 4, "Dose Distribution for SC Laboratories" (0-100 mrem is gray, 100-500 mrem is blue, 500-1000 mrem is green, and 1000-2000 mrem is yellow).

## Ames Laboratory (Ames)

In 2005, the collective dose at Ames Laboratory dropped to 0.3 person-rem, down from 1.1 person-rem the previous year. The radiological work at Ames includes use of x-ray devices, remediation of legacy contamination, stewardship of radioactive materials, and intermittent research involving small amounts of radioactive materials. There are currently 17 x-ray systems and approximately 90 trained x-ray workers.

Radioactive materials work has been minimal over the past five years, with primary use consisting of sealed source materials and irradiated metals. Ames Laboratory radiological activities are subject to a readiness review process and ALARA committee review.

Occupational Radiation Dose Distribution (2001-2005)

Ames — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 138 | 13 | 174 | 13 | 125 | 13 | 0 | 0 | 0 | 0 | 0 |
| 2002 | 135 | 9 | 76 | 8 | 126 | 9 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 138 | 21 | 448 | 21 | 117 | 21 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 148 | 40 | 1152 | 29 | 108 | 40 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 147 | 14 | 339 | 24 | 133 | 14 | 0 | 0 | 0 | 0 | 0 |

Contractual Performance Measures for Radiological Control:

Ames uses the average total effective dose equivalent (TEDE) to measure the effectiveness of management commitments to ALARA. The rating is based on the average TEDE per person who received a measurable dose, as follows:

Outstanding = less than 30 millirem
Excellent = 30-42 millirem
Good = more than 42 and less than 79 millirem
Marginal = between 79-91 millirem
Unsatisfactory = more than 91 millirem

## Argonne National Laboratory (ANL)

The collective dose at ANL was approximately 17 person-rem in 2005, down from 21 person-rem the previous year. There were no workers with an annual dose exceeding 750 millirem.

A major dose contributor in 2005 was the Intense Pulsed Neutron Source. The dose was accrued primarily during periods of maintenance on the accelerator. In past years the Alpha Gamma Hot Cell Facility (AGHCF) has been the principal dose contributor. Less programmatic work was done at nuclear facilities such as AGHCF during the last half of 2005 as a result of efforts to address nuclear safety issues identified by the DOE Office of Assessment.

Occupational Radiation Dose Distribution (2001-2005)

ANL — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 2819 | 187 | 23033 | 123 | 2632 | 136 | 32 | 10 | 1 | 1 | 7 |
| 2002 | 2793 | 233 | 23560 | 101 | 2560 | 180 | 35 | 10 | 1 | 1 | 6 |
| 2003 | 2370 | 231 | 21379 | 93 | 2139 | 159 | 51 | 18 | 3 | 0 | 0 |
| 2004 | 2347 | 172 | 20514 | 119 | 2175 | 122 | 28 | 12 | 3 | 5 | 2 |
| 2005 | 3752 | 267 | 16984 | 64 | 3485 | 222 | 27 | 14 | 4 | 0 | 0 |

Contractual Performance Measures for Radiological Control:

Performance expectations for the Laboratory include the collective dose equivalent to monitored individuals, an index based on the number of radioactive contaminations and contaminated individuals, and other radiological measures. The contract provides that a joint committee of Argonne Site Office (ASO) and ANL representatives appointed by the ASO Manager and the ANL Director, respectively, will review the occupational radiation protection performance measures quarterly and agree on adjustments to performance expectations as necessary to account for changes in the scope of radiological work.

## Brookhaven National Laboratory (BNL)

In 2005, the collective dose at BNL dropped significantly to 10.2 person-rem, down from 23.7 person-rem the previous year. The decrease can be attributed to the completion of remediation activities, especially the Brookhaven Graphite Research Reactor Project to remove below ground duct work. It should be noted that in 2005, there were no workers with doses over 500 mrem, for the first time since 2001.

Removal of the graphite pile is scheduled to begin next year, which will probably increase the collective dose.

Occupational Radiation Dose Distribution (2001-2005)

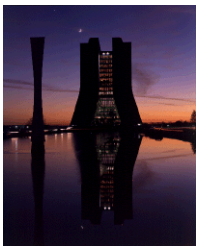
BNL — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 5048 | 387 | 14627 | 38 | 4661 | 351 | 28 | 8 | 0 | 0 | 0 |
| 2002 | 4672 | 439 | 26244 | 60 | 4233 | 368 | 48 | 15 | 5 | 3 | 0 |
| 2003 | 4135 | 306 | 12183 | 40 | 3829 | 273 | 29 | 3 | 1 | 0 | 0 |
| 2004 | 2639 | 301 | 23678 | 79 | 2338 | 246 | 36 | 8 | 5 | 6 | 0 |
| 2005 | 2518 | 216 | 10216 | 47 | 2302 | 189 | 16 | 11 | 0 | 0 | 0 |

Performance Measures for Radiological Control:

The performance measures define an effective ALARA program as comprised of dose goals and administrative control levels that are challenging and consider both historical exposures and planned operations; supportive of changes to those goals when operating assumptions change; communicates ALARA initiatives that help to optimize radiological exposures, and ensures dose is shared among all qualified workers.

## Fermi National Accelerator Laboratory (Fermilab)



In 2005, the collective dose at Fermilab dropped to 16.1 person-rem, down significantly from about 20.6 person-rem in 2004. The principal activities at Fermilab that resulted in occupational radiation exposures were associated with repairs and maintenance necessary for maintaining accelerator performance. Nearly all of the collective dose to personnel was due to exposures to items activated by the accelerator beams.

The repair and maintenance work included extensive ALARA pre-job planning, implementation of specific ALARA activities during radiological work, and post-job analyses. During the dismantling and removal of the MP and ME beamlines located in the Meson Detector Building, a customized steel and lead blanket shield was used to protect personnel working inside the beam cavity of the SM12 Magnet, which reduced collective doses by an estimated 80 percent. A 12 hour cool-down time was instituted for the replacement of the Anti-Proton Prevault Enclosure Beam Pipe and Torroid, which reduced the collective dose from an estimated 1.46 person-rem to an actual dose of 0.096 person-rem. Similarly, a three hour cool-down time was employed to hook up a vacuum pump in this same area, which reduced the collective dose from an estimated 0.143 person-rem to an actual dose of 0.008 person-rem. An automated system to move radioactive sources was installed in the Radiation Physics Calibration Facility, which reduced doses for operators in this facility by 90 percent.

Occupational Radiation Dose Distribution (2001-2005)

Fermi — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 1344 | 368 | 10650 | 29 | 976 | 352 | 13 | 3 | 0 | 0 | 0 |
| 2002 | 1424 | 389 | 12790 | 33 | 1035 | 363 | 21 | 5 | 0 | 0 | 0 |
| 2003 | 1879 | 612 | 25670 | 42 | 1267 | 556 | 43 | 10 | 3 | 0 | 0 |
| 2004 | 1855 | 498 | 20570 | 41 | 1357 | 451 | 34 | 13 | 0 | 0 | 0 |
| 2005 | 1600 | 425 | 16130 | 38 | 1175 | 385 | 29 | 11 | 0 | 0 | 0 |

Contractual Performance Measures for Radiological Control:

The ES&H Section Radiation Protection Group led formal reviews focused on ALARA and designed to identify both significant innovations recently made and opportunities for further improvement. For this measure, an identified innovation or opportunity for improvement that credibly can improve the control of radiation exposures is considered to be "significant." The measure was evaluated based on the number of reviews conducted and the number of significant actions identified and documented. In 2005, an adjectival rating of "Outstanding" was achieved for this measure.

## Lawrence Berkeley National Laboratory (LBNL)

In 2005, LBNL had a collective dose of 1.2 person-rem, up from 0.7 person-rem the previous year. This collective dose was the lowest among the five SC multi-program laboratories, and the third lowest among all SC laboratories. Radiological work includes research in life sciences and physical sciences involving small amounts of radioactive materials, operation of the Advanced Light Source and 88-inch Cyclotron, and closure activities at the former Bevatron accelerator. The Laboratory has a number of policies within the framework of Integrated Safety Management that contribute to maintaining occupational radiation doses ALARA. Radiation safety professionals perform a "walk down" on any operation that yields a dosimeter reading exceeding 50 millirem to any worker. Also, the LBNL Radiation Safety Committee (RSC) meets quarterly, and the "top 5" worker doses are reviewed to ensure that the doses are commensurate with the work performed. The RSC also evaluates dose trends for each building.

Radiopharmaceutical development and functional imaging with positron emission tomography represent areas of growth in radiological work with increasing numbers of research protocols.

Occupational Radiation Dose Distribution (2001-2005)

LBNL — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 1694 | 21 | 682 | 32 | 1673 | 21 | 0 | 0 | 0 | 0 | 0 |
| 2002 | 1538 | 33 | 895 | 27 | 1505 | 32 | 1 | 0 | 0 | 0 | 0 |
| 2003 | 1384 | 20 | 1037 | 52 | 1364 | 17 | 2 | 1 | 0 | 0 | 0 |
| 2004 | 1290 | 18 | 739 | 41 | 1272 | 17 | 1 | 0 | 0 | 0 | 0 |
| 2005 | 1143 | 22 | 1180 | 54 | 1121 | 19 | 3 | 0 | 0 | 0 | 0 |

Contractual Performance Measures for Radiological Control:

An Outstanding rating requires that the number of individual exposures exceeding 100 millirem must be less than or equal to the control level of 10, plus the average individual positive dose is less than the control level of 50 millirem, all without an increase in workload.

The LBNL performance measure for reportable occurrences of personnel contamination provides an Outstanding rating for a weighted number of contaminated individuals less than or equal to 4.0 (with unusual occurrences having a weighting factor of 1.5, and off-normal at 1.0). The performance measure for control of radioactive material and spread of contamination provides an Outstanding rating for 2.0 or less weighted occurrences (with unusual occurrences using a weighted factor of 1.5 and off-normals 1.0).

## Oak Ridge Institute for Science and Education (ORISE)

For the last five years, ORISE has never had a worker with a dose exceeding 100 millirem. The only sources of radiological exposure are some sealed sources for calibration and some environmental samples for analysis.

Occupational Radiation Dose Distribution (2001-2005)

ORISE — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 87 | 55 | 327 | 6 | 32 | 55 | 0 | 0 | 0 | 0 | 0 |
| 2002 | 99 | 69 | 274 | 4 | 30 | 69 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 89 | 59 | 289 | 5 | 30 | 59 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 68 | 48 | 249 | 5 | 20 | 48 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 73 | 36 | 253 | 7 | 37 | 36 | 0 | 0 | 0 | 0 | 0 |

Contractual Performance Measures for Radiological Control:

A performance measure is in place for worker radiation dose to assess the effectiveness of the ORISE personnel exposure program and to document that the ALARA Program is in place and active. The average ORISE employee occupational dose is calculated by dividing the collective total effective dose equivalent for all monitored ORISE employees by the total number of employees with a measurable dose. A rating of Meets Expectation is assessed if the average dose falls below 10 millirem, and a rating of Does Not Meet Expectation is assessed if the average exceeds 10 millirem.

## Oak Ridge National Laboratory (ORNL)

In 2005, the collective dose at ORNL was 26 person-rem, down slightly from 28 person-rem the previous year. The major contribution to the collective dose at ORNL is the work at the Radiochemical Engineering Development Center and the High Flux Isotope Reactor. The collective dose at ORNL will remain a challenge because of future projects and activities, including the consolidation of hot cell facilities, continued cleanup of legacy radioactive materials, and the operation of the Spallation Neutron Source.

There is an ALARA Steering Committee and an ALARA Working Committee which discuss ongoing projects and share lessons learned on dose reductions. The ALARA awards are routinely presented to employees who develop methods of reducing dose for particular jobs.

Occupational Radiation Dose Distribution (2001-2005)

ORNL — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 5345 | 389 | 47039 | 121 | 4956 | 255 | 73 | 43 | 14 | 4 | 0 |
| 2002 | 5995 | 354 | 27046 | 76 | 5641 | 273 | 55 | 22 | 4 | 0 | 0 |
| 2003 | 6562 | 375 | 28591 | 76 | 6187 | 296 | 52 | 22 | 4 | 0 | 1 |
| 2004 | 6489 | 342 | 27675 | 81 | 6147 | 262 | 55 | 19 | 3 | 3 | 0 |
| 2005 | 6759 | 365 | 26122 | 72 | 6394 | 294 | 47 | 21 | 2 | 1 | 0 |

Contractual Performance Measures for Radiological Control:

Performance measures are in place for both worker radiation dose and radiological operations. The measure for worker radiation dose is based on the average measurable dose for workers with a positive dose; ratings range from Outstanding for 90 millirem or less, to Marginal for more than 110 millirem.

The radiological operations measure is based on five factors:

- the number of radiological workers that exceed their ORNL ALARA goal by five percent
- the number of radiological workers exceeding 30 percent of any dose limit in 10 CFR 835
- the number of occurrences for radiation exposure
- the number of occurrences for personnel contamination
- the number of occurrences for loss of control of radioactive material or spread of contamination

## Pacific Northwest National Laboratory (PNNL)

In 2005, the collective dose at PNNL was 20 person-rem, up very slightly from 19 person-rem the previous year. More than 80 percent of the collective dose is from operations at the Radiochemical Processing Laboratory (RPL). The dose from the RPL correlates primarily to projects that support Hanford Site cleanup, the RPL Inventory Reduction Initiative, the Prostate Seed Development Project, and decontamination and evaluation of nuclear power reactor control rod drive mechanisms.

The PNNL collective dose was below anticipated levels, primarily due to highly effective implementation of ALARA controls supporting the Waste Inventory Reduction Initiative within the RPL.

Occupational Radiation Dose Distribution (2001-2005)

PNNL — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 1474 | 207 | 17639 | 85 | 1267 | 160 | 29 | 15 | 3 | 0 | 0 |
| 2002 | 1788 | 212 | 17690 | 83 | 1576 | 168 | 21 | 19 | 2 | 2 | 0 |
| 2003 | 2067 | 218 | 20407 | 94 | 1849 | 166 | 31 | 11 | 6 | 4 | 0 |
| 2004 | 2204 | 229 | 19340 | 84 | 1975 | 170 | 41 | 12 | 6 | 0 | 0 |
| 2005 | 2035 | 194 | 20073 | 103 | 1841 | 141 | 30 | 15 | 6 | 2 | 0 |

Contractual Performance Measures for Radiological Control:

The PNNL radiological control demonstrated mature performance through the implementation of corrective actions and improvement initiatives identified through the use of assessments and Radiological Problem Report (RPR) Tracking and Trending. There were no statistically significant negative trends indicated in the RPR data over FY05. Results from programmatic assessments indicated stable or improved performance in all areas assessed.

## Princeton Plasma Physics Laboratory (PPPL)

The collective dose at PPPL was 1.16 person-rem in 2005, up just slightly from 0.97 person-rem in 2004. Most of the dose received on site is due to activated components in the vicinity of the National Compact Stellarator Experiment Coil Winding Facility. This area contains components and materials that were activated during Tokamak Fusion Test Reactor operations.

Occupational Radiation Dose Distribution (2001-2005)

PPPL — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 484 | 108 | 7420 | 69 | 376 | 87 | 11 | 9 | 1 | 0 | 0 |
| 2002 | 426 | 145 | 3707 | 26 | 281 | 130 | 15 | 0 | 0 | 0 | 0 |
| 2003 | 348 | 110 | 552 | 5 | 238 | 110 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 355 | 123 | 972 | 8 | 232 | 123 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 345 | 136 | 1164 | 10 | 209 | 136 | 0 | 0 | 0 | 0 | 0 |

Contractual Performance Measures for Radiological Control:

Performance measures are in place for collective dose. A TEDE that is 15 percent below the annual radiological goal established per the PPPL ALARA Plan is rated as Outstanding.

## Stanford Linear Accelerator Center (SLAC)

The collective dose at SLAC in 2005 increased to 10.4 person-rem, up from 3.9 person-rem the previous year. This represents an increase by a factor of 2.5, which was directly attributable to a corresponding increase in maintenance activities conducted inside Radiological Control Areas (RCA) where activated accelerator components are present.

For comparison, in 2005 there were 2,547 Radiological Work Permit (RWP) entries into these areas, up from 998 RWP entries during 2004. Thus, maintenance activities inside RCAs also increased by a factor of 2.5 in 2005 compared to 2004.

Occupational Radiation Dose Distribution (2001-2005)

SLAC — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 3155 | 35 | 1368 | 39 | 3120 | 32 | 3 | 0 | 0 | 0 | 0 |
| 2002 | 2676 | 79 | 3075 | 39 | 2597 | 76 | 1 | 2 | 0 | 0 | 0 |
| 2003 | 3023 | 109 | 3127 | 29 | 2914 | 106 | 3 | 0 | 0 | 0 | 0 |
| 2004 | 5156 | 149 | 3916 | 26 | 5007 | 141 | 8 | 0 | 0 | 0 | 0 |
| 2005 | 5403 | 359 | 10370 | 29 | 5044 | 349 | 10 | 0 | 0 | 0 | 0 |

Contractual Performance Measures for Radiological Control:

Performance measures are in place for unplanned radiation exposures and personnel contamination control. An Outstanding rating requires no occurrences of ORPS-reportable radiation doses or contamination. An unplanned radiation exposure includes a dose in excess of 100 millirem/year to non-radiological workers.

## Thomas Jefferson National Accelerator Facility (TJNAF)

The collective dose at TJNAF increased slightly to 1.5 person-rem in 2005, up from 1.1 person-rem the previous year. The number of workers with a measurable dose increased to 72, up from 43 in 2004. Approximately 800 person-mrem of the 1541 person-mrem collective dose can be directly related to maintenance, repairs, and disassembly associated with a unique experimental set up involving separated electron and photon beams in one of the high power experimental halls in the Continuous Electron Beam Accelerator Facility.

There is an Exposure Alert Level of 250 millirem per year; any individual dose exceeding this level triggers an ALARA review. Additionally, any individual who receives a total dose exceeding 120 mrem in a six month period, either through Thermo Luminscent Dosimeter (TLD) badge readings, or Self Reading Pocket Dosimeter (SRPD) readings is placed on a monthly TLD badge frequency for the remainder of the monitoring year. This enables closer monitoring for individuals who may be approaching administrative alert levels.

Occupational Radiation Dose Distribution (2001-2005)

TJNAF — Total Workers In Each Dose Range (mrem) >

| Year | Total Workers Monitored | Total Workers With Dose | Total Person - mrem | Avg. Dose (mrem) | Total With No Dose | Below 100 | 100-250 | 250-500 | 500-750 | 750-1000 | 1k-2k |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 1625 | 89 | 2317 | 26 | 1536 | 87 | 2 | 0 | 0 | 0 | 0 |
| 2002 | 1583 | 34 | 1113 | 33 | 1549 | 30 | 4 | 0 | 0 | 0 | 0 |
| 2003 | 1406 | 39 | 992 | 25 | 1367 | 38 | 1 | 0 | 0 | 0 | 0 |
| 2004 | 1475 | 43 | 1074 | 25 | 1432 | 42 | 1 | 0 | 0 | 0 | 0 |
| 2005 | 1601 | 72 | 1519 | 21 | 1529 | 70 | 2 | 0 | 0 | 0 | 0 |

Contractual Performance Measures for Radiological Control:

The Performance Evaluation and Measurement Plan (PEMP) incentivizes the percentage of pre and post Radiation Work Permit (RWP) reviews that are conducted by a Radiological Engineer, when the projected cumulative dose for the RWP exceeds 100 mrem. Performance on the accounting of Sealed Radioactive Sources is measured for those subject to 10 CFR 835.1201, as well as Sealed Radioactive Sources that are not subject to the rule.

Another measure requires a comprehensive peer review of the Radiological Control Program at least once every three years.