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Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy



# Hanford Radiological Protection Support Services Annual Report for 1999

T. P. Lynch
D. E. Bihl
M. L. Johnson
J. A. MacLellan
R. K. Piper

May 12, 2000

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Pacific Northwest National Laboratory
Richland, Washington 99352

# Summary

During calendar year (CY) 1999, the Pacific Northwest National Laboratory (PNNL) performed its customary radiological protection support services in support of the U.S. Department of Energy (DOE) Richland Operations Office (RL) and the Hanford contractors. These services included: 1) external dosimetry, 2) internal dosimetry, 3) in vivo measurements, 4) radiological records, 5) instrument calibration and evaluation, and 6) calibration of radiation sources traceable to the National Institute of Standards and Technology (NIST). The services were provided under a number of programs as summarized here.

Along with providing site-wide nuclear accident and environmental dosimetry capabilities, the Hanford External Dosimetry Program (HEDP) supports Hanford radiation protection programs by providing external radiation monitoring capabilities for all Hanford workers and visitors to help ensure their health and safety. Processing volumes decreased in CY 1999 relative to prior years for all types of dosimeters, with an overall decrease of 19%. During 1999, the HEDP passed the National Voluntary Laboratory Accreditation Program (NVLAP) performance testing criteria in 15 different categories. HEDP computers and processors were tested and upgraded to become Year 2000 (Y2K) compliant. Several changes and improvements were made to enhance the interpretation of dosimeter results.

The Hanford Internal Dosimetry Program (HIDP) provides for the assessment and documentation of occupational dose from intakes of radionuclides at the Hanford Site. Performance problems carried over from CY 1998 continued to plague the in vitro bioassay contractor. A new contract was awarded for the in vitro bioassay program. A new computer system was put into routine operation by the in vivo bioassay program. Several changes to HIDP protocols were made that were related to bioassay grace periods, using field data to characterize the amount of alpha activity present and using a new default particle size. The number of incidents and high routine investigations that required follow-up were lower compared with 1998. Also, the number of excreta analyses performed decreased by 9% compared with CY 1998.

The In Vivo Monitoring Program for Hanford (formerly the Hanford Whole Body Counting Project) provides the in vivo counting services for Hanford Site radiation workers. New computer hardware and software were put into routine operation to acquire, analyze, and store the measurement data. The technical procedures were revamped to reflect operational changes implemented with the new computer system. The U.S. Department of Energy Laboratory Accreditation Program (DOELAP) accreditation was extended to include two additional categories. New detectors were purchased for wound counting applications. The 8,085 in vivo measurements performed in 1999 represent a 2% decrease from 1998. Several high-purity germanium detectors were repaired at the In Vivo Radioassay and Research Facility, thereby saving out-of-service time and money compared with returning the detectors to the vendor. There were 11 phantom loans made through the DOE Phantom Library in 1999, including 2 international loans.

The Hanford Radiological Records Program (HRRP) preserves and administers all Hanford records of personnel radiological exposure, historical radiation protection, and radiological dosimetry practices and policies. It also produces reports for DOE Headquarters, RL, Hanford contractors, individuals, and

other authorized agencies and provides data for epidemiology and research projects. During CY 1999, the Access Control Entry System and the Radiological Exposure (REX) system were upgraded to be fully Y2K compliant. Work began on the redevelopment of REX.

The Instrumentation Services and Technology Program (IS&TP) provides complete and reliable radiation protection instrument services for site contractors to ensure personnel safety in the Hanford workplace. During CY 1999, 14,200 calibrations were performed by project staff, a slight decrease from CY 1998. One hundred ten instruments were found to be significantly out-of-tolerance upon return for calibration, a 35% increase compared with CY 1998. A major improvement during the year was the implementation of the new calibration database that resides on a network fileserver. A computerized system to archive and retrieve individual calibration records for instruments was also implemented. IS&TP also continued to support the Hanford Instrument Evaluation Committee by maintaining the approved instrument list and the record files of all instrument evaluations. The IS&TP staff also supported the International Nuclear Safety Program.

The Radiation Standards and Calibration Program (RS&CP) maintains the radiological standards necessary to support the characterization and calibration needs of instrument and external dosimetry projects. This includes maintaining any necessary special instrument and dosimeter response-characterizing equipment and supplemental radiation reference fields. This program provides the means to characterize response to radiation fields encountered at Hanford and ensures that the calibration fields comply with and are traceable to recommended standards and guides (notably those of NIST). During CY 1999, the traceability to recognized standards of the various reference radiological fields in the 318 Building were confirmed. Characterization and type testing efforts were performed to support external dosimetry and instrument calibration. RS&CP staff continued with the development of five International Standards Organization filtered X-ray techniques started in 1998 in anticipation of future dosimetry proficiency testing needs within both the NVLAP and the DOELAP. Other improvements included procurement of a new $^{204}$Tl source, recalibration of a $^{252}$Cf source by NIST, and implementation of the back-up Pantak X-ray system to replace the two failed Philips systems. Two performance tests were administered involving calibration of an ionization chamber using specific X-ray techniques and evaluation of an extrapolation ionization chamber response to reference beta fields.

# Abbreviations and Acronyms

| | |
|---|---|
| AC | air changes |
| ACES | Access Control Entry System |
| ACL | Administrative Control Limit |
| AIC | air-equivalent ionization chamber |
| AIM | acquisition interface module |
| ALARA | as low as reasonably achievable |
| ANSI | American National Standards Institute |
| | |
| BEGe | broad energy germanium |
| BHI | Bechtel Hanford Incorporated |
| BOMAB | bottle-manikin absorption |
| | |
| CAM | continuous air monitor |
| CAR | computer-assisted retrieval |
| CD | compact disc |
| CEDE | committed effective dose equivalent |
| CEMRC | Carlsbad Environmental Monitoring and Research Center |
| CFR | Code of Federal Regulations |
| CR&A | Calibration Research and Accreditation (subgroup) |
| CY | calendar year |
| | |
| DEC | Digital Equipment Corporation |
| DNFSB | Defense Nuclear Facility Safety Board |
| DOC | U.S. Department of Commerce |
| DOE | U.S. Department of Energy |
| DOELAP | DOE Laboratory Accreditation Program |
| DOT | U.S. Department of Transportation |
| DR&T | Dosimetry Research and Technology |
| | |
| EDF | Emergency Decontamination Facility |
| EFCOG | Energy Facility Contractors Operating Group |
| EH-10 | DOE's Office of Inspection and Enforcement |
| EIC | extrapolation ionization chamber |
| ERC | Environmental Restoration Contractor |
| ES | Enterprise Server |
| | |
| FDH | Fluor Daniel Hanford |
| FFTF | Fast Flux Text Facility |
| FHI | Fluor Hanford, Inc. |
| FOIA | Freedom of Information Act |
| FY | fiscal year |

| | |
|---|---|
| GM | Geiger-Mueller |
| HC | homogeneity coefficient |
| HCND | Hanford combination neutron dosimeter |
| HEDP | Hanford External Dosimetry Program |
| HEF | High-Exposure Facility |
| HEHF | Hanford Environmental Health Foundation |
| HIDP | Hanford Internal Dosimetry Program |
| HIEC | Hanford Instrument Evaluation Committee |
| HLAN | Hanford Local Area Network |
| HPDAC | Hanford Personnel Dosimetry Advisory Committee |
| HPGe | high-purity germanium |
| HPIC | Health Physics Instrument Committee |
| HPS | Health Physics Society |
| HQ | Headquarters |
| HRRP | Hanford Radiological Records Program |
| HSD | Hanford standard dosimeter |
| HSRCM | Hanford Site Radiological Control Manual |
| HVL | half-value layer |
| IAEA | International Atomic Energy Agency |
| IARC | International Agency for Research on Cancer |
| ICRP | International Commission on Radiological Protection |
| ICRU | International Commission on Radiological Units and Measurements |
| ID | identifier |
| IODR | Investigation of Dosimetry Result |
| IPUL | low-level isotopic plutonium |
| ISO | International Standards Organization |
| IS&TP | Instrumentation Services and Technology Program |
| IVRRF | In Vivo Radioassay and Research Facility |
| LaserCAL | CD-ROM imaging system for calibration records |
| LaserREX | CD-ROM imaging subsystem to REX |
| LEPD | low-energy photon detector |
| LLNL | Lawrence Livermore National Laboratory |
| LMSI | Lockheed Martin Services Incorporated |
| LN | liquid nitrogen |
| LSR | Low-Scatter Room |
| MA | (DOE) Management and Administration |
| MDA | minimal detectable activity |
| MDI | minimum detectable intake |
| MTL | minimum testing level |
| MQA | measurement quality assurance |

| | |
|---|---|
| NBS | National Bureau of Standards |
| NIOSH | National Institute for Occupational Safety and Health |
| NIST | National Institute of Standards and Technology |
| NPL | National Physical Laboratory |
| NRPB | National Radiation Protection Board (United Kingdom) |
| NRC | Nuclear Research Corporation |
| NVLAP | National Voluntary Laboratory Accreditation Program |
| | |
| ORP | Office of River Protection |
| | |
| PAM | portable air monitor |
| PC | personal computer |
| PEPA | Performance Evaluation Program Administrator |
| PFP | Plutonium Finishing Plant |
| PHMC | Project Hanford Management Contractor |
| PNNL | Pacific Northwest National Laboratory |
| PTB | Physikalisch-Technische Bundesanstalt |
| PTW | Physikalisch-Technische Werkstäten |
| PUREX | Plutonium-Uranium Exaction facility |
| | |
| QA | quality assurance |
| QC | quality control |
| QUS | U-natural soluble |
| | |
| REX | Radiological Exposure (system) |
| R&HT | Radiation and Health Technology |
| RL | U.S. Department of Energy Richland Field Office |
| ROI | region of interest |
| RPG | Radiochemistry Process Group |
| RS&CP | (Hanford) Radiation Standards and Calibrations Program |
| RWP | Radiation Work Permit |
| | |
| SAIC | Science Applications International Corporation |
| SBMS | Standards Based Management System |
| SCMP | Software Configuration Management Plan |
| SOW | Statement of Work |
| | |
| TEPC | tissue-equivalent proportional counter |
| TIBM | thoron in-breath monitor |
| TL | thermoluminescent (dosimetry) |
| TLD | thermoluminescent dosimeter |
| TRU | transuranium radionuclide(s) |

| | |
|---|---|
| UK | United Kingdom |
| USE | U.S. Ecology |
| USTUR | U.S. Transuranium and Uranium Registry |
| WBC | whole body count |
| WBCP | (Hanford) Whole Body Counting Program |
| WIPP | Waste Isolation Pilot Project |
| Y2K | Year 2000 |

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# 1.0 Introduction

Specific radiation protection services are performed routinely by the Pacific Northwest National Laboratory (PNNL)[a] for the U.S. Department of Energy (DOE) Richland Operations Office (RL) and the Hanford Site contractors. These site-wide services are provided by programs in 1) external dosimetry, 2) internal dosimetry, 3) whole body counting, 4) radiation records, 5) instrument calibration and evaluation, and 6) calibration of radiation sources traceable to the National Institute of Science and Technology (NIST). The program work is performed by staff in the Radiation and Health Technology (R&HT) technical group, which falls under the purview of the Environmental Technology Division. The R&HT group consists of the former Radiation Protection Services technical group and Dosimetry Research and Technology (DR&T) technical group. The former DR&T technical group is now an R&HT program that continues to be responsible for calibration of radiation sources traceable to NIST.

In addition to the DR&T group, R&HT is organized into four functional groups: 1) Dosimetry Services, 2) Instrumentation Services and Technology, 3) Radiation Records, and 4) Administration. The Dosimetry Services group includes the Hanford External Dosimetry Program, the Hanford Internal Dosimetry Program, and the In Vivo Monitoring Program for Hanford, which includes the operational and technical staff at the In Vivo Radioassay and Research Facility (IVRRF); and the Dosimetry Operations Program, which includes all of the Dosimetry Services technician staff that perform the processing of dosimeters, handling of dosimeters, and bioassay scheduling for the Project Hanford Management Contractor (PHMC) and RL, and Radiological Exposure (REX) data processing (which was transferred from the Hanford Radiological Records Program). The Instrumentation Services and Technology group includes three programs: Calibration Services, Instrument Repair, and Instrument Testing and Qualification. The Hanford Radiation Records Program includes the Records Library, Exposure Reporting, and Data Administration tasks. Information Services policy and planning for R&HT are assigned to a staff position reporting directly to the R&HT manager. The Administration group is responsible for financial planning and secretarial support.

Although some of the programs described in this report are involved in activities funded by other sources, only those activities funded by RL, DOE Headquarters (HQ), or the Hanford contractors are addressed here. Services provided for non-RL activities are performed only to the extent that they do not adversely affect services to DOE and its contractors. These non-RL services provide funds that support the overall program and reduce costs to RL and to the Hanford contractors.

Each of the six primary programs of R&HT is described in a separate chapter of this report: 1) the Hanford External Dosimetry Program, 2) the Hanford Internal Dosimetry Program, 3) the In Vivo Monitoring Program for Hanford, 4) the Hanford Radiation Records Program, 5) the Hanford Instrumentation Services and Technology Program, and 6) the Hanford Radiation Standards and Calibrations Program. Program descriptions include:

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(a) Pacific Northwest National Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

- the routine operations
- program changes and improvements
- program assessments
- other program-related activities, such as publications, presentations, and professional memberships.

During calendar year (CY) 1999, the Hanford contractors consisted of PNNL, Bechtel Hanford, Inc. (BHI, also referred to as the Environmental Restoration Contract team [ERC]), the Hanford Environmental Health Foundation (HEHF), and Fluor Hanford Inc. (FHI). In 1999, the former PHMC, consisting of six subcontractors and six enterprise companies, was consolidated and FHI was formed. FHI consists of these five primary projects: Spent Nuclear Fuel, Waste Management, Nuclear Material Stabilization, River Corridor, and the Fast Flux Test Facility.

The PNNL and RL management structure and communication interfaces for each PNNL-operated program are shown in the organizational chart in Figure 1.1. The RL Science and Technology Programs Division is now responsible for PNNL services in this area.

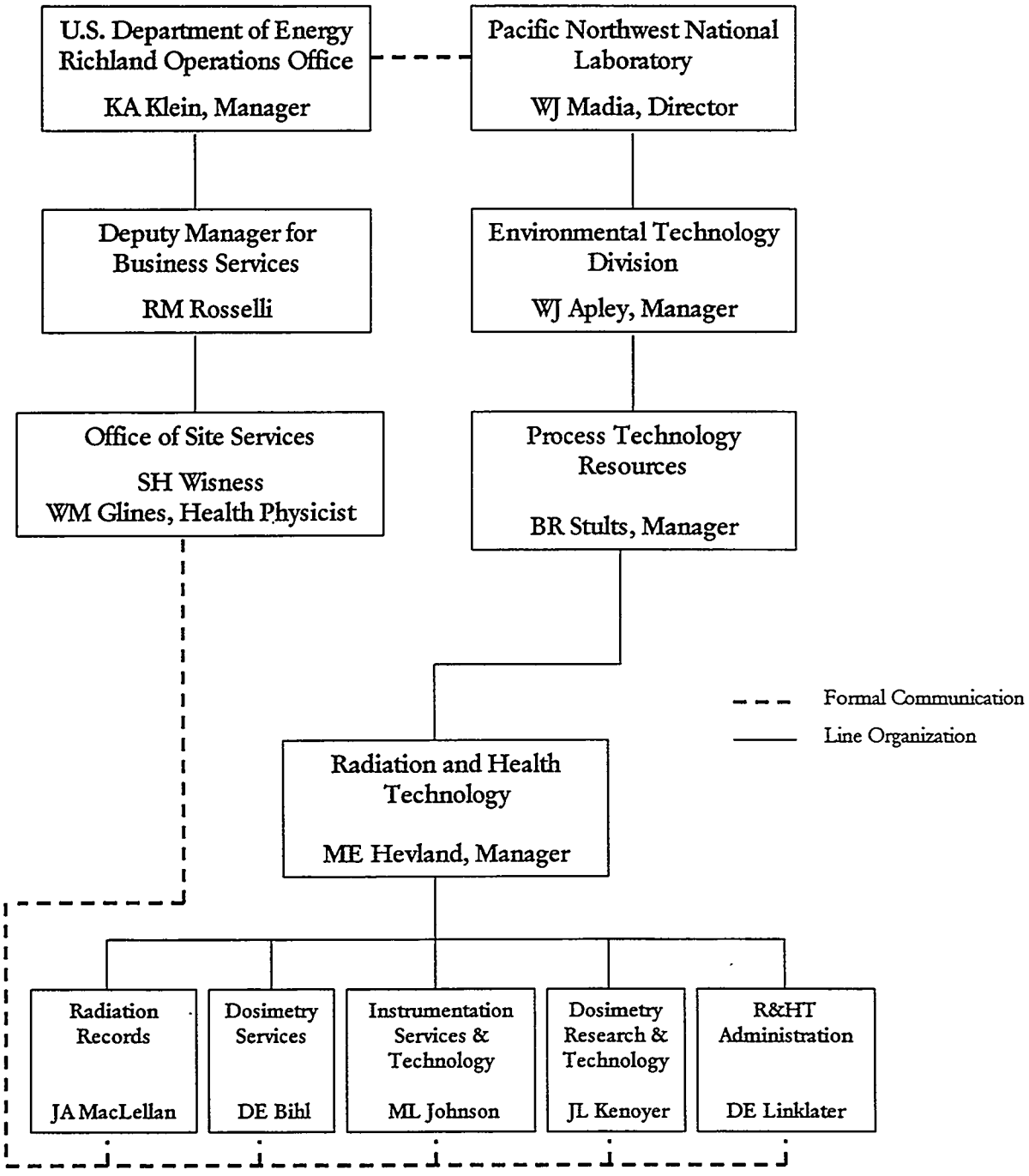


**Figure 1.1.** Management Structure and Major Communication Interfaces for Hanford Radiation Protection Services Through September 1999

# 2.0 Hanford External Dosimetry Program

The Hanford External Dosimetry Program (HEDP) provides the official dose from external radiation for all Hanford personnel in support of Hanford radiation protection programs. HEDP dosimeter results provide the means used by contractor personnel to project, control, and measure radiation doses received by personnel. The program also provides site-wide nuclear accident, environmental, and building area dosimetry capabilities. The program operates in compliance with DOE requirements as set forth in 10 CFR 835, *Occupation Radiation Protection* and the *Hanford Site Radiological Control Manual* (HSRCM-1; RL 1994), and the program is accredited by both the DOE Laboratory Accreditation Program (DOELAP) and the Department of Commerce National Voluntary Laboratory Accreditation Program (NVLAP).

The Hanford whole body personnel dosimetry system consists of a commercially procured thermoluminescent (TL) dosimetry system (manufactured by Bicron/Harshaw).[a] Dosimeters include the Hanford standard dosimeter (HSD), the Hanford combination neutron dosimeter (HCND), an extremity dosimeter, and the Hanford environmental dosimeter. The HCND also has the provision for a CR39 track-etch dosimeter, although the track-etch dosimeter was not used for personnel in 1999. The HSD also has a neutron response capability that will detect exposure to neutron radiation. Beginning in 1999, after receiving accreditation in 1998, the HSD was considered acceptable for monitoring neutron exposures, nominally below 100 mrem, with the understanding that the HSD will over-respond to low-energy neutrons. The Hanford extremity personnel dosimetry system consists of a commercially procured Bicron/Harshaw "chipstrate" extremity dosimeter insert enclosed in an ICN/MeasuRing[b] ring casing (DOE contractors only). The HSD is also used as an extremity (wrist or ankle) dosimeter. Both the HSD and the HCND are used for monitoring areas, the HCND being mounted on 19-L (5-gal) water-filled carboys. Cleaning of dosimeter holders is subcontracted to Columbia Industries.

Physical and functional details concerning the HSD, HCND, finger ring, and the environmental dosimeter are provided in the *Hanford External Dosimetry Technical Basis Manual*.[c] Additional details on program operation are documented in the *Hanford External Dosimetry Quality Manual*,[d] the

(a) Bicron, Saint-Gobain/Norton Industrial Ceramic Corporation, Solon, Ohio.
(b) ICN Biomedicals, Inc., Costa Mesa, California.
(c) Internal manual, PNL-MA-842, Pacific Northwest National Laboratory, Richland, Washington (current version).
(d) Internal manual, PNL-MA-859, Pacific Northwest National Laboratory, Richland, Washington (current version).

*Hanford External Dosimetry Project Procedures Manual,*[a] the *Quality Assurance Plan for Hanford External Dosimetry,*[b] and the *Hanford External Dosimetry Program Data Management Manual.*[c]

## 2.1 Routine Operations

During 1999, 42,622 official personnel dose results were reported for Hanford customers. This processing volume represented a 19% decrease from the total of 52,393 during 1998. The annual number of dose results is illustrated in Figure 2.1 for 1995 through 1999 for each type of dosimeter. The numbers in Figure 2.1 do not include internal quality control (QC) dosimeter cards or cards processed in support of DOELAP testing, and each HCND counts as one even though there really are two dosimeters in the packet.

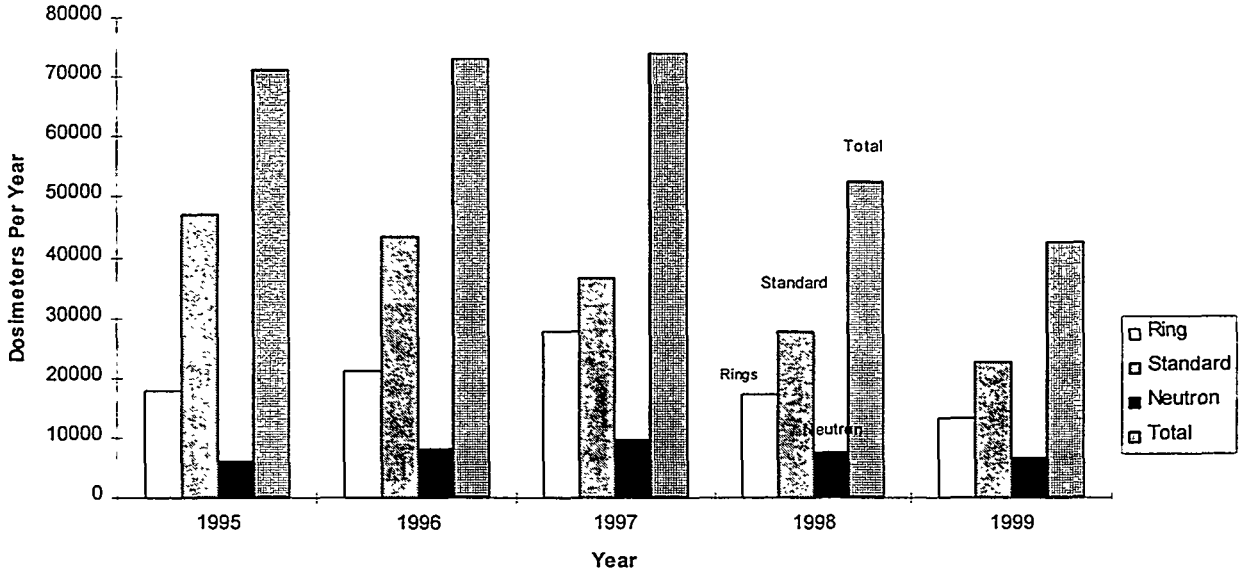


**Figure 2.1.** Trend in Reported Hanford Personnel Dosimeter Results

The volume decreased for all categories of personnel dosimeters (HSD down 18%, HCND down 14%, rings down 22%). This continues a trend from 1998 with the overall total decreasing 42% in 2 years. The decreases in 1999 resulted primarily from reducing the dosimeter exchange frequency for many workers (e.g., from monthly to quarterly and quarterly to annual) and revising the policy for issuing finger rings.

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(a) Internal manual, PNL-MA-841, Pacific Northwest National Laboratory, Richland, Washington (current version).

(b) Internal document, Quality Assurance (QA) Plan No. LSC-022, Pacific Northwest National Laboratory, Richland, Washington (current version).

(c) Internal manual, PNL-MA-844, Pacific Northwest National Laboratory, Richland, Washington (current version).

As in previous years, the CR39 track-etch capability of the HCND was not used. This action was recommended by the Hanford Personnel Dosimetry Advisory Committee (HPDAC) and was based on the relatively low-energy neutron spectra at the Plutonium Finishing Plant (PFP). Plutonium at PFP is primarily being stored awaiting DOE decisions about its eventual disposition. As such, the neutron energy spectra are greatly moderated because of the extensive shielding, and the neutrons are primarily less energetic than the approximate 100-keV energy threshold of the track-etch foil. See Section 2.4.2 for a summary of the latest study on TLD and track-etch performance in PFP environments.

Statistics on external whole body doses received by the Hanford workforce are provided in Table 2.1. These statistics were first gathered in 1998. The total number of monitored workers was 10,025 in 1999 compared with 9,979 in 1998. The highest external dose for an individual worker was 1,499 mrem in 1999 compared with a highest dose of 1,204 mrem in 1998. The number of workers in the 1,000- to 1,999-mrem range increased from 3 in 1998 to 23 in 1999.

**Table 2.1.** External Whole Body Doses Received by Hanford Workers in 1999[a]

| Dose Range (mrem) | Number of Workers in Dose Range | | | | | | |
|---|---|---|---|---|---|---|---|
| | ERC | PHMC[b] | PNNL | DOE[c] | HEHF | Other | Total |
| Zero | 828 | 4129 | 1339 | 1006 | 34 | 844 | 8180 |
| 1-99 | 77 | 948 | 187 | 35 | 0 | 168 | 1415 |
| 100-249 | 3 | 198 | 30 | 2 | 0 | 16 | 247 |
| 250-499 | 0 | 84 | 15 | 0 | 0 | 7 | 106 |
| 500-749 | 0 | 33 | 1 | 0 | 0 | 0 | 34 |
| 750-999 | 0 | 20 | 0 | 0 | 0 | 0 | 20 |
| 1000-1999 | 0 | 23 | 0 | 0 | 0 | 0 | 23 |
| >2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(a) For monitored workers.
(b) Includes Lockheed Martin employees under the Office of River Protection.
(c) Includes Office of River Protection.

Statistical tracking of dosimeters that were issued then subsequently lost or not returned for whatever reason was renewed in 1998 after being suspended for a couple of years. Because there are lag periods before unreturned dosimeters are declared lost, not all potentially lost dosimeters are included in these statistics. The lag periods are 60 days for monthly exchanged dosimeters, 180 days for quarterly exchanged dosimeters, and 465 days for annually exchanged dosimeters. The numbers of dosimeters declared lost in 1999 were as follows: 106 HSDs, 3 HCNDs, 48 finger rings, and 4 area dosimeters.

There were 622 Investigation of Dosimeter Results (IODRs) processed in 1999 (DOE—28, PHMC—514, PNNL—48, and ERC—32).

In addition to personnel dosimeters, the HEDP also processed 2,101 area dosimeters, 848 environmental dosimeters, and 91 fixed nuclear accident dosimeters. These numbers are increased slightly compared with 1998 numbers.

## 2.2 Program Changes and Improvements

Major modifications to HEDP practices are discussed during HPDAC meetings. Changes in program practices made during 1999 are described in the following sections.

### 2.2.1 Change in Criterion for Assigning Extremity and Eye Dosimetry

The site-wide criterion for assigning extremity dosimetry was changed to allow for a gradient of dose from the extremity (versus the whole body) of a factor of 10 and provided a 500-mrem threshold. The criterion for assigning eye dosimetry was likewise changed to incorporate a gradient of a factor of 3 and a threshold of 100 mrem. The changes were incorporated into the *Hanford External Dosimetry Technical Basis Manual.*

### 2.2.2 Improvement of Fade and Superlinearity Corrections for Mixture of Neutrons and Photons

As part of the implementation of an annually exchanged HCND, a study was conducted to determine a model for the fading of neutron dose signal in TLD 600 chips. Previously, a single fade model was used for both gamma and neutron dose in TLD 600. Studies published in the open literature, however, suggested that there are differences in fading for gamma and neutron dose, with the neutron fading being more severe. As part of the study, the dose algorithms for HSD and HCND were revised to incorporate independent fade corrections for neutron signal and gamma signal in TLD 600, weighted on the basis of the estimated contributions of the two signals to the total chip reading.

In conjunction with improvements in the fade corrections, improvements were also made in the supralinearity corrections. Studies conducted by other researchers indicate that in TLD 600, the supralinearity for gamma dose differs from the supralinearity for neutron dose, with the gamma supralinearity correction being larger. Previously, a single supralinearity correction was applied, based on observed supralinearity for gamma dose. For accident-level doses involving a large neutron component, there was the potential for reported neutron dose on the HSD or HCND to underestimate the true dose because of the application of a supralinearity correction that was too large. The HCND and HSD algorithms have been revised to include independent gamma and neutron supralinearity corrections for TLD 600 that are weighted on the basis of the estimated contribution of the two signals to the total reading.

### 2.2.3 Dose Reporting Thresholds

The dose reporting threshold for area dosimeters was reduced from 10 mrem to 0 mrem.

The dose reporting threshold for neutron doses was changed from 10 mrem to 10 "reader units" (raw chip readings in mR). In essence this allows the detection of dose to be based on the signal produced in the reader. For dose from high-energy neutrons, there is roughly a 1:1 correspondence between reader units and mrem, so a reader detection level of about 10 reader units still results in a dose reporting threshold that is basically unchanged. But for low-energy (moderated) neutrons, the raw chip readings are 5 to 10 times greater than the reported dose, so the readers can easily detect neutron signal that results in doses in the 1- to 2-mrem range. The change allowed for these easily detected neutron doses to be reported without a final 10-mrem cutoff.

Under some conditions the correction factor for low-energy neutrons in the plutonium flouride algorithm could become extremely and unrealistically large, leading to reported doses in decades or hundreds of mrem from a barely detectable signal. This correction factor was capped at 10, pending results of the study of the dosimeter response versus tissue-equivalent proportional counter (TEPC) response in actual neutron fields at the PFP (see Section 2.4.2).

### 2.2.4 Regeneration of Element Correction Coefficients

A study was conducted in 1998 to determine if the sensitivity of the population of chips in the HSD cards had drifted from the time of initial generation of the element correction coefficients. As a consequence of the study, a decision was made to start recalibrating all HSD and HCND cards so that all dosimeters issued after January 1, 1999 would have newly determined element correction coefficients. That task was carried out during the summer and fall of 1998. In 1999 all cards being returned to the processing lab were recalibrated before being reissued. Cards used for QC and blank readings were also recalibrated and in the process many cards were found to have poor heat transfer were removed from service.

### 2.2.5 Incorrect Tin Filter Thickness in HSD Holders

On May 25, HEDP was notified by the HSD holder manufacturer (Bicron) that most holders sold since 1996 probably have tin filters that are 19 mils (0.48 mm) thick instead of being 25 mils (0.635 mm) thick as specified. HEDP acceptance test procedures were not designed to detect such a small variation in filter thickness. The eddy current testing equipment was improved to be able to make such a determination and the acceptance test procedure was revised. Most of the holders purchased since 1996 were used for Hanford area dosimeters and for non-Hanford customers. Holders for the non-Hanford customers were tested and the thin filters were removed from service as part of the next regular exchange for those customers. A plan was devised to test and remove from service all holders with the thin filters by the end of CY 2000.

In addition to removing thin-filter holders from service, tests were conducted on the effect of the thinner filter on dose results. A series of cards in the defective holders was irradiated to X-rays at PNNL's NIST-accredited irradiation lab. Emphasis was particularly on X-rays that had an average photon energy less than 150 keV where the absorption cross section for tin changes rapidly as a function of energy. The bias in dose results from the X-rays caused by the thin filters was shown to be

inconsequential. A similar irradiation study was conducted for beta radiation, and a quick review also indicated that the bias was not significant, however, a complete analysis was still pending as of year-end.

## 2.3 Program Assessments and Quality Assurance

Each year internal audit dosimeters are processed to ensure the integrity of dosimeter processing. During 1999, 1550 internal audit dosimeters were processed. A breakdown of the internal audit dosimeters is shown in Table 2.2.

**Table 2.2.** Audit Dosimeters Processed During 1999

| Dosimeter Type | No. of Dosimeters |
|---|---|
| HSD | 840 |
| HCND | 340 |
| Rings | 240 |
| CR39 Track-Etch | 170 |

Data analysis programs are used to statistically evaluate the performance for each of the audit dosimeter categories against DOELAP criteria. Reports are prepared for every dosimeter and radiation type for each of the 13 dosimeter processings (i.e., every month plus annual) conducted each year. A QC checklist is prepared for each processing. Copies of the checklists and audit dosimeter performance reports are provided to the Hanford Radiation Protection Historical Files.

### 2.3.1 Blind Audit Personnel Dosimeters

FHI routinely submits audit dosimeters to be processed along with the personnel dosimeters. Audit dosimeters are submitted each month of the year, and performance is analyzed each quarter for shallow, deep, and neutron dose, and dose to the finger ring dosimeters. HEDP successfully passed each of the quarterly evaluations in 1999 using DOELAP performance criteria. Documentation of HEDP results of these audits is included in the Hanford Radiation Protection Historical Files.

### 2.3.2 Blind Audit Environmental Dosimeters

Staff from PNNL's Surface Environmental Surveillance Program routinely submit audit dosimeters to be processed along with their quarterly exchanged environmental dosimeters. The given exposures typically range between 15 and 30 mrem of $^{137}Cs$ gamma radiation. For the 12 audit dosimeters submitted during 1999, the overall bias in the reported dose compared with the delivered dose was 3.1%, with a range in the bias of individual dosimeters from -5.4% to 9.9%. The bias plus precision statistic was 0.078. These are all acceptable results.

### 2.3.3 Department of Energy Laboratory Accreditation Program

Performance testing and an onsite inspection occur every 2 years for DOELAP and were last performed in 1998. No performance testing occurred in 1999. Work continued on corrective actions from the previous onsite assessment.

### 2.3.4 National Voluntary Laboratory Accreditation Program

Performance testing and an onsite inspection occur approximately every 2 years for NVLAP. Performance testing was conducted at the end of 1999, but the onsite inspection had not yet occurred by the end of the year. The HEDP was tested for the HSD, HCND, and the EXTRAD finger ring in a total of 15 categories. HEDP successfully passed all requested categories. Testing results for Hanford whole body and extremity dosimeters are summarized in Tables 2.3 and 2.4, respectively. Exposures included personnel and accident-level (as high as 500 rem) doses for personnel whole body dosimeters. Whole body and extremity dosimeter performance testing followed recommendations in the American National Standards Institute/Health Physics Society standards N13.11, *An American National Standard for Personnel Dosimetry Performance—Criteria for Testing*, and N13.32, *An American National Standard for Performance Testing of Extremity Dosimeters*, respectively (ANSI/HPS 1993; ANSI/HPS 1995). Even though the same algorithm is used for both DOELAP and NVLAP performance testing, and even though the dose conversion factors are different for the two testing programs, the Hanford dosimeters performed well. This is demonstrated in Tables 2.3 and 2.4 by comparing the calculated performance of

**Table 2.3.** NVLAP Performance Test Data for Hanford Whole Body Dosimeter

| NVLAP Category Description | NVLAP Criterion for P | Performance[(a)] | | | |
|---|---|---|---|---|---|
| | | HSD | | HCND | |
| | | Shallow | Deep | Shallow | Deep |
| I. Accident, Low-Energy Photons | 0.3 | N/A | 0.057 | N/A | N/A |
| II. Accident, High-Energy Photons | 0.3 | N/A | 0.036 | N/A | N/A |
| IIIA. Low-Energy Photons, General | 0.5 | 0.346 | 0.095 | N/A | N/A |
| IIIB. Low-Energy Photons, High-Energy Techniques | 0.5 | 0.157 | 0.128 | N/A | N/A |
| IV. High-Energy Photons, $^{137}Cs$ | 0.5 | N/A | 0.033 | N/A | N/A |
| VC. Beta Particles, General | 0.5 | 0.094 | N/A | N/A | N/A |
| VI. Photon Mixtures | 0.5 | 0.251 | 0.093 | N/A | N/A |
| VII. Photon Plus Beta Particles | 0.5 | 0.199 | 0.085 | N/A | N/A |
| VIII. Photons Plus Neutrons (Total) | 0.5 | N/A | 0.084 | N/A | 0.057 |
| VIII. Photons Plus Neutrons (Neutron) | 0.5 | N/A | 0.125 | N/A | 0.082 |

(a) Performance quotients (P) for Hanford standard dosimeter (HSD) and Hanford combination neutron dosimeter (HCND) are calculated as $P = |B| + S$ where B is the systematic error in the reported dose and S is the random error. Dosimeter performance quotients must be less than the NVLAP criterion in each category for satisfactory performance.

**Table 2.4.** NVLAP Performance Test Data for the Hanford Finger Ring Dosimeter[a]

| | | Performance[b] |
|---|---|---|
| **NVLAP Category Description** | **NVLAP Criterion** | **Shallow** |
| I. Accident, Low-Energy Photons | 0.3 | 0.101 |
| II. Accident, High-Energy Photons | 0.3 | 0.042 |
| IIIA. Low-Energy Photons, Mixed X-Rays | 0.5 | 0.087 |
| IVA. High-Energy Photons, $^{137}Cs$ | 0.5 | 0.066 |
| VC. Beta Particles, General | 0.5 | 0.090 |

(a) EXTRAD dosimeter only.

(b) Performance quotients (P) for Hanford extremity ring dosimeter are calculated as $P = |B| + S$ where B is the systematic error in the reported dose and S is the random error. Dosimeter performance quotients must be less than the NVLAP criterion in each category for satisfactory performance.

the respective dosimeters with the NVLAP criterion in each irradiation category. In all but one category, the Hanford performance was well below the 0.3 or 0.5 criterion. Figures 2.2 through 2.4 illustrate the performance using Horlick diagrams, where each point represents the bias and precision results for a category and each point must fall within the six-sided figure.

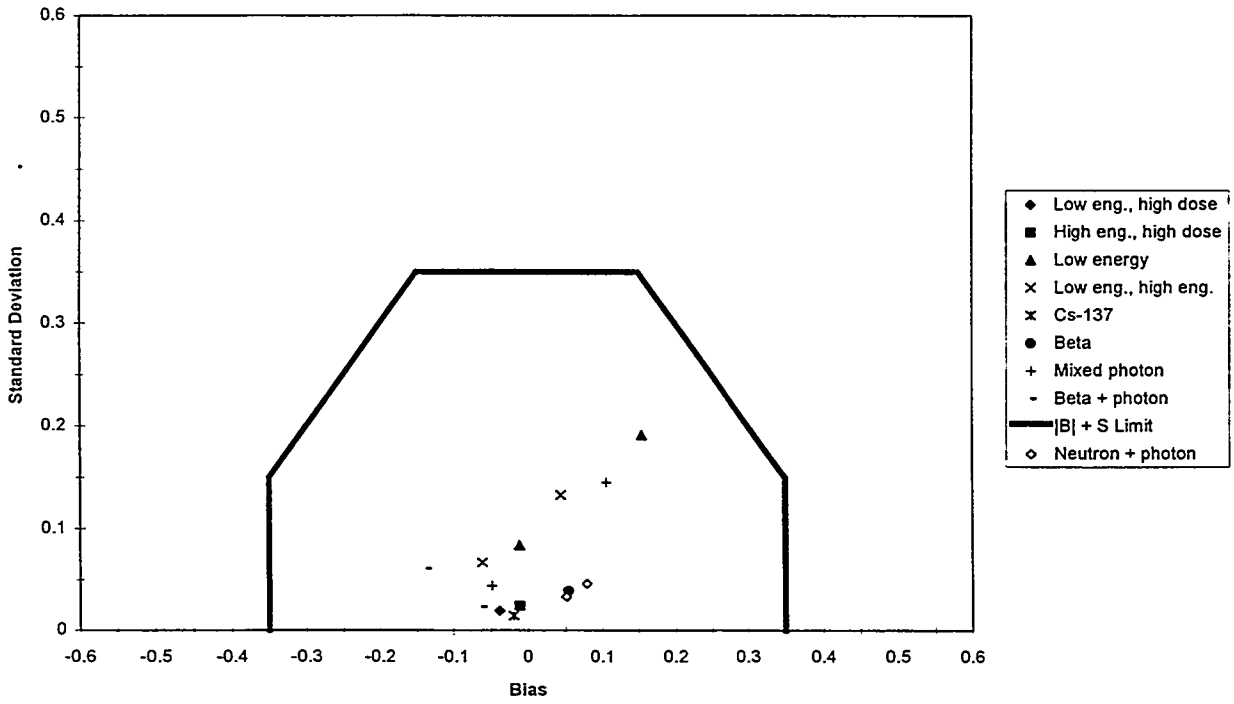


**Figure 2.2.** NVLAP Performance Test Results for the HSD Whole Body Dosimeter

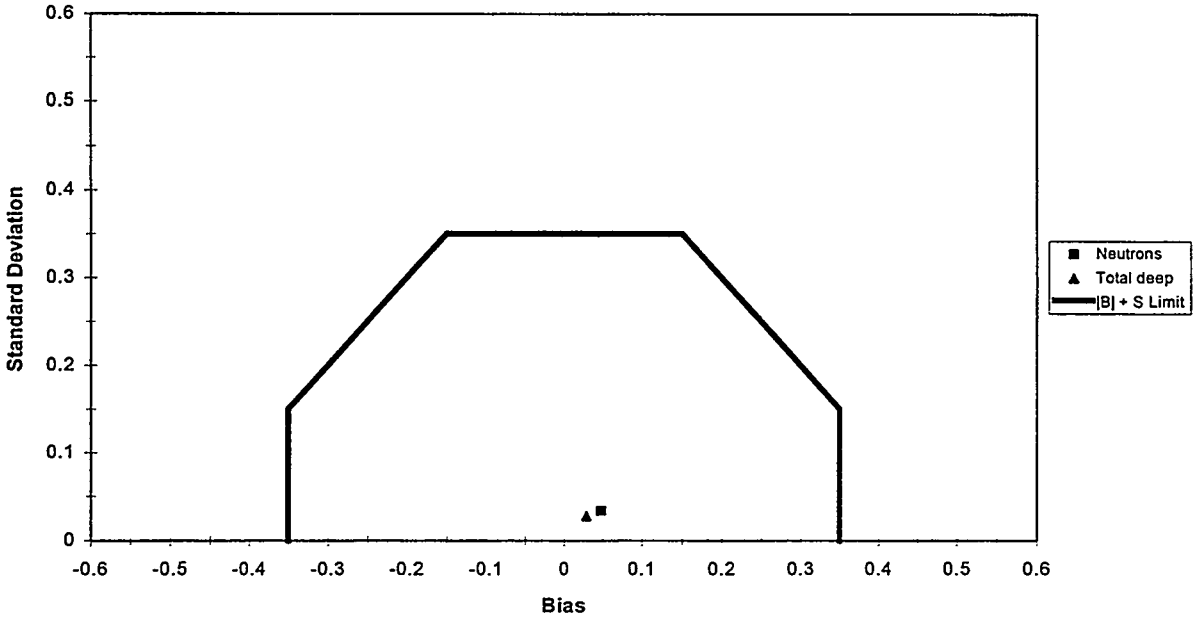


**Figure 2.3.** NVLAP Performance Test Results for the HCND Neutron Dosimeter

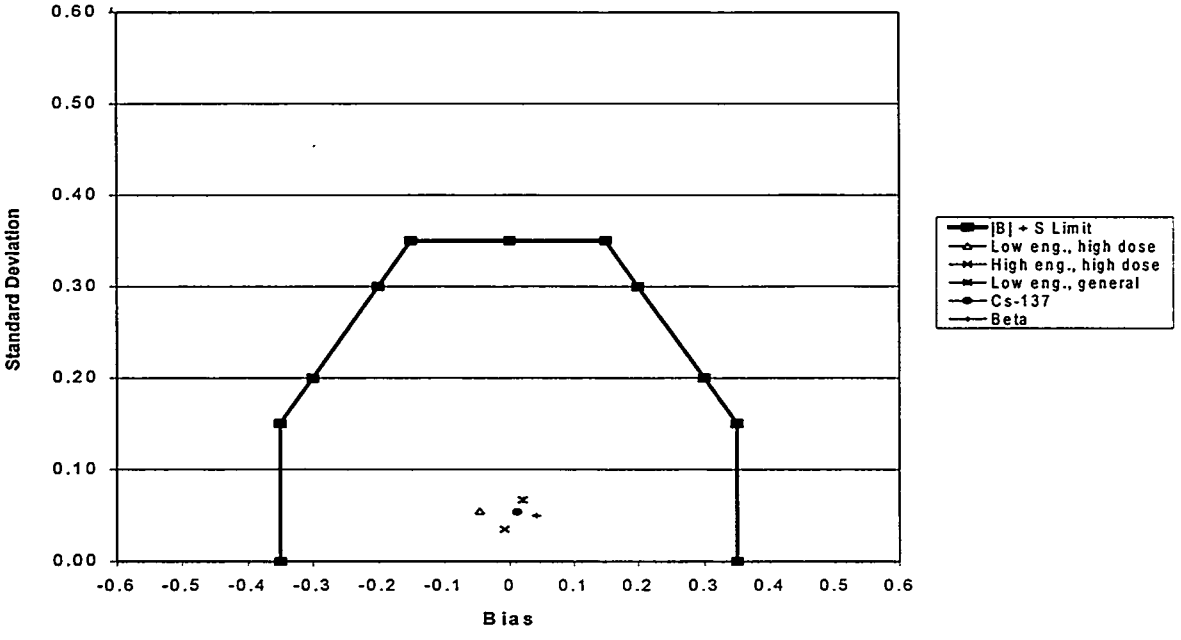


**Figure 2.4.** NVLAP Performance Test Results for the EXTRAD Finger Ring Dosimeter

### 2.3.5 Contractors' Assessment of Criticality Dosimetry

10 CFR 835.102 requires auditing of all aspects of radiation protection programs at least once every 3 years. Because external dosimetry is a fundamental part of the radiation protection programs of all the Hanford contractors, the contractors performed a joint audit of HEDP's criticality dosimetry in March to satisfy the 835.102 requirement. The audit resulted in four observations concerning the HEDP, which are paraphrased below.

- No backup analytical facility has been identified to perform analysis of biological samples or activation foils in the nuclear accident dosimeters if the 325 Building is unavailable.

- The distribution list for results from annual processing of the fixed nuclear accident dosimeters did not include the PNNL nuclear safety engineer.

- The performance of the TLDs used in nuclear accident dosimeters had not been tested at doses up to 10,000 rads.

- The technical basis for ensuring that the neutron foils can measure neutron doses up to 10,000 rads was not in place.

Corrective actions on all four observations were completed by November and the action items were closed.

### 2.3.6 Self-Assessments

Self- (or internal) assessments of the HEDP are conducted annually. The 1999 self-assessment focused on the status of corrective actions from the large number of outside assessments conducted in 1997 and 1998.

In addition to the routine self-assessment, a critique was held and an Off-Normal Occurrence was issued resulting from a failure to report a batch of finger ring dosimeters. The batch was processed in September but the group file was not transferred to the VAX cluster for final processing and reporting. The error was discovered by the PNNL radiological control organization in October. The long-term corrective action was to create a routine report on the VAX that will list the following:

- dosimeters logged into the REX database as returned from use but not scanned into the processing lab

- dosimeters scanned into the processing lab but not read and reported to the VAX

- dosimeters scanned into the processing lab but not reported to REX.

The report was to be set up to run automatically at a selected interval. The milestone for the corrective action was set for January 31, 2000 because of the hold on code changes to the VAX in December in response to Year 2000 (Y2K) compliance rules. (This milestone was met and the report is now in place.)

## 2.4 Supporting Technical Studies

Three technical studies were undertaken during 1999, as described in the following sections.

### 2.4.1 Year 2000 Preparations and Results of the Millennium Change

The HEDP was determined to be mission critical according to DOE-HQ guidelines. Use of computers and processors by HEDP would have had to have been tested and fixed, if necessary, regardless of the mission-critical status by DOE; but being mission critical meant more rigor in documentation and more formal oversight. In 1998 both the model 8800 readers (for the whole body dosimeters) and the model 6600 readers (for the finger rings) were determined to not be Y2K compliant. Fixes for two model 8800 readers were procured, installed, and tested in 1998, and the fix for a third model 8800 was installed in 1999. These were major upgrades to the readers, including most of the hardware. Fixes for the two model 6600 readers were also installed. These fixes were simpler, involving only a new processing chip.

The VAX cluster was tested and found to be Y2K compliant. Overall testing of the complete system (readers and VAX cluster), referred to as end-to-end testing, was conducted in February with validation and verification performed by an outside expert independent of the HEDP or Battelle. The contingency plan for failure of the processing equipment in the 318 Building was tested in June, and a personal computer (PC) code that could be used in lieu of the VAX cluster for small numbers of dosimeters was developed in December.

The readers and VAX cluster were shut down over the millennium change as a precaution against loss of power or power spikes to the building. Some difficulties were encountered with the VAX cluster upon restart that related to the extended shutdown not to the millennium change. A new battery had to be procured and installed in the box controlling the array of hard drives, a backup tape drive had to be replaced, and coding changes were required on a few minor subroutines. The readers worked fine, and there was no impact on processing of dosimeters, calculating doses, or reporting results to the REX database.

### 2.4.2 Validation of Hanford Personnel and Extremity Dosimeters in Plutonium Environments

A study was performed to validate HSDs, HCNDs (including the track-etch component), and extremity neutron dosimeters in various work environments at the PFP (Scherpelz, Fix, and Rathbone 2000). Neutron doses from the aforementioned dosimeters were compared with simultaneous measurements obtained with TEPCs. Measurements were also obtained with a Bubble Technology Industries bubble detector, an Apfel REMBrandt survey meter, and a Snoopy survey meter. The study

showed that highly scattered neutron fields exist at the PFP work locations. The HSD consistently overestimated the neutron dose, sometimes by as much as a factor of 18. The HCND without the track-etch plastic performed well, with an overall positive bias of 1.3. However, some individual dose results were under-reported by a factor of 5. The HCND with the track-etch plastic had good precision but consistently under-responded because of the low-energy neutrons (as expected). The extremity neutron-to-gamma ratios ranged from 0.09 to 0.65. A letter report documenting the study was issued at the end of December and a formal PNNL technical report was issued a month later.

### 2.4.3 Evaluation of the HSD Neutron Response in Air

In response to a DOE-RL finding against the PNNL Area Dosimetry Program, HEDP was asked for a correction factor that could be used to correct neutron dose results calculated for HSD area dosimeters. The HSD reports neutron dose based on a calibration to bare $^{252}Cf$ (high-energy neutrons) whereas in most if not all workplace applications, the HSDs are exposed to neutrons that have passed through substantial shielding and are of substantially lower energy. The HSD over-responds to low-energy neutrons, and this caused some area dosimeter results to exceed the threshold for posting and radiological control. A study was conducted to evaluate the response of the HSD in air (i.e., not on a phantom) to low-energy neutrons. A correction factor of 2.66 was determined based on response in air to neutrons from a $D_2O$-moderated $^{252}Cf$ source without cadmium cover.

## 2.5 Skin Contaminations

Hanford skin contamination statistics are provided in Table 2.5. In general, there were fewer skin contaminations in 1999 than in 1998.

**Table 2.5.** Number of Skin Contaminations (Worker-Events)[a] in 1999

| Contractor | Number of Contaminations |
|---|---|
| PHMC | 39 |
| PNNL | 18 |
| ERC | 0 |
| DOE | 0 |
| Total | 57 |

(a) Each contamination event for a single worker counted separately.

## 2.6 Program-Related Professional Activities

Staff activities, presentations, publications, and professional memberships during 1999 are listed in this section.

### 2.6.1 Activities

Jack J. Fix was involved in professional external dosimetry activities, outside of the Hanford Site, as follows:

- Conducted DOELAP onsite technical assessment of the Lawrence Livermore National Laboratory from June 20-24, 1998 and Thomas Jefferson National Accelerator Facility from November 3-6, 1998.

- Participated as a member of the dosimetry subcommittee in meetings of the International Agency for Research on Cancer (IARC) from March 29 to April 3, 1998 in Lyon, France regarding a collaborative epidemiologic study of nuclear workers from 14 countries. This study includes Hanford worker data.

Bruce A. Rathbone participated in professional external dosimetry activities, outside of the Hanford Site, as follows:

- Technical reviewer for papers published in the proceedings of the 12th Conference on Solid State Dosimetry.

### 2.6.2 Presentations

None.

### 2.6.3 Publications

Scherpelz, R. I., J. J. Fix, and B. A. Rathbone. 2000. *Validation of Hanford Personnel and Extremity Dosimeters in Plutonium Environments*, PNNL-13136, Pacific Northwest National Laboratory, Richland, Washington.

### 2.6.4 Professional Memberships

Fix, J. J., Member of DOELAP Oversight Board.

Fix, J. J., Chair of Health Physics Society Standards Committee.

Fix, J. J., Consultant to ANSI N13.29, *American National Standard for Dosimetry - Environmental Dosimetry Performance Criteria for Testing*, and N13.37, *American National Standard for Dosimetry, Performance Testing and Procedural Specifications for Environmental Thermoluminescent Dosimetry*, working groups.

Rathbone, B. A., Member, HPS Working Group for ANSI N13.37, *American National Standard for Environmental Dosimeters*.

# 3.0 Hanford Internal Dosimetry Program

The Hanford Internal Dosimetry Program (HIDP) was initiated in 1946 to provide for the assessment and documentation of occupational doses from intakes of radionuclides at the Hanford Site. The program is administered in support of Hanford radiation protection programs, as required by 10 CFR 835, *Occupational Radiation Protection* and the HSRCM-1 (RL 1994). Additional guidance is provided by the implementation guide (DOE 1999a). The program provides the following internal dosimetry services:

- administration of a routine excreta monitoring program
- investigation and assessment of potential intakes
- monitoring performance of the contract excreta bioassay laboratory
- selection and application of models, procedures, and practices for evaluating intakes
- technical support to DOE-RL and to Hanford Site contractors
- 24-hour, single-point-of-contact technical support for radiological incidents at Hanford
- bioassay scheduling for the FHI companies and DOE-RL.

## 3.1 Routine Operations

Operational details of the HIDP are described in the following documents:

- The technical aspects of internal dose calculations are established in the *Technical Basis for Internal Dosimetry at Hanford*, Rev. 1 (Sula, Carbaugh, and Bihl 1991).
- The protocols and practices for operation of the project and coordination with the Hanford Site contractors are established in the *Hanford Internal Dosimetry Program Manual.*[a]
- Detailed procedures are contained in the *Hanford Internal Dosimetry Procedures Manual.*[b]

(a) Internal manual, PNL-MA-552, Rev. 3, Pacific Northwest National Laboratory, Richland, Washington (current version).
(b) Internal manual, PNL-MA-565, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington (current version).

- Protocols for responding to radiological incidents are contained in the *On-Call Exposure Evaluator Manual.*[a]

- Quality assurance for the program is covered in the *Quality Assurance Plan for the Operation of the Hanford Internal Dosimetry Project.*[b]

- The technical agreements with the excreta lab are established by a Statement of Work (SOW).

The practices and technical aspects of operating the In Vivo Monitoring Program for Hanford are established in the *In Vivo Monitoring Program Manual*[c] (see Chapter 4.0). Individual assessments of internal dose are documented in each individual's file in the Hanford Radiological Records Program files. Bioassay measurement results and internal doses are maintained in the REX database, which is operated by the Hanford Radiological Records Program (see Chapter 5.0).

Intakes of radionuclides are generally prevented by containment or other protective measures; therefore, intakes are normally assumed to result from an acute intake. Dose assessment is based on this assumption, except for work with tritium. Tritium intake is generally assumed to occur chronically throughout the period of exposure, and urine samples are normally obtained at the beginning and end of discrete work periods. There were 12 cases of intermittent tritium intakes that were tracked throughout the year and assessed at the end of the year.

The "bioassay needs review," referred to in the 1997 annual report (Lyon et al. 1998), was not active in CY 1999.

### 3.1.1 Bioassay Capabilities

Bioassay monitoring is performed regularly for workers who might inhale, ingest, or absorb radionuclides into their bodies in the course of their jobs. Measurement types and frequencies are based on the radionuclides of concern, their anticipated physical and chemical form, the relative risks of intakes for workers, and the costs of the bioassay (both analysis cost and cost of the worker's time away from the job). Minimum detectable activities (MDAs) and screening levels for routine excreta and in vivo bioassay measurements are shown in Tables 3.1 and 3.2. MDAs for emergency and expedited excreta measurements are provided in Table 3.3.

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(a) Internal manual, PNL-MA-857, Pacific Northwest National Laboratory, Richland, Washington (current version).

(b) Internal manual, LSC-026, Pacific Northwest National Laboratory, Richland, Washington (current version).

(c) Internal manual, PNL-MA-574, Pacific Northwest National Laboratory, Richland, Washington (current version).

**Table 3.1.** Specified Minimum Detectable Activities and Screening Levels for Routine Excreta Analyses During 1999

| Analysis[a] | Contractual MDA[b,c] | Screening Level And Sampling Frequency[c,d] |
|---|---|---|
| $^{238}Pu$, $^{239}Pu$ | 0.02 dpm | 0.01 dpm (A) |
| $^{238}Pu$, $^{239}Pu$ (IPUL) | 0.005 dpm | 0.003 dpm (A) |
| $^{90}Sr$ | 10 dpm | 5 dpm (A)<br>5 dpm (BE) |
| $^{234}U$,[e] $^{238}U$ | 0.02 dpm | 0.15 dpm (A,Q)[f] |
| $^{235}U$ | 0.02 dpm | 0.01 (A, Q) |
| $^{241}Am$, $^{243}Am$,[g] $^{242}Cm$ | 0.02 dpm | 0.01 dpm (A) |
| $^{228}Th$, $^{229}Th$, $^{232}Th$ | 0.10 dpm | 0.05 dpm (not established) |
| $^{225}Ac$, $^{227}Th$ | 0.10 dpm | 0.05 dpm (not established) |
| Elemental U | 0.06 µg | 0.2 mg (Q)[f] |
| Elemental U (QUS)[h] | 0.50 µg | 11 µg (BW)<br>4 µg (M) |
| Tritium | 20 dpm/ml | 80 dpm/ml[i] |

(a) Analysis of urine samples, unless otherwise indicated.
(b) Specified MDA based on Type I and Type II errors of no greater than 5%, as described in the SOW (a copy is available in the Hanford Radiation Protection Historical Files).
(c) Amount per total sample volume, unless otherwise indicated.
(d) Follow-up actions are taken when this value is exceeded (routine bioassay monitoring frequency: A – annual, BE – biennial, BW – biweekly, M – monthly, Q – quarterly).
(e) The lab cannot discriminate between $^{233}U$ and $^{234}U$ and reports the results as $^{234}U$ (beginning in 1994).
(f) Upper level of expected environmentally derived uranium in urine for the Hanford region.
(g) New in 1998.
(h) Eliminated in the new contract starting September 11, 1999.
(i) Special screening levels are established for short-term tritium work where beginning and ending work samples are obtained instead of monthly routine sampling.

**Table 3.2.** Minimum Detectable Activities and Screening Levels for Routine In Vivo Measurements During 1999

| Measurement/Radionuclide[a] | Nexec[b] MDA (nCi) | Abacos[b,c] MDA (nCi) | Screening Level[d] (nCi) |
|---|---|---|---|
| Standup Whole Body Count | | | |
| $^{60}Co$ | 4 | 1.25 | 4 |
| $^{154}Eu$ | 8 | 3.75 | Any detected |
| $^{137}Cs$ | 4 | 1.30 | Any detected |
| Coaxial Germanium Whole Body Count | | | |
| $^{137}Cs$ | 1.2 | 0.83 | Any detected |
| Lung Count | | | |
| $^{235}U$ | 0.095 | 0.09 | Any detected |
| $^{238}U$ (by $^{234}Th$) | 1.6 | 1.5 | Any detected |
| $^{241}Am$ | 0.18 | 0.16 | Any detected |

(a) For selected radionuclides. (The detection of radionuclides not listed resulted in follow-up, except for $^{214}Bi$.)

(b) For each in vivo count, the decision levels (approximately half of the MDAs) were reported under the heading "detection limit" to REX, but, in terms of overall detectability for all measurements, the above MDAs were still applicable.

(c) Abacos replaced Nexec on October 25, 1999 (see Section 4.2).

(d) Level for which an investigation of internal exposure was considered. Any detected activity above background (i.e., above the decision level) was reported to the HIDP.

**Table 3.3.** Specified Minimum Detectable Activities for Emergency and Expedited Excreta Bioassay During 1999

| Analysis[a] | MDA (Per Sample) | |
|---|---|---|
| | Urine | Feces |
| Emergency Analyses[b] | | |
| Isotopic Plutonium by Alpha Spectrometry | 0.5 dpm | 9 dpm |
| Isotopic Uranium by Alpha Spectrometry | 1.0 dpm | 12 dpm |
| $^{241}$Am by Alpha Spectrometry | 1.0 dpm | 20 dpm |
| $^{241}$Am by LEPD[c] | 20 dpm | 20 dpm |
| Total Radiostrontium | 80 dpm | 450 dpm |
| Elemental Uranium | 7 μg | 8 μg |
| Tritium | 100 dpm/ml | — |
| Expedited Analyses[d] | | |
| Isotopic Plutonium by Alpha Spectrometry | 0.08 dpm | 3 dpm |
| Isotopic Uranium by Alpha Spectrometry | 0.12 dpm | 4 dpm |
| $^{241}$Am by Alpha Spectrometry | 0.08 dpm | 6 dpm |
| $^{241}$Am by LEPD | 5 dpm | 5 dpm |
| Total Radiostrontium | 50 dpm | 150 dpm |
| Elemental Uranium | 0.5 μg | 5 μg |
| Tritium | 100 dpm/ml | — |

(a) For the more critical analyses only. The list does not contain all of the analyses covered in the contract.
(b) Verbal reporting time was generally within 8 hours after receipt of the sample; reporting times were even shorter for some analyses.
(c) Low-energy photon detector; direct counting of X-rays without radiochemical separation.
(d) Verbal reporting time was by 9:00 a.m. on the second business day after receipt of the sample.

Two major events affected bioassay in 1999. A major change in vivo counting was implemented in October when Abacos replaced NEXEC as the software for spectrum analysis. (See Section 4.2 for a more detailed discussion of this change.) Changes in analysis parameters resulting from the switch to Abacos are shown in Table 3.2.

The other event was the competitive procurement and award of a new contract for excreta analyses, effective September 11, 1999. The new contract was awarded to Quanterra Environmental Services, which was the previous holder of the contract. Changes implemented with the new contract include the following:

- a requirement to hold waste fractions of emergency, expedite, or priority (with reason code of special) until the radiochemical yield of the sample is determined to meet requirements

- a change in the method for calculating the decision level for alpha spectroscopy analyses (see Section 3.4.2)

- removal of the QUS category of elemental uranium processing (was specifically designed for workers routinely handling soluble uranium)

- removal of the $^{225}Ac$ analysis

- a requirement to report any sample with special reason code and priority processing for which the results will not be completed on time.

Except as listed above, the excreta analyses parameters listed in Tables 3.1 and 3.3 were unchanged from 1998.

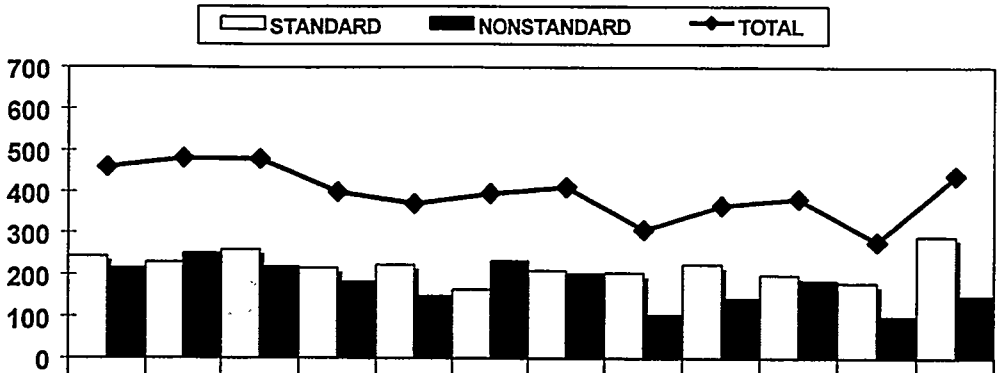
### 3.1.2 Excreta Bioassay Contract Activities

As discussed in Section 3.1.1, the excreta bioassay contract was due to expire on June 30, 1999; however, a series of 1-month extensions was made while a new competitive procurement was in progress. Based on the competitive procurement process, an award of a new 3-year contact was made to Quanterra, and the new contract began on September 11, 1999.

Quanterra began to have trouble with low yields on routine plutonium analyses in November 1998. At first Quanterra tried to investigate the problem while continuing to process samples, but by January the percentage of low-yield samples became unacceptable, and Quanterra shut down the process. Over the next several months, Quanterra made numerous attempts to solve the problem, test changes (seemingly getting good results), and restart processing, only to shut down again after the problem returned during the first couple of batches of worker samples. The rate of failed analyses was very high during this period. Ultimately, a series of problems was discovered and fixed, and plutonium processing returned to full-time operation in June. Yields remained high for the rest of the year, but a tremendous backlog of samples had developed, and most results for samples collected from December 1998 through May 1999 were late. Some were months late. Quanterra began to have trouble meeting contractual turnaround times again in October and a large backlog was still present at the end of the year. Quanterra attributed the latter problems to a difficulty in hiring and retaining staff and to a large influx of samples from non-Hanford customers.

### 3.1.3 Excreta Bioassay Monitoring Activities

Sample requests can be categorized as standard or nonstandard. Standard requests are those generated by the REX database from a predetermined, routine schedule (e.g., a worker may be scheduled for an annual sample collected every April). These requests are downloaded from REX and electronically transferred to the analysis laboratory just before the start of each month. All other requests are considered nonstandard requests. Contractors and HIDP staff manually enter the nonstandard requests into REX. HIDP staff check the nonstandard request file in REX for input errors and perform the electronic transfer of the requests to the laboratory. Figure 3.1 shows the monthly distribution of standard and nonstandard




| | Jan-99 | Feb-99 | Mar-99 | Apr-99 | May-99 | Jun-99 | Jul-99 | Aug-99 | Sep-99 | Oct-99 | Nov-99 | Dec-99 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STANDARD | 244 | 229 | 260 | 216 | 223 | 163 | 209 | 203 | 224 | 198 | 179 | 291 |
| NONSTANDARD | 216 | 252 | 219 | 183 | 148 | 233 | 202 | 104 | 142 | 184 | 99 | 148 |
| TOTAL | 460 | 481 | 479 | 399 | 371 | 396 | 411 | 307 | 366 | 382 | 278 | 439 |

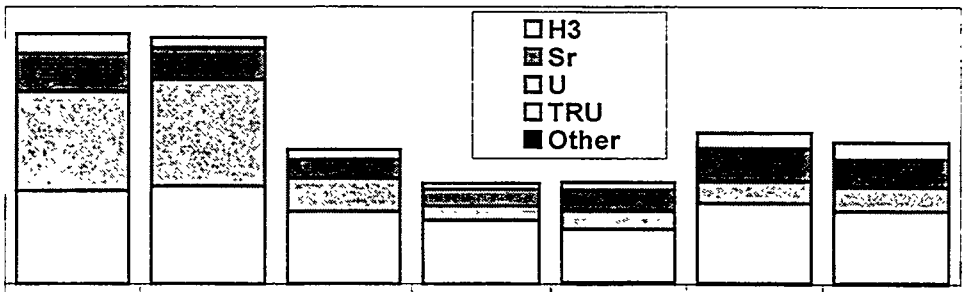
**Figure 3.1.** Standard and Nonstandard Excreta Requests by Month

requests for 1999. A total of 4769 samples was requested in 1999, down 19% from the 1998 requests and about comparable to the number of requests in 1997. Reversing a trend from the last couple of years, the number of standard requests (56%) slightly exceeded the number of nonstandard requests.

During 1999, 4840 excreta bioassay measurements were successfully performed in support of Hanford activities, excluding cancellations, no-samples, samples without valid results, and QC samples (isotopic results for each element count as one measurement). Of these, 95% were classified as routine (including measurements on visitors) and 5% were due to special circumstances, such as response to unplanned potential intakes or follow-up analyses to high routine measurements.

Figure 3.2 shows the trend in routine urinalyses since 1993. The figure shows that the number of routine measurements in 1999 was slightly less than for 1998, with decreases in $^{90}Sr$ and plutonium analyses and slight increases in tritium and uranium analyses. Routine analyses in both 1998 and 1999 exceed the numbers in 1995 and 1996, reflecting both increased work in contaminated areas and the suspension of the "bioassay needs review" with its subsequent waiving of unnecessary bioassay by the FHI. The large decrease between 1994 and 1995 to 1996 demonstrates the results of major efforts to tighten the requirements for placing workers on routine bioassay schedules and to remove workers from routine schedules who were at negligible risk for intakes.

Details on the type of excreta measurements categorized by contractor are provided in Table 3.4. Overall, the number of excreta measurements decreased about 9% from 1998, with the largest decrease in $^{90}Sr$ analyses. The percentages of excreta measurements for the three major contractors remained about the same.




| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|
| H3 | 644 | 334 | 327 | 188 | 235 | 497 | 549 |
| Sr | 1248 | 1029 | 610 | 534 | 684 | 1061 | 898 |
| U | 3248 | 3494 | 1080 | 468 | 603 | 728 | 781 |
| TRU | 2980 | 3144 | 2321 | 2049 | 1716 | 2572 | 2329 |
| Other | 0 | 0 | 0 | 0 | 40 | 26 | 22 |

**Figure 3.2.** Routine Urine Measurements Made from 1993 Through 1999

**Table 3.4.** Worker Excreta Measurements Reported in 1999

| Type/Reason | DOE | PNNL | ERC | FHI | Other | Total |
|---|---|---|---|---|---|---|
| $^{3}$H-urine | | | | | | |
| Routine Schedule[(a)] | 0 | 533 | 0 | 16 | 0 | 549 |
| Special Request[(b)] | 0 | 3 | 0 | 0 | 0 | 3 |
| $^{90}$Sr-urine | | | | | | |
| Routine Schedule | 17 | 209 | 267 | 405 | 0 | 898 |
| Special Request | 0 | 1 | 0 | 52 | 0 | 53 |
| Uranium-Urine | | | | | | |
| Routine Schedule | 23 | 315 | 173 | 270 | 0 | 781 |
| Special Schedule | 0 | 16 | 1 | 5 | 0 | 22 |
| Plutonium-Urine | | | | | | |
| Routine Schedule | 66 | 263 | 397 | 1389 | 1 | 2116 |
| Special Schedule | 0 | 5 | 6 | 109 | 0 | 120 |
| Other-Urine | | | | | | |
| Routine Schedule | 0 | 127 | 0 | 108 | 0 | 235 |
| Special Schedule | 0 | 0 | 0 | 13 | 0 | 13 |
| TRU-Fecal | | | | | | |
| Routine Schedule | 0 | 0 | 0 | 5 | 0 | 5 |
| Special Schedule | 0 | 0 | 0 | 45 | 0 | 45 |
| Analyses Totals | 106 | 1472 | 844 | 2417 | 1 | 4840 |

(a) Routine measurements include those with reason codes of routine (PR), baseline (BL), contractor request (CR), ending work (EA), and termination (TM).

(b) Special measurements are those with reason code of special (SP), recount (R1 or R2), and reanalysis (RA and RB).

Not all excreta bioassay requests produce valid measurement results; these are referred to as "no-samples." When a sample is not obtained, it has to be requested again. (Note: the following statistics refer to the number of unsuccessful attempts to obtain a sample within the 10-day window specified in the SOW with the laboratory; statistics in the next paragraph address the question as to whether or not a sample was eventually collected). In 1999, 697 excreta sample requests were designated as no-samples, compared with 1060 no-samples in 1998. In terms of percentage of total requests, the 1999 rate (15%) was somewhat less than previous years (18%, 21%, and 19% in 1998, 1997, and 1996, respectively). In addition there were 162 canceled requests that also show in the records. Unsuccessful sample collections (their associated no-sample code and percentage of the total no-samples) were attributed to the following causes: kit not delivered (ND, 3%), no sample received (NS, 21%), lost container (LC, 36%), insufficient sample volume (IS, 17%), and failed analyses (FA, 23%). The percentage of each type of unsuccessful sample is similar to previous years except for fewer lost containers and a few more in the no-sample-received category. The number of failed analyses was similar to the 1998 rate, however, the rates for both of those years were considerably above the historical average, both being related to the major trouble the lab had with the plutonium procedure.

There is special interest in whether or not bioassay samples are ultimately (i.e., after several attempts) collected within the grace period (see Section 3.2.1 for a description of the grace period). Figure 3.3 shows the number of excreta bioassay samples not collected within the grace period. Tracking of this statistic started in May, and special emphasis was promoted in June on the importance of collecting the samples within the allowed period. The few not collected in the grace period can be compared with the approximate 2500 samples requested during the same portion of the year. The statistics do not include situations where collecting a sample was not considered reasonable, such as during pregnancy leave, short- or long-term disability leave, or a long-term work assignment at another location. Figure 3.4 shows a similar statistic for samples requested from terminating workers, i.e., samples not ultimately collected.

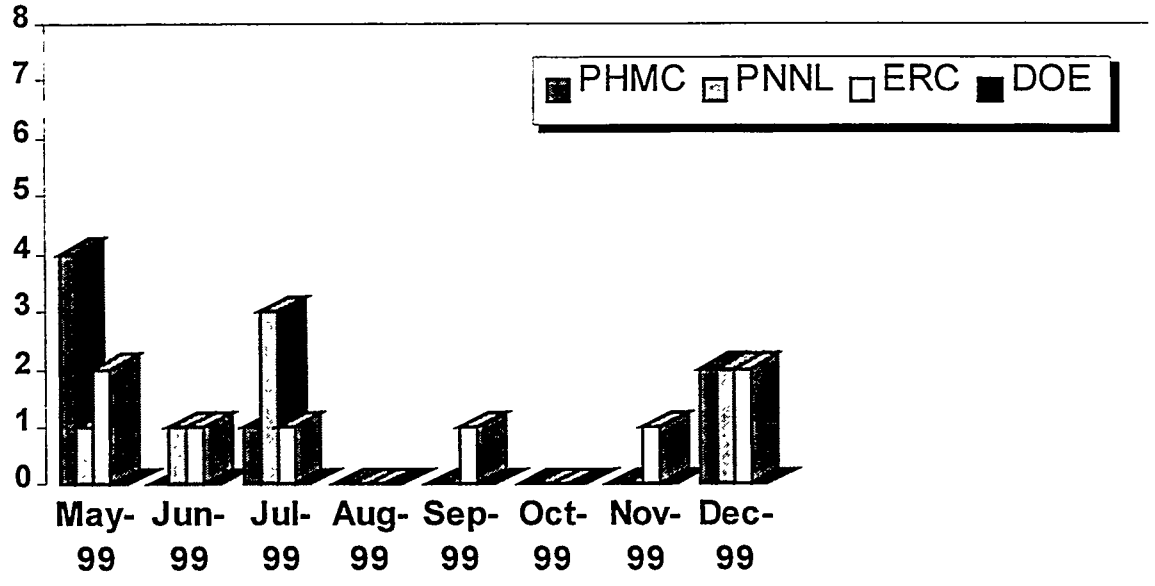



**Figure 3.3.** Excreta Samples Not Obtained in the Grace Period

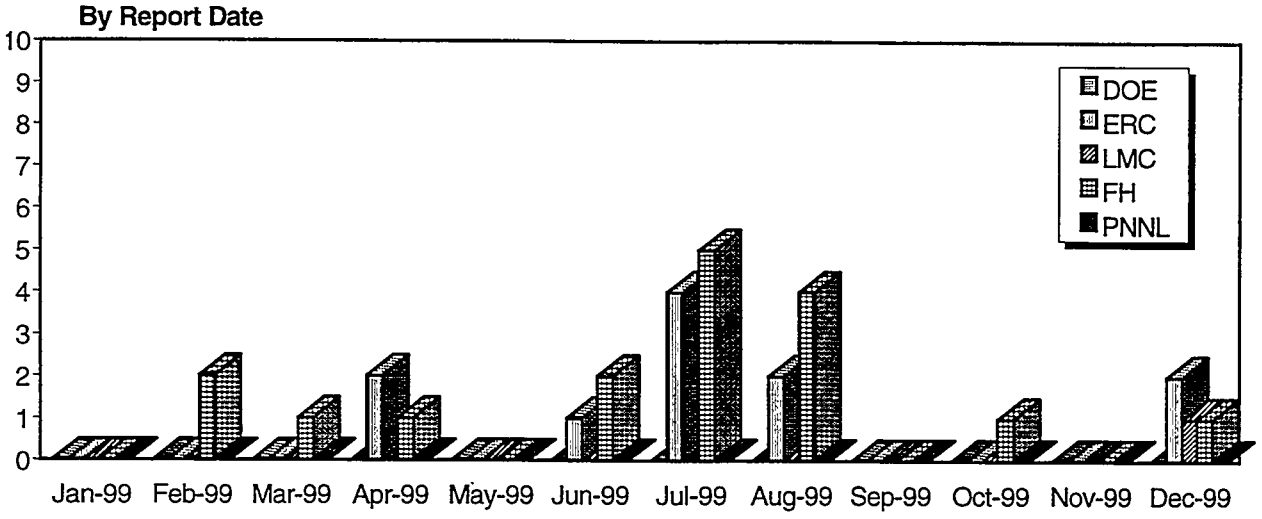



**Figure 3.4.** Termination Excreta Samples Not Obtained

### 3.1.4 Potential Intake Evaluations

Investigations of possible radionuclide intakes are performed following an indication from a routinely scheduled bioassay measurement (high routine) or for a potential exposure incident identified in the workplace (incident). Potential exposure incidents are identified by workplace indicators such as air sampling, contamination surveys, nasal smears, or smears from potentially contaminated wounds. Evaluations are also performed for newly hired workers who incur intakes prior to their Hanford employment to ensure that the intake information is converted to dose in a manner consistent with DOE regulations (pre-Hanford). Reevaluations of internal dose may also be conducted for workers with significant long-term body burdens (reevaluations).

During 1999, 17 incidents with the potential for intake, involving 57 workers, were identified through workplace monitoring. Of the 57 workers involved in the incidents, intakes were confirmed for only 15 workers, those coming from 6 of the incidents. The highest calculated dose among the 15 workers was 59-mrem committed effective dose equivalent (CEDE). Table 3.5 shows the incident breakdown by contractor, facility, and principal radionuclides.

In addition to incidents, potential intakes can be discovered through the routine bioassay program, although in recent years very few actual (i.e., confirmed) intakes have been discovered this way. In 1999, 108 evaluations were started because of routine bioassay results that exceeded the criteria for investigation (excluding evaluations started because of intakes incurred prior to employment at Hanford). Intakes were assigned for 16 workers. Twelve workers had intermittent exposure to tritium, which was treated as chronic intake. One worker had two separate intakes, both resulting from trips to Chornobyl. The highest internal dose revealed through the routine bioassay program was 12 mrem CEDE. Table 3.6 shows internal dose evaluations for 1999 resulting from high routine bioassay results. Table 3.7 indicates the trends in all types of potential intake evaluations since 1993.

**Table 3.5.** Summary of Potential Intake Incidents During 1999

| Area | Facility | Custodian | Number of Incidents | Number of Workers | Worker Contractor | Principal Radionuclide |
|---|---|---|---|---|---|---|
| 100 K | 105 K East | FHI | 1 | 1 | FHI | $^{90}Sr$ |
| 200 E | 241-AZ | FHI | 2 | 12 | FHI | $^{90}Sr$, $^{137}Cs$ |
| 200-W | 233-S | ERC | 1 | 1 | ERC | Pu mix |
| 200-W | 241-SX | FHI | 1 | 1 | FHI | $^{90}Sr$ |
| 200-W | 241-SY | FHI | 1 | 14 | FHI | $^{137}Cs$, Pu mix |
| 200-W | 241-U | FHI | 1 | 3 | FHI | $^{90}Sr$ |
| 200-W | 241-Z | FHI | 1 | 4 | FHI | Pu mix |
| 200-W | 234-5 Z | FHI | 1 | 8 | FHI | Pu mix |
| 200-W | 212R Railroad Spur | FHI | 1 | 2 | FHI | $^{137}Cs$ |
| 300 | 324 | FHI | 2 | 5 | FHI | $^{137}Cs$ |
| 300 | 327 | FHI | 1 | 1 | FHI | $^{137}Cs$ |
| 300 | South Processing Pond | ERC | 1 | 1 | ERC | $^{60}Co$, U mix |
| 3000 | Life Sciences Lab | PNNL | 2 | 3 | PNNL | $^{3}H$ |
| 3000 | Research Technology Lab | PNNL | 1 | 1 | PNNL | $^{238}U$ |
| Total | | | 17 | 57 | | |

**Table 3.6.** Summary of Intake Cases Identified Through the Routine Bioassay Program During 1999

| Area | Building | Custodian | Number of Workers | Contractor | Principal Nuclide |
|---|---|---|---|---|---|
| 200-E | 241-AZ | FHI | 1 | FHI | $^{90}Sr$ |
| 300 | 325 | PNNL | 13 | PNNL | $^{3}H$[(a)] |
| 300 | 327 | FHI | 1 | FHI | $^{137}Cs$ |
| Chornobyl, Ukraine | | Ukraine gov. | 1[(b)] | PNNL | $^{137}Cs$ |
| Total | | | 16 | | |

(a) Twelve cases were treated as chronic intakes; i.e., one dose evaluation each at the end of the year.
(b) One worker had intakes on two separate occasions that were handled as separate evaluations.

**Table 3.7.** Comparison of Potential Intakes by Reason Code, 1993-1999

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|
| Incident, Total | 51 | 33 | 51 | 42 | 51 | 186 | 57 |
| Confirmed | 17 | 7 | 12 | 11 | 12 | 8 | 15 |
| Unconfirmed | 34 | 26 | 39 | 30 | 33 | 178 | 42 |
| Open | | | | 1 | 6 | | 0 |
| Unconfirmed But Assigned[a] | | | | | | | |
| High Routine, Total | 65 | 91 | 59 | 40 | 85 | 136 | 96 |
| Confirmed | 1 | 15 | 1 | 5 | 10 | 22 | 5[b] |
| Unconfirmed | 64 | 76 | 58 | 33 | 75 | 114 | 91 |
| Open | | | | | | | 0 |
| Chronic Exposure, Total | 6 | 0 | 0 | 0 | 2 | 0 | 12 |
| Confirmed | 0 | | | | 2 | | 12 |
| Unconfirmed | 6 | | | | 0 | | 0 |
| Pre-Hanford, Total | 3 | 35 | 9 | 12 | 10 | 13 | 24 |
| Confirmed | 3 | 31 | 9 | 11 | 10 | 9 | 23 |
| Unconfirmed | 0 | 4 | | 1 | | 4 | 1 |
| Open | | | | | | | |
| Totals | 126 | 162 | 119 | 94 | 148 | 335 | 189 |
| Confirmed | 22 | 53 | 22 | 27 | 34 | 39 | 55 |
| Unconfirmed | 104 | 109 | 97 | 64 | 108 | 296 | 134 |
| Open | | | | | | | 0 |
| Reevaluations | | 8 | 17 | 1 | 0 | 3 | 0 |

(a) Unconfirmed by bioassay but dose assigned based on air sample data.
(b) One worker had two intakes.

Figure 3.5 shows the workload of open cases as recorded at the end of each month. At the start of the year, there was a large backlog of cases that had built up in 1998, due in large part to the fruit fly contamination incident, as described in last year's report (MacLellan et al. 1999). The hiring and subsequent training of a new dosimetrist in October 1998 substantially contributed to working off the backlog in the first half of 1999.

The range of internal doses assigned to the Hanford work force in 1999 is summarized in Table 3.8. 1999 is the first year since the start of tracking of these statistics that there was no assignment of internal dose exceeding 100 mrem CEDE.

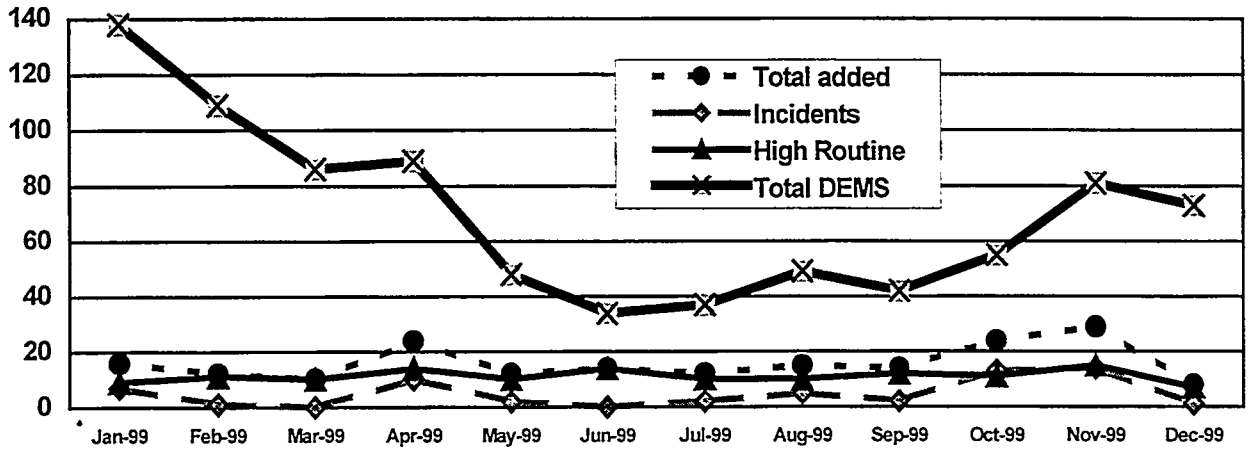



**Figure 3.5.** Number of Open Evaluations by Month (Top curve shows number of evaluations open on the last day of each month.)

**Table 3.8.** Range of New Internal Doses assigned to the Hanford Work Force in 1999

| Dose (mrem)[a] | Number of Workers | | | | |
|---|---|---|---|---|---|
| | DOE | FHI | PNNL | ERC | Total |
| < 100 | 0 | 8 | 11 | 0 | 19 |
| 100 – < 500 | 0 | 0 | 0 | 0 | 0 |
| 500 – < 2000 | 0 | 0 | 0 | 0 | 0 |
| 2000 – < 5000 | 0 | 0 | 0 | 0 | 0 |
| > 5000 | 0 | 0 | 0 | 0 | 0 |

(a) CEDE, based on 1999 evaluations, although the intake could have occurred in any year; excludes reevaluations.

## 3.2 Program Changes and Improvements

Five program changes and improvements were made during 1999 as described in the following sections.

### 3.2.1 Grace Period for Obtaining Bioassay

Clarification of the time period for obtaining bioassay samples or measurements was introduced to the HPDAC in late 1998, and was accepted and incorporated into the *Hanford Internal Dosimetry Program Manual* in early 1999. The policy establishes the target for obtaining a bioassay measurement or sample at the end of the month after the scheduled month. The policy was based on the following:

- the small change in the minimum detected dose for bioassay not obtained until approximately 7 weeks after the scheduled date

- a reasonable time frame for being notified of an unsuccessful sample collection and the scheduling of another attempt, taking into account numerous obstacles including worker vacations, shift changes, sicknesses, business travel, change in home addresses, etc.

A provision was made for a successfully collected sample that was later declared a failed analysis due to no fault of the worker. Bioassay measurements or samples obtained within the target period are considered to be in compliance with 10 CFR 835 and 10 CFR 830.120 requirements. A new set of statistics was created to track the success at getting the bioassay within the target period (see Figure 3.3).

### 3.2.2 Alpha-to-Beta Ratio on Incident Smear (or Air) Samples

A study was performed to evaluate the impact on internal dose of ignoring the alpha component of the source material in potential intakes. HIDP staff rely on information obtained at work locations by radiological control staff concerning the mix of alpha-emitting and beta-emitting radionuclides in a smear sample or air sample associated with a potential intake. Many facilities at Hanford are characterized as having waste or contamination that is principally made up of beta-emitting radionuclides (mostly $^{137}Cs$, $^{90}Sr$, or a mixture of both). However, there may be some, albeit a very small amount of, plutonium or $^{241}Am$ in the contamination, and that small activity of long-lived alpha-emitters may significantly impact the total dose from an intake. The study showed that even for ratios up to 100,000 to 1 $^{137}Cs$ to plutonium, the plutonium produces half or more of the internal dose (CEDE). For ratios of up to 10,000 to 1 $^{90}Sr$ to plutonium, the plutonium produces half or more of the internal dose. Because field survey and counting instrumentation can not normally detect alpha activity in samples that have beta activities at 10,000 to 100,000 times the alpha activity, the HPDAC agreed that field measurements are not sufficient to conclude that a potential intake incident is free of concern for alpha-emitting radionuclides. Specifically, the HPDAC concluded the following:

- Facilities are not able to rule out the presence of alpha-emitters in principally beta mixtures at the level required for accurate internal dosimetry.

- Ignoring the alpha contribution based solely on a low-dose criterion is not acceptable.

- In general, whenever $^{137}Cs$ is detected in the whole body count following an incident, a sample of the contamination source should be analyzed for $^{137}Cs$, $^{90}Sr$, and alpha-emitters using separations radiochemistry with an excellent MDA.

- Bioassay for the $^{90}Sr$, plutonium, or $^{241}Am$ can be used in lieu of the smear sample.

- Facility characterization data can also be used in lieu of the other techniques if the contractor dosimetry representative agrees that the data are representative of the intake and provides those instructions in writing to HIDP.

### 3.2.3 Default Particle Size Changed to 5 Microns

As part of the work on the complete revision of the internal dosimetry technical basis document, (subsequently released in part in January 2000), a proposal was made and accepted by the HPDAC to change the default particle size for intakes at Hanford to 5 μm AMAD. The change was based on the recommendation by the International Commission on Radiological Protection in publication 66, *Human Respiratory Tract Model for Radiological Protection* (ICRP 1994), which was supported by several studies of particle sizes in workplace environments. Other aspects of the new lung model introduced in the same report were not implemented because the HIDP did not have the computer codes necessary for their implementation.

### 3.2.4 Backup Laboratory for Rapid Plutonium and $^{90}$Sr Urinalyses Reinstated

With the concurrence of Hanford contractors, a task was budgeted for FY 2000 to reinstate capabilities for performing rapid urinalyses for plutonium and $^{90}$Sr by PNNL's Radiochemistry Process Group (RPG). Procedures were developed in 1999. Testing of the RPG staff and procedures was scheduled for two different periods in 2000. These capabilities are intended to serve as backup for the contract laboratory. This action was taken in response to an observation made during the self-assessment directed by DOE's Office of Inspection and Enforcement (DOE EH-10) (See Section 3.3.4).

### 3.2.5 Changes to the Hanford Internal Dosimetry Program Manual

Changes to the program instituted through the *Hanford Internal Dosimetry Program Manual* are summarized in Table 3.9.

**Table 3.9.** Changes to the *Hanford Internal Dosimetry Program Manual*

| Section | Changes |
|---|---|
| 2. Practices of the HIDP | Changed frequency of reevaluations from 5 years to "as requested by contractor." Added policies concerning the bioassay grace period. |
| 3. Assessment of Internal Dose | Added policy that contractors will provide statements for intake evaluations on the radionuclide composition of the material involved in incidents |
| 5. Bioassay Monitoring | Added a multiple acute intake scenario to the bioassay capability table for tritium. Added Exhibit 5.9, "Grace Period Technical Justification." |

## 3.3 Program Assessments

Six program assessments were conducted as described in the following sections.

### 3.3.1 Excreta Quality Control Oversight Program

The excreta QC oversight program operated as usual throughout 1999; however, the Quality Control Report for the period July 1, 1998 through the end of the contract with the bioassay laboratory (September 1999) was still being drafted at the end of the year.

### 3.3.2 Onsite Inspections of the Excreta Contract Laboratory

A series of surveillances of Quanterra's daily assembly and preparation of excreta kits was conducted in May and June. No findings or concerns were discovered.

Because the contract was coming to its end, the annual audit, usually performed in June, was not performed in 1999. Instead, a pre-award audit of the company to be awarded the new bioassay contract was scheduled. Because Quanterra was subsequently awarded the new contract, this latter audit, performed October 4 to 5, 1999, served in lieu of the annual audit. The inspection resulted in six findings and one observation, although three of the findings were repeats from an audit in July from another group in PNNL. In general the findings addressed differences between procedures and actual practices and other weaknesses in the paperwork.

### 3.3.3 DOELAP for Bioassay

Although the DOELAP performance testing of Quanterra and the onsite assessment of HIDP occurred in 1998, HIDP was informed that the program passed and we received the certificate of accreditation in 1999. DOELAP bioassay testing and reaccredidation normally occur every 3 years, however, the DOELAP Performance Evaluation Program Administrator requested that the next round of testing for excreta be moved to 2000 to be synchronized with the cycle for the In Vivo Monitoring Program for Hanford.

### 3.3.4 Assessment in Response to the DOE EH-10 Moratorium

As directed by DOE EH-10, a self-assessment of internal dosimetry (both HIDP and field implementation aspects) was conducted by PNNL's Safety and Health Technical Support Group with emphasis on concerns and findings made by EH-10 during prior assessments at other DOE sites. The assessment was conducted from December 1998 through February 1999, with the final report issued on March 12, 1999. The report produced one finding and four concerns that related to HIDP, summarized as follows:

- Annual dose report cards do not include all of the dose if there are internal dose cases still pending.
- HIDP tracks statistics on samples that are not collected within 10 days but does not have statistics on whether samples were ultimately collected.
- HIDP does not produce adequate statistics on the turnaround times of excreta samples.

- HIDP does not have a contingency plan for excreta analyses in the event of trouble with the contract bioassay lab.

- HIDP has been unable to meet QA requirements concerning timely review and revision of procedures and manuals.

The finding and concerns, including corrective actions, were tracked in PNNL's Action Tracking System. However, FHI rewrote several of the concerns and placed them in DOE's Noncompliance Tracking System. As of the end of the year, HIDP had implemented the new statistics, had caught up on procedure reviews and evaluations, and had made significant progress toward issuing a revision of the technical basis manual by the milestone of January 31, 2000. Corrective actions on the report cards and the bioassay contingency plan were due later in 2000.

### 3.3.5 Inspector General's Office Inspection

The Oak Ridge branch of the Inspector General's Office assessed several DOE sites, including Hanford from September 27 to 29, 1999. The purpose of the assessment was to review the comparative costs of excreta bioassay at the various DOE sites and to determine the merits of having a single contract used by all DOE sites. No findings were made that were specific to HIDP. At the exit meeting on January 13, 2000, held at DOE-HQ in Washington, D.C., the inspectors concluded that a DOE-wide contract was feasible and would save money. DOE-Management and Administration (MA) was tasked with proceeding with development of such a contract, and DOE-MA in turn assigned the task to the Sample Management Group at the Rocky Flats Environmental Restoration Site. HIDP asked for representation on a committee to develop the requirements for the complex-wide contract, as did other sites.

### 3.3.6 Program Self-Assessments

A self-assessment of HIDP was conducted by the quality engineer and a staff member from PNNL's Safety and Health Technology Support Group from February 22 to 26, 1999. A few findings were made relative to the correctness of procedures, a few gaps in the training records, and references between desk instructions and procedures. All items were corrected over the course of the year.

A second assessment was conducted on June 2, 1999, specifically related to work conducted for HIDP by staff in PNNL's RPG that prepares the spiked excreta samples for the QC oversight program. No findings were made, but some suggestions for improvement were made, and these were addressed by HIDP and RPG staff later in the year.

## 3.4 Supporting Technical Studies

Two supporting studies were conducted as described in the following sections.

### 3.4.1 Analysis of Plutonium Oxide in Artificial Fecal Samples

A question had surfaced at bioassay conferences over the last couple of years concerning the adequacy of bioassay procedures for analyzing plutonium oxide contamination in fecal samples, especially if the plutonium oxide had been formed at temperatures of several hundred degrees centigrade or more. Because current processes at the PFP and past operations at both the PFP and at the Plutonium-Uranium Extraction facility (PUREX) produced plutonium oxide at these temperatures, a test of the excreta bioassay laboratory's ability to measure plutonium oxide in fecal samples was conducted. HIDP was able to obtain some well-characterized plutonium oxide and americium oxide soil from the Radiological and Environmental Sciences Laboratory at the Idaho National Engineering and Environmental Laboratory. PNNL's RPG spiked known amounts of this material into artificial fecal samples, and the samples were sent to the contract bioassay laboratory for analysis using the normal procedure for fecal analyses. That procedure includes wet-ashing with nitric acid and hydrogen peroxide, followed by hydrofluoric acid digestion, and anion exchange. The hydrogen peroxide and hydrofluoric acid steps are specific for fecal analyses (i.e., they are not performed for urinalyses) to enhance the digestion of the plutonium oxide.

The laboratory procedure worked well, with average biases of -2% for the plutonium oxide samples and -13% for the americium oxide samples, both considered acceptable results considering the number of samples involved (five in each category). Spikes made from the same material were analyzed by the RPG as a check of the validity of the spiking procedure and as a check of the activity stated by the Radiological and Environmental Sciences Laboratory. The average bias on the RPG results on four samples was -7% for the plutonium oxide and -13% for the americium oxide.

The conclusion of the test was that the contract excreta bioassay lab's procedure produces correct measurements of plutonium and americium in fecal samples, even if the material is in the oxide form.

### 3.4.2 Review of the Decision Level for Excreta Bioassay Applied to Alpha Spectrometry

Prior to 1989, the value used to decide if plutonium was present in an excreta sample was the contractual detection level. The same was true for uranium isotopes determined using alpha spectrometry and for transuranium radionuclides. Since 1989, Hanford has used one-half of the contractual detection level as the decision level based on concepts presented in the HPS Standard N13.30 (HPS 1996) among other documents. Beginning in 1998, HIDP began to look at methods to more closely tie the decision level to individual samples or batches of samples.

Jay MacLellan and Dan Strom performed a study of the various formulas put forth over the years to make the decision that activity is present in a sample, using both analytical solutions and Monte Carlo simulations. The study compared the number of false positive results predicted by the formulas with the actual number of false positives obtained as a function of the background counts in the region of interest. The study showed that none of the formulas tested worked perfectly well for backgrounds of a few counts or less, and that the HPS N13.30 approach produced too many false positives even up to 100 total

background counts. The formula by Turner (1995) gave the best results and gave excellent results for background counts exceeding 5 for rates of Type I errors that are generally used in bioassay (i.e., alpha values of 0.05 to 0.002).

Background counts for the 2500-min. count time for bioassay samples using alpha spectrometry typically range from 0 to 3 counts. Based on the study, HIDP proposed and received concurrence from the HPDAC to implement the Turner decision rule for excreta bioassay analysis using alpha spectrometry. The decision level will be set at 2.05 times the total propagated uncertainty associated with each separate result; hence, every result from each analysis will have its own decision level. The contract lab was notified but considerable time for implementation was needed, partly because the lab was bringing a new computer system on line. No specific date for implementation was set.

## 3.5 Project-Related Professional Activities

HIDP staff activities, presentations, and professional memberships during 1999 are listed in this section.

### 3.5.1 Activities

Eugene H. Carbaugh was involved in professional dosimetry activities, outside of the Hanford Site, as follows:

- DOELAP Assessor Training, June 1-2, 1999, Las Vegas, Nevada.
- DOELAP onsite assessment of Thermo NUtech Company, Albuquerque, November 1999

Jay A. MacLellan was involved in professional dosimetry activities, outside of the Hanford Site, as follows:

- DOELAP Assessor Training, June 1-2, 1999, Las Vegas, Nevada.
- DOELAP onsite assessment of Sandia National Laboratory, September 27-29, 1999.

### 3.5.2 Presentations

Carbaugh, E. H. 1999. "Aspects of Internal Dosimetry at Hanford." PNNL-SA-30795. Presentation to the Cascade Chapter, Health Physics Society, February 5, 1999, Kelso, Washington.

MacLellan, J. A., and D. J. Strom. 1999. "Traditional Formulas for Decision Levels are Wrong for Small Numbers of Counts." Presented at the 45th Bioassay, Analytical, and Environmental Radiochemistry Conference, October 18-22, 1999, Gaithersburg, Maryland.

### 3.5.3 Publications

None.

### 3.5.4 Professional Memberships and Other Activities

Bihl, D. E., Chair of the HPS Standards Committee N13.39, *Internal Dosimetry Programs*

Carbaugh, E. H., Member of the HPS Standards Committee N13.25, *Internal Dosimetry Standard for Plutonium*

Carbaugh, E. H., Member Bioassay/ Internal Dosimetry DOELAP Oversight Board

Carbaugh, E. H., Member DOE Working Group on Stable Tritium Compounds

MacLellan, J. A., Chair of the American Academy of Health Physics Appeals Committee

MacLellan, J. A., Treasurer of the Columbia Chapter of the Health Physics Society through June

# 4.0 In Vivo Monitoring Program for Hanford

The In Vivo Monitoring Program for Hanford (IVMPH; formerly the Hanford Whole Body Counting Program) has been an integral part of the comprehensive radiological protection program for Hanford workers since 1959. IVMPH staff provide routine in vivo counting services as well as emergency services. The majority of the measurements are performed in the 747-A Building at the corner of Knight Street and Goethals Avenue in Richland. Additional radiation detection equipment is maintained and operated at the Emergency Decontamination Facility located next to the Kadlec Medical Center. Mobile in vivo equipment is also maintained in a semi-trailer next to the 747-A Building. Collectively the facilities are called the In Vivo Radioassay and Research Facility (IVRRF).

The primary function of the IVMPH is to provide accurate and highly sensitive in vivo measurements in a timely manner for workers who have the potential for experiencing an intake from an occupational source of radioactive material. The documentation of the measurement results and supporting information (e.g., calibrations) is also an essential function. The results are provided to the HIDP to be used in determining the dose to workers from internally deposited radionuclides. All of the Hanford contractor measurement, calibration, and QC data are transmitted to the Hanford Radiological Records Program. Information copies of the measurement records are maintained at the IVRRF.

Four systems continued to be used to perform the routine measurements during 1999. The standup counter employs five sodium-iodide detectors for measuring fission and activation products in the body with energies >200 keV. The system in the Palmer Room uses seven coaxial high-purity germanium (HPGe) detectors for measuring radionuclides that emit high-energy photons. The Iron and Stainless Steel rooms each contain planar HPGe detector arrays optimized for the detection of uranium, transuranic radionuclides, and other nuclides that emit low-energy photons. Additional sodium-iodide and HPGe detectors are located in the Lead Room and are infrequently used for organ and whole body counting.

## 4.1 Routine Operations

A total of 8085 in vivo measurement results were sent to the REX database for DOE and the Hanford contractors during 1999. The results were from 6421 whole body measurements, 1657 chest measurements, and 7 miscellaneous measurements. The FHI values include the ORP measurements performed during the year. The miscellaneous measurements included wound, skeletal, thyroid, and liver measurements. The total number of counts represents slightly less than a 2% decrease compared with CY 1998. There were 57 fewer whole body counts than in 1998 and 77 fewer chest counts than in 1998. The statistical breakdown by contractor is shown in Table 4.1. A summary of the number of in vivo counts made from 1991 through 1999 is presented in Table 4.2 and depicted graphically in Figure 4.1.

**Table 4.1.** In Vivo Measurements Performed During 1999 and Entered in the REX Database

| Count Type and Reason | FHI | PNNL | ERC | Other (DOE and US) |
|---|---|---|---|---|
| Whole Body Counts | | | | |
| Routine Schedule | 4424 | 614 | 907 | 255 |
| Special Request | 139 | 7 | 5 | 1 |
| Contractor Request | 14 | 51 | 4 | 0 |
| Total | 4577 | 672 | 916 | 256 |
| Chest Counts | | | | |
| Routine Schedule | 1147 | 243 | 104 | 40 |
| Special Request | 80 | 25 | 4 | 1 |
| Contractor Request | 6 | 6 | 0 | 1 |
| Total | 1233 | 274 | 108 | 42 |
| Other | | | | |
| Routine Schedule | 1 | 1 | 0 | 0 |
| Special Request | 2 | 2 | 0 | 0 |
| Contractor Request | 1 | 0 | 0 | 0 |
| Total | 4 | 3 | 0 | 0 |
| Grand Total | 5814 | 949 | 1024 | 298 |

**Table 4.2.** In Vivo Count Summary from 1991 Through 1999

| Year | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|
| **WBC**[(a)] | 9965 | 12197 | 11401 | 11031 | 9020 | 7407 | 6506 | 6478 | 6421 |
| **Lung** | 2549 | 3164 | 2838 | 2752 | 1915 | 1632 | 1433 | 1734 | 1657 |
| **Special** | 66 | 56 | 38 | 82 | 27 | 26 | 4 | 21 | 7 |
| **Total** | 12580 | 15417 | 14277 | 13865 | 10962 | 9065 | 7943 | 8233 | 8085 |

(a) WBC = whole body count.

The IVMPH was operated within budget in 1999. Monday planning meetings were held to schedule and prioritize the work. Monthly safety meetings were conducted by the IVMPH staff to address program-specific topics. Quarterly safety self-assessments were conducted. No off-normal events were recorded. Formal presentations were made quarterly to DOE-RL and the contractors to summarize the status of the program. The measurement QC data were reviewed and analyzed for quarterly trends.

The daily QC measurement results indicated that the calibration factors based on the measurements of the calibration phantoms were applicable to all of the official measurement results recorded in CY 1999. In the rare cases where the daily QC results were out of tolerance, worker data were reviewed for validity and when necessary workers were scheduled for recounts.

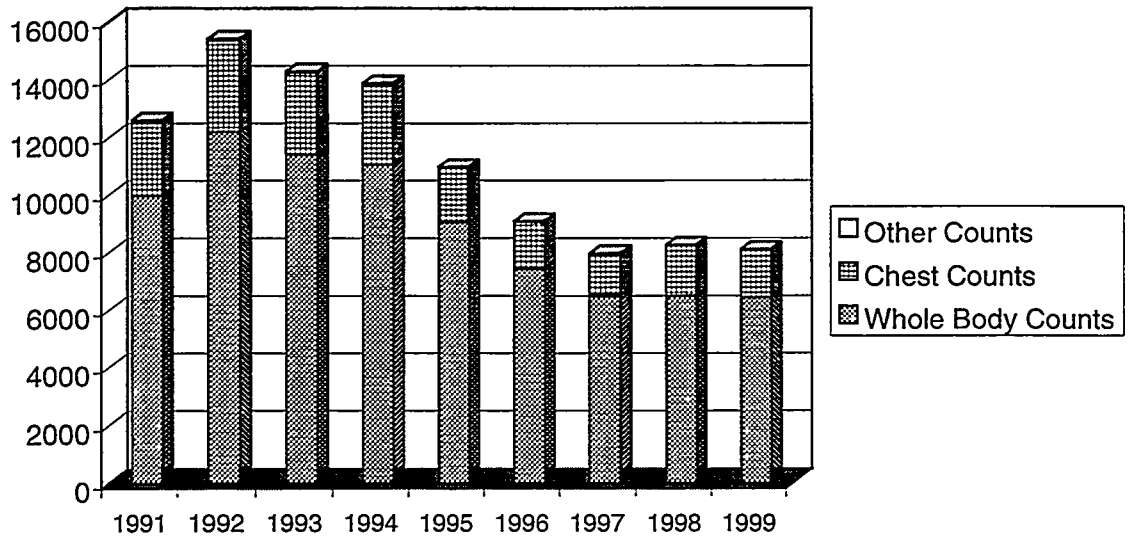



**Figure 4.1.** Summary of the Number and Types of In Vivo Measurements Performed from 1991 Through 1999

A decision was made in conjunction with the HIDP that wound count results would not require a recount unless the result was 0.1 nCi or greater. The decision was based on the fact that in vivo wound counts are made to provide an indication of the level of activity to assist in making treatment decisions (e.g., excision). Dose estimates are usually based on urine sample results. It was concluded that there was no value added by recounting a worker when results are below 0.1 nCi; in fact this can add to a worker's anxiety level.

The handling of positive results for naturally occurring radioactive materials (e.g., radon progeny, thoron progeny) and nuclear medicine nuclides (e.g., $^{201\text{-}202}$Tl, $^{99m}$Tc) was formally documented in a letter to the contractors. These nuclides are not routinely reported if found by peak search except in the case of $^{131}$I where notification is made to HIDP staff, who then contact the contractor field dosimetrist to see if there was a possible occupational iodine exposure.

The oxygen concentrations were monitored during liquid nitrogen- (LN-) filling operations in the counting rooms in response to an off-normal occurrence related to the 329 Building LN-filling operations. The oxygen levels remained above 20% during fill operations using a transfer dewar. However, the oxygen levels dropped to 19.4% during filling using the installed piping system (an infrequently used method). A procedure modification was made to add the use of an air mover, oxygen monitor, and steps to reduce the spread of nitrogen vapors during filling with the installed piping system.

### 4.1.1 Program Documentation

Three internal PNNL program manuals were updated. Revision 3 of PNL-MA-574, *In Vivo Monitoring Program Manual*, was issued in June. The revision primarily updated organizational

information and some operational information. Section 7.0 on statistical analysis techniques will be updated in CY 2000 after the Abacos software has been in routine use for an extended period of time.

Revision 4 to the *QA Plan*, LSC-021, was issued in August. The changes resulted from the annual review of the plan and updated the information on the organizational structure.

The operating procedures in PNL-MA-574 were revised on an as-needed basis to ensure that the procedures accurately reflect the methods used to perform the work.

### 4.1.2 Department of Energy Laboratory Accreditation Program

The DOELAP accreditation for the IVMPH was officially extended to include the test categories for the measurement of $^{241}$Am and $^{235}$U activity in the lungs. The accreditation was for the now defunct Nexec software system. In preparation for operations with the Abacos Plus software, the technical equivalency documentation was submitted to DOE-RL in late September for delivery to the DOELAP Performance Evaluation Program Administrator. The documentation demonstrated the equivalency of the Abacos and Nexec software for quantifying the in vivo measurement results in four test categories. Equivalency for two categories (II and IV) was granted. The request will be revised and resubmitted in CY 2000 to explicitly request accreditation in categories III and VI.

### 4.1.3 Equipment Maintenance and Repair

Six HPGe detectors used for the IVMPH required repair during the year. All repairs were made by the IVMPH staff. This resulted in an estimated $20,000 cost savings compared with shipping the detectors offsite to the vendor for repair. Five planar HPGe detectors, which are used for detecting radioactive material that emits low-energy photons (e.g., $^{241}$Am, $^{234}$Th), were repaired. One coaxial HPGe was also repaired. Repairs were made to two beryllium window retaining rings, a malfunctioning preamplifier, a leak in a vacuum vessel, and an internal assembly defect was corrected. Figure 4.2 shows repair work being done on a planar HPGe detector.

A one-page flier advertising the detector repair capabilities at the IVRRF was distributed to Hanford contractors early in the year. This flier and word-of-mouth references resulted in requests from Hanford contractors to repair 18 HPGe detectors from Hanford contractors. In response to a request to repair surface barrier detectors, the client was told it would cost more to repair the detectors than it would to purchase new ones.

The portable 28-cm$^2$ by 20-mm-thick planar HPGe detector was received from the vendor along with the Inspector module. Along with the laptop PC, they comprise a portable wound counting system. The Inspector module contains the amplifier, analog-to-digital converter, and high-voltage power supply needed to operate the detector. The 7-l dewar when full of liquid nitrogen and the Inspector module together weigh ~30 lb. Figure 4.3 shows these components. The Genie 2000 software resides on the laptop PC and is used to acquire, store, and analyze the spectral data. The system will be calibrated, tested, and readied for operation in CY 2000.

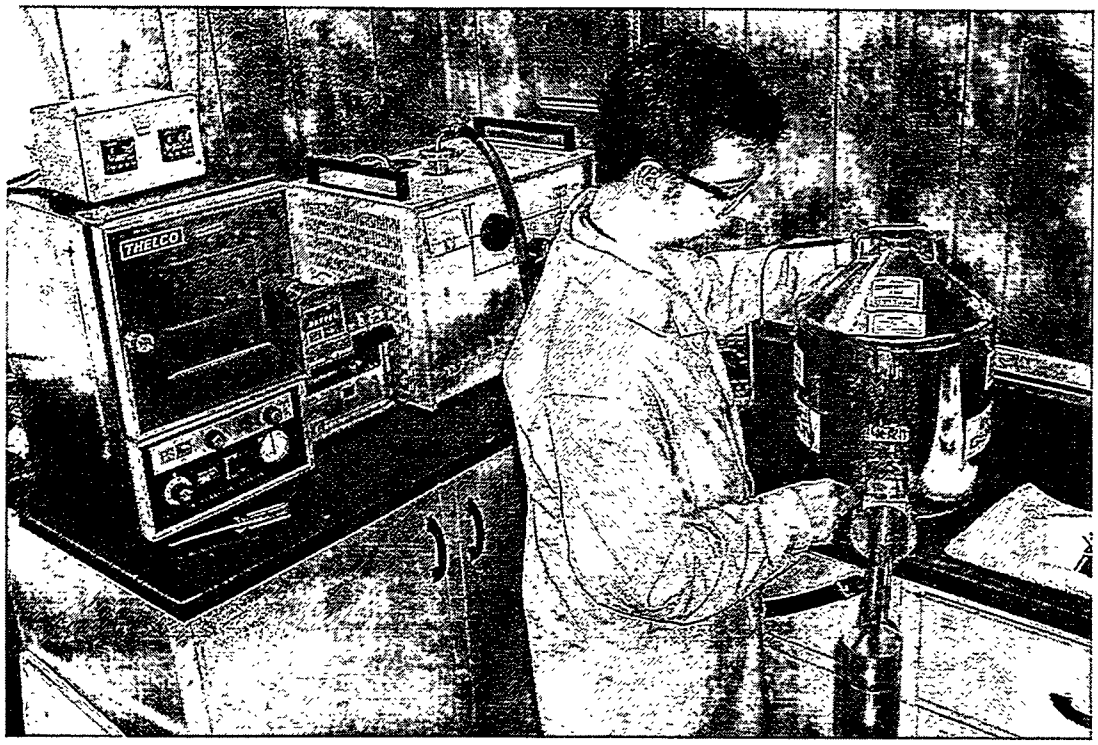



**Figure 4.2.** Vacuum, Leak Detection, and Test Systems for Repair of Planar HPGe Detectors

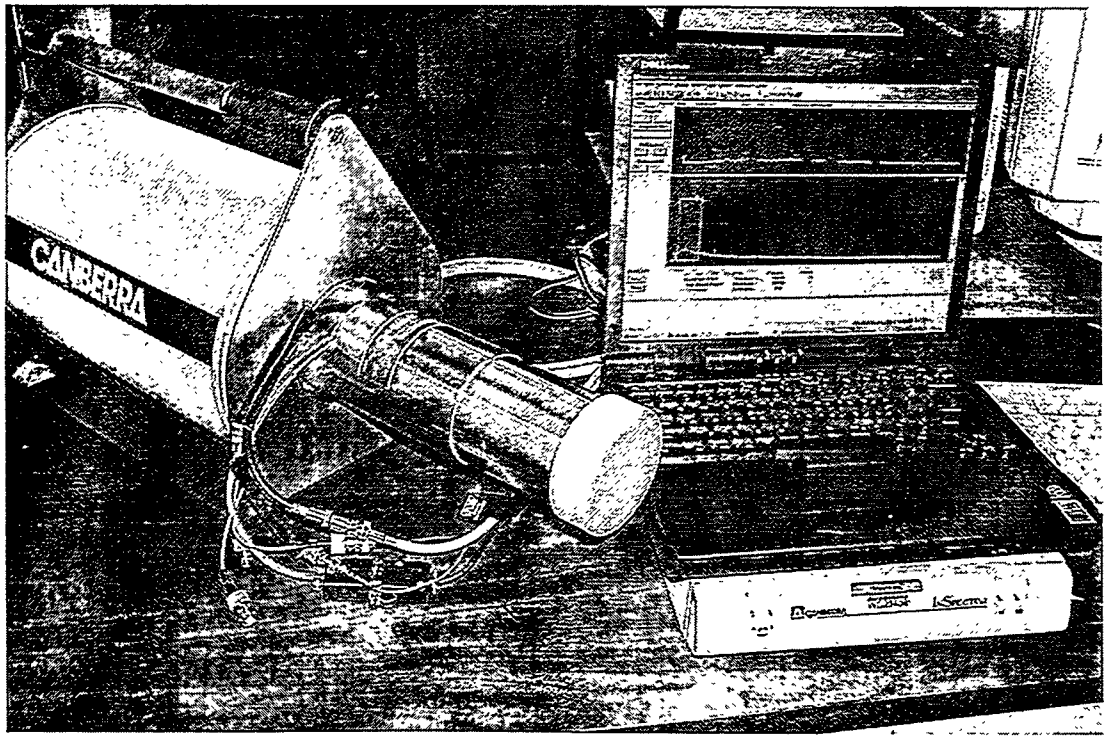



**Figure 4.3.** Portable Wound-Counting Equipment

It was concluded that additional efforts to restore the older style "organ-pipe" HPGe detectors are no longer warranted. Based on experience with one detector, it does not appear that the level of performance that can be achieved is adequate to justify the time required to make the modifications.

### 4.1.4 Cadmium-Telluride Detector

A CdTe detector was purchased for low-energy wound counting applications. Figure 4.4 shows the detector and the associated electronic module. The crystal volume is 66 $mm^3$. This small crystal is useful for detailed mapping of a contaminated body surface. At the same time the measurement results are very dependent on the measurement geometry. Because of its relatively low detection efficiency it is also useful for measurement of high count rates without suffering large amounts of dead time. The approximate decision level at 59.5 keV for an $^{241}Am$ small surface wound is 10 picocuries (pCi) with a corresponding MDA of 30 pCi. This is a factor of 5 higher than the MDA using a 38-$cm^2$ HPGe detector. However, the MDA at $^{239}Pu$ L-X-ray energies with the CdTe detector is slightly lower compared with the HPGe detector for a small surface wound.

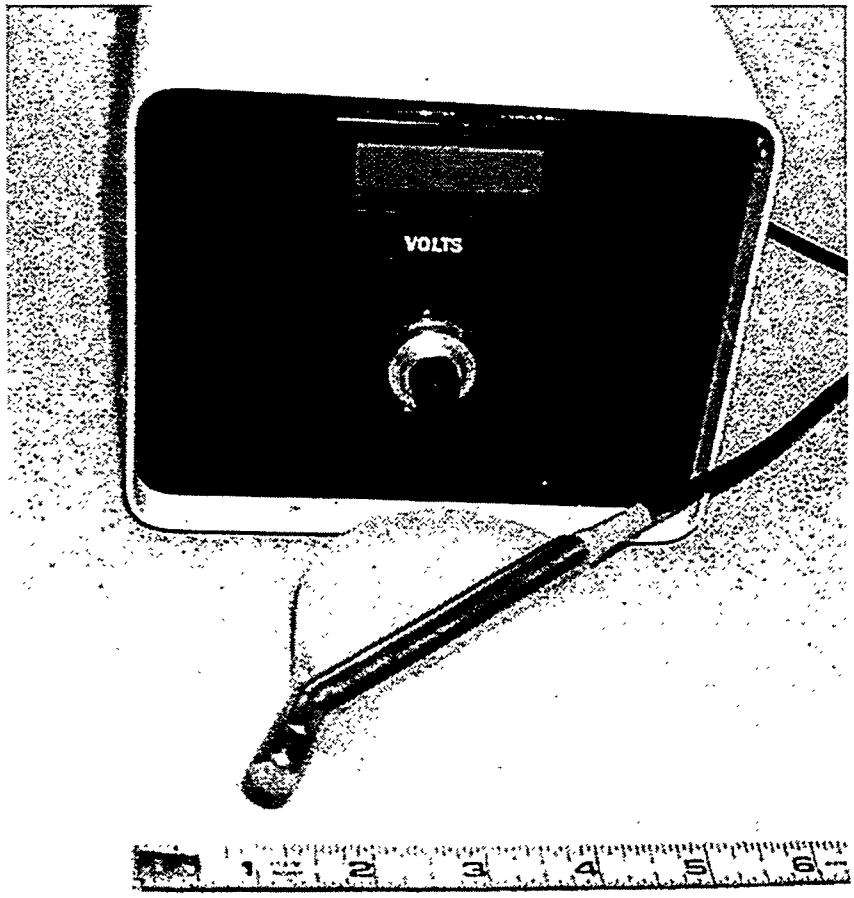



**Figure 4.4.** Cadmium-Telluride Detector and Electronics Module

A preliminary estimate of the detection efficiency was determined for $^{241}$Am and $^{239}$Pu sources in contact with the probe. The sources were slightly larger than the 1-cm-diameter probe. The probe was centered over the source. The $^{241}$ Am efficiency for this geometry was determined to be 45 cpm/nCi at 59.5 keV. At the L X-ray energies for $^{241}$Am the efficiency was dependent on the number of channels selected for the region of interest. For a region of interest (ROI) including channels 29 through 39 (14.5 keV to 19.5 keV), the efficiency was 5.4 cpm/nCi; for channels 24 through 48 (12 keV to 24 keV) the efficiency was 10 cpm/nCi.

### 4.1.5 Facility-Related Activities

There were two major facility-related changes that occurred during the year. Stainless steel molding was installed in the men's shower stalls to cover the corroding sections at the base of the walls. This is a temporary fix until Facilities and Operations can obtain funding to replace the shower stalls. A new motor and fan for the supply ventilation system for the Palmer and Stainless Steel rooms were installed in October. The performance of the old equipment had degraded to the point where the noise levels and reliability were unacceptable to support routine operations. After the new equipment was installed, the air change rates in all the counting rooms were measured. The estimated rates were 12 air changes per hour (AC/hr) in the Stainless Steel Room, 17 AC/hr in the Iron Room, and 18 AC/hr in the Palmer and Lead rooms.

## 4.2 Program Changes and Improvements

The most significant change in 1999 was the implementation of the Abacos Plus software for acquiring, analyzing, and storing in vivo measurement data. The Abacos Plus application software runs under the VMS operating system on a Compaq (formerly Digital Equipment Corporation) Model 255UP-A Alpha Workstation. The system consists of a 255-MHz processor with 96 Mb RAM, a 9-gigabyte hard disk, 17-inch monitor, 600 Mb CD ROM, and a DAT tape drive.

Abacos represents a philosophical change from the previous Nexec system in how the activity is calculated. The Nexec calculations were made with the assumption that the worker contained no activity. The Abacos system initially performs a peak search analysis to determine whether identifiable peaks are present. If no peaks of interest are present, then an ROI calculation is executed to calculate an activity. Nexec summed the counts in user-defined ROIs with a fixed number of channels to quantify activity. Abacos calculates a net peak area for identified peaks as determined by the peak search algorithm to quantify activity. When no peaks associated with the nuclides in the library are identified, the software bases the size of the ROIs on the system resolution and a user selectable variable peak-width factor. The calibration factor is calculated from the net counts determined by the peak search on a phantom count. The ROI used for a person count where no peak is identified may be different than the ROI used to determine the calibration factor. The operational impacts of this difference are being evaluated.

Testing of the Abacos system showed that its performance was comparable to Nexec. During testing, it was possible to transfer data from Nexec to Abacos to compile enough records to evaluate the false positive rate and the distribution of net counts in unexposed workers using the Abacos software. The false positive rate was evaluated and found to be acceptable. The Abacos Y2K test was successfully

completed on July 6, 1999. A DEC 3000 workstation was loaded with the same operating system, Canberra software, and internally developed software that is being used on the primary Alphastation. It will function as the essential spare system in the event of a failure of the primary Alpha Workstation.

The Abacos Plus system was rushed into service ahead of schedule when the Nexec system failed on the morning of October 22 due to a hard disk malfunction. The disk contained the Oracle database and the failure prevented use of the system. The transition was about as smooth as could be expected following the failure of the primary computer system used for routine counting. There was no loss of data caused by the failure. Records were recovered from backup files. Work began on restoring the Nexec Oracle database and converting all the data since 1995 to a more recent version of Oracle and into ASCII format. The conversions will allow for easier access to the data if they are needed in the future.

A decision was made with concurrence from the contractors to not pursue placing the mobile in vivo counting trailer in the 200 Areas for routine counting. Initially, it was suggested that because some physical examinations are to be performed in the 200 Area the workers could also receive their in vivo counts at the same time. However, several operational issues, including the need to perform any recounts at the 747A Building in Richland, made this option untenable at this time. It also became necessary to move the detectors from the mobile counter to the Lead Room as a part of a whole body counting system being installed there. The system is needed as a backup for the standup counter, which has become less reliable.

## 4.3 Program Assessments

Procedure compliance surveillance and computer configuration management surveillance were conducted as part of the 1999 management assessment. Corrective actions for the findings were completed in January 2000.

Representatives from U.S. Ecology (USE) conducted a one-day audit of the program. No findings resulted from the audit. The IVMPH remains on the USE-approved vendor listing for in vivo services.

## 4.4 Supporting Technical Studies

Three technical studies were undertaken during 1999, as described in the following sections.

### 4.4.1 Thyroid Radioiodine Intercomparison Program

The IVMPH staff once again participated in the Thyroid Radioiodine Intercomparison Program. A Plexiglas neck phantom meeting the ANSI N44.3 (ANSI 1973) criteria is filled with a 30-ml vials containing either $^{131}I$ or $^{125}I$ that are supplied by Lawrence Livermore National Laboratory (LLNL). The results from the measurements are shown in Table 4.3. All of the IVMPH results were well within the DOELAP acceptable bias range of +50% to -25%.

**Table 4.3.** Results from the Thyroid Radioiodine Intercomparison Program

| I-125 Result (dpm) | I-125 True Activity (dpm) | I-125 Bias | I-131 Result (dpm) | I-131 True Activity (dpm) | I-131 Bias |
|---|---|---|---|---|---|
| 4th Quarter 1998 | | | | | |
| 1.93E+05 ± 3.27E+04 | 1.98E+05 ± 5.94E+04 | -0.03 | 2.65E+05 ± 4.61E+04 | 2.72E+05 ± 8.06E+04 | -0.03 |
| 1st Quarter 1999 | | | | | |
| 7.80E+05 ± 5.10E+04 | 7.66E+05 ± 2.30E+04 | 0.02 | 8.12E+05 ± 2.95E+04 | 8.37E+05 ± 2.51E+04 | -0.03 |
| 2nd Quarter 1999 | | | | | |
| 4.45E+05 ± 7.95E+04 | 4.46E+05 ± 1.34E+04 | 0.00 | 7.27E+05 ± 8.68E+04 | 7.35E+05 ± 2.21E+04 | -0.01 |
| 3rd Quarter 1999 | | | | | |
| 3.27E+05 ± 1.23E+04 | 3.44E+05 ± 1.03E+04 | -0.05 | 9.20E+05 ± 7.88E+04 | 9.70E+05 ± 2.91E+04 | -0.01 |

### 4.4.2 Thoron In-Breath Monitor Study

To continue last year's thoron in-breath monitor (TIBM) project-related activities, many facilities licensed by the Nuclear Regulatory Commission for handling thorium were contacted. A letter describing the TIBM was sent to several of the contacts. A book chapter on the TIBM was submitted to the publisher of the Current Protocols in Field Analytical Chemistry. A TIBM workshop has been proposed jointly by Andrea Eisenmanger from Germany and Keith Terry from Brazil. The workshop would likely be held in Perth, Australia. An intercomparison study involving mineral sands workers from Australia is also being proposed. Funding is needed for both and is being sought from the International Atomic Energy Agency (IAEA). Negotiations are ongoing to establish a contract to perform TIBM measurements for a non-DOE client.

### 4.4.3 Measurement Quality Control

As part of the ongoing measurement QC program, measurements are performed to estimate the activity content of phantoms. These phantoms may come from various sources and their activity is not known to the IVMPH staff prior to making the measurements. This year the Abacos results from measurements made on a bottle-manikin absorption (BOMAB) phantom containing an unknown amount of $^{137}Cs$, $^{88}Y$, and $^{152}Eu$ were within 6.5% of the stated activity in the phantom. Measurements were also made of a liver phantom fabricated at the University of Cincinnati. The results were in good agreement with the stated $^{241}Am$ activity in the phantom. The IVMPH-measured value was 866 nCi compared with the stated activity of 860 nCi; a less than 1% positive bias. In addition, six lung phantoms with MDA levels of activity were counted using Abacos. These phantoms were used for early rounds of DOELAP performance testing and the activity content was not known prior to the measurements. Even at these

activity levels, which are well below the minimum testing level used for DOELAP performance testing, the results were within the acceptable bias range. The results of this testing at the MDA were included in the technical equivalence documentation submitted to DOELAP.

### 4.4.4 $^{241}$Am Calibration for Deep Wounds

Small puncture wounds are the most frequent type of contaminated wound seen at Hanford. The associated radioactivity is initially calculated based on contact measurements using an $^{241}$Am point source. If the activity is covered with tissue then a revised estimate of the wound activity must be made to avoid underestimating the activity. As a first step the $^{241}$Am source (#40) used to make the wound calibrations was counted with different thickness of overlying dental wax. The wax has a density similar to soft tissue. The differences in calibration factors relative to the bare source were a factor of 1.25 at the 5-mm depth and a factor of 3 at the 20-mm depth. A plot of the calibration factors versus depth is shown in Figure 4.5. The data were collected with the Nexec computer system and will be repeated with the Abacos Plus software in CY 2000.

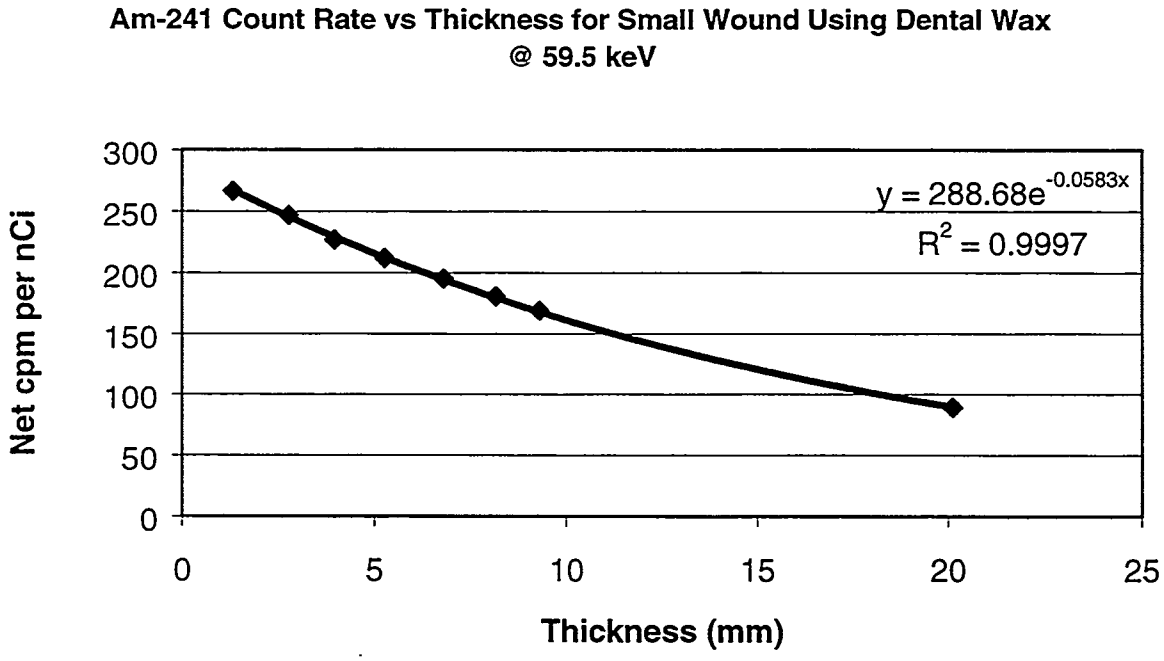



**Figure 4.5.** Calibration Factors Versus Overlying Tissue Thickness for $^{241}$Am Point Source

## 4.5 Program-Related Professional Activities

Staff activities, presentations, and professional memberships during 1999 are listed in this section.

### 4.5.1 Activities

T. P. Lynch was involved in the following professional in vivo counting activities outside of Hanford:

- Assessor for the onsite DOELAP assessment at the Waste Isolation Pilot Project (WIPP) site
- Lead assessor for the onsite DOELAP assessment at Los Alamos National Laboratory (LANL)
- DOELAP Assessor Training, June 1-2, 1999, Las Vegas, Nevada.

### 4.5.2 Presentations

None.

### 4.5.3 Publications

As chairman of the working group, Tim Lynch finalized changes and submitted the final version of the ANSI N13.35 standard, *ANSI Standard for the Bottle Manikin Absorption Phantom,* for publication. The standard was published as part of the February 2000 Health Physics Society Newsletter.

Tim Lynch submitted the camera-ready copy of the manuscript "Estimating Thorium Activity in the Body by Measuring Thoron in Exhaled Breath." The chapter was published in March 2000 in "Current Protocols in Field Analytical Chemistry." The manuscript was co-authored with John Johnson and Rick Traub.

### 4.5.4 Professional Memberships

T. P. Lynch served as Chair of the working group for ANSI N13.35, *ANSI Standard for the Bottle Manikin Absorption Phantom.*

# 5.0 Hanford Radiation Records Program

The Hanford Radiation Records Program (HRRP) supports DOE-RL and Hanford contractor radiation protection programs by administering and preserving radiological exposure records for all Hanford workers and visitors, past and present, and by providing specified and requested reports using these records. The program is also responsible for maintaining the Hanford Radiation Protection Historical Files; operating the computer systems and library equipment necessary to input, store, verify, and retrieve the records; and producing the required reports and downloads. Although data processing functions are now the responsibility of Dosimetry Services, data entry and validation are reported in this section.

## 5.1 Overview

The HRRP is organized into four major functional areas: data administration, data processing, report issuance, and the Records Library, as described below. Data processing and part of report issuance are performed by the HRRP Dosimetry Services Dosimetry Operations.

### 5.1.1 Database Administration

The database administrators evaluate systems, troubleshoot, resolve system and user problems, train users, oversee system security, serve as liaison with the Lockheed Martin Services, Inc. (LMSI) computer analysts, and initiate and test modifications of the databases for the REX database and Access Control Entry System (ACES).

The ACES was created to implement a system for computerized supplemental dose tracking and radiation area/hazardous waste site access control. It is a computerized access control program that electronically compares worker qualifications with controlled area access requirements. Although HRRP has data administration responsibilities of ACES, FHI retains ownership. However, the HRRP manager works closely with the FHI ACES manager and LMSI personnel in the operation and maintenance of the system. ACES is a client-server system, hosted on an HP 9000 computer (four 180-MHz processors) using the Hewlett Packard Unix operating system and ORACLE software to manage the database and provide entry screens and reports. Users access the server via PCs connected to the Hanford Local Area Network (HLAN) using Windows-based software residing on the users' (clients') computers. The database receives data from several other Hanford computer systems (e.g., PeopleSoft, REX, and PeopleCORE).

The REX system is a computerized database that maintains all of the radiological exposure records and supplementary and support data for individuals who have worked at the Hanford Site since 1946. The REX system contains the individual radiological exposure records on all Hanford DOE, contractor, and subcontractor employees as well as Hanford visitors. The system also contains other information used by site radiation protection organizations such as individual skin contamination reports and bioassay schedules and delivery addresses. These data are readily retrievable via a system of PCs and terminals

operated by the HRRP and Hanford contractor dosimetry staffs. The REX system also includes supporting exposure documentation on microfilm and compact disk that are indexed into computer-assisted retrieval (CAR) systems. The CAR systems allow for rapid retrieval of the documents for any individual person using identifiers (IDs). These IDs include payroll numbers, social security numbers, names, and/or REX IDs, which are unique numbers generated by the computer for each individual to tie all of their records together. The HRRP also uses a compact disk imaging subsystem (called LaserREX). Since January 1, 1992, all hard-copy exposure records have been preserved on LaserREX. Hard-copy records generated prior to 1992 are maintained on microfilm. The LaserREX also stores the electronic records created by the REX transaction log subsystem, which logs all changes to the database data fields.

### 5.1.2 Data Processing

Data processing includes entering data into the REX database and validating all data entry. This function is actually the responsibility of the Dosimetry Processing Center for DOE and FHI data, and PNNL Safety and Health Technology and Bechtel Radiological Control for their own data. Data validation is accomplished by reviewing field data entry, establishing audits to be matched to entries of results, resolving unmatched results, and interacting directly with contractor personnel. Data handlers also deal directly with contractor personnel and data suppliers to assist them and solve data problems. Dosimetry Processing also issues, tracks, and processes dosimeters for FHI and DOE.

### 5.1.3 Report Issuance

The report issuance function is shared by HRRP and the Data Processing Center. Dosimetry Operations is responsible for generating and issuing routine exposure status reports to the contractors, quarterly person-rem and annual statistical reports to DOE, and annual reports to employees. This function requires close contact with RL, the contractors, and other personnel dosimetry functions. Special reports requested by former employees, as well as those requested by the contractors, RL, the United States Uranium and Transuranium Registries, and Privacy Act and Freedom of Information Act petitions are the responsibility of HRRP.

### 5.1.4 Records Library

The Records Library maintains individual exposure records and backup documentation that are not reducible to database elements, as well as the HRRP Historical Files. The library staff scan, index, and retrieve hard-copy documents; prepare documents for long-term storage; and track and account for the documents through the imaging and indexing process. The library contains the individual exposure records of all Hanford personnel since Hanford's inception in 1944 (almost five-million microforms), except for those individuals who transferred from Hanford when DuPont left in 1946. These exposure records and the Historical File microforms are retrievable through index systems that are maintained by the library staff.

Although the results from the dosimeter and excreta processing, as well as the in vivo counts, are received by electronic transmission, a large amount of data is entered manually by the field dosimetry organizations and the Data Processing Center staff. The hard copies are then sent to the library for

preservation on the imaging systems. Records in the HRRP Historical Files include documents such as policies, procedures, reports, and important communications that define the Hanford radiological dosimetry and radiation protection programs throughout their history. The historical records are microfilmed and indexed into an additional CAR system. These records are retrievable by author, date or range of dates, document number (if applicable), document title, and up to three keywords.

Starting September 20, 1999, the LaserREX document scanning and retrieval hardware was shared with a new document database for Instrument Services and Technology, LaserCal. The system was cloned from LaserREX, and is operated by the Records Library staff.

The program is operated under the applicable sections of 10 CFR 835; ANSI N13.6, *American National Standard Practice for Occupational Radiation Exposure Records Systems* (ANSI 1972); as well as the following DOE Orders: DOE G 1324.5B, *Implementation Guide for Use with 36 CFR Chapter XII – Subchapter B Records Management* (DOE 1996a); DOE G 441.1-11, *Occupational Radiation Protection Record-Keeping and Reporting Guide* (DOE 1999b), DOE Order 231.1-1, *Environment, Safety and Health Reporting* (DOE 1996b); and DOE Manual 231.1-1, *Environment, Safety and Health Reporting Manual* (DOE 2000). The program also complies with the applicable sections of the Privacy Act (1974) and the Freedom of Information Act (FOIA 1966).

## 5.2 Routine Operations

Staff routinely administer and process data, issue reports, and maintain the Records Library.

### 5.2.1 Data Administration

Over 2800 Radiation Work Permits (RWPs) were created/closed, and over 238,000 access instances occurred in ACES in 1999. The REX database administrator completed 91 software change requests in 1999.

### 5.2.2 Data Processing

With the exception of Exposure History Forms and Employee and Dosimetry Change Forms, the number of documents sent from Dosimetry Operations to the HRRP records library changed little from 1998 (see Table 5.1). The increases in those forms were due mainly to the mass personnel transfers in 1999, and the correction of new data errors. Lockheed Martin Hanford sold its business at Hanford to the CH2M Hill Hanford Group, resulting in the transfer of all employees. Also, employees of most PHMC subcontractors were transferred to FHI. A discrepancy report that compares REX data with security data identified a number of name discrepancies. As each error was corrected, a change form was produced and indexed. Over 3000 errors were identified and corrected in 1999.

**Table 5.1.** Records Activity for Calendar Year 1999[(a)]

| Document Type | Number Processed | |
|---|---|---|
| | 1998 | 1999 |
| Personal Radiation Exposure History Form (used to document exposure history prior to Hanford and to initiate a record for a new or rehired employee) | 2,142 | 3,050 |
| Employee and Dosimetry Change Forms (used to document personnel data or dosimetry changes) | 6,717 | 11,340 |
| Termination Letters (used to document employee terminations, many changes were done electronically not requiring forms) | 1,599 | 1,221 |
| Temporary Dosimeter Assignment Forms (used for issuing temporary dosimeters to employees due to new hires, changes in dosimetry requirements, multiple dosimetry needs, or employees who forgot their dosimeters) | 5,080 | 5,090 |
| Visitor and Subcontractor Dosimeter Issue Forms (used to issue dosimetry to visitors and subcontractors who have not completed radiological worker training) | 2,116 | 2,189 |
| Investigation of Dosimeter Result Forms and Change Letters (used to estimate exposure for lost, damaged, or otherwise suspect dosimeter results) | 614 | 743 |
| Special Process Forms (used to document data for specially processed dosimeters) | 1,547 | 1,672 |
| (a) These document totals are included in the records library summary below for records scanned and indexed into LaserREX. | | |

### 5.2.3 Report Issuance

As shown in the following tables and figures, work was relatively consistent with 1998, with the exception of internal dosimetry evaluation reports.

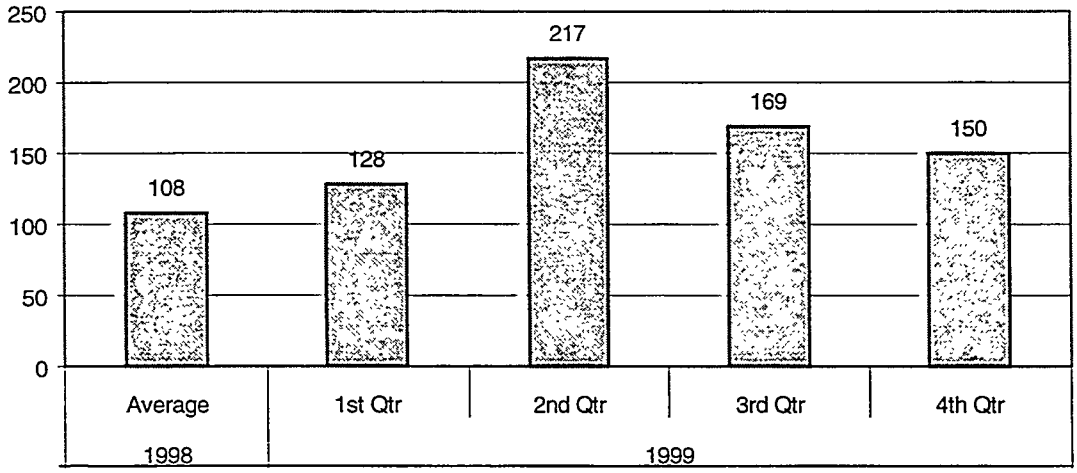



**Figure 5.1.** Requests for Previous Exposure

**Table 5.2.** Responses to Requests for Previous Exposure

| Source of Request | 1998 Average | 1999 | | | |
|---|---|---|---|---|---|
| | | 1st Qtr | 2nd Qtr | 3rd Qtr | 4th Qtr |
| Miscellaneous | 4 | 26 | 7 | 0 | 0 |
| Privacy Act/FOIA | 1 | 7 | 5 | 1 | 1 |
| Current Employees | 2 | 7 | 1 | 4 | 2 |
| Former Employees | 2 | 2 | 0 | 0 | 0 |
| Companies | 75 | 47 | 120 | 84 | 43 |

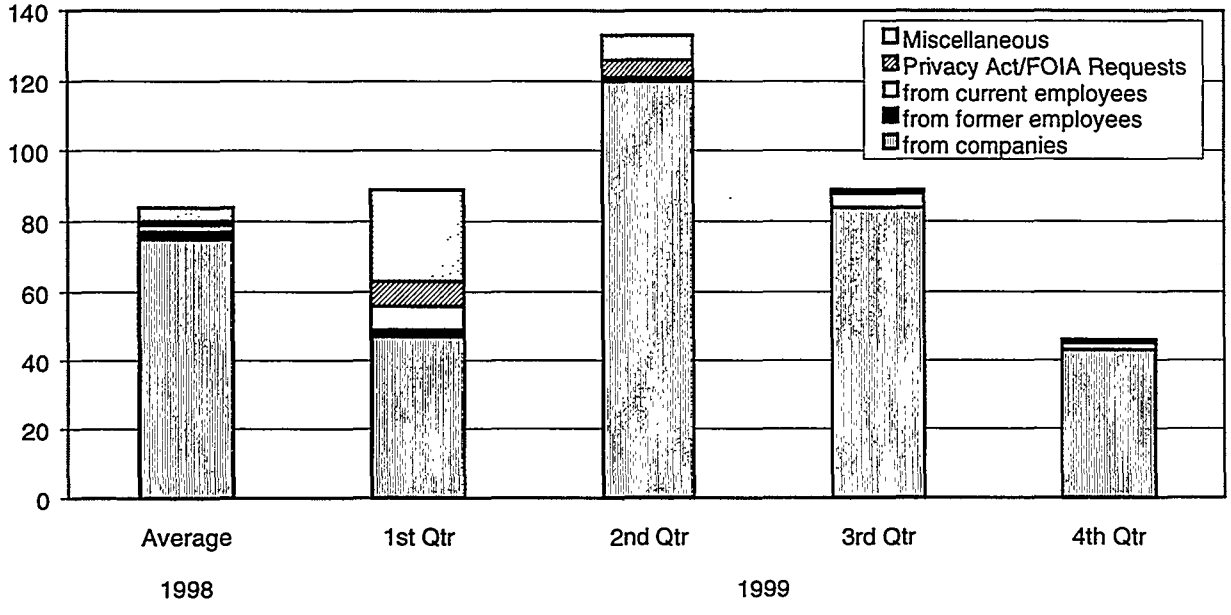



**Figure 5.2.** Responses to Requests for Previous Exposure

**Table 5.3.** Responses to Requests for Previous Exposure

| Organization | 1998 Average | 1999 | | | |
|---|---|---|---|---|---|
| | | 1st Qtr | 2nd Qtr | 3rd Qtr | 4th Qtr |
| DOE-HQ | 25 | 16 | 29 | 31 | 35 |
| DNFSB[(a)] | 13 | 7 | 4 | 14 | 13 |
| IAEA | 7 | 6 | 7 | 7 | 8 |
| Miscellaneous | 480 | 464 | 507 | 667 | 437 |
| (a) DNFSB = ? | | | | | |

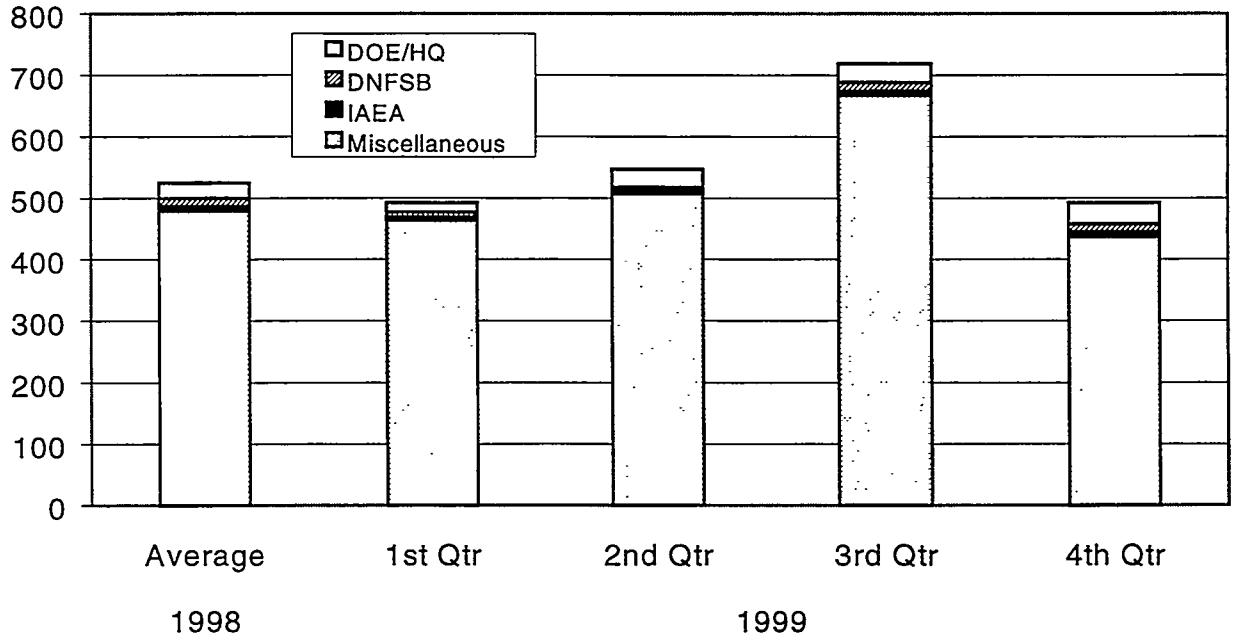



**Figure 5.3.** Visitor Exposure Letters

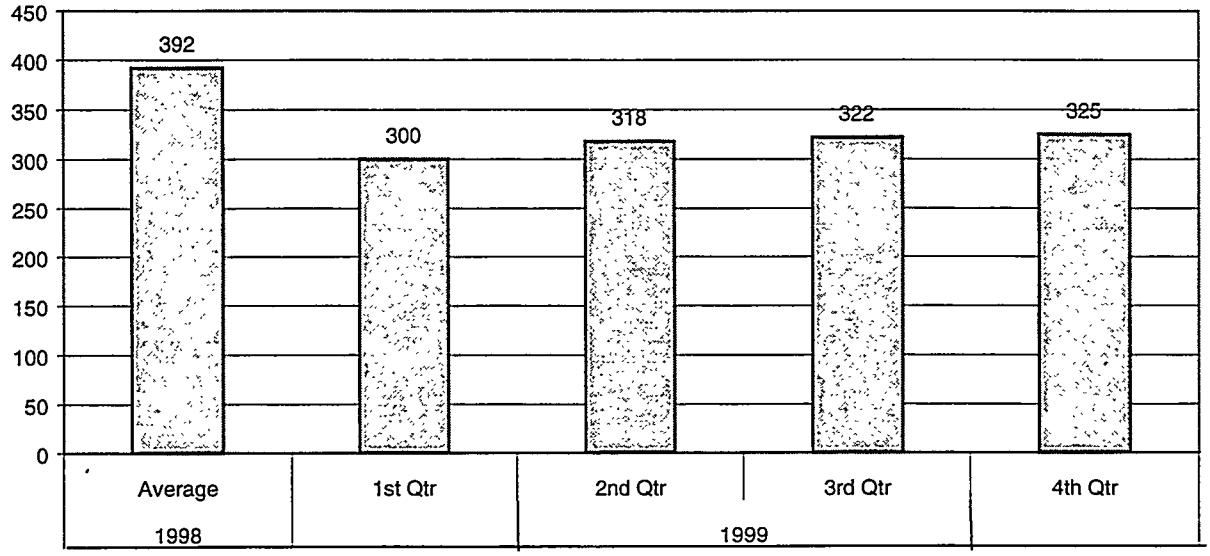



**Figure 5.4.** Termination Letters

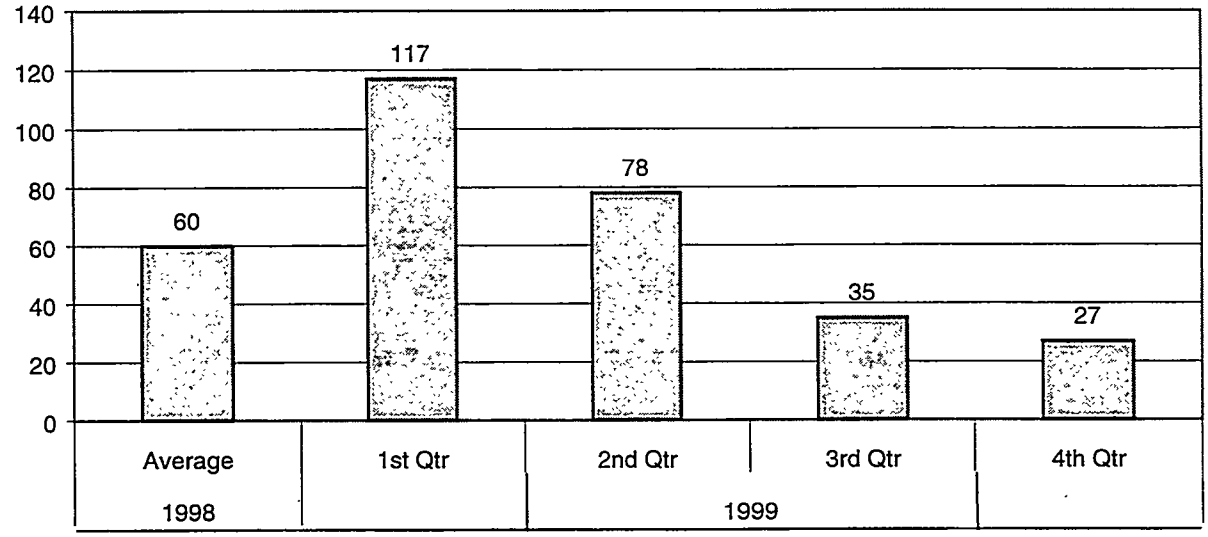



**Figure 5.5.** Internal Dosimetry Evaluation Reports

### 5.2.4 Records Library

The number of documents scanned and indexed into the LaserREX system this year was up only slightly over 1998, but the new LaserCal system added significantly to the Records Library workload in 1999. LaserCal records are expected to account for about one-third of the documents in 2000.

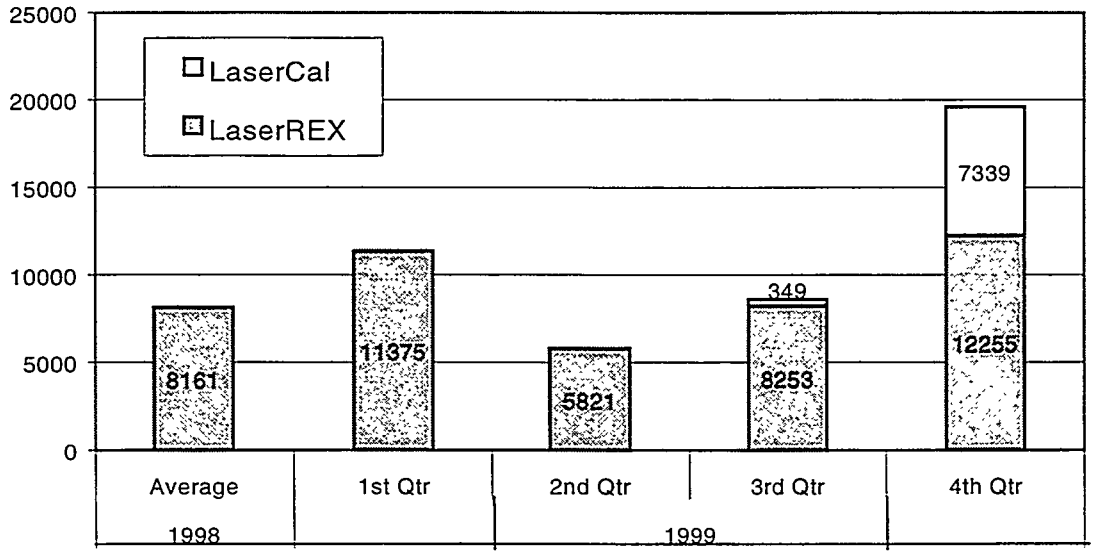



**Figure 5.6.** Documents Scanned/Indexed

## 5.3 Program Changes and Improvements

Database and document scanning improvements were made during 1999, as described in the following sections.

### 5.3.1 ACES Database

The original version of ACES was determined to not be Y2K compliant. Therefore, an upgrade (Version 6.0) was initiated in 1998 that maintained the established functionality, but in a Windows-based client-server environment that is fully Y2K compliant. The new system was implemented in early 1999. The ACES data administrator was very involved with testing screens and reports in Version 6.0 prior to its release, coordinating user field-testing, developing the user manual, and training the users on the new system.

The ACES data administrator provides monthly reports of entry and dose data to PNNL and FHI. Upon request, the data administrator also provides personnel qualification reports to federal and state regulators, and adjusts the Administrative Control Limits (ACLs) for individuals in accordance with established policies. The data administrator monitors data downloads for accuracy, and is the point of contact for access qualification or system problems. The data administrator also initiates, tracks, and participates in the evaluation and review of system change requests.

### 5.3.2 REX Database

The REX database resides on the multi-user Enterprise Server (ES) operated by LMSI. Major systems continued to be removed from the ES in 1999, decreasing the processing volume. The resultant

increase in cost per processing minute was offset by LMSI by reducing support staff and canceling software maintenance agreements. These actions were successful in reducing total LMSI support charges to near 1997 levels. Unfortunately, most of the savings were not implemented until late in the fiscal year—too late to impact our clients' budgets.

Battelle, along with the major REX users, agreed in 1999 that the system needed to be redeveloped/ re-hosted into a more cost-effective environment, and a client-server environment was selected to replace the current system. A contract was signed with the Science Applications International Corporation (SAIC) to redevelop the system. The new system is based on an Oracle database residing on a UNIX platform with the user interface developed using the Oracle Developer 2000 suite of tools. Four of eleven modules (Personnel, Administration, Transaction Log, and Dose Tracking) were completed in 1999. Implementation for the new system is scheduled for September 30, 2000.

Although REX has always been Y2K compliant through a subroutine that converted each date to a four-digit year as it was entered, the Gener/OL user interface and Platinum Report Facility query utility of REX were upgraded in 1999 to fully Y2K-compliant versions. REX made it into the Year 2000 with minimal hardship. During December any changes to REX required approval by upper-level Battelle management and the DOE-RL Y2K coordinator. The restrictions were intended to discourage unnecessary changes and reduce the risk of creating unintended date problems. LMSI took the ES off-line the afternoon of December 31, and then brought it back on-line after the power source was certified as stable on January 1, 2000. A few date-related problems were identified prior to January 1, and corrected.

The REX database performed very well all year. The majority of the Software Change Requests issued during the year were for changes and enhancements to make the operations more efficient and data entry less cumbersome. The REX User's Group, initiated late in 1993, was instrumental in proposing and defining many of the enhancements and changes. Some of the significant changes included the following:

- addition of a new Regulatory Code to REX that identifies whether a bioassay was collected for confirmatory or mandatory monitoring
- provision of a daily list of failed analyses requiring follow-up
- provision of a manually initiated deficiency report that identifies uncompleted bioassay orders that need to be rescheduled.

### 5.3.3 Document Scanning

The original LaserREX system consisted of two PC computers (the compact disc [CD] writer that compiled images and created compact disks and the CD controller that controlled the CD jukebox), and two computer workstations each with an optical scanner. A hardware upgrade in 1998 consolidated the hardware into a single 350-MHz dual processor Gateway ALR 7200 server using Windows NT. A persistent "time-out" problem experienced after the upgrade was ultimately determined to be related to HLAN hardware. While working on the solution, LMSI informed HRRP that the Gateway through which

LaserREX accesses REX consisted of obsolete hardware, for which replacement parts were not available. The solution (moving to a new Gateway) required upgrading the workstations to Windows NT, and placing them directly on the PNNL LAN. The transfer was accomplished, but indexing was delayed in the interim. System problems, believed to be related to network communications, persisted through most of 1999. The R&HT computer specialist was directly involved with system upgrades and trouble shooting during 1999. The experience he gained has proven invaluable in diagnosing problems and expediting corrections.

LaserCal uses existing LaserREX hardware with modified software cloned from Laser REX. LaserCal provides a retrievable document database for Instrument Services and Technology. The system became operational September 20, 1999. About one-third of the documents scanned and indexed by Radiation Records are now for Instrument Services and Technology.

## 5.4 Program Assessments

There were no assessments or surveillances of Radiation Records performed during 1999.

## 5.5 Supporting Projects

None.

## 5.6 Program-Related Professional Activities

Jay A. MacLellan served as

- Chair of the American Academy of Health Physics Appeals Committee.
- Treasurer, Columbia Chapter of the Health Physics Society through June 1999.

# 6.0 Instrumentation Services and Technology Program

The Instrumentation Services and Technology Project (IS&TP) provides complete and reliable radiation protection instrument services for Hanford Site contractors to ensure personnel safety in the Hanford workplace. Specific tasks performed under this program during 1999 included calibration, maintenance, and repair of portable instrumentation; procurement and testing of new radiological control instruments; administration and technical support of the Hanford Instrument Evaluation Committee (HIEC); and maintenance of a pool of portable survey instruments available for use by site contractors.

The operation of a complete radiation protection instrument calibration and maintenance program is an integral part of the Hanford Site Radiological Control Program. During CY 1999, IS&TP continued to provide complete instrument services including calibration, maintenance, repair, and records management.

Calibration and maintenance of the Hanford pool of portable radiation protection instruments has historically been separate from the calibration and maintenance of contractor-owned instruments. During CY 1998 the transition was made to new unit prices, which effectively eliminated any differences between pool and contractor-owned instruments. Instead, unit prices are based on the complexity of the instrument calibration. In addition, instrument maintenance and non-calibration services, such as instrument testing and configuration control, provided by IS&TP were unbundled from the unit prices. Maintenance is costed at an hourly rate with the required parts and labor charged to the last contractor to use the instrument. The result is a cost structure that allows for a more direct comparison between IS&TP and commercial calibration services. The concept of using unit rates was continued during CY 1999 although the actual rates were adjusted based on the level of effort to support each of the calibration types during CY 1998.

Procurement of new instruments is initiated by the site contractors, or jointly by the contractors through the HIEC, and the procurement costs are charged to the contractor using the instruments. The Hanford contractors, through the evaluation, calibration, and maintenance programs of IS&TP provide the site with high-quality instrumentation that is reliable, accurate, and capable of performing at the level necessary to ensure personnel safety as required by 10 CFR 835 and HSRCM-1 (RL 1994). Calibrations are performed using the mandatory guidance in ANSI N323-1978, *Radiation Protection Instrumentation Test and Calibration* (ANSI 1978). IS&TP activities fall under several basic tasks. These basic tasks are: 1) administration of the Hanford Site pool of portable survey instruments; 2) calibration and maintenance service of Hanford pool, FHI, PNNL, and BHI radiation protection instruments; 3) evaluation and publication to the Hanford Site of all site portable survey instrument environmental parameters; 4) maintenance of a calibration records database; 5) maintenance of all the necessary radiological, electronic, and mechanical standards traceable to NIST; and 6) administration and technical support of the HIEC. Several of these basic tasks and other important supporting tasks performed in CY 1999 are described in this chapter.

## 6.1 Routine Operations

Routine instrument pool, calibration and maintenance, and calibration database services are described in the following sections.

### 6.1.1 Administration of Portable Instrument Pool

IS&TP manages a pool of portable radiation survey instruments for use by Hanford Site contractors. The pool consists of large inventories of the most commonly used instruments. Two new instrument models were added to the Portable Instrument Pool during CY 1999: the Bicron Micro Rem meter and the Eberline RO-7 high-range ion chamber, both of which were previously available at some facilities. As a result, these instruments are now available to any facility on the Hanford Site.

IS&TP also excessed a number of obsolete instruments that will no longer be used onsite. The DCA SuperDad electronic pocket dosimeters were removed from service and excessed. Several facilities converted from RA Stephens GammaCom dosimeters to SAIC PD-3 dosimeters, thereby freeing up a sufficient inventory of GammaComs to completely replace all the SuperDads that were still in service.

In addition to the SuperDads, the high-range totem pole ion chamber survey instruments were removed from service. The instruments, circa 1954 (Howell et al. 1989), were supplied to field organizations as part of emergency response kits. When facilities ceased using the PNNL-supplied emergency response kits, there was no longer a demand for the high-range totem pole instruments.

### 6.1.2 Calibration and Maintenance Service

During CY 1999, approximately 14,200 calibrations were performed by IS&TP. Table 6.1 details the number of instruments calibrated by calibration class and compares the volume with the number of calibrations performed last calendar year. Tables 6.2 through 6.5 provide additional detail on the number of calibrations performed for each prime contractor during CY 1999. The same information is illustrated in Figures 6.1 through 6.4.

The total number of calibrations performed decreased only slightly from the 14,500 calibration performed in CY 1998, whereas CY 1998's volume was significantly lower than CY 1997. This may indicate that the annual calibration volume is leveling off.

On October 1, 1999, the Tank Waste Remediation Project was moved under the DOE's Office of River Protection (ORP), and a new prime contractor (Lockheed Martin Services). For the purposes of the annual report, the ORP was included in the Fluor Daniel Hanford calibration volume because the split was in effect for only the last 3 months of the calendar year.

A similar split occurred in the calibration classifications. Two new calibration classes were created for FY 2000: air sampler and mini-scaler. These instruments were previously classed as "full" calibrations. The "full" calibration class was eliminated because only air sampler and mini-scalers, which require significantly different levels of effort, were included in this class. For the purposes of the 1999 Annual Report, these two categories were combined and reported as "full" calibrations because the split was in effect for only the last 3 months of the year.

**Table 6.1.** Calendar Year 1998 Instrument Calibrations by Unit-Price Category

| Calibration Class | Description of Class | Number of Calibrations by Calendar Year | | |
|---|---|---|---|---|
| | | CY 1997 | CY 1998 | CY 1999 |
| CAMs | Continuous air monitors | 495 | 458 | 465 |
| Exposure Rate | Exposure or dose rate survey instrument | 2,219 | 1,896 | 1,808 |
| Probes | Probe or detector only | 3,944 | 3,670 | 3,406 |
| Electronic Dosimeters | Direct reading, electronic dosimeter | 804 | 647 | 842 |
| Full Calibration[a] | Integral meter and detector | 265 | 320 | 293 |
| Meter only | Electronic calibration of meter or readout | 3,973 | 3,558 | 3,593 |
| Pencils | Pocket ionization chamber dosimeter | 3,946 | 3,149 | 2,690 |
| Smart Probes | Stand-alone calibration of a "smart" detector | 487 | 486 | 597 |
| Sources | Certification of source activity or emission rate | 386 | 324 | 300 |
| Special Calibrations | Complex calibrations charged by the hour | 68 | 112 | 87 |
| Total | | 16,637 | 14,620 | 14,173 |

(a) On October 1, 1999, the full calibration class was replaced with two new classes: mini-scalers and air samplers. For purposes of the 1999 Annual Report, mini-scaler and air sampler calibrations performed from 10/1/1999 through 12/31/1999 were combined and added to the full calibration class.

**Table 6.2.** CY 1999 Calibration Volume for All Hanford Contractors

| Calibration Class | Calibrations Completed, by Month, for CY 1999 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total Hanford Units** |
| Exposure Rate | 165 | 117 | 139 | 156 | 217 | 148 | 148 | 217 | 152 | 92 | 138 | 119 | 1,808 |
| Full | 23 | 12 | 31 | 28 | 39 | 9 | 22 | 21 | 13 | 21 | 48 | 26 | 293 |
| Meter | 305 | 217 | 210 | 307 | 434 | 310 | 324 | 390 | 323 | 238 | 298 | 237 | 3,593 |
| Electronic Dosimeter | 39 | 25 | 165 | 70 | 70 | 113 | 177 | 24 | 31 | 54 | 52 | 22 | 842 |
| Probe | 290 | 225 | 213 | 321 | 395 | 257 | 269 | 315 | 295 | 266 | 301 | 259 | 3,406 |
| Smart Probe | 18 | 13 | 57 | 58 | 85 | 68 | 64 | 91 | 60 | 21 | 46 | 16 | 597 |
| CAM | 39 | 36 | 37 | 41 | 44 | 48 | 34 | 22 | 29 | 36 | 56 | 43 | 465 |
| Pencil | 210 | 168 | 215 | 66 | 142 | 89 | 384 | 444 | 179 | 411 | 297 | 85 | 2,690 |
| Source | 27 | 46 | 39 | 19 | 23 | 15 | 35 | 22 | 28 | 17 | 12 | 17 | 300 |
| Specials | 6 | 4 | 13 | 5 | 6 | 14 | 11 | 8 | 4 | 10 | 3 | 3 | 87 |
| Battery Change Only | 8 | 4 | 13 | 6 | 15 | 7 | 12 | 12 | 15 | 0 | 0 | 0 | 92 |
| Total | 1,130 | 867 | 1,132 | 1,077 | 1,470 | 1,078 | 1,480 | 1,566 | 1,129 | 1,166 | 1,251 | 827 | 14,173 |

**Table 6.3.** CY 1999 Calibration Volume for Fluor Hanford, Inc. (Includes ORP)

| Calibration Class | Calibrations Completed, by Month, for CY 1999 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total FHI Units |
| Exposure Rate | 136 | 91 | 99 | 107 | 141 | 93 | 133 | 187 | 128 | 71 | 113 | 88 | 1,387 |
| Full | 20 | 9 | 30 | 24 | 31 | 9 | 19 | 17 | 11 | 11 | 36 | 21 | 238 |
| Meter | 213 | 166 | 159 | 237 | 320 | 209 | 210 | 249 | 220 | 190 | 197 | 176 | 2,546 |
| Electronic Dosimeter | 29 | 25 | 102 | 66 | 59 | 98 | 173 | 24 | 31 | 54 | 52 | 18 | 731 |
| Probe | 221 | 175 | 161 | 277 | 346 | 215 | 213 | 244 | 230 | 226 | 220 | 192 | 2,720 |
| Smart Probe | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 15 | 12 | 2 | 0 | 0 | 30 |
| CAM | 29 | 32 | 31 | 39 | 38 | 41 | 25 | 22 | 24 | 34 | 49 | 39 | 403 |
| Pencil | 177 | 127 | 185 | 61 | 113 | 89 | 368 | 352 | 118 | 267 | 189 | 71 | 2,117 |
| Source | 20 | 43 | 37 | 19 | 21 | 13 | 33 | 21 | 24 | 16 | 12 | 17 | 276 |
| Specials | 0 | 2 | 7 | 3 | 4 | 5 | 4 | 4 | 0 | 8 | 2 | 1 | 40 |
| Battery Change Only | 8 | 4 | 10 | 4 | 7 | 7 | 11 | 9 | 14 | 0 | 0 | 0 | 74 |
| Total | 853 | 675 | 821 | 837 | 1080 | 779 | 1,189 | 1,144 | 812 | 879 | 870 | 623 | 10,562 |

**Table 6.4.** CY 1999 Calibration Volume for Bechtel Hanford, Inc.

| Calibration Class | Calibrations Completed, by Month, for CY 1999 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total BHI Units |
| Exposure Rate | 6 | 4 | 5 | 9 | 25 | 11 | 5 | 14 | 14 | 10 | 12 | 11 | 126 |
| Full | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 5 |
| Meter | 34 | 15 | 24 | 40 | 66 | 51 | 42 | 55 | 61 | 23 | 54 | 38 | 503 |
| Electronic Dosimeter | 2 | 0 | 49 | 3 | 6 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 64 |
| Probe | 21 | 2 | 15 | 9 | 13 | 10 | 8 | 3 | 23 | 4 | 7 | 13 | 128 |
| Smart Probe | 18 | 12 | 57 | 58 | 85 | 68 | 64 | 76 | 48 | 19 | 46 | 16 | 567 |
| CAM | 1 | 0 | 1 | 0 | 1 | 1 | 5 | 0 | 1 | 0 | 0 | 1 | 11 |
| Pencil | 0 | 19 | 0 | 1 | 21 | 0 | 9 | 22 | 14 | 63 | 12 | 10 | 171 |
| Source | 2 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 4 | 1 | 0 | 0 | 11 |
| Specials | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 5 |
| Battery Change Only | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 6 |
| Total | 85 | 57 | 154 | 122 | 221 | 143 | 137 | 171 | 165 | 121 | 132 | 89 | 1,597 |

**Table 6.5.** CY 1999 Calibration Volume for PNNL

| Calibration Class | Calibrations Completed, by Month, for CY 1999 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total PNNL Units** |
| Exposure Rate | 23 | 22 | 35 | 40 | 51 | 44 | 10 | 16 | 10 | 11 | 13 | 20 | 295 |
| Full | 3 | 0 | 1 | 3 | 8 | 0 | 3 | 4 | 2 | 9 | 12 | 5 | 50 |
| Meter | 58 | 36 | 27 | 30 | 48 | 50 | 72 | 86 | 42 | 25 | 47 | 23 | 544 |
| Electronic Dosimeter | 8 | 0 | 14 | 1 | 5 | 15 | 0 | 0 | 0 | 0 | 0 | 4 | 47 |
| Probe | 48 | 48 | 37 | 35 | 36 | 32 | 48 | 68 | 42 | 36 | 74 | 54 | 558 |
| Smart Probe | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CAM | 9 | 4 | 5 | 2 | 5 | 6 | 4 | 0 | 4 | 2 | 7 | 3 | 51 |
| Pencil | 33 | 22 | 30 | 4 | 8 | 0 | 7 | 70 | 47 | 81 | 96 | 4 | 402 |
| Source | 5 | 1 | 2 | 0 | 2 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 13 |
| Specials | 5 | 2 | 3 | 2 | 2 | 9 | 7 | 4 | 4 | 2 | 0 | 2 | 42 |
| Battery Change Only | 0 | 0 | 3 | 1 | 4 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 12 |
| Total | 192 | 135 | 157 | 118 | 169 | 156 | 154 | 251 | 152 | 166 | 249 | 115 | 2,014 |

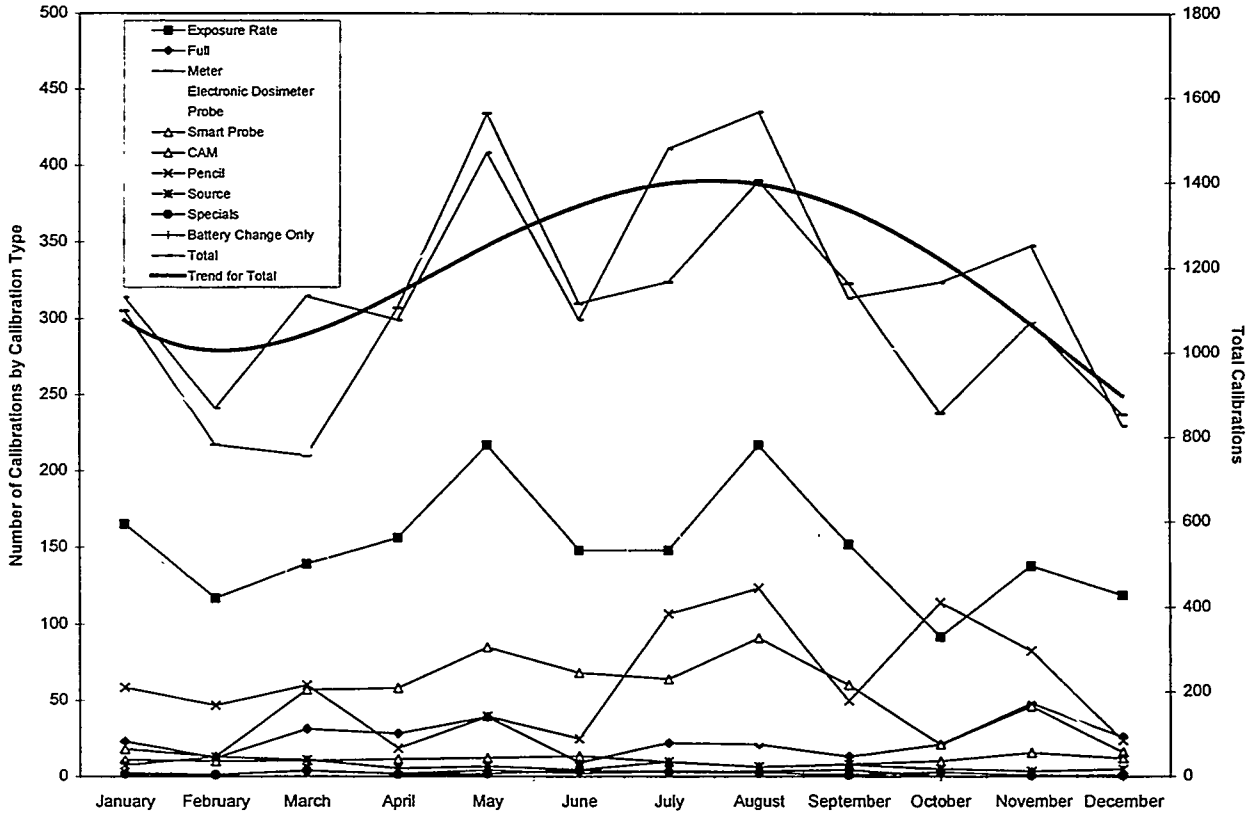



**Figure 6.1.** Hanford Calibrations During CY 1999

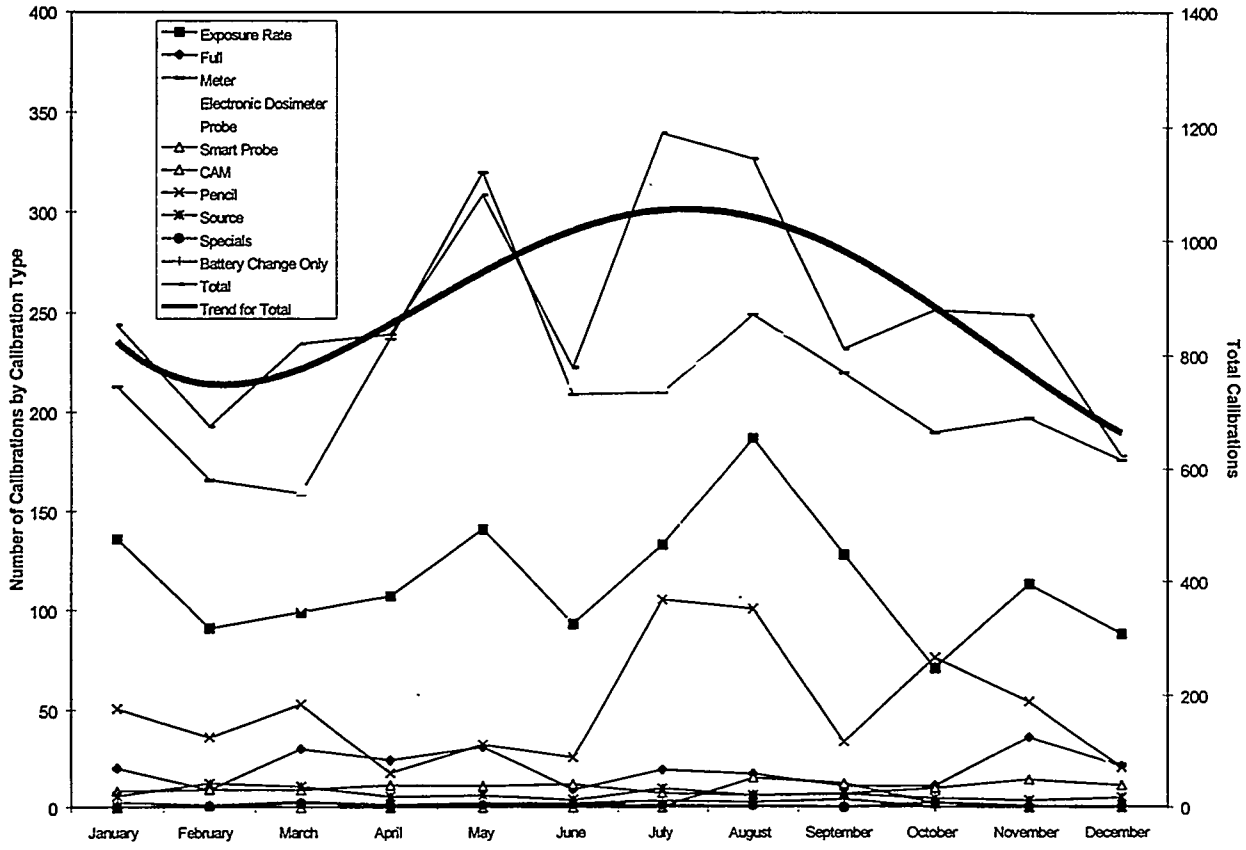



**Figure 6.2.** FHI Calibrations During CY 1999

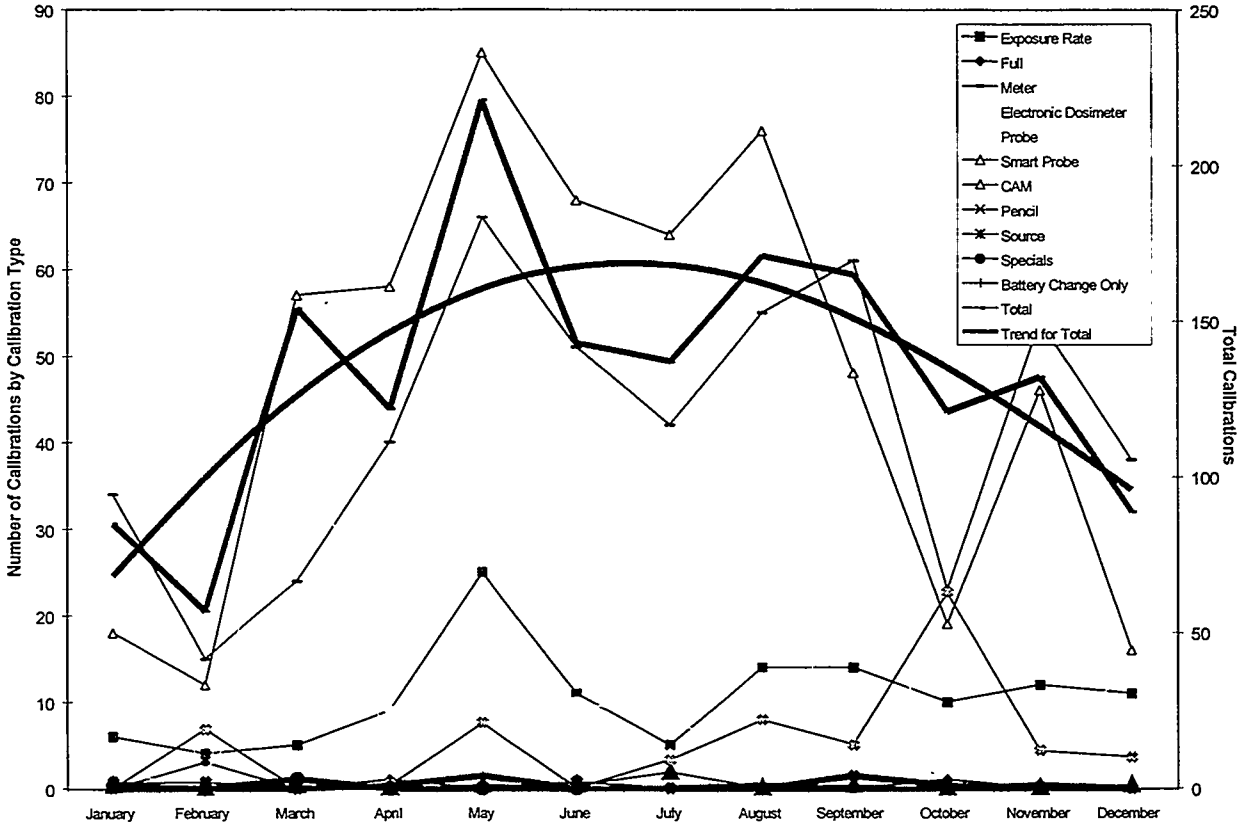



**Figure 6.3.** BHI Calibrations During CY 1999

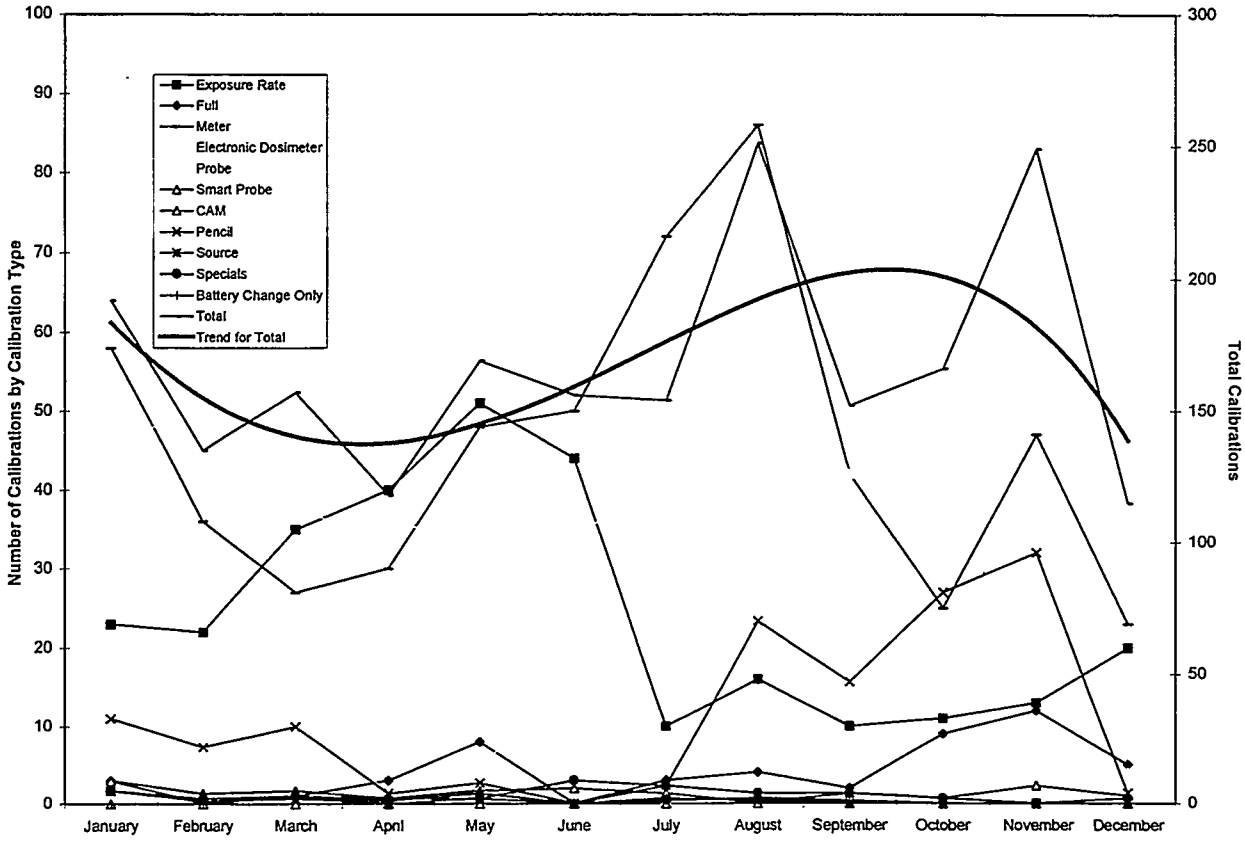



**Figure 6.4.** PNNL Calibrations During CY 1999

### 6.1.3 Calibration As-Founds Out-of-Tolerance

Part of the calibration service provided by IS&TP is quantifying the as-found condition of each instrument when it is returned for calibration. The as-found condition is typically documented as the instrument's response to the calibration standards and is recorded before any adjustments are made to the instrument's response.

A total of 110 instruments calibrated during CY 1999 were found to be significantly out-of-tolerance when returned for calibration (that is, the instrument's response was not within ± 20% of the conventionally true value of the calibration field). This total does not include instruments that were returned for calibration with flaws or defects that would render the instrument obviously unusable to the user. Nor does it include instruments that were repaired prior to calibration because any repairs would invalidate the as-found readings.

The number of as-found out-of-tolerance conditions reported by instrument type is summarized Table 6.6. When a single instrument model seems to have a large number of calibration as-founds

**Table 6.6**. Calibration Out-of-Tolerance Notifications by Instrument Type

| Number of Out-of-Tolerance Reports | Instrument Type |
|---|---|
| 21 | Pencil dosimeters |
| 3 | Air flow measuring devices |
| 19 | Area radiation monitors |
| 1 | Air sample pumps |
| 3 | Bench monitor (e.g., AC-powered count rate meter) |
| 12 | GM count rate meters |
| 3 | Sample counters |
| 3 | High range exposure rate instruments (RO-7; TPC) |
| 4 | Alpha/beta contamination detectors (GM; SHP380AB) |
| 2 | Electronic dosimeters |
| 12 | Ion chamber exposure rate survey instruments (RO-3B; RO-20) |
| 3 | Neutron dose rate monitors |
| 5 | Extendable, high range exposure rate survey instruments |
| 1 | Low level monitor (e.g., Bicron Micro Rem Meter) |
| 12 | Alpha continuous air monitors (CAMs) |
| 3 | Portable alpha monitors (PAMs) |
| 2 | Eberline E-600 "smart" count rate meters |
| 1 | Noble gas continuous air monitor (CAMs) |
| 110 | Total |

out-of-tolerance, a detailed review of all calibration as-founds for that instrument model is conducted. If more than 15% of the instruments returned for calibration have as-founds out-of-tolerance, the calibration interval for that instrument model is shortened.

### 6.1.4 Maintenance of the Calibration Database

IS&TP manages the calibration records for all instruments, source, and dosimeters calibrated by IS&TP. The records are scanned to allow for ready retrieval (see Section 6.2.2) before being sent to record storage. Upon request, copies of calibration records are provided to customers.

## 6.2 Program Improvements in Calibration and Maintenance Operations

The calibration database and electronic database retrieval were improved as described below.

### 6.2.1 Calibration Database

A primary improvement during CY 1999 was developing and implementing a new calibration database. The calibration database, which previously resided on a non-networked HP 9000 mini-computer, was migrated to an ACCESS database on a network file server. The migration to the ACCESS database significantly improved IS&TP's capability to document instrument repairs and instrument service. Because the database is on a networked file server, Hanford customers can now access information on their instruments through a web page. The web page allows customers to generate reports of instruments assigned to their location, review quotas for pool instruments, and review instrument maintenance and repair histories.

### 6.2.2 Electronic Datasheet Capture

Each calibration performed by IS&TP results in a hard-copy calibration record. This means that more than 14,000 calibration records (many consisting of multiple pages) are generated, filed, and stored each year. The result of internal assessments and experience indicated that record retrieval was a challenge. To improve the ease with which datasheets could be retrieved, a system was implemented to scan and index each calibration record. This allows for retrieval of calibration records using the calibration date and/or the instrument barcode.

The system, called LaserCal, is a slightly modified clone of the LaserREX system used by the HRRP to scan and index dosimetry and exposure records.

## 6.3 Hanford Instrument Evaluation Committee

The HIEC was established to provide a Hanford intercontractor information exchange mechanism to ensure that the highest-quality portable and semi-portable radiological protection instrumentation program is maintained at Hanford. The responsibilities of the committee include the following:

- Discuss and propose solutions to ongoing or potential radiological instrumentation problems and needs onsite.

- Identify new radiological instrumentation available from manufacturers that may be useful to Hanford Site operations.

- Oversee the procurement of the instruments and review the evaluations of the performance by contractor organizations.

- Establish or review minimum acceptable operational criteria for portable and semi-portable radiological instrumentation used for safety on the Hanford Site.

- Promote information exchange between contractors on radiological protection instrumentation usage and problems/resolutions.

Representatives from all of the Hanford contractors and a representative of RL are on this committee.

During 1999, the HIEC continued to perform evaluations on instruments identified as needing further evaluations before being approved and placed on the "approved instrument list." The "approved instrument list" was developed to meet HSCRM-1 (RL 1994) requirements that only approved instruments may be used onsite. Although the HSRCM-1 is no longer a driver, the HIEC maintains the "approved instrument list" as a mechanism to demonstrate compliance with the 10 CFR 835 requirement that instruments "shall be appropriate for their environment."

IS&TP supports the HIEC by serving as the organization's secretary and providing administrative and technical support. In this role, IS&TP maintains the approved instrument list and the record files of all instrument evaluations completed for Hanford Site customers. IS&TP also provides technical support in the areas of instrument testing and design.

## 6.4 Supporting Technical Studies

IS&TP supported two international efforts during 1999.

### 6.4.1 International Support

An IS&TP staff member participated in the following programs involving detection of weapons of mass destruction: U.S. Customs Project Amber, Interdict/Raddicad, and Project Emerald Green. The Government's Weapons of Mass Destruction Program includes chemical, biological, nuclear, and missile technology. Project Amber involves a course that instructs the host country Customs and Border Police Officials on methods to use to detect weapons of mass destruction. The course was held in Tashkent, Uzbekistan. The Interdict/Raddicad course is an in-depth course on detection of weapons of mass destruction, and the courses are held in Richland, Washington. Emerald Green involves site evaluation

and placement of radiation detectors at international border crossings in the former Soviet Union. Countries visited under the Emerald Green Program include Latvia, Lithuania, Moldova, and Romania.

### 6.4.2 Chornobyl Shelter and Decommissioning Program

Support was provided in the development of a whole body counter that also doubled as a lung-counting system. This was possible due to the introduction of a new style of HPGe detector, also known as broad energy germanium (BEGe) detector. The BEGe detector allows the user to identify and quantify low-level transuranic radioactive materials in the body. The modification of an existing system saved approximately $400,000 and allowed DOE to spend this money on other valuable equipment supporting the Chornobyl Shelter and Decommissioning Program.

IS&TP staff also provided training at the Chornobyl site on the use, maintenance, and calibration of radiation monitoring equipment provided to Chornobyl by DOE.

## 6.5 Program-Related Professional Activities

Staff presentations and external professional activities during 1999 are listed in this section.

### 6.5.1 Presentations

Johnson, M. L., DMC 2000S Performance Testing, presented at the MGP Instruments, Inc., User's Group Meeting, Atlanta, Georgia, June 1999.

### 6.5.2 External Professional Activities

Johnson, M. L., Co-Chairperson of the Working Group for ANSI N323C, *Radiation Protection Instrumentation Test and Calibration – Air Monitoring Instruments.*

Johnson, M. L., Member of the Working Group for ANSI N323A, *Radiation Protection Instrumentation and Calibration – General Requirements and Portable Instruments.*

Johnson, M. L., Member of the Working Group for ANSI N323D, *Radiation Protection Instrumentation and Calibration – Fixed Instruments.*

Johnson, M. L., Member of the International Electrotechnical Commission's Technical Advisory Group for IEC 45B, *Radiation Protection Instruments.*

# 7.0 Radiation Standards and Calibrations Program

The primary function of the Radiation Standards and Calibrations Program (RS&CP) is to maintain the necessary radiological reference fields to facilitate appropriate characterizations and calibrations within the Hanford IS&TP and HEDP. In support of this task, special instrument and dosimeter response-characterizing equipment and supplemental radiological reference fields are maintained, as necessary. This activity provides the means to characterize instrument and dosimeter response to various radiation fields encountered at Hanford and to ensure that calibration capabilities are available in accordance with recommended standards and guides. The RS&CP is coordinated by the Calibration Research and Accreditation (CR&A) subgroup of the DR&T technical group. This group also supports other Hanford entities as well as DOE-HQ, other departments of the U.S. Government, and the private sector within its NVLAP scope of accreditation as a Calibration Laboratory for Ionizing Radiation, which has been maintained since 1994. Standards and methodologies developed in support of non-Hanford applications serve to enhance the capabilities available to the Hanford Site. Typical project activities include the following:

- providing a pathway of traceability for the calibration sources to the NIST
- maintaining radioactive sources, X-ray-generating devices, and instruments that serve as radiological standards
- reviewing calibration standards, regulations, and handbooks to ensure that calibration and characterization protocols agree with technically accepted methods.

Project activities conducted during CY 1999 are discussed in the following sections.

## 7.1 Routine Operations

Routine activities conducted by project personnel included maintenance of radiological standards, including reference class instruments and reference fields traceable to national standards, and the development of new and/or specialized capabilities. These existing and new capabilities support a variety of applications at the Hanford Site, within the DOE and other U.S. Government communities, and throughout the international radiological protection industry, in both the private sector and government programs. The activities related to radiological standards and capabilities and applications are discussed in the following sections.

### 7.1.1 Standards and Capabilities

The radiological reference fields maintained include gamma, beta, and neutron isotopic sources and X-ray-generating devices. These standards and capabilities are configured to deliver well-characterized and easily reproduced quantities of radiation dose or exposure to environmental or personnel dosimeters, radiological survey instruments, etc., for providing NIST-traceable calibration and/or response

characterization. In addition, a battery of reference-class instrumentation is maintained for the purpose of calibration, characterization, constancy verification, and traceability transfer.

### Gamma Ray Reference Fields

Available photon sources include various activities of $^{137}Cs$ and $^{60}Co$ configured in either collimated-beam, well, or open-field geometries, and an $^{241}Am$ source configured for irradiation in a $2\pi$ geometry, as listed in Table 7.1. These sources are located in the 318 Building. The "open" sources listed in Table 7.1 are placed in the center of a circular, aluminum table via a pneumatic air-transfer system. Exposure rates at two discrete distances from the source are typically characterized. "Beam" sources, with the exception of source 318-131, provide a continuum of exposure rates via use of an artifact positioning stand located

**Table 7.1.** Available Gamma-Ray Sources (1999)

| Source | Geometry | Nominal Rate/Range[a] (R[rem]/hr) | Location in 318 Bldg. (Room) | Reference No. | Primary Photon Energy (MeV) |
|---|---|---|---|---|---|
| $^{60}Co$ | Open ($4\pi$) | 0.6 / 2 | 106 | 318-164 | 1.17/1.33 |
| | Beam[b] | 0.18 – 88[c]<br>2 – 1000[d] | 8 | 318-037 | |
| | Beam[e] | 2 – 750[c]<br>26 – 8500[d] | 8 | 318-036 | |
| | Beam | 11.8 – 3700[c]<br>135 – 42500[d] | 8 | 318-353 | |
| $^{137}Cs$ | Well | $10^{-4}$ – 0.007[c]<br>0.001 – 0.130[d] | 121 | 318-031 | 0.662 |
| | Well | 0.025 – 2.700 | 121 | 318-030 | |
| | Well | 0.004 – 1.3[c]<br>0.065 – 22.0[d] | 121 | 318-288 | |
| | Beam | .001 – 0.25[c]<br>0.070 – 24.0[d] | 8 | 318-040 | |
| | Open ($4\pi$) | 0.34 / 1.3 | 106 | 318-001 | |
| | Beam | 0.008 – 2.5[c]<br>0.7 – 240[d] | 8 | 318-044 | |
| | Open ($4\pi$) | 1.8 / 6.8 | 106 | 318-029 | |
| | Beam | 2.3 / 21 | 6 | 318-131 | |
| $^{241}Am$ | Open ($2\pi$) | 0.125 | 6 | 318-184 | 0.060 |

(a) Values separated by "/" indicate discrete calibration points. Values separated by "–" indicate inclusive range of calibrated rates.
(b) Source removed from irradiator system September 1999.
(c) Attenuated (Pb).
(d) Unattenuated.
(e) Source installed into irradiator system September 1999.

on a sliding-rail system. Source 318-131 also includes a moveable stand, but it is typically characterized and used only at the 1- and 3-m distances. Artifact placement for the most commonly used positions within these beam irradiation facilities is enhanced by laser alignment capabilities. Well sources also provide a continuum of exposure rates and facilitate instrument adjustments during irradiation with minimal exposure to personnel. The source-to-artifact distance is controlled by moving the sources, on a trolley system, up and down within the well via computer interface.

In addition to the sources listed above, a Nordion Model GB650 "high-intensity" gamma irradiator is available within the 331 Building; it produces high-energy gamma fields from $^{60}$Co. This facility uses 12 sources that can be placed in a variety of geometries within tubes set in a circular pattern (see Figure 7.1). The exposure rate is adjusted by selecting a particular source or combination of sources and the specific orientation of the irradiation tube(s) in proximity to the item being irradiated. The range of available exposure rates extends from 7 to $10^6$ R/h and has been applied to ultra high-range instrument calibration/ characterization, as well as evaluations of radiation fatigue for materials and components. The calibration of this facility is maintained traceable to the NIST through the use of reference standards and methods identical to those used for the 318 Building sources, as described elsewhere in this report. In addition, radiochromic QC dosimeters are provided, where necessary, for establishing a dose gradient within a sample volume or for confirming delivered dose within an irradiated item.

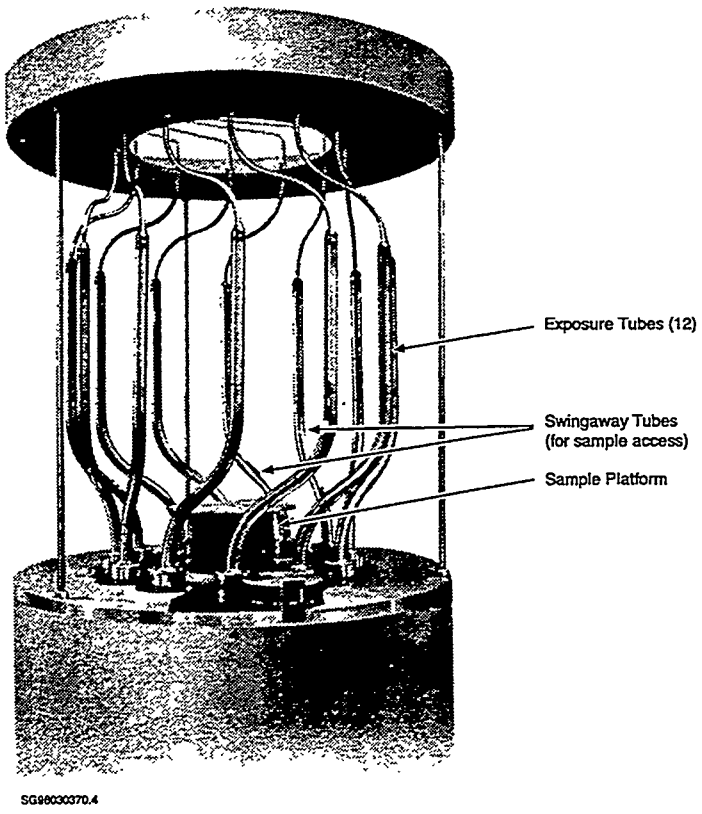



**Figure 7.1.** GB650 $^{60}$Co Irradiator

### X-Ray Photon Sources

A Pantak Model HS320/Series II and two identical Philips Model-324 tungsten-target X-ray machines are currently used by the RS&CP. One Philips machine and the Pantak system are used to produce bremsstrahlung photon spectra (e.g., NIST techniques M30, S60, M150, H150, and ISO techniques NS150, HK100, etc.), while the second is configured for K-fluorescence technique (narrow) secondary photon spectra (e.g., ISO 4037 techniques F-Mo [17.5 keV], F-Cs [31.0 keV], F-W [59.0 keV], etc., [ISO 1996a; 1996b]) within a shielded enclosure. These reference fields are used for characterization of dosimeter or instrument photon energy dependence in the general region of 10 to 250 keV. The NIST techniques are titled based on the characteristics of the filters used to modify the primary X-ray beam, where "M," "H," and "S" indicate moderate, heavy, and special filters, respectively. In general, M and S techniques are characterized by broader spectra and consequently lower homogeneity coefficients. The average energy listed for such techniques is only a rough indicator of the beam energy. H technique spectra are typically narrower and their energy can be described more readily as an effective photon energy (i.e., compared with a gamma source with a photon energy of the same half-value layer). As such, they are well suited, and recommended by NIST, for evaluations of dosimeter or instrument photon energy dependence. The International Standards Organization (ISO) techniques titled "NS" are characterized by narrow spectra, while "HK" techniques are generally characterized by broader spectra. K-fluorescence techniques have highly discrete peak energies and are also well suited for energy characterization studies, although the maximum energy currently available is 59 keV.

Figure 7.2 shows an example of several X-ray techniques that have a similar quoted average or effective energy. Tables 7.2a – 7.2c provide a complete list of currently available techniques, their

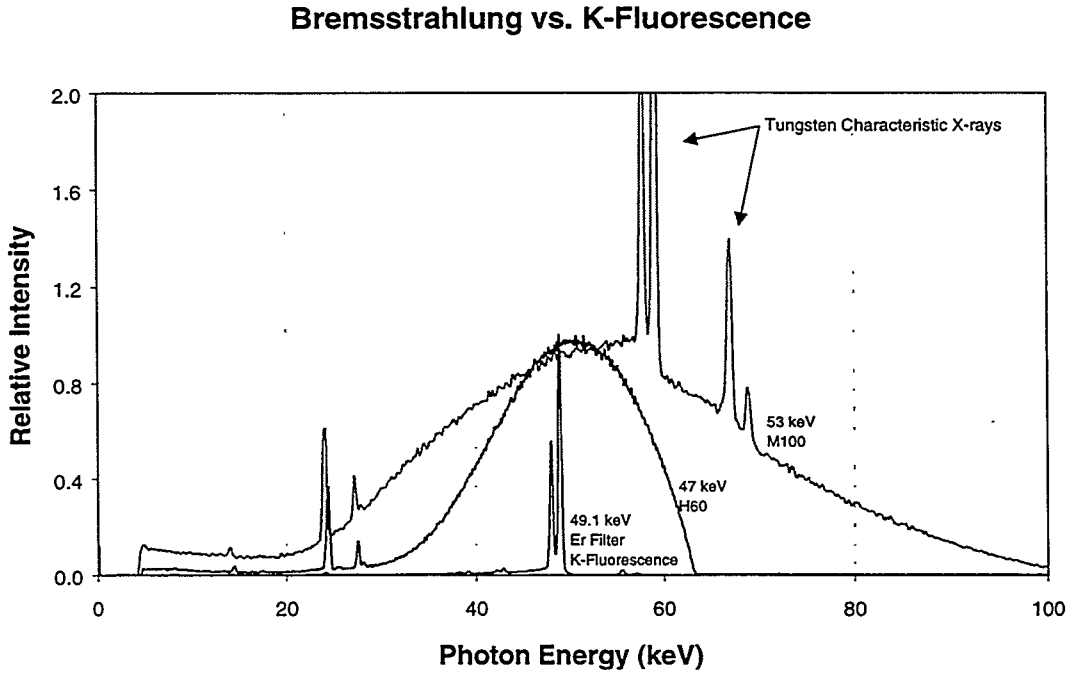



**Figure 7.2.** Example Spectrum of X-Ray Configurations (peak or average energy normalized to 1.0)

**Table 7.2a.** Available NIST-Specified Bremsstrahlung X-Ray Reference Fields (1999)

| Technique | Energy (keV)[a] | | Half-Value Layer (mm Al) | | Homogeneity Coefficient (Al) | | Exposure Rate (R/h) | |
|---|---|---|---|---|---|---|---|---|
| | Average | Effective | Philips | Pantak | Philips | Pantak | Minimum | Maximum |
| M20 | 14 | | 0.150 | 0.149 | 0.79 | 0.76 | 2.9 | 290 |
| M30 | 20 | | 0.352 | 0.368 | 0.63 | 0.68 | 3.2 | 330 |
| M50 | 29 | | 1.005 | 1.016 | 0.64 | 0.64 | 3.4 | 350 |
| M60 | 35 | | 1.640 | 1.738 | 0.72 | 0.70 | 3.2 | 310 |
| M100 | 53 | | 4.880 | 5.089 | 0.71 | 0.72 | 1.5 | 300 |
| M150 | 73 | | 9.870 | 10.30 | 0.85 | 0.86 | 3.8 | 390 |
| M200 | 100 | | 14.62 | 15.10 | 0.94 | 0.93 | 4.3 | 430 |
| S60 | 38 | | 2.650 | 2.850 | 0.71 | 0.77 | 0.6 | 120 |
| S75 | 40 | | 1.817 | 1.928 | 0.61 | 0.62 | 4.6 | 470 |
| H40 | 33 | | 2.976 | 3.003 | 0.92 | 0.90 | 0.02 | 4.2 |
| H50 | | 38 | 4.070 | 4.398 | 0.90 | 0.91 | 0.05 | 9.4 |
| H100 | | 80 | 13.49 | 13.98 | 1.01 | 0.98 | 0.02 | 3.1 |
| H150 | | 120 | 17.19 | 17.49 | 1.01 | 0.97 | 0.12 | 16 |
| H200 | | 166 | 19.46 | 20.31 | 0.98 | 0.98 | 0.09 | 9.2 |
| H250 | | 211 | 21.67 | 22.46 | 0.99 | 0.96 | 0.09 | 8.5 |
| H300 | | 251 | 23.31 | 23.41 | 0.97 | 1.00 | 0.09 | 9.4 |

(a) Nominal.

**Table 7.2b.** Available ISO-Specified Bremsstrahlung X-Ray Reference Fields (1999) – Philips System

| Technique | Energy (keV)[a] | | Half-Value Layer (mm) Al | Homogeneity Coefficient Al | Exposure Rate (R/h) | |
|---|---|---|---|---|---|---|
| | Average | Resolution[b] | | | Minimum | Maximum |
| Narrow Series | | | | | | |
| NS 150 | 118 | 37 | 16.97 | 1.00 | 0.14 | 21.0 |
| NS 250 | 208 | 28 | 21.68 | 0.98 | 0.06 | 6.0 |
| High Air Kerma Rate Series | | | | | | |
| HK 60 | 37.3 | [c] | 2.30 | 0.73 | 1.5 | 300 |
| HK 100 | 57.4 | | 6.26 | 0.81 | 2 | 390 |
| HK 250 | 122 | | 16.74 | 0.96 | 6.5 | 650 |

(a) Nominal (per ISO 4037).
(b) FWHM ($\Delta E/E*100$, where $\Delta E$ represents the spectrum width corresponding to half the maximum ordinate of the spectrum).
(c) Not specified.

**Table 7.2c.** Available K-Fluorescence Reference X-Ray Fields (1999)

| Technique[a] | Theoretical Peak Energy (keV)[a] | Production Method | | | | Demonstrated Traceability[c] (Year Tested) | Exposure Rate (R/hr)[b,c] | |
|---|---|---|---|---|---|---|---|---|
| | | Pre-Filter | Radiator/ Attenuator | Filter | kVcp | | Minimum | Maximum |
| F-Zn | 8.6 | Not Used | Zinc | ----- | 50 | No | 0.13 | 19.8 |
| F-Zr | 15.8 | Not Used | Zirconium | $SrCO_3$ | 80 | Yes (1986) | 0.02 | 3.2 |
| F-Mo | 17.5 | Not Used | Molybdenum | Zr | 80 | No | 0.02 | 3.4 |
| F-Sn | 25.3 | Not Used | Tin | Ag | 100 | No | 0.02 | 3.5 |
| F-Cs | 31.0 | Not Used | Cesium | $TeO_2$ | 100 | Yes (1986) | 0.02 | 3.2 |
| F-Nd | 37.4 | Not Used | Neodymium | Ce | 110 | No | 0.009 | 1.4 |
| F-Sm | 40.1 | Not Used | Samarium | $CeO_2$ | 120 | No | 0.01 | 1.4 |
| F-Er | 49.1 | Not Used | Erbium | $Gd_2O_3$ | 120 | No | 0.005 | 0.8 |
| F-$W_c$ | 59.3 | Not Used | Tungsten | $Yb_2O_3$ | 170 | Yes (1986) | 0.005 | 0.8 |
| F-$W_m$ | 59.3 | Not Used | Tungsten | Yb | 170 | No | 0.006 | 0.9 |

(a) As identified by ISO/DIS 4037-3:1996. Subscripts on F-W Techniques differentiate between filters made of chemical compound (c) and pure metal (m).
(b) Nominal.
(c) Minimum/maximum estimated at 0.1/15.0 mA.
(d) Demonstrated traceability is established through measurement intercomparison with the NRPB.

characteristics or production methods, and the nominal exposure rates available. All of these systems are equipped with laser alignment capabilities to aid in detector/dosimeter positioning.

### Neutron Sources

Two configurations of $^{252}Cf$ neutron sources are available. One configuration allows for the use of available sources within a pneumatic transfer system in the 318 Building Low-Scatter Room (LSR). During use, these sources are placed near the geometric center of a room 10 m wide, 14 m long, and 8.8 m high. Such placement minimizes scattered neutrons from the walls, floor, and ceiling at the point of the detector and facilitates the quantification of scatter influence upon the detection device. Sources may be used bare or moderated by a sphere of deuterated water ($D_2O$) 15 cm in radius, enclosed within a thin stainless steel shell, and covered by 0.051 cm of cadmium. These provide neutron fields useful for instrument calibrations as well as for dosimeter characterization in accordance with the specifications of DOE/EH-0027, the *Department of Energy Standard for the Performance Testing of Personnel Dosimetry Systems* (DOE 1986); HPS N13.11, *Personnel Dosimetry Performance – Criteria for Testing* (ANSI/HPS 1993); and ISO 8529, *Neutron Reference Radiations for Calibrating Neutron-Measuring Devices Used for Radiation Protection Purposes and for Determining Their Response as a Function of Neutron Energy* (ISO 1989). In addition, a $D_2O$-moderator sphere, similar to the one described above, is available without the shell of cadmium. This sphere, while originally intended as a backup, has been used, upon request, to provide neutron test fields with a larger component of thermal neutrons.

The second configuration involves a $^{252}Cf$ source placed in a well to facilitate easy access for instrument calibration. This source provides a fission spectrum that is significantly altered by the scattering from the concrete sides of the well; however, its calibration is established such that instrument calibrations will be referenceable to bare $^{252}Cf$ under free-field conditions, for selected instruments.

### Beta Particle Sources

Beta particle sources ($^{147}Pm$, $^{204}Tl$, and $^{90}Sr/^{90}Y$) are maintained for dosimetry and instrument characterization. Available sources are listed in Table 7.3 and include those manufactured by Amersham-Buchler, which are calibrated directly by the Physikalisch-Technische Bundesanstalt (PTB), Germany's national physical standards organization, and those manufactured in the United States by Amersham and Isotope Products Laboratory. Measurements have been made of most "point" geometry sources to verify

**Table 7.3.** Available Beta Reference Fields (1999)

| Geometry | Isotope[(a)] (Source No.) | Window Material and Areal Density ($mg/cm^2$) | Protective Coating Material and Areal Density ($mg/cm^2$) | Residual Maximum Energy -$E_{res}$ (MeV) (M-Measured, T-Theoretical) | Absorbed Dose Rate[(b)] (rad/h) (Calibration Distance [cm]) |
|---|---|---|---|---|---|
| Point | $^{147}Pm$ (318-290) | n/a | Titanium (2.3) | 0.1504 (M) | 0.06 (20) |
| | $^{204}Tl$ (318-109) | Silver (20) | Gold (5) | $0.53 \le E_{res} \le 0.76$ (T) | 0.006 (30) |
| | $^{204}Tl$ (318-192) | Glass (6.6) | Kapton (~0.8) | 0.608 (M) | 0.8 (35) |
| | $^{85}Kr$ (318-009) | Not Available | Not Available | Not Available | 2.9 (50) |
| | $^{90}Sr/^{90}Y$ (318-013) | Silver (50) | Stainless Steel (~75) | $1.80 \le E_{res} \le 2.274$ (T) | 0.48 (30) |
| | $^{90}Sr/^{90}Y$ (318-102) | Titanium (100) | Aluminum (20) | Not Available | 0.44 (35) |
| | $^{90}Sr/^{90}Y$ (318-012) | Silver (50) | Stainless Steel (~75) | 2.046 (M) | 19 (30) |
| | $^{90}Sr/^{90}Y$ (318-103) | Titanium (100) | Not Available | 2.085 (M) | 13 (35) |
| Distributed | $^{14}C$ (318-032) | Not Available | PMMA[c] | Has not been measured for these sources. | 2.2 (0.2) |
| | $^{147}Pm$ (318-113) | Not Available | Kapton (1.5) | | 0.37 - 0.006 (0.2 -15) |
| | $^{204}Tl$ (318-128) | Not Available | Kapton (9.5) | | 0.70 - 0.03 (0.2 - 30) |
| | $^{90}Sr/^{90}Y$ (318-129) | Not Available | Kapton (23.5) | | 4.09 - 0.16 (0.2 - 30) |
| | $^{106}Ru/^{106}Rh$ (318-130) | Not Available | Kapton (30.7) | | <0.01 (0.2) |
| | Depleted Uranium (318-166) | Not Available | Aluminized Mylar (7) | | 0.204 (0.15) |

(a) Routine calibration maintained only for shaded techniques. All others are calibrated as needed.
(b) Nominal at 7 $mg/cm^2$ as of mid-year (1999).
(c) The source is polymerized with the Polymethylemethacrylate. Sheet thickness is approximately 1 mm with activity uniformly distributed throughout.

satisfactory compliance with HPS N13.11 (ANSI/HPS 1993); DOE/EH-0027 (DOE 1986); and ISO 6980, *Reference Beta Radiations for Calibrating Dosimeters and Dose Rate Meters and for Determining Their Response as a Function of Beta Radiation Energy* (ISO 1984), as applicable.

### 7.1.2 Traceability to National Standards

Maintaining radiological reference fields traceable to national standards is one of the primary goals of this project. The traceability pathway has evolved over the history of this effort and was initially discussed in the *Hanford Radiological Protection Support Services Annual Report for 1993* (Lyon et al. 1994). Because the method of traceability is often unclear and can vary periodically, the current pathway for PNNL radiological reference fields is provided here.

#### Philosophy

Traceability to national standards infers an assurance that calibration fields are established and used in a manner that is consistent with those standards. There are two accepted types of consistency measurements that are commonly used to infer traceability: 1) implied consistency, which is established through the use of a laboratory standard submitted to NIST for calibration within radiation fields applicable to the laboratory; and 2) demonstrated consistency, which can be established through an MQA interaction with NIST. This latter method is akin to a performance test administered by NIST and is instrumental in verifying measurement traceability, as opposed to simply obtaining or maintaining a traceable source or reference instrument. A disadvantage of traceability based only upon implied consistency is the lack of demonstration to indicate that measurements made of traceable sources or using reference instruments are consistent with those made of or using national standards. Traceability based upon demonstrated consistency provides the assurance that traceable instruments and/or sources are being used properly (whether to calibrate additional sources [or reference fields] or laboratory instrument standards) so that traceability is appropriately extended as desired.

NIST supports the use of both techniques in maintaining traceability, but favors the practice of performing MQA interactions on a routine basis coupled with providing infrequent instrument or source calibrations. The RS&CP mirrors the NIST philosophy where possible; however, there are some limitations of the NIST capability that require a variance in the normal process. The following sections describe the traceability pathway for each of the radiation types applicable within this project.

#### Photon Standards

Photon sources (i.e., gamma sources and X-ray techniques) are maintained traceable via both implied and demonstrated consistency verifications. On an as-needed basis, one or more selected laboratory standards (air-equivalent ionization chambers [AICs]) are submitted to NIST for calibration to specific radiation fields. Through CY 1999, six commonly used AICs had been submitted for calibration to $^{137}Cs$, $^{60}Co$, and many of the available NIST and ISO X-ray techniques, including all but one (M20) of the bremsstrahlung techniques listed in Table 7.2a. In calibrating these instruments directly to NIST "primary standard" reference fields, they are deemed "secondary standards" and are used in the process of calibrating other radiological reference fields and/or reference instruments for use as tertiary or working

standards. The most current representation of the traceability pathway is depicted in Figure 7.3. In some cases, secondary standard instruments have been used to calibrate or verify the constancy of working standard radiation fields such as the well calibrators. This practice is acceptable but avoided whenever practical, because it exposes the valuable secondary standards to increased use and the potential for damage.

To achieve demonstrated consistency, NIST has conducted MQA assessments of PNNL photon reference fields since 1984, each time selecting a subset of the available sources and/or X-ray techniques for intercomparison. In CY 1999, NIST performed another MQA evaluation as part of the continued NVLAP accreditation of PNNL. This intercomparison is reviewed further in section 7.3.

Currently, NIST does not maintain capabilities for K-fluorescence X-ray or $^{241}$Am reference fields. Although traceability for these fields has been established using two additional AICs and a pathway similar to that identified in Figure 7.3 for a limited number of fluorescence techniques, the primary reference fields are maintained by the National Radiation Protection Board (NRPB) of the United Kingdom (UK). Traceability for irradiations and calibrations made using these reference fields are implied. The accuracy of these reference fields is confirmed via long-term trending of the transmission chamber output and/or reference standard AIC measurements.

**Neutron Standards**

Neutron traceability for all irradiations and measurements performed using PNNL sources is currently only implied. The primary pathway to NIST is through direct calibration of PNNL $^{252}$Cf sources, in terms of neutron emission rate, within the NIST Manganous Sulfate Bath Facility. Free-field dose-equivalent rates are calculated for these sources in their bare and moderated configuration based on NIST recommendations provided in the National Bureau of Standards (NBS) Special Publication 633, *Procedures for Calibrating Neutron Personnel Dosimeters* (DOC/NBS 1982). A Nuclear Research Corporation (NRC) Model NP-2 portable neutron monitor (Snoopy) and an Eberline NRD neutron probe are maintained as tertiary standards, which are used to calibrate a well-geometry $^{252}$Cf source referenced to free-field conditions. The calibration well is currently established as a working standard specifically for use with these two detector configurations of survey instruments. Use of the well for calibrating any other neutron survey instrument would not necessarily preserve any implied traceability. The traceability pathway for neutrons is shown in Figure 7.4.

MQA interactions are especially desirable for neutron sources as a means to confirm that various parameters are properly determined and/or are accounted for in the use of these sources. Influences such as air scatter, room return (scattered neutrons from walls, ceiling, and floor), source anisotropy, and inherent photon contribution must be properly characterized, either by measurement, calculation, or both. Source aging is a concern due to the magnitude of isotopic contaminants (primarily $^{249}$Cf, $^{250}$Cf, and $^{251}$Cf), which remain following source manufacture and are not directly identifiable via a single NIST calibration. Also, when configured with the $D_2O$ moderating sphere, there are concerns about subtle differences between the NIST design and the PNNL assembly. The NIST design almost completely surrounds the source and is more closely related to the referenced dose equivalent conversion factor, while the PNNL assembly, with an inherent void, allows placement of the sphere around the end tube of

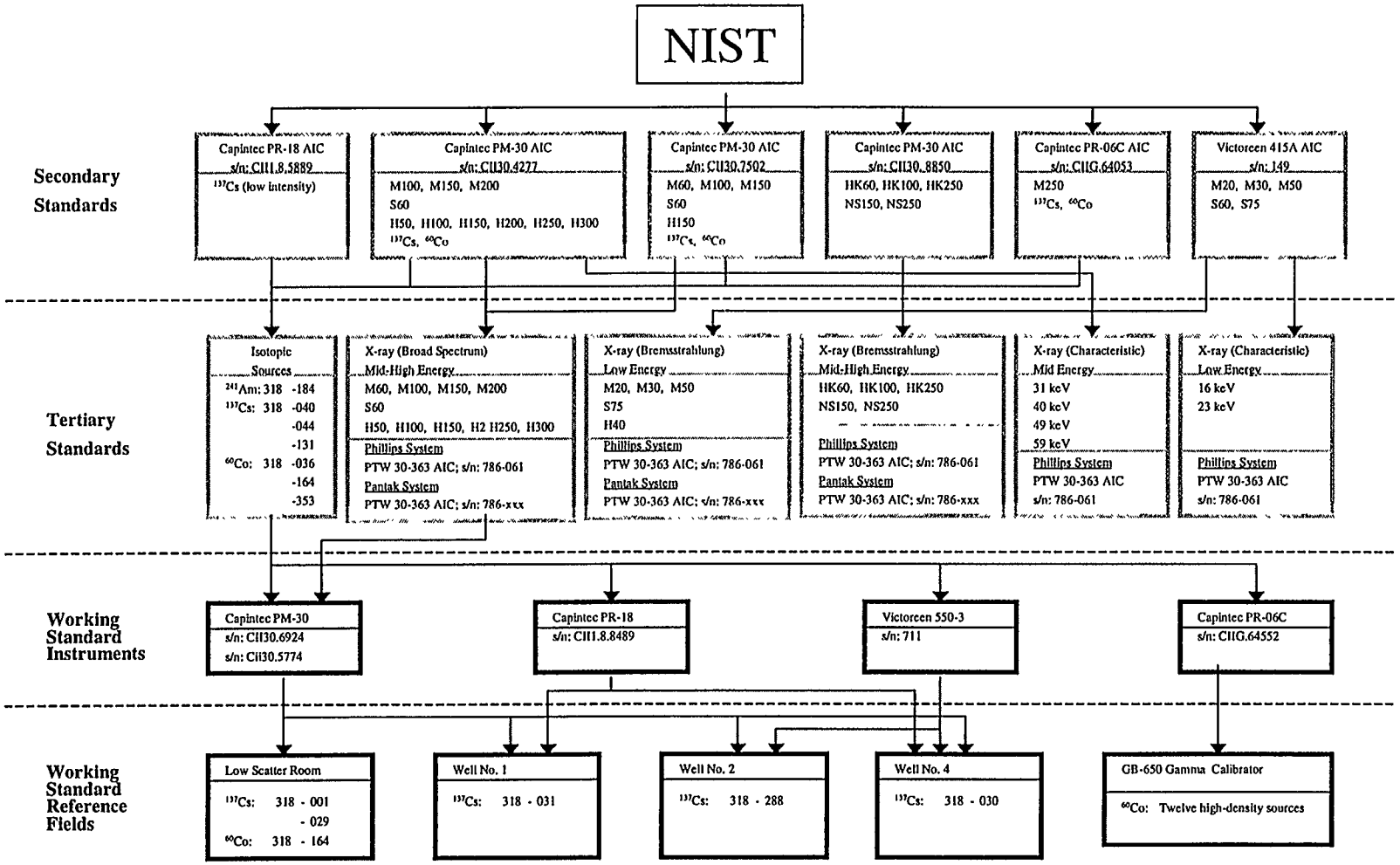



**Figure 7.3.** Typical Traceability Pathway for PNNL Photon Reference Fields

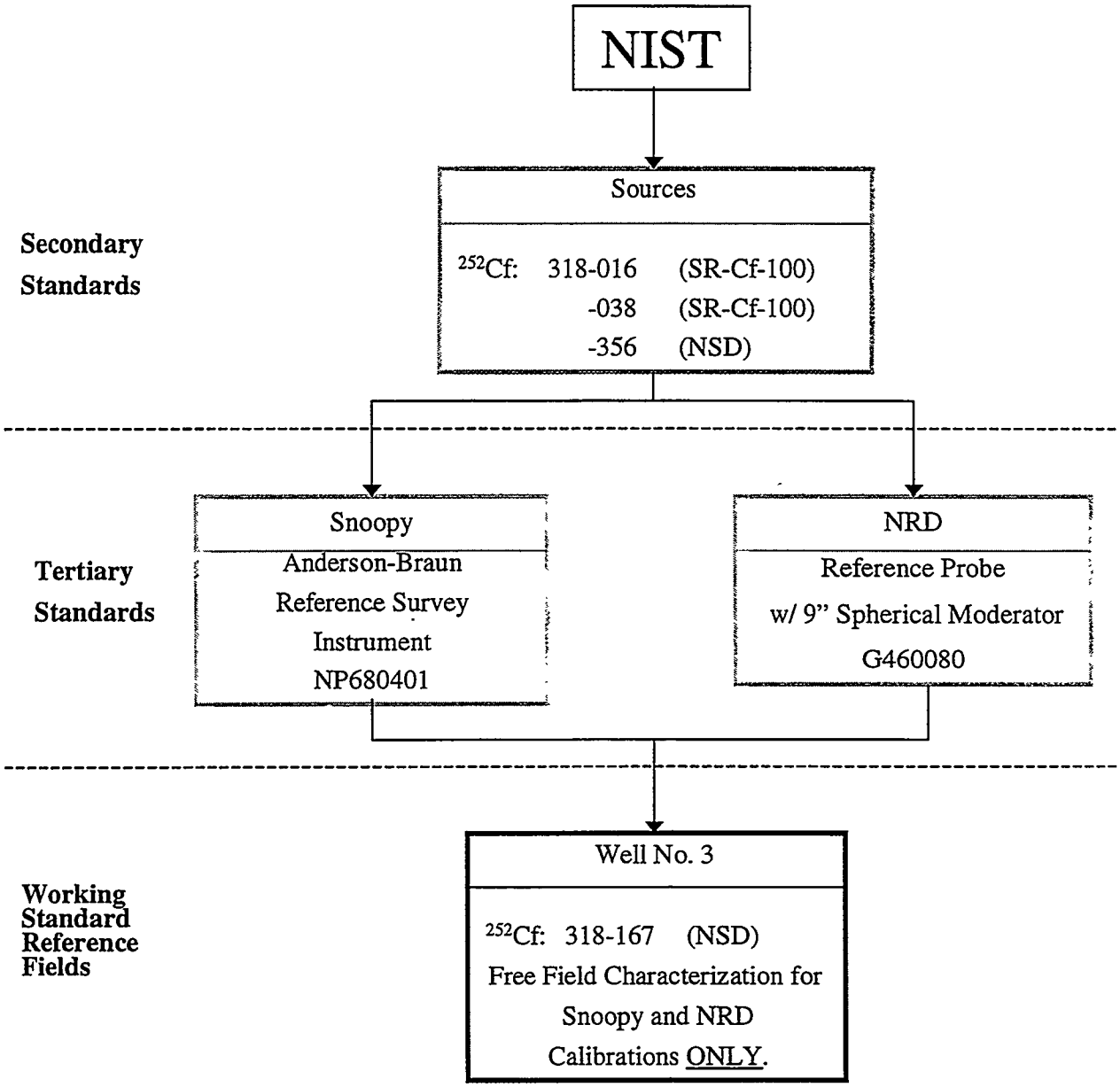



**Figure 7.4.** Typical Traceability Pathway for PNNL Neutron Reference Fields

the pneumatic transfer system. Monte Carlo modeling suggests that the effect of this void is substantial; however, reliable measurements that can substantiate this model have not been completed. Until measurements confirm or refine the magnitude of this effect, the calculated value will continue to be treated as a component of uncertainty rather than being used as a correction factor applied to the dose equivalent rate.

During the past several years, numerous joint efforts by NIST and PNNL have been conducted to establish a suitable method for neutron MQA intercomparisons in order to demonstrate traceability.

These intercomparisons have steadily improved as sources of uncertainty are reduced or better understood; however, there continues to be a bias in intercomparison results induced, in theory, by the acknowledged differences in the PNNL source configurations versus those of NIST. A clear explanation and resolution for the measured bias is not a trivial matter and will continue to be investigated.

**Beta Sources**

The NIST-traceability of beta reference fields is based upon both implied and demonstrated consistency. Of highest order in the PNNL reference field hierarchy are the PTB sources identified in Section 7.1.1, including $^{90}Sr/^{90}Y$ (sources 318-012 and 318-013) and $^{204}Tl$ (sources 318-014 and -109). These sources are considered secondary standards because they were initially calibrated and are certified through the PTB and continue to be periodically intercompared with NIST via MQA interactions. The NIST maintains a similar set of sources at its facility that have been characterized/verified both quantitatively and qualitatively.

PNNL maintains a Physikalisch-Technische Werkstäten (PTW) extrapolation ionization chamber for use in performing measurements of absorbed dose rate from the various sources. This chamber is generally considered to be an absolute standard; however, in conforming with the methods used for other radiation fields within the laboratory, it is designated as a tertiary standard. As such, it is the primary link between the PTB sources and all other beta sources.

In many cases, beta irradiations/calibrations are performed using alternate point sources of isotopic distribution similar to the PTB sources, but with subtle differences in construction material and/or activity, including sources 318-102, -103, and -192 (see Table 7.3). The $^{90}Sr/^{90}Y$ sources (318-102 and -103) were calibrated directly by NIST (source 318-102 [74 MBq] in 1986 at NIST and source 318-103 [1.85 GBq] at PNNL by a visiting NIST scientist). The latter source was calibrated with PNNL's PTW extrapolation ionization chamber. Based on the level of these calibrations, source 318-102 is also considered a secondary standard and source 318-103 is relegated to the tertiary level. The traceability pathway for beta reference fields and the extrapolation chamber is shown in Figure 7.5.

The periodic MQA intercomparison that NIST conducts with the PNNL calibration laboratory involves the use of a NIST or NIST-approved transfer standard. Intercomparisons were made from 1984 to 1985 and again from 1991 to 1992 between the NIST and PNNL Amersham-Buchler (PTB-style) sources. These sources were selected to preserve similar geometry, encapsulation, and activity, because it is suspected that the NIST transfer standard used for these measurements may be sensitive to differences in these parameters. In CY 1999, another intercomparison was performed through NIST using PNNL's PTW extrapolation ionization chamber. This comparison is detailed further in Section 7.3.

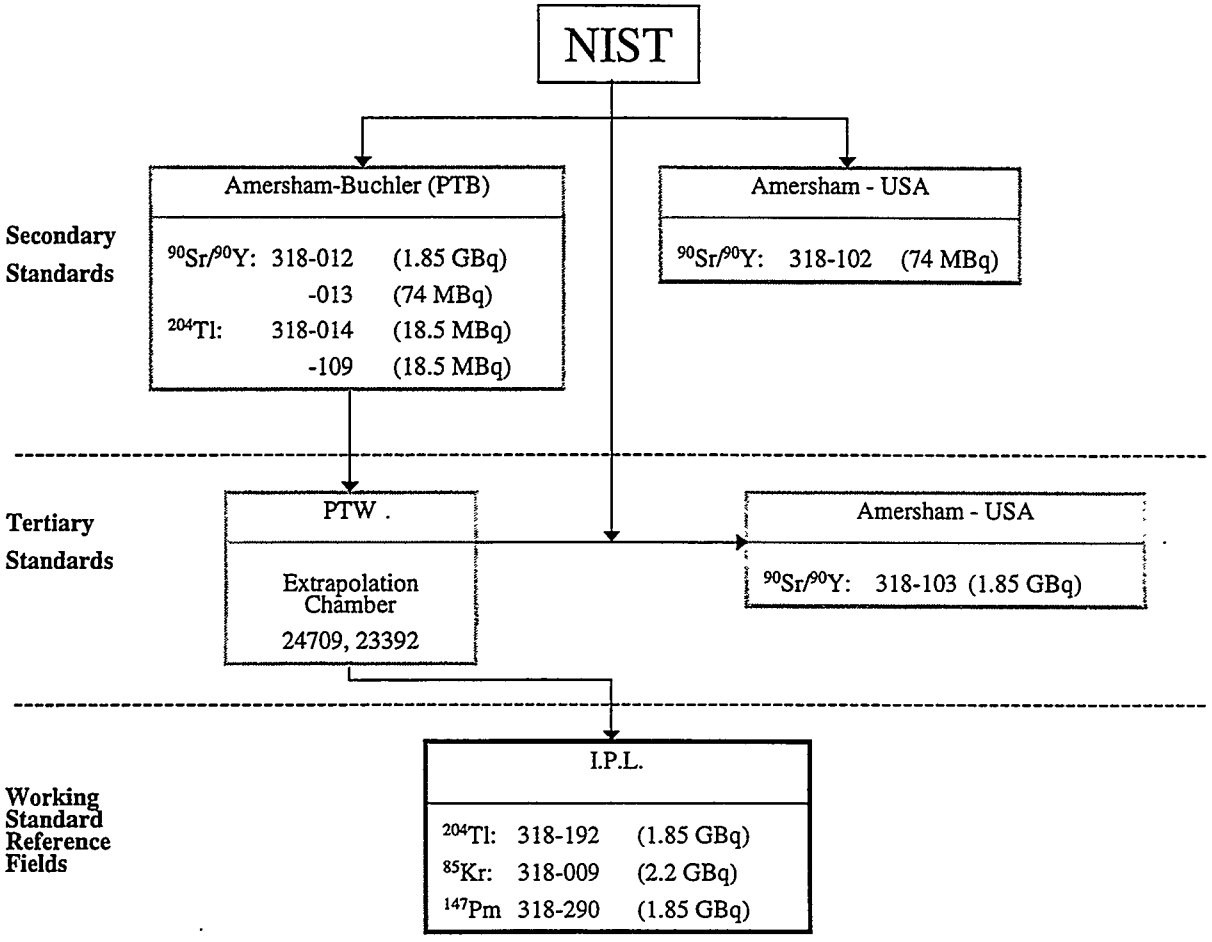



**Figure 7.5.** Typical Traceability Pathway for PNNL Beta Reference Fields

### 7.1.3 Quantitative and Qualitative Confirmation of Standards

Radiological reference fields originating from isotopic sources are dynamic in their output due to both the effects of radioactive decay and to the general content of the source material. If the isotopes are generally pure, then changes are typically limited to source decay. If impurities exist or if the decay of the primary isotope results in a radioactive decay product, then changes in the apparent strength and quality of the reference field are more complex. Reference fields generated by X-ray devices may also be dynamic. The eventual degradation of the components of the system may affect the quality and intensity of the primary beam. Furthermore, filters used to condition the useable beam may degrade over time, also potentially altering the radiation quality.

Initial calibrations and characterizations are designed to ensure that PNNL reference fields are adequate and comply with industry standards as identified above. Subsequent measurements are performed at suitable intervals to ensure that source dynamics are as expected. As a minimum, these measurements take into consideration the following criteria for isotopic sources:

- the general content (including possible impurities) of the source material
- the half-life
- the age and/or historical stability
- whether or not an automated positioning system is used to obtain a continuum of exposure/dose equivalent rates and, if so, the stability of such a system
- the stability and/or reproducibility of the source position or positioning system
- the constancy of ambient conditions (e.g., addition of major structures, equipment, or other sources of potential scatter).

For X-ray reference fields, criteria for consideration include the following:

- the constancy/stability of the X-ray equipment
- the quantity of use
- the properties of the materials used within the various beam filters
- the constancy of ambient conditions (e.g., addition of major structures, equipment, or other sources of potential scatter).

Given the above criteria, both the initial and subsequent constancy verification measurements of reference field quantity and quality are typically unique for each capability.

The verifications performed in CY 1999 are summarized in the following sections.

**Photon Sources**

Well-geometry photon sources were verified during the year using an approach that examines critical exposure rates most commonly used for calibration of detectors and which also assesses the calculational functions of the positioning system in a comprehensive manner. All three systems were found to be consistent with their respective prior calibrations and no complete recalibrations were found to be necessary. However, it was determined that the calibration of Well 1 (318-031) with the attenuator in place, which uses the large-volume PR-18 ion chamber as the reference standard, was inconsistent with practices applied on the other wells. The previous full calibration of this system used a response correction factor established under ideal conditions for the calibration chamber, which has a wall thickness of 212 mg/cm$^2$. For other wells, the calibration has been normalized to a buildup thickness of 725 mg/cm$^2$ (i.e., that of the PM-30 reference ion chambers), which is more consistent with the normal wall thickness of field detectors calibrated using the wells. Data from the last full calibration of Well 1

(December 1997) were compensated appropriately for this difference and reference fields in the nominal range of 0.1 to 7.0 mR/h were adjusted higher by 4% to 5%.

High-Exposure Facility (HEF) sources were verified using a similar approach as those used for well-geometry sources. During CY 1999, measurements were also performed to confirm the attenuation factor for a lead plug available for this system to attain reduced exposure rates. Measurements were conducted at selected distances over the entire available calibration range using both the smaller $^{137}Cs$ and $^{60}Co$ sources within the available HEF inventory. The measurements confirmed that the reduction factors for each isotope were consistent with those establish several years ago.

LSR gamma sources were verified using the new measurement protocol developed in 1998. Other photon isotopic sources were verified as in prior years and found to be consistent.

Beginning in CY 1999, calibration intervals for X-ray reference fields were extended from 6 months to 1 year based on the long history of stable calibration data at 3- and 6-month intervals. A single calibration of all available techniques was performed during CY 1999, and the result for each was added to the moving average transmission chamber calibration factor, which subsequently yields exposure rate. To assess the on-going stability of the system characteristics, half-value layer (HVL) and homogeneity coefficient (HC) measurements were also performed for each technique. During these measurements, it was found that many of the thinnest aluminum attenuators, procured for the purpose of gauging beam quality, appeared to be less uniform and consistent than expected. This conclusion was based on internal measurements of the material using an "indication only" micrometer and it was further observed that the surfaces of many of these attenuators were not ideally flat, but rather slightly wavy. It is possible that the contours of the surface prevented accurate assessments of the filter thickness. Regardless, an accurate assessment of attenuator thickness will be sought in order to reduce the potential error in beam quality assessment. In the interim, an older attenuator set will continue to be used.

Spectra measurements were also attempted to supplement the assessment of beam quality of the PNNL technique. Due to problems with the HPGe spectrometer, these measurements could not be accomplished. The detector has since been repaired and measurements will be targeted for CY 2000.

**Neutron Sources**

Well 3, containing a $^{252}Cf$ source (318-167), was verified using the NRC Rem-Rad (Snoopy) to confirm consistency. It was determined that a measurement with either of the two detectors for which the well is characterized (e.g. Snoopy or Eberline NRD) would be suitable to validate the consistency for both characterizations, because either detector would be nearly equally capable of detecting changes in the source conditions and/or potential positioning discrepancies. A decision was made to alternate confirmations between the two detector types.

### Beta Sources

Beta sources used most commonly for calibration or characterization purposes were confirmed via extrapolation chamber measurement. Due to the extensive efforts required to perform complete measurements of absorbed dose from beta sources, those used only occasionally are calibrated/confirmed only when needed.

### Reference Standard Instruments

Routinely used instrument standards were verified for consistency, as necessary, to ensure their subsequent accuracy for measuring reference fields. These included various AICs used to perform photon reference field measurements, the PTW extrapolation chamber used to assess beta reference fields, and the reference NRC-Snoopy survey instrument used to convey calibration to Well 3.

## 7.1.4 Applications

The capabilities maintained, in part, via the RS&CP and under the custodianship of the CR&A subgroup can be subdivided into general areas of support for passive and active radiation measurement and dosimetry. These areas are described below.

### Traceability Transfer

The radiological reference fields and reference class instruments available within the RS&CP suit the function of establishing or extending traceability to NIST. Most importantly under this project, this applies to the calibration/characterization of working class reference fields such as the well calibrators and panoramic gamma calibration fields available within the 318 Building and the calibration of dosimeter devices used in support of external dosimetry efforts (e.g., calibration/testing of dosimeters, dosimeter readers, and automated dosimeter irradiation devices).

Similar transfers of traceability are available to those outside of the immediate facility as well. These are facilitated by the submission of dosimetry devices or reference instruments for irradiation/calibration within the NIST-traceable reference fields. These irradiations serve to establish implied traceability for the user/owner reference field or dosimetry analysis capabilities.

### Traceability Confirmation

The radiological reference fields are used to provide a blind evaluation of performance, either in the area of instrument calibration or external dosimetry analysis. Such MQA tests help ensure that the participant uses NIST-traceable artifacts consistently and, if necessary, appropriately addresses external influences characteristic of related analytical equipment and/or the calibration environment.

**Unique Calibration or Investigative Needs**

Traceable radiological reference fields may be configured specifically to meet or approximate the needs of a select application for evaluation of field instrument response, reference class instruments, and dosimetry. Historically, reference fields have been structured to account for alternate radiation field geometries, special beta source attenuation configurations, and interpolation of detector response to atypical calibration energies, short-lived nuclides, and mixed fields.

**Characterization/Type Testing**

Reference fields are used to evaluate lower level of detection; neutron, beta, and photon energy dependence; the influence of contaminating radiation fields on detectors; response linearity; geometry dependence; and acceptance testing.

**CY 1999 Summary**

During CY 1999, efforts focused on the above described scopes of work. Within the scope of traceability transfer, calibration of the various radiological reference fields within the 318 Building were confirmed as described in Section 7.1.3.

In support of traceability confirmation, Hanford dosimeters were exposed on a monthly, quarterly, and annual basis to provide audit and QC evaluations of the PNNL external dosimetry analysis system. In addition, the FHI contracted for exposed dosimeters on a monthly basis as an independent evaluation of the PNNL external dosimetry analysis system. In all, approximately 1454 Hanford dosimeters were exposed to controlled doses of radiation for this process.

Characterization and type testing efforts during CY 1999 supported both external dosimetry and instrument calibration efforts. Collectively, approximately 443 dosimeters were exposed to investigate dosimeter configuration, angular and energy dependence, and the effects of specific irradiation geometry conditions on the response of Hanford whole body and/or extremity dosimeters. Electronic dosimetry devices were irradiated in support of photon, angular, and energy dependence testing and evaluations of sensitivity to beta and neutron radiation.

## 7.2 Improvements

Operational improvements were made to develop and enhance techniques, systems, and processes.

### 7.2.1 ISO Filtered X-Ray Techniques

Development of five ISO bremsstrahlung X-ray techniques, initiated in CY 1998, continued during CY 1999. Of primary significance was the attainment of a calibrated reference class ionization chamber from NIST. As with other photon capabilities, a Capintec Model PM-30 reference class ionization chamber was submitted to NIST for calibration using the recently developed and implemented ISO-specified X-ray techniques in the high air kerma rate techniques HK 60 (37.3 keV), HK 100 (57.4 keV),

and HK 250 (122 keV), and in the narrow spectrum techniques NS 150 (118 keV) and NS 250 (208 keV). Calibration of this chamber facilitated the NIST-traceable calibration of the same techniques at PNNL. In addition, HVL and HC measurements were completed to assess the quality of these fields. The HK techniques compared well with the conditions specified in the ISO-4037 standard; however, HVL and HC criteria for NS techniques are referenced only using copper attenuators in the ISO standard. a copper-based attenuator set is not currently available at PNNL. Although the HVL and HC characterizations typically suffice to ensure adequate quality for NIST-specified techniques, ISO 4037 (1996a) also provided specifications for the spectrum characteristics (i.e., peak energy and full-width-half-max). Consequently, spectrum measurements will play a more important roll in the further characterization of ISO-specified techniques. Upon repair of the HPGe detector, these measurements will be performed for the new ISO-specified techniques to complete the development.

### 7.2.2 Beta Source Upgrade

Available beta reference fields for evaluations at the "moderate" energies are typically performed using $^{204}$Tl. The highest activity source used within the RS&CP has been used since 1990 and, due to its relatively short half-life of 3.77 years, typical uses demand greater exposure times to attain desired exposures. A new $^{204}$Tl source was procured during CY 1999 to help reduce exposure times and the heavy demand these times place on the beta irradiation facility. It was designed to procure a source that was equal in window composition and original source strength as the currently used source; however, the manufacturer was no longer able to provide an encapsulation to precisely match the existing source. Furthermore, the age of the manufacturer's $^{204}$Tl stock limited the new source output to only about twice that of the current source—about four times less than desired. The manufacturer was able to provide an encapsulation that met the requirements of ISO 6980 (1984), as was determined via acceptance testing of the source upon arrival at PNNL; however, there are subtle differences in the energy spectrum that possibly would yield response differences in some types of detectors. Consequently, the source was not placed into routine use, pending the outcome of further characterizations necessary to inform clients of potential expected response differences. These characterizations were continued into CY 2000.

### 7.2.3 $^{252}$Cf Source Recalibration

The $^{252}$Cf source removed from Well 3 in 1998 was submitted to NIST for recalibration. This source was last calibrated at NIST in 1983; however during its use within the well geometry (and associated calibration technique) since 1990, its NIST-quoted strength was not relevant.

The source was submitted to NIST in July 1999 and was calibrated at NIST in October within the recently, upgraded Manganese Sulfate Bath facility. The calibrated source strength was approximately 13% higher than estimated using the prior NIST calibration results, decayed using a half-life of 2.646 years. This type of difference is anticipated due to the half-life uncertainty and was evidenced in the recalibration of source 318-016 in 1997.

### 7.2.4 $^{60}$Co Source Transition

To compensate for the decay of $^{60}$Co sources within the HEF, it was necessary to rotate a formerly used source, Ref. No. 318-036 extracted from the system in CY 1995, in place of 318-037, which had grown too weak for intended facility processes. Source 318-036 was placed through a complete calibration cycle (i.e., exposure rate measurements performed at 25 positions relative to the source). The exposure rates at each distance were compared with rates for its last calibration in CY 1994, decayed to the most recent calibration date. The rates were found to be consistent, which generally indicates that the source has little or no contaminating, photon-emitting isotopes.

### 7.2.5 Implementation of the Backup X-Ray System

In October, both Philips X-ray systems (bremsstrahlung and k-fluorescence configurations) failed. The failed components included both X-ray tubes, one positive generator, and one negative generator. Because the causes of the system failures were not immediately apparent, nor was there immediate funding available for a complete system replacement, it was decided to implement the backup Pantak system to compensate for the loss of bremsstrahlung capabilities.

Beam filter packs used for the Philips system were also used on the Pantak system. Because the Philips system has a long history of quality reference fields, there was confidence regarding the beam quality generated using these filters on the Pantak system. The most frequently used techniques were calibrated. The HVL and HC were examined for each technique and found to be in good agreement with NIST specifications without deviating from the respective recommended tube potential. Finally, the beam uniformity was mapped via ion-chamber measurements and photographic emulsions. The beam was found to be slightly larger than that of the Philips system. It also appeared to be slightly skewed downward; however, the non-uniformity due to this focus was not significant and no physical adjustment was attempted.

The Pantak system was determined to be of suitable quality for implementation. However, the litmus test for radiological reference fields is the response of dosimetry. Reference ionization chambers and HVL/HC measurement techniques are typically inefficient in detecting subtle differences in photon spectra. Consequently, an evaluation using HSD was planned and executed. Although a direct intercomparison of dosimeter response to the Philips X-ray system was not possible, data from earlier tests were used for the comparison. These data were normalized to compensate for differences in TLD reader calibration at each respective processing period.

The implemented evaluation involved the irradiation of sets of 5 or 10 dosimeters, each using S60, M30, M60, M100, M150, and H150 techniques. Of specific interest in identifying potential differences in beam quality were individual corrected element responses and the ratios of selected elements. The results were summarized and presented as ratios of the two systems for each of the indicator parameters (see Figure 7.6). It was determined that the Pantak system was adequately characterized and mirrored the qualities of the Philips system, at least to the extent of resolution using the HSD. The system was placed in service in mid October.

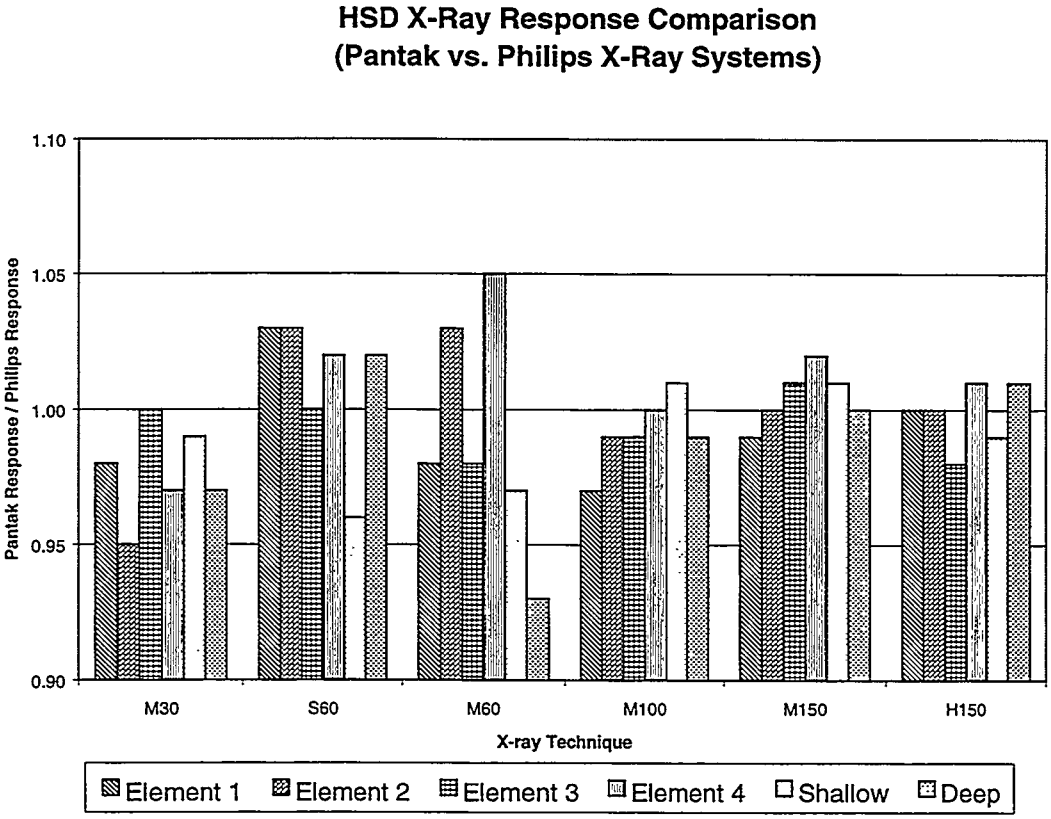



**Figure 7.6.** Evaluation of Pantak Beam Quality Using Hanford Standard Dosimeter

## 7.3 Program Assessments

During CY 1999, there were no exclusive onsite assessments of the RS&CP; however, the program was examined as part of audits of the IS&TP and of the HEDP, each by one of their respective clients. There were no findings associated with these assessments regarding the RS&CP.

Two performance tests were administered during the year. The first test involved the proficiency test as part of the NVLAP accreditation process. NIST submitted an Exradin Model A4, reference class ionization chamber for calibration using H40 and H300 X-ray techniques. Calibration of the intercomparison chamber was performed using the Philips system.

An evaluation was also performed of beta reference field capabilities. This was accomplished by submitting the PNNL extrapolation ionization chamber (EIC) to NIST along with calibration factors (rad/Coulomb) established for a fixed gap (i.e., the EIC was used as a fixed-volume chamber). Strontium/yttrium-90 and thallium-204 reference fields were evaluated. The outcome of both evaluations are provided in Table 7.4.

**Table 7.4.** Results of 1999 Proficiency Testing/MQA with NIST

| Reference Field | Percent Difference from NIST |
|---|---|
| Photons | |
| H40 (Philips X-ray) | 0.48 |
| H300 (Philips X-ray) | 1.92 |
| Betas | |
| $^{204}$Tl (50 mCi) | -4.7 |
| $^{90}$Sr/$^{90}$Y (50 mCi) | -1.3 |
| $^{90}$Sr/$^{90}$Y (2 mCi) | 2.2 |

## 7.4 Project-Related Professional Activities

None.

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