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Hanford Radiological Protection Support Services Annual Report for 1997

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D. E. Bihl
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R. K. Piper

June 1998

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**Hanford Radiological Protection
Support Services
Annual Report for 1997**

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Pacific Northwest National Laboratory
Richland, Washington 99352

Abstract

Various Hanford Site radiation protection services provided by the Pacific Northwest National Laboratory for the U.S. Department of Energy Richland Operations Office and Hanford contractors are described in this annual report for calendar year 1997. These activities include external dosimetry measurements and evaluations, internal dosimetry measurements and evaluations, in vivo measurements, radiological exposure record keeping, radiation source calibration, and instrument calibration and evaluation. For each of these activities, the routine program and any program changes or enhancements are described, as well as associated tasks, investigations, and studies. Program-related publications, presentations, and other staff professional activities are also described.

Summary

During calendar year (CY) 1997, 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). During the year, some of the services (1, 2, 4, and 5 above) were consolidated in one building and then reorganized under the Radiation Protection Services (RPS) technical group in anticipation of being outsourced.

The Hanford External Dosimetry Project (HEDP), which provides external radioactive monitoring capabilities for all Hanford workers and visitors, became accredited by the Department of Commerce National Voluntary Laboratory Accreditation Program (NVLAP) in October. It successfully passed 1) all requested categories for the Hanford standard and combination neutron whole body dosimeters and the Hanford extremity ring dosimeter, and 2) the onsite technical assessment of external dosimetry documentation and practices. HEDP also successfully passed each of the quarterly blind audit personnel and environmental dosimeter evaluations conducted, respectively, by Flour Daniel Hanford (FDH) and PNNL staff. HEDP staff reported 73,980 official personnel dose results for the year, which represented a slight increase from the 72,908 reported during 1996. Changes made to the routine project included 1) a change in the dosimeter labeling process to reduce costs, 2) implementation of a ring dosimeter correction factor of 2 for plutonium work, 3) changes in the eye dose algorithm, and 4) DOELAP accreditation of the Hanford Standard Dosimeter as an extremity dosimeter. Supporting studies and projects conducted during the year included 1) the initiation of a neutron dosimeter fading response study, 2) the use of the Hanford Combination Neutron Dosimeter as an area dosimeter, 3) use of effective dose equivalent methodology for assigning multiple dosimetry and calculating the dose, 4) upgrades to the extremity ring dosimeter, 5) study of the effectiveness of leaded gloves to reduce extremity dose while drawing samples from waste tanks, and 6) publication of a report describing the history of neutron dosimetry practices at Hanford.

The Hanford Internal Dosimetry Project (IDP) provides for excreta bioassay monitoring and the associated evaluation and documentation of internal radiological exposure and dose to Hanford workers and visitors. Its scope of activities was expanded in February when excreta and in vivo bioassay scheduling tasks were transferred from FDH to RPS, which subsequently modified a Project Hanford Management Contractor (PHMC) bioassay scheduling practice to save them \$100 K before some inappropriate bioassay waivers were noted and the task was suspended at the end of the year. Changes in excreta bioassay contract activities realized further reduced bioassay unit prices and improved data transfer between the bioassay lab and Hanford contractors. During CY 1997, the project provided oversight to 4569 excreta bioassay requests (up 26% from 1996) and 3439 successful excreta bioassay measurements (including some results requested in 1996). Of the incidents with potential for intake that were identified through workplace monitoring, intakes were confirmed for 11 workers; 6 others had doses assigned based on air sample data only. Intakes discovered through the routine bioassay program

were assigned for 9 workers. Some changes to the program made during the year included 1) expanding the questionnaire given to workers after potential occupational radioactivity is detected by whole body counts and 2) providing recommended bioassay programs for a wide range of ^{137}Cs -to-plutonium and ^{137}Cs -to- ^{90}Sr ratios to be used in place of default ratios.

The Hanford Whole Body Counting Project (WBCP) provides the capability to detect radioactive materials deposited in individuals using in vivo techniques. During CY 1997 the project performed 7737 in vivo measurements, a decrease of 15% from 1996. Installation and calibration of a seven-detector coaxial high-purity germanium system in the In Vivo Radioassay and Research Facility's Palmer Room completed a several-year effort to improve measurement sensitivity for ^{239}Pu . WBCP also successfully underwent three narrow-scope audits and the initial DOELAP onsite assessment to which staff responded with appropriate corrective actions. Development of the thoron-in-breath monitor concentrated on establishing and verifying the primary calibration, accumulating measurements of non-occupationally exposed individuals, and developing the biokinetic model for thorium. The DOE Phantom Library Program, operated by WBCP staff, loaned 26 phantoms during the year; this represents a 326% increase over 1995.

The Hanford Radiological Records Project (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 1997, PHMC field dosimetry functions were moved from FDH to RPS, so HRRP took over data administration responsibilities for the Access Control Entry System, while FDH retained ownership of the system. The Hanford Radiological Exposure (REX) database system was changed in response to evolving requirements and the operational environment and to enhance its operational efficiency. As a result of the changes, overtime during year-end processing was eliminated. The REX database was also determined to be Year 2000 compliant. Corrective actions were undertaken in response to independent assessments conducted by the PNNL Quality Programs and RL Performance Assessment Division to evaluate the performance of the records program.

The Instrumentation Services Project (ISP) provides complete and reliable radiation protection instrument services for site contractors to ensure personnel safety in the Hanford workplace. Specific tasks performed under this project during CY 1997 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 HIEC continued to evaluate instruments for approval and placement on the "approved instrument list" and made the 100-cm² portable alpha meter available to Hanford customers. ISP performed more than 16,000 calibrations of instruments in nine calibration classes. Staff also provided technical support to several projects related to the Chernobyl Shelter and Decommissioning Program and to the Waste Encapsulation and Storage Facility in characterizing and calibrating the on-line beta monitor.

The Radiation Standards and Calibration Project maintains the radiological standards necessary to support the characterization and calibration needs of the instrument calibration and external dosimetry projects. This includes maintaining any necessary special instrument and dosimeter response-characterizing equipment and supplemental radiation reference fields. This project provides the means to characterize response to various radiation fields encountered at Hanford and ensures that the calibration fields comply with recommended standards and guides (notably those of NIST). During CY 1997, NIST performed measurements at PNNL to establish suitable methods for various source measurement quality assurance intercomparisons to demonstrate traceability. The consistency of routinely used instrument standards was verified to ensure their accuracy for field measurements. Updating and refining the estimates of uncertainty for the various calibrated reference fields also remained an on-going effort during CY 1997. Supporting studies included an indirect intercomparison of PNNL's ^{241}Am source and an analysis of the differences between PNNL's and NIST ^{252}Cf neutron reference fields.

Acknowledgments

The authors would like to thank the staff members whose professional skills and technical expertise ensure the success of the Hanford External Dosimetry Project, Internal Dosimetry Project, Whole Body Counting Project, Radiological Records Project, Instrumentation Services Project, and Radiation Standards and Calibrations Project.

Abbreviations and Acronyms

ACES	Access Control Entry System
AIC	air-equivalent ionization chamber
ANSI	American National Standards Institute
AMAD	aerodynamic mean activity diameter
ASTM	American Society for Testing Materials
BHI	Bechtel Hanford Incorporated
BOMAB	bottle-manikin absorption
CAR	computer-assisted retrieval
CEDE	committed effective dose equivalent
CFR	Code of Federal Regulations
CP	cutie-pie (survey instrument)
CY	calendar year
DEC	Digital Equipment Corporation
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
DOELAP	DOE Laboratory Accreditation Program
DRET	Dosimetry Research and Technology (technical group)
EDE	effective dose equivalent
EDF	Emergency Decontamination Facility
ERC	Environmental Restoration Contractor
FDH	Fluor Daniel Hanford
FY	fiscal year
HC	homogeneity coefficient
HCND	Hanford combination neutron dosimeter
HEDP	Hanford External Dosimetry Project
HEHF	Hanford Environmental Health Foundation
HHS	Hanford Health Scheduling
HIEC	Hanford Instrument Evaluation Committee
HLAN	Hanford Local Area Network
HPDAC	Hanford Personnel Dosimetry Advisory Committee
HPGe	high-purity germanium
HPS	Health Physics Society
HPSSC	Health Physics Society Standards Committee
HQ	Headquarters

HRRP	Hanford Radiological Records Project
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
ID	identifier
IDP	(Hanford) Internal Dosimetry Project
IODR	Investigation of Dosimetry Result
IS	Information Services
ISO	International Standards Organization
ISP	Instrumentation Services Project
IVRRF	In Vivo Radioassay and Research Facility
LaserREX	CD-ROM imaging subsystem to REX
LEPD	low-energy photon detector
LifMCP	lithium fluoride:magnesium, copper, phosphorus
LLNL	Lawrence Livermore National Laboratory
LMSI	Lockheed Martin Services Incorporated
LSR	Low-Scatter Room
MDA	minimal detectable activity
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)
NTA	nuclear track emulsion, type A
NVLAP	National Voluntary Laboratory Accreditation Program
OLBM	on-line beta monitor
OSIA	Onsite Inspection Agency
PAD	Performance Assessment Division
PAM	portable alpha meter
PC	personal computer
PFP	Plutonium Finishing Plant
PHMC	Project Hanford Management Contractor
PNADs	personal nuclear accident dosimeters

PNNL	Pacific Northwest National Laboratory
PTB	Physikalisch-Technische Bundesanstalt
PTW	Physikalisch-Technische Werkstätten
PRF	Platinum Report Facility
QA	quality assurance
QC	quality control
RCT	Radiological Control Technician
RESL	Radiological and Environmental Systems Laboratory
REX	Radiological Exposure (system)
RIS	Radcon Instrumentation Services (project)
RL	U.S. Department of Energy Richland Field Office
RPS	Radiation Protection Services
RS&C	Radiation Standards and Calibrations (project)
RWP	Radiation Work Permit
SOW	statement of work
TE	track-etch (dosimetry system)
TEDA	track-etch detector analysis
TEPC	tissue-equivalent proportional counter
TIBM	thoron in-breath monitor
TL	thermoluminescent (dosimetry)
TLD	thermoluminescent dosimeter
TRU	transuranium radionuclide(s)
UPS	uninterruptible power supply
USTR	U.S. Transuranium Registry
WESF	Waste Encapsulation and Storage Facility
WBCP	Hanford Whole Body Counting Project

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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 projects in 1) external dosimetry, 2) internal dosimetry, 3) whole body counting, 4) radiological records, 5) instrument calibration and evaluation, and 6) calibration of radiation sources traceable to the National Institute of Science and Technology (NIST). The project work is performed by staff in the Radiation Protection Services (RPS) and Dosimetry Research and Technology (DR&T) technical groups, which are within the purview of the Environmental Technology Division. The RPS group includes external and internal dosimetry, whole body counting, radiological records, and instrument calibration and evaluation. The DR&T group is responsible for the calibration of radiation sources traceable to NIST.

New scope was added to the project in February 1997, when the handling of external dosimetry and excreta and in vivo bioassay scheduling tasks, previously performed by Fluor Daniel Hanford (FDH) Field Dosimetry staff was transferred to RPS. These services are performed only for RL and Project Hanford Management Contractor (PHMC) employees. Most of the personnel performing these tasks for the PHMC were also transferred to RPS.

In October, RPS was reorganized and its projects were formed into four groups: 1) Dosimetry Services, 2) Instrumentation Services, 3) Information Services, and 4) Administration. The Dosimetry Services group includes the Hanford External Dosimetry Project, the Internal Dosimetry Project, the Whole Body Counting Project, which includes the operational and technical staff at the In Vivo Radioassay and Research Facility (IVRRF); and the Dosimetry Operation Project, which includes all of the Dosimetry Services technician staff that perform the processing of dosimeters, handling of dosimeters for PHMC and RL, bioassay scheduling, and Radiological Exposure (REX) data processing (which was transferred from the Hanford Radiological Records Project). The Instrumentation Services group was divided up into three projects: Calibration Services, Instrument Repair, and Instrument Testing and Qualification. The creation of the Information Services group brought all of the computer and data administration personnel in RPS under one management and retained the Records Library and Exposure Reporting tasks previously performed by the Hanford Radiological Records Project (which has been discontinued). The Administration group is responsible for financial planning and secretarial support.

Although the Hanford Radiological Records Project has been discontinued, this report is written as if the project continued until the end of the calendar year.

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In anticipation of being outsourced, the RPS projects (all but the Whole Body Counting Project) were consolidated in the 318 Building in June.

Each of the six original projects is described in a separate section of the report. Project descriptions include

- the routine program, including any significant changes and improvements
- investigation, studies, and tasks performed in support of the routine program
- other project-related activities, such as publications, presentations, and professional memberships.

Although some of the projects 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.

During CY 1997, the Hanford contractors comprised PNNL; Bechtel Hanford, Inc. (BHI); the Hanford Environmental Health Foundation (HEHF); and the PHMC contractor, subcontractors, and enterprise companies. The PHMC became the prime maintenance and integration contractor in 1996 and includes FDH, six subcontractors, and seven enterprise companies. Three of the subcontractors and enterprise companies changed names during the year. The six present subcontractors are 1) Babcock and Wilcox Hanford Company; 2) Duke Engineering & Services Hanford, Inc.; 3) Dyncorp Hanford; 4) Lockheed Martin Hanford Company; 5) Numatec Hanford, Inc.; and 6) Waste Management Federal Services of Hanford, Inc. The seven enterprise companies presently are 1) Babcock and Wilcox Protec, Inc.; 2) Duke Engineering & Services Northwest, Inc.; 3) Fluor Daniel Northwest; 4) Fluor Daniel Northwest Services; 5) Lockheed Martin Services, Inc.; 6) Waste Management Federal Services Northwest; and 7) Cogema Engineering Corporation. In general, the term PHMC will be used when referring to the new contractor, subcontractors, and enterprise companies.

The PNNL and RL management structure and communication interfaces for each PNNL-operated project 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.

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Figure 1.1. Management Structure and Major Communication Interfaces for Hanford Radiological Support Services During 1997

2.0 Hanford External Dosimetry Project

The Hanford External Dosimetry Project (HEDP) is a multifaceted effort involving all Hanford contractors. Dose-of-record information from external radiation for Hanford personnel is provided by this project in compliance with DOE requirements as set forth in 10 CFR 835, *Occupation Radiation Protection* (DOE 1993). HEDP dosimeter results provide the means used by contractor personnel to project, control, and measure radiation doses received by personnel. Project staff also provide site-wide nuclear accident and environmental dosimetry capabilities in compliance with applicable DOE requirements.

The Hanford whole body personnel dosimetry system consists of a commercially procured thermoluminescent (TL) dosimetry system (manufactured by Bicon/Harshaw)^(a) and a PNNL-developed track-etch (TE) dosimetry system. Dosimeters include the Hanford standard dosimeter (HSD), the Hanford combination neutron dosimeter (HCND), an extremity dosimeter, and the Hanford environmental dosimeter. Personnel who are assigned a personnel dosimeter receive the HSD, which may also be used as an extremity wrist/ankle dosimeter. The HSD has a neutron response capability that will detect exposure to neutron radiation even though no official dose is determined. If the HSD detects neutrons, the result is held up until the contractor evaluates dose. If personnel are potentially exposed to neutron radiation, then an HCND is assigned to them. The Hanford extremity personnel dosimetry system consists of a commercially procured Bicon/Harshaw "chipstrate" extremity dosimeter insert enclosed in an ICN/MeasuRing^(b) ring casing.

2.1 Performance Evaluations

HEDP participated in four performance reviews during 1997 as discussed in the following sections.

2.1.1 NVLAP Accreditation

The DOE Laboratory Accreditation Program (DOELAP) and the Department of Commerce (DOC) National Voluntary Laboratory Accreditation Program (NVLAP), administered by NIST, are working together to develop onsite assessments using consistent criteria for primary dosimetry technical capabilities, and to ensure that these criteria are consistent with international guidance. During 1997, HEDP (using Battelle private funding) completed its first performance testing and an onsite technical assessment under NVLAP. Performance testing occurred from April through July 1997. Testing involved approximately 300 dose evaluations for a variety of single- and mixed-exposure conditions. HEDP successfully passed all requested categories for the Hanford standard and combination neutron whole body dosimeters and the Hanford extremity ring dosimeter. The NVLAP test was the first formal accreditation testing for the Hanford extremity ring dosimeter. Testing results for Hanford whole body

(a) Bicon, Saint-Gobain/Norton Industrial Ceramic Corporation, Solon, Ohio.

(b) ICN Biomedicals, Inc., Costa Mesa, California.

and extremity dosimeters are summarized in Tables 2.1 and 2.2, 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 American National Standards Institute/Health Physics Society standard HPS N13.11-1993, *An American National Standard, Personnel Dosimetry Performance - Criteria for Testing*, and HPS N13.32, *An American National Standard, Performance Testing of Extremity Dosimeters*, respectively (ANSI/HPS 1993; ANSI/HPS 1995a). Even though the same algorithm is used for both DOELAP and NVLAP performance testing (with significant differences in dose conversion factors), excellent performance was shown by the Hanford dosimeters. This is demonstrated in Tables 2.1 and 2.2, by comparing the calculated performance of the respective dosimeters against the NVLAP criterion in each irradiation category. In every category, the Hanford performance is well below the 0.3 or 0.5 NVLAP criterion. Figures 2.1 and 2.2 illustrate the HSD and Hanford ring dosimeter performance in the respective NVLAP exposure categories using Horlick diagrams.

The onsite technical program assessment was conducted from August 19 to 21, 1997, to examine HEDP documentation and practices relative to the requirements of the NIST Handbook 150-4 (NIST 1994a). The assessment noted one deficiency and four concerns.^(a) The deficiency was resolved with

Table 2.1. HSD and HCND Shallow- and Deep-Dose NVLAP Performance Test Data

NVLAP Category Description	NVLAP Criterion	Limit on B and on S	Performance ^(a)			
			HSD		HCND	
			Shallow	Deep	Shallow	Deep
I. Accident, Low-Energy Photons	0.3	N/A	N/A	0.154		
II. Accident, High-Energy Photons	0.3	N/A	N/A	0.077		
IIIA. Low-Energy Photons, General	0.5	0.35	0.322	0.119		
IIIB. Low-Energy Photons, High-Energy	0.5	0.35	0.084	0.126		
IV. High-Energy Photons, ¹³⁷ Cs	0.5	0.35	N/A	0.086		
VC. Beta Particles: General	0.5	N/A	0.113	N/A		
VI. Photon Mixtures	0.5	0.35	0.173	0.140		
VII. Photon Plus Beta Particles	0.5	0.35	0.245	0.101		
VIII. Photons Plus Neutrons (Total)	0.5	0.35	N/A	0.060	N/A	0.042
VIII. Photons Plus Neutrons (Neutron)	0.5	N/A	N/A	0.112	N/A	0.036
IX. Varied Angles of Incidence	0.5	N/A	0.107	0.069		
(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.						

(a) Deficiencies are issues that can preclude obtaining DOELAP accreditation, and concerns are issues that require a formal corrective action plan.

Table 2.2. Hanford Extremity Dosimeter Shallow-Dose NVLAP Performance Test Data

NVLAP Category Description		Performance ^(a)	
		NVLAP Criterion	Shallow
I.	Accident, Low-Energy Photons	0.3	0.166
II.	Accident, High-Energy Photons	0.3	0.065
IIIA.	Low-Energy Photons, Mixed X-rays	0.5	0.101
IVA.	High-Energy Photons, ¹³⁷ Cs	0.5	0.055
VC.	Beta Particles, General	0.5	0.186

(a) 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.

Figure 2.1. HSD NVLAP Performance Testing

the preparation of PNL-MA-859^(a), *Hanford External Dosimetry Quality Manual*, which addressed HEDP quality assurance (QA) practices as required by International Standards Organization Guide 25 (ISO 1990).

(a) Internal Manual, PNL-MA-859, Pacific Northwest National Laboratory, Richland, Washington.

Figure 2.2. Hanford Ring Dosimeter NVLAP Performance Testing

The four concerns noted during the NVLAP onsite assessment were as follows:

1. Consideration should be given to enhancing the re-training process to make it more meaningful to individuals receiving the training, perhaps by giving greater emphasis to "hands on" direct instructional type training rather than relying on an annual self-conducted records review.
2. A procedure should be developed to periodically verify the accuracy of the digital thermometers used to monitor the oven anneal.
3. NIST Handbook 150, Section 285.32(j) (NIST 1994b) requires that the period of retention for records be specified in the quality manual. Completion of this requirement will help to highlight the specific records related to the ionizing radiation dosimetry program and NVLAP accreditation criteria.
4. ISO Guide 25 (ISO 1990) establishes detailed requirements that must be followed if a laboratory subcontracts any part of the calibration or testing operation. This topic needs to be specifically addressed in the Quality Manual.

Resolution of concerns 3 and 4 was provided with the December 1997 issuance of PNL-MA-859,^(a) *Hanford External Dosimetry Project Quality Manual*. Resolution of concerns 1 and 2 will be

(a) Internal Manual, PNL-MA-859, Pacific Northwest National Laboratory, Richland, Washington.

accomplished through revised procedures to be included during 1998 in PNL-MA-841,^(a) *Hanford External Dosimetry Project Procedures Manual*. The success of HEDP staff in passing performance testing and the onsite assessment resulted in formal NVLAP accreditation of the HEDP during October 1997.

2.1.2 DOE Environmental Dosimetry Pilot Testing

HEDP provides environmental dosimetry support to all Hanford contractors. The Hanford four-element environmental dosimeter is commercially procured from Bicon/Harshaw and consists of two LiF (TLD-700) and two CaSO₄ thermoluminescent phosphors. The HEDP is also evaluating the super-sensitive aluminum oxide and lithium fluoride:magnesium, copper, phosphorus (LiF:MCP) thermoluminescent phosphors available from Bicon/Harshaw. These phosphors can be readily used in Hanford dosimeters and processed using existing readout equipment. DOE has currently funded pilot testing of draft HPS N13.29, *An American National Standard, Environmental Dosimeter Performance Testing Criteria* (ANSI/HPS 1995b), for potential application to DOE facilities. The HEDP is participating in the pilot test. Once the standard is finalized, DOE is expected to require compliance with the HPS N13.29 performance testing criteria. HPS N13.29 contains new requirements for measuring ambient and directional dose equivalent. These recommendations provide similarity between U.S. environmental dosimetry practices and the International Commission on Radiological Protection Publication 75 (ICRP 1997) operational quantities that are used internationally. Testing is conducted in three rounds. Only one of the rounds was conducted during 1997.

2.1.3 Blind Audit Personnel Dosimeters

During 1997, FDH routinely submitted audit dosimeters to be processed along with PHMC personnel dosimeters. HEDP successfully passed each monthly blind audit dosimeter evaluation conducted by FDH staff during 1997. HEDP also passed each of the quarterly evaluations conducted using DOELAP criteria. Documentation of HEDP results of these audits is included in the Hanford Radiation Protection Historical Files operated by RPS Hanford Radiological Records Program (HRRP) staff.

2.1.4 Blind Audit Environmental Dosimeters

PNNL Environmental Surveillance Program staff routinely submit audit environmental dosimeters to be processed along with their quarterly exchanged environmental dosimeters. The given exposure ranges are typically between 15 and 30 mrem of ¹³⁷Cs gamma radiation. A result is noted as abnormal if the reported exposure is outside of pre-established HEDP tolerance levels. Approximately 20% of the reported results are typically noted as abnormal because of the tight tolerance levels established. HEDP environmental dosimeter processing data are routinely included in the annual Hanford environmental surveillance reports (Dirkes and Hanf 1997).

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

2.2 Hanford Dose Results During 1997

During 1997, HEDP staff reported 73,980 official personnel dose results. This processing volume represented a slight increase from the total of 72,908 during 1996. The annual number of reported official dose results is illustrated in Figure 2.3 for 1993 to 1997 for each type of dosimeter, including the HCND, which has two cards. In this figure, the comparison is complicated because the current whole body personnel dosimetry system was implemented in January 1995 and the current extremity dosimetry system was implemented in July 1996. Previously, the Hanford personnel dosimetry system included several thousand single-chip basic dosimeters, typically assigned to employees who had little potential for occupational exposure. The current personnel dosimetry system has only multi-component dosimeters, which are typically issued only to individuals with a potential for exceeding the 10 CFR 835.402 monitoring thresholds. Ring dosimeter processing during 1997 continued the trend for higher processing volumes observed in recent years. The dramatic increase in 1997 is due significantly to the need to process all of the individually labeled chipstrate dosimeters. During 1997, the track-etch foil 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 Hanford Plutonium Finishing Plant (PFP). Plutonium at PFP is primarily being stored awaiting

Figure 2.3. Trend in Reported Hanford Personnel Dosimeter Results

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. Field measurements at PFP have shown consistent under-estimation of the actual neutron dose with the track-etch foil (Endres et al. 1996).

Actual dosimeter processing exceeded the 73,980 official personnel dose results reported for the following reasons:

- Processing a neutron dosimeter actually involves processing two separate TL dosimeters (TLDs).
- Environmental dosimeter processing is not included.
- Unused temporary personnel dosimeters (i.e., unassigned) are processed to provide an official dose result if it is subsequently determined that the dosimeters were actually worn.
- A minimum of four quality-control (QC; e.g., blank and dosed) dosimeters are processed along with a maximum of every 50 personnel dosimeters.
- All personnel and environmental dosimeters are reader- and oven-annealed prior to being issued to ensure that all residual signals have been removed.
- Replacement dosimeter inserts are acceptance tested. Each acceptance test includes five separate tests involving dosimeter processing.

Each year numerous internal audit dosimeters are processed to ensure the integrity of dosimeter processing. During 1997, a total of 790 internal audit dosimeters were processed. A breakdown of the internal audit dosimeters is shown in Table 2.3.

Table 2.3. Audit Dosimeters Processed During 1997

Dosimeter	Dose Category			
	Shallow	Deep	Fast Neutron	Blank
Standard	170	170	NA ^(a)	80
Combination Neutron	NA	NA	170	80
Rings	NA	120	NA	Controls
(a) NA = Not Applicable.				

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 are distributed to all Hanford contractor radiation protection organizations, as well as the Hanford Radiation Protection Historical Files. Copies of the audit dosimeter performance reports are also provided to the Historical Files.

2.3 Changes in Routine HEDP Practices During 1997

Modifications to HEDP practices are discussed during HPDAC meetings. Changes in project practices made during 1997 are described in the following sections.

2.3.1 Change in External Dosimetry Administration

Changes in HEDP administration were described during the HPDAC July 1997^(a) meeting. These changes were implemented in anticipation of PNNL RPS being outsourced and to provide a more cost-effective organization. Hanford external and internal dosimetry staff and functions were combined into a single dosimetry services organization under the leadership of Don Bihl. Jack Fix, previously the HEDP project manager, transferred to the PNNL Dosimetry Research and Technology organization, but he continues to provide technical support to HEDP as needed. These changes were communicated to HEDP accreditation representatives as required.

2.3.2 Change in HEDP Documentation

During the HPDAC October 1997^(b) meeting, changes in HEDP documentation were discussed. The objective of planned changes is to eliminate externally distributed manuals that are not specific to HEDP responsibilities and to eliminate manuals that contain old or duplicate information. The plan, which was accepted by HPDAC representatives, eliminates the following three existing internal manuals:

- PNL-MA-568, *Hanford External Dosimetry Project Manual*
- PNL-MA-583, *Locations of Criticality Detectors and Nuclear Accident Dosimeters at Hanford*
- PNL-MA-865, *Hanford Site Criticality Incident Response Plan.*

(a) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on July 16, 1997." (A copy is available in the Hanford Radiation Protection Historical Files.)

(b) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on October 15, 1997." (A copy is available in the Hanford Radiation Protection Historical Files.)

PNL-MA-583 will be eliminated after September 30, 1998. In the future, the HEDP will maintain only two manuals for use by other Hanford organizations. These are

- PNL-MA-842, *Hanford External Dosimetry Technical Basis Manual*
- PNL-MA-859, *Hanford External Dosimetry Project Quality Manual*.

The HEDP plans to continue to use the following existing internal project manuals:

- HEDP Quality Assurance Plan, LSC-022,^(a) used to identify quality assurance requirements
- PNL-MA-841, *Hanford External Dosimetry Project Procedures Manual*
- PNL-MA-843, *Track-Etch Detector Analysis (TEDA) Users Manual*
- PNNL-MA-844, *Hanford External Dosimetry Project Data Management Manual*.

2.3.3 Dosimeter Labeling

For many years, HEDP has used two permanently labeled dosimeter holders for each permanent staff assigned a HSD or HCND. During 1997, hardware and software changes were implemented that provide capabilities to relabel each dosimeter holder for each scheduled exchange. This change provides for a more cost-effective operation. In addition, cleaning and inspection of holders is improved because selected holders can be removed from service for the time period necessary for cleaning and repair.

2.3.4 Neutron Dose to Extremities

During the HPDAC May 1997^(b) meeting, it was decided to implement a ring correction factor of 2 for all plutonium work. This was done to compensate for any under-estimated neutron dose, which could occur from the neutron dose that is not measured by the Hanford ring dosimeter. The factor of 2 was applied to all 1997 (i.e., January to December) reported dose to affected workers.

(a) Internal Manual, LSC-022, *Quality Assurance Plan for Hanford External Dosimetry Project*, Pacific Northwest National Laboratory, Richland, Washington.

(b) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on May 21, 1997." (A copy is available in the Hanford Radiation Protection Historical Files.)

2.3.5 Eye Dose Algorithm Changes

HEDP staff implemented changes in the eye dose algorithm on April 1, 1997. The changes were described during the March 1997 HPDAC^(a) meeting. These changes correct problems observed in the HSD algorithm that resulted in over-estimating the shallow dose and under-estimating the eye dose under most conditions encountered at Hanford when beta radiation is predominant. These changes were particularly important to handle the extremely large beta-to-photon dose rate ratios (i.e., exceeding 100 to 1) observed for samples from some Hanford waste storage tanks. HEDP obtained the response data needed to improve the algorithm by irradiating the HSD with heavily filtered ⁹⁰Y beta sources. The shallow- and eye-dose rates for these sources were accurately determined using extrapolation chamber measurements. The responses of the HSD to these degraded beta spectra are considered to be representative of Hanford beta environments. The response data obtained were used to develop a continuous beta response function for eye dose that exactly fit the empirical data and an improved beta response function for shallow dose, which is less prone to over-estimating the actual shallow dose. A characteristic of the vendor-supplied algorithm prevented deep dose from being reported by the "beta only" branch of the algorithm. This was corrected so that the deep dose is always reported based on the response of the deep-dose dosimeter element regardless of the algorithm branch.

2.3.6 Dose Correction Documentation Protocol

During the HPDAC July 1997^(b) meeting, a protocol was adopted to ensure that contractor-signed investigation reports are received for HEDP reported notecode 53 results. Dose records reported by HEDP staff that have some modification to the processing record are noted either as a notecode 50 (indicating that HEDP is unable to estimate a dose) or a notecode 53 (indicating that the HEDP staff were able to estimate a dose by modifying one or more of the process data identified as abnormal). For records reported by HEDP as notecode 50, Hanford contractor organizations must estimate the dose to be recorded. For records reported by HEDP as notecode 53, Hanford contractor organizations representatives sign the form, indicating either 1) their concurrence with the reported dose, or 2) their preference for an alternate dose and supporting justification. HEDP reported notecode 53 records are automatically entered into the REX system. To ensure that Radiological Records receives contractor concurrence (or alternate) with HEDP reported notecode 53 records, a procedure was adopted for HEDP staff to send two copies of the associated documentation: one to the contractor and one to Radiological Records. Radiological Records staff put their copy into a holding file. When the signed copy from the contractor is received by Radiological Records, the copy in the holding file is shredded. The holding file is frequently checked for forms that have been outstanding for a considerable time and the appropriate contractors are notified that they have an overdue form.

(a) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on March 18, 1997." (A copy is available in the Hanford Radiation Protection Historical Files.)

(b) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on July 16, 1997." (A copy is available in the Hanford Radiation Protection Historical Files.)

2.3.7 Hanford Standard Dosimeter Used as an Extremity Dosimeter

The HSD is used as an extremity dosimeter on the ankle and on the wrist in some field situations. An examination of REX files regarding the annual frequency at which an HSD is used to assess dose to the extremities yielded an estimate of 1200 times per year. The issue of DOELAP accrediting the HSD as an extremity dosimeter for this purpose was discussed during the HPDAC September 1997^(a) meeting based on new DOE accreditation requirements for extremity dosimetry. Hanford extremity dosimeters are now scheduled for DOELAP performance testing (beginning during January 1998 for the first time). It was decided to DOELAP accredit the HSD capability for use as an extremity dosimeter using the DOELAP wrist phantom. DOELAP accreditation requires "one time only" documentation of the HSD lower level of detection and angular response characteristics according to specifications provided in HPS N13.32 (ANSI/HPS 1995a). Backscatter radiation from the wrist phantom is a major contributor to the HSD response, and varies with the thickness of the backscattering material and the distance between the phantom and the dosimeter.

2.3.8 Damaged Mylar

As described in the previous annual report, damage to the thin MylarTM-covered window on HSDs has been a significant problem. Damage to the Mylar results in abnormal shallow dose results because of the effects of light, dust, and other chemicals on the response of the thin chip located behind the Mylar filter. To minimize potential damage to the Mylar (as discussed during the April 1996 HPDAC^(b) meeting) from the dosimeter clip, HEDP staff procured new clips and made these available to all Hanford contractors. However this step does not appear to have significantly reduced the number of damaged Mylar windows. The Mylar windows are thin to enable accurate dose measurement of the beta radiation in many Hanford work environments.

2.3.9 Personal Nuclear Accident Dosimeters

The effort to modify all Hanford personal nuclear accident dosimeters (PNADs) was completed during 1997. During its meeting of December 20, 1995,^(c) the HPDAC recommended that each of the existing PNADs be modified by inserting a TLD-700 chip. The modified PNAD would meet all 10 CFR 835 performance criteria and would eliminate the need to wear personnel dosimeters to meet the photon radiation performance requirements. HEDP staff took thermoluminescent chips (TLD-700) from the old Hanford ring dosimeter system that was terminated on June 30, 1996, and installed them into existing Hanford PNADs. A small red label is used to distinguish between modified and unmodified PNADs.

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- (a) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on September 17, 1997." (A copy is available in the Hanford Radiation Protection Historical Files.)
 - (b) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on April 17, 1996." (A copy is available in the Hanford Radiation Protection Historical Files.)
 - (c) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on December 20, 1995." (A copy is available in the Hanford Radiation Protection Historical Files.)

2.4 Supporting Studies

Several supporting studies were conducted by HEDP staff during 1997 as described in this section.

2.4.1 Dosimeter-Fading Response for Neutron Radiation

A 14-month study was begun during 1997 to determine the neutron fading factors. The results of this study are needed to evaluate the accuracy of the calculated neutron dose for HCNDs, which are to be exchanged annually. The option for annual exchange is desired because many Hanford workers show little, if any, reported neutron dose for quarterly exchanged HCNDs. The study will include an assessment of performance using DOELAP performance testing criteria and a calculation of the lower limit of detection.

2.4.2 Use of Hanford Combination Neutron Dosimeters as Area Dosimeters

Hanford contractors want the option to use HCNDs as area dosimeters to provide a sensitive measurement of potential neutron dose. The response of the HCND requires the presence of a suitable phantom. Changes in the reporting of dose results for area dosimeters are also desired. HEDP staff have reported area dosimeter results directly to Hanford contractors for many years. These results have not been sent to REX.

2.4.3 Multiple Dosimetry

Hanford multiple dosimetry practices were discussed during several HPDAC meetings. During the October 1997 HPDAC^(a) meeting an ad hoc committee was formed to investigate several issues. The results of the ad hoc committee efforts were discussed during the HPDAC December 1997^(b) meeting. The discussion primarily involved the specific criterion to be used to assign multiple dosimetry with respect to guidance in the *Hanford Site Radiological Control Manual* (HSRCM-1; RL 1994). The HSRCM-1 guidance is presently not based on an effective dose equivalent (EDE) calculation. There was general agreement that the criterion for assigning multiple dosimetry should be based on the same system used for calculating dose. The consensus of the ad hoc committee was that the Hanford method for EDE calculation should be based on HPS N13.41, *American National Standard, Criteria for Performing Multiple Dosimetry* (ANSI/HPS 1997), and it should use the same weighting factors. The ad hoc committee also recommended that the results of the EDE calculation should be used for dose of record, regardless of the length of time that multiple dosimeters are used. However, it was further recommended that any single multi-pack not be used for more than one month. The ad hoc committee

(a) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on October 15, 1997." (A copy is available in the Hanford Radiation Protection Historical Files.)

(b) D.E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on December 3, 1997." (A copy is available in the Hanford Radiation Protection Historical Files.)

recommended that a Technical Equivalency Determination be made regarding the proposed alternative HSRCM-1 Article 512.5 and presented to the Hanford Radiological Control Forum.

2.4.4 Neutron Measurements

HEDP staff assisted in making measurements of neutrons in a sand filter backwash settling tank used as part of the 107-N Basin clean-up system. Based on prior TLD measurements and calculations, there was concern that significant quantities of plutonium might be present in the sediment in this tank. To rule out criticality concerns, a special BF_3 detector with an ASP-1 integrating count rate meter was prepared and calibrated at the 318 Building for use in conducting the measurements. The detector and a 35-foot cable were water-proofed for use under up to 28 feet of water. The successful preparation and calibration of this instrument required cooperative efforts among RPS instrumentation and dosimetry staff.

2.4.5 Hanford Extremity Ring Dosimetry System Improvements

HEDP staff have been involved with upgrading equipment to support the Hanford extremity ring dosimetry program. The upgrades have been generally associated with the acceptability of the molding of the ring casings and with the ultrasonic welding equipment used to seal the ring casings. Hanford work environments require that the ring casings be capable of being used by workers without leaking. Substantial amounts of perspiration are present within the protective clothing and gloves used by the workers. Residues of perspiration, oils, dirt or various chemicals (i.e., talc, hand lotion, etc.) can significantly affect the accuracy of the processed dosimeter. Substantial improvements have been achieved during 1997: the relocation of the ring casing manufacturing capability to the local area allowed HEDP staff to assist in optimizing manufacturing parameters, and cooperative efforts with the ultrasonic welder manufacturer optimized the various welding parameters. Additional improvements in this equipment have been achieved by PNNL staff modifying the carousel used to place and weld the ring dosimeter casings. These changes have led to a 50% increase in throughput. HEDP staff also developed capabilities for providing individual barcode labels with an easily read label for Hanford workers. These labels are sealed inside each ring casing along with the chipstrate.

2.4.6 Dose Reduction with Leaded Gloves

HEDP staff conducted a study to determine the effectiveness of leaded gloves to reduce dose to the extremities for a specific work scope that involved drawing samples from Hanford waste tanks. These samples sometimes have beta-to-gamma shallow-dose ratios exceeding 100 to 1. A major focus of the study was to determine if a change of field practices from a 220-mg/cm² shoulder-length glove to a 128-mg/cm² wrist-length glove would result in an under-estimate of the extremity dose by virtue of having the forearms unshielded. MICROSHIELD 5.01 and VARSKIN MOD2 computer codes were used to calculate beta and photon doses from cylindrical sources to various targets under different cover thicknesses. The results of the study affirmed that use of the Hanford ring calibration correction factors for high beta fields is sufficiently conservative to handle the work to be performed.

2.4.7 Hanford Personnel Neutron Dosimetry Practices

The report entitled *Retrospective Assessment of Personnel Neutron Dosimetry for Workers at the Hanford Site* was completed during 1997 (Fix, Wilson, and Baumgartner 1997). This report describes the history of personnel neutron dosimetry practices at Hanford, including the complex history of neutron dosimetry regulations, dosimetry, calibration, and dose calculation. Many of the practices used at Hanford were similar to those used at other DOE, or predecessor agency, facilities. This report concludes that under-recorded neutron dose did occur with the nuclear track emulsion, type A (NTA) film dosimeter used to measure neutron radiation. This occurred primarily in work environments with lower-energy neutron radiation such as the Hanford PFP workers. This effect has been studied previously at Hanford and was one of the primary motivations for designing and implementing the Hanford albedo thermoluminescent dosimetry system in January 1972. The report states that a retrospective analysis of the corrected neutron dose and the whole body dose (i.e., photon and neutron dose) could be done. However, tremendous time, effort, and funding would be necessary to determine the best estimate of dose for each worker based on the type and location of work performed. Work on this task was concluded with an effort that identified all potentially impacted workers, and a letter to this effect was placed in the appropriate individual worker exposure history files.

2.5 Project-Related Professional Activities

Staff activities, presentations, publications, and professional memberships during 1997 are listed in this section.

2.5.1 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 Princeton Plasma Physics Laboratory dosimetry program from July 1 to 16, 1997.
- participated as a member of the DOELAP Oversight Board in meetings from February 10 to 13 and September 8 to 11, 1997, to review the status of DOELAP accreditation and protocol for DOE laboratories.
- participated as a member of the dosimetry subcommittee in meetings of the International Agency for Research on Cancer (IARC) during March 1997 in Lyon, France, regarding a collaborative epidemiologic study of nuclear workers from 14 countries. This study includes Hanford worker data.
- participated as a voting member in meetings of the Health Physics Society Standards Committee (HPSSC) during January and July 1997. The HPSSC reviews all technical scientific standards being developed by HPS working groups.

- participated in the 6th annual NIST-sponsored Council on Ionizing Radiation Measurements and Standards (CIRMS) meeting from November 11 to 14, 1997.
- participated as one of four invited international technical experts in personnel dosimetry to prepare an International Agency for Atomic Energy (IAEA) Safety Report regarding selection and implementation of personnel dosimetry systems.

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

- conducted DOELAP onsite technical assessments of Brookhaven National Laboratory and Martin Marietta Y-12 dosimetry programs from May 7 to 8, and November 3 to 4, 1997, respectively.

2.5.2 Presentations

Fix, J. J. 1997. *Retrospective Assessment of Recorded Dose*. PNL-SA-28273, presented at the annual Health Physics Society Meeting, June 28-July 3, 1997, San Antonio, Texas.

Fix, J. J. 1997. *Epidemiologic Assessments of Hanford Workers by the International Agency for Research on Cancer*. PNL-SA-29410, presented at the University of Washington conference on the Ecological, Community, and Occupational Health Issues at Hanford, December 3-4, 1997, Richland, Washington.

2.5.3 Publications

Fix, J.J., R.H. Wilson, and W.V. Baumgartner. 1997. *Retrospective Assessment of Personnel Neutron Dosimetry for Workers at the Hanford Site*. PNNL-11196, Pacific Northwest National Laboratory, Richland; Washington.

2.5.4 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 Working Groups on ANSI/HPS N13.29, *American National Standard for Dosimetry - Environmental Dosimetry Performance Criteria for Testing*, and ANSI N13.37, *American National Standard for Dosimetry, Performance Testing and Procedural Specifications for Environmental Thermoluminescent Dosimetry*.

Rathbone, B. A. and J. J. Fix, DOELAP Technical Assessors in personnel dosimetry.

3.0 Hanford Internal Dosimetry Project

The Hanford Internal Dosimetry Project (IDP) 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 Part 835, *Occupational Radiation Protection* (DOE 1993) and the HSRCM-1 (RL 1994). Additional guidance is provided by the implementation guide (DOE 1994a). The project provides the following internal dosimetry services:

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

3.1 Routine Tasks

Operational details of the IDP 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 Project Manual*.^(a)
- Detailed procedures are contained in the *Hanford Internal Dosimetry Procedures Manual*,^(b) which was completely revised and reissued in 1995.
- The *Quality Assurance Plan for the Operation of the Hanford Internal Dosimetry Project*.^(c)

(a) Internal Manual, PNL-MA-552, Rev. 3, Pacific Northwest National Laboratory, Richland, Washington.

(b) Internal Manual, PNL-MA-565, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

(c) Internal Manual, LSC-026, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

- The technical agreements with the excreta lab are established by a Statement of Work (SOW).
- The division of responsibilities for meeting internal dosimetry and bioassay requirements of 10 CFR 835 are specified in a memorandum of agreement between FDH and RPS.

The practices and technical aspects of operating the Hanford Whole Body Counting Project are established in the *Whole Body Counting Manual*^(a) (see Chapter 4.0). Individual assessments of internal dose are documented in each individual's file in the HRRP files. Bioassay measurement results and internal doses are maintained in the REX database, which is operated by the HRRP (see Chapter 5.0).

New scope was added to the project in February when excreta and in vivo bioassay scheduling tasks were transferred from FDH to RPS. These services are performed for RL and PHMC employees only. A major cost-savings task was added for the PHMC bioassay scheduling activities in July. This task (referred to as a "bioassay needs review") involved searching through the Access Control Entry System (ACES) database each month prior to sending the monthly routine requests to the excreta analysis laboratory or to the in vivo counting laboratory. If the search revealed that a worker had not entered a radiation area under a Radiation Work Permit (RWP) that actually required the bioassay being scheduled, then the routine bioassay request was waived. The time spent doing the search and modifying the requests was more than compensated by the nearly \$100K savings to the PHMC obtained through the end of the year. However, the task was suspended just after the end of the year when a fault was uncovered in the query that had resulted in some inappropriate waivers.

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. However, routine bioassay in December detected an intake of depleted uranium that may have been due to low-level chronic intakes, and this intake was still under investigation at the end of the year.

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.

(a) Internal Manual, PNL-MA-574, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Table 3.1. Specified Minimum Detectable Activities and Screening Levels for Routine Excreta Analyses During 1997

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)	0.05 dpm	0.003 dpm (A)
⁹⁰ Sr	10 dpm	26 dpm (A) 11 dpm (BE)
²³⁴ U ^(e) , ²³⁸ U	0.02 dpm	0.15 dpm (A,Q) ^(f)
²³⁵ U	0.02 dpm	0.01 (A) 0.02 dpm (Q)
²⁴¹ Am, 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 µg (Q) ^(f)
Elemental U (QUS)	0.50 µg	11 µg (BW) 4 µg (M)
Tritium	20 dpm/mL	80 dpm/mL ^(g)
<p>(a) Analysis of urine samples, unless otherwise indicated.</p> <p>(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).</p> <p>(c) Amount per total sample volume, unless otherwise indicated.</p> <p>(d) Investigation of a potential internal exposure is performed when this value is exceeded (routine bioassay monitoring frequency: A-annual, BE-biennial, BW-biweekly, M-monthly, Q-quarterly).</p> <p>(e) The lab cannot discriminate between ²³³U and ²³⁴U and reports the results as ²³⁴U (beginning in 1994).</p> <p>(f) Upper level of expected environmentally derived uranium in urine for the Hanford region.</p> <p>(g) Special screening levels are established for short-term tritium work where beginning and ending work samples are obtained instead of monthly routine sampling.</p>		

**Table 3.2. Minimum Detectable Activities and Screening Levels for
Routine In Vivo Measurements During 1997**

Measurement/Radionuclide ^(a)	MDA ^(b) (nCi)	Screening Level ^(c) (nCi)
Stand-Up Whole Body Count		
⁶⁰ Co	4	4
¹⁵⁴ Eu	8	Any detected
¹³⁷ Cs	4	Any detected
Coaxial Germanium Whole Body Count		
¹³⁷ Cs	1.2	Any detected
Lung Count		
²³⁵ U	0.095	Any detected
²³⁸ U (by ²³⁴ Th)	1.6	Any detected
²⁴¹ Am	0.18	Any detected
<p>(a) For selected radionuclides. (The detection of radionuclides not listed resulted in follow-up.)</p> <p>(b) For each in vivo count, the decision levels (approximately half of the MDAs) were reported under the "detection limit" to REX, but, in terms of overall detectability for all measurements, the above MDAs were still applicable.</p> <p>(c) 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 IDP.</p>		

The values for the excreta analyses did not change from 1996 values.

A major improvement in whole body counting was implemented in May when a seventh detector was added to the coaxial germanium detector system in the Palmer Room and the system was placed into use for routine counts. Prior to this change the germanium system was used only after a worker had one or two counts on the NaI-based stand-up counter and the improved resolution of the germanium system was needed to better identify and quantify radionuclides detected in the first counts. After consultation with the Hanford contractors, the decision was made to use the germanium system for first counts for workers considered at risk for ¹³⁷Cs-plutonium mixtures. (See Section 3.1.4 for additional discussion on mixtures and Chapter 4.0 for additional discussion on the germanium system.)

Table 3.3. Specified Minimum Detectable Activities for Emergency and Expedited Excreta Bioassay During 1997

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

3.1.2 Excreta Bioassay Contract Activities

Staff cutbacks at Quanterra in January, including the loss of experienced personnel in the group that manages kit delivery and pick-up, resulted in considerable difficulties in getting bioassay kits delivered and picked up on time. The problem was discussed with Quanterra several times during the ensuing weeks, and the problem was rectified when the original kit-tracking supervisor was rehired.

The contract with Quanterra was extended through the second option year (July 1997 to June 1998). For the second consecutive year bioassay unit prices were reduced; prices for the second optional year were about 10% less than the previous year.

An improvement in the transfer of data between Quanterra and the Hanford contractors was implemented in January. Information about the status of samples (such as received and valid, kit not out, lost kit, insufficient volume, etc.) started being transferred electronically, daily, to the REX database. The information was then also downloaded to ACES daily. This provided the contractors with much more timely information about who had provided a valid sample and who had not.

An Inspection of Services was performed in June 1997 to review contract compliance. With the intent of minimizing duplication of efforts and holding down costs, the inspection was conducted jointly with the technical administrator for Battelle's contract with Quanterra for environmental radiochemical analyses. The audit team was headed by staff from Battelle's QA group. The inspection resulted in eight findings and four observations.^(a) Two findings were totally unrelated to bioassay, and five findings primarily involved minor deviations from general QA practices. Only one finding related directly to bioassay: Quanterra did not notify PNNL of the status change of several bioassay kits within the contractually specified time. By November 1997, corrective actions on all findings were completed.

3.1.3 Excreta Quality Control Oversight Program

The Quality Control Report for the period July 1, 1996 through June 30, 1997 was completed in December.^(b) Urine analyses for tritium, ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am , ^{234}U , ^{235}U , ^{238}U , and elemental uranium; and fecal analyses for ^{238}Pu , ^{239}Pu , and ^{241}Am were tested. The QC samples submitted by PNNL during

-
- (a) A finding is a statement of fact relating to noncompliance with previously agreed-upon codes, standards, specifications, or other forms of contractual or legal obligation. An observation is a conclusion (usually based upon the auditor's experience) that presents the results of a generally subjective evaluation of implementation practices or management systems related to the area(s) under review. It may or may not relate to specific noncompliance(s) with agreed-upon requirements, but it is based upon the auditor's evaluation of factual evidence.
- (b) J. A. MacLellan. December 2, 1997. Letter report to Distribution, "Results of the PNNL Excreta Bioassay Quality Control Oversight Program for July 1, 1996 Through June 30, 1997." Copy available in the Hanford Radiation Protection Historical Files.

the report period represented about 2% of the total samples submitted. This is slightly less than the percentage for the 1996 report period.

Based on an evaluation of all QC data, all analyses met or exceeded statistical specifications in the SOW. The number of statistical outliers and false negatives were also within statistical expectations.

Artificial fecal samples were added to the routine oversight program in 1997. Artificial fecal samples had previously been used as part of the two intercomparison programs that IDP participated in until 1995. Procedures for making and spiking artificial fecal matrix at Hanford were developed in 1996 (PNNL 1996) and were first used in 1997 (6 samples).

3.1.4 Policy and Documentation Changes

Revision 3 of the *Hanford Internal Dosimetry Project Manual*^(a) was issued in September. Changes from Revision 2 are listed in Table 3.4. Two changes merit specific discussion. The questionnaire given to workers after possible occupational radioactivity is detected in whole body counts was expanded in scope. The new questionnaire was applied to all in vivo counts and all unexplainable radionuclides (not just ^{137}Cs in whole body counts). It also included questions relating to possible sources of occupational intake as well as possible background sources.

The second notable policy issue responded to a body of knowledge, which had been accumulating slowly over several years and which indicated that there were many sources of contamination at Hanford where the predominant radionuclide (activity-wise) was ^{137}Cs , but where there was enough plutonium mixed in to add significantly to the potential internal dose. Traditional thought had been that certain facilities were associated with only beta-gamma-emitting contamination; examples of such facilities were tank farms and the production reactors. However, several factors contributed to the realization that mixtures were a problem for internal dosimetry at such facilities; these were:

- better characterization of contamination, especially at tank farms
- the switch to the committed dose equivalent as the dose of record, in which the dose per unit intake from plutonium increased significantly relative to the dose per unit intake from ^{137}Cs
- more work tasks involving sludge in the bottom of basins, tanks, pits, etc.

Because the ratio of ^{137}Cs to plutonium, or in some cases the ratio of ^{137}Cs to ^{90}Sr , was highly variable and not necessarily consistent with default ratios previously used by the IDP, changing the default ratio or even establishing facility-specific default ratios were no longer the preferred choices. Instead discussions of recommended bioassay programs for wide ranges of ratios were provided in the project

(a) Internal Manual, PNL-MA-552, Rev.3, Pacific Northwest National Laboratory, Richland, Washington.

Table 3.4. Changes to the *Hanford Internal Dosimetry Project Manual*

Section	Changes
Preface	Incorporated minor editorial changes
1. Introduction	Revised explanation of project funding and authority, contractor relationships, and project oversight. Covered use of letter of instruction, memorandum of agreement, statements of work as authority for projects. Added discussion of compliance policy with regard to 10 CFR 835, <i>Hanford Site Radiological Control Manual</i> (RL 1994), and other guidance and standards.
2. Practices of the IDP	Added Health Physics Society standards as guidance. Changed criteria for re-evaluations from a 1-rem committed effective dose equivalent (CEDE) to a 5-rem CEDE. Added new Section 2.3.1, "Objectives for Periodic Bioassay Monitoring," containing five objectives adopted by the HPDAC. Added use of letters, memos, and special reports, as acceptable for adjusting bioassay suggestions and recommendations from default recommendations in the manual.
3. Assessment of Internal Dose	Was revised in February 1997. Changed when a dose evaluation summary letter was to be sent directly to the worker versus when sent to Field Dosimetry representative. Also added AMERIN to list of computer codes, and replaced the old ^{137}Cs Questionnaire with the new In Vivo Exam Questionnaire.
5. Bioassay Monitoring	Reformatted the section, moving material more important to customers to the front (suggested bioassay programs). Added discussion and guidance on neptunium, thorium, and mixtures of strontium+cesium and cesium+plutonium.
6. Bioassay Services	Updated tables of available bioassays and associated MDAs
A. Screening Levels	Clarified use of Oral Reporting Levels.
E. Example Potential Intake Responses	Deleted the obsolete incident response plan, but retained the information from the plan that related directly to bioassay recommendations and capabilities.
4, 7, 8, 9, 10, B, C, D, Glossary, Index	Incorporated minor editorial changes.

manual. It was left to facilities to characterize their local ratios for specific tasks and select the preferred bioassay from the categories presented in the project manual. Recommendations for follow-up bioassay measurements in response to high routine samples based on the range of ratios were also included.

Bioassay recommendations specific for work at Life Sciences Laboratory-2 (LSL-2) involving tritium and ^{14}C were developed and documented by a letter^(a) to the Historical Files.

(a) Letter, E. H. Carbaugh, PNNL, to M. P. Long, PNNL, April 4, 1997, "Bioassay for LSL-2 Animal Study." Available in the Hanford Radiation Protection Historical Files.

3.1.5 10 CFR 835 Assessment

10 CFR 835 section 102 states that "Internal audits of all functional elements of the radiation protection program shall be conducted no less frequently than every 3 years." Representatives from the PHMC, the Environmental Restoration Contractor (ERC) team, and PNNL's Radiological Control Department conducted the required assessment of the IDP in May. At the request of the project manager, the project's quality engineer teamed with the others on the audit to fulfill the requirement for an annual self-assessment of the project as well. There were one finding concerning the adequacy of the training records and eight observations. Three observations indicated that the major documents, the technical basis, the project manual, and the procedures manual, were not being updated in a timely manner. Corrective actions to the finding and most of the observations were implemented by the end of the fiscal year. As mentioned in the previous section, the project manual was updated and revised. Under present tightness in staffing for the project, updating the procedures manual and the technical basis document were considered long-term tasks, and 2-year schedules were established for them.

3.1.6 Audit by RL's Performance Assessment Division

An audit of bioassay and internal dosimetry programs across the Hanford Site was performed by RL's Performance Assessment Division (PAD) during the summer. The assessment actually started in the spring with a scope limited to IDP's oversight and contract management of the excreta bioassay contract. However, in response to a directive from the DOE Assistant Secretary of Environmental Management to all DOE field offices, the scope was increased to include all aspects of internal dosimetry including implementation in the facilities. The results of the assessment were transmitted to Hanford contractors in October. IDP took ownership for parts of several findings and observations and coordinated responses with all of the Hanford contractors. Major findings and responses affecting the IDP are summarized in Table 3.5.

3.1.7 Final Dose Assessment for HAN-01

A worker with an unusual retention pattern of plutonium in the lung and who had been on a special monitoring program since the time of the inhalation retired. His intake had been evaluated and reevaluated several times, but was due for another review. At his request a final reevaluation was completed and presented to him a few months after his retirement. The reevaluation showed that the retention in the lung was even longer than previously assessed; that is, the removal half-time for the majority of the material initially deposited in the lung was increased to 80 years.

Table 3.5. RL Performance Assessment Division's Audit

Findings		Responses
97-PAD-033-1	Characterization data supporting the technical arguments contained in evaluations of worker dose from bioassay results need improvement; the decisions in several cases were not valid based on characterization data at the facility level.	Will improve documentation of characterization data from facilities used in each dose assessment. Will relook at protocols for special bioassays following high routine bioassay results, and present to HPDAC.
97-PAD-033-2	Implementation and documentation of the facility technical basis for determining bioassay requirements from characterization data need improvement.	Revise project manual to provide better information on mixtures.
97-PAD-033-4	Completion of termination bioassays and management oversight of the number of persons failing to achieve this monitoring need improvement.	Resume quarterly termination bioassay reports. Include review of termination in vivo count no-shows and offer to mail excreta kits.
97-PAD-033-5	There is no participation in independent, third-party intercomparison studies for excreta bioassay.	IDP will draft a technical equivalency document for approval by the HPDAC and the Hanford Radiological Control Forum.
97-PAD-033-6	Bioassay dose assessments do not contain previous exposure histories.	IDP will draft a technical equivalency document for approval by the HPDAC and the Hanford Radiological Control Forum.
Observations		
97-PAD-033-1	The <i>Whole Body Counting Manual</i> should be added to the list comprising the Internal Dosimetry Technical Basis in the <i>Hanford Site Radiological Control Manual</i> .	IDP will make the recommendation to the group writing the next revision to the <i>Hanford Site Radiological Control Manual</i> .
97-PAD-033-2	The current version of the <i>Technical Basis for Internal Dosimetry at Hanford</i> is out of date.	A 2-year schedule for revising the document and converting it to a manual was developed.

3.2 Monitoring and Assessment Activities

The IDP excreta bioassay monitoring and internal dose assessment activities during 1997 are summarized in this section. The Whole Body Counting Project and its associated statistics are discussed in Chapter 4.0.

3.2.1 Excreta Bioassay Monitoring Activities

Sample requests can be categorized as standard or nonstandard. Standard requests are those generated by REX 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 non-standard requests. Contractors and IDP staff manually enter the nonstandard requests into REX. IDP 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 requests for 1997. A total of 4569 samples were requested in 1997, up 26% from the 1996 requests and about comparable to the number of requests in 1995. The remarkable characteristic of the requests in 1997 is that the nonstandard requests outnumber the standard requests. (Standard requests were only 46% of the total in 1997, compared with 69%, 68%, and 62% in 1996, 1995, and 1994, respectively.) This is the first time since these statistics have been reported (starting in 1992) that this has happened. It may reflect the new contracting trend to subdivide the work into smaller discrete contracts with a more mobile workforce moving between contracts.

Figure 3.1. Standard and Nonstandard Excreta Requests by Month

During 1997, 3439 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 provides the trend in routine urinalyses since 1991. The figure shows that the number of routine measurements in 1997 leveled off after 2 years of sharp decreases from the high numbers in the first half of the 1990s. Major efforts were made in 1995 and 1996 to tighten the requirements for placing workers on routine bioassay schedules and to remove workers from routine schedules that were at negligible risk for intakes. The flatness of the 1996 and 1997 numbers reflects a balance between

Figure 3.2. Routine Urine Measurements Made from 1991 through 1997

opposing effects — the waiving of routine bioassay for many PHMC workers on one hand (see discussion about “bioassay needs review” in Section 3.1), and increased cleanup work involving mixtures enhanced in ^{90}Sr or plutonium on the other hand (see discussion about mixtures in Section 3.1.4). Details on the type of excreta measurements categorized by contractor are provided in Table 3.6. Overall the number of excreta measurements increased slightly over 1996 (+4%) but was substantially less than previous years. The mix of analysis types remained about the same. Excreta measurements for the ERC team increased significantly from 1996 (+423, +330%) while measurements for the PHMC decreased by approximately the same number (-455, -20%). This reflects the nature of the transfer of work between the companies where the PHMC is shutting down, cleaning, and stabilizing contaminated facilities or areas, whereas the ERC team is ramping up its work in contaminated areas.

Not all excreta bioassay requests produce valid measurement results; these are referred to as no-samples. When this happens the sample has to be requested again. In 1997, 817 excreta sample requests were designated as no-samples, up from 671 no-samples in 1996. In terms of percentage of total requests, the 1997 rate (21%) was similar to previous years (19%, 19%, and 14%, in 1996, 1995 and 1994, respectively). In addition there were 219 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, 0.7%), no sample received (NS, 18%), lost container (LC, 56%), insufficient sample volume (IS, 13%), lost in lab (LL, 13%). The percentage of each type of unsuccessful sample is similar to previous years except that the lost-in-lab category decreased from last year’s unusually high percentage.

Table 3.6. Worker Excreta Measurements Reported in 1997

Type/Reason	DOE	PNNL	ERC	PHMC	Other	Total
³ H-urine						
Routine Schedule ^(a)	0	225	0	10	0	235
Special Request ^(b)	0	0	0	0	0	0
⁹⁰ Sr-urine						
Routine Schedule	12	172	86	411	3	684
Special Request	0	5	2	8	0	15
Uranium-urine						
Routine Schedule	20	185	51	347	0	603
Special Schedule	0	9	1	10	0	20
Plutonium-urine						
Routine Schedule	31	236	337	1008	2	1614
Special Schedule	2	12	17	20	0	51
Other-urine						
Routine Schedule	0	116	0	26	0	142
Special Schedule	0	4	0	4	0	8
TRU-fecal						
Routine Schedule	0	0	3	0	0	3
Special Schedule	0	1	55	8	0	64
Analyses Totals	65	965	552	1852	5	3439
Recounts or Reanalyses						
Plutonium-urine	0	4	10	7	0	21
²⁴¹ Am-urine	0	3	0	0	0	3
Uranium-urine	0	2	0	0	0	2
(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).						

3.2.2 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 incurred 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 are also conducted periodically for workers with significant long-term body burdens (reevaluations).

During 1997, 18 incidents with the potential for intake, involving 51 workers, were identified through workplace monitoring. Of the 51 workers involved in the incidents, intakes were confirmed for only 11 workers, and 6 other workers had doses assigned based on air sample data only (bioassay did not confirm intakes). (Another two cases were still undetermined at the time of this report.) The highest calculated dose among the 17 workers was 160 mrem CEDE. The radionuclides and groups involved included ^{137}Cs and/or ^{90}Sr (4 incidents with 6 workers), transuranium radionuclides (TRU; 4 incidents with 11 workers). Table 3.7 shows the incident breakdown by contractor, area, and facility.

Table 3.7. Summary of Potential Intake Incidents during 1997

Facility		Custodian	Number of Incidents	Number of Workers	Worker Contractor	Principal Nuclide
Area	ID					
100	100C	ERC	1	1	ERC	Pu mix
100	108F	ERC	1	12	ERC	Pu mix
100	100K East Basin	PHMC	1	3	PHMC	^{137}Cs
100	100 N	ERC	3	3	ERC	Pu mix, ^{60}Co
200E	101AY	PHMC	1	2	PHMC	^{137}Cs
200E	224B	ERC	1	4	ERC, DOE	Pu mix
200E	2412	PHMC	1	1	PHMC	^{137}Cs
200W	233S	ERC	1	5	ERC	Pu mix
200W	234-5Z	PHMC	3	11	PHMC	Pu mix
200W	236Z	PHMC	1	2	PHMC	Pu mix
300	324	PHMC	1	1	PHMC	^{137}Cs
300	325	PNNL	1	1	PNNL	^{90}Sr
300	326	PNNL	1	1	PNNL	Pu mix
300	327	PHMC	1	4	PHMC	^{137}Cs
		Total	18	51		

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 1997, 89 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 9 workers. For 7 workers the CEDEs were less than 10 mrem and the intakes for some may have been due to environmental sources of ^{137}Cs . For 2 workers, the dose assessments

were still in progress at the time this report was drafted. However, intakes of depleted uranium from work in the 306-W Building have been confirmed for both workers. Intermittent but frequent intakes of uranium are suspected, but the circumstances of the intakes are still under investigation. CEDEs for these workers could range up to a couple of rem. Table 3.8 shows internal dose evaluations for 1997 resulting from high routine bioassay results. Table 3.9 provides the trends in all types of potential intake evaluations since 1990.

No workers were identified as having potential chronic exposures to tritium in 1997.

The range of internal doses assigned to the Hanford work force in 1997 is summarized in Table 3.10.

Table 3.8. Summary of Intake Cases Identified through the Routine Bioassay Program during 1997

Facility		Custodian	Number of Workers	Contractor	Principal Nuclide
Area	Building				
100	105N	ERC	1	ERC	$^{137}\text{Cs}^{(a)}$
200W	T Plant	PHMC	1	PHMC	$^{137}\text{Cs}^{(a)}$
200E	Tank Farms	PHMC	1	PHMC	^{137}Cs
300	306W	PNNL	2	PNNL	U
300	325	PNNL	1	PNNL	^{137}Cs
300	327	PHMC	1	PHMC	$^{137}\text{Cs}^{(a)}$
Chornobyl, Ukraine		Ukraine gov.	1	PNNL	^{137}Cs
Undetermined		PHMC	1	PHMC	^{137}Cs
		Total	9		
(a) Occupational intake assigned; environmental source possible.					

Table 3.9. Comparison of Potential Intakes by Reason Code, 1990-1997

	1990	1991	1992	1993	1994	1995	1996	1997
Incident, Total	30	90	30	51	33	51	42	51
Confirmed				17	7	12	11	11
Unconfirmed				34	26	39	30	32
Open								2
Unconfirmed but assigned ^(a)							1	6
High Routine, Total	93	69	141	65	91	59	40	89
Confirmed				1	15	1	5	9
Unconfirmed				64	76	58	33	55
Open							2	25
Chronic Exposure, Total	95	30	4	6	0	0	0	0 ^(b)
Confirmed				0	0	0		
Unconfirmed				6	0	0		
Pre-Hanford, Total			20	3	35	9	12	11
Confirmed				3	31	9	11	10
Unconfirmed				0	4		1	0
Open								1
Totals	223	189	195	126	162	119	94	151
Confirmed				22	53	22	27	36
Unconfirmed				104	109	97	64	87
Open							2	28
Revaluation, Total	5	1	4	3	12	11	2	0
Initiated				0	8	17	1	1
Completed							1	
Open								
(a) Unconfirmed by bioassay but dose assigned based on air sample data.								
(b) Two intakes were discovered through high routine bioassay results that are probably due to chronic intakes starting in 1996, but the circumstances are still under investigation.								

Table 3.10. Range of New Internal Doses Assigned to the Hanford Work Force in 1997

Dose (mrem) ^(a)	Number of Workers				
	DOE	PHMC	PNNL	ERC	Total
< 100	0	13	4	5	22
100 - < 500	0	0	1	1	2
500 - < 2000	0	0	0	0	0
2000 - < 5000	0	0	0	0	0
>5000	0	0	0	0	0
(a) CEDE, based on 1997 evaluations, although the intake could have occurred in any year; excludes reevaluations. Two open cases have potential for doses in the 500 to <2000 range.					

3.3 Project-Related Professional Activities

IDP staff presentations and professional memberships during 1997 are listed in this section.

3.3.1 Presentations

MacLellan, J. A. 1997. An invited presentation in a workshop on "Detection Limits and MDA" at the 43rd Conference on Bioassay, Environmental and Analytical Radiochemistry, November 10-13, 1997, Charleston, South Carolina.

3.3.2 Professional Memberships

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

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

Carbaugh, E. H., Treasurer of the Columbia Chapter of the Health Physics Society.

MacLellan, J. A., Member of the ANSI Standards Committee N13.30, *Performance Criteria Against Which Radiobioassay Laboratories Will Be Tested*.

MacLellan, J. A., Council Member of the Columbia Chapter of the Health Physics Society.

4.0 Hanford Whole Body Counting Project

The Hanford Whole Body Counting Project (WBCP) has been an integral part of worker radiation protection for the Hanford Site since 1959. The WBCP provides for the detection of radionuclides in Hanford workers by direct (in vivo) measurement, and the associated management, operation, and maintenance of the onsite in vivo facilities and equipment. The project staff operate and maintain equipment in the 747-A Building, the 747-A Trailer, a mobile whole body counting trailer, and the Emergency Decontamination Facility (EDF) located next to Kadlec Medical Center in Richland, Washington. Collectively, the facilities are known as the In Vivo Radioassay and Research Facility (IVRRF). The project documentation includes the *Whole Body Counting Manual*,^(a) the *Whole Body Counting Procedures Manual*,^(b) and the *Quality Assurance Plan for the Whole Body Counting Project*.^(c)

A summary of the project activities, which include routine measurements of Hanford workers, special studies, and measurement instrumentation development work, are described in this chapter. The primary function of the WBCP is to provide accurate, highly sensitive, well-documented, and timely measurements of workers potentially exposed to radionuclides encountered from occupational sources at Hanford. Measurement results are provided to the IDP for use in quantifying potential intakes and estimating internal doses. All measurement results and calibration data are transmitted as permanent records to the HRRP. The results for personnel measurements are stored online in the REX database and the spectra data are sent to the HRRP for permanent storage. Information copies of the measurement records are maintained at the IVRRF.

Four measurement systems are used for routine counting at the IVRRF. These include the stand-up counter, used for screening whole body measurements; the Iron Room and Stainless Steel Rooms, each containing germanium counting systems designed to optimize detection of low-energy photons; and the Palmer Room, which contains a scanning coaxial germanium whole body counter designed to optimize detection of high-energy photons. Additional germanium detectors are housed in the lead room and are used for the less frequently performed measurements. Whole body and wound counting equipment are also maintained at the EDF. Routine counts are scheduled from 8:00 a.m. to 12:00 p.m. and 1:00 p.m. to 3:00 p.m. on weekdays. Upon request, the WBCP staff will arrange for additional counting hours to help cover periods of peak demand. The WBCP staff are also available on an on-call basis for incident response during off-hours through the PNNL exposure evaluator.

(a) Internal Manual, PNL-MA-574, Pacific Northwest National Laboratory, Richland, Washington.

(b) Internal Manual, PNL-MA-554, Pacific Northwest National Laboratory, Richland, Washington.

(c) Internal Manual, LSC-021, Pacific Northwest National Laboratory, Richland, Washington.

4.1 Summary of 1997 IVRRF Measurements

The number and types of measurements performed in 1997 are shown in Table 4.1. A total of 7738 measurements were performed in 1997 for the Hanford Site contractors. This represents a 15% decrease from 1996. The reduction reflects the ongoing contractor efforts to identify only those individuals who are at risk for incurring an intake and scheduling those individuals for routine in vivo measurements. However, the total number of measurements in 1997 was 29% higher than the projected 6000 measurements. A summary of the number and types of in vivo measurements performed since 1991 is shown in Table 4.2 and Figure 4.1. The "special count" category includes wound counts, liver counts, and skeletal counts.

Table 4.1. In Vivo Measurements Performed During 1997 and Entered in the REX Database

Count Type and Reason	PHMC	PNNL	ERC	Other (DOE and HEHF) ^(a)
Whole Body Counts				
Routine Schedule	4052	808	1136	165
Special Request	20	6	8	0
Contractor Request	41	78	35	21
TOTAL	4113	892	1179	186
Lung Counts				
Routine Schedule	933	278	59	31
Special Request	24	20	1	0
Contractor Request	2	9	8	0
TOTAL	959	307	68	31
Other				
Routine Schedule	0	0	0	0
Special Request	0	2	0	0
Contractor Request	0	1	0	0
TOTAL	0	3	0	0
GRAND TOTAL	5072	1202	1247	217
(a) HEHF = Hanford Environmental Health Foundation				

Table 4.2. In Vivo Count Summary from 1991 through 1997

Year	1991	1992	1993	1994	1995	1996	1997
WBC	9,965	12,197	11,401	11,031	9,020	7,407	6,370
Lung	2,549	3,164	2,838	2,752	1,915	1,632	1,364
Special	66	56	38	82	27	26	3
Total	12,580	15,417	14,277	13,865	10,962	9,065	7,737

Figure 4.1. Summary of In Vivo Counts by Type, 1991 to 1997

4.2 Routine Program

During 1997, the WBCP staff conducted Monday planning meetings to prioritize and schedule work at the IVRRF. Staff conducted monthly safety meetings on a rotating basis throughout the year and quarterly safety self-assessments were also performed. No off-normal events were recorded in 1997. Formal quarterly presentations were made to RL and the contractors to summarize the progress, activities, and issues related to operation of the WBCP. Quarterly reviews and trend analyses were performed on the daily QC data for each routine counting system.

Project documentation was updated in 1997 including several operating procedures and the QA Plan. The project QA Plan (LSC-021) was updated to replace references to the former PNL-MA-70 with references to the new online Standards Based Management System. WBCP staff received training to cover the changes made to the QA Plan.

The in vivo count record form question about whether a worker has worked at K-Basins or other areas where low levels of TRU contamination occur along with higher levels of fission and activation product contamination was revised. This was in response to a FDH request to help alleviate worker concerns about unknown exposures to TRU.

Two important facility changes were made in 1997. With the closure of the adjacent 747 Building, the use of the oversized compressor in that building to operate the Stainless Steel Room shielding door became a liability. A smaller compressor was purchased and installed in the 747-A Building to operate the shielding door. Also, the 747-A power distribution system was reconfigured to separate critical instrumentation circuits from other loads and to place the critical instrumentation on an uninterruptible power supply (UPS) system. The system is a FERRUPS FE 4.3 to 18KVA UPS manufactured by Best Power Inc. (Necedah, Wisconsin 54646). The radiation detectors, high-voltage bias supplies, associated electronic components, and the primary computer systems were placed on the UPS circuits. After the switchover to the UPS a successful acceptance test was performed and the system was put into routine operation. The UPS provides up to 30 minutes of battery back-up power and conditions the incoming power to minimize voltage fluctuations.

Water leaks occurred in the 747-A Building and the 747-A Trailer during 1997. Fortunately damage and impact on operations was kept to a minimum. The leak in a 747-A water line damaged the IBM graphics monitor for the primary computer system, so a replacement monitor was procured. This situation did not impact operations, because the operations normally performed from this terminal could be done from a secondary terminal. The entire section of the water line was replaced. Two other leaks developed as a result of melting snow. One leak developed in Room 10 in the 747-A Trailer and caused minimal damage that was limited to water accumulated in an electric typewriter. The typewriter was not permanently damaged and the leak was patched. When the roof above the Iron Room also developed a leak, water was observed along one of the inside walls of the counting room, but no counting instrumentation was damaged. The leak site was repaired and this appears to have corrected the problem.

4.2.1 Program Audits

Three narrow-scope audits of the WBCP and the initial DOELAP onsite assessment were performed during 1997. The audit conducted by representatives of the major Hanford contractors in April concluded that the WBCP was in compliance with the requirements in 10 CFR 835. One finding and three observations resulted from the audit. Corrective actions were completed for the finding and two observations. The third observation pertained to updating the Records Inventory and Disposition Schedule; significant progress was made on this item and the update should be complete by early 1998.

A short project review was conducted on July 16 as part of the Hanford Internal Dosimetry Audit by RL. No findings or observations resulted directly from the review.

Finally, a US Ecology representative conducted a one-day audit of the WBCP operations. No findings resulted from the audit, so the WBCP remains on the US Ecology approved vendor list.

4.2.2 DOELAP Performance Testing

In 1997, the WBCP staff participated in DOELAP performance testing and hosted an onsite assessment by a team of three DOELAP assessors. The performance testing was conducted in four categories: fission and activation products in the whole body and lungs, ^{238}Pu in lung, and natural uranium in lung. The testing consisted of making a series of five measurements of the DOELAP phantoms and reporting the results. All results were well within the bias (+50% to -25%) and precision (+/- 40%) requirements prescribed by DOELAP.

The WBCP staff hosted the DOELAP onsite assessment team on October 7 and 8. No deficiencies were noted during the assessment. Six concerns and 13 observations were noted.^(a) A corrective action plan to address the concerns was forwarded to the DOELAP Performance Evaluation Program Administrator. By year-end the corrective actions for three of the concerns were complete with the remaining three to be completed in early 1998. The WBCP staff also worked to incorporate the assessment team's observations although a formal response to the observations was not required. The DOELAP assessors complimented the WBCP staff for their professionalism and dedication to the project.

4.2.3 Calibrations and QC of Routine Counting Systems

Each in vivo counting system requires calibration to convert the measured count rates from people to estimates of activity. This is accomplished by using phantoms that simulate the size, shape, and radiation interaction properties of the body. The phantoms contain a known amount of radioactive material(s) and are measured with the counting system. The calibration factor is calculated by dividing the count rate measured with the counting system by the phantom activity. The count rate from a person is divided by the calibration factor to estimate the activity. For lung counting, the calibration factors are expressed as a function of the thickness of the tissue overlying the lungs. The correct calibration factor is based on estimates of the individual chest wall thickness determined by an individual's weight-to-height ratio or the ultrasonically measured thickness if the result exceeds the detection level.

During 1997, the installation and calibration of the seven-detector coaxial high-purity germanium (HPGe) system in the Palmer Room was completed. The system includes a computer-controlled motion control system with an automatic return feature. Figure 4.2 shows the seven-detector system that was put into routine operation on May 1. This completed a several-year effort to improve the sensitivity so that measurements of ^{137}Cs could be used as a tracer for ^{239}Pu . Workers potentially exposed to mixtures composed primarily of fission and activation products with trace amounts of plutonium activity are now scheduled for routine 10-minute counts on this system. The typical decision level for ^{137}Cs for a 10-minute count is 0.6 nCi. (Level of detection refers to a typical decision level, not the MDA.) This is

(a) Deficiencies are issues that can preclude obtaining DOELAP accreditation, concerns are issues that require a formal corrective action plan, and observations are noted for good practices or recommendations for enhancing quality.

Figure 4.2. Coaxial HPGe Detector System

a factor of 5 lower than the level of detection for the stand-up counter. The sensitivity of the system to interference from environmental radon progeny initially caused a higher than expected number of positive results. Adjustments were made to the background prediction algorithm to successfully account for the radon-generated interference. During this period, the spectral data were manually reviewed to preclude unnecessary recounts.

A three-detector calibration was completed for routine lung counting in the Stainless Steel Room. This was necessitated by the removal from service of one detector due to degradation in the resolution. Routine counting with three detectors began on September 8. The three-detector decision level is about 15% higher than the four-detector value. Counting with four detectors resumed on October 15.

Quarterly measurements of the calibration phantoms were performed to verify current calibrations on the routine counting systems. The measurement results verified that the performance of the measurement systems remained stable through the year and that the calibration factors used to estimate activity were traceable to the primary calibration.

The algorithms for the routine counting systems were modified to include propagated error terms that included positioning error, counting statistics, and the calibration error. The unit for the error associated with the in vivo measurements was changed from percent to nCi beginning with the measurements performed on September 15, 1997. The HRRP staff converted the error values for the historical in vivo results in REX from percent to nCi.

4.2.4 Training

Training for the WBCP staff included training in specific procedures after revisions were made and monthly safety meetings. Periodic training sessions were also held to address technical issues as they arose. The instrument technician for the project attended a week-long training session at the Princeton Gamma Tech facility on the repair and maintenance of the 38-cm² HPGe detectors used for lung counting.

Training for a part-time technician to help cover activities at the front desk was completed. This included training in the whole body counting, the lung counting, and the facility end-of-day procedures.

4.2.5 Mobile Counter

In response to a request from the contractors to try to avoid having workers in the outer areas come into Richland for whole body counts, a technical review of the capabilities of portal monitors to function as whole body counters was performed in 1996. Based on cost, lack of sensitivity, and other operational issues a consensus decision was reached in 1997 with the contractors to not pursue the use of portal monitors as screening whole body counters. Instead it was decided to proceed with the deployment of the mobile whole body counting system in the outer areas. Initial planning for deployment of the trailer was started. However, input received from the PNNL, FDH, and ERC field dosimetry representatives later in the year indicated that they would not need the mobile counter in the 200 Area in FY 1997. The unit was placed in cold standby near the 747-A Building.

4.2.6 Equipment Maintenance

In 1997, six 38-cm² planar HPGe detectors required repairs. These detectors are used for routine lung counting. The WBCP staff repaired five of the detectors and one detector had to be returned to the factory for repairs. Three detectors suffered vacuum leaks, the preamplifier pole zero setting on one detector required an adjustment, and another detector's preamplifier had to be replaced. A replacement detector housing and a beryllium window assembly were purchased to facilitate testing and repair of the planar HPGe detectors. A spare beryllium window for the 38-cm² planar HPGe detectors was also purchased.

The hard disk on the IBM RS6000 failed on September 24. This prevented measurement results from being calculated with the routine algorithms and the data from being inserted into the ORACLE database. The hard disk was replaced, the operating system software and back-up data were reinstalled, and the system was put back in service on October 3. During the downtime, back-up procedures were used to continue counting. Measurement results for three individuals were lost, so the individuals were recounted. However, the impact of this major failure on the services provided to the Hanford contractors was minimal due to the concerted efforts of the staff.

The bearings for one of the axles for the Iron Room shielding door wore out and the axle fractured making the movement of the door impossible. The bearings and axle were replaced and the door control system was placed back into operation. During the time the door was inoperable lung counts in the Iron Room were performed with the shielding door open wide enough to allow persons to enter and exit safely. This slightly elevated the detection level for those measurements.

4.3 Supporting Investigations and Studies

The WBCP staff pursued six additional project related activities during 1997.

4.3.1 Am-241 Inhalation Case

A ninth set of lung, liver, and skeletal measurements was performed in May on an individual who sustained an inhalation of pure ^{241}Am in February 1996. Funding for the measurements was provided through the U.S. Transuranium Registry (USTR). The clearance half-time from the lung is estimated to be 240 days in this case, which is consistent with a material having a solubility between Class M (moderate) and Class S (slow). The lung clearance and uptake by the liver and skeleton are all adequately described with single exponential curves. Figure 4.3 is a graphic depiction of the clearance of the americium from the lungs in this case. At 450 days post intake, 18% of the measured activity (1.5 nCi) was in the liver, 32% in the skeleton (2.7 nCi), and 50% (4.2 nCi) remained in the lung.

Figure 4.3. Am-241 Activity in Lung Versus Time after Intake

4.3.2 Thoron-in-Breath Monitor

The development of the thoron-in-breath monitor (TIBM) was concentrated in three areas in 1997. These included establishing and verifying the primary calibration, accumulating measurements of non-occupationally exposed individuals, and developing the biokinetic model for thorium. Attempts to obtain reproducible calibration results were marginally successful. Although groups of three or four calibration results agreed within 15%, there were several results that were 30% to 40% different. Many factors were reviewed and tested in the search for an explanation, including the effects of humidity, purity of the air used for calibration, measurement of flow rate, tidal versus steady-state flow, and detection efficiency. The effects from these parameters did not completely account for the variation in the calibration data. The effects of grounding the chamber will be evaluated in early 1998.

Ten non-occupationally exposed subjects were counted with the TIBM. The preliminary results indicated a minimum detection level of about 0.1-0.2 Becquerel of thoron, which was slightly higher than anticipated. Adjustments made to the high-voltage and discriminator settings of the counters did not significantly reduce the counter's background.

The renewal paperwork required by the Institutional Review Board for Human Subjects for TIBM project was submitted and approved.

As part of the TIBM project, an integrated thorium metabolic model was coded and tested. The model incorporates the ICRP 66 respiratory tract model, the ICRP 69 thorium metabolic model, and a metabolic gas model for transporting the thoron that is produced systemically to the lungs (ICRP 1994 and 1995). Figure 4.4 graphically depicts the model. Applying the model to estimates of the exhaled thoron activity allows estimates to be made of the activity of ^{232}Th and progeny in different compartments of the body as a function of time after intake and ultimately to estimates of the original intake amount. The model is superior to previous thorium metabolic models because it treats the metabolism of thorium and radium separately instead of assuming that the metabolism of thorium and radium are identical and that it handles the transport of thoron produced systemically to the lungs. Figure 4.5 illustrates the thoron exhalation versus time after the acute intake of 1 Becquerel of 5-micron aerodynamic mean activity diameter (AMAD) particles with the ^{232}Th in equilibrium with all progeny. Similar data were generated for 1-, 10-, and 15- micron AMAD particles also. The modeling data will be used in 1998 to test the agreement between the TIBM results and in vivo measurement results.

4.3.3 DOE Phantom Library

WBCP staff continued to operate the DOE Phantom Library Program in 1997. The program is funded through DOE-HQ and makes in vivo calibration phantoms available to bioassay laboratories for calibrating measurement systems. The phantoms are loaned to DOE and other facilities for the cost of round-trip transportation. The program maintains the records and calibration information for the phantoms, provides technical assistance in the field of radiobioassay, and conducts validation measurements for organ phantoms.

Figure 4.4. PNNL Integrated Thorium Metabolic Model

Figure 4.5. Intake of 1 Becquerel ^{232}Th in Equilibrium with All Progeny, 5-micron AMAD

The DOE Phantom Library includes an inventory of 22 lung phantoms, 8 liver phantoms, 8 bottle-manikin absorption (BOMAB) phantoms, two sets of lymph node phantoms, an ^{241}Am skeletal phantom, a fission product phantom, a Lawrence Livermore National Laboratory (LLNL) torso phantom, and three thyroid phantoms. The 26 phantom loans made in 1997 represent a 326% increase over 1996.

4.3.4 Support to Pantex

Measurements of ^{228}Ac , ^{208}Tl , and ^{212}Pb were made to estimate the ^{232}Th lung and skeletal activity for several Pantex employees in January. The potential exposures to thorium oxide from weapons components occurred at least several years ago. There were no results above the detection level.

4.3.5 New In Vivo Counting Hardware and Software

A Digital Equipment Corporation (DEC) Alpha Workstation with the ABACOS in vivo counting applications software was purchased. The hardware was installed and the operating system configured for operation. This system will eventually replace the NEXEC system, which includes three platforms: the IBM RS6000, the DEC WS 3100, and the IBM personal computers (PCs). In 1998, the ABACOS system will be used to establish calibrations and set QC parameters, and it will be configured for handling personnel information and data transfer to REX.

4.4 Project-Related Professional Activities

Staff activities, presentations, publications, and professional memberships during 1997 are listed in this section.

4.4.1 Activities

Tim P. Lynch was involved in professional internal dosimetry activities outside of the Hanford Site, as follows:

- attended the DOE Intercalibration Lung Counting Workshop held at the Savannah River Site May 5-7.
- was lead assessor for the DOELAP onsite assessment of the bioassay programs at the Fernald Site on September 9-11.

Peter C. Olsen was involved in professional internal dosimetry activities outside of the Hanford Site, as follows:

- attended a meeting of the NIST Radiochemistry Intercomparison Program to discuss the establishment of NIST traceability and accreditation programs for radiochemistry and bioassay.

4.4.2 Presentations

Lynch, T.P. *The Giants of Lung Counting Detectors*. Presented at the DOE Intercalibration Lung Counting Workshop, May, 1997, Aiken, South Carolina.

Lynch, T.P., and R.L. Kathren. *The Assessment of Acute Am-241 Inhalation Intake Using In Vivo Counting Data*. Presented at the DOE Intercalibration Lung Counting Workshop, May, 1997, Aiken, South Carolina

Lynch, T.P., R.J. Traub, and J.R. Johnson. *A Status Report on Development of a Thoron-in-Breath Monitor*. Presented at the DOE Intercalibration Lung Counting Workshop, May, 1997, Aiken, South Carolina

4.4.3 Professional Memberships

Lynch, T.P., Chairman of the working group developing the ANSI N13.35 standard, *ANSI Standard for the Bottle Manikin Absorption Phantom*.

Lynch, T.P., Member of American Society for Testing Materials (ASTM) Task Group E-10.04.27, which is writing the ASTM standard, *Estimation of Low Energy Photon Emitters in a Wound*.

Olsen, P.C., Chairman of ANSI N13.31 Working Group writing the ANSI Standard, *ANSI Standard for the Torso Calibration Phantom for In Vivo Radiobioassay*.

Olsen, P.C., Member of ANSI N13.35 Working Group writing the ANSI Standard, *ANSI Standard for the Bottle Manikin Absorption Phantom*.

Olsen, P.C., Member of ANSI N13.44 Working Group writing the ANSI Standard, *ANSI Standard for Thyroid Calibration Standard Phantoms*.

5.0 Hanford Radiological Records Project

The HRRP supports 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. Despite the fact that the HRRP functions were split into two groups when the RPS was reorganized in October, this chapter reports on the 1997 radiological records activities as if the HRRP continued for the entire calendar year.

The HRRP uses the REX^(a) system, which includes a database of personnel radiological exposure data. 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 all of the 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 using identifiers (IDs), including 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 project also uses a compact disk imaging subsystem (called the LaserREX). All hard-copy exposure records, starting with January 1, 1992, are preserved on the LaserREX. The LaserREX also stores the electronic records created by the REX transaction log. Hard-copy records generated prior to 1992 are maintained on microfilm.

In 1996, FDH decided to contract the PHMC field dosimetry functions to RPS. The move of the responsibilities to RPS was completed in February 1997. As part of this move, HRRP took over the data administration responsibilities of the ACES (Access Control Entry System), but FDH retained ownership of ACES. The manager of HRRP (now Instrumentation Services) works closely with the FDH ACES manager in the operation and maintenance of the system.

The ACES was created to implement a system for computerized 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. ACES uses the SUN Solaris operating system with ORACLE software to manage the database and provide entry screens and reports from the SUN SPARCserver 1000 minicomputer. The database receives data from several other Hanford computer systems (e.g., PeopleSoft, REX, PeopleCORE, and Hanford Health Scheduling [HHS]). Users access the minicomputer via PCs connected to the Hanford Local Area Network (HLAN). Further information on ACES can be found HRRP-02, *Access Control Entry System (ACES) User's Manual* (PNNL 1997).

(a) A description of the REX database is provided by Lyon et al. (1994).

Records in the Hanford Radiation Protection 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.

The program is operated under the applicable sections of 10 CFR 835 (DOE 1993); the HSRCM-1 (RL 1994); ANSI N13.6, *American National Standard Practice for Occupational Radiation Exposure Records Systems* (ANSI 1972); as well as the following DOE Orders: 1324.5B, *Records Management Program* (DOE 1995a); and 231.1 *Environment, Safety and Health Reporting* (DOE 1995b). The program also complies with the applicable sections of the Privacy Act (1974) and the Freedom of Information Act (1966).

5.1 Routine Project

The HRRP is organized into four major functional areas: data administration, data handling, report issuance, and the Records Library. Both data handling and report issuance are performed by the HRRP Data Processing Center.

The database administrator evaluates systems, troubleshoots, resolves system and user problems, trains users, oversees system security, serves as liaison with the Lockheed Martin Services, Inc. (LMSI) computer analysts, and initiates and tests modifications of the databases for both the REX system and ACES.

Data handling includes entering data into the REX database and validating all data entry. 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.

The report issuance function provides for generation and issuance of routine exposure status reports to the contractors, quarterly person rem and annual statistical reports to DOE, annual reports to employees, and special reports requested by former employees, as well as those requested by the contractors, RL, the Uranium and Transuranium Registries, and Privacy Act and Freedom of Information Act petitions. This function requires close contact with RL, the contractors, and other personnel dosimetry functions.

The Records Library maintains individual exposure records that are not reducible to database elements and back-up documentation as well as the Hanford Radiation Protection 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 HRRP Data Processing Center staff. The hard copies are then sent to the library for preservation on the imaging systems. Table 5.1 presents CY 1997 statistical information on many of the documents that are entered into the database and indexed into LaserREX. Some documents, such as the Employee and Dosimetry Change Form, may contain several pieces of information that require data entry.

The HRRP was moved from the 331 Building to the 318 Building in June when RPS (except the Whole Body Counter) was consolidated in a single facility.

Table 5.1. Records Activity for Calendar Year 1997

Document Type	Number
Personal Radiation Exposure History Form (used to document exposure history prior to Hanford and to initiate a record for a new or rehired employee)	2,455
Employee and Dosimetry Change Forms (used to document personnel data or dosimetry changes)	4,099
Employee and Dosimetry Change Forms (used to document employee terminations; many changes were done electronically not requiring forms)	4,095
Temporary Dosimeter Assignment Forms (used for issuing temporary dosimeters to employees due to new hires, changes in dosimetry requirements, multiple dosimetry, or employees who forgot their dosimeters)	13,237
Visitor and Subcontractor Dosimeter Issue Forms (used to issue dosimetry to visitors and subcontractors not completing radiological worker training)	2,891
Investigation of Dosimeter Result Forms and Change Letters (used to estimate exposure for lost, damaged, or otherwise suspect dosimeter results)	2,275
Special Process Forms (used to document data for specially processed dosimeters)	8,796
Requests for Exposure Summaries (summaries requested for current and prior Hanford employees)	422
Letters Sent to Request Prior Exposure (to request summaries for new employees with prior exposure or existing employees receiving exposure at offsite facilities)	1,069
Total number of hard-copy records scanned and indexed into LaserREX ^(a)	39,751
(a) This total is for all of the hard-copy records scanned and indexed into LaserREX, some of which are not listed in this table.	

5.1.1 Assessments and Surveillances

An independent assessment was conducted by PNNL Quality Programs in August and the resulting report listed 8 minor observations. The corrective actions were being worked on at year's end.

The RL PAD performed a surveillance to evaluate the performance of the Hanford contractor dosimetry records program. The RL surveillant requested a number of records, primarily Investigation of Dosimeter Result (IODR) and dose adjustment forms from the HRRP. There was one finding:

Personnel dose records contain an unacceptably high percentage of deficiencies and the processes to prepare and review these records lack formality and detail. These deficiencies were primarily associated with records for determining the dose of record when the primary dosimeter is not available (lost/damaged).

The discussion focused on four elements, as follows:

- Personnel dose records contain errors and insufficient justification for the doses being assigned.
- Records do not contain required policy and technical support information necessary to understand changes in methods for documenting dose estimates.
- Procedures and training for processing the dose assessment documents for lost, damaged, or multiple dosimeters need significant improvement.
- An excessive number of records result from lost dosimeters.

The finding involved all contractors, as well as RPS. The HRRP manager coordinated the responses and prepared the joint response letter for RPS and PNNL's Radiological Control Operations. Corrective actions were implemented by all concerned. The following corrective actions were performed by RPS.

- For the first element, the HRRP manager agreed to perform a quality check on all IODRs and dose adjustment forms. HRRP Procedure QC-03, "Reviewing Contractor IODRs and Dose Revision Paperwork" was finalized and placed in the *Hanford Radiological Records Project Procedures Manual*^(a)
- For the second element, Dosimetry Operations staff finalized Procedure 800.1.35, "Dose Adjustments on Multi-Paks," which is used to assess multiple dosimetry results for PHMC, and placed it in the *Hanford External Dosimetry Project Procedures Manual*.^(b)

(a) Internal Manual, HRRP-01, Pacific Northwest National Laboratory, Richland, Washington.

(b) Internal Manual, PNL-MA-841, Volume 2, Pacific Northwest National Laboratory, Richland, Washington.

- For the third element, Dosimetry Operations staff finalized Procedure 800.1.136, "Issuing Estimate Letters" used by PHMC for documenting estimated doses for lost dosimeters for inclusion in the *Hanford External Dosimetry Project Manual*. While the procedure was being prepared and approved, an approved Desk Instruction was used.

No RPS responses were required for the fourth element. The contractors have made significant improvement in decreasing the number of lost dosimeters.

5.1.2 REX Database

Due to changes in the REX system and operating procedures over the past several years, overtime required during the year-end processing was eliminated, compared with the 1 to 4 days required in prior years.

The REX database was also determined to be Year 2000 compliant. This means that it will recognize that the entry of the numbers '00' are for the year 2000, not the year 1900; and '01' means 2001, not 1901, etc. This is because of a program inserted during the development that converts all two-digit year entries to a four-digit number behind the screens, and recognizes when 20XX should be used instead of 19XX.

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:

- A number of new exposure status reports were requested by the PHMC^(a) because the organization codes (also called "cost codes") no longer supplied doses in the order needed to respond to contract requirements. The new reports were sorted by department ID (also called "tracking code") and facility location (with certain buildings defined in each facility) code. This programming took about 3 months because new tables had to be established and new programs written.
- There were a number of screen and code changes to make the system more efficient for the users and to account for new processes. For example:
 - A number of changes were made allowing users to easily toggle back and forth between different frequently used screens, reducing the time required to perform certain functions.
 - A comment field was added to screen DU06 where notecode 64 dosimeters will be returned.

(a) A description of the PHMC is provided by Lyon et al. (1997; in Chapter 5.0).

- The new notecode 64 was added, which designates a partial period monthly or quarterly dosimeter that will not be special processed; it is not a frequency change.
- A new whole body examination code was added to account for a new type of whole body count using the coaxial counter instead of the stand-up counter. The new code WC will be used for the coax counter and WB will be used for the stand-up counter.
- The subcontractor report that was used previously to report a subcontractor's employees exposure directly to the subcontractor management was discontinued. The report was no longer needed, because of changes in the DOE regulations specifying to whom to send exposure records and because any subcontractor employee that is a radiation worker will be issued a Resident Non-Employee payroll number. The Resident Non-Employee will be listed on the status report and receive a termination letter upon termination. Anyone not issued a Resident Non-Employee number will be considered a visitor and will be listed on the visitor status report and receive a visitor exposure letter when they leave the site.
- The Whole Body Counter changed the reporting of error from percent to nCi. REX was programmed to accept the new data and convert all of the old data to the new error reporting format. This effort coincided with the preparation of a data feed to the University of Washington (discussed below under Special Projects), because all off-line data had to be brought on-line so every record was changed to the new format.
- Changes in the batch control screen were programmed and adjustments were made to each of the applicable printers, because the REX PRINT software was moved from an OS server to a NT server.
- REX was modified to resolve problems in ACES deleting pencil dosimeter results improperly when REX downloads the results of two dosimeters issued on the same date (in multi-pak situations).
- REX was modified to note when the bioassay is waived, because the contractors are now waiving bioassays if individuals have not worked on a RWP that needs a bioassay since the last sample. A new screen was developed, a function key was added to screen GU01 to toggle to the new screen, a waiver letter was programmed to be printed automatically, and the waiver was added to the ACES download.
- The Performance Indicator reports for RL were modified to provide more and better data.

In July, an upgrade to the DB2 and CICS software on the Enterprise Server created problems with the Platinum Report Facility (PRF) ad hoc reporting facility, some REX screens, and the communications between LaserREX and the host. The PRF and screens were corrected within days; however LaserREX had to be reprogrammed to accommodate the changes and the ability to index documents into the system was negated for several weeks.

5.1.3 LaserREX Imaging System

A major upgrade to LaserREX allowed designated RPS staff to have access to the jukebox, through the HLAN. This enables them to bring documents that have been scanned and indexed into the system up at their own work stations. This has saved considerable time and effort by data processing, data administration staff, and the Records Library, who previously had to provide the documents to staff upon request.

The LaserREX consultant worked with some local PNNL hardware and software technicians to train them to work on the system and reduce the need to contact the consultant.

5.2 Supporting Projects

Epidemiology data were supplied to the University of Washington for the Hanford Worker Health Studies Project. The University staff requested radiation exposure data for every worker at Hanford since 1944. This required bringing all off-line records on line for a period of time.

Project personnel met with staff from the National Institute of Occupational Safety and Health (NIOSH) to find a way to supply NIOSH with most of the personnel radiation exposure microfilm file and the microfilm of the Hanford Radiation Protection Historical Files (which consist of over 2,000 reels) and their indices at a reasonable cost. It was proposed that the original microfilm negatives be copied onto new diazo film for NIOSH and the indexes be put into an electronic form so that NIOSH can install them in their computer. It was estimated that this process could be accomplished for slightly over \$22K. The original estimate to provide paper copies of the 2,000 plus reels was in the neighborhood of \$160,000. Funding was still being pursued at the end of the calendar year.

In 1996, HEHF decided they could no longer provide in vivo scheduling services to the site, because of new risk-based medical scheduling protocols that had to be developed for their new computer systems. It was decided that a new in vivo scheduling program would be developed in REX. This effort was started during 1996 and completed in February. The requirements were completed by meeting with the contractor field schedulers and the whole body counting staff. The new system performs some functions that the HEHF system did not. This was a major programming effort and the resulting program has performed very well.

At the request of the PHMC ACES manager, the original ACES user's manual, which was produced several years ago by Westinghouse Hanford Company, was completely rewritten and published as a PNNL document (PNNL 1997).

5.3 Project-Related Professional Activities

Staff professional memberships during 1997 are listed in this section.

5.3.1 Professional Membership

Lyon, M., Chairman of the Health Physics Society Standards Committee Working Group to Revise ANSI N13.6, *American National Standard Practice for Occupational Radiation Exposure Records Systems*.

6.0 Instrumentation Services Project

The ISP 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 project during 1997 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.

6.1 Project Description

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 1997, the ISP continued to provide complete instrument services. As the Hanford Site's mission and scope continued to evolve to a more privatized, cost-efficient operation, the ISP made required scope and operational changes.

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 1997 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 ISP 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 ISP and commercial calibration services.

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 the ISP 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 (DOE 1993), and HSRCM-1 (RL 1994). Calibrations are performed using the mandatory guidance in ANSI N323-1978, *Radiation Protection Instrumentation Test and Calibration* (ANSI 1978). The ISP activities fall under the base tasks that comprise the CY 1997 program: 1) administration of the Hanford Site pool of portable survey instruments; 2) calibration and maintenance service of Hanford pool, PHMC, PNNL, and BHI radiation protection instruments; 3) evaluation and publication to the 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. These basic tasks and other important supporting tasks performed in CY 1997 are described in this section.

During CY 1997, approximately 16,000 calibrations were performed by ISP (see Table 6.1). The total number of calibrations performed cannot be directly compared with the volumes reported for previous years due to redefinition of the calibration classes.

Table 6.1. Calendar Year 1997 Instrument Calibrations by Unit-Price Category

Calibration Class	Description of Class	Number of Calibrations
CAMs	Continuous air monitors	495
Detectors	Probe or detector only	3944
Electronic Dosimeters	Direct reading, electronic dosimeter	804
Full Calibration	Integral meter and detector	265
Meter only	Electronic calibration of meter or readout	3973
Pocket Ionization Chambers	"Pencil" dosimeter	3946
Smart Detectors	Stand-alone calibration of a "smart" detector	487
Sources	Certification of source activity or emission rate	386
Special Calibrations	Complex calibrations charged by the hour	68
Total		16,637

6.2 Project Improvements in Calibration and Maintenance Operations

A primary improvement during CY 1997 was the unbundling of the calibration costs for Hanford contractors. The traditional calibration charge has included numerous services beyond routine calibration. These services include instrument pick-up and delivery, records maintenance, and instrument configuration control. To allow customers to select desired services, and to not pay for undesired services, the individual services were separated from the base calibration charge. One of these services was the maintenance of the internal *Radiation Protection Instrument Manual* (PNL-MA-562). Based on input from Hanford Site customers, who did not choose to continue funding it as a separate project, the manual was retired during CY 1997.

6.2.1 Instrument Evaluation and Testing

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. 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 1997, 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.

The HIEC also revised its charter during CY 1997. The new charter allows for the chair position to rotate annually between each of the prime contractors. ISP maintained responsibility for the HIEC records and continues to serve as the committee Secretary. This structure is similar to the structure used by the RadCon Forum and was selected to give contractors greater ownership of HIEC activities.

6.3 Supporting Investigation and Studies

Six supporting investigations or studies were undertaken during the year.

6.3.1 Testing to Qualify Site Instruments for Use in the Hanford Environment

In support of the site contractors' requirements for 10 CFR 835, several radiation detection instruments used onsite were evaluated for compliance with the required qualification and documentation of being appropriate for use in the Hanford Site environment. The instruments included a modified Eberline RO-7 mid-range detector with increased sensitivity, the Eberline RO-20 ionization chambers, a Siemens EPD2 electronic dosimeter with beta window, and the Eberline E-600 smart portable with associated "smart" detectors.

6.3.2 Chornobyl Neutron Monitoring System Technical Assistance

In support of the DOE International Nuclear Safety Program, technical support was provided to several projects related to the Chornobyl Shelter and Decommissioning Program. These projects included technical support in the design and manufacturing of a Neutron Monitoring System to be installed in the Chornobyl Shelter to monitor for and characterize changes in neutron flux. Other projects included procurement and acceptance testing of instruments and equipment for the Shelter Dose Reduction Project. The equipment ranged from routine survey equipment to installed gamma spectroscopy and whole body counters.

6.3.3 RO-20 Correction Factors

A new ionization chamber was selected by several customers to replace the standard Eberline RO-3B "CP" (cutie-pie) offered through the portable instrument pool. The replacement instrument is the Eberline RO-20. The ionization chambers are frequently used to establish exposure rates from sources smaller than the instrument's open window and/or from beta sources. In these situations, ionization chambers under-respond, and a correction factor needs to be applied to accurately determine the exposure rate. The RO-3B CP was fully characterized many years ago and appropriate correction factors are provided to the field on a label that is permanently attached to the instrument. This same type of information was required for the RO-20. ISP completed an extensive study comparing true exposure rates from various sizes of gamma and beta sources with the exposure rate reported by the RO-20. The results allowed for the development of a family of correction factors for the RO-20 similar to those provided with the CP.

6.3.4 Development and Introduction of the 100-cm² Portable Alpha Meter

The drive to detect lower and lower levels of alpha contamination led to a need for alpha survey instruments with lower detection limits than could be met with the standard Hanford portable alpha meter (PAM), which has a 50-cm² window. Because lower (i.e., better) detection limits can be achieved with larger windowed detectors, a 100-cm² detector was developed by ISP to replace the 50-cm² PAM detectors (see Figure 6.1). The 100-cm² PAM detector has several advantages over similar commercially available detectors, the chief one being that it is far cheaper to produce. Secondary advantages are its thinner profile for surveying in tight areas and its lighter weight.

The 100-cm² PAM was evaluated and approved by the HIEC. Following its approval, the 100-cm² PAM was made available to Hanford customers.

In addition to introducing the 100-cm² PAM to the Hanford Site, several commercial manufacturers entered into negotiations with Battelle for the rights to license and market the detector design. Ultimately, none of the commercial manufacturer's elected to license the design.

Figure 6.1. 100-cm² Portable Alpha Meter Detector

6.3.5 Evaluation of Waste Encapsulation and Storage Facility On-Line Beta Monitor

Technical support was provided to the Waste Encapsulation and Storage Facility (WESF) in characterizing and performing a primary calibration of the on-line beta monitor (OLBM). The OLBM is a scintillation detector that is in intimate contact with the water from the WESF storage pools. The primary calibration required replicating the operational conditions (i.e., calibration required the use of liquid sources). ISP completed the evaluation and primary calibration.

6.3.6 Radiological Control Technician Recertification Training

ISP provided support and facility space in the Cycle I Radiological Control Technician (RCT) retraining performed by FDH. The focus of the RCT training cycle was the use and limitations of portable survey instruments. ISP assisted in developing several hands-on laboratory type exercises designed to illustrate specific capabilities and limitations of typical instruments. The exercises demonstrated differences in instrument response to different photon energies and source dimensions. They also demonstrated the effectiveness of various shielding materials and the penetration capabilities of beta radiation.

6.4 Project-Related Professional Activities

Staff presentations and external professional activities during 1996 are listed in this section.

6.4.1 Presentations

Froelich, T.J., "Introduction to Radiation and Radioactive Material," "Health Effects of Radiation," and "Radiation Protection and Instrumentation," classes presented to Hungarian and Slovakian Border Officials at the Hammer Facility sponsored by U.S. Customs and U.S. Onsite Inspection Agency (OSIA), September 23, 1997.

6.4.2 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*.

Johnson, M. L., President of the Columbia Chapter Health Physics Society.

7.0 Radiation Standards and Calibrations Project

The primary function of the Radiation Standards and Calibrations (RS&C) Project is to maintain the necessary radiological reference fields to facilitate appropriate characterizations and calibrations within the Hanford RadCon Instrumentation Services (RISP) Project 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 response to various radiation fields encountered at Hanford and ensures that calibration fields are described in accordance with recommended standards and guides. Typical project activities include

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

Project activities conducted during CY 1997 are discussed in the following sections.

7.1 Routine Tasks

Routine activities conducted by project personnel included maintaining radiological standards and capabilities and radiological reference fields traceable to national standards.

7.1.1 Standards and Capabilities

The radiological standards and capabilities maintained for the various entities of Hanford Radiological Protection Support Services 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 artifacts (e.g., environmental or personnel dosimeters and radiological survey instruments) for providing NIST-traceable calibration and/or response characterization.

Gamma Ray Sources

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 2π 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 318-131, provide a continuum of exposure rates via use of an artifact positioning

Table 7.1. Available Gamma-Ray Sources (1997)

Source	Geometry	Nominal Rate/Range [R(rem)/hr]	Location in 318 Bldg.	Reference No.	Primary Photon Energy (MeV)
⁶⁰ Co	Open	2 / 7	Rm. 106	318-164	1.17/1.33
	Beam	3 - 1500	Rm. 8	318-037	
	Beam	210 - 57000	Rm. 8	318-353	
¹³⁷ Cs	Well	10 ⁻⁴ - 0.130	Rm. 121	318-031	0.662
	Well	0.026 - 2.700	Rm. 121	318-030	
	Well	0.005 - 25.600	Rm. 121	318-288	
	Beam	0.080 - 25.600	Rm. 8	318-040	
	Open	0.400 / 2.000	Rm. 106	318-001	
	Beam	1 - 250	Rm. 8	318-044	
	Open	1 / 8	Rm. 106	318-029	
	Beam	3 / 30	Rm. 6	318-131	
²⁴¹ Am	Open (2 π)	0.125	Rm. 6	318-184	0.060

stand located on a sliding-rail system. Source 318-131 also includes a moveable stand, but is typically characterized and used only at the 1- and 3-meter 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 without undue exposure to personnel. 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 ⁶⁰Co. 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 artifact being irradiated. The range of available exposure rates extends from 30 to 10⁷ 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 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

Two identical Philips Model-324 tungsten-target x-ray machines are currently in use in support of the RS&C Project. One machine is used to produce bremsstrahlung (broad) photon spectra (e.g., NIST techniques M30, S60, M150, H150, etc.) while the second is configured for K-fluorescence technique (narrow) secondary photon spectra (e.g., 17 and 59 keV) within a shielded enclosure. These reference fields are used for characterization of artifact photon energy dependence in the general region of 10 to 200 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 artifact photon energy dependence. K-fluorescence techniques have highly discrete peak energies and are also well suited for energy characterization studies, although the maximum energy currently obtainable 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 and 7.2b provide a complete list of currently available techniques, their characteristics, or production methods and the nominal exposure rates available. Both of these systems are equipped with laser alignment capabilities to aid in detector/dosimeter positioning.

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

Neutron Sources

Two configurations of ^{252}Cf neutron sources are available. One configuration allows 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 meters wide, 14 meters long, and 8.8 meters high, such that a low-scatter environment is established. Sources may be used bare or moderated by a sphere of deuterated water (D_2O) 15 centimeters in radius, enclosed within a thin stainless steel shell and covered by 0.051 centimeters 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 International Standards Organization (ISO) Standard 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).

Table 7.2a. Available Bremsstrahlung X-Ray Reference Fields (1997)

Technique ^(a)	Energy (keV) ^(b)	Average	Effective	Half Value Layer (mm Al)		Homogeneity Coefficient		Last HVL & HC Assessed	Demonstrated Traceability ^(c) (Last Year Tested)	Exposure Rate (R/hr) ^(d)			
				PNNL ^(e)	NIST ^(d)	% Diff.	NIST			% Diff.	Minimum	Maximum	
M20		14		0.150	0.152	-1.3	0.79	0.79	0.0	10/86	No	2.9	288.6
M30		20		0.3521	0.36	-2.2	0.6287	0.64	-1.8	8/93	Yes (1992)	3.2	326.1
M50		29		1.005	1.02	-1.5	0.643	0.66	-2.6	8/93	Yes (1995)	3.4	350.9
M60		35		1.598	1.68	-4.9	0.690	0.68	+1.5	3/95	No	3.2	310.0
M100		53		4.949	5.0	-1.0	0.721	0.72	+0.1	3/95	Yes (1992)	1.5	305.0
M150		73		9.90	10.2	-2.9	0.85	0.87	-2.3	9/97	Yes (1997)	3.8	391.4
M200		100		(f)	14.9	(f)	(f)	0.95	(f)	(f)	No	4.3	431.0
S60		38		2.659	2.8	-5.0	0.768	0.75	+2.4	3/95	Yes (1989)	0.6	119.6
S75		40		1.817	1.86	-2.3	0.61	0.63	-3.2	7/93	No	4.6	472.2
H40		33		(f)	2.9	(f)	(f)	0.94	(f)	(f)	No	0.02	4.20
H50		38		4.102	4.2	-2.3	0.922	0.92	+0.2	6/86	No	0.05	9.40
H100		80		13.472	13.5	-0.2	0.964	1.00	-3.6	6/86	No	0.02	3.07
H150		120		17.09	17.0	+0.5	1.003	1.00	+0.3	9/97	Yes (1995)	0.12	16.5
H200		166		20.22	19.8	+2.1	0.994	1.00	-0.6	6/86	No	0.09	9.22
H250		211		22.48	22	+2.2	0.987	1.00	-1.3	6/86	No	0.09	8.50

(a) Routine calibration maintained only for shaded techniques. All others are calibrated as needed.

(b) Nominal

(c) All PNNL techniques are characterized and referenced at a distance of 100 cm

(d) Most NIST techniques are characterized and quoted at a distance of 50 cm if distance is critical to the quality of the spectra.

(e) Demonstrated traceability is established through measurement QA interactions with the NIST. In most cases, NIST arbitrarily selects one or more techniques for intercomparison approximately every other year.

(f) Projected full characterization in 1998.

Table 7.2b. Available K-Fluorescence Reference X-Ray Fields (1997)

Theoretical Peak Energy (keV) ^(a)	Production Method				Demonstrated Traceability ^(c) (Year Tested)	Exposure Rate (R/hr) ^(b,c)	
	PreFilter	Radiator/Attenuator	Filter	kVcp		Minimum	Maximum
8.6	Not Used	Zinc	---	50	No	0.13	19.8
15.8	Not Used	Zirconium	SrCO ₃	80	Yes (1986)	0.02	3.2
17.5	Not Used	Molybdenum	Zirconium	80	No	0.02	3.4
25.3	Not Used	Tin	Silver	100	No	0.02	3.5
31.0	Not Used	Cs ₂ SO ₄	TeO ₂	100	Yes (1986)	0.02	3.2
37.4	Not Used	Neodymium	Cerium	110	No	0.009	1.4
40.1	Not Used	Sm ₂ O ₃	CeO ₂	120	No	0.01	1.4
49.1	Not Used	Erbium	Gadolinium	120	No	0.005	0.8
59.3	Not Used	Tungsten	Yb ₂ O ₃	170	Yes (1986)	0.005	0.8
59.3	Not Used	Tungsten	Ytterbium	170	No	0.006	0.9
(a) Routine calibration maintained only for shaded techniques. All others are calibrated as needed.							
(b) Nominal							
(c) Minimum/maximum estimated at 0.1/15.0 mA							
(d) Demonstrated traceability is established through measurement intercomparison with the NRPB.							

The second configuration involves a ²⁵²Cf 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 ²⁵²Cf under free-field conditions, for selected instruments.

Beta Particle Sources

Beta particle sources (¹⁴⁷Pm, ²⁰⁴Tl, and ⁹⁰Sr/⁹⁰Y) are maintained for dosimetry and instrument characterization. Available sources are listed in Table 7.3 and include those manufactured by Amersham-Buchler and 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. Currently available Amersham-Buchler ¹⁴⁷Pm sources have decayed to the extent that renders them useless for most dosimeter irradiation or instrument characterization purposes. A higher activity replacement was procured; however, during its characterization, above-normal photon contamination was indicated. An investigation of this continues prior to its acceptance for general use. Measurements have been made of all Amersham-Buchler sources and the Amersham-U.S. ⁹⁰Sr/⁹⁰Y sources to verify satisfactory compliance with HPS N13.11 (ANSI/HPS 1993); DOE/EH-0027 (DOE1986b); and ISO Standard 6980, *Reference Beta Radiations for Calibrating Dosimeters and Doseratemeters and for Determining Their Response as a Function of Beta Radiation Energy* (ISO 1984).

Table 7.3. Available Beta Reference Fields (1997)

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)	0.15 (20)
	²⁰⁴ Tl (318-109)	Silver (20)	Gold (5)	0.53 ≤ E _{res} ≤ 0.76 (T)	0.009 (30)
	²⁰⁸ Tl (318-192)	Glass (6.6)	Kapton (~0.8)	0.608 (M)	1.16 (35)
	⁸⁵ Kr (318-009)	Not Available	Not Available	Not Available	3.29 (50)
	⁹⁰ Sr/ ⁹⁰ Y (318-013)	Silver (50)	Stainless Steel (~75)	1.80 ≤ E _{res} ≤ 2.274 (T)	0.50 (30)
	⁹⁰ Sr/ ⁹⁰ Y (318-102)	Titanium (100)	Aluminum (20)	Not Available	0.47 (35)
	⁹⁰ Sr/ ⁹⁰ Y (318-012)	Silver (50)	Stainless Steel (~75)	2.046 (M)	19.75 (30)
	⁹⁰ Sr/ ⁹⁰ Y (318-103)	Titanium (100)	Not Available	2.085 (M)	13.84 (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)		0.48 - 0.008 (0.2 - 15)
	²⁰⁴ Tl (318-128)	Not Available	Kapton (9.5)		0.84 - 0.03 (0.2 - 30)
	⁹⁰ Sr/ ⁹⁰ Y (318-129)	Not Available	Kapton (23.5)		4.19 - 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/cm² as of mid-year (1997)

(c) The source is polymerized with the Polymethylemethacrylate. Sheet thickness is approximately 1 mm with activity uniformly distributed throughout.

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 been evolving 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: 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 demonstrated consistency, which can be established through a measurement quality assurance (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 (i.e., artifact

traceability). A disadvantage of traceability based only upon implied consistency is the lack of demonstration that indicates 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 it be 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&C Project 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 descriptions provide 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. Prior to 1997, five AICs had been submitted for calibration to ^{137}Cs , ^{60}Co , and many of the available NIST x-ray techniques, including all but one (M20) of the bremsstrahlung techniques listed in Table 7.2. In calibrating these instruments directly to NIST "primary standard" reference fields, they are deemed "secondary standards" and are used within the process of calibrating other radiological reference fields and/or reference instruments for use as tertiary or working standards. The most common traceability pathway currently in use 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 and, in fact, tends to slightly reduce the calibration uncertainty; however, it exposes the valuable secondary standards to increased use and the potential for damage. This practice is, therefore, gradually being reduced.

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 1997, NIST selected ^{137}Cs and M150 x-rays for intercomparison. The results of this intercomparison were well within the NIST-specified tolerance of $\pm 5\%$, as shown in Table 7.4.

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 a pathway similar to that identified in Figure 7.3, the primary reference field is maintained by the National Radiation Protection Board (NRPB) of the United Kingdom. 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.

AIC = Air Ionization Chamber

Figure 7.3. Typical Traceability Pathway for PNNL Photon Reference Fields

Table 7.4. Results of 1997 Photon Measurement Quality Assurance Test

Reference Field	NIST Value (Gy/Coulomb)	PNNL Value (Gy/Coulomb)	Percent Difference
M150	9.0559E+05	9.067E+05	0.12
¹³⁷ Cs	9.3880E+05	9.368E+05	-0.21

Neutron Standards

Neutron traceability for all irradiations and measurements performed using PNNL sources is currently implied only. The primary pathway to NIST is through direct calibration of PNNL ²⁵²Cf 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 Model NP-2 portable neutron monitor (SNOOPY) and an Eberline NRD neutron probe, are maintained as tertiary standards, which are used to convey the free-field dose-equivalent rate established in a low-scatter environment to a calibration well equipped with a bare ²⁵²Cf source. 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 ²⁴⁹Cf, ²⁵⁰Cf and ²⁵¹Cf), which are difficult to eliminate during source manufacture and are not directly identifiable via a single NIST calibration. Also, when configured with the D₂O moderating sphere, there are concerns about subtle differences between the NIST design, which almost completely surrounds the source, and the PNNL assembly with an inherent void, which allows for placement of the sphere around the end tube of 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 continues to be treated as a component of uncertainty rather than being used as a correction factor applied to the dose equivalent rate.

Figure 7.4. Typical Traceability Pathway for PNNL Neutron Reference Fields

During the past several years, numerous joint efforts have been made between NIST and PNNL to establish a suitable method for neutron MQA intercomparisons in order to demonstrate traceability. These intercomparisons have involved various measurement devices and outcomes and, although nominal agreement has been somewhat poorer than is typically observed for beta and photon fields, the results are encouraging. NIST performed measurements at PNNL during 1997 in their continuing effort to establish a suitable method for demonstrating traceability. As in previous pilot intercomparisons, there were noteworthy differences for both bare and D₂O-moderated source configurations. The latest measurements were performed using a Harwell REM-meter, which is configured with a ³He detector placed in the center of a 9-inch polyethylene moderator. It is reported that the moderator contains an inner spherical shell of cadmium mesh. Results from these measurements are shown in Table 7.5.

These results spawned further modeling efforts (described in Section 7.2.2) with the intent of identifying viable physical reasons for these differences. Notably, source anisotropy is one such term.

Table 7.5. Results of 1997 ^{252}Cf Neutron MQA Measurements
(50 cm distance; no corrections for PNNL source anisotropy)

Reference Field	NIST Value (rem/h)	PNNL Value (rem/h)	Percent Difference
Bare	6.949	7.832	12.7
D ₂ O-Moderated	1.568	1.890	20.5

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 $^{90}\text{Sr}/^{90}\text{Y}$ (318-012 and 318-013) and ^{204}Tl (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, which it has characterized/verified both quantitatively and qualitatively.

PNNL maintains a Physikalisch-Technische Werkstätten (PTW) extrapolation 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 similar isotopic distribution as the PTB sources, but with subtle differences in construction material and/or activity, including 318-102, -103 and -192 (see Table 6.3). The $^{90}\text{Sr}/^{90}\text{Y}$ 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 G Bq] at PNNL by a visiting NIST scientist). The latter source was calibrated with PNNL's PTW extrapolation chamber. Based on the level of these calibrations, source 318-102 is also considered a secondary standard and source 318-103 is relegated to tertiary level. The traceability pathway for beta reference fields and the extrapolation chamber is shown in Figure 7.5.

The periodic MQA intercomparison NIST conducts with the PNNL calibrations laboratory involves the use of a NIST 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 the transfer standard used for these measurements may be sensitive to differences in these parameters. No beta MQA measurements were performed during 1997.

Figure 7.5. Typical Traceability Pathway for PNNL Beta Reference Fields

7.1.3 Calibrations and Constancy Checks

Following initial or annual calibrations, periodic verification measurements are performed to ensure constancy of characteristics and magnitude for most radiation reference fields maintained by the RS&C Project. Historically, the philosophy has been to perform extensive annual calibrations and less-involved constancy verifications, typically on a quarterly frequency. The stability of reference fields demonstrated for previous years, along with continuing efforts to reduce costs, has prompted consideration of a revision of this methodology. Although some reference fields were still verified in this way during most of 1997, further changes will be initiated for selected sources during subsequent years using several criteria. For radioactive sources, these criteria may include, but are not limited to

- 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 will include

- 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).

The format for source verifications in 1997 are summarized in the following sections.

Photons

For each beam and open geometry photon field generated by a radioactive source in which no automated positioning system is involved (including ^{60}Co source 318-164; ^{137}Cs sources 318-001, -029, and -131, and ^{241}Am source 318-184) verifications were performed to ensure constancy at intervals not greater than 6 months. Each of these reference fields is monitored by a QC device capable of verifying continued accuracy within $\pm 3\%$ between constancy verifications. No out-of-tolerance conditions were identified for these sources during 1997 and the exposure rate of record for each source was left unchanged, except for routine decay corrections where needed.

Photon calibration ranges employing positioning systems (including ^{60}Co source 318-037 and -353 and ^{137}Cs sources 318-030, -031, -040, -044 and -288) were recalibrated once during the year to provide data for modifying the computerized exposure rate calculational routine, which determines programmatic instrument calibration positions. In addition, Well 1 (318-031) was calibrated an additional time after the installation of new laser distance-measuring equipment. To ensure relative constancy of these systems, at least one interim verification was performed during the year. No out-of-tolerance conditions were identified from these verifications.

Frequently used x-ray reference fields, as identified in Table 7.2, were verified at the beginning of each calendar quarter. These verifications involve an assessment of the transmission chamber exposure-to-charge-output ratio using a suitable working standard (AIC) for each selected technique. The 1997 verifications were plotted in addition to historical data from the past several years to assess the long-term stability of the system. The results of this assessment, shown in Figure 7.6, indicate that the system is in reasonable control. Selected K-fluorescence x-ray techniques were verified at the beginning of each calendar quarter or as necessary, such that any technique used was verified within the 90 days prior to its use.

Figure 7.6. Long-Term Stability of X-Ray Reference Fields

In addition to the routine exposure rate verification measurements for the bremsstrahlung x-ray reference fields, several techniques underwent qualitative assessment, including the assessment of the half value layer (HVL) and homogeneity coefficient (HC). The beam codes assessed in 1997 included M150, M100, and H150. As part of these measurements, a new set of aluminum attenuators was incorporated and validated via comparative measurements with an older set using the M150 beam code. The new set of filters, quoted as 99.99% pure aluminum, compared favorably with the older set. The results of the HVL and HC measurements confirmed the constancy of beam quality and results agreed well with the $\pm 5\%$ and $\pm 10\%$ respective tolerances allowed by NIST. The updated values are provided in Table 7.2a.

Neutrons

The LSR ^{252}Cf neutron source 318-167 continued to be verified on a quarterly basis as a byproduct of the quarterly verification of the SNOOPY tertiary standard. This source was originally due for recalibration at NIST in September 1996. Its calibration period was extended for an additional year on the merits of its constancy as determined in the SNOOPY confirmations. The extension was, in part, driven by fiscal issues as well, given its planned move to Section 3.3 and the resulting effective uselessness of the NIST-certified emission rate for a source used in non-free field geometry. In 1997, the calibration was again extended on the basis of supporting evidence from three measurement results.

First, a TLD comparison performed in 1996 indicated good agreement, with no specific biases, between 318-167 and the newer source 318-365, which was procured and calibrated at NIST in late 1995. Second, QC monitoring data for this source, collected during routine use for TLD irradiations, continued to indicate stability with a clear lack of trends in the source output. Both of these data sets were presented in the *Hanford Radiological Protection Support Services Annual Report 1996* (Lyon et al. 1997). Finally, the on-going calibration and constancy verifications of the SNOOPY working standard, using this source and the current calibration protocol (extending from 1993 to the present), has resulted in detector efficiencies that vary randomly within the allowable tolerance. The lack of apparent long-term trends in these data significantly increases the confidence that the NIST calibration of this source continues to be valid. Evidence of a trend in such data, if apparent, would be an indication of a gradual deviation in the actual source output versus the decayed source output. On the strength of these three indications, it was judged that the calibration provided by NIST would be deemed valid for another year, or until the source can be transferred to Section 3.3, whichever occurs first.

The ^{252}Cf source (318-038) mounted within Section 3.3 was not provided with a full calibration at any time during 1997. In continued anticipation of exchanging this source for 318-167, which is currently in the LSR, its calibration period has been extended quarterly based on successful routine constancy verifications. The constancy verifications have substantiated the accuracy and stability of the calculated SNOOPY-specific and, by relation, Eberline NRD-specific dose equivalent rates within the well.

Source 318-016, which had previously been removed from the LSR to facilitate placement of the newer source 318-356, was submitted to NIST for recalibration. The neutron emission rate determined by NIST, as of August 27, 1997, was $5.46\text{E}+06$ n/s ($\pm 3.91\%$). By comparison with the previous emission rate determined by NIST in 1981 and decayed to August 27, 1997, the source has retained about 11.9% more of its activity than predicted using the recommended half-life of 2.646 years. This source has not been used within this program for verification of the SNOOPY transfer standard since 1994 due to uncertainties in the californium isotopic content. As of the end of 1997, source 318-016 was not yet reinstalled in the LSR pneumatic system.

Beta Sources

Absorbed dose rates from beta sources were verified using an extrapolation chamber at fixed distances to ensure constancy with original calibration data. The methods used to interpret PTW extrapolation chamber data were enhanced during 1997. Among these enhancements were the use of the measured effective diameter of the entrance window instead of the manufacturer's specification of the physical dimension, the use of recombination corrections, and the application of all of the correction factors recommended in PTB Dos-13, *The National Primary Standard of the PTB for Realizing the Unit of the Absorbed Dose Rate to Tissue for Beta Radiation* (PTB 1996). While most of these corrections produce a cumulative effect that is relatively insignificant, the measurement technique is more representative of other national and international standards laboratories. It also enables a more comprehensive means for estimating the measurement uncertainties.

The most frequently used beta sources were assessed in 1997 using the enhanced measurement and computational extrapolation chamber methods. The resulting shallow dose rate was compared with the existing decayed rate for each source. For $^{90}\text{Sr}/^{90}\text{Y}$ sources 318-102 and 318-103 (see Table 7.3), the new rates were 3.6% lower and 2.6% lower, respectively, than the values based upon the measurements performed by a NIST scientist during a visit to PNNL in 1987. For $^{90}\text{Sr}/^{90}\text{Y}$ source 318-012, the measured shallow dose rate was 0.5% higher than the decayed value referenced from the original PTB certificate. The measured value for ^{204}Tl source 318-192 was 1.4% lower than the existing reference value, originally determined in-house. No changes were made to the conventionally true value for any of these sources in 1997. A detailed review of the NIST-measured values for 318-102 and 318-103 was not performed as of the end of 1997; however, it is suspected that the resulting dose rates may be altered if the same calculational enhancements are applied to the original 1987 data. The differences for sources 318-012 and 318-192 are within the respective measurement uncertainties. Investigation of these values will continue.

The dose rate emitted from the depleted uranium slab standard, source 318-166, was also measured. The enhanced method resulted in a dose rate of 204 mrad/h, quoted at a distance of 1.5 millimeter away from the surface. The existing conventionally true value was 206 mrad/h at a distance of 3 millimeters based on in-house measurements performed in 1985. A review of all prior measurements and of the applications for which this source is used prompted a revision to the new dose rate, even though the net change did not exceed the confidence interval of this newest measurement. The primary justification for this revision is the use of more appropriate measurement techniques and sufficient data to perform a complete uncertainty analysis.

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 air ionization chambers used to perform photon reference field measurements, the PTW extrapolation chamber used to assess beta reference fields, and the reference SNOOPY survey instrument used to convey calibration to Section 3.3. The Eberline NRD transfer probe, used in calibrating Section 3.3 for this configuration in 1996, was not used in 1997. Instead, the NRD constancy of the well was verified by relation to the SNOOPY verification results.

The 1997 MQA intercomparison was also chosen to confirm the on-going validity of the various PNNL secondary standard instruments. To accomplish this, each of the existing, directly traceable, reference class instruments was placed in the ^{137}Cs reference field in the same position of measurement used for the NIST MQA transfer standard. Cesium-137 was chosen for this check because all of the PNNL standards have an established calibration factor for this photon energy. Also, if any of the chambers had developed problems, or were somehow damaged since their calibration at NIST, it is anticipated that all calibration factors for each instrument would be affected. Consequently a direct replacement comparison against a NIST transfer standard using ^{137}Cs resulting in a value consistent with

the original NIST ^{137}Cs calibration confirms all other NIST calibration factors (e.g., for M150, M100, H150, ^{60}Co , etc.). These measurements, coupled with the accurate outcome of the NIST MQA, verified the continued accuracy of the secondary standards. The results are listed in Table 7.6.

Table 7.6. Outcome of Validation Measurements of Secondary Standard AICs

Secondary Standard		NIST		Confirmatory Measurement (R/Coul.)	% Error
Model	Serial No.	Calibration Factor (R/Coul.)	Date Established		
PM-30	CII30.4277	1.140E+08	1/84	1.145E+08	0.5
PM-30	CII30.7502	1.144E+08	9/92	1.144E+08	0.0
PR-18	CII1.8.5889	1.835E+06	5/92	1.850E+06	0.8

7.1.4 Uncertainties of Reference Calibration Fields

Efforts continued in 1997 to update and refine the estimates of uncertainty for the various calibrated reference fields. The methods used to determine uncertainty were referenced from NIST Technical Note 1297, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results* (DOC/NIST 1994). This document is an interpretation and abridgement of the ISO *Guide to the Expression of Uncertainty in Measurement* (ISO 1993). Various uncertainties are categorized, based on whether they are determined by statistical or other means. Type A evaluations of uncertainty involve a statistical analysis of series of observations. Type B evaluations are determined by means other than a statistical analysis of a series of observations and are usually based on scientific judgment using all of the relevant information available (e.g., previous measurement data, manufacturer's specifications, reference data taken from handbooks, etc.). For the calibration of each reference field, the various components affecting uncertainty are determined using Type A and/or B evaluations. The uncertainties within each category are propagated as recommended in the NIST Technical Note to arrive at a total estimated value for each. These two categories of uncertainties are summed in quadrature and adjusted such that they represent approximately a 95% confidence level. Table 7.7 provides an example of a typical uncertainty analysis.

The analysis of uncertainty is an on-going effort that involves the continual identification of sources of error and refinement of estimated values for each identified component. Furthermore, it involves an effort to reduce individual components, where feasible, via refinement of measurement protocol and/or capabilities. The current uncertainty estimates for commonly used reference fields are provided in Table 7.8.

Table 7.7. Typical Uncertainty Analysis for the Determination of Gamma Reference Field Exposure Rate

Uncertainty Description	Symbol	Type		Value (%) ^(a)	
Total Chamber Current	δI_{tot}	A	B	0.14	0.20
Background plus leakage current	δI_{d}	A	B	0.14	0.20
Net Ionization Current	δI_{ref}	A	B	0.1	0.20
Total Chamber Charge	δQ_{ref}	A	B	0.1	0.20
Background plus leakage charge	δQ_{d}	A	B	1.0	0.20
Time Measurement	δt	A	B	0.1	0.004
Calibration Distance	δd_{c}	A	B	0.0	0.05
Chamber Distance	δd_{ch}	A	B	0.10	0.05
Primary Lab Transfer Standard R/C Calibration	δR_{pri}	A	B	0.22	0.45
Temperature/Pressure Correction	δC_{TP}	A	B	0.02	0.03-0.4 (0.2)
Chamber Temperature	δT	A	B	0.2	0.3-2.0
Chamber Pressure	δP	A	B	0.10	0.20
Electrometer Response Correction	δC_{e}	A	B	0.10	0.20
Exposure rate, X	δX_{sec}	A	B	0.33	0.61
<p>NOTE: δX due to type A: 0.330; δX due to type B: 0.669; δX total using RSS: $0.746 \times 1.96 = 1.46\%$ at 95% C.L.</p> <p>(a) Values are in the form of $\delta x/x \times 100$ and at 1σ.</p>					

Table 7.8. Summary of Uncertainties (1997)

Reference Field	Total Uncertainty (95% C.L.)	Notes
Shepherd ¹³⁷ Cs (318-131)	±1.5%	Distance = 1 meter
HEF ¹³⁷ Cs (318-040, -044) ^(a)	±1.9% to ±4.1%	Dependant on distance, total charge collected from the ion chamber and standard error of replicate readings
HEF ⁶⁰ Co (318-037, -353) ^(a)		
²⁴¹ Am (318-184)	±5.2%	Distance = 0.5 meter; No correction for room scattered photons
²⁵² Cf:Bare (318-167)	±14%	Distance = 0.5 meter; No correction for source anisotropy
²⁵² Cf:D ₂ O-Moderated (318-167)	±22%	Distance = 0.5 meter; No correction for source anisotropy; No correction for effect of D ₂ O-moderator void
PTB ⁹⁰ Sr/ ⁹⁰ Y (318-012, -013)	±3.0%	Distance = 0.30 meter; Flattening filter used for -013 only.
ANSI ⁹⁰ Sr/ ⁹⁰ Y (318-102, -103)	±3.0%	Distance = 0.35 meter; No flattening filters used.
²⁰⁴ Tl (318-192)	±4.4%	Distance = 0.35 meter; No flattening filters used.
Depleted Uranium (318-166)	±3.3%	Distance = 1.5 millimeter.
Well #1:attenuated (318-031) ^{(a)(b)}	±1.1% to ±2.2%	Dependant on source position, total charge collected from the ion chamber and standard error of replicate readings
Well #1:unattenuated (318-031) ^{(a)(b)}	±1.1% to ±3.6%	Dependant on source position, selection of ion chamber, total charge collected from the ion chamber and standard error of replicate readings
Well #2:attenuated (318-288) ^{(a)(b)}	±1.1% to ±2.5%	
Well #2:unattenuated (318-288) ^{(a)(b)}	±1.9% to ±3.0%	Dependant on source position, total charge collected from the ion chamber and standard error of replicate readings
Well #4: unattenuated (318-030) ^{(a)(b)}	±1.9% to ±2.0%	Dependant on source position, total charge collected from the ion chamber and standard error of replicate readings
<p>(a) Quoted values applicable to discrete measured points only. Range covers all points assessed. Dose rates associated with the use of the computer controlled positioner are not covered within this quoted value since an uncertainty component for the applied equation has not been determined.</p> <p>(b) Characteristics of the reference field(s) emitted by these sources within the well geometry may differ in energy spectra in comparison to an ideal beam geometry from which the reference chamber is established traceable to NIST. Use of this value to establish uncertainty for the calibration of dissimilar instruments must account for the potential differences in energy dependence.</p>		

7.2 Supporting Studies

Two supporting studies were conducted under this project during 1997.

7.2.1 ²⁴¹Am Intercomparison

As identified in Section 7.1.2, ²⁴¹Am traceability to the NRPB is implied. An indirect intercomparison was performed between PNNL, the Radiological Environmental Sciences Laboratory (RESL) and the National Physical Laboratory (NPL) of the United Kingdom. This process involved the use of an Exradin Model A6 AIC. The chamber was calibrated at PNNL using the ²⁴¹Am source

318-184, then forwarded to RESL for use in calibrating a new ^{241}Am reference field. RESL subsequently obtained a calibration of the chamber at the NPL. The correction factors established by PNNL and NPL were $3.917\text{E}+04 \text{ Gy/Coulomb}$ ($\pm 2.4\%$) and $3.973\text{E}+04 \text{ Gy/Coulomb}$ ($\pm 2\%$), respectively. The indicated difference is 1.4%; however, both correction factors are within the confidence interval established for both of the respective calibrations.

7.2.2 Neutron Characterization

Efforts continued to answer questions regarding the differences between the PNNL and NIST ^{252}Cf neutron reference fields. Work in 1996 focused on measurements of source anisotropy to evaluate prior Monte Carlo modeling estimates for neutron sources of the SR-Cf-100 style encapsulation. Having verified the modeling parameters to an acceptable level of accuracy, efforts in 1997 focused on calculating, via the confirmed modeling techniques, the anisotropy characteristics of the newer NSD-style encapsulation. The model identified a 6.2% increase in the neutron fluence in the direction perpendicular to the cylindrical axis of the source, relative to the currently quoted isotropically-distributed fluence calculated from the NIST-measured emission rate (see Figure 7.7). Using this value to adjust the quoted dose equivalent rate improves the agreement with NIST in both the 1997 measurements and prior measurements using a tissue-equivalent proportional counter (TEPC)-based intercomparison device; however, it does not completely solve the difference.

Figure 7.7. Results of Anisotropy Calculations for the NSD Encapsulated ^{252}Cf Source (Includes additional pneumatic transit capsule)

Further consideration of the potential differences between NIST and PNNL reference fields revolved around the acknowledged probability that the respective encapsulation designs produce non-trivial differences in the neutron energy spectra. Although this difference is expected to be subtle, it was considered possible that both the Harwell and TEPC-based detector designs may have enough energy dependence to result in the observed differences. To investigate this, each of the intercomparison detectors were modeled, in general terms, and, via simulation, were exposed to the modeled NIST and PNNL sources. Both detectors responded higher when exposed, via the model, to the PNNL source than to the NIST source. These results are consistent with the measured results. The modeled Harwell detector response was 7.7% higher using the PNNL source. If considered within the NIST measurements, this would reduce the intercomparison difference to about 5%. Using this method, a separate correction for the anisotropy in neutron fluence from the source is not necessary. Instead, this factor represents an instrument-specific combined *response* correction for source anisotropy and encapsulation. Questions remain regarding this model, including the accuracy of the detector configuration and the potential influence from other facility structures which, traditionally, have been considered to be inert, relative to neutron measurements.

7.3 Project-Related Professional Activities

Staff presentations during 1997 are listed in this section.

7.3.1 Presentation

Piper, R.K., M.K. Murphy, and J.C. McDonald. "PNNL's Secondary Calibration Laboratory for Ionizing Radiation and the Role of NIST Measurement Quality Assurance." Presented at the Sixth Annual Meeting of the Council on Ionizing Radiation Measurements and Standards, November 12-14, 1997, Gaithersburg, Maryland.

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