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Pacific Northwest
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U.S. Department of Energy

Hanford Radiological Protection Support Services Annual Report 1996

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D. E. Bihl
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R. K. Piper
S. A. Schulze

June 1997

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

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Pacific Northwest National Laboratory
Richland, Washington 99352

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 1996. 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

This report describes certain radiological protection support services performed by the Pacific Northwest National Laboratory (PNNL) during calendar year 1996, in support of the U. S. Department of Energy (DOE) Richland Operations Office (RL) and the Hanford contractors. Projects providing these sitewide services included 1) external dosimetry, 2) internal dosimetry, 3) in vivo measurements, 4) radiological records, 5) calibration of radiation sources traceable to the National Institute of Standards and Technology (NIST), and 6) instrument calibration and evaluation. Described in this report are the project routine tasks, any significant changes to the routine tasks, and any supporting studies performed during calendar year 1996. Also described are tasks performed by the projects that are funded by DOE Headquarters. Related professional activities, such as publications, presentations, and memberships on standards or industry committees, are also described.

The Hanford External Dosimetry Project (HEDP) provides external radioactive monitoring capabilities for all Hanford workers and visitors. The project was reaccredited for 2 years by the DOE Laboratory Accreditation Program (DOELAP). The HEDP implemented the new extremity dosimeter system on July 1, 1996. The new system consists of a commercially provided thermoluminescent (TL) dosimetry "chipstrate" dosimeter insert manufactured by Bicron/Harshaw (generally referred to as Harshaw) enclosed in an ICN/Seimens ring dosimeter holder. During 1996, HEDP staff passed all external dosimeter performance reviews. Several changes, as coordinated during meetings with the Hanford Personnel Dosimeter Advisory Committee, were made in routine project practices during the year. Several technical dosimetry reviews were also conducted during the year.

The Hanford Internal Dosimetry Project provides excreta bioassay monitoring, as well as associated evaluation and documentation of internal radiological exposure and dose to Hanford workers and visitors. During 1996 the project provided oversight to 3622 excreta bioassay requests (a decrease of 19% from 1995 and 60% from 1994) and 3292 successful excreta bioassay measurements (including some results requested in 1995). Changes to the routine project included 1) several policy and documentation changes, 2) cost reduction activities, and 3) development of an upgraded computer code for certain Am/Pu calculations. Some work-specific bioassay monitoring programs were evaluated.

The Hanford Whole Body Counting Project provides the capability to detect radioactive materials deposited in individuals using in vivo techniques. During 1996 the project performed 9065 in vivo measurements, a decrease of 17% from 1995. As a part of the preparation for DOELAP review, the project participated in pilot testing mixed fission, plutonium, and uranium phantoms. Some non-routine tasks included 1) evaluation of spectra analysis/acquisition software, 2) participation in a female Bottle-Manikin Absorption intercomparison program, and 3) internal measurements made on children from Belarus. Improvements to the project included 1) a number of cost reductions, 2) implementation of a new lung counting detection system, 3) measurement sensitivity improvements, and 4) development of a new thyroid counting calibration. Supporting studies and programs participated in during 1996 included

1) portal monitoring bioassay, 2) portable wound counting, 3) DOE Phantom Library, 4) support of the U.S. Transuranium and Uranium Registries, 5) development of a gas scintillation detector, and 6) development of a thoron-in-breath monitor.

The Hanford Radiological Records Project preserves and administers all Hanford records of personnel radiological exposure as well as records of historical radiation protection and radiological dosimetry practices and policies. In addition to producing reports for DOE Headquarters, RL, Hanford contractors, individuals, and other authorized agencies, the project provides data for epidemiology and research projects. A number of changes and some new programs were made to the Hanford Radiological Exposure (REX) system, some based on changing requirements and environment, and others to enhance the operational efficiency of the system. A large number of dosimetry changes were made electronically in REX to save the field dosimetry units from having to complete large numbers of paper forms. The laser optical disk system was converted to CD-ROM technology and had a juke box installed to enhance the operation of the system.

The Radcon Instrumentation Services Project 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 1996 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; and maintenance of a pool of portable survey instruments available for use by site contractors. Project improvements during 1996 included 1) streamlined instrument calibration services to reduce costs; 2) developed and implemented an instrument bar code system to simplify the logging, tracking, and labeling tasks; 3) developed and implemented a computer-generated and -printed calibration labeling process; and 4) included a complete, stand alone, fully traceable calibration data sheet into each procedure.

The Radiation Standards and Calibration Project maintains radiological standards necessary for appropriate characterization and calibration for the instrument calibration and external dosimetry projects. In support of this task, special instrument and dosimeter response-characterizing equipment and supplemental radiation reference fields are maintained, as necessary. This activity provides the means to characterize response to various radiation fields encountered at Hanford and ensures the calibration fields are in accordance with recommended standards and guides. Supporting studies conducted included 1) construction and characterization of a distributed geometry beta calibration reference field for a specially designed instrument, 2) development of alternate beta reference fields, and 3) evaluation of neutron source anisotrophy for an older design source.

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, Radiation Standards and Calibrations Project, and Radcon Instrumentation Services Project.

Abbreviations and Acronyms

ACE	Achieving the Competitive Edge
ACES	Access Control Entry System
ADP	Automated Data Processing
AIM	Acquisition Interface Modules
ALC	Absolute Lung Counter
ANSI	American National Standards Institute
ASSP	Analytical Support Services Program
BCF	beta correction factor
BCSR	Boeing Computer Services-Richland
BHI	Bechtel Hanford Incorporated
BOMAB	Bottle-Manikin Absorption
CAR	computer-assisted retrieval
CEDE	committed effective dose equivalent
CP	cutie-pie (survey instrument)
CY	calendar year
DBMS	database management system
DEC	Digital Equipment Corporation
DME	distance measuring equipment
DOE	U.S. Department of Energy
DOE-HQ	DOE Headquarters
DOELAP	DOE Laboratory Accreditation Program
EDF	Emergency Decontamination Facility
EM	Environmental Management
ERC	Environmental Restoration Contractor
ES	Enterprise Server (computer type)
FDH	Fluor Daniel Hanford
FY	fiscal year
GM	Geiger-Müeller (detector)
GSPC	Gas Scintillation Proportional Counter
HCND	Hanford combination neutron dosimeter
HED	Hanford environmental dosimeter
HEDP	Hanford External Dosimetry Project

HEHF	Hanford Environmental Health Foundation
HHS	Hanford Health Scheduling
HID	Hanford Identification Number
HIEC	Hanford Instrument Evaluation Committee
HPDAC	Hanford Personnel Dosimetry Advisory Committee
HPGe	high-purity germanium
HPS	Health Physics Society
HPSSC	Health Physics Society Standards Committee
HRRP	Hanford Radiological Records Project
HSD	Hanford standard dosimeter
HSRCM	Hanford Site Radiological Control Manual
HSS	Hanford Scheduling System
IARC	International Agency for Research on Cancer
ICFKH	ICF Kaiser Engineers Hanford Company
ICPMS	Inductively Coupled Plasma Mass Spectrometry
ICRP	International Commission on Radiological Protection
IDP	Hanford Internal Dosimetry Project
ISO	International Standards Organization
IT	IT Corporation
IVRRF	In Vivo Radioassay and Research Facility
KEH	Kaiser Engineers Hanford
LAN	local area network
LANL	Los Alamos National Laboratory
LaserREX	CD-ROM imaging subsystem to REX
LLNL	Lawrence Livermore National Laboratory
LMSI	Lockheed Martin Services Incorporated
LSR	Low Scatter Room
MCA	multi-channel analyzer
MDAs	minimal detectable activities
M&I	Maintenance and Integration (contractor)
MQA	measurement quality assurance
NaI	sodium iodide
NBS	National Bureau of Standards
NCRC	National Calibration Reference Centre
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission

NTA	nuclear track emulsion, type A
ORNL	Oak Ridge National Laboratory
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 Werkstäten
QA	quality assurance
QC	quality control
QUS	quick uranium soluble
RCM	Radiological Control Manual
RDA	Reliably Detected Activity
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
ROIs	regions of interest
RS&C	Radiation Standards and Calibrations (project)
SOW	statement of work
TE	track-etch (dosimetry system)
TEPC	tissue equivalent proportional counter
TIBM	Thoron in Breath Monitor
TL	thermoluminescent (dosimetry)
TLD	thermoluminescent dosimeter
TRU	transuranium
USTR	U.S. Transuranium Registry
WBC	whole-body count
WBCP	Hanford Whole Body Counting Project
WHC	Westinghouse Hanford Company
WIPP	Waste Isolation Pilot Plant

Contents

Figures

Tables

1.0 Introduction

This annual report documents the calendar year (CY) 1996 activities of specific radiation protection services performed by the Pacific Northwest National Laboratory (PNNL)[a] for the U.S. Department of Energy (DOE) Richland Field Office (RL) and the Hanford Site contractors. These sitewide services are provided by projects in 1) internal dosimetry, 2) whole body counting, 3) external dosimetry, 4) instrument calibration and evaluation, 5) calibration of radiation sources traceable to the National Institute of Science and Technology (NIST), and 6) radiological records. All of these services fall within the purview of the Health Protection Department of the PNNL Health Division.

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, 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. They also reduce costs to the Hanford contractors, which comprised Boeing Computer Services - Richland (BCSR); the Hanford Environmental Health Foundation (HEHF); ICF Kaiser Engineers Hanford Company (ICFKH); PNNL; Bechtel Hanford, Inc; and Westinghouse Hanford Company (WHC) through September 30, 1996. On October 1, 1996, the new Project Hanford Management Contractor (PHMC) took over the operation of Hanford. The PHMC replaced WHC, BCSR, and ICFKH with the prime contractor (Fluor Daniel Hanford [FDH]), six subcontractors, and seven enterprise companies. The six 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) Rust Federal Services of Hanford, Inc. The seven enterprise companies 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) Rust Federal Services Northwest; and 7) SGN Eurisys Services Corporation. In general, the term PHMC will be used when referencing the new contractor, subcontractors, and enterprise companies.

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

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

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

The 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.

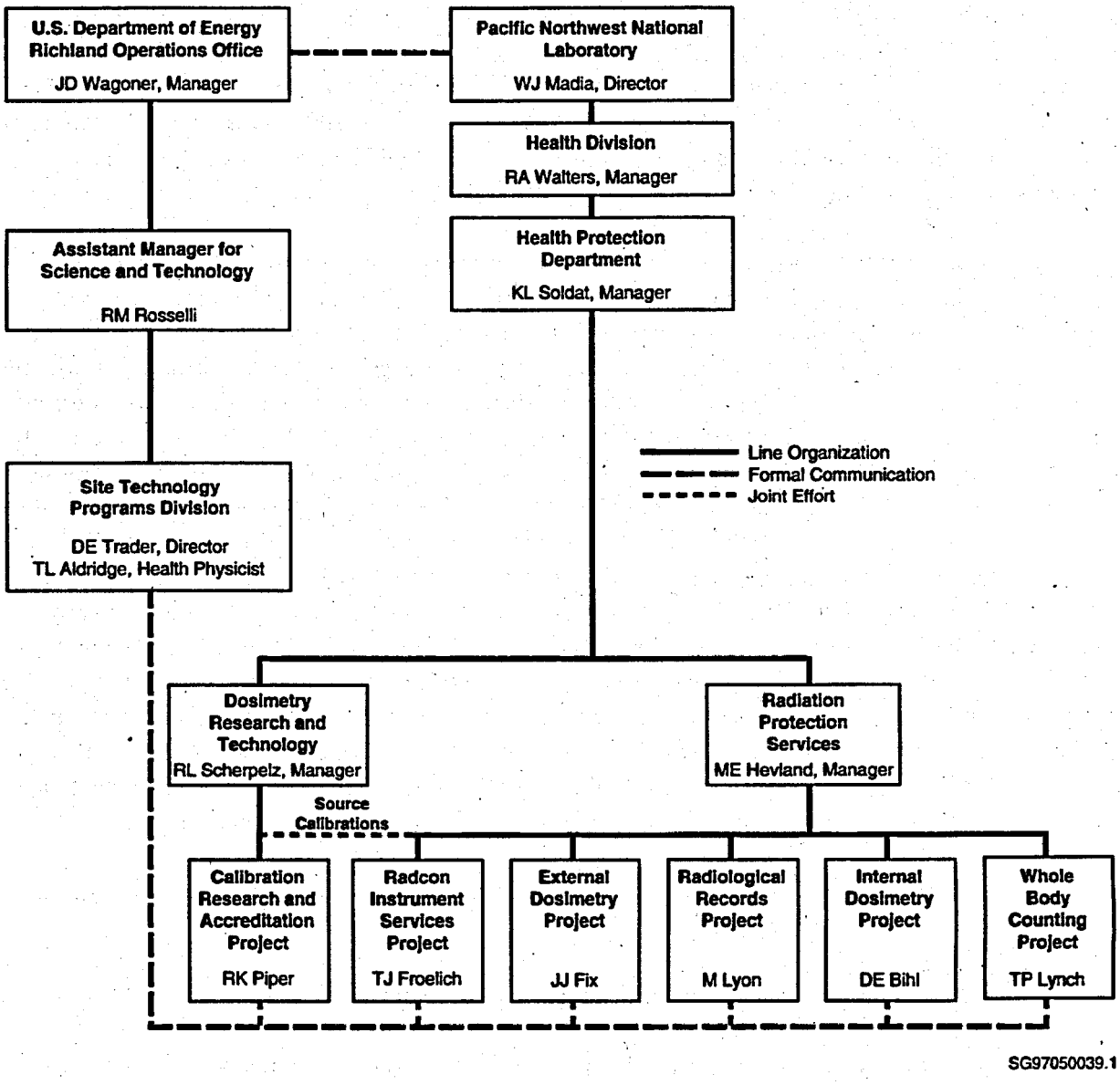

Figure 1.1. Management Structure and Major Communication Interfaces for Hanford Radiological Support Services During 1996

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 Part 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 sitewide nuclear accident and environmental dosimetry capabilities in compliance with applicable DOE requirements.

The Hanford dosimetry system consists of a commercially procured thermoluminescent (TL) dosimetry system (manufactured by Bicron/Harshaw)[a] and a PNNL-developed track etch (TE) dosimetry system. Dosimeters include the Hanford standard dosimeter (HSD), the Hanford combination neutron dosimeter (HCND), and the Hanford environmental dosimeter (HED). All personnel assigned a dosimeter receive the HSD, except for personnel potentially exposed to neutron radiation where an HCND is assigned. The HSD does have a neutron response capability which detects exposure to neutron radiation even though no official dose is determined. Effective July 1, 1996, a new Hanford Bicron/Harshaw "chipstrate" extremity dosimeter insert enclosed in an ICN/Seimens[b] ring dosimeter was implemented to provide the official extremity dose of record. This system replaced the Hanford site-specific, two-chip ring dosimeter used for the past several years.

2.1 Performance Evaluations

HEDP personnel participated in four performance reviews during 1996 as discussed in the following sections.

2.1.1 DOELAP Accreditation

The HEDP completed performance testing and an onsite technical assessment under the Department of Energy Laboratory Accreditation Program (DOELAP) during 1996. Figure 2.1 shows HEDP staff receiving the DOE "certificate of accreditation" from Terri Aldridge and Joe Wiley, DOE/RL. Performance testing occurred from January to June 1996 and involved approximately 350 dose evaluations for a variety of single- and mixed-exposure conditions. Hanford successfully passed all requested categories for the Hanford standard and combination neutron dosimeters. The results are summarized in Table 2.1. Exposures included personnel and accident level (as high as 500 rem) doses. Excellent performance was shown by the Hanford dosimeters, as demonstrated in Table 2.1, by comparing the calculated performance of the respective dosimeters against the DOELAP criterion in each irradiation category. In every category, the Hanford performance is well below the 0.3 or 0.4 DOELAP criterion.

(a) Bicron, Saint-Gobain/Norton Industrial Ceramic Corporation, Solon, Ohio.
(b) ICN Pharmaceuticals, Inc., Costa Mesa, California.

Figure 2.1. HEDP Staff Receiving DOE "Certificate of Accreditation"

The onsite technical program assessment was conducted during July 9-10, 1996, to examine program documentation and practices relative to the requirements of the DOELAP Handbook (DOE 1986). No deficiencies or concerns were identified. The assessors did note six observations (two noteworthy practices and four recommendations) during the assessment. The success of the HEDP in passing performance testing and the onsite assessment resulted in accreditation of the HEDP during November 1996 for another two-year period. The next cycle of DOELAP performance testing is scheduled to begin during January 1998.

2.1.2 Eleventh International Environmental Dosimetry Intercomparison

The HEDP participated in the 11th International Environmental Dosimetry Intercomparison during 1996 although final results have not yet been received. Dose results were reported for super sensitive aluminum oxide and lithium fluoride:magnesium, copper, phosphorus (LiF:MCP) thermoluminescent phosphors, procured from Bicron/Harshaw, in addition to the standard lithium fluoride (LiF) phosphor used for routine environmental dosimetry in the Hanford environs. Reported dose results were in good agreement among all three dosimeter types. The LiF:MCP required essentially no energy correction for the low energy laboratory exposure to ^{241}Am (60 keV) conducted to prepare for the intercomparison testing.

Table 2.1. DOELAP Shallow and Deep Dose Performance Test Data

		Performance[a]			
		HSD		HCND	
DOELAP Category Description	DOELAP Criterion	Shallow	Deep	Shallow	Deep
Low-Energy Photons, Accident Levels	0.3	N/A	0.000	N/A	0.008
High-Energy Photons, Accident Levels	0.4	N/A	-0.001	N/A	0.010
Low-Energy Photons, Mixed X-rays	0.3	0.184	0.080	0.175	0.056
Low-Energy Photons, Plutonium Environments	0.3	0.042	0.085	0.056	0.098
High-Energy Photons, ^{137}Cs	0.3	0.074	-0.009	0.063	0.002
Beta Particles, General	0.4	0.044	N/A	0.056	N/A
Neutrons, Unmoderated ^{252}Cf	0.3	N/A	N/A	N/A	0.039
Mixtures:					
Low-Energy Photons + High Energy Photons	0.4	0.117	0.073	0.114	0.064
Low-Energy Photons + Beta	0.4	0.172	0.114	0.100	0.101
Low-Energy Photons + Neutrons	0.4	N/A	N/A	N/A	0.004
High-Energy Photons + Beta	0.4	0.226	-0.005	0.220	-0.011
High-Energy Photons + Neutrons	0.4	N/A	N/A	N/A	-0.001

(a) Performance quotients (P) for Hanford Standard Dosimeter (HSD) and Hanford Combination Neutron Dosimeter (HCND) are calculated as $P = |B| + S - E$ where B is the systematic error in the reported dose, S is the random error, and E is the uncertainty in the delivered dose. Dosimeter performance quotients must be less than the DOELAP criterion in each category for satisfactory performance.

2.1.3 Blind Audit Personnel Dosimeters

During 1996, WHC continued the long standing practice to routinely submit audit dosimeters to be processed along with their personnel dosimeters. This practice was continued until completion of the WHC contract on September 30, 1996. Thereafter, the processing of blind audit dosimeters was continued by FDH who assumed a PHMC Contract effective October 1, 1996. The HEDP successfully passed each monthly blind audit dosimeter evaluation conducted during 1996. The HEDP also passed each of the quarterly evaluations conducted by WHC using DOELAP methodology and criteria. Documentation of HEDP results of these audits is included in the Hanford Radiation Protection Historical Files operated by the Hanford Radiological Records Project.

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 between 15 and 30 mrem of ^{137}Cs gamma radiation. A result is noted as abnormal if the

reported exposure is outside of pre-established 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 1996).

2.2 Dose Results During 1996

During 1996, HEDP reported 72,908 official dose results. This processing volume represented a slight increase from the total of 71,049 during 1995. The annual number of reported official dose results is illustrated in Figure 2.2 for 1991 to 1996 for each type of dosimeter. Comparison of processing volume from year to year is complicated because the current whole body personnel dosimetry system was implemented effective January 1995 and the current extremity dosimetry system was implemented effective July 1996. The Hanford personnel dosimetry system prior to 1995 included several thousand single-chip basic dosimeters, typically assigned to employees with 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 1996 continued the trend for higher processing volumes observed in recent years. During 1996, the track-etch (TE) dosimeter 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 currently observed at the Hanford Plutonium Finishing Plant (PFP). Currently, plutonium at PFP is primarily being stored awaiting DOE decisions as to its

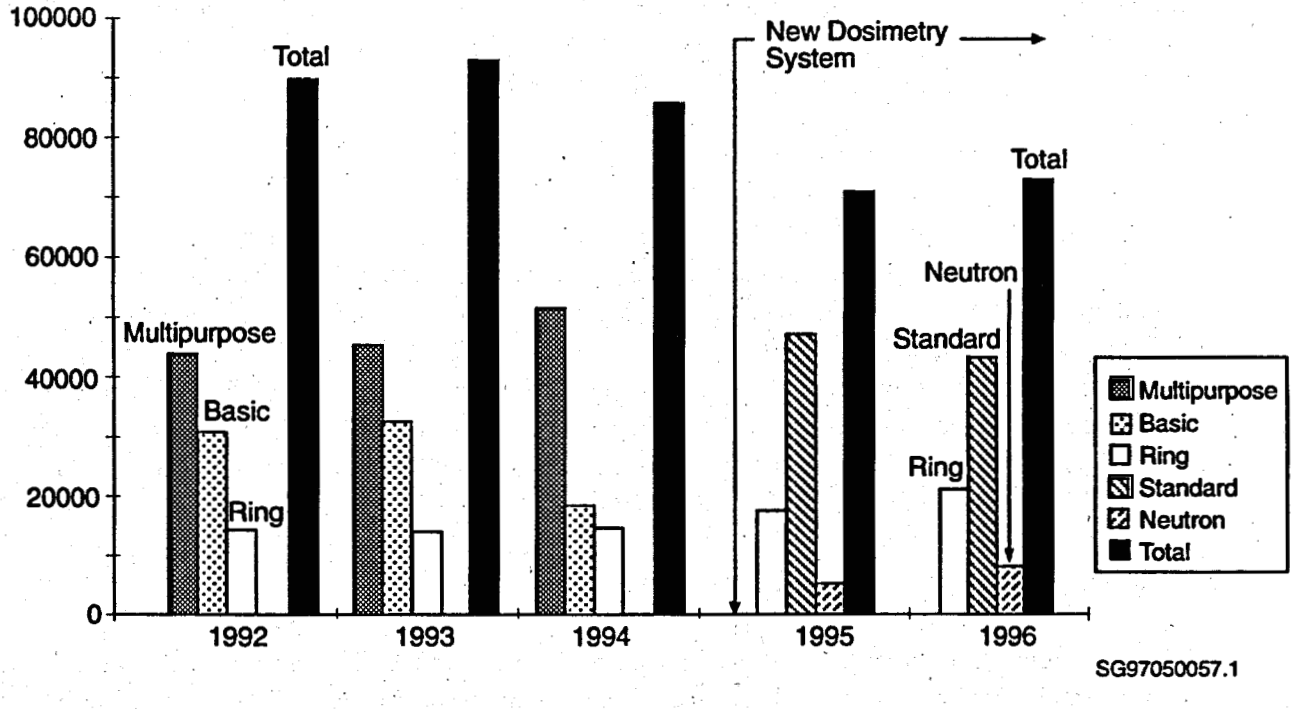

Figure 2.2. Trend in Reported Hanford Personnel Dosimeter Results

eventual disposition. As such, workers are primarily exposed to neutron energy spectra is being greatly reduced because of the extensive shielding and is primarily less-than the approximate 100-keV energy threshold of the TE foil. Field measurements at PFP have shown consistent under-estimation of the actual neutron dose with the TE foil (Endres et al. 1997).

Actual dosimeter processing exceeded the 72,908 official dose results reported due to the following:

- Processing a neutron dosimeter actually involves processing two separate TL dosimeters.
- Unused temporary personnel dosimeters (i.e., unassigned) are processed in the event it is subsequently determined the dosimeter was actually worn.
- A minimum of four quality-control (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 issue to ensure all residual signals have been removed.
- During 1996, 15,000 new extremity dosimeter chipstrate inserts were acceptance tested. Each acceptance test includes four separate tests involving dosimeter processing.

Each year numerous internal audit dosimeters are processed to ensure the integrity of dosimeter processing. During 1996, a total of 790 internal audit dosimeters were processed. A breakdown of the internal audit dosimeters is shown in Table 2.2.

Control charts are used to evaluate the results for each of the audit dosimeter categories. Charts 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 quality control report is prepared for each processing. Copies are distributed to all Hanford contractor radiation protection organizations, as well as the Hanford Radiation Protection Historical File. Copies of the control charts are also provided to the historical file.

Table 2.2. Audit Dosimeters Processed During 1996

	Dose Category			
Dosimeter	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				

2.4 Changes in Routine HEDP Practices During 1996

Modifications to HEDP practices are discussed during HPDAC meetings. Changes in project practices made during 1996 are described in the following sections.

2.4.1 Contamination Monitor

Effective October 1, 1996, an Eberline[a] automated ACM-10 Contamination Monitor was implemented to monitor all incoming dosimeters. This system provides timely and high-quality radioactive contamination monitoring of the many tens of thousands of dosimeters received for routine processing. HEDP staff continue to use portable instrumentation to monitor the relatively few dosimeters received for rapid processing. Prior to the use of the automated monitor, all incoming dosimeters were manually monitored using portable alpha and beta/gamma instrumentation.

2.4.2 Ring Correction Factors

As described in Section 2.3, Hanford extremity dose is measured using a "ring" dosimeter. The ring response is calibrated with a ^{137}Cs gamma exposure. Correction factors are used to multiply the ring dosimeter processing result to account for potential under-response of the dosimeter in Hanford work environments with low-energy beta fields (i.e., ring dose = processing result x correction factor). The choice of which factor to be used in the calculation of the ring dose is provided by the respective Hanford contractor organization when the ring is submitted for processing. With the Hanford ring used prior to implementation of the new ring on July 1, 1996, ring correction factors of 3 or 4 were used, depending upon the contractor, unless the contractor specified use of another factor. As described in Section 2.3, Hanford extremity dosimeters have been exposed to ^{90}Sr and ^{204}Tl beta sources and heavily filtered ^{90}Sr sources, having degraded beta spectra, to measure the dosimeter response. This data was used to establish an appropriate Hanford default ring correction factor. Based on this information, a default ring correction factor of 1.5 was adopted. This factor has been shown to be adequate for even the most heavily filtered of the $^{90}Sr/^{90}Y$ sources, but a factor of 3 is needed for ^{204}Tl. Beta emission energies for ^{204}Tl (0.267 MeV) and ^{137}Cs (0.195 MeV) sources are similar. Hanford waste tank sample data indicate Cs/Sr activity ratios as high as 15:1 for some work environments. Under these conditions, a ring correction factor of 3 may be necessary.

2.4.3 Statement of Work

With the new PHMC as of October 1, 1996, there are several new contractors at Hanford using HEDP supplied dosimeters and dose data. To assist in the administration of sitewide dosimetry services, a detailed statement of work (SOW) was developed and adopted through the Hanford Personnel

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(a) Eberline Instrument Corporation, Santa Fe, New Mexico.

Dosimetry Advisory Program.[a] Coordination among Hanford contractor organizations is considered necessary to provide a single set of specifications adequate to provide dosimetry services to all organizations. Modifications to the SOW are coordinated through the HPDAC. All contractors are informed of any planned changes and have an opportunity to make modifications.

2.4.4 Dose Threshold for Suspect Dosimeter Results

During the October 1996 HPDAC meeting,[b] dose thresholds were adopted for cost-effective dose evaluation of dosimeter results to be reported as suspect using the HEDP Suspect Dosimeter Form. Suspect dosimeter forms will be provided by HEDP only for dosimeter results which exceed a change in value corresponding to 10% of the first level RL administrative controls presented in the Hanford Site Radiological Control Manual (HSRCM) (RL 1994). The dose threshold values are shown in Table 2.3.

These dose thresholds were based on consideration of the most effective use of Hanford contractor field staff time. Confirming small changes in dose made by HEDP staff based on processing data was considered an ineffective use of resources. HEDP will continue to identify all records with dose changes below these threshold values for which a change in the processing data has been made. A note code 53 is entered into the official dosimeter processing record for these changes. Any dose change exceeding the threshold values will continue to be flagged in the dose record and a suspect dosimeter form will be sent to the respective contractor representative.

Table 2.3. Dose Threshold Values for Suspect Dosimeter Forms

Dose Category	Dose Threshold (mrem)
Whole Body deep or neutron dose	50
300 mg/cm^2 (lens of eye) dose	450
Whole Body shallow dose	1,500
Extremity shallow dose	1,500

(a) D. E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting Held on November 20, 1996." (A copy is available in the Hanford Radiation Records Historical File, Pacific Northwest National Laboratory, Richland Washington.)

(b) J. J. Fix, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting Held on October 2, 1996." (A copy is available in the Hanford Radiation Records Historical File, Pacific Northwest National Laboratory, Richland Washington.)

2.4.5 Damaged Mylar

Damage to the thin Mylar-covered window on HSDs precludes the use of the dosimeter to assess the shallow dose for a few dosimeters each month. The main source of damage appears to be caused by the clip used to affix the dosimeter to personnel. Several attempts have been made to minimize this damage. During the April 1996 HPDAC meeting,[a] the option of procuring new clips was adopted. Options for replacement clips were evaluated by HEDP staff. This resulted in procurement of a different clip, that will minimize damage to the window, used to affix the dosimeter. The new clips were distributed to the respective Hanford dosimetry organizations for use beginning with the October 1996 dosimeter issue.

2.4.6 Personal Nuclear Accident Dosimeters (PNADs)

The HPDAC recommended, during its meeting of December 20, 1995[b], that each of the existing PNADs be modified by inserting a thermoluminescent dosimeter (TLD)-700 chip. The modified PNAD would meet all 10 CFR Part 835 performance criteria and would eliminate the need to wear personnel dosimeters to meet the photon radiation performance requirements. As reported during the August 1996 HPDAC meeting,[c] HEDP took TL chips (TLD-700) from the old Hanford two-chip ring dosimeter system terminated on June 30, 1996, and installed these into existing Hanford PNADs. A small red label is used to distinguish between modified and original PNADs. This effort is scheduled to be completed during 1997 when all of the original PNADs will have been removed from Hanford facilities.

2.5 Technical Reviews

Several technical dosimetry reviews were conducted by HEDP during 1996 as described in this section.

2.5.1 222-S Building Extremity Dose

HEDP evaluations of an extremity dose investigation at the 222-S Laboratory were finalized during January 1996. The investigation concluded, for the work environments studied, that a ring correction factor of 2 should be applied to the older Hanford ring dosimeter results for most work at the 222-S Laboratory with the exception of work involving extremely high $^{90}Sr/^{137}Cs$ activity ratios (i.e., > 100:1)

(a) 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 Records Historical File, Pacific Northwest National Laboratory, Richland, Washington.)

(b) 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 File, Pacific Northwest National Laboratory, Richland Washington.)

(c) D. E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting Held on August 21, 1996." (A copy is available in the Hanford Radiation Records Historical File, Pacific Northwest National Laboratory, Richland, Washington.)

where a ring correction factor of 3 is more appropriate for this dosimeter. The HEDP provided descriptions of the variables and uncertainties associated with dose evaluation under these high beta dose work environments.[a]

2.5.2 241-AZ-101 Waste Tank

HEDP staff were involved in an exposure incident at the 241-AZ-101 Waste Tank in the 200-East Area tank farms. A thermocouple tree was being removed from the tank when high beta dose rates were encountered. HEDP staff performed special evaluations to provide adjusted dosimeter readings for all personnel involved. This incident further demonstrated a need for improved understanding of complex beta radiation fields in some Hanford work environments and limitations of dosimeter and portable instrument response in these high beta fields. As a result of the high shallow doses incurred in this incident, particularly for high beta to gamma radiation fields, improvements in the HSD algorithm were identified and implemented. These improvements provide an estimate of the eye and deep dose in all cases even if extreme beta to gamma radiation fields are encountered well beyond requirements in the DOELAP performance standard. Previously, the deep dose was being set to zero when the dosimeter interpreted a pure beta radiation environment even though a relatively small amount of gamma radiation was present. Similarly, the eye dose was being set to zero when a pure beta radiation field was interpreted, unless the dosimeter element ratios indicated the beta energy was sufficient to produce significant eye dose. These changes were described during the HPDAC meeting[b] on March 20, 1996.

2.5.3 Beta Dose Reduction

A study was conducted during the spring of 1996 to determine the extremity dose reduction that would occur with the use of lead impregnated gloves during sludge sample collection activities. Measurements were made with new and old Hanford extremity dosimeters when irradiated by a heavily filtered ^{90}Y source, an unfiltered ^{90}Y source, and a ^{137}Cs source. Dosimeter response measurements were made with and without samples of the tested glove material (220 mg/cm^2). This study concluded the gloves under consideration would be very effective in handling sludge in glass sample jars and in plastic bags (with heavily filtered and unfiltered sources of $^{90}Sr + ^{90}Y + ^{137}Cs$) during sample collection activities.

(a) B. A. Rathbone, J. J. Fix, and A. W. Endres. January 22, 1996. Letter report, "Evaluation of Extremity Dose Associated with Handling Waste Tank Sludge Samples at the Westinghouse Company 222-S Facility." (A copy is available in Hanford External Dosimetry Project Files, Pacific Northwest National Laboratory, Richland Washington.)

(b) J. J. Fix, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting Held on March 20, 1996." (A copy is available in the Hanford Radiation Records Historical File, Pacific Northwest National Laboratory, Richland, Washington.)

2.5.4 Technical Basis Documentation for Hanford Chipstrate Extremity Dosimeter

Several technical studies of the Hanford chipstrate dosimeter implemented on July 1, 1996, were conducted. Summaries of these studies were included in the October 1996 revision to PNL-MA-842, "*Hanford External Dosimetry Technical Basis Manual.*" The revised manual contains energy and dose response characteristics of the new dosimeter. Studies were conducted in which dosimeters were exposed to ^{90}Sr and ^{204}Tl beta sources and heavily filtered ^{90}Sr sources, having degraded beta spectra, to measure the dosimeter response. This data was used to establish the technical basis for the Hanford default ring correction factor of 1.5. This factor is used for all Hanford work environments unless the contractor identifies a different factor to be used when the dosimeter is submitted for processing. During these studies, HSDs were also exposed to the same sources to allow correlation of HSD element ratios with known ring correction factors for these laboratory sources. These studies show the default beta correction factor (BCF) of 1.5 is adequate for even the most heavily filtered of the $^{90}Sr/^{90}Y$ sources as shown in Figure 2.4. Similar measurements have shown a correction factor of 3 is needed for ^{204}Tl. Both ^{204}Tl (0.267 MeV) and ^{137}Cs (0.195 MeV) have similar beta emission energies. Waste tank sample data indicate Cs/Sr activity ratios as high as 15:1 for some work sites. Under these conditions, a correction factor of 3 may be necessary.

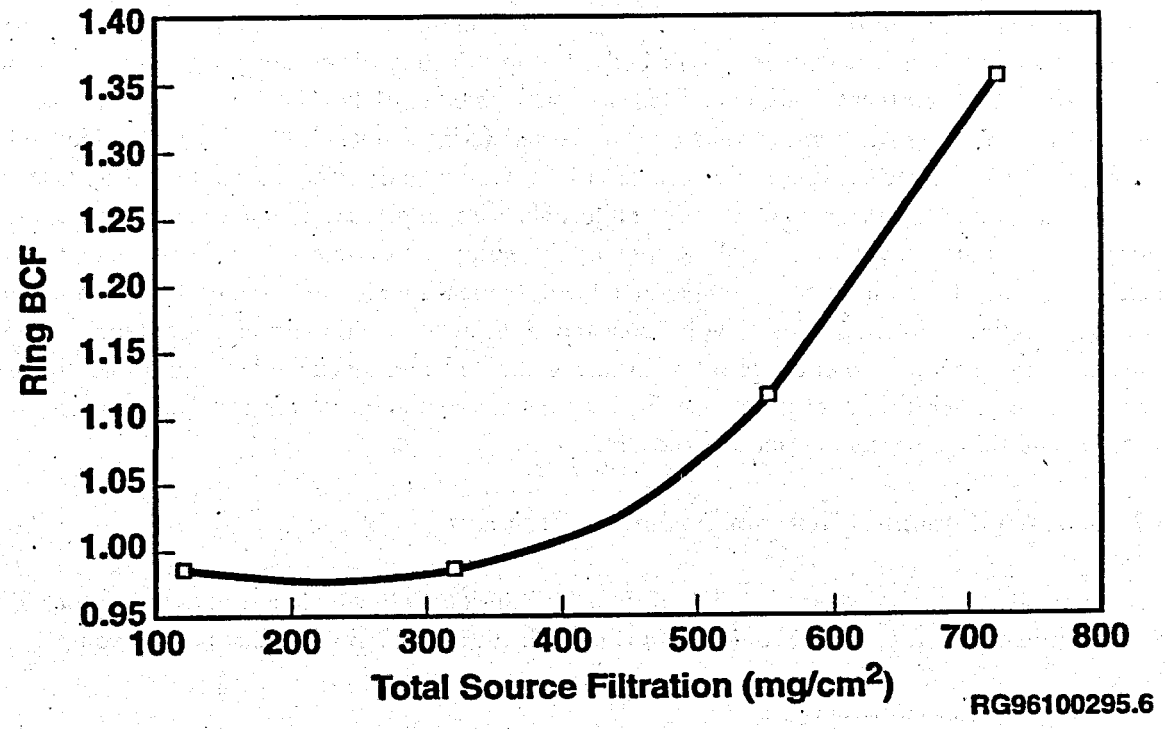

Figure 2.4. Beta Correction Factor for Hanford Chipstrate Ring (sealed $^{90}Sr/^{90}Y$ source)

2.5.5 Neutron Dose to Extremities

Using neutron to gamma ratios to assign a neutron dose to the extremities was considered during the November and December HPDAC meetings.[a][b] This practice would supplement the historical Hanford practice of calculating the recorded extremity dose as the sum of the whole body skin dose, which also includes the whole body neutron dose, plus the extremity dose measured using ring dosimeters. This practice would be implemented using the facility-specific calibration factors currently used to calculate the recorded neutron dose with whole body personnel dosimeters. A technical basis for the new approach is being prepared for inclusion during 1997 in the *Hanford External Dosimetry Technical Basis Manual* (PNL-MA-842).

2.5.6 Multiple Dosimetry

During the November and December HPDAC meetings, the Hanford practice for multiple dosimetry was discussed. A specific issue concerned the question of whether multiple dosimetry is needed if relocation of the primary dosimeter will provide a result which can be taken as a conservative estimate of external *effective dose equivalent*. An example was cited for a repetitive job where characterization of the radiation field showed that the calculated effective dose equivalent would always be lower than the deep dose equivalent result from a single dosimeter located on the waist (abdomen). Because the dose rate varied by more than 50% over the whole body, multiple dosimetry was explicitly required by the HSRCM (RL 1994). Further discussion of this issue was tabled until the ANSI standard HPS N13.32, "*Criteria for Performing Multiple Dosimetry,*" was issued during January 1997. General guidance for assigning multiple dosimeters is complex because of the number and variety of work conditions at Hanford involving nonuniform fields. Competing philosophies are to place the primary dosimeter at the position of the whole body with the highest dose, or use multiple dosimeters to evaluate the dose at selected positions of the whole body compared to the dose measured by the primary dosimeter located at the front of the torso. Related issues involve considerations of short-term versus longer-term multiple dosimeter assignments, whether the primary dosimeter should be removed while the multiple dosimeters are worn, and whether different multiple dosimetry practices should be used in cases of nonuniform neutron, in addition to photon, radiation exposure.

2.5.7 Hanford Personnel Neutron Dosimetry Practices

A technical report was completed in draft final form during 1996 which describes the history of personnel neutron dosimetry practices at Hanford (Fix et al. 1997). This report describes the complex

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(a) Bihl, D. E. "Minutes of Hanford Personnel Dosimetry Advisory Committee Meeting on November 20, 1996." (A copy is available in the Hanford Radiation Protection Historical Files, Pacific Northwest National Laboratory, Richland, Washington.)

(b) Bihl, D. E. "Minutes of Hanford Personnel Dosimetry Advisory Committee Meeting on December 18, 1996." (A copy is available in the Hanford Radiation Protection Historical Files, Pacific Northwest National Laboratory, Richland, Washington.)

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 occured primarily in work environments with lower-energy neutron radiation such as PFP. This effect has been studied at Hanford previously and was one of the primary motivations to develop the Hanford albedo TLD system during the 1960s, leading to its sitewide implementation during 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. This effort was concluded with the plan to identify all potentially impacted workers and place a letter indicating this potential in the respective individual exposure history files.

2.6 Documentation

Several manuals are used to administer the HEDP. A summary of all project manuals follows:

1. PNL-MA-568. *Hanford External Dosimetry Project Manual.* Pacific Northwest National Laboratory, Richland, Washington (internal manual).

2. PNL-MA-583. *Location of Criticality Alarms and Nuclear Accident Dosimeters at Hanford.* Pacific Northwest National Laboratory, Richland, Washington (internal manual).

3. PNL-MA-841. *Hanford External Dosimetry Project Procedures Manual.* Pacific Northwest National Laboratory, Richland, Washington (internal manual).

4. PNL-MA-842. *Hanford External Dosimetry Project Technical Basis Manual.* Pacific Northwest National Laboratory, Richland, Washington (internal manual).

5. PNL-MA-843. *Track-Etch Detector Analysis (TEDA) Users Manual.* Pacific Northwest National Laboratory, Richland, Washington (internal manual).

6 PNNL-MA-844 *Hanford External Dosimetry Project Data Management Manual.* Pacific Northwest National Laboratory, Richland, Washington (internal manual).

The HEDP Quality Assurance Plan, LSC-022,[a] is used to identify quality assurance requirements of the project.

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

2.7 Project-Related Professional Activities

Staff activities, presentations, publications, and professional memberships during 1996 are listed in this section.

2.7.1 Activities

Alan Endres was involved in professional external dosimetry activities, outside of the Hanford site, as follows:

- Participated in the Harshaw/Bicron TLD User Symposium October 7-11, 1996, in Cleveland, Ohio.

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

- Participated in DOELAP assessor qualification training May 20-21, 1996.
- Conducted DOELAP onsite technical assessments of the Nevada Test Site, Los Alamos National Laboratory, and Argonne National Laboratory dosimetry programs January 10-12, September 18-19, and December 3-4, 1996, respectively.
- Participated as a member of the DOELAP Oversight Board in meetings during March 11-12 and September 9-10, 1996 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 June and October 1996 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 1996. The HPSSC reviews all technical scientific standards being developed by working groups of the Health Physics Socieity.

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

- Participated in the Harshaw/Bicron TLD User Symposium October 7-11, 1996 in Cleveland, Ohio.
- Participated in DOELAP assessor qualification training May 20-21, 1996.
- Conducted a DOELAP onsite technical assessment of the Waste Isolation Pilot Plant dosimetry program August 26-27, 1996.

2.7.2 Presentations

Endres, A. W. 1996. *Performance Evaluation: Hanford Combination Neutron Dosimeter.* Presented at the Harshaw/Bicron TLD User Symposium, October 7-11, 1996, Cleveland, Ohio.

Fix, J. J. 1996. *History of External Radiation.* Presented at the annual Health Physics Society Summer School, July 15-19, 1996, Seattle, Washington.

Rathbone, B. A. 1996. *Beta Dosimetry at Hanford and Beta Dose Algorithm Improvements for the 8825 Dosimeter.* Presented at the Harshaw/Bicron TLD User's Symposium, October 7-11, 1996, Cleveland, Ohio.

2.7.3 Publications

Endres, A. W., L. W. Brackenbush, W. V. Baumgartner, J. J. Fix, and B. A. Rathbone. 1996. *Hanford Combination Neutron Dosimeter.* PNNL-10561, Pacific Northwest National Laboratory, Richland, Washington.

Fix, J. J. 1996. "History of External Radiation." In *Applications of New Technology: External Dosimetry*, Medical Physics Publishing, Madison, Wisconsin.

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.

Gilbert, E.S., and J.J. Fix. 1996. *Laboratory Measurement Error in External Dose Estimates and Its Effects on Dose-Response Analyses of Hanford Worker Mortality Data.* PNNL-11289, Pacific Northwest National Laboratory, Richland, Washington.

2.7.4 Professional Memberships

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

Fix, J. J. Voting member of HPSSC.

Fix, J. J. Consultant to ANSI N13.29, "American National Standard for Dosimetry - Environmental Dosimetry Performance Criteria for Testing."

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 assess and document 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 *Hanford Site Radiological Control Manual* (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 et al. 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, PNNL-MA-552, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.
(b) Internal Manual, PNNL-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 an SOW.

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 Hanford Radiological Records Project (HRRP) files. Bioassay measurement results and internal doses are maintained in the REX database, which is operated by the HRRP (see Chapter 5.0).

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

Intakes, and resulting internal doses, have always been confirmed by bioassay measurements. However, as best could be recalled by staff in the IDP, the first assignment of internal dose based solely on an air sample result occurred in 1996. The intake actually occurred in October 1995 in the 100-BC Area. A worker was momentarily exposed to a cloud of dust in a contaminated area. There was no contamination on his person and nothing was detected on a whole body count. However, analysis of the personal air sampler filter showed a small concentration of plutonium, which by the time it was determined, was unverifiable through bioassay. The Environmental Restoration Contractor (ERC) Radiological Control Group requested that internal dose be assigned based on the air sample results.

Some facility operations that potentially impacted the IDP during 1996 include the following:

- The contract for the work performed by WHC, ICFKH, and BCSR expired on September 30. It was replaced by the PHMC, which was composed of many companies, some considered prime government contractors and others considered non-government subcontractors, also called "enterprise companies." Coordination and oversight of radiological control for the PHMC companies was retained by the lead prime contractor, FDH, so the group of people fulfilling the dosimetry needs for the PHMC contractors did not change.

- Clean-out of the 232-Z Incinerator was completed in April, and a production-scale calciner to stabilize 3500 liters of plutonium solution was fabricated at the PFP.

- Seven hundred six metric tons of uranium billets were shipped to the United Kingdom, reducing Hanford's inventory of uranium by 26 % and allowing cleanup of fuel storage facilities.

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

- Cleanup of the fuel storage basins at 100 K and N Reactor was a major activity during 1996. Characterization of contamination associated with those activities showed different mixtures of radionuclides between the water in the basins and the sludge, equipment, and debris at the bottom of the basins.

- Staff working in and custodianship of the 324 and 327 buildings were transferred from PNNL to Babcock and Wilcox Hanford Company (one of the PHMC contractors) on November 1, 1996. PNNL ordered termination bioassay for staff who were on routine bioassay schedules.

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 workers for intakes, 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 follow-up 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.

The values for the excreta analyses did not change from 1995 values (several new routine sequential analyses were implemented on July 1, but the MDAs for these were the same as the MDAs for the single analyses). Limited use of the very low-level plutonium urinalysis method (code IPUL) occurred in 1996 so that capability was added to Table 3.1.

Several changes occurred to the nature of lung counting in 1996 that impacted lung count capabilities. These changes included new, larger detectors; four instead of six detectors in the array; and an increase in the count time from 20 to 50 minutes (see also Chapter 4.0). In Table 3.2, the combination of the new detectors, new configuration, and 50-minute counting time is referred to as "new configuration." The equipment changes occurred in the stainless steel room first (September 1994) and the 50-minute counts were initiated when the equipment changes in the iron room were completed (July 1996).

3.1.2 Excreta Bioassay Contract Activities

Earlier efforts of the DOE-RL Waste Programs Division to establish a sitewide sample management office for Hanford did not impact the excreta bioassay contract during 1996. A series of meetings were held between the bioassay technical administrator and Paul Carter of DOE-RL Waste Programs in which the uniqueness of the bioassay contract was discussed. Following these meetings, DOE-RL Contracts authorized a one-year extension of the Quanterra contract.

Lower unit prices were negotiated with Quanterra based on their commercial price list and competitors' prices. Because of changes in federal contracting requirements, government contractors are no longer required to justify price changes on a per product basis, and work on Quanterra's cost model was

Table 3.1. Specified Minimum Detectable Activities and Screening Levels for Routine Excreta Analyses During 1996

Analysis[a]	Contractual MDA[b,c]	Screening Level and Sampling Frequency [c,d]
^{238}Pu, ^{239}Pu	0.02 dpm	0.01 dpm (A)
^{238}Pu, ^{239}Pu (IPUL)	0.005 dpm	0.003 dpm (A)
^{90}Sr	10 dpm	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]

(a) Analysis of urine samples, unless otherwise indicated.
(b) Specified MDA based on Type I and Type II errors of 5%, as described in the SOW (a copy is available in the Hanford Radiation Protection Historical Files).
(c) Amount per total sample volume, unless otherwise indicated.
(d) Investigation of a potential internal exposure is performed when this value is exceeded; when the screening level is less than the MDA, it is set at about half of the MDA. (Routine bioassay monitoring frequency: A-annual, BE-biennial, BW-biweekly, M-monthly, Q-quarterly.)
(e) The lab cannot discriminate between ^{233}U and ^{234}U and reports the results as ^{234}U (beginning in 1994).
(f) Upper level of expected environmentally derived uranium in urine for the Hanford region.
(g) Special screening levels are established for short-term tritium work where beginning and ending work samples are obtained instead of monthly routine sampling.

dropped. The new prices will result in a savings of $100,000 during the first option year of the contract ending June 30, 1997. The decision was made in December 1996 to extend the contract with Quanterra through the second option year (June 1998).

An Inspection of Services was performed in June 1996 to review contract compliance as it related to 1) implementation of analytical procedures generated for isotopic plutonium in urine, 2) implementation of analytical procedures generated for all fecal analyses, 3) compliance to Quality Assurance requirements of the contract, and 4) review of data packages for completeness. In the hopes of minimizing duplication of efforts and unnecessary costs, the technical administrator for Battelle's contract with

Table 3.2. Minimum Detectable Activities and Screening Levels for Routine In Vivo Measurements During 1996

Measurement/Radionuclide[a]	MDA[b] nCi	Screening Level[c] (nCi)
Whole-Body Count[d]		
^{60}Co	4	4
^{154}Eu	8	Any detected
^{137}Cs	4	Any detected
Lung Count, Old Config.		
^{235}U	0.2	Any detected
^{238}U (by ^{234}Th)	3	Any detected
^{241}Am	0.3	Any detected
Lung Count, New Config.		
^{235}U	0.095	Any detected
^{238}U (by ^{234}Th)	1.6	Any detected
^{241}Am	0.18	Any detected

(a) For selected radionuclides. (The detection of radionuclides not listed resulted in follow-up.)
(b) For each in vivo count, the decision levels (approximately half of the MDAs) were reported under "detection limit" to REX, but, in terms of overall detectability for all measurement, these MDAs were still applicable. Different detectors, number of detectors in an array, and count times were used for lung counting at various times during the year, each combination resulting in different MDAs. The lung counting MDAs shown are the highest of the combinations.
(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.
(d) MDAs apply to the preview counter only; lower MDAs were obtained using the germanium array which was used when activity was first detected using the preview counter.

Quanterra for environmental radiochemical analyses participated in the inspection as an observer. The inspection resulted in one finding and two observations primarily pertaining to procedures. By January of 1997, all findings and observations were closed.

3.1.3 Excreta Quality Control Oversight Program

The Quality Control Report for the period July 1, 1995 through June 30, 1996 was completed in November.[a] Urine analyses for tritium, ^{90}Sr, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{234}U, ^{235}U, ^{238}U, and elemental uranium

(a) J. A. MacLellan. November 14, 1996. Letter report to Distribution, "Results of the PNNL Excreta Bioassay Quality Control Oversight Program for July 1, 1995 Through June 30, 1996". (A copy is available in the Radiological Records Historical File, Pacific Northwest National Laboratory, Richland, Washington.)

Table 3.3. Specified Minimum Detectable Activities for Emergency and Expedited Excreta Bioassay During 1996

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

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

and fecal analyses for ^{238}Pu, ^{239}Pu, ^{241}Am, ^{228}Th, ^{230}Th, and ^{232}Th were tested. The quality control samples submitted by PNNL during the report period represented about 3% of the total samples submitted. This is only slightly less than the percentage for the 1995 report period.

Based on an evaluation of all quality control data, all analyses met or exceeded statistical specifications in the SOW. The unacceptable number of statistical outliers and false negatives observed previously [a] were not repeated in the July 1995 - June 1996 period.

(a) J. A. MacLellan, November 21, 1996. Letter report to Distribution, "Results of the PNNL Excreta Bioassay Quality Control Oversight Program for July 1, 1994 Through June 30, 1995."

3.1.4 Policy and Documentation Changes

Until April 1995, small-scope changes to the practices or technical aspects of the IDP were documented by Project Change Records. The Project Change Record identified the change, its effective date, and the reasons for and impacts of the change. A copy of the record was placed in the Hanford Radiological Protection Historical Files. Since April 1995, policy and procedure changes were incorporated into the *Hanford Internal Dosimetry Project Manual*[a] and the *Hanford Internal Dosimetry Procedures Manual*[b] according to methods established in the project QA plan. Generally, the project manual undergoes page changes, whereas procedures are revised and reissued as whole procedures.

In 1996, changes to the project manual involved incorporating the use of Inductively-Coupled Plasma Mass Spectrometry (ICPMS) for evaluation of high uranium urinalyses and addition of minimum detectable dose tables for uranium, plutonium, and the embryo/fetus for various radionuclides. Two proposed revisions were in review by the HPDAC at year end. One would establish guidance on balancing cost versus sensitivity for design of routine bioassay programs; the other addressed possible changes to routine plutonium bioassay based on advanced technology and "aging" of the Hanford plutonium mixtures.

Major procedure changes included

- suspension of worker-specific screening levels for uranium urinalysis until the validity of the screening level can be checked using ICPMS
- incorporating ICPMS into uranium bioassay review methods
- allowing the evaluation summary letter to go directly to the worker for all cases where no dose is assigned.

Procedures for using the Potential Intake Tracking System and the Chronic Assessment Tracking System were declared inactive. A major change to the way the project handles bioassay for declared pregnant workers (i.e., removing the special tracking requirements if the bioassay result is below the screening level) was presented and approved by the HPDAC, and the procedure revision was in progress at year-end.

Clarification of an unwritten policy occurred at the direction of DOE-RL and HEHF as a result of an activation of the Emergency Decontamination Facility (EDF) by HEHF for an injured, contaminated worker from the Washington Public Power Supply System. Because the worker was not a Hanford

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(a) Internal Manual, PNL-MA-552, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.
(b) Internal Manual, PNL-MA-565, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

contractor employee and was not working on Hanford property, the on-call Exposure Evaluator did not officially respond to the EDF activation. However, in the incident critique, DOE-RL clarified the policy that the Exposure Evaluator will respond to any EDF activation.

3.1.5 Special Bioassay Requirements Evaluations

The sensitivity of ^{137}Cs whole body counting for different ^{137}Cs:^{90}Sr mixtures was evaluated based on a 10-mrem committed effective dose equivalent (CEDE) screening level, a 100-mrem CEDE bioassay goal, and a 5-rem CEDE regulatory limit. Annual whole body counting using the sodium iodide stand-up counter system (also called Preview Counter), with an MDA of 3.8 nCi for ^{137}Cs, came sufficiently close to the 100-mrem bioassay goal to be considered adequate for up to a 1:10 mixture. Even at the 1:100 ratio, the whole body exam would be capable of demonstrating compliance with the 5-rem CEDE regulatory limit. Ratios in excess of 1:10 were considered appropriate for routine ^{90}Sr urinalysis. If a worker was not routinely monitored by ^{90}Sr urinalysis, it was concluded appropriate to perform a special ^{90}Sr urinalysis as follow-up to a high routine whole body count. The current use of a 1:1 ratio for routine bioassay program design was not changed based on this evaluation; however, facility source sample data indicate that a very wide range of the ^{137}Cs:^{90}Sr ratio exists at Hanford, and the suitability of a single default mixture for routine program design is tenuous. Work on this subject will continue next year as part of the technical basis revision.

Routine bioassay monitoring for ^{226}Ra was evaluated in support of PNNL glove box work in the LSL-2 and the 325 buildings. For short-term projects (90 days or less), ending work chest counts performed within 30 days of the completion of work were considered adequate, easily demonstrating compliance with the 5-rem regulatory requirement and the 500-mrem administrative control level, but falling short of the 100-mrem investigation level criterion. For continuing work, quarterly or semiannual chest counts can demonstrate compliance with the regulatory limit, but not the administrative control level. Urine sampling would be substantially more sensitive; however, some initial control samples from unexposed workers would need to be obtained to identify possible natural background levels. Because ^{226}Ra is not a routinely calculated result for chest counts, workers being monitored for ^{226}Ra would require particular identification to assure that the ^{226}Ra result is calculated.

3.1.6 Cost Reduction Activities

Fiscal year (FY) 1996 was marked by some significant fiscal changes. Cost reduction became a paramount concern in FY 1995 leading to activities such as brainstorming, planning, and implementing cost reduction ideas and employee downsizing incentives. As a consequence, the FY 1996 budget for the project was 48% less than the FY 1995 budget; and the actual cost for FY 1996 was also 48% less than actual cost for FY 1995. The cost savings resulted mostly from reduced numbers of bioassay measurements and intakes. Savings also occurred because two special projects were completed in FY 1995 and no new ones were begun, reductions were made in the excreta QC oversight program (e.g., the intercomparison task was eliminated), and costs for incident response and intake evaluations were removed from the budget.

Fiscal Year 1996 was also the first year that portions of the IDP were funded by charging a fixed price per unit. Three tasks were funded that way: 1) excreta bioassay scheduling, contract administration, and excreta QC oversight; 2) review of high-flagged or otherwise special bioassay results; 3) review of records sent to or received from offsite locations. Also for the first time, some tasks that benefitted one contractor only were invoiced directly to the impacted contractor on an hourly rate, such as incident response and intake evaluations.

3.1.7 AMERIN Replaces PUBURD and PUCHEST

The AMERIN (AMERicium INgrowth) computer code was developed and accepted as a tool for calculating biological clearance half-times and ^{241}Am ingrowth for mixtures of ^{241}Am and ^{241}Pu in a single biological clearance compartment.[a] The code was an upgrade and replacement for the PUCHEST and PUBURD codes, which had been developed about 1984 for use on first-generation personal computers. AMERIN can be executed either from DOS or Windows, uses radiological half-lives for ^{241}Am and ^{241}Pu from the International Commission on Radiological Protection's Publication 38 (ICRP 1983), and provides a printout of the results. The verification and validation of AMERIN included similar checks on the original PUCHEST and PUBURD codes which had never undergone formal validation and verification.

3.2 Monitoring and Assessment Activities

The IDP excreta bioassay monitoring and internal dose assessment activities during 1996 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 nonstandard requests. Contractors and IDP staff enter the nonstandard requests into REX manually. 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 1996. A total of 3622 samples were requested in 1996, down 19% from the 1995 requests and 60% from 1994 requests. This major decrease reflects the cleanup and deactivation of many

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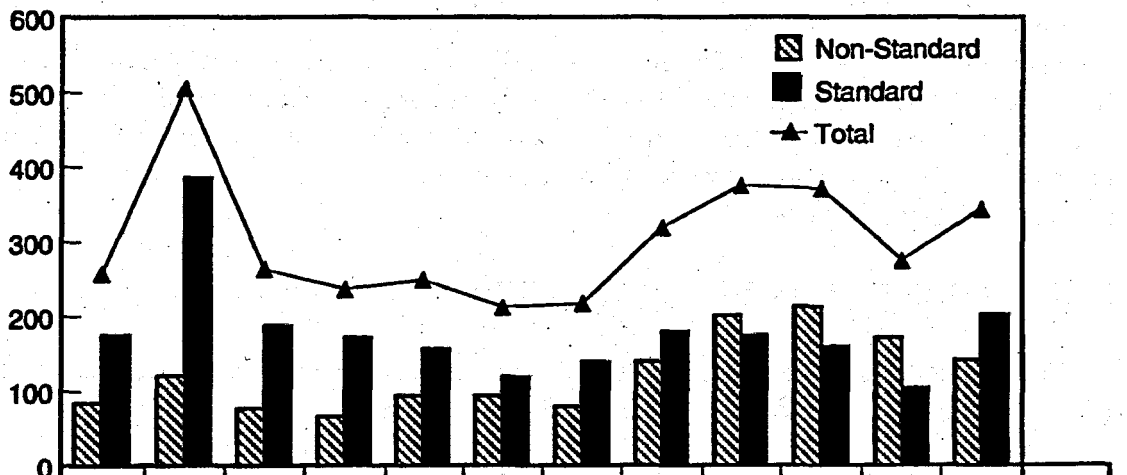
(a) E. H. Carbaugh. November 14, 1996. Letter report to D. E. Bihl, "Software Validation and Verification - AMERIN, PUCHEST, and PUBURD Codes." (A copy is available in the Radiological Records Historical File, Pacific Northwest National Laboratory, Richland, Washington.)



	1	2	3	4	5	6	7	8	9	10	11	12	Total
Non-Standard	83	120	76	65	93	93	79	139	201	212	171	141	1473
Standard	174	385	187	171	156	119	138	180	174	159	104	202	2149
Total	257	505	263	236	249	212	217	319	375	371	275	343	3622

1996

SG96030311.2

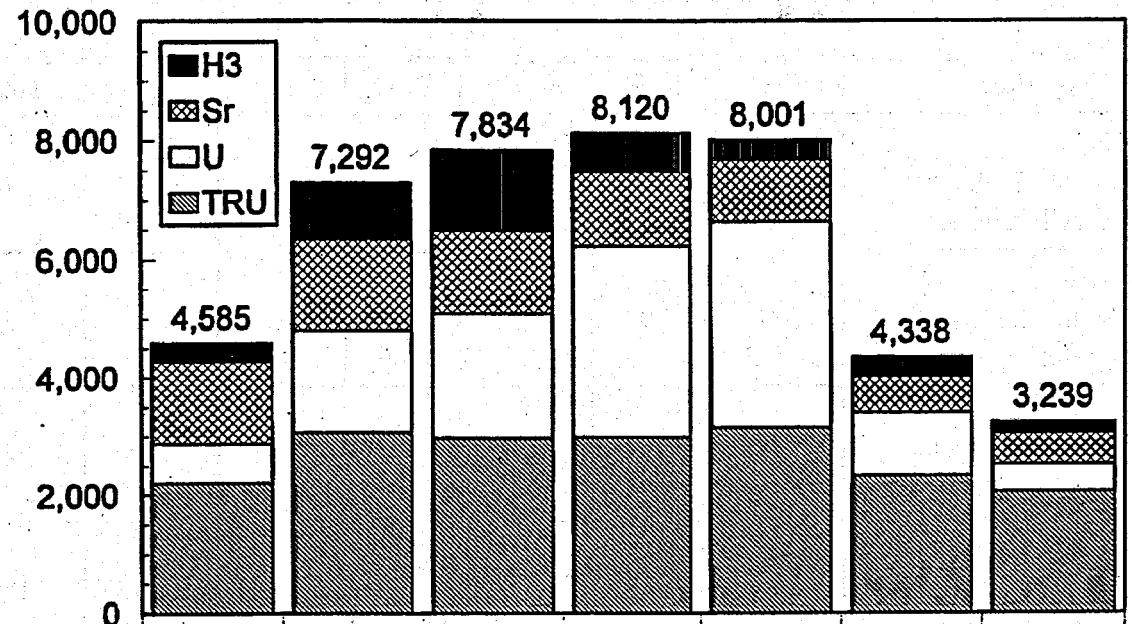
Figure 3.1. Standard and Nonstandard Excreta Requests by Month

contaminated facilities and increased scrutiny of who truly needs to participate in the excreta bioassay program. As usual, the majority of the samples, 69%, were standard requests, compared to 68% in 1995 and 62% in 1994.

During 1996, 3292 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, 98% were classified as routine (including measurements on visitors) and 2% 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 1990. The figure shows that the number of routine measurements in 1996 continued the decreasing trend started in 1995 and was similar to numbers in the mid 1980s. Details on the type of excreta measurements categorized by contractor are provided in Table 3.4. Overall the number of excreta measurements decreased by 27% from 1995. Uranium analyses showed the largest change, decreasing by 56% relative to 1995 analyses and 87% from the 1994 level. This reflects the decontaminating and locking of most uranium-contaminated facilities. Among contractors, PNNL and the ERC team had slightly increased use of excreta bioassay, while the WHC/ICFKH/PHMC combination had a large decrease in use.

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 1996, 671 excreta sample requests were designated as no-samples, down from 860 no-samples in 1995. In terms of percentage of



	1990	1991	1992	1993	1994	1995	1996
H3	315	950	1,348	644	334	327	188
Sr	1,393	1,543	1,400	1,248	1,029	610	534
U	676	1,735	2,124	3,248	3,494	1,080	468
TRU	2,201	3,064	2,962	2,980	3,144	2,321	2,049

Figure 3.2. Routine Urine Measurements Made from 1990 Through 1996

total requests, the 1996 rate (19%) was similar to previous years (19%, 14% , and 23% in 1995, 1994, and 1993, respectively). In addition there were 209 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, 0.6%), no sample received (NS, 15%), lost container (LC, 52%), insufficient sample volume (IS, 13%), and lost in lab (LL, 20%). The lost in lab category more than doubled from the 9% in 1995, due mostly to two unrelated episodes of batches of samples with bad chemical yields.

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 that incurred intakes prior to their Hanford employment to assure that the intake information is converted to dose in a manner consistent with DOE regulations (pre-Hanford). Reevaluation of internal dose are also conducted periodically for workers with significant long-term body burdens (reevaluations).

Table 3.4. Worker Excreta Measurements Reported in 1996

Type/Reason	WHC	KEH	PNNL	ERC	PHMC	Other	Total
^{3}H-urine							
Routine Schedule[a]	0	6	161	0	21	0	188
Special Request[b]	0	0	0	0	0	0	0
^{90}Sr-urine							
Routine Schedule	47	94	293	51	32	13	530
Special Request	3	0	0	0	0	0	3
Uranium-urine							
Routine Schedule	63	180	186	7	21	10	467
Special Schedule	1	3	12	0	0	0	16
Plutonium-urine							
Routine Schedule	1025	385	284	67	99	36	1896
Special Schedule	7	2	4	2	0	0	15
Other-urine							
Routine Schedule	6	23	123	1	0	0	153
Special Schedule	1	1	4	0	0	0	6
TRU-fecal							
Routine Schedule	0	0	0	1	0	0	1
Special Schedule	11	0	0	0	6	0	17
Analyses Totals	1164	694	1067	129	179	59	3292
Recounts or Reanalyses							
Plutonium-urine	8	6	2	0	4	0	20
^{241}Am-urine	0	0	4	0	0	0	4
Curium-urine	0	0	6	0	0	0	6

(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).

During FY 1996, 18 incidents with the potential for intake, involving 42 workers, were identified through workplace monitoring. Of the 42 workers involved in the incidents, intakes were confirmed for only 12 workers. The highest calculated dose among the 12 workers was 250 mrem CEDE. The radionuclides and groups involved included ^{137}Cs and/or ^{90}Sr (9 incidents with 23 workers), TRU (7 incidents with 17 workers), and miscellaneous, non-Hanford radionuclides (2 incidents with 2 workers). Table 3.5 shows the incident breakdown by contractor, area, and facility.

Table 3.5. Summary of Potential Intake Incidents During 1996

Facility		Custodian	Number of Incidents	Number of Workers	Worker Contractor	Principal Nuclide
Area	ID					
100N	Emer. Dump Basin	ERC	1	1	WHC	^{134}Cs[a]
200E	202A	WHC	1	1	WHC	Pu mix
200E	225B	PHMC	1	1	PHMC	^{131}I[b]
200E	241C	WHC	2	3	WHC	^{137}Cs
200E	241SX	WHC	1	1	WHC	^{137}Cs
200W	222S	WHC	2	9	WHC,KEH	^{137}Cs, ^{90}Sr
200W	234-5Z	WHC	2	4	WHC	Pu mix
200W	234-5Z	PHMC	1	6	PHMC	Pu mix
300	324	PNNL	2	2	PNNL	^{137}Cs, ^{239}Pu
300	325	PNNL	1	7	PNNL	^{137}Cs
300	327	PNNL	1	1	PNNL	^{137}Cs
300	331	PNNL	1	1	PNNL	^{239}Pu
300	3720	PNNL	1	4	PNNL	^{244}Cm
600		WHC	1	1	WHC	^{137}Cs
		Total	18	42		

(a) Not confirmed; isotope not likely associated with Hanford.
(b) Non-occupational source.

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 were discovered this way. In 1996, there were 40 evaluations started because of routine bioassay results that exceeded the criteria for investigation. From these, intakes were assigned for three workers. For two the CEDE was much less than 100 mrem. For the third, an old intake of plutonium believed to be due to an incident in 1963, was discovered using a new, ultra-sensitive urinalysis method (Code IPUL). The dose was calculated to be 1.3 rem CEDE. Table 3.6 shows internal dose evaluations for 1996 resulting from high routine bioassay results. Table 3.7 provides the trends in all types of potential intake evaluations since 1990.

There were no workers who had been identified as having potential chronic exposures to uranium or tritium in 1996.

The range of internal doses assigned to the Hanford work force in 1996 is summarized in Table 3.8.

Table 3.6. Summary of Intake Cases Identified Through the Routine Bioassay Program During 1996

Facility		Custodian	Number of Workers	Contractor	Principal Nuclide	Reason
Area	Building					
200W	234-5Z	GE[a]	1	WHC	Pu mix	High Routine
undetermined		WHC	1	WHC	^{137}Cs	High Routine
300	undetermined	PNNL	1[b]	KEH	U mix	High Routine
		Total	3			

(a) Intake assigned to 1963.
(b) Two intakes assigned to 1994 and 1995.

Table 3.7. Comparison of Potential Intakes by Reason Code, 1990-1996

	1990	1991	1992	1993	1994	1995	1996
Incident, Total	30	90	30	51	33	51	42
Confirmed				17	7	12	12
Unconfirmed				34	26	39	30
High Routine, Total	93	69	141	65	91	59	40
Confirmed				1	15	1	3
Unconfirmed				64	76	58	27
Open							10
Contractor Request, Total	5	0	0	1	3	0	0
Confirmed				1	0		
Unconfirmed				0	3		
Chronic Exposure, Total	95	30	4	6	0	0	0
Confirmed				0	0	0	
Unconfirmed				6	0	0	
Pre-Hanford, Total			20	3	35	9	12
Confirmed				3	31	9	11
Unconfirmed				0	4		1
Totals	223	189	195	126	162	119	94
Confirmed				22	53	22	26
Unconfirmed				104	109	97	58
Open							10
Revaluation, Total Initiated	5	1	4	3	12	11	2
Completed				0	8	17	1
Open							2

Table 3.8. Range of New Internal Doses Assigned to the Hanford Work Force in 1996

Dose (mrem)[a]	Numbers of Workers						
	DOE	WHC	ICFKH	PNNL	ERC	PHMC	Total
< 100	0	4	3	1	0	5	13
100 - < 500	0	1	0	0	0	0	1
500 - < 2000	0	1	0	0	0	0	1
2000 - < 5000	0	0	0	0	0	0	0
>5000	0	0	0	0	0	0	0

(a) CEDE. Based on 1996 evaluations, although the intake could have occurred in any year. Excludes reevaluations.

3.3 Supporting Studies

There were no supporting studies conducted in 1996.

3.4 Project-Related Professional Activities

IDP staff presentations, publications, and professional memberships during 1996 are listed in this section.

3.4.1 Presentations

Carbaugh, E. H. 1996. *Practical Applications of Internal Dosimetry Calculations*. A professional enrichment course presented at the 41st Annual Meeting of the Health Physics Society, July 21-25, 1996, Seattle, Washington.

MacLellan, J. A. 1996. "Application of ANSI N13.30 Counting Statistics." An invited presentation in a workshop on "Application of Detectable Limit and Critical Level Concepts" at the 42nd Conference on Bioassay, Environmental and Analytical Radiochemistry, October 13-17, 1996, San Francisco, California.

3.4.2 Publication

Health Physics Society. 1996. *An American National Standard - Performance Criteria for Radiobioassay*. HPS N13.30-1996, Health Physics Society, McLean, Virginia. J. A. MacLellan was member of the committee that wrote the standard.

3.4.3 Professional Memberships

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

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

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

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

MacLellan, J. A. Council Member, Columbia Chapter-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. As part of the Hanford Radiological Protection Services Program operated by PNNL, the project 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 operates and maintains equipment in the 747-A Building, the 747-A Trailer, a mobile whole body counting trailer, and the EDF located next to Kadlec Hospital in Richland, Washington. Collectively, the facilities are known as the In Vivo Radioassay and Research Facility (IVRRF). Project requirements for the WBCP are outlined in the *Whole Body Counting Manual*.[a]

A summary of the project activities, which include routine measurements of Hanford workers, special request 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 data 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 and spectra for personnel measurements are stored online in the REX database. Information copies of the measurement records are maintained at the IVRRF.

The measurement facilities routinely used at the IVRRF include the Preview Counter, used for rapid screening, whole body measurements; the Iron Room, Stainless Steel Room, and Lead Room, each containing germanium counting systems designed to optimize detection of low energy photons; and the Palmer Room, containing the scanning coaxial germanium whole body counter designed to optimize detection of high-energy photons. There is also some counting equipment in the EDF. Routine operating hours are currently from 8:00 a.m. to 12:00 p.m. and 1:00 p.m. to 3:00 p.m. on weekdays. By special request, additional hours can be scheduled to cover off-shift or after-work counts. The facilities and equipment are also available on an on-call basis for incident response during off-hours.

4.1 Summary of 1996 IVRRF Measurements

The total number and type of measurements made on personnel during 1996 are given in Table 4.1. In 1996, a total of 9065 measurements were made for DOE-RL and the Hanford contractors, representing a 17% decrease from the number performed in 1995. This decrease primarily represents contractor-identified reductions in the total personnel requiring lung counts and whole-body counts (WBCs). However, the projected workload and the basis for funding for 1996 was 6000 measurements, which the actual workload exceeded by 50%. Figure 4.1 depicts the in vivo measurements made at the IVRRF during the past six years.

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

Table 4.1. In Vivo Measurements Performed During 1996 and Recorded in the REX Database

Count Type and Reason	BCSR	DOE	ERC	ICFKH	Contractor Code			Other[a]	Total
					PMHC	PNNL	WHC		
Whole Body Count									
Routine Schedule	37	195	963	1,095	900	1,023	2,800	21	7,034
Special Request	0	0	1	4	2	16	13	0	36
Contractor Request	0	78	22	15	12	147	64	0	338
Total	37	273	986	1,114	914	1,186	2,877	21	7,408
Lung									
Routine Schedule	4	22	53	313	243	295	675	1	1,606
Special Request	0	1	0	2	0	3	11	0	17
Contractor Request	0	3	3	0	0	1	1	0	8
Total	4	26	56	315	243	299	687	1	1,631
Other									
Routine Schedule	0	0	0	0	0	0	0	0	0
Special Request	0	0	0	0	0	8	16	0	24
Contractor Request	0	0	0	0	0	2	0	0	2
Total	0	0	0	0	0	10	16	0	26
Grand Total	41	299	1,042	1,429	1,157	1,495	3,580	22	9,065

(a) Other represents Hanford Environmental Health Foundation and US West.

4.2 Routine Tasks

Routine activities of the WBCP for 1996 included technical services for direct radiobioassay, data processing, equipment maintenance, quality assurance support, and project management.

4.2.1 Routine In Vivo Radiobioassay

Many different types of direct bioassay measurements are performed for the work force at the Hanford Site. Both routine (periodic) measurements and special request or incident analyses are supported. The frequency of measurements for personnel is established by the contractor using guidance from the IDP. Contractors schedule routine IVRRF measurements through the Hanford Scheduling System (HSS), which is administered by HEHF. HSS reports to the IVRRF a daily roster of personnel scheduled to be counted.

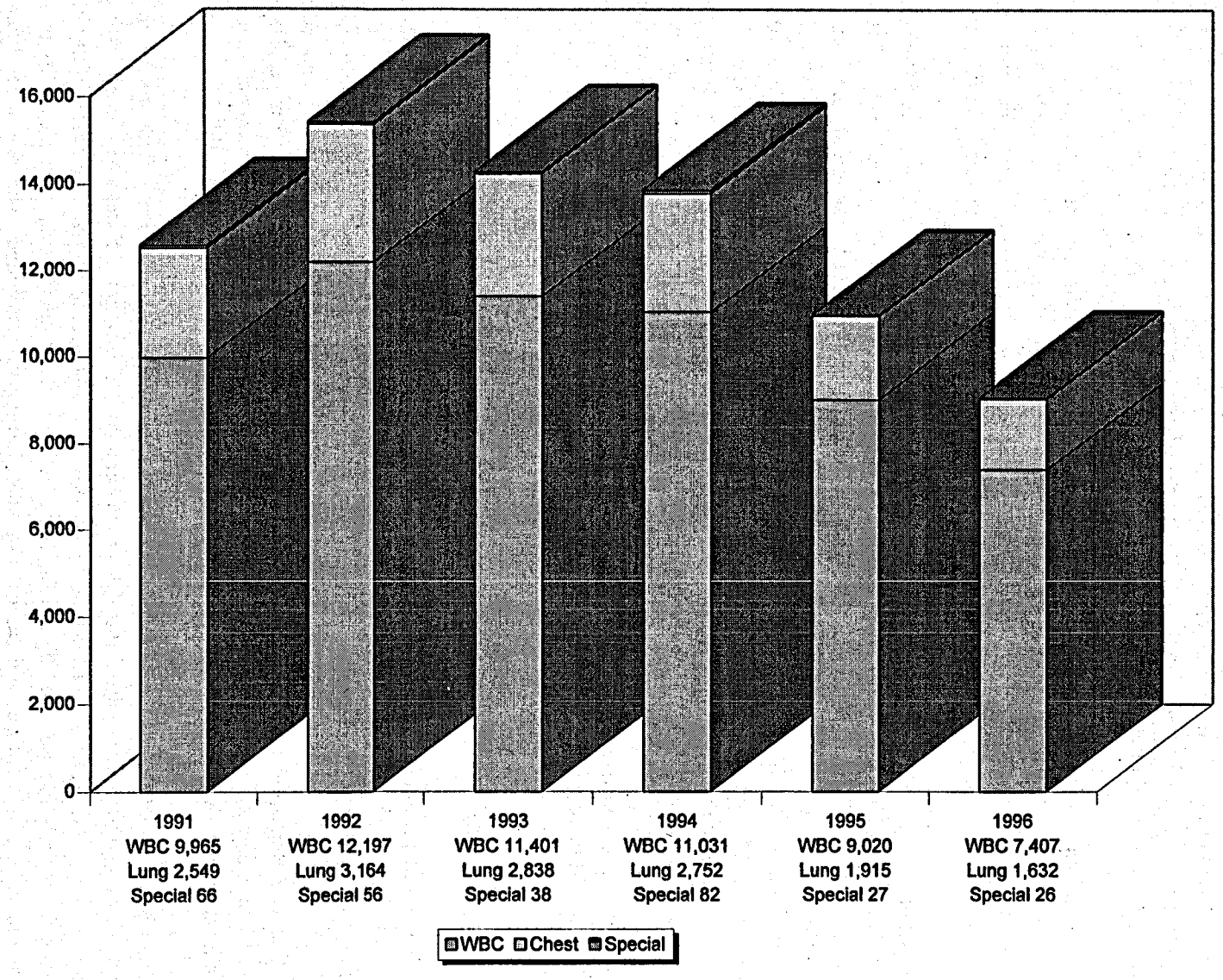


Figure 4.1. In Vivo Measurements Made at the IVRRF From 1991 Through 1996

The type of measurement is determined by the exposure scenario or the physiological location of a potential intake. Generally, an employee with potential exposure to intakes of radionuclides which emit high-energy gamma rays (e.g., fission products such as ^{137}Cs or activation products such as ^{60}Co) receives an annual WBC performed on the Preview Counter. The Preview Counter consists of a short (200-second) count in a standing position using five sodium iodide (NaI[Tl]) detectors. Verification of any positive result is performed with the scanning coaxial germanium system in order to identify and quantify the specific radionuclides present.

If the work involves transuranium radionuclides or insoluble uranium isotopes, lung counts are performed. A routine lung count consists of a 50-minute count using four high-purity germanium (HPGe) detectors. Radioactivity that is detected by lung counting is verified by a second count. Several other types of counts may also be done to provide more accurate quantification and localization of the intake.

All of the routine counting systems are interfaced to Acquisition Interface Modules (AIM) which are connected by a local area network (LAN) to two Digital Equipment Corporation (DEC) Model 3100 workstations. The workstations control the counting functions and retrieve the acquired data from the AIMs. Computer codes developed at PNNL are used to evaluate spectra results collected during the in vivo measurement. Additional commercial software residing on the DEC Model 3100 workstations (Genie™ System Spectroscopy Applications, obtained from Canberra Industries and written for VAX/VMS) can be used to analyze spectra. The VAX workstations are in turn interfaced by the LAN to an IBM RISC 6000 computer. The IVRRF measurement results are maintained in an Oracle™ database management system (DBMS) that resides on the RISC 6000. Results in the Oracle™ DBMS are transferred to the REX database, operated by the HRRP (see Section 5.0). The Vax Workstations, the RISC/6000, and PCS running a Visual Basic application are combined into the NEXEC computer system.

4.2.2 Data Administration

Data administration for the IVRRF provides for the maintenance of the computer hardware and software related to the analysis and storage of in vivo measurement results. Verification of PNNL-developed software that is run on the computer platforms used at the IVRRF is also performed. New software written to augment and replace existing algorithms is verified, validated, and documented prior to routine use. Repair or replacement of computer hardware or components is also performed. Database management is performed at IVRRF to store, archive, backup, and analyze all measurements. The database currently runs Oracle™ software and backups are performed both daily and monthly.

Significant enhancements were made to the NEXEC computer system in 1996. The programming language was upgraded from Visual Basic 3.0 to version 4.0. This upgrade fixed a Microsoft error in accessing Oracle™ databases with Microsoft Network drivers. Users were given more flexibility in querying for records and the resulting information. To allow technician switch over, the ability to change the technician identifier without logging out of the system was added. The Plot Spectra function was improved with a zoom feature that allowed the user to view a chosen area of interest.

The Windows operating system was upgraded to Windows 95. This allowed NEXEC to take advantage of the full range of upper memory and handle seven detector spectra. The personal computers that run NEXEC were upgraded to run Windows 95 efficiently. Several algorithms for calculating results were written, verified, validated and put into routine operation. The calculation method for determining the average chest wall thickness was changed from an arithmetic average to an exponential average.

4.2.3 Technical Services

Routine technical services are provided to support the operation of the IVRRF. The resources under this task directly supported the performance, analysis, and documentation of over 9000 routine measurements in 1996. Additionally, more than 3000 calibration and daily QC measurements were performed. Technical services included the calibration, operation, procurement, and routine maintenance of the counting systems; the record-keeping and receptionist duties of the operating station; and the training, qualification, and testing of technical personnel. An inventory of radioactive calibration sources was maintained and semiannual witnessed inventories were preformed.

At the close of 1996, the counting systems at IVRRF included two low-energy lung counting systems (Iron and Stainless Steel Rooms); two WBC systems (Palmer Room and Preview Counter); wound, thyroid, and organ counting detectors (Lead Room); two whole body counting systems (Stand Up and Shadow Shield) in the remote WBC trailer; and, at the EDF, a wound counting system and a backup shadow shield whole body counting system.

4.2.4 Equipment Maintenance

Specific preventive maintenance is performed by PNNL Craft Services personnel on the components of the many counting systems used at the IVRRF. Maintenance is necessary as well for counting systems that require repair or replacement of electronic components. Expense-funded equipment needed to keep the counting instrumentation and associated computer systems operating reliably is also procured. Due to the high number of routine measurements performed at the IVRRF, new electronic equipment is often necessary to replace older, worn equipment. Components that require periodic replacement include power supplies, preamplifiers, line amplifiers, analog-to-digital converters, signal routers, and LAN interface modules. Replacement of detectors is a less frequent event, caused by either detector failure or gradual degradation in performance.

Three HPGe detectors were repaired in 1996. After in-house efforts were unsuccessful, a 38 cm^2 HPGe planar detector and a coaxial HPGe detector were successfully repaired by the vendors. Another 38 cm^2 HPGe planar detector with a vacuum leak around the beryllium window was successfully repaired at the IVRRF. One of the two shadow shield counters was disassembled and removed from the EDF in September 1996.

4.2.5 Quality Assurance Support

Quality Assurance (QA) and QC measures impact every part of the routine counting program. The WBCP has a formal QA program based on specifications of the *Quality Assurance Manual*[a] and other current guidelines. Reviews of project quality are performed by outside QA engineers and supplemented by industry QA inspections from independent subject experts from other DOE radiobioassay facilities. Additional reviews of project quality are performed in accordance with 10 CFR Part 835 (DOE 1993), which requires a planned functional audit of the project every three years. The Hanford contractors also perform joint audits of the WBCP.

The WBCP has historically been designated as a QA Impact Level III project. However, upgrades have been made in the QA area in preparation for DOELAP accreditation. New procedures were written, reviewed, and approved for all routine operations in February 1996. These procedures were incorporated into the *Whole Body Counting Procedures Manual*.[b] The current QA Plan[c] went through a review in December 1996 and an update will be released in early 1997.

An Annual Management Assessment of the WBCP was made by the Process Quality Department in September 1996. The results of the assessment found that the QA Plan and procedures established for the WBCP were effectively implemented on the whole, and the project staff members demonstrated a good understanding of the procedures. The observations reported from the assessment were primarily administrative areas where the QA Plan was not yet fully implemented or portions of procedures or other documents which had become outdated. Most of the observations from the assessment were addressed during 1996.

4.2.6 Preparation for DOELAP Accreditation

Preparing the WBCP to achieve DOELAP accreditation continued in 1996. Participation in performance testing and procedure development was the primary focus. The DOE will likely implement the formal accreditation in FY 1998. The WBCP will need to achieve DOELAP accreditation by 2000.

The WBCP participated in the DOELAP pilot testing conducted through the Radiological and Environmental Sciences Laboratory (RESL) at the Idaho Falls operations office. It was determined that IVRRF will apply for accreditation in all seven in vivo measurement categories. Measurements were made on mixed fission, plutonium, and uranium lung phantoms in August 1996. The measurement results were submitted to the DOELAP Administrator in September 1996.

(a) Internal Manual, PNL-MA-70, Rev. 2, Pacific Northwest National Laboratory, Richland, Washington.
(b) Internal Manual, PNL-MA-554, Pacific Northwest National Laboratory, Richland, Washington.
(c) Internal Manual, LSC-021, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

4.2.7 Project Management

Routine project management activities include supervision of staff, financial control activities, annual development, updating of planning documents (WBCP Long-Range Plan, Fiscal Year Work Plan), quarterly status presentation to DOE-RL, and contributions to the Hanford Radiological Protection Support Services Annual Report. Unit pricing for in vivo counts was used in 1996 for the first time to recover costs. Two technicians and a full time secretary volunteered for reduction of force in 1995. These employees were not replaced based on the 1996 projections of the number of counts required by the Hanford contractors. In spite of the actual volume exceeding the projections by 50%, the WBCP staff were able to successfully complete several supporting tasks and make improvements to the project as described in Sections 4.3 and 4.4.

4.3 Non-Routine Tasks

Several supporting tasks were performed in 1996. These included an evaluation of spectral analysis software, an international intercomparison program with 22 other laboratories, and the measurements of two children from Belarus.

4.3.1 Evaluation of Spectra Analysis/Acquisition Software

Spectra acquisition is currently performed using a VAX WS3100 running VMS and Genie™ System Spectroscopy Application Software. This system was put into routine operations in 1990 and has come close to the end of its lifespan. In an effort to find a replacement, an evaluation of the spectra analysis/ acquisition software was started.

An evaluation copy of Raygun was acquired from the Nuclear Chemistry Section. The Raygun software is a DOS application written in Fortran and owned by PNNL which has been through a full QA audit. Raygun is only a spectra analysis package and does not acquire spectra. It operates on a summed spectrum using a linear fit between calibration points for the calibration curve. After a full analysis of the performance and the user interface, it was decided that Raygun would not fit the needs of the WBCP.

An evaluation copy of Seeker was acquired from Vertechs Software Solutions. Seeker will currently run with EG&G Ortec spectra acquisition modules. Vertechs would attempt to access the AIMs currently in use, but the drivers are OS2 compatible and would not run on a Windows operating system. An evaluation of the current system found that it would require replacing all the current spectra acquisition modules currently in use, which was not cost effective.

4.3.2 Female BOMAB Intercomparison Program

The IVRRF participated this year in a radiobioassay international intercomparison program operated by the Canadian National Calibration Reference Centre (NCRC). The intercomparison program will take two years and include 22 countries on six continents. Currently, laboratories calibrate their whole body

counting equipment using Bottle-Manikin Absorption phantoms (BOMAB) which consist of ten polyethylene cylinders of various sizes which are filled with radioactive solutions or tissue-substitute materials. When appropriately assembled, the BOMAB phantom approximates the size, weight, and shape of Reference Man.[a] Reference Man is larger than the female BOMAB and a positive bias is expected. Measurements of the female BOMAB were completed in May 1996 in the Palmer Room and the Preview Counter.

The results were sent to the Canadian NCRC in August 1996. Radionuclides included in the intercomparison were ^{60}Co and ^{137}Cs. A summary of the PNNL measurement bias from the inter-comparison is shown in Table 4.2. The preview counter results had a negligible positive bias and the Palmer room results had a slight positive bias. The Palmer room bias results from the mass centroid of the female BOMAB phantom being closer to the detectors compared to the male BOMAB phantom. Consequently, a calibration factor based on the male BOMAB phantom overestimates the activity in female-sized BOMAB phantom.

Table 4.2. Summary of Female BOMAB Intercomparison Study Results

Detection System	^{137}Cs Bias	^{60}Co Bias
Preview Counter	4%	1%
Palmer Room	11%	11%

4.3.3 Measurements of Children from Belarus

The IVRRF staff performed measurements on two sisters from Minsk in Belarus. The girls were in the United States as part of the Children of Chornobyl program. The youngest child suffers from alopecia universalis (loss of body hair) and the primary care physician wanted to rule out the possibility of radiation induced epilation. A very small amount of ^{137}Cs was detected in the youngest girl and no activity was detected in the older girl. The use of chromosome aberration studies to detect significant levels of external exposure was discussed with the physician and he was referred to Radiation Emergency Assistance Center/Training Site in Oak Ridge, Tennessee.

4.4 Improvements to the Whole Body Counting Project

Several improvements were completed at the IVRRF during 1996 that affected counting equipment and the cost of operating the WBCP. These improvements are described in the following sections.

(a) Reference Man is based on ICRP 23 (1984).

4.4.1 New Lung Counting Detection System

Three 38-cm^2 HPGe detectors were delivered in 1995 in an effort to upgrade the current detection system. The fourth and final 38-cm^2 HPGe detector was received from the vendor and completed acceptance testing in May 1996. The Iron Room detection system, using six 20-cm^2 HPGe detectors, was replaced with four new 38-cm^2 HPGe detectors in June 1996. The calibration of the Iron Room was derived from the existing calibration in the Stainless Steel Room when it was determined that the responses from the two detection systems were statistically identical. The new system was installed affecting only one day of routine operations. The older detectors were moved into the Lead Room for increased nonroutine counting capabilities. This completed the multi-year effort to replace the aged lung counting detectors. Figure 4.2 shows the new counting system in the Iron Room and Figure 4.3 shows the counting system in the Stainless Steel Room.

4.4.2 Measurement Sensitivity Improvements

In 1995, a plan was drawn up and initiated to improve the efficiency of the current counting system in the Palmer Room. The plan was intended to lower the detection level and lower the minimum detectable dose to workers exposed to mixtures containing small amounts of transuranic activity along with much higher fission and activation product activities. A new sled drive for the Palmer room was received and tested in July 1996. The actual installation was delayed until higher priority items were addressed. The computer-controlled sled drive provides the capability to set any count time desired and includes an automatic return to starting position feature. Two 120% large coaxial detectors were received from the vendor in August 1996. The configuration in the Palmer room was modified to insert the new detectors, to create a seven-detector system. The seven-detector coaxial array was upgraded with new high-voltage bias supplies in October 1996. Routine operation of the seven-detector system is planned for early 1997.

4.4.3 Cost Savings Implementation

The subcontract with Strategix Integrated Software, Inc., that provided programming support for NEXEC development, was canceled early in an effort to save costs. The software support effort continued using existing staff. A review was made of routine tasks for the possible elimination of low value added tasks in May. Discontinuing the checks for duplicate spectra and generating hard copy reports of the weekly summary of measurement details will save about 60 hours of technician time annually. The consolidation of the Radiation Protection Services (RPS) computer resources was found to be an area for potential cost savings. As a first step to this goal, an Automated Data Processing (ADP) Strategic Plan was written to guide the RPS projects.

4.4.4 New Thyroid Counting Calibration

An ^{125}I insert for the thyroid phantom was made using NIST traceable Standard Reference Material and received in May 1996. A calibration based on measurements made with two 20-cm^2 HPGe detectors was developed in May 1996. A calibration based on measurements made with one 38-cm^2 HPGe

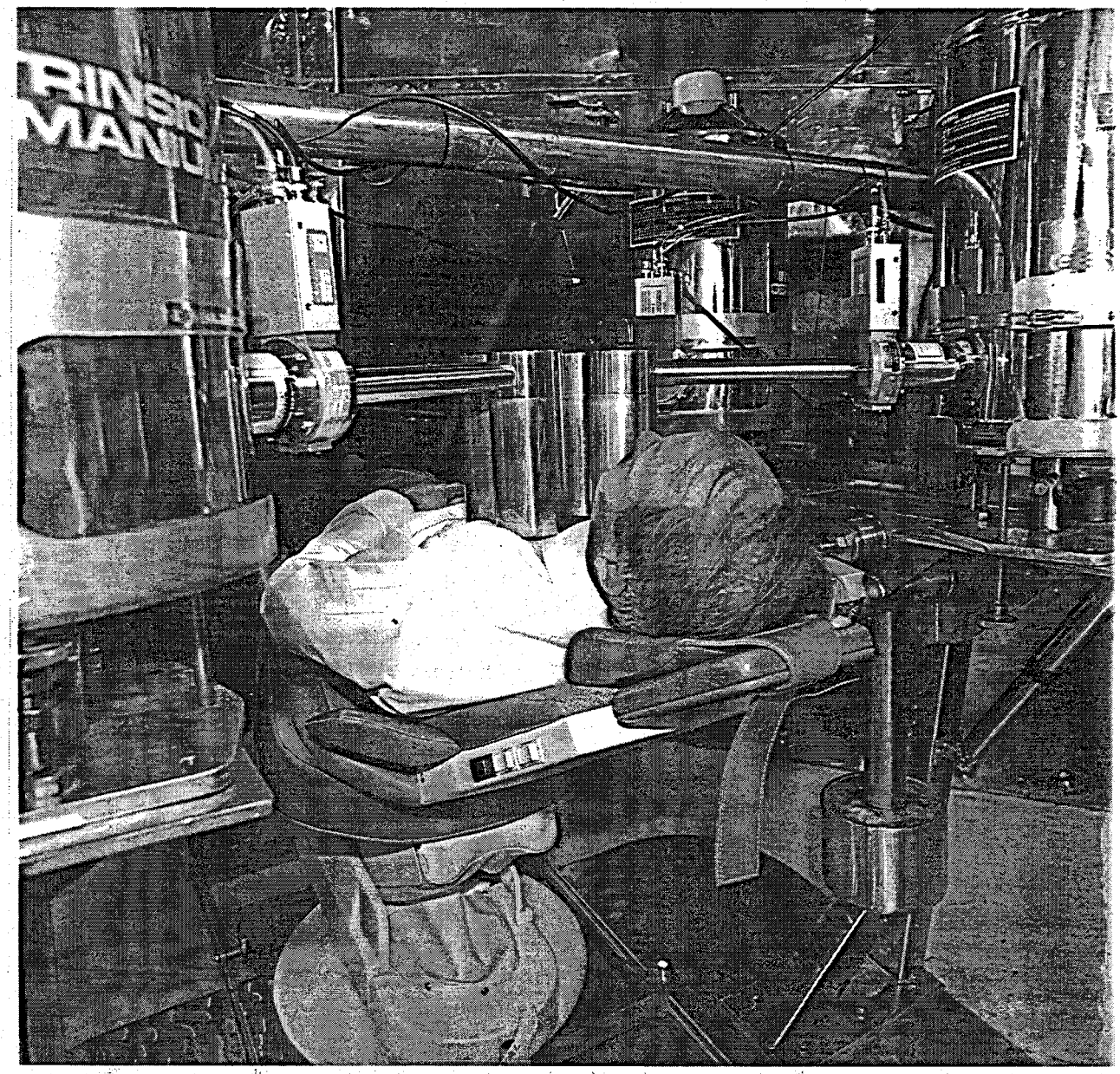


Figure 4.2. New Iron Room Counting System

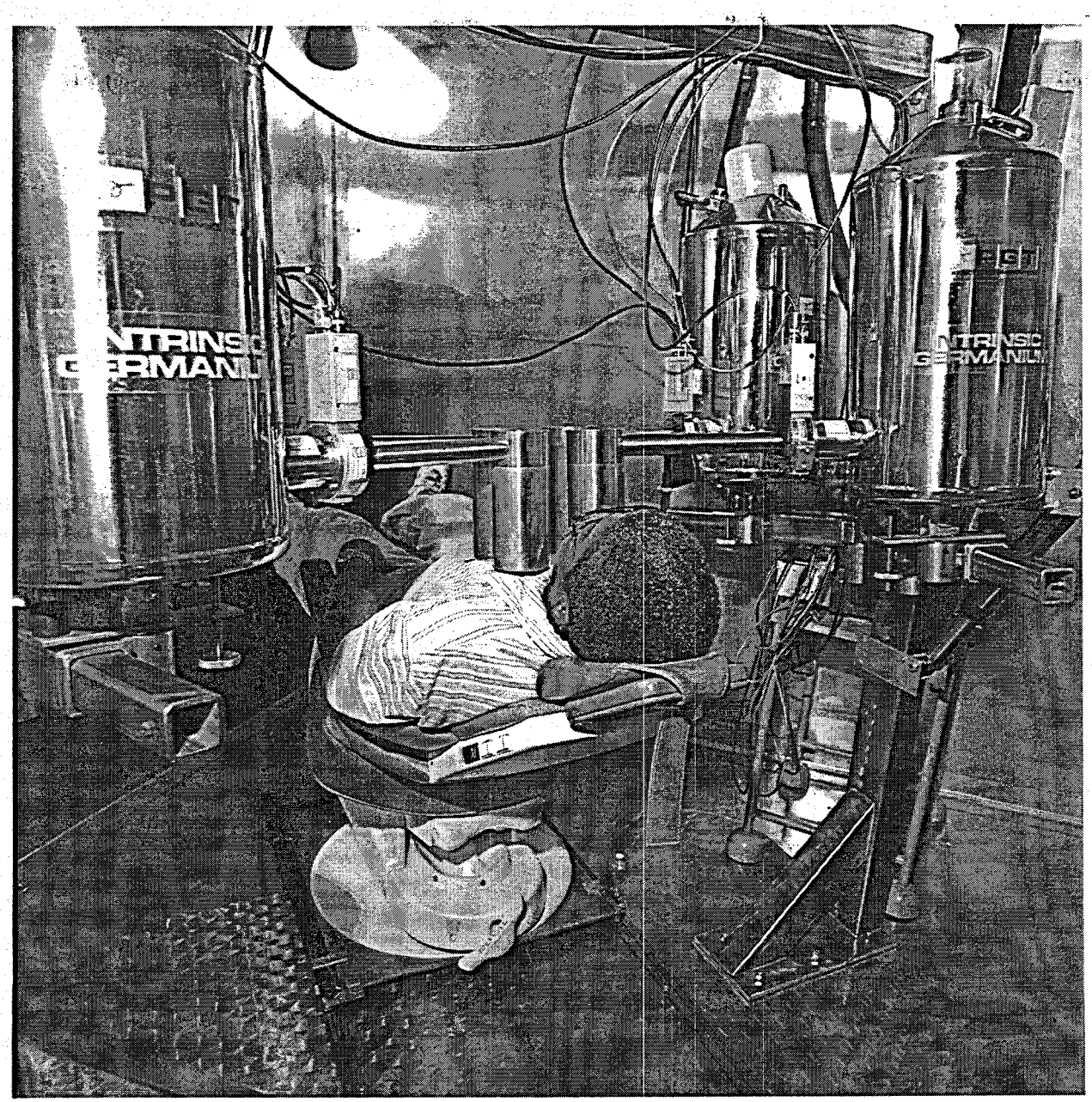


Figure 4.3. Stainless Steel Counting System

detector was developed using a new positioning method to increase counting precision on the ^{125}I thyroid phantom in December 1996. A brief step-by-step protocol on how to perform the count will be written, but not handled as a controlled procedure due to the small number of counts currently performed.

4.5 Supporting Programs and Studies at the IVRRF

The following programs and studies were conducted by the IVRRF staff in 1996.

4.5.1 Portal Monitor Bioassay Study

A study was performed on the technical capabilities of a National Nuclear Corporation, Inc., Gamma 60 portal monitor for performing whole body counting at the Hanford site. The study used in vivo calibration phantoms from the DOE Phantom Library to assess the ability to detect the primary fission-product radionuclide ^{137}Cs. The ratio of $^{90}Sr/^{137}Cs$ and the percent transuranics in typical Hanford mixtures were used to determine minimum detectable doses using ^{137}Cs as an indicator of exposure. Both whole-body distributions of ^{137}Cs and early-post-intake lung distributions were tested against the sensitivity of the monitor for detecting an intake.

The results indicated that, as with current methods of whole body counting, the fraction of ^{90}Sr and the presence of transuranics in mixtures are the limiting factors. Transuranics and beta-emitters that are internal to the body are not detected by the portal monitor. The counting time for a portal WBC is six to ten times longer than the usual portal monitor scan and the Reliably Detected Activity (RDA) result is about ten times higher than the annual count performed at the IVRRF. To incorporate portal monitors in assessing intakes, a count would be required each month to give the same level of sensitivity that a yearly screening measurement now provides. A summary of the results from the Gamma 60 portal monitor is found in Table 4.3.[a] After a review of the study results, a consensus decision was made with the Hanford contractors to not pursue the use of portal monitors as screening whole body counters at this time.

4.5.2 Hanford Portable ^{241}Am and ^{239}Pu Wound Counting Capability Study

Portable wound counting is needed in the event that contaminated injuries must be assessed and treated at a location other than the EDF. A study was conducted to determine the current capabilities at IVRRF to perform a wound count at a remote site. It was found that current systems require 110-V AC power at the count site. The three systems that were recommended are a Donald S. Davidson (DSD) multi-channel analyzer (MCA) set to 0.5 KeV/channel, using a 2-inch diameter NaI(Tl) detector with a

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(a) Internal Report by P. C. Olsen, E. J. Gould, and G. A. Rieksts, 1996. "Evaluation of a Stand-and-Count Portal Monitor for Bioassay Monitoring at Hanford." (A copy is available in the Hanford Radiation Protection Historical Files, Pacific Northwest National Laboratory, Richland, Washington.)

Table 4.3. Results of Testing the Sensitivity of a Gamma 60 Portal Monitor Using Calibration Phantoms

^{137}Cs Phantom	RDA Method	Diffuse RDA (nCi) with Subject Measurement Counting Time		
		10 sec	60 sec	200 sec
Whole Body	NNC[a]	54 nCi	19 nCi	11 nCi
	INPO[b]/σ_0[c]	61 nCi	22 nCi	12 nCi
Lung	NNC	32 nCi	12 nCi	6.7 nCi
	INPO/σ_0	36 nCi	13 nCi	7.6 nCi

(a) National Nuclear Corporation, Inc. automatic calculation.
(b) Calculation based on Littleton, M. *High Sensitivity Portal Monitors - A Review*. INPO 82-001-EPN-01. January 1982. Institute of Nuclear Power Operations. Atlanta, GA.
(c) Counting error in the net blank count.

crystal thickness of 2 mm; a HPGe detector, its liquid nitrogen dewar, a power supply, and an IBM-PC with MCA software/hardware; and an Eberline ESP-1 Portable Survey Meter with a 1" NaI(Tl) detector.

A summary of the portable wound counter capabilities in terms of minimum detectable dose is found in Table 4.4.[a] The current systems, except the ESP-1, use equipment that is up to 20 years old. A recommendation was made to update the current wound counting capabilities with newer, more reliable technology.

4.5.3 DOE Phantom Library

Operation of the DOE Phantom Library by IVRRF staff continued in 1996. Funded by DOE-HQ, this program loans state-of-the-art in vivo calibration phantoms to bioassay laboratories for calibration of measurement systems. The loans are made to DOE laboratories and other government agencies at no cost other than the shipping costs. The program also maintains records and calibration information on phantoms, provides technical assistance to others in the field of direct radiobioassay, and performs validation measurements on organ phantoms. The DOE Phantom Library has an inventory of 20 lung sets, six liver phantoms, eight BOMAB phantoms, two sets of lymph node phantoms, an Americium bone phantom[b], a Fission Product Phantom, a Lawrence Livermore National Laboratory (LLNL) torso phantom, and three thyroid phantoms. There were eight phantom loans to other in vivo measurement

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(a) Internal Report by E. H. Carbaugh and G. A. Rieksts. 1996. "Hanford Portable ^{241}Am and ^{239}Pu Wound Counting Capability." (A copy is available in the Hanford Radiation Protection Historical Files, Pacific Northwest National Laboratory. Richland, Washington.)
(b) On permanent loan from the U.S. Transuranium and Uranium Registry.

Table 4.4. Portable Wound Counter Capabilities in Terms of MDA[a] and MDD[b]

System	^{241}Am Capability		^{239}Pu Capability	
	MDA (nCi)	MDD (rem)	MDA (nCi)	MDD (rem)
ESP-1 w NaI(Tl) (60 sec count)	0.114	0.422 CEDE[c]	2.8	8.96 CEDE
		8.44 BS[d]		202 BS
DSD MCA w NaI(Tl) (100 sec count)	0.212	0.784 CEDE	2.63	8.42 CEDE
		15.7 BS		189 BS
DSD MCA w NaI(Tl) (1000 sec count)	0.052	0.192 CEDE	0.645	2.06 CEDE
		3.84		46.4 BS
HPGe w PC-MCA (1000 sec count)	0.030	0.111 CEDE	0.552	1.77 CEDE
		2.22 BS		39.7 BS

(a) Minimum detectable activity
(b) Minimum detectable dose, based on total systemic uptake of MDA from wound, calculated using the transportable injection dose conversion factors of the Technical Basis for Internal Dosimetry at Hanford, PNL-6866 Rev 1.
(c) Committed effective dose equivalent (annual limit = 5 rem)
(d) Committed dose equivalent to bone surface as limiting tissue (annual limit = 50 rem)

facilities in 1996, a reduction of 40% over the previous year. Staffing was also reduced in 1996, in line with PNNL's Achieving the Competitive Edge (ACE) Program.

The Absolute Lung Counter (ALC), which performs phantom activity verifications was reassembled in the 747-A Building in 1996; previously it was located in the ESB. A lead chamber was constructed using the lead from the dismantled shadow shield counter from the EDF in September 1996. The system will be studied for possible simplification and optimization in early 1997.

4.5.4 U.S. Transuranium and Uranium Registry Support

An individual involved in a pure ^{241}Am inhalation incident had initial measurements performed at the IVRRF at the employer's request in March 1996. Preliminary results indicated detectable amounts of ^{241}Am in the lungs, liver, and skeleton. After the initial measurement, the individual joined the U.S. Transuranium and Uranium Registry and continued to participate in monthly bioassay and in vivo measurements. The measurement frequency was decreased to quarterly in September 1996.

This case provided an excellent opportunity to monitor the lung clearance, the uptake and clearance from the liver and skeleton, and the elimination of pure ^{241}Am from the body. A half-time of about 200 days was observed for clearance from the lung. The in vivo results indicated an activity distribution of 45% in lung, 22% in liver, and 33% in the skeleton approximately one year after the intake.

A set of fossilized horse bones from the Hagerman fossil beds in Idaho was measured for gamma radiation. A Gieger-Müeller (GM) survey indicated measurable count rates over most of the samples. Measurements were made using a 38-cm^2 HPGe detector in October 1996. Most of the samples contained detectable amounts of uranium decay progeny. Nanocurie amounts of ^{238}U and ^{226}Ra were measured in the samples in approximately a 1:1 activity ratio.

4.5.5 Gas Scintillation Proportional Detector

The development of a Gas Scintillation Proportional Counter (GSPC) is continuing this year at IVRRF. The GSPC is a detector designed to measure low-energy x-rays from radioactive materials deposited in the body. It has high intrinsic efficiency and superior resolution to NaI(Tl) detectors. Work has included mentoring a Washington State University graduate student, testing a working design for operating characteristics, and making improvements to electronic components. A successful design may enhance the IVRRF capability to measure potential depositions of plutonium in the lungs and liver of workers. This task was funded with Battelle funds.

4.5.6 Thoron in Breath Monitor

A prototype Thoron in Breath Monitor (TIBM) was assembled and testing started. Progress was made on the calibration of the measurement system and on defining a physiologic model to allow estimates of thorium in the body based on the thoron activity exhaled. The Human Subjects Committee approved the use of non-PNNL volunteers for the TIBM beta testing measurements. Development was supported with Battelle funds. The TIBM will add additional detection capability at the IVRRF.

4.6 Project-Related Professional Activities

Staff activities, presentations, publications, and professional memberships during 1996 are listed in this section.

4.6.1 Activities

Gene Gould was involved in professional internal dosimetry activities outside of the Hanford site, as follows:

- Participated in training on the repair and maintenance of 38-cm^2 HPGe detectors at the Princeton Gamma Tech facility in Princeton, New Jersey, November 18-21, 1996.

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

- Participated in the annual Health Physics Society meeting in Seattle, Washington, July 22-25, 1996.

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

- Participated in a Gas Scintillation Proportional Counter development meeting at UC Berkeley Center for Particle Astrophysics, October 16-19, 1996.

4.6.2 Presentation

Kramer, G. H., R. M. Loesch, and P. C. Olsen. *The Canadian NCRC and the US Department of Energy's International In Vivo Intercomparison.* Presented at the 42nd Conference on Bioassay, Analytical, and Environmental Radiochemistry, October 1996, San Francisco, California.

4.6.3 Publication

Kramer, G. H., R. M. Loesch, and P. C. Olsen. *The Canadian NCRC for In Vivo Monitoring and the US Department of Energy's International In Vivo Intercomparison.* Presented at the International Radiation Protection Association Conference, April 17, 1996, Vienna, Austria.

4.6.4 Professional Memberships

Lynch, T. P. Chairman of ANSI N13.35 Working Group which is completing the ANSI Standard *ANSI Standard for the Bottle Manikin Absorption Phantom.*

Lynch, T. P. Member of 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 which is 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 which is completing the ANSI Standard *ANSI Standard for the Bottle Manikin Absorption Phantom.*

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

5.0 Hanford Radiological Records Project

The Hanford Radiological Records Project (HRRP) supports RL and Hanford contractor radiation protection programs. The HRRP administers and preserves radiological exposure records for all Hanford workers and visitors, past and present, and provides specified and requested reports using these records. The program is also responsible for maintaining the Hanford Radiation Protection Historical Files. Program personnel operate the computer systems and library equipment necessary to input, store, verify, and retrieve the records and produce the required reports and downloads.

The HRRP uses the REX[a] system, which includes a database containing the personnel radiological exposure data. These data are readily retrievable via a system of personal computers 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 which are indexed into computer-assisted retrieval (CAR) systems. The CAR systems allow for rapid retrieval of the documents for any individual using identifiers, including payroll numbers, social security numbers, names and/or REX IDs (REX IDs 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 LaserREX). All hardcopy exposure records starting with January 1, 1992, are preserved on LaserREX. LaserREX also stores the electronic records created by the REX transaction log. Hardcopy records generated prior to 1992 are maintained on microfilm.

The Hanford Radiation Protection Historical File records include documents such as policies, procedures, reports, and important communications that define the Hanford radiological dosimetry and radiation protection programs during 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 Part 835 (DOE 1993); the *Hanford Site Radiological Control Manual* (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 library. Both data handling and report issuing are performed by the Radiological Records Data Processing Center.

(a) A description of the REX database can be found in Lyon et al. (1994).

The database administration function performs system evaluations, troubleshooting, resolution of system and user problems, training of users, oversight of system security, liaison with the BCSR/ Lockheed Martin Services, Inc. (LMSI) computer analysts, and initiation and testing of modifications to the databases.

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-handling also includes dealing 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 backup 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 its inception (almost five-million microforms), except 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 are 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 1996 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.

A significant change occurred in the Hanford contractor structure on October 1, 1996. The new PHMC brought a new contractor structure to the site. FDH replaced the WHC team (WHC, BCSR, ICFKH) as the Maintenance and Integration (M&I) contractor. FDH brought 6 subcontractors with them. In addition, FDH and the subcontractors formed 7 enterprise companies. The existing WHC team employees were integrated into the 14 different entities. The personnel assigned to the enterprise companies are no longer considered contractor employees. Those enterprise company individuals not assigned dosimeters were terminated in REX; those issued dosimeters were changed to resident non-employee status and issued resident non-employee PAY IDs in REX. The new contractor/enterprise

Table 5.1. Records Activity for Calendar Year 1996

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)	2,973
Employee and Dosimetry Change Forms (used to document personnel data or dosimetry changes)	6,112
Employee and Dosimetry Change Forms (used to document employee terminations)(many changes were done electronically not requiring forms)	4,632
Temporary Dosimeter Assignment Forms (used for issuing temporary dosimeters to employees due to new hires, changes to dosimetry requirements, multiple dosimetry, employees who forgot their dosimeters)	14,845
Visitor and Subcontractor Dosimeter Issue Forms (used to issue dosimetry to visitors and subcontractors not completing radiological worker training)	3,379
Investigation of Dosimeter Result Forms and Change Letters (used to estimate exposure for lost, damaged, or otherwise suspect dosimeter results)	3,605
Special Process Forms (used to document data for specially processed dosimeters)	8,726
Requests for Exposure Summaries (summaries requested for current and prior Hanford employees)	276
Letters Sent to Request Prior Exposure (to request summaries for new employees with prior exposure or existing employees receiving exposure at off-site facilities)	777
Total number of hardcopy records scanned and indexed into LaserREX[a]	89,118
(a) This total is for all of the hardcopy records scanned and indexed into LaserREX, some of which are not listed in this table.	

company organization will be referred to as PHMC in this chapter, except for the computer analyst's employer. The BCSR computer analyst that has supported REX for many years is now assigned to one of the enterprise companies, LMSI, as is the management of the central computer that REX is located on.

There was a major change in the unit pricing structure of the project for FY 1997.[a] Because of the changes brought about by the PHMC where many site employees were assigned to the enterprise companies, the unit price for each contractor employee and resident non-employee was deleted. All project costs included in this unit price have been included in the unit price for each result or result change entered into REX.

The project had an independent assessment conducted by PNNL Quality Programs in August. There were 11 minor observations listed in the report. The corrective actions were completed by year's end.

(a) A description of the original unit pricing structure can be found in Lyon et al. (1996).

Due to a number of changes in REX and operating procedures, overtime required during the year-end processing was reduced to one day, compared to 4 days in prior years.

To reduce costs, the project was moved from the Federal Building to the 331 Building in June. At about the same time, the IBM mainframe computer used by REX and the historical file CAR was replaced by an IBM Enterprise Server (ES) which was also moved from the Federal Building to the 300 Area. The moves required replacement of the direct connection of LaserREX to the host computer and the connection from REX to the dedicated printer. A communications controller was purchased to replace the direct connection to LaserREX. A device was installed with the printer so it could be accessed over the LAN. Several software and hardware problems had to be solved during testing to make both new connections work. Because the PNNL LAN has different protocols than the BCSR LAN previously connected to, a personal computer (PC) was connected to the PNNL LAN in the 331 Building and tested to assure the host computer could be accessed. Some software changes were necessary to the PCs to successfully access the host computer.

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:

- BCSR reduced the amount of report printing allowed at the Central Site (where the ES is located). A number of reports in REX had to be reprogrammed so they could be printed on a LAN laser printer.

- BCSR discontinued producing microfiche, which the project used to document some files and reports. They developed a DISPATCH system which allows online viewing of reports and files. Field dosimetry units were given access to view DISPATCH.

- Programming was completed to accommodate the new extremity chipstrate dosimetry system, which was put into service July 1. (See Chapter 2 for a description of the system.)

- Organization codes were added to extremity dose records for accounting purposes. Apparently the contractors were going to assess the users of the dosimeters by the number of dosimeters they used.

- At the request of the HPDAC, the system was reprogrammed to allow Note Code 53 results (results adjusted by External Dosimetry prior to reporting the dose to REX) to be entered directly into REX instead of being place in the reject file. Some problems were encountered on certain results that required further programming to solve.[a]

- The Hanford Identification Number (HID) was added to the REX person table. REX is not using the HID at this time, but it can be used as an additional identifier.

- Programming was completed to provide daily dose results to the WHC Access Control Entry System (ACES). Other changes were made to the download file at the request of the ACES data management.

- A view of the REX contractor work history table was set up for WHC human resources. Apparently, REX has the only complete work history data on site.

- The long-term REX analyst is expected to retire early in 1997. To accommodate this many of the REX batch jobs were changed to be initiated automatically or by a project clerk.

- There were a number of screen changes to make the system more efficient for the users. Some examples of these changes were

  - a number of changes were made allowing users to easily toggle back and forth between different screens used frequently, reducing the time required to perform certain functions

  - two new screens were programmed for use with multiple dosimetry (one was for issuing dosimeters only, one can be used for issue and return at the same time when the multiple dosimeter packs are sent to the field and the individuals wearing them are not known until the packs are returned) significantly increased the efficiency of issue and return of multiple dosimeters

  - screen CU01 was modified to bring in a previous name for the employee when applicable

  - several screens were reorganized to be more efficient for the users.

A number of dosimetry changes were made during 1996. The HRRP data administrator and LMSI analyst wrote programs to make many of the changes electronically. This process considerably reduced data entry and paperwork requirements for the contractors. Each of these programs also produced a list report that could be scanned and indexed into LaserREX for documentation purposes. Two of the major changes were

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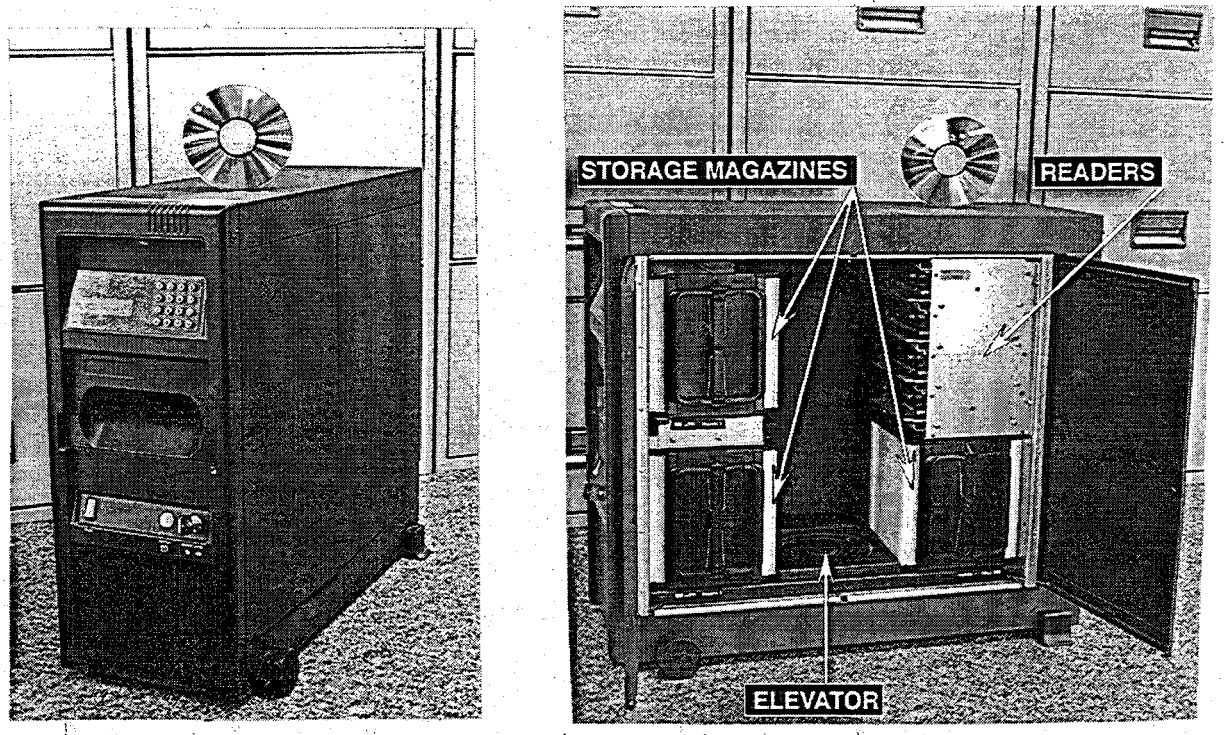
(a) Bihl, Donald. "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting Held On August 21. 1996." Also: Bihl, Donald. "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting Held On November 20, 1996." (Both are available in the Hanford Radiation Protection Historical Files, Pacific Northwest National Laboratory, Richland, Washington.)

- Electronic files from the new PHMC contractor were used to integrate the WHC team employees into the 14 new PHMC entities. This included assigning new resident non-employee PAY ID numbers to the enterprise company employees issued dosimeters. The LaserREX consultant, working with the LMSI analyst and project personnel, mass indexed the four different files into LaserREX. This effort saved having to produce over 7000 paper change forms, data entry of the forms, and indexing the forms into LaserREX.

- Some WHC 1995 ring doses were tripled prior to year-end processing. The effort processed 1367 results and modified 1059. The list was scanned and indexed into LaserREX. This effort saved the completion of 1059 IODR forms.

A major upgrade to LaserREX completed during the year was the conversion from laser optical disk to compact disk technology (CD-ROM) and the installation of a juke box (see Figure 5.1). All the data on the laser optical disks were converted to compact disks. There were getting to be so many optical disks that they were becoming inefficient to manually insert in a reader when needing to retrieve documents, so a juke box was needed to save time and increase efficiency. The juke box keys off the



97020223-13cn

97030262-1df

Figure 5.1. Compact Disk Jukebox. Disks are stored in the storage magazines. When requested, the elevator retrieves a disk and inserts in into a reader. If the readers are all full an inactive disk will be removed and replaced into its proper storage slot and the requested disk then inserted.

computerized index, inserts the desired disk automatically, and brings the image to the monitor screen without having to handle the disk. The operator only has to request a particular document and does not need to know which disk it is on. Additionally, the compact disks are considerably less expensive than optical disks and the compact disk technology is standardized (which the laser optical disk technology is not). It was found that the system could be converted to compact disk technology and the juke box installed for less than the capital cost of a laser optical disk juke box. The conversion worked well except for a few minor bugs which were corrected.

5.2 Supporting Projects

Epidemiology data were supplied to the University of North Carolina for a National Institute of Occupational Safety and Health (NIOSH) Multiple Myeloma Case Control study. Exposure data was supplied to DOE Headquarters epidemiology staff for use in a pilot project.

Programming was completed to supply certain Performance Indicator data to DOE-RL.

Because of new risk-based medical scheduling protocols that had to be developed for HEHF's new computer systems, HEHF decided they could no longer provide in vivo scheduling services to the site. It was decided that a new in vivo scheduling program should be developed in REX. This effort was under way at year end; the requirements had been completed by meeting with the field schedulers and the whole body counting staff. This is a major effort.

Because of the new PHMC contract provisions, DOE-RL requested that the HRRP take over the field dosimetry for DOE-RL. This would include physical handling of the dosimeters and distributing and collecting them; data entry into the REX and ACES databases; dosimetry scheduling; issuing temporary dosimeters to visitors, tour groups, and DOE-RL employees and subcontractors that have forgotten their dosimeters; and other miscellaneous tasks required. Because the WHC field dosimetry group had been doing this task, it was decided that the most efficient way to handle this was to contract it back to the PHMC (formerly WHC) field dosimetry group. Because the PHMC field dosimetry group will be transferred to PNNL in early 1997, this task will continue to be performed by the same personnel.

5.3 Project-Related Professional Activities

Staff publications and professional memberships during 1996 are listed in this section.

5.3.1 Publication

Lyon, M., and J. B. Martin. 1996. "Automating Occupational Protection Records Systems." *Applied Occupational Environmental Hygiene* 11(4):377-379.

5.3.2 Professional Membership

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

6.0 Radcon Instrumentation Services Project

The Radcon Instrumentation Services (RIS) Project 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 1996 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; and maintenance of a pool of portable survey instruments available for use by site contractors. In support of site contractor restructuring, the Project completed the first full fiscal year with a restructured, more cost-efficient operation, and unit prices for calibrations and services.

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 1996, the RIS Project continued to provide complete instrument services. As the mission and scope of the Hanford Project continued to evolve into a more privatized, cost-efficient operation, the RIS Project made required scope and operational changes. The contractor companies under the new PHMC led by FDH replaced the WHC radiological operations, and joined Bectel Hanford, Inc. (BHI) and PNNL as a major Hanford contractor. As noted earlier, the PHMC includes 6 subcontractors and 7 enterprise companies in addition to FDH. This multiplication of contractors increased the administrative billing requirements of the project.

The Hanford pool of portable radiation protection instruments is separate from the calibration and maintenance of each contractor controlled instruments. Pool and non-pool instruments are calibrated with a unit price cost to the site contractors. Maintenance is costed at an hourly rate with the required parts and labor charged to the last contractor to use the instrument. Calibration intervals, set to one year for all instruments that can be response checked in the field, will be shortened only if analysis of instrument returns indicates a shorter calibration interval. Procurement of new instruments is initiated by the site contractors, or jointly by the contractors through the Hanford Instrument Evaluation Committee (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 RIS Project provide the site with quality, reliable, and accurate instrumentation capable of performing at the level necessary to ensure personnel safety as required by 10 CFR Part 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 RIS Project activities fall under the base tasks that comprise the CY 1996 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

Table 6.1. Calendar Year 1996 Instrument Calibrations by Unit-Price Category

Month	Portable	Fixed	CAM	Special	Sources	Pencils	Private
Janaury	518	47	25	0	36	177	4
February	476	43	48	1	11	187	0
March	903	71	44	1	30	487	8
April	672	47	48	1	49	127	0
May	542	44	37	0	28	443	1
June	904	55	49	4	28	681	6
July	767	28	36	1	40	166	6
August	1,115	52	47	0	30	671	0
September	1,315	75	51	3	55	342	0
October	949	89	42	1	15	463	0
November	963	60	55	0	35	442	0
December	917	46	50	1	27	290	0
Total	10,041	657	532	13	384	4,476	25

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 1996 are described in this section.

6.2 Project Improvements in Calibration and Maintenance Operations

As part of the response to the site contract restructuring, core instrumentation calibration and evaluation needs of the Hanford Site were identified, and a new, highly defined Project scope was developed. The streamlining of instrument calibration services, that have resulted from this process, has produced significant savings to the site and has provided RIS with a competitive position in the marketplace.

The cost-effective, price-driven changes in Project philosophy; operational developments designed to automate equipment tracking, improve procedural accuracy, increase operational efficiency, and capture manpower; and parts costs associated with routine RIS calibration operations have been shown to be effective in CY 1996.

Along with bar coding of instruments, computer-generated and printed calibration labels were developed and implemented to increase productivity. Bar coding automation will save costs by significantly simplifying the tasks of accurately logging, tracking, and labeling calibrated instruments.

All laboratory and instrument-shop work stations have been fully equipped with computer terminals and bar code readers, and this equipment has been fully integrated into the RIS calibration database system. These new work-station/database links allow detailed manpower and parts costs associated with routine instrument maintenance to be automatically logged and costed. Accounting for specific instrument maintenance costs is an important, integral component of the RIS unit-priced operating budget.

To reduce Project record management costs, all *Radiation Protection Instrument Manual*[a] procedures include a complete, stand-alone, fully traceable calibration data sheet. This system for maintaining instrument calibration records was shown to improve record management productivity while readily providing the means of supplying customers with calibration information that is normally provided by commercial vendors.

Bar code mnemonics will provide the basis of an easily understood and navigable directory structure within which calibration records will be stored and easily retrieved. The year of calibration and a bar code number will be the only parameters required to extract a complete, signed calibration record for any instrument processed by RIS.

6.2.1 Instrument Evaluation and Testing

The HIEC was established to provide a Hanford intercontractor information exchange mechanism to assure 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 on site
- identify new radiological instrumentation available from manufacturers that may be useful to the 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 DOE-RL are on this committee.

(a) Internal Manual, PNNL-MA-563, Pacific Northwest National Laboratory, Richland, Washington.

During 1996, the committee continued to perform evaluations on instruments identified as needing further evaluations before approval and placement on the "approved instrument list." The "approved instrument list" was developed to meet *Hanford Site Radiological Control Manual* (RL 1994) requirements that only approved instruments may be used on site.

6.3 Supporting Investigation and Studies

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

In support of the site contractors' requirements for 10 CFR Part 835, several radiation detection instruments used on site were evaluated for compliance to the required qualification and documentation of being appropriate for use in the Hanford Site environment.

6.3.2 Facility Monitoring Systems Technical Assistance

During 1996, RIS provided technical assistance in testing and documenting response characteristics of fixed facility monitoring systems, developing formalized procedures for calibrating these devices at their site locations, and assisting and coordinating their calibration and acceptance as record-qualified instrumentation. RIS provided significant assistance to facilities in maintaining and calibrating stack monitoring systems installed at the 324 and 325 Buildings. To meet new state and federal requirements for measuring and tracking radiological stack emissions, the facilities installed sophisticated monitoring systems. Unfortunately, the only instruments that could meet the stringent regulatory performance requirements were fabricated by a German company that had only recently been acquired by a U.S.-owned firm. Significant system electronic design problems resulted when the vendor integrated these components into the requested stack monitor. Because the U.S. firm was unable to diagnose and remedy the operational problems that beset both monitoring systems after they were installed, RIS' assistance was requested, and all problems were successfully overcome. Both monitors have been calibrated and are now operational.

6.4 Project-Related Professional Activities

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

6.4.1 Presentations

Johnson, M. L. 1996. "Status of ANSI N323A and N323C," Presented to the GOCO Health Physics Instrument Committee, December 2-5, 1996, Las Vegas, Nevada.

Froelich, T. J. 1996. "Health Physics Instrumentation" and "Reactor Health Physics," classes presented during Columbia Chapter Health Physics Society's American Board Of Health Physics Exam Review Class, Washington State University Tri-Cities, May 1996, Richland, Washington.

6.4.2 External Professional Activities

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

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

Johnson, M. L. Member of Working Group for ANSI N323D, "Radiation Protection Instrumentation and Calibration - Fixed Instruments."

Johnson, M. L. President Elect, 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 RIS Project and HEPD. 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 assure that calibration and characterization procedures are in agreement with technically accepted methods.

Project activities conducted during CY 1996 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 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 to the source are typically characterized. "Beam" sources, with the exception of 318-131, provide a continuum of exposure rates via use of a detector/dosimeter positioning stand located on a sliding-rail system. Source 318-131 also includes a moveable stand, but is

Table 7.1. Available Gamma-Ray Sources (1996)

Source	Geometry	Nominal Rate/Range [R(rem)/hr]	Location in Bldg. 318	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 (2π)	0.125	Rm. 6	318-184	0.060

typically characterized and used only at the one- and three-meter distances. Device (instrument and/or dosimeter) 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-detector/dosimeter 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 which produces high-energy gamma fields from ^{60}Co. This facility uses 12 sources which can be placed in a variety of geometries within tubes set in a circular pattern (Figure 7.1). The exposure rate is adjusted by selection of a particular source or combination of sources and the specific orientation of the irradiation tube(s) in proximity to the detector or other artifact being irradiated. The range of available exposure rates extends from 30 to 10^7 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 use of reference standards and methods identical to those used for the 318 Building sources, as described in this report.

X-Ray Photon Sources

Two identical Philips Model-324 x-ray machines are currently in use in support of the RS&C Project. One machine is used to produce Bremstrahlung (broad) photon spectra (e.g., NIST techniques

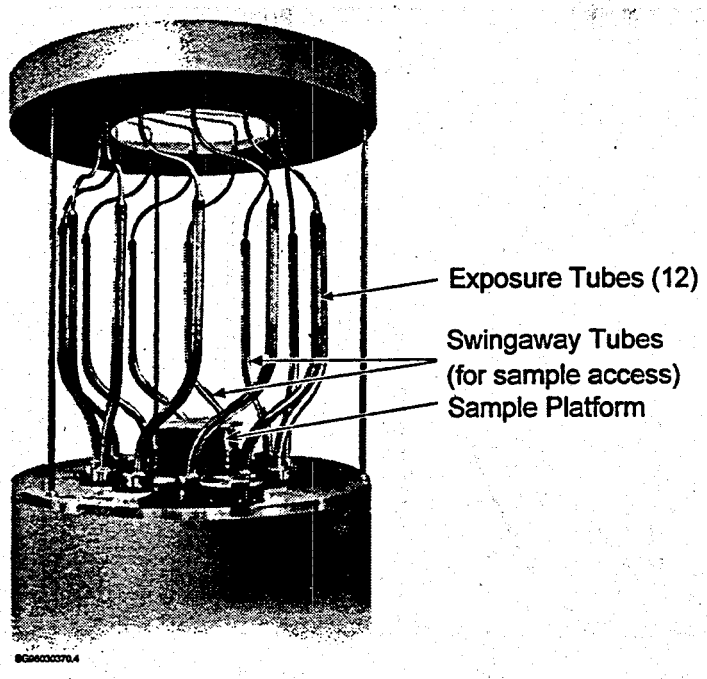


Figure 7.1. GB650 ^{60}Co Irradiator

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 energy dependence for dosimetry and instrumentation 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. As such, 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 to a gamma source with a photon energy of the same half value layer). K-fluorescence techniques have highly discrete peak energies and are 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 which have a similar quoted average or effective energy. Table 7.2 provides a complete listing of available techniques, their characteristics, and the nominal exposure rates available. Both of these systems are equipped with laser alignment capabilities to aid in detector/dosimeter positioning.

Neutron Sources

Two configurations of ^{252}Cf neutron sources are available. One configuration allows 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

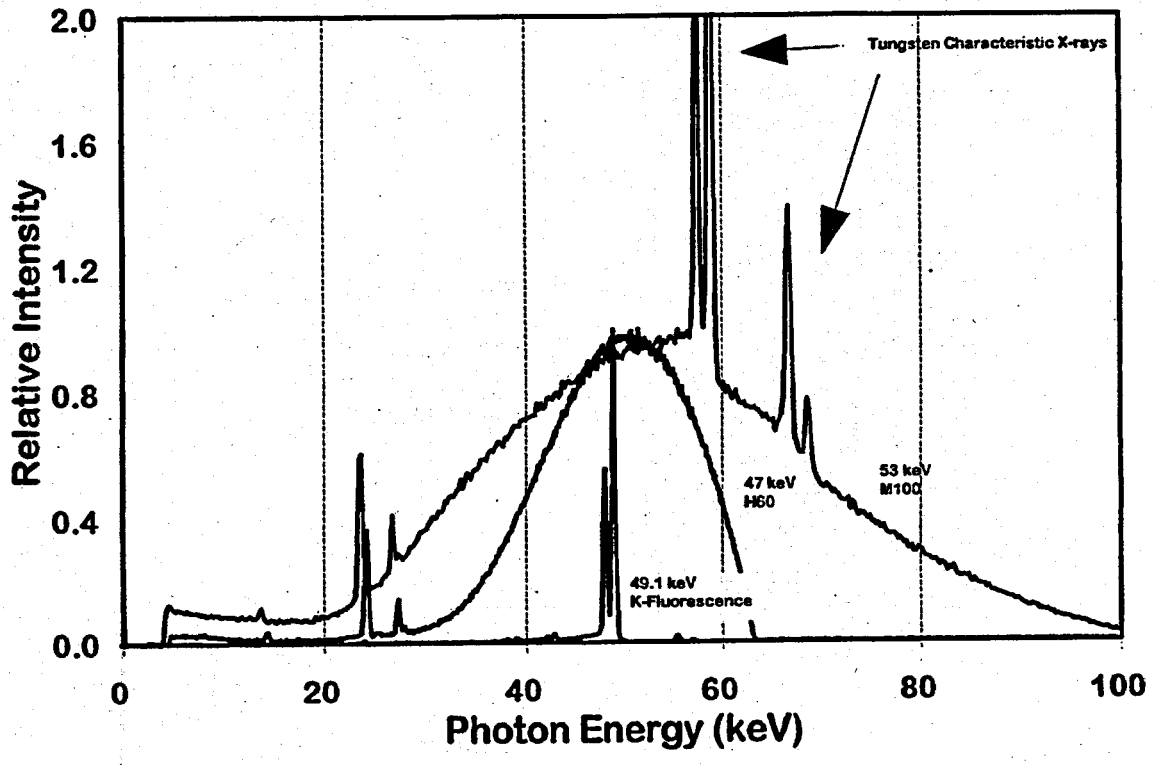


Figure 7.2. Example Spectrum of X-Ray Configurations

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 specifications of DOE/EH-0027, the *Department of Energy Standard for the Performance Testing of Personnel Dosimetry Systems* (DOE 1986); ANSI Standard HPS N13.11, *Personnel Dosimetry Performance-Criteria for Testing* (ANSI 1983); and International Standards Organization (ISO) 8529, *Neutron Reference Radiations for Calibrating Neutron-Measuring Devices Used for Radiation Protection Purposes and for Determining Their Response as a Function of Neutron Energy* (ISO 1989).

The second configuration involves a ^{252}Cf source placed in a well to facilitate easy access for instrument calibration. This source provides a fission spectra which 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 free-field conditions.

Beta Particle Sources

Beta particle sources (^{147}Pm, ^{204}Tl, and $^{90}Sr/^{90}Y$) are maintained for dosimetry and instrument characterization. Available sources are listed in Table 7.3 and include those manufactured by

Table 7.2. Available X-Ray Reference Fields (1996)

Style	Technique	Average/Effective Energy (keV)[b]	Half Value Layer (mm Al)	Homogeneity Coefficient	Exposure Rate/Range (R/hr)[b]
Bremstrahlung	M20	14	0.152	0.79	2.9 - 288.6
	M30	20	0.36	0.64	3.2 - 326.1
	M50	29	1.02	0.66	3.4 - 350.9
	M60	35	1.68	0.68	3.2 - 310.0
	M100	53	5.0	0.72	1.5 - 305.0
	M150	73	10.2	0.87	3.8 - 391.4
	M200	100	14.9	0.95	4.3 - 431.0
	S60	38	2.8	0.75	0.6 - 119.6
	S75	40	1.86	0.63	4.6 - 472.2
	H40	33	2.9	0.94	Not established
	H50	39	4.2	0.92	0.05 - 9.40
	H100	83	13.5	1.00	0.02 - 3.07
	H150	118	17.0	1.00	0.12 - 16.5
	H200	162	19.8	1.00	0.09 - 9.22
	H250	204	22	1.00	0.09 - 8.50
K-Fluorescence	K8.6	8.6	N/A	N/A	20.43
	K17.0	17.5	N/A	N/A	3.64
	K25.3	25.3	N/A	N/A	3.74
	K31.0	31.0	N/A	N/A	1.55
	K40.1	40.1	N/A	N/A	1.51
	K49.1	49.1	N/A	N/A	0.86
	K59.0	59.3	N/A	N/A	0.96

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

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 ^{147}Pm sources have decayed to the extent that renders them useless for most dosimeter irradiation or instrument characterization purposes. A higher activity replacement has been 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. $^{90}Sr/^{90}Y$ sources to verify satisfactory compliance with HPS N13.11; DOE/EH-0027; and ISO 6980,

Table 7.3. Available Beta Reference Fields (1996)

Geometry	Isotope[a] (Source No.)	Window Material and Areal Density (mg/cm²)	Protective Coating Material and Areal Density (mg/cm²)	Residual Maximum Energy -E_{res} (MeV) (M-Measured, T-Theoretical)	Absorbed Dose Rate[2] (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 ≤ 0.76 (T)	0.01 (35)
	^{204}Tl (318-192)	Glass (6.6)	Kapton (~0.8)	0.608 (M)	1.39 (30)
	^{90}Sr/^{90}Y (318-013)	Silver (50)	Stainless Steel (~75)	1.80 ≤ E ≤ 2.274 (T)	0.51 (30)
	^{90}Sr/^{90}Y (318-102)	Titanium (100)	Aluminum (20)	Not available	0.48 (35)
	^{90}Sr/^{90}Y (318-012)	Silver (50)	Stainless Steel (~75)	2.046 (M)	20.24 (30)
	^{90}Sr/^{90}Y (318-103)	Titanium (100)	n/a	2.085 (M)	14.18 (35)
Distributed	^{147}Pm (318-113)	n/a	Kapton (1.5)	Has not been measured for these sources.	0.62 - 0.01 (0.2 -15)
	^{204}Tl (318-128)	n/a	Kapton (9.5)		1.01 - 0.04 (0.2 - 30)
	^{90}Sr/^{90}Y (318-129)	n/a	Kapton (23.5)		4.29 - 0.16 (0.2 - 30)
	^{106}Ru/^{106}Rh (318-130)	n/a	Kapton (30.7)		<0.01 (0.2)
	Depleted Uranium (318-166)	n/a	Aluminized Mylar (7)		0.21 (0.2)

(a) Routine calibration maintained only for shaded techniques. All others are calibrated as needed.
(b) Nominal at 7 mg/cm² as of mid-year (1996)

Reference Beta Radiations for Calibrating Dosimeters and Doseratemeters and for Determining Their Response as a Function of Beta Radiation Energy (ISO 1984).

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 1993 annual report (Lyon et al. 1994). Since the method of traceability is often unclear and can vary periodically, the current pathway for PNNL radiological reference fields is provided here.

Philosophy

Traceability infers an assurance that calibration fields are established and used in a manner consistent with national standards. There are two accepted types of consistency measurements which 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 administrated 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 with traceability based only upon implied consistency is the lack of demonstration which 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) such 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. This project mirrors the NIST philosophy where possible; however, there are some limitations of the NIST capability which 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. Periodically, one or more selected "reference class instruments" are submitted to NIST for calibration to specific radiation fields. Prior to 1996, five air ionization chambers 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 Bremstrahlung 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

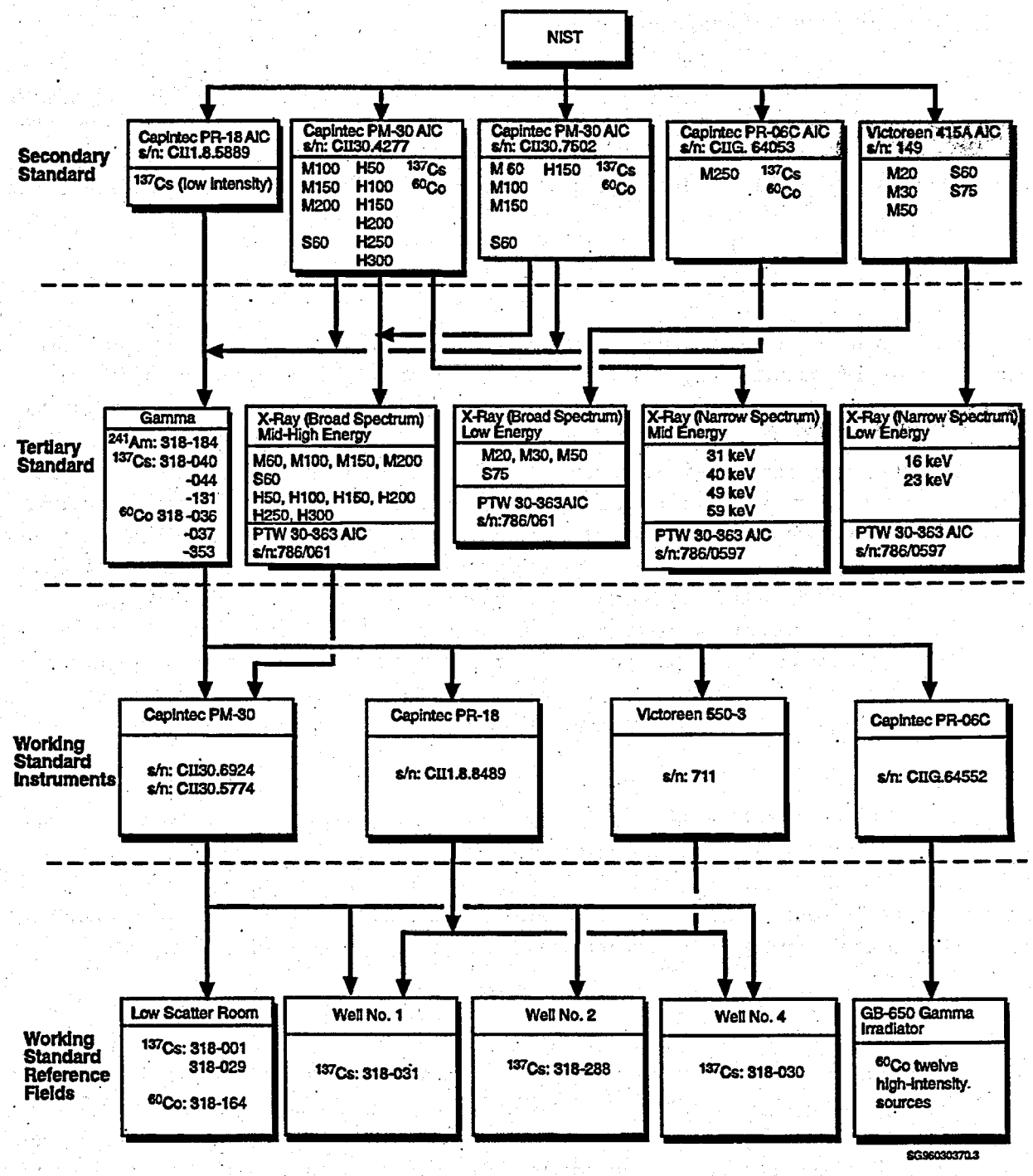


Figure 7.3. Typical Traceability Pathway for PNNL Photon Reference Fields

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. Although no interactions were performed in 1996, investigation continued regarding the 4% discrepancy noted with M50 x-rays during the 1995 test. The initial belief was that an earlier proposed change in the high voltage supplied to the x-ray tube would compensate for the 4% error. When evaluated using a cavity chamber similar to the MQA device, this was not the case. Although NIST was not concerned about this relatively small discrepancy, the issue remains open and will continue to be investigated.

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 similar pathway as that identified in Figure 7.3, the primary reference field is maintained by the National Radiation Protection Board 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 chamber measurements.

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 ^{252}Cf sources, in terms of neutron emission rate, within the NIST Manganous Sulfate Bath Facility. Free field dose equivalent rates are calculated for these sources in their bare and moderated configuration based on NIST recommendations provided in the National Bureau of Standards (NBS) Special Publication 633, *Procedures for Calibrating Neutron Personnel Dosimeters* (DOC/NBS 1982). A Nuclear Research Corporation Model NP-2 portable neutron monitor (SNOOPY), and, beginning this year, an Eberline NRD neutron probe, are maintained as tertiary standards which are used to convey the dose equivalent rate in a low scatter environment to a calibration well equipped with a bare ^{252}Cf 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. Such influences 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 possible isotopic contaminants which are difficult to eliminate during source manufacture and are not directly identifiable via a single NIST calibration. Also, when configured with the D_2O moderating sphere, there are concerns about subtle differences between the NIST

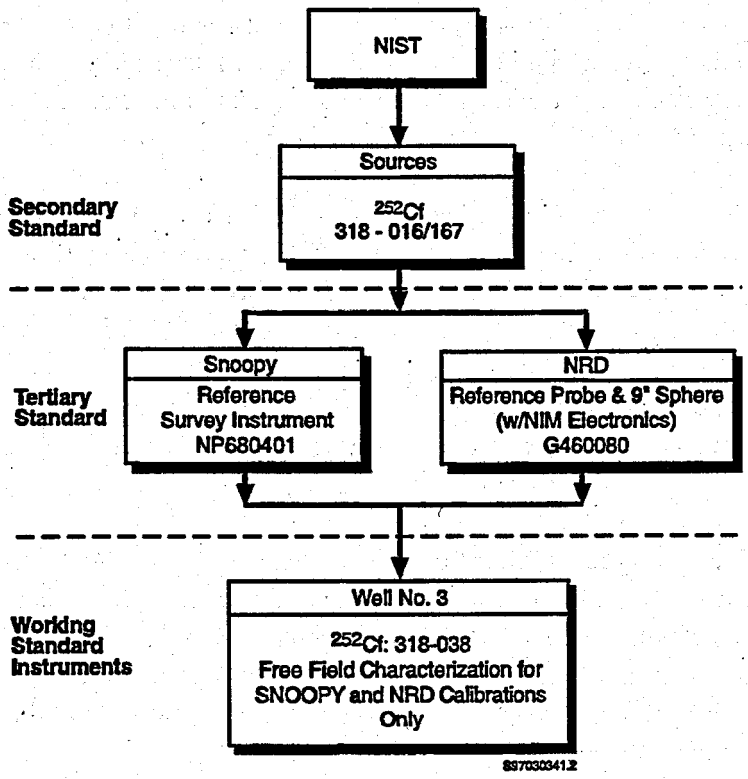


Figure 7.4. Typical Traceability Pathway for PNNL Neutron Reference Fields

design, which almost completely surrounds the source, and the PNNL assembly with an inherent void which allows placement of the sphere around the end tube of the pneumatic transfer system. Monte Carlo modeling suggests the effect of this void is substantial; however, reliable measurements have not been completed which can substantiate this model. Until measurements confirm or refine the magnitude of this effect, the calculated value is being treated as a component of uncertainty rather than being used as a correction factor applied to the dose equivalent rate.

During the past several years, numerous joint efforts 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. No evaluations were performed during 1996. NIST had tentatively planned to perform measurements at PNNL during the year; however, these measurements were postponed to March of 1997.

Beta Sources

The NIST-traceability of beta reference fields is based upon both implied and demonstrated consistency. Of highest order in the PNNL reference field hierarchy are the PTB sources identified in Section 7.1.1, including $^{90}Sr/^{90}Y$ (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 Werkstäten (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 utilized 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 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 $^{90}Sr/^{90}Y$ sources (318-102 and -103) were calibrated directly by NIST (source 318-102 [74 MBq] in 1986 at NIST and source 318-103 [1.85 Gbq] at PNNL by a visiting NIST scientist). This latter calibration was performed with the 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.

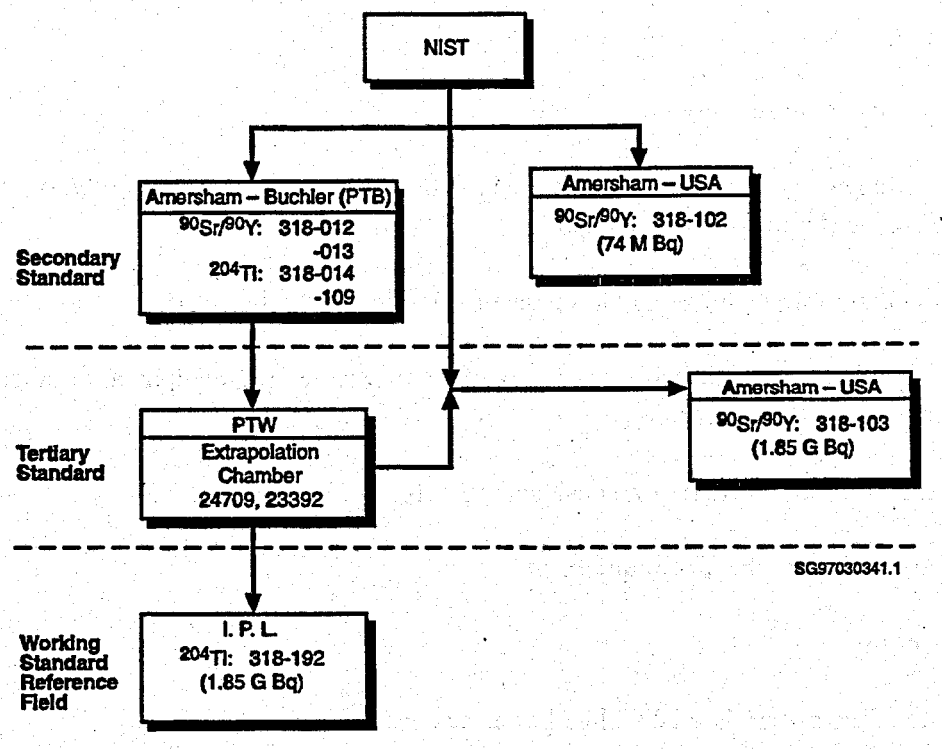


Figure 7.5. Typical Traceability Pathway for PNNL Beta Reference Fields

The periodic MQA intercomparison NIST conducts with the PNNL calibrations laboratory involves the use of a NIST transfer standard. Intercomparisons were made in 1984-85 and again in 1991-92 between the NIST and PNNL Amersham-Buchler (PTB-style) sources. These sources were selected to preserve similar geometry, encapsulation, and activity since it is suspected the transfer standard used for these measurements may be sensitive to differences in these parameters. There were no beta MQA measurements performed during 1996.

7.1.3 Calibrations and Constancy Checks

Following initial or annual calibrations, periodic verification measurements are performed to assure 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 for a revision to this methodology. Although reference fields were still verified in this way during most of 1996, it is anticipated that gradual 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 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).

Throughout 1996, the format for source verifications generally followed that of prior years. These actions are summarized below:

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) an annual verification was performed along with periodic interim checks to assure constancy at intervals from three to six months. Each of these reference fields is monitored by a quality control device capable of verifying continued accuracy within 3% between constancy verifications. No out-of-tolerance conditions were identified for these sources during 1996.

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. Periodic interim checks were also performed at three- to six-month intervals to assure relative constancy. Again, no out-of-tolerance conditions were identified.

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 (reference class ionization chamber) for each selected technique. The 1996 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 a system which appears to be in reasonable control.

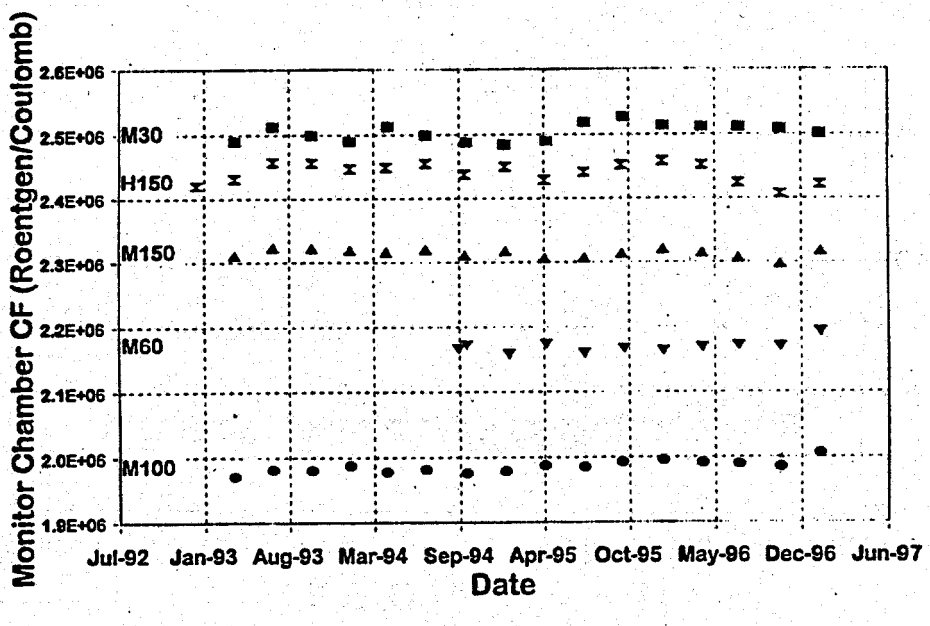


Figure 7.6. Long-Term Stability of X-Ray Reference Fields

Neutrons

Low scatter room ^{252}Cf neutron source 318-167 was verified on a quarterly basis as a byproduct of the quarterly verification of the SNOOPY tertiary standard. To investigate alternatives for source constancy verification, the performance history of the QC monitoring chamber used for bare and D_2O-moderated ^{252}Cf irradiation of dosimeters was examined. This monitor, an X-Radin brand tissue equivalent ion chamber, is mounted on the framework near the LSR-tower irradiation end tube. These data (see Figure 7.7) indicate generally good performance, at least since late 1993. Prior to that, however, unmoderated source measurements appeared to be in question. This indication was traced to positioning uncertainty of the irradiation end tube following removal of the D_2O-moderator. While the moderator tended to maintain precision in relative positioning of the source and QC monitor, following its removal, the end tube position tended to fluctuate. Artifact irradiations and calibrations were not effected by this situation, since their position relative to the source has always been verified manually prior to beginning measurements. However, this example illustrates the need for selection of proper constancy check instruments and methodology.

The ^{252}Cf source (318-038) mounted within Well #3 was not provided with a full calibration at any time during 1996. In anticipation of exchanging this source for 318-167, 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

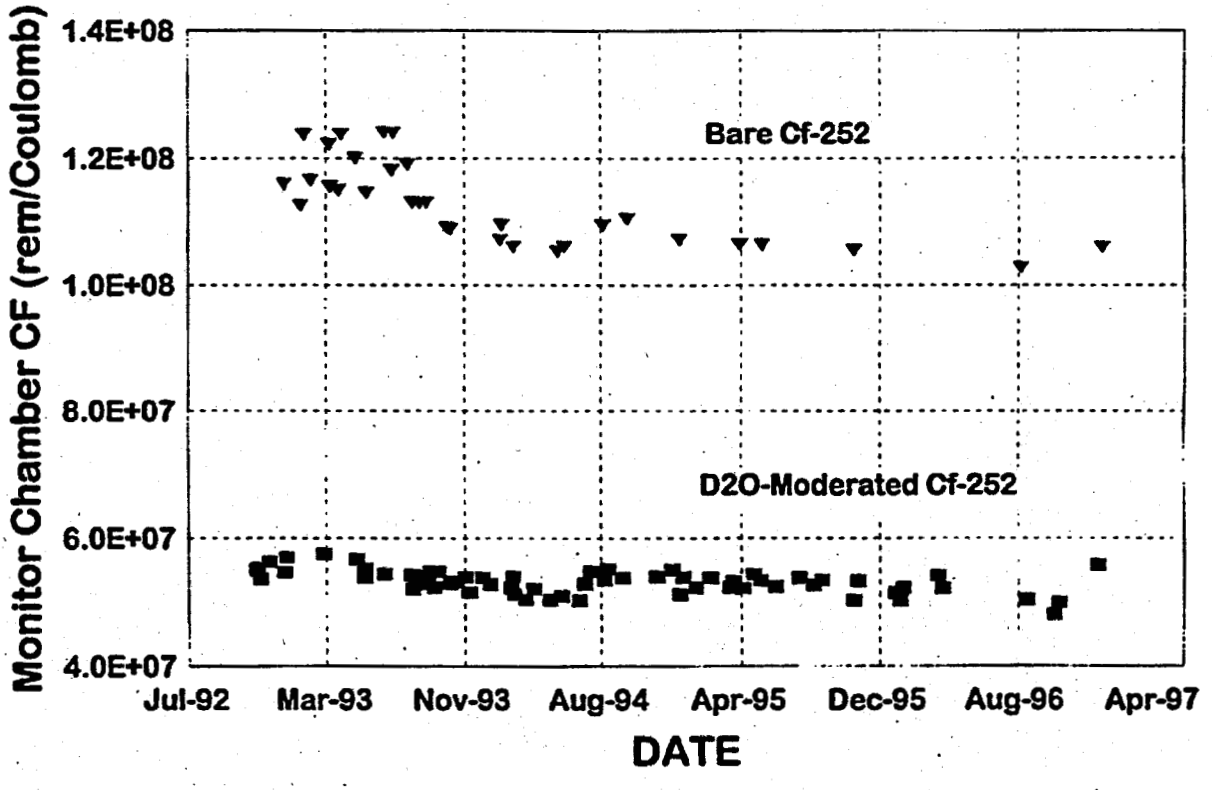


Figure 7.7. Long-Term Stability of LSR Neutron Source Output

dose equivalent rates within the well. Previously, it had been considered necessary to annually recalibrate this well, in part due to the relatively short ^{252}Cf half-life and its effect on the overall range of dose equivalent rates. Furthermore, uncertainties in the calibration measurements could manifest increasing errors in the dose equivalent rate calculational technique over time. As a result of these continual calibration extensions, however, it has been observed, in one test case, that over a difference in source position of 1.2 meters needed to provide 5 mrem/h SNOOPY indication, there is no discernable sign of trending (see Figure 7.8). While this may not be indicative of long-term effects or a representative sample of each position of the source within the well, it will strongly support a move toward longer calibration periods for this configuration upon installation of the new source.

Well #3 was also calibrated for use in subsequent calibrations of detectors employing Eberline NRD Probes with 9-inch moderating spheres. A procedure similar to that used for SNOOPY calibrations was used with only minor exceptions due to a significantly reduced counting efficiency. The comparative dose rates were found to deviate from -17% to +24% in comparison to the SNOOPY calibration points as shown in Figure 7.9. This illustrates the importance of an independent calibration for each instrument type.

Finally, in preparation for its use as the prime reference source within the Low Scatter Room, ^{252}Cf source 318-356 was evaluated for output characteristics. This source was installed in the LSR in late

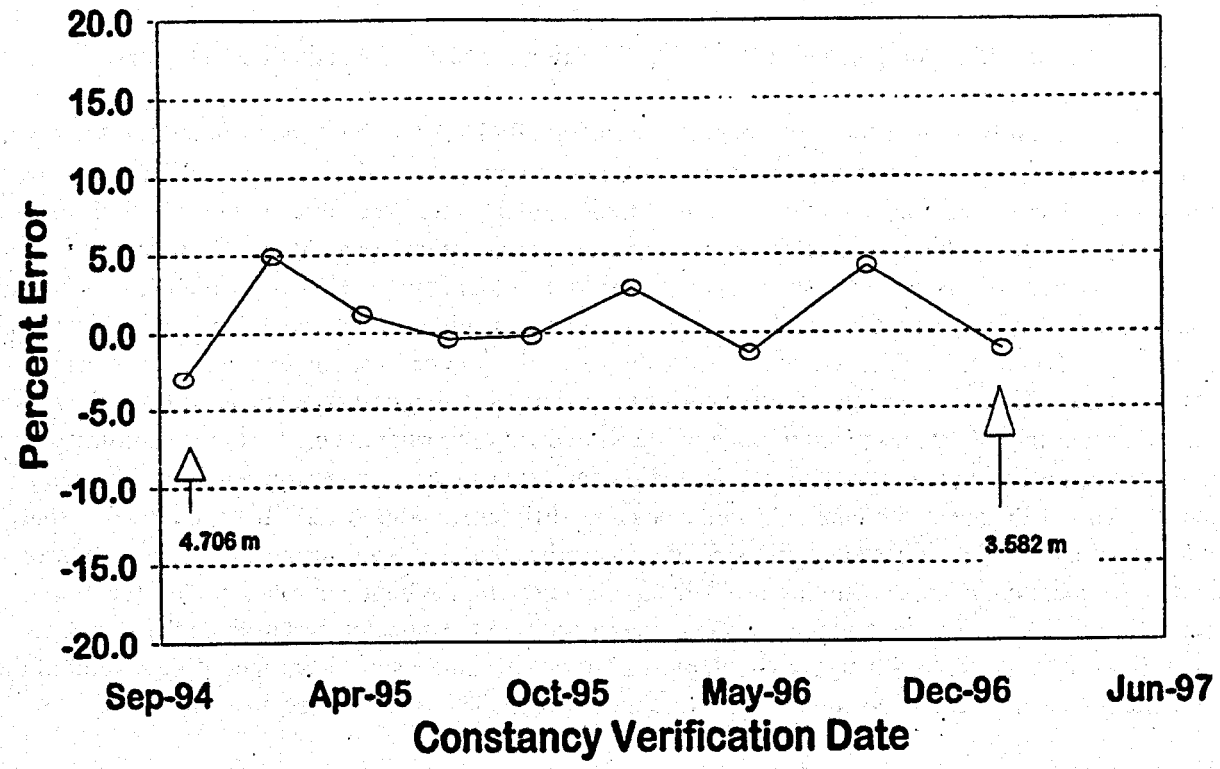


Figure 7.8. Stability of Sample SNOOPY Calibration Point From Single Calibration Performed 2½ Years Prior

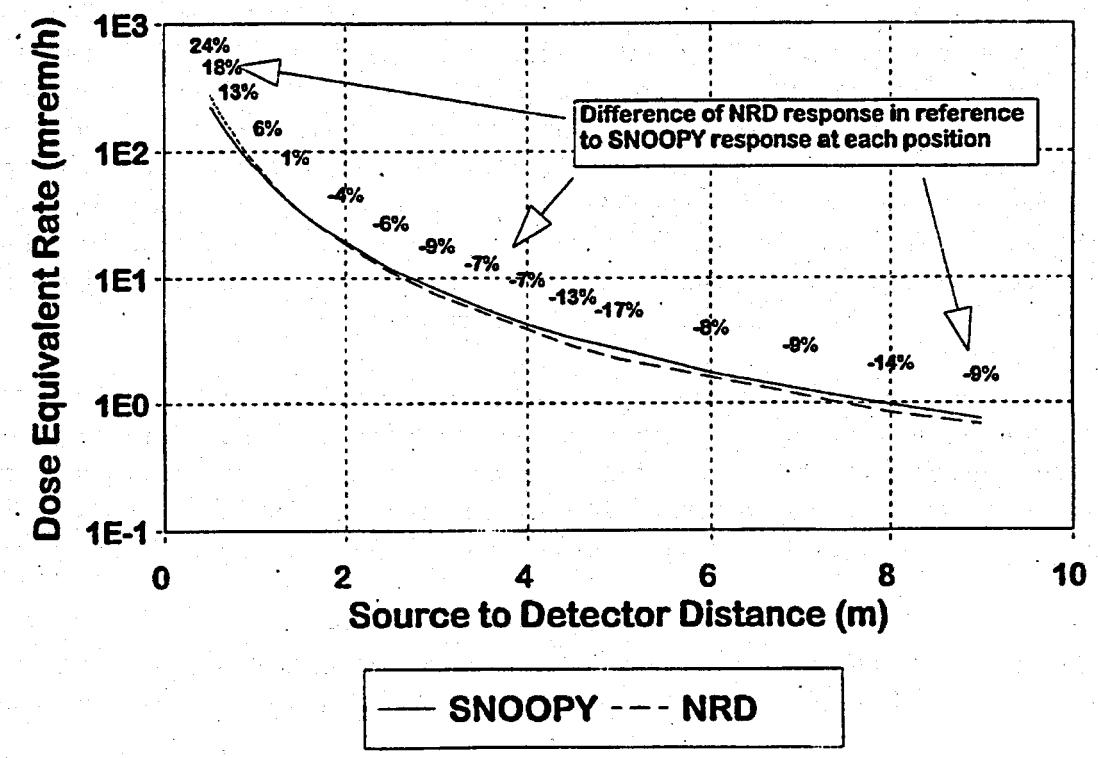


Figure 7.9. Comparison of Well #3 Calibration for SNOOPY and NRD Detectors

1995 following calibration of the neutron emission rate at NIST. Although its neutron output is known, it was considered important to perform a qualitative investigation, as well, since the NIST Manganous Sulfate bath characterization cannot determine isotopic content, spectral characteristics or details associated with anisotropy due to source distribution and/or encapsulation. In addition, this investigation would be expected to identify the effect of impurities in the older source (318-167) which may influence its effective half-life. This effect would manifest itself as indications of delivered dose equivalent which are greater or less than the decayed theoretical value, especially in comparison to a more recent calibrated source. This investigation involved performing comparative measurements using several available neutron sensitive detectors, including a tissue equivalent proportional counter (TEPC), multisphere measurements utilizing a lithium iodide scintillation detector and various neutron sensitive dosimetry devices. The TEPC measurements indicated a possible difference of up to 7.2% between the two sources relative to dose equivalent based on the NIST quoted emission rates. The various multisphere measurements were plagued by pulse counting problems associated with the high neutron output of the newer source (318-356). Subsequent attempts were made to position the detector further from the source to lower the counting rate; however, backscatter uncertainties became a significant factor for several of the component measurements. No conclusions were therefore made based on these measurements.

The most beneficial intercomparisons were obtained using various dosimetry devices. Sample dosimeters containing various neutron sensitive materials were obtained. The various materials used (see Table 7.4) represent dosimeters commonly used throughout the nuclear industry which would be

Table 7.4. Neutron Source Intercomparison Summary

Detector Type	$^{nat}Li_2B_4O_7$	$^{6}Li_2B_4O_7$	^{6}LiF	CR-39	Polycarbonate Film
Characteristic Samples[a]	1	3	4	3	1
Bare Response ratio (-356/-167) ± 1 std.dev.[b]	1.095 ± .012	1.008 ± .025	1.001 ± .004	1.011 ± .006	0.936 ± .016
D_2O-Moderated Response ratio (-356/-167) ± 1 std.dev.	0.996 ± .007	0.962 ± .008	1.000 ± .001	0.991 ± .008	0.851 ± .018

(a) Represents the number of sample types used in comparison (e.g., a three chip ^{6}LiF dosimeter, each with various combinations of front and back filtrations would represent three samples.
(b) Represents only the propogated standard deviation of the dosimeter results. This does not represent the overall uncertainty of the irradiation and analysis processes.

expected to indicate non-trivial variations in source characteristics. Irradiations were performed using five dosimeters of each type for four different conditions which included bare and D_2O-moderated configurations of both sources (318-167 and 318-356). All dosimeters were exposed at a distance of 50 cm to acquire a "theoretical" delivered neutron dose equivalent of 0.5 rem for the D_2O-moderated configuration and 1 rem for the bare source configuration. The results of this investigation showed no statistically identifiable differences between the neutron dose delivered for each of these sources, although possible trends were noted for future investigation. Consequently, source 318-356 was placed into service.

Beta Sources

Absorbed-dose rates from beta sources were verified using an extrapolation chamber at fixed distances to assure constancy with original calibration data. Measurements were also performed for various selected sources to assure that spectral characteristics were as expected and stable.

Reference Standard Instruments

Routinely utilized instrument standards were verified for consistency, as necessary, to assure 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 and Eberline NRD survey instruments used to convey calibration to Well #3.

Although no significant abnormalities were found, the micrometer adjustment on the PTW extrapolation chamber was found to be slightly sticky which appeared to have biased one or more beta field constancy measurements from 1- 3%. No further actions were taken since 1) adjustments to source absorbed dose rates were not made as a result of this data and 2) beta source stability appeared constant based on indications from QC monitoring equipment used to confirm delivered doses from beta reference fields.

7.1.4 Uncertainties of Reference Calibration Fields

Efforts continued in 1996 to update and refine the estimates of uncertainty for the various calibrated reference fields within the 318 Building Radiological Calibrations Facility. The methods used to determine uncertainty were referenced from NIST Technical Note 1297, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*. This document is an interpretation and abridgement of ISO *Guide to the Expression of Uncertainty in Measurement*. 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 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 effecting uncertainty are determined using Type A 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 interval. Table 7.5 provides an example of a typical uncertainty analysis.

Table 7.5. Uncertainty Analysis for the Determination of Gamma Reference Field Exposure Rate

Uncertainty Description	Symbol	Type[a]		Value (%)[b]		Ref.[c]
Total Chamber Current	δI_{tot}	A	B	0.14	0.20	5
Background plus leakage current	δI_d	A	B	0.14	0.20	4
Net Ionization Current	δI_{ref}	A	B	0.1	0.20	6
Total Chamber Charge	δQ_{ref}	A	B	0.1	0.20	2
Background plus leakage charge	δQ_d	A	B	1.0	0.20	1
Time Measurement	δt	A	B	0.1	0.004	3
Calibration Distance	δd_c	A	B	0.0	0.05	14
Chamber Distance	δd_{ch}	A	B	0.10	0.05	13
Primary Lab Transfers Standard R/C Calibration	δR_{pri}	A	B	0.22	0.45	11
Temperature/Pressure Correction	δC_{TP}	A	B	0.02	0.03-0.4 (0.2)	9
Chamber Temperature	δT	A	B	0.2	0.3-2.0	7
Chamber Pressure	δP	A	B	0.10	0.20	10
Electrometer Response Correction	δC_e	A	B	0.10	0.20	10
Exposure rate, X	δX_{sec}	A	B	0.33	0.61	29

NOTE: δ X due to type A: 0.330; δ X due to type B: 0.669; δ X total using RSS: 0.746 x 1.96 = 1.46% at 95% CI

(a) Type A and Type B uncertainties as defined in NIST Technical Note 1297 and ISO/TAG4/WG3.

(b) Values are in the form of $\delta x/x * 100$ and at 1σ.

(c) The method by which each error value was obtained can be found in the numbered references cited in the draft revision of the Quality Manual for Secondary Calibration for Ionizing Radiation (NVLAP), which is scheduled for issuance in 1997.

The analysis of uncertainty is an on-going effort which 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 7.6.

7.2 Supporting Studies

Three supporting studies were conducted in 1996. One project involved the construction and characterization of a distributed geometry beta calibration reference field for use in characterizing a specially designed instrument used to evaluate HEPA filter dose rates at the B-Plant. A second task involved the development of alternate beta reference fields, generated via attenuation of $^{90}Sr/^{90}Y$, which were needed to confirm extremity dosimeters and eye depth response of whole body dosimeters, as well as correlation of survey instrument readings for site-specific beta field applications. A third activity involved the evaluation of neutron source anisotropy for an older design ^{252}Cf source. This latter measurement was primarily intended to verify the quantity predicted via Monte Carlo modeling techniques performed several years prior therefore confirming the model for use on additional sources.

Table 7.6. Summary of Uncertainties (1996)

Reference Field	Total Uncertainty (95% C.I.)	Notes
Shepherd ^{137}Cs (318-131)	±1.5%	Distance = 1 meter
^{252}Cf:Bare (318-167)	±5.8%	Distance = 0.5 meter; No correction for source anisotropy
^{252}Cf:D_2O-Moderated (318-167)	±15.5%	Distance = 0.5 meter; No correction for source anisotropy; No correction for effect of D_2O-moderator void
PTB $^{90}Sr/^{90}Y$ (318-012, -013)	±2.1%	
ANSI $^{90}Sr/^{90}Y$ (318-102, -103)	±4.1%	
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]		
Well #1:attenuated (318-031)[a]	±1.1% to ±2.2%	
Well #1:unattenuated (318-031)[a]	±1.1% to ±3.6%	Dependant on distance/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]	±1.1% to ±2.5%	
Well #2:unattenuated (318-288)[a]	±1.9% to ±3.0%	Dependant on distance, total charge collected from the ion chamber and standard error of replicate readings
(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.		

7.2.1 Distributed Geometry Beta Reference Field

During 1996, a task-specific directional beta-gamma detector was developed and constructed within the RS&C task area. The goal of this detector was to provide information regarding $^{90}Sr/^{90}Y$ and ^{137}Cs dose rates emanating from banks of HEPA filters located at B-Plant. From these values, modeling techniques were to be used to determine activity contained within each filter. Beta detection calibrations are highly susceptible to the geometry of the beta source and the distance of the detector in relation to the source of radiation. Available sources within the RS&C inventory included a small (100 cm^2) planar source and several point sources as described in the Table 7.3. A calibration from any of these sources alone was insufficient to represent the anticipated field geometry. The task was further complicated by the small ion chamber used within the detection system which was purposely chosen for its low sensitivity.

To achieve an appropriate beta calibration, a plan was devised to use several of the available point sources, as well as the planar source to achieve an "apparent" distributed geometry. A special jig was constructed to facilitate placement of these sources reproducibly (see Figure 7.10). The jig allowed for placement of the sources in a variety of locations to allow maximum flexibility of this tool. The placement of the sources along with the appropriate distance of the detector allowed for a good representation of its field application. To calibrate the system, the tertiary standard PTW extrapolation chamber was utilized at the chosen reference distance. The appropriate distance was chosen such that the solid angle subtended by the detector window sufficiently covered the area of source placement and, since the extrapolation chamber was anticipated to cover nearly a 2π area, the dose rate determined from its response was a direct representation of the "calibrated" dose rate used for the special detector.

This specialized calibration capability remains available for further use in calibrating detectors for distributed area beta response. Its calibration is highly specific, depending on the source placement and the detector distance. Furthermore, specific dose rates obtainable using various geometries and sources are, to a large degree, unknown in advance so that determining the appropriate parameters is a trial and

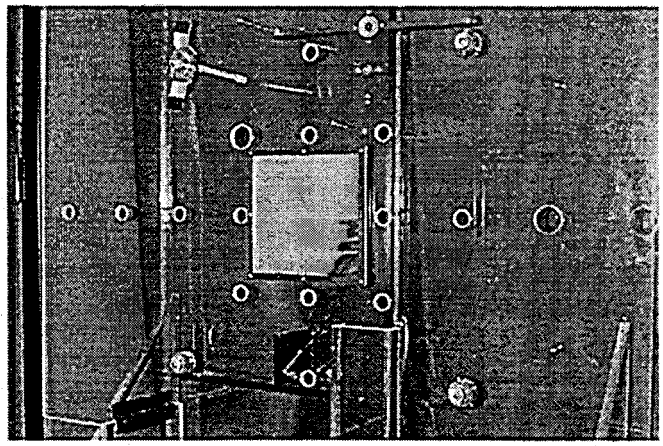


Figure 7.10. Distributed Area Beta Calibration Jig and Sources. The 100-cm^2 planar source is shown in the center along with four point sources in corners.

error process. Dose rate estimates can be determined based on source activities and calibrated rates at their typically used distances, but these estimates will have a high degree of uncertainty. If future use of this source is demanded for a wide variety of conditions, modeling techniques would be useful to help refine the target calibration positions.

7.2.2 Alternate Beta Calibration Fields

In support of dosimetry work described in Sections 2.5.3 and 2.5.4, a series of filtered $^{90}Sr/^{90}Y$ reference fields were established. These fields originated from the 50 mCi PTB source (see Table 7.3), subsequently modified by various plastic filters, approximately 5 cm in width and 7 cm in length, placed directly in front of the window covering the active area of the source. Initially, the filters had been placed at distances varying from 1 - 5 cm away from the source due to limitations of the beta source holder/irradiation jig; however, extrapolation chamber and beta spectrometer measurements indicated a high degree of dependence on the specific position. The beta jig is mounted in a plastic shield designed to reduce the amount of backscattered beta radiation during normal operations. The dependence on filter position was due, in part, to multiple backscatters from the filters and this plastic shielding as well as a large degree of air scattering of the incident beta field around the filters.

To characterize the resulting reference fields, extrapolation chamber measurements were made to determine the shallow (7 mg/cm^2) absorbed dose rates and the residual maximum beta energy (E_{res}) was assessed. In addition, the fractional photon component was determined, since its influence was found to become significant with the thicker absorbers. The associated photons result primarily from bremstrahlung interactions in the silver window covering the PTB source. The modified calibration reference fields were characterized at a single distance of 30 cm, source to detector entrance window or, for TLD irradiations, to the surface of the phantom on which dosimeters are placed. The various sources and their characteristics are listed in Table 7.7.

7.2.3 Neutron Source Anisotropy Measurements

Measurements were performed to assess the degree of anisotropy evident from an older ^{252}Cf source within an SR-100 encapsulation, one of the two encapsulation designs used within the LSR. Although this parameter had been estimated several years prior based on Monte Carlo modeling, these estimates have never been confirmed by measurement. All sources for which this effect was a concern were installed in the pneumatic system and, consequently, could not be reasonably assessed without an elaborate positioning apparatus that could place a detector in a vertical arc around the source. This was not considered feasible at the time even though the estimated effect of anisotropy for source calibrations and the irradiation of dosimeters, based on the model, was an increase in dose equivalent rate by 7.3%. This value has, in recent years, been treated as an uncertainty rather than factoring it into the calibrated dose equivalent rate.

During late 1995, this source (318-016) was removed from the LSR pneumatic transfer system to allow placement of the newest source. Having removed it from the system, it facilitated its manual placement and orientation such that it could be placed on its side and rotated about its horizontal axis to

Table 7.7. Attenuated Beta Reference Fields (1996)

Nuclide	Attenuation at Source Window (mg/cm²)	Depth Dose at 30 cm (rad/h)[a]			Depth Dose Ratio[b] (7:50)
		7 mg/cm²	550 mg/cm²	300 mg/cm²	
$^{90}Sr/^{90}Y$ (318-012)	0	20.44	21.63	10.17	0.94
	72	16.27	17.02	7.205	0.96
	275	6.043	6.193	1.643	0.98
	507	1.125	1.061	0.0941	1.06
	677	0.1578	0.1359	0.0097	1.16
	1472[c]	0.0087	--	--	--
^{204}Tl (318-192	0	1.272	0.6229	--	2.04
	86	0.1475	0.0496	--	2.97

(a) Reference date is June 7, 1996.
(b) E_{res} measurements were not performed for each attenuated condition; therefore, the ratio of the dose rates at 7 mg/cm² and 50 mg/cm² is provided as a rough comparative value for the quality of each field.
(c) The 1472 mg/cm² measurement is provided to indicate the magnitude of the Bremstrahlung component from source 318-012.

specific angles, θ (see Figure 7.11). A precision long counter was utilized to perform measurements of neutron source output with the source rotated in increments of 10°. This evaluation indicates that the 90° neutron output is 8.4% higher than the dose equivalent rate based on the assumption of isotropic neutron emissions. The measurement results for 360° of rotation are shown in Figure 7.12.

These measurements provide confidence in the calculational model established for this source. The sources currently in use within the low scatter facility have been manufactured at Oak Ridge National Laboratory (ORNL) and are slightly different in design and source distribution than the earlier SR-100 sources made at Savannah River. These newer designs, designated NSD by ORNL, are well described, facilitating the calculation of their anisotropy factors based on the modeling technique used for the SR-100 sources. Upon completion of this task, the neutron dose rates used for LSR sources may be adjusted. This will lead to equivalent adjustments for the SNOOPY reference instrument and the Well #3 source.

7.3 Project-Related Professional Activities

Staff presentations during 1996 are listed in this section.

7.3.1 Presentation

McDonald, J. C. 1996. *Calibration and Traceability of Reference Radiation Fields at PNNL*, presented at the 15th Annual Panasonic TLD Symposium, Sante Fe, New Mexico, June 10-13, 1996.

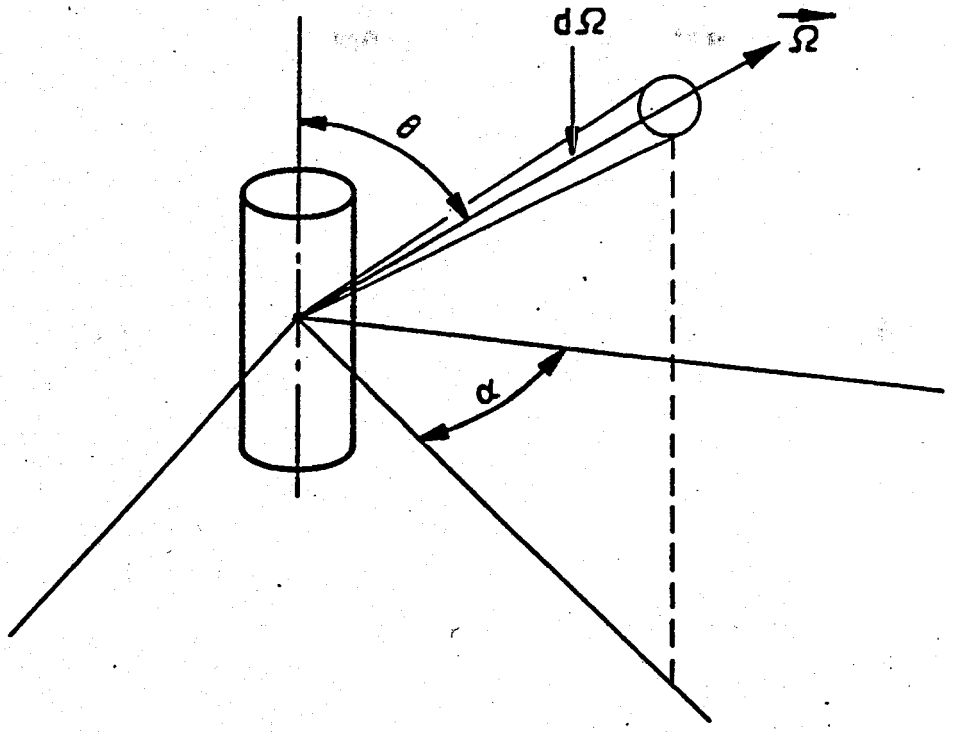


Figure 7.11. Coordinate System for an Anisotropically Emitting Source

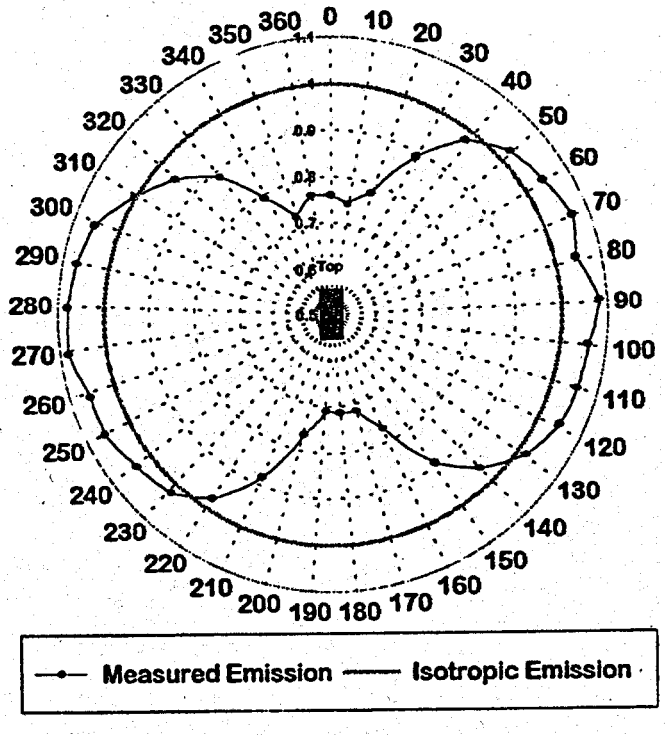


Figure 7.12. Results of Anisotropy Measurements for SR-100 Encapsulated ^{252}Cf Source (318-016)

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