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**HANFORD RADIOLOGICAL PROTECTION
SUPPORT SERVICES
ANNUAL REPORT FOR 1993**

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ABSTRACT

Various Hanford Site radiation protection services provided by the Pacific Northwest Laboratory for the U.S. Department of Energy Richland Operations Office and Hanford contractors are described in this annual report for calendar year 1993. These activities include internal dosimetry measurements and evaluations, in vivo measurements, external dosimetry measurements and evaluations, instrument calibration and evaluation, radiation source calibration, and radiological record keeping. 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 Laboratory (PNL) during calendar year 1993, in support of the U.S. Department of Energy (DOE) Richland Operations Office (RL) and the Hanford contractors. These Sitewide services were provided by projects in 1) internal dosimetry, 2) in vivo measurements, 3) external dosimetry, 4) instrument calibration and evaluation, 5) calibration of radiation sources traceable to the National Institute of Standards and Technology (NIST), and 6) radiological records. The routine project tasks, and any significant changes to the routine tasks, are described in this report, along with any supporting studies performed during calendar year 1993. Related professional activities, such as publications, presentations, and memberships on standards or industry committees, are also described.

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 1993, the project provided oversight to 9100 excreta sample requests and 8384 excreta bioassay measurements. Changes to the routine tasks included revisions in certain tritium and uranium sampling procedures, changes to the Statement of Work (SOW) for the excreta bioassay laboratory contractor, revisions to practice-based changes to the *Hanford Site Radiological Control Manual* (RL 1992) and changes resulting from implementation of the new Radiological Exposure (REX) System, and a complete revision of the project manual. Supporting tasks performed during 1993 included establishing a backup excreta bioassay capability, studying the possibility of work group bioassay sampling, requesting an expert appraisal of the Internal Dosimetry and In Vivo Measurement projects, and preparing an internal exposure incident response plan.

The **Hanford In Vivo Measurement Project** provides the capability to detect radioactive materials deposited in individuals using in vivo counting techniques. During 1993 the project completed 14,277 measurements. The project prepared for DOELAP accreditation based on the draft ANSI N13.30, *Performance Criteria for Radiobioassay*. Changes to facilities and equipment included acquiring a new set of four large-area planar germanium detectors, upgrading the efficiency equation for the coaxial germanium system, producing a high-energy gamma-emitter Bottle Manikin Absorption (BOMAB) calibration phantom, implementing a new in vivo scheduling system, and instituting in vivo capability for ^{90}Y . Other activities included a U.S./Canadian intercomparison study of a child BOMAB phantom, support of the U.S. Transuranium/Uranium Registries, and participation in a calibration intercomparison program.

The **Hanford External Dosimetry Project** officially received renewal of the DOE Laboratory Accreditation Program (DOELAP) Certificate of Accreditation effective November 23, 1993. This certificate maintains the accreditation of Hanford basic, beta/photon, and multipurpose dosimeters in selected performance categories and is effective for the next two years. During the year, the project also demonstrated good performance on the Westinghouse Hanford Company

(WHC) monthly blind audit dosimeters where results met established tolerance limits in all tested categories. The project also demonstrated good performance in the 10th International Environmental Dosimeter Intercomparison Study. This study involved over 100 laboratories throughout the world and covered a testing period of several months. A total of 214,422 dosimeters were processed during 1993 to support reported dose-of-record for 94,103 personnel dosimeters. The remainder were for quality control purposes. This volume of processing maintained the trend in recent years of a 5% overall increase in reported results. Changes were made in the routine program, effective October 1, 1993, involving 1) lowering the administrative dose "priority" reporting levels, and 2) changing the status of priority reported results from preliminary to final. Procurement was completed for essentially all items necessary to the planned implementation of the new Hanford thermoluminescent dosimetry (TLD) system and track-etch dosimetry (TED) system scheduled to begin January 1, 1995.

The Instrument Calibration and Evaluation Program provides complete and reliable radiation protection instrument services for Hanford contractors to ensure personnel safety in the Hanford workplace. Specific tasks performed under this program during 1993 included operating the routine instrument pool and the Hanford Test and Evaluation Project, providing direct support to the HP-9000 Database which includes all instrument calibration records, performing technical reviews of instrument calibration procedures for the Site contractors, maintaining the Site radiation protection instrument manual, and evaluating commercially available ion-chamber dose rate survey instruments to replace the Site Cutie-Pie. The program provided an administrative mechanism for the equitable sharing of maintenance costs for the Hanford Site Radiological Standards and the *Hanford Site Radiological Control Manual* by proportioning contractor shares to instrument pool usage. Supporting activities included determining the minimum detectable activity (MDA) for portable radiation detection instruments and adding procedure requirements to the program manual for performance testing of portable instruments.

The Radiation Standards and Calibrations 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 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 in accordance with recommended standards and guides. Highlights for 1993 include additional refinements in low-exposure-rate reference fields, improvements in assessment of a neutron source, and assessment of the bare ^{252}Cf room scatter effects within the low scatter room for the SNOOPY reference instrument. A significant accomplishment was receiving accreditation as a Secondary Calibration Laboratory for Ionizing Radiation (SCLIR) through the National Voluntary Laboratory Accreditation Program (NVLAP).

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. In addition to producing reports for DOE Headquarters, RL, Hanford contractors, individuals, and other authorized agencies, the project provided data for epidemiology and research projects. The REX System database was implemented after a three-and-one-quarter year development project. The implementation was a difficult process; however, the system was performing well by year-end. A requirements analysis was completed for instituting a one-point contact for locating the custodian of all Hanford radiological control records.

ACKNOWLEDGMENTS

The authors would like to thank the staff members whose professional skills and technical expertise ensure the success of the Internal Dosimetry Project, In Vivo Measurement Project, Hanford External Dosimetry Project, Instrument Calibration and Evaluation Program, Radiation Standards and Calibrations Project, and Radiological Records Project.

ACRONYMS AND ABBREVIATIONS

ACL	Analytical Chemistry Laboratory
ANSI	American National Standards Institute
BCSR	Boeing Computer Services-Richland
BOMAB	Bottle Manikin Absorption (phantom)
CAM	continuous air monitor
CAR	computer-assisted retrieval
CEDE	committed effective dose equivalent
CEDR	Comprehensive Epidemiologic Data Resource
CY	calendar year
DA	Data Administration
DEC	Digital Equipment Corporation
DOE	U.S. Department of Energy
DOE-HQ	DOE Headquarters
DOELAP	DOE Laboratory Accreditation Program
EDF	Emergency Decontamination Facility
FY	fiscal year
GM	Geiger-Mueller
HEHF	Hanford Environmental Health Foundation
HHS	Hanford Health Scheduling (system)
HIEC	Hanford Instrument Evaluation Committee
HMPD	Hanford Multipurpose Personnel Dosimeter
HPDAC	Hanford Personnel Dosimetry Advisory Committee
HP	Hewlett Packard
HRRP	Hanford Radiological Records Program
HSRCM	<i>Hanford Site Radiological Control Manual</i>
IARC	International Agency for Research on Cancer
ICP/MS	inductively-coupled plasma mass spectrometry
IDP	Hanford Internal Dosimetry Program
IPUL	enhanced sensitivity plutonium analysis (test method)
IRM/ISS	Information Resource Management/Information and Scientific Systems
ISO	International Standards Organization
ITAS	International Technology Analytical Services

IVRRF	In Vivo Radioassay and Research Facility
KEH	Kaiser Engineers Hanford Company
LLD	lower limit of detection
LOD	laser optical disk
LSIS	Large Scale Information System (NSAS 9080 mainframe)
MCA	multichannel analyzer
MDA	minimum detectable activity
MDCR	minimum detectable count rate
MIS	Management Information Systems
MQA	measurement quality assurance
NBS	National Bureau of Standards
NIST	National Institute of Standards and Technology (previously called the National Bureau of Standards, NBS)
NMC	Nuclear Measurements Corporation
NRC	Nuclear Research Corporation
NVLAP	National Voluntary Laboratory Accreditation Program
ORE	Occupational Radiation Exposure (system)
PAM	portable alpha monitor
PGT	Princeton Gamma Technology
PC	personal computer
PNL	Pacific Northwest Laboratory
PRF	Platinum Report Facility
PTB	Physikalisch-Technische Bundesanstalt
PTW	Physikalisch-Technische Werkstätten
QC	quality control
QUS	quick uranium soluble (test method)
RESL	DOE Radiological and Environmental Sciences Laboratory
REX	Radiological Exposure (system)
RL	DOE Richland Operations Office
RS&C	Radiation Standards and Calibrations (Project)
SCLIR	Secondary Calibration Laboratory for Ionizing Radiation
SCR	software change request (form)
SDD	Software Design Document

SOW	Statement of Work
SSN	social security number
SQL	Standard Query Language
TED	track-etch dosimetry (system)
TEPC	tissue equivalent proportional counter
TLD	thermoluminescent dosimetry (system)
TRU	transuranic (radionuclides)
UNAT	natural uranium (test method)
USTR/USUR	United States Transuranium/Uranium Registries
WBC	whole-body count
WHC	Westinghouse Hanford Company
WORM	write-once/read-many (laser optical disk)
WSU	Washington State University

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1.0 INTRODUCTION

This annual report documents the calendar year (CY) 1993 activities of specific radiation protection services performed by the Pacific Northwest Laboratory (PNL)^(a) for the U.S. Department of Energy (DOE) Richland Operations Office (RL) and the Hanford Site contractors. These Sitewide services are provided by projects in 1) internal dosimetry, 2) in vivo measurement, 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 PNL Health Protection Department.

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 DOE. They also reduce costs to the Hanford contractors, which comprise Boeing Computer Services - Richland (BCSR), the Hanford Environmental Health Foundation (HEHF), Kaiser Engineers Hanford Company (KEH), PNL, and Westinghouse Hanford Company (WHC).

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

- 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.

The PNL and DOE management structure and communication interfaces for each PNL-operated project are shown in the organizational chart in Figure 1.1. The DOE Safety and Environmental Division is responsible for PNL services in this area.

The Health Physics Department was reorganized late in 1993 and was renamed the Health Protection Department. The support service programs were retitled projects to bring their titles in line with PNL internal descriptions and the Personnel Dosimetry Program was created and

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Figure 1.1. Management Structure and Major Communication Interfaces for Hanford Radiological Support Services in 1993

brought under one management. This program includes the External Dosimetry Project, the Internal Dosimetry Project, the In Vivo Measurement Project, and the Radiological Records Project. Each of these projects are covered in a separate chapter of this report. The Instrument Calibration and Evaluation Program was divided into three projects: the Portable Instrumentation Project, the Instrument Applications Project, and the Hanford Instrument Evaluation Committee (HIEC) Project. The Instrumentation Calibration and Evaluation Program is covered in one chapter of this report.

2.0 HANFORD INTERNAL DOSIMETRY PROJECT

The Hanford Internal Dosimetry Project (IDP) was initiated in 1946 to provide for the assessment and documentation of occupational doses from intakes of radionuclides at the Hanford Site. The program is administered in support of Hanford radiation protection programs, as required by DOE 5480.11, "Radiation Protection for Occupational Workers" (1990); the *Hanford Site Radiological Control Manual*, HSRCM-1 (RL 1992); and the *Hanford Site Services Handbook*.^(a)

The program provides the following internal dosimetry services:

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

2.1 THE ROUTINE PROJECT

Intakes of radionuclides are generally prevented by containment or other protective measures; therefore, intakes are generally assumed to result from an acute intake. Dose assessment is based on this assumption, although exceptions occur for work with tritium and uranium. Tritium intake is generally assumed to occur chronically throughout the period of exposure, so assessment of work in the hot cell in the 324 Building was planned accordingly. Because entries into the hot cell did not occur daily, samples were taken the day or so after each entry and an acute intake scenario was assumed. However, based on a history of bioassay data showing little or no intakes on this project, the workers were placed on a monthly sampling regime in June. Work on this task was completed in September. Westinghouse Hanford Company workers became involved with tritium in December, when Hanford started receiving waste drums from Princeton with curie-levels of tritium. These workers are sampled after each receipt and burial of waste drums.

(a) U.S. Department of Energy Richland Operations Office (RL), 1993, RL 1400.1A, Richland, Washington (available online in HanInfo).

For years, chronic exposure conditions were also assumed for uranium work. However, with the changing mission at Hanford and increased emphasis on reducing intakes, the assumed nature of exposure to uranium changed. Many WHC workers were placed on quarterly, as opposed to monthly, uranium urinalysis because they rarely entered uranium contaminated zones. Their urinalysis results were interpreted assuming a possible acute intake. Work in the uranyl nitrate load-out facility at PUREX (203A) was also treated as a potentially acute exposure because respiratory protection was required for all work. The Uranium Trioxide (UO₃) Plant had a processing campaign from April to June. Workers involved in that campaign were placed on a frequency of every three weeks, and any observed activity was assumed to be from chronic intake. Outside of that campaign, UO₃ Plant workers on monthly sampling were assumed to be chronically exposed and workers on quarterly sampling were assumed to be possibly acutely exposed.

Other operational aspects 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*, revision 1 (Sula, Carbaugh, and Bihl 1991)
- the protocols and practices for operation of the project and coordination with the Site contractors are established in the *Hanford Internal Dosimetry Project Manual*^(a)
- detailed procedures are contained in the *Hanford Internal Dosimetry Procedures Manual*^(b); although many of the procedures in this manual were not applicable after April 5 because of the change from the Occupational Radiation Exposure (ORE) system to the Radiological Exposure (REX) database (see Section 7.2.1)
- the technical agreements with the excreta lab are established by a Statement of Work (SOW).

The practices and technical aspects of operating the Hanford In Vivo Measurement Program are established in the *Whole Body Counting Manual*,^(c) and were supplemented in May 1992 by the "In Vivo Bioassay Statement of Work."^(d) Individual assessments of internal dose are documented in each individual's file in the Hanford Radiological Records Project microfilm files. Bioassay measurement results and internal doses are maintained in the REX database, which is operated by the Hanford Radiological Records Project.

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- (a) Internal manual, PNL-MA-552, Pacific Northwest Laboratory, Richland, Washington.
(b) Internal manual, PNL-MA-565, Rev. 0, Pacific Northwest Laboratory, Richland, Washington.
(c) Internal manual, PNL-MA-574, Pacific Northwest Laboratory, Richland, Washington.
(d) T. P. Lynch, J. A. MacLellan, and D. E. Bihl. 1992. "In Vivo Bioassay Statement of Work." (A copy is available in the Hanford Radiation Protection Historical Files.)

2.1.1 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 and their anticipated physical and chemical form. Minimum detectable activities (MDAs) and follow-up levels for routine excreta and in vivo bioassay measurements are shown in Tables 2.1 and 2.2. MDAs for other categories of excreta analyses are shown in Table 2.3. All values in the tables were unchanged from 1992.

2.1.2 Excreta Bioassay Contract Activities

A number of problems and concerns were discussed at meetings with International Technology Analytical Services (ITAS) throughout the year.

The plutonium sample backlog mentioned in last year's report was completed early in 1993. There were very few late samples after that time.

International Technology Analytical Services was asked to evaluate and comment on perceived problems with the uranium procedure. Test results for ITAS' aliquoting procedure for uranium verified the procedure's adequacy. Because ITAS started rinsing all containers prior to this test, we learned only that the present procedure appeared adequate, not what might have caused the previous problems. The draft third-year SOW was modified to include requirements to periodically check on the adequacy of aliquoting. Meanwhile, the quality control (QC) oversight program data for fiscal year (FY) 1993 indicated that the problem might not be entirely solved (see Section 2.1.3).

International Technology Analytical Services also conceded that the proposed enhanced sensitivity plutonium analysis (IPUL) procedure may never be able to meet the specified contract requirements. They looked into the possibility of implementing a new inductively-coupled plasma mass spectrometry (ICP/MS) procedure for low-level plutonium analyses, but later reported that ICP-MS analysis will not be able to meet the IPUL specifications.

While not admitting a problem with low chemical yields for fecal samples, ITAS said they will limit aliquot size to 1.5 g of fecal ash material and will provide additional training for analysts on the possibility of interferences from the fluorine if adequate care is not taken with the perchlorate-HF dissolution step. This action resulted from a series of low chemical yields on fecal samples obtained in response to a March incident.

Table 2.1. Specified Minimum Detectable Activities and Screening Levels for Routine Excreta Analyses During 1993

Analysis ^(a)	Contractual MDA ^(b,c)	Screening Level and Sampling Frequency ^(c,d)
²³⁸ Pu, ²³⁹ Pu	0.02 dpm	0.01 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)
Elemental U	0.06 µg	0.2 µg (Q) ^(f,g) 0.5 µg (Q) ^(h)
Elemental U (QUS)	0.5 µg	11 µg (BW) 1 µg (M) ⁽ⁱ⁾ 4 µg (M) ^(h)
Tritium	20 dpm/mL	80 dpm/mL ^(j)

- (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 (routine bioassay monitoring frequency: A-annual, BE-biennial, BW-biweekly, M-monthly, Q-quarterly).
- (e) The lab cannot discriminate between ²³³U and ²³⁴U and reports the results as ²³³U; however, no work was done with ²³³U in 1993 so results were interpreted as representing ²³⁴U.
- (f) Upper level of expected environmentally derived uranium in urine for the Hanford region.
- (g) When this level is exceeded, the worker's results are evaluated at the end of the year for possible chronic intake for some operations and as a possible acute intake for other operations.
- (h) When this level is exceeded, an immediate investigation for a possible acute intake is started.
- (i) When this level is exceeded, the worker's results are evaluated at the end of the year for possible chronic intake.
- (j) Special screening levels were established for the tritium cell clean-out work in the 324 Building because of acute exposure conditions and short times between exposure and sampling. These levels were documented in Program Change Record 92-004.

Table 2.2. Minimum Detectable Activities and Screening Levels for Routine In Vivo Measurements During 1993

Measurement/Radionuclide ^(a)	MDA ^(b) (nCi)	Screening Level ^(c) (nCi)
Whole-Body Count^(d)		
⁶⁰ Co	6	8
¹⁵⁴ Eu	12	8
¹³⁷ Cs	3	9
Lung Count		
²³⁵ U	0.2	Any detected
²³⁸ U (by ²³⁴ Th)	3	Any detected
²⁴¹ Am	0.12	Any detected

- (a) For selected radionuclides. (The detection of radionuclides not listed resulted in follow-up.)
- (b) Under ORE, the MDAs were reported; under REX, the decision levels (approximately half of the MDAs) were reported, but these MDAs were still applicable.
- (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 is used when activity is first detected using the preview counter.

International Technology Analytical Services reported a low-level plutonium contamination problem in October. They originally suspected that samples from another client contributed to the contamination, but no causal connection could be identified through the data. The incident resulted in three samples being declared "lost." All analytical activities were discontinued as soon as the "unusual" number of results above the detection level were noted. All standard laboratory glassware and containers from the plutonium lab were then discarded and nonstandard glassware and other equipment thoroughly cleaned. The process was thoroughly tested before plutonium analyses were resumed later in October.

As a means of identifying specific causes for problems with ITAS bioassay kit delivery and providing appropriate documentation to expedite corrective actions, an inspection of services was conducted by the PNL Process Quality Department in April, 1993. The inspection included a thorough review of the ITAS scheduling and record keeping functions and an extended surveillance of the ITAS drivers while they deliver and retrieve the bioassay kits. Management from ITAS recognized that the level of performance had not only resulted in customer dissatisfaction, but also in a significant loss of revenue from uncompleted orders. Both PNL and ITAS viewed the inspection as an opportunity to correct a persistent problem. As a result of the inspection, ITAS made significant improvements to their written procedures and committed to improved

Table 2.3. Specified Minimum Detectable Activities for Emergency and Expedited Excreta Bioassay During 1993

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	1.0 dpm	20 dpm
Total radiostrontium	80 dpm	450 dpm
Elemental uranium	7 µg	8 µg
Tritium	100 dpm/mL	—
Expedited Analyses^(c)		
Isotopic plutonium by alpha spectrometry	0.08 dpm	3 dpm
Isotopic uranium by alpha spectrometry	0.12 dpm	4 dpm
²⁴¹ Am	0.08 dpm	6 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) Verbal reporting time was by 9:00 a.m. on the second business day after receipt of the sample.

management oversight of the delivery functions of the contract. An inspection conducted in December included a surveillance of uranium mass analyses and a follow-up inspection of the April inspection on kit delivery functions. None of the previous findings were closed as a result of the December follow-up inspection, but ITAS started a reorganization of responsibilities and made a commitment to fully implement corrective actions.

The contract SOW was revised for the second operational year to include all changes needed for implementation of REX. International Technology Analytical Services agreed to no price increases for the new operational year, so PNL Subcontracts implemented the REX requirements through a change order to the contract. The draft third operational year SOW to the ITAS contract was modified to include a chemical yield evaluation criterion, requirements to periodically check the adequacy of aliquoting of samples, and new sequential analyses (combination of analyses on a single sample). When estimates for developmental costs were received, WHC decided the new procedures were not needed, but PNL Laboratory Safety agreed to fund \$15K in development costs for new sequential procedures. However, at year-end the

third-year SOW had not been promulgated yet due to difficulties in auditing ITAS' financial records to verify prices.

New financial procedures for the bioassay costs were implemented. To help WHC track their bioassay costs, a monthly accrual was implemented for outstanding bioassay analytical costs (as opposed to waiting for the invoices to clear the financial system). Special accounts were also established to track the accruals for work outstanding at the end of FY 1993.

2.1.3 Excreta QC Oversight Program

A total of 216 urine samples with known amounts of various radionuclides (blanks and spikes) were submitted in FY 1993^(a) to ITAS by IDP to check the accuracy, precision, and detection levels of their urinalyses for tritium, ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am , ^{234}U , ^{235}U , ^{238}U , and natural uranium analyses. No quality control fecal samples were submitted to ITAS during FY 1993.

Results from the single blind (Oak Ridge National Laboratory intercomparison) samples and double blind (PNL QC) samples did not show any appreciable differences, and were combined for statistical analysis. The QC samples submitted during the report period represented about 3% of the total samples submitted. This is down slightly from the FY 1992 samples submitted (4%).

In addition to the samples provided by IDP, ITAS was also required to conduct their own QC program and submit the results of analyses to IDP. International Technology Analytical Services' performance in analyzing for tritium, ^{90}Sr , ^{238}Pu , ^{239}Pu , ^{241}Am , and natural uranium met or exceeded the specifications in the SOW of the contract with ITAS.

The mass of natural uranium was determined by two different methods: quick uranium soluble (QUS) and natural uranium (UNAT). International Technology Analytical Services now uses laser phosphorimetry for both mass uranium analyses, the only analytical difference being the size of the samples submitted (QUS sample size is approximately one-half the UNAT sample size). Because the same size aliquot is taken from each sample, the QUS minimum detectable activity (MDA) per sample is expected to be one-half the UNAT MDA. The less sensitive method, QUS, exceeded all performance criteria.

The more sensitive uranium procedure, UNAT, also exceeded all performance criteria based on ITAS results, but IDP samples identified a relative bias and precision problem. The mean value and relative precision statistic of UNAT blanks decreased considerably over the last two years, apparently due to improved analytical performance. Consequently, in FY 1993 the UNAT procedure now met the MDA criterion without adjusting for the natural occurrence of uranium in urine. On the other hand, 17% of the uranium samples spiked by IDP at the contractual detection level were not detected by ITAS. These results were not considered acceptable. IDP believed the problem resulted from the ITAS aliquoting procedure. International Technology Analytical Services started transferring the entire sample and thoroughly rinsing the container prior to aliquoting during the year, but spikes analyzed since then did not show definite improvement.

(a) Data from the QC oversight program is analyzed on a fiscal-year basis.

2.1.4 Program Change Records

Small-scope changes to the practices or technical aspects of the IDP are documented by Program Change Records. Ultimately, these changes become incorporated into the *Technical Basis for Internal Dosimetry at Hanford* (Sula, Carbaugh, and Bihl 1991), the *Hanford Internal Dosimetry Project Manual*,^(a) or the *Hanford Internal Dosimetry Procedures Manual*.^(b) The Program Change Record identifies the change, its effective date, and the reasons for and impacts of the change. A copy of the record is placed in the Hanford Radiation Protection Historical Files. Program Change Records issued by the IDP in 1993 are shown in Table 2.4.

Table 2.4. Program Change Records for 1993

PCR No.	Effective Date	Title	Affected Areas of Program
93-001	03-17-93	DEMS Reason Code Modification	Updated database reason codes used to explain why an evaluation was performed.
93-002	02-01-93	Policy Changes Due to the <i>Hanford Site Radiological Control Manual</i>	Changed key dose reporting parameters from annual to committed doses. Identified basis dose levels for design of monitoring program capability, as well as assessment and recording actions.
93-003	12-16-92	Hanford Practice to Monitor Internal Exposure to the Embryo/Fetus	Provided explanation of internal dose monitoring, assessment and recording practices for the embryo/fetus. Adopted dose calculation methods of USNRC Regulatory Guide 8.36.

2.1.5 Impact of the REX System Database on the Internal Dosimetry Project

The REX System database commenced operation on April 5, 1993, replacing the former ORE System. Startup of this system changed many of the operating practices of the IDP. This system brought online access to all recorded internal doses (committed and annual, effective and organ) for assessed cases. In addition, a uniform set of bioassay measurement reason codes was implemented for both in vivo and excreta bioassays. Scheduling of standard excreta bioassay requests was transferred to the field dosimetry organizations.

(a) Internal manual, PNL-MA-552, Rev. 1, Pacific Northwest Laboratory, Richland, Washington.

(b) Internal manual, PNL-MA-565, Rev 0, Pacific Northwest Laboratory, Richland, Washington.

Numerous problems and inefficiencies resulted from the REX startup. Almost immediately, an extensive list was created of rejected and outstanding records for excreta bioassay requests and results. Resolution of this list was still in process at year's end. Screens limited access to one analysis result at a time, rendering the process of reviewing bioassay histories and data very time consuming. The cumbersome nature of using REX for these reviews led to the June termination of monthly courtesy verifications by IDP that excreta bioassays, as scheduled were, indeed, appropriate for workers having previously assessed intakes.

2.1.6 Revision of the *Hanford Internal Dosimetry Project Manual*

A complete revision of the *Hanford Internal Dosimetry Project Manual* was drafted in 1993 to incorporate the extensive changes to the project since the manual's original 1989 issue. The revision incorporated program change records, as well as numerous technical and administrative changes which have occurred as a result of implementing the *Hanford Site Radiological Control Manual*, using ITAS excreta bioassay, startup of REX, and general experience with the use of the manual. As of year-end, revisions were complete, and the document was in the approval process with distribution expected in early CY 1994.

2.2 MONITORING AND ASSESSMENT ACTIVITIES

The IDP excreta bioassay monitoring and internal dose assessment activities during 1993 are summarized in this section. The in vivo bioassay monitoring program and its associated statistics are discussed in Chapter 3.0, "Hanford In Vivo Measurement Project."

2.2.1 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 ITAS laboratory just before the start of each month. All other requests are considered nonstandard requests. Contractors and IDP 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 2.1 shows the monthly distribution of standard and nonstandard requests for 1993. A total of 9100 samples were requested in 1993, down 8% from the 1992 requests. The majority of the samples (57%) were standard requests, with 43% being nonstandard. The respective percentages in 1992 were 62% and 38%. The monthly request rate was more variable in 1993 than in 1992, with a peak in requests in March which corresponded with the preparation to put REX into service.

1993

S9406040.2

Figure 2.1. Standard and Nonstandard Excreta Requests by Month

During FY 1993, 8384 excreta bioassay measurements were successfully performed in support of Hanford activities, excluding cancellations, no-samples, samples without valid results, and quality control samples. Of these, 97% were classified as routine (including measurements on visitors) and about 3% were due to special circumstances, such as response to unplanned potential intakes or follow-up analyses to high routine measurements. The percentage of successfully performed excreta bioassay measurements was 92% for 1993, up from 80% for 1992.^(a)

The 1993 excreta results statistics are summarized in Table 2.5. Even with the number of requests down, the total number of successful measurements continued the increasing trend of prior years, as depicted in Figure 2.2 (i.e., more samples were successfully collected and analyzed on the first attempt which led to fewer second requests). Major increases occurred in the number of uranium and plutonium-fecal analyses. A major decrease occurred in the number of tritium analyses (largely because of a switch from once-every-entry to once-a-month sampling on the 324 Building Hot Cell Project), and modest decreases in the number of strontium and other transuranic (americium and curium) analyses. The number of plutonium-urine analyses

(a) The numbers of samples requested, measurements not obtained, and measurements performed are not expected to balance because many samples receive multiple measurements.

Table 2.5. Worker Excreta Measurements Reported for 1993 Samples

Type/Reason	DOE	KEH	PNL	WHC	OTHER	TOTAL
³ H-urine						
Routine schedule ^(a)	0	108	527	9	0	644
Special request ^(b)	0	6	0	4	0	10
⁹⁰ Sr-urine						
Routine schedule	30	260	19	919	20	1248
Special request	0	8	1	5	0	14
Uranium-urine						
Routine schedule	52	143	163	2842	48	3248
Special request	0	5	6	78	0	89
Plutonium-urine						
Routine schedule	24	456	208	2217	47	2952
Special request	0	22	12	72	0	106
Other TRU-urine						
Routine schedule	0	0	17	11	0	28
Special request	0	0	1	5	0	6
Plutonium-fecal						
Routine schedule	0	0	0	3	0	3
Special request	0	0	0	36	0	36
Analyses Totals	106	1008	954	6201	115	8384
Recounts or Reanalysis						
Plutonium - urine	0	14	6	16	0	36
⁹⁰ Sr - urine	0	4	0	0	0	4
³ H - urine	0	0	0	0	0	0
Uranium - urine	0	4	0	25	0	29

(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 include those with reason codes of special (SP), recount (R1 or R2) and reanalysis (RA or RB).

remained essentially the same. Overall, there was a 5.7% increase over 1992 in the total number of measurements.

In addition, a total of 2056 excreta sample analysis requests were designated as no-result samples for 1993. Unsuccessful sample collections (their associated no-result code and percentage of the total no-results) were attributed to the following causes: kit not delivered (ND, 3%), no sample received (NS, 19%), lost container (LC, 55%), insufficient sample volume (IS, 16%), and lost in lab (LL, 7%).

S9406040.1

Figure 2.2. Routine Urine Measurements Made from 1988 Through 1993

The unsuccessful-sample retrieval rate of 23% for 1993 was slightly lower than the rate for the preceding year (28%). The high 1992 unsuccessful-sample rate was attributed to the startup of the new permanent analytical support laboratory. A decrease in the unsuccessful-sample rate, therefore, was expected.

2.2.2 Potential Intake Evaluations

Investigations of possible radionuclide intakes are performed following an indication from a routinely scheduled bioassay measurement or for a potential exposure incident identified in the workplace. Potential exposure incidents are identified by workplace indicators such as air sampling, contamination surveys, nasal smears, or smears from potentially contaminated wounds. Special-request bioassay measurements are also performed at the request of workers through the contractor dosimetry group.

During FY 1993, 18 incidents with the potential for intake, involving 51 workers, were identified through workplace monitoring. Of these workers, no confirmation of intake was determined for 34 workers, and intakes were confirmed for 17 workers. The highest calculated dose for the 51 workers was 1500 mrem committed effective dose equivalent (CEDE). The radionuclides and groups involved included ^{137}Cs and/or ^{90}Sr (7 incidents with 16 workers), TRU (6 incidents with 22 workers), U (3 incidents with 5 workers), tritium (1 incident with 2 workers), and ^{228}Th (1 incident with 6 workers). Table 2.6 shows the incident breakdown by contractor, area, and facility. Trends for the last five years are included in Table 2.7.

Initial evaluations were issued for the following radionuclides or groups: TRU (51 cases), ^{137}Cs and/or ^{90}Sr (19 cases), U and/or ^{234}Th (46 cases), tritium (4 cases), and other radionuclides (9 cases). Of these, 96 cases received no occupational internal doses (i.e., no confirmation of any occupational intake), 10 cases received CEDEs less than 100 mrem, and 11 cases received CEDEs greater than 100 mrem. Table 2.8 shows internal dose evaluations for 1993 resulting from high routine-bioassay results (i.e., those not associated with known incidents or known potential-chronic-exposure situations, and exceeding the criteria for investigation).

Table 2.6. Summary of Potential Exposure Incidents During 1993

Facility		Custodian	Number of Incidents	Number of Workers	Worker Contractor	Principal Nuclide
Area	ID					
100B	B4-4	WHC	1	1	PNL	^{137}Cs
100K	100KE	WHC	1	1	WHC	^{137}Cs
100 N	105-N	WHC	2	10	WHC	^{137}Cs
200E	221-B	WHC	1	1	WHC	^{239}Pu
	241-C	WHC	1	1	KEH	^{90}Sr
	203-A	WHC	1	2	WHC	U-nat
200W	222-S	WHC	3	4	WHC	^{235}U , ^3H , ^{137}Cs
	224-S	WHC	1	2	WHC	U-nat
	234-5Z	WHC	3	19	WHC	^{239}Pu
300	324	PNL	1	2	PNL	^{137}Cs
	325	PNL	2	2	PNL, WHC	^{239}Pu
	327	PNL	1	6	PNL	^{238}Th
Total			18	51		

Table 2.7. Comparison of Potential Intakes By Reason Code, 1989-1993

	1989	1990	1991	1992	1993
Incident, Total	33	30	90	30	51
Confirmed					17
Unconfirmed					34
High Routine, Total	51	93	69	141	65 ^(a)
Confirmed					0
Unconfirmed					62
Contractor Request, Total	3	5	0	0	1
Confirmed					1
Unconfirmed					0
Chronic Exposure, Total	197	95	30	4	6
Confirmed					0
Unconfirmed					6
Pre-Hanford	---	---	---	20	3
Confirmed					3
Unconfirmed					0
Reevaluation	7	5	1	4	3 ^(b)
Confirmed					---
Unconfirmed					---
Total	291	228	130	190	129 ^(a,b)
Confirmed					21
Unconfirmed					96

(a) Three evaluations were assigned in 1993 but were not completed at the time of this compilation.

(b) Three reevaluations were assigned in 1993 but were not completed at the time of this compilation.

Table 2.8. Summary of Confirmed Intake Cases Identified Through the Routine Bioassay Program During 1993

Facility		Building Custodian	Number of Workers	Worker Contractor	Principal Nuclide	Reason
Area	ID					
	Non-Hanford		1	WHC	¹³¹ I	New hire
	Non-Hanford		1	WHC	²³⁹ Pu	New hire
	Non-Hanford		1	WHC	⁶⁰ Co	New hire
Total			3			

Workers who were identified as having potential chronic exposures to uranium or tritium were reviewed at the end of the year if any single sample result exceeded the monthly screening level. Dose assessments were issued only for those workers who then exceeded the chronic intake investigation level, defined as the result which could have indicated a potential first-year effective dose equivalent greater than 10 mrem, based on conservative assumptions. None of the chronic intake evaluations resulted in CEDEs in excess of 10 mrem.

The range of internal doses assigned to the Hanford work force in 1993 is summarized in Table 2.9.

Table 2.9. Range of Internal Doses Assigned to the Hanford Work Force in 1993

Dose (mrem)	Numbers of Workers				
	DOE	KEH	PNL	WHC	Total
CEDE (any year by 1993 evaluations)					
< 100	0	0	0	10	10 (3) ^(a)
100 - < 500	0	0	1	7	8
500 - < 2000	0	0	0	3	3
2000 - < 5000	0	0	0	0	0
≥ 5000	0	0	0	0	0

(a) Refers to assessed doses due to offsite exposures.

2.3 SUPPORTING STUDIES

Special studies and investigations conducted by the Hanford Internal Dosimetry Project are described in the following subsections.

2.3.1 Backup Excreta Bioassay Capability

As a contingency for the potential loss of emergency bioassay analytical capabilities at PNL's long-term analytical contractor, the IDP maintains a work agreement with the PNL Analytical Chemistry Laboratory (ACL) for maintenance of emergency bioassay capabilities to rapidly analyze urine samples for plutonium and radiostrontium. The ACL maintains a staff of three analysts trained on emergency plutonium and radiostrontium procedures, and participates in two drills per year on each emergency procedure. Participation in a drill consists of receipt, analysis, and verbal and written reporting of analytical results by ACL for one to three samples each for

plutonium and radiostrontium. The ACL met all performance expectations for the drills run in March and September of 1993.

2.3.2 Workgroup Bioassay Measurements

A Work Group Monitoring Report was drafted and submitted to the Hanford Personnel Dosimetry Advisory Committee (HPDAC) for review and comment. This letter report investigated the feasibility of operating a work group bioassay program at Hanford, addressing criteria for application of work group sampling and logistics for operation at Hanford. Work group monitoring was concluded to be a viable alternative to individual-specific monitoring for a limited number of workers at Hanford, but implementation will require a joint effort of the IDP staff and the Contractor dosimetry organizations. The HPDAC's comments were incorporated into the final report which will be published as a PNL report.

2.3.3 Independent Appraisal

In an effort to continuously improve the project, a team of three experts performed a requested appraisal of the IDP and the Whole Body Counting Project. The team was headed by Richard Toohey from Argonne National Laboratory and included Cinthia Bloom from EG&G at the Idaho National Engineering Laboratory, and Gerald (Ged) Payne from Oak Ridge National Laboratory. The purpose of the team was to assess the capabilities and performance of the projects versus the DOE and *Hanford Site Radiological Control Manual* (RL 1992), applicable DOE orders, draft ANSI N13.30 (ANSI 1993), the draft DOE Implementation Guide 4.1X (DOE 1993), the *Hanford Internal Dosimetry Project Manual*,^(a) and accepted good practices.

Many findings and recommendations were made, most of which could be summarized as a need to upgrade the quality assurance (QA) aspects of our respective projects. A summary of the findings and recommendations and the programmatic responses to the findings was compiled and distributed to RL and contractor dosimetry representatives.^(b)

2.3.4 Internal Exposure Incident Response Plan

The "Implementation Guide for Use with Title 10, Code of Federal Regulations, Part 835, Internal Dosimetry Program" (DOE 1993) recommends that facilities should have an action plan for medical response to any potential or accidental intake of radioactive material. This plan "should be developed as a cooperative effort between medical and radiation protection organizations...." In anticipation of imminent release of the regulation, the IDP led the task to produce the "Hanford Internal Incident Response Plan." The plan discussed actions taken by

(a) Internal manual, PNL-MA-562, Pacific Northwest Laboratory, Richland, Washington.

(b) Bihl, DE and TP Lynch. 1993. "Appraisal of Internal Dosimetry and Whole Body Programs." Available in the Radiation Protection Historical Files, Pacific Northwest Laboratory, Richland, Washington.

various groups at Hanford in response to an incident with potential for an intake of radioactive material. The plan addressed responsibilities of the various groups, action levels to initiate response, types of bioassay measurements to be obtained, guidelines on what CEDE can be determined at various times after the potential intake, and action levels for consideration of medical treatment. Review and concurrence to the plan were obtained from WHC Health Physics, WHC Fire Department, PNL Radiation Protection, HEHF Occupational Medicine, PNL Personnel Dosimetry, and RL Occupational Safety Programs. The plan was included as Appendix E in the *Hanford Internal Dosimetry Project Manual*, revision 1.

2.4 PROGRAM-RELATED PROFESSIONAL ACTIVITIES

IDP staff presentations, publications, and professional memberships during 1993 are listed in this section.

2.4.1 Presentations

MacLellan, J. A. 1993. "Identification of Environmentally Derived ^{137}Cs Burdens in a Worker Population." PNL-SA-23481-A. Presented at the Health Physics Society Midyear Topical Symposium, January 25-27, 1993, Coeur d'Alene, Idaho. Paper was published in the proceedings.

Carbaugh, E. H., and D. E. Bihl. 1993. "Bioassay Criteria for Environmental Restoration Workers." PNL-SA-21011. Presented at the Health Physics Society Midyear Topical Symposium, January 25-27, 1993, Coeur d'Alene, Idaho. Paper was published in the proceedings.

Strom, D. J., J. H. Selby, E. H. Carbaugh, M. M. Lardy, and T. P. Lynch. 1993. "Internal Dosimetry Monitoring Equipment - Present and Future." PNL-SA-22263. Oral presentation at the Workshop on Intake of Radionuclides, September 13-17, 1993, in Bath, United Kingdom. The paper will be published in the workshop proceedings.

2.4.2 Publications

Bihl, D. E., R. L. Buschbom, and M. J. Sula. 1993. "Experience with a Routine Fecal Sampling Program for Plutonium Workers." *Health Physics* 65(5):550-555.

2.4.3 Professional Memberships

Bihl, D. E. Chair of a new ANSI Standards Committee on internal dosimetry programs. The committee had not received the official ANSI number by the end of the year.

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

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

3.0 HANFORD IN VIVO MEASUREMENT PROJECT

The Hanford In Vivo Measurement Project, which provides the ability to detect radioactive materials in Hanford employees, has been an integral part of personnel dosimetry at Hanford since 1959. Project requirements are outlined in the *Hanford Site Services Handbook*.^(a) The In Vivo Measurement Project provides for the management, operation, and maintenance of the in vivo counting facilities and equipment located in the 747-A Building, the 747-A Trailer, a mobile in vivo counting facility, and the Emergency Decontamination Facility (EDF). The facilities are collectively known as the In Vivo Radioassay and Research Facility (IVRRF). The routinely used measurement facilities, located in the 747-A Building, include the Preview Counter (used for rapid standup-screening, whole-body measurements); the Iron Room and Stainless Steel Room (each containing germanium lung counting systems); and the Palmer Room (containing the coaxial germanium detector system). Operating hours are currently from 7:30 a.m. to 4:00 p.m. on weekdays. For special requests, 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 during off-hours.

Worker data and results of measurements are transmitted to the REX system database for permanent record. Daily operational and functional checks are performed on all routinely used counting systems, which are also periodically calibrated to ensure accuracy in personnel measurements. The program participates in intercomparison programs to further improve the quality of operations. The activities of the in vivo measurement program, including program changes, special studies and development work performed during 1993 are described in this chapter.

3.1 THE ROUTINE PROJECT

Activities of the routine in vivo measurement program included making in vivo measurements, preparing for DOE accreditation, completing requirements as detailed in the new *Hanford Site Radiological Control Manual* (RL 1992), and upgrading equipment and procedures used in the performance of routine in vivo measurements.

3.1.1 Routine In Vivo Measurements

Numerous types of routine in vivo measurements are made on personnel at the Hanford Site. The frequency of these measurements for occupational workers is determined by the DOE requirements or limits for radiation exposure. The frequency of measurements for personnel is

(a) U.S. Department of Energy Richland Operations Office (RL), 1993, RL 1400.1A, Richland, Washington (available online in HanInfo).

determined by the contractor internal dosimetry representatives. Hanford Environmental Health Foundation (HEHF) schedules the required measurements with the IVRRF using a new computerized Hanford Health Scheduling (HHS) system. The type of measurement is determined by the radionuclide that is encountered where the individual is employed at the Hanford Site and/or the location in the body of a potential intake. Generally, if an employee does not work in areas where uranium or TRU radionuclides are located, a whole-body count (WBC) is performed on the preview standup counter to detect the higher-energy gamma rays emitted by fission products or activation products. If the work involves TRU radionuclides or insoluble uranium isotopes, both lung and whole-body counts are completed. Figure 3.1 depicts the normal configuration for the 6-detector lung counting system used at the IVRRF. If radioactivity is detected by either of these measurements, several other types of counts may be done to verify the activity in the body and to provide more accurate quantification of the radionuclide.

Figure 3.1. Lung Monitoring System Used at IVRRF for the Detection of TRU Radionuclides and Uranium

All of the routine counting systems are interfaced to multichannel analyzers (MCAs) resident on two Digital Equipment Corporation (DEC) Model 3100 workstations. The workstations are interfaced to the Hewlett Packard (HP) 9000 computer. Computer codes developed at PNL are used to evaluate each spectra result collected with 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. Additionally, PNL software was written for these workstations to back up the routine calculation codes on the HP 9000.

3.1.2 Remote Counter

The trailer housing the remotely operated in vivo counter is located in the 200 East area. The primary function of the remote counter is to facilitate WBCs for workers in the 200 areas, thus reducing the amount of time required if the testing were conducted in Richland. The remote counter is a stand-up multi-detector NaI(Tl) counting system, connected to an IBM Model 25 in the trailer. This equipment is interfaced with the main facility at the 747-A Building via telephone modem. Technicians in 747-A remotely control the operation of the counting system without having to physically be present at the remote location. During remote measurements, continuous audio and visual communications are maintained with the subjects in the trailer. Visual images are transmitted to 747-A via a photophone system, while a dedicated phone line between the trailer and 747-A provides audio communications. Personnel from WHC are trained to assist in the setup for the performance tests conducted before the system is used. This eliminates the need for IVRRF staff to travel to and from the counter for routine operations. In 1993 a total of 481 remote counter measurements were made, an increase of 300% over 1992.

3.1.3 Number of Measurements Performed

The total number and type of measurements made on personnel during 1993 are given in Table 3.1. In 1993, according to REX, a total of 14,277 measurements were made for RL and the Hanford contractors representing a 7.4% decrease from the number performed in 1992. The new REX database was fully on line for the first time this year, and queries of this database for the annual totals were performed. This decrease represents several changes to the internal dosimetry and in vivo measurements programs. Specifically, improvements in the false positive rate requiring re-counts of personnel, and reductions in the total personnel requiring chest and whole body counts were made. Figure 3.2 depicts the in vivo measurements made at the IVRRF during the past six years.

Table 3.1. In Vivo Measurements Performed During 1993 and Recorded in the REX Database

Type/Reasons	BCSR	DOE	HEHF	KEH	PNL	WHC	Total
Whole-Body Count							
Routine schedule	137	179	38	1,550	1,823	7,051	10,778
Special request	0	0	0	2	12	19	33
Contractor request	1	376	0	0	42	171	590
TOTAL	138	555	38	1,552	1,877	7,241	11,401
Chest Count							
Routine schedule	33	18	1	603	331	1,774	2,760
Special request	0	0	0	3	21	54	78
Contractor request	0	0	0	0	0	0	0
TOTAL	33	18	1	606	352	1,828	2,838
Other							
Head	0	0	0	0	7	17	24
Hand/wound	0	0	0	2	2	3	7
Thyroid	0	0	0	0	2	0	2
Other	0	0	0	0	0	5	5
TOTAL	0	0	0	2	11	25	38
GRAND TOTAL	171	573	39	2,160	2,240	9,094	14,277

Figure 3.2. In Vivo Measurements Made at the IVRRF from 1988 Through 1993

3.1.4 Preparation for DOELAP Accreditation

One of the major areas of emphasis in the routine monitoring program is preparation for the DOE Laboratory Accreditation Program (DOELAP), as specified in the draft standard, ANSI N13.30, "Performance Criteria for Radiobioassay." This standard sets forth the requirements for accreditation of bioassay laboratories, based on performance criteria and program quality measures. Planning for this accreditation requires upgrading several areas of the routine program operations.

A third-party programmatic evaluation of the IVRRF was completed this year by a team of bioassay specialists headed by Dr. Richard Toohey of Argonne National Laboratory. The goal of this appraisal was to assess the capabilities and performance of the IVRRF and the Internal Dosimetry Program in accordance with applicable DOE Orders, consensus standards, and other guidance documents. Much of the audit focused on improvements in QA and QC, in particular as they pertained to recordkeeping. The results of this audit were incorporated into the IVRRF

Strategic Plan developed during 1993. The findings were reported to the IVRRF in the May 1993 appraisal of the IDP.^(a)

The drafting of detailed procedures for all IVRRF activities was initiated in 1993 and the work will be completed in 1994. A QA plan was written as the basis for evaluating the program for DOELAP accreditation. Part of this QA plan involves the collection and retention of performance measures used to track the program capabilities. In 1993, the IVRRF began tracking mean blank value data for each counting system. The mean blank value statistic is used to ensure that the background or blank counting rates estimated for each radionuclide and counting system are not significantly different from zero. A second statistic now being tracked is the false positive rate for each counting system. This ensures that the false positive rate for IVRRF measurements is not significantly different from 5%, as defined in the In Vivo Bioassay SOW.^(b)

The first pilot testing of the DOELAP by the Radiological and Environmental Sciences Laboratory (RESL) at Idaho Falls, Idaho, was completed this year when the RESL sent two BOMAB calibration phantoms with unknown radionuclides and amounts to the IVRRF for quantification. Even though these phantoms did not use a solid tissue-equivalent fill material and the gel-based filler leaked from the bottles, the results that were transmitted to the RESL were correct within 5%. The DOELAP pilot testing for chest and thyroid measurements will be conducted in 1994 in preparation for actual DOELAP accreditation.

3.1.5 Program Change Requests for 1993

No Program Change Requests for the IVRRF were initiated or completed in 1993.

3.1.6 Program Changes Due to the *Hanford Site Radiological Control Manual*

The implementation of the new *Hanford Site Radiological Control Manual* (RL 1992) resulted in minimal changes to the routine counting program. Many required changes had already been completed in previous years, anticipating the change to committed dose, and the concurrent increase in monitoring of Hanford personnel. Thus, IVRRF staff had already adapted to the increased load of in vivo measurements performed at the facility.

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- (a) Toohey, R. E., C. W. Bloom, and G. F. Payne. 1993. "Appraisal of Internal Dosimetry Program at Battelle Pacific Northwest Laboratories (PNL)." May 3-7, 1993. Unpublished report.
 - (b) Lynch, T.P., J.A. MacLellan, and D.E. Bihl. 1992. "In Vivo Bioassay Statement of Work." Copy available in the Hanford Radiation Protection Historical Files.

Some new program changes were forthcoming in 1993, however. These included the following:

- New training documentation was developed, including a training matrix for technician training for all routine IVRRF duties and detailed procedures and flow-charts for the evaluation of training adequacy.
- A new Quality Assurance Plan was written.^(a)
- A new ultrasound measurements training program and procedure development task was completed. This closed out a RL audit finding in 1992 of inadequate documentation and training when performing ultrasonic determinations of chest wall thickness.
- Tracking of "no shows" (scheduled individuals not showing up for their counts) was initiated this year, as required by 10 CFR 835. The results of this tracking program indicated an 8% no-show rate for termination in vivo counts scheduled in the fourth quarter of 1993.

3.2 UPGRADES OR IMPROVEMENTS TO IN VIVO MEASUREMENTS PROJECT

Several additions and improvements were made to equipment, facilities, and procedures for the In Vivo Measurement Project in 1993. These changes are described in the following subsections.

3.2.1 New Database Computer and Software for IVRRF Operations

A new database and IVRRF operations client/server computer was installed in 1993. The computer is an IBM RISC System/6000 model 560 database server, and will be used at the IVRRF for all data storage and support for IVRRF operations. The New WBC system software (NEXEC) will reside on this computer when it is completed. The NEXEC design project is progressing concurrently with the development of the IBM database server. Figure 3.3 depicts the organizational flow of in vivo measurement data that will be controlled using NEXEC.

In 1993, much of the work for the software upgrade to NEXEC was completed. Project management plans were developed and preliminary and detailed design of the software was completed. The computer screens were also designed and have been modified to the needs of IVRRF technical staff. Software design has also been completed for the VAX workstations and the personal computers that will replace them. Current work includes building the database dictionary, designing the data model, writing the VAX computer code, and building the screens. The project is scheduled to be completed during 1994.

(a) Internal manual, PNL QA Plan No. LSC-021 Rev. 0, Pacific Northwest Laboratory, Richland, Washington.

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Figure 3.3. Flow Diagram of In Vivo Data at IVRRF Using New NEXEC Software

3.2.2 New Princeton Gamma Technology Large Area Detectors

A set of four large-area planar germanium detectors was purchased this year from Princeton Gamma Technology (PGT) for a new, more sensitive chest counting array. These detectors are almost twice as large (3800 mm² vs 2000 mm²) as the current detector arrays in use at Hanford. They have passed acceptance testing and are now being installed in the Stainless Steel Room of the 747-A Building to replace the older six-detector chest counting system located there. The efficiency of four of these detectors is equal to or better than the current six-detector systems at the IVRRF. For a 3.2-cm chest wall thickness, the new array results in a calibration factor of 9.42 cpm/nCi while the 2000-mm² array results in a 9.00 cpm/nCi calibration factor. A second benefit of the new system is lower maintenance and downtime from detector malfunctions.

3.2.3 Upgraded Efficiency Equation for Coaxial Germanium System

A study of the efficiency calibration of the coaxial germanium scanning bed detector array was completed this year. This study showed that the current method of determining net counts in certain peak areas of the spectrum was incorrect and resulted in an efficiency equation that did not reflect the true capabilities of the array. Using newly-procured spectral analysis software

from EG&G Atlanta^(a) (GDR/P), calibration measurements of all of the DOE Phantom Library BOMAB phantoms were analyzed. New efficiency points incorporating counting, emission yield, and activity errors were developed. A new calibration curve consisting of two separate equations was fit to the data points. The new calibration equation set is:

Low Energy Region (87 - 250 keV):

$$Y = -1.097E-3 + 2.813E-5X - 1.129E-7X^2 + 1.427E-10X^3$$

High Energy Region (250 - 2700 keV):

$$Y = -2.7175E-4 \ln(X) + 2.6355E-3$$

Figure 3.4 displays a graph of this calibration curve.

Figure 3.4. Efficiency Calibration Curve of IVRRF Coaxial Germanium Array

(a) EG&G Ortec, Marietta, Georgia 30067.

3.2.4 High-Energy BOMAB Calibration Phantom

A whole-body calibration phantom was produced for the routine counting program at the IVRRF this year. Utilizing ^{88}Y , a high-energy gamma emitter, and ^{152}Eu , the energy calibration of the coaxial germanium scanning system was extended to 2.7 MeV. This full-size reference-male phantom is now used for routine calibrations and is loaned out to other DOE facilities for calibration purposes. The phantom was fabricated by IVRRF personnel in the Phantom Development Laboratory located in the 300 Area.

3.2.5 New Hanford Health Scheduling System

A new method of scheduling routine in vivo counts of Hanford personnel was instituted this year. Known as the Hanford Health Scheduling (HHS) system, this medical scheduling system operated by HEHF incorporates the IVRRF scheduling of workers, and sends a daily schedule of appointments to the WBC program staff. The HHS download outputs the personnel information necessary for a routine count to a standard form which is used to enter results data into the REX system. This change reduces the errors and incorrect information sometimes submitted by personnel on the previous blank forms.

3.2.6 ^{90}Y Lung Calibration

Pacific Northwest Laboratory is currently performing research using substantial quantities of ^{90}Y . An internal dosimetry evaluation of this material determined that due to its short half-life and the biokinetics of yttrium there was a need to have in vivo measurement capability of ^{90}Y . In an accident scenario, only in vivo bioassay could be used to determine doses to the individual. Because ^{90}Y is a pure beta-emitter, the detection of the radionuclide must be based on bremsstrahlung emissions due to interactions of the beta particle in the body. The IVRRF fabricated a set of ^{90}Y calibration lungs using NIST standard reference radionuclides. This calibration lung set was then used with a PNL torso phantom, and a chest-counting calibration was developed for ^{90}Y deposition in the lung.

3.2.7 Rocky Flats Worker Measurements

As part of an intercomparison of in vivo measurement capabilities, five Rocky Flats nuclear workers were evaluated here at the IVRRF. This intercomparison was prompted by worker concerns about the quality of the measurement data obtained at Rocky Flats. Four known positive ^{241}Am cases and one unknown blank were included in the study. The results were consistent with past Hanford cases and the information will be sent to the study sponsors in early 1994.

3.3 SUPPORTING PROGRAMS AND STUDIES AT IVRRF

The following programs and studies were conducted by the In Vivo Measurement Project or the staff at the IVRRF in 1993.

3.3.1 DOE Phantom Library

The official operation of the DOE Phantom Library began in 1993. This program, supported by DOE-HQ and operated by personnel at the IVRRF, loans high quality calibration phantoms to U.S. bioassay laboratories for calibration of in vivo measurement systems. The loans are made to DOE laboratories and other government agencies at no cost other than the shipping costs. The official announcement of the library was made in May by DOE-HQ in the *Health Physics Newsletter*.

There were 21 loans of phantoms to other facilities in 1993, representing an 85% increase over the previous year. The inventory of the library was increased by the addition of two BOMAB phantoms, two lung sets, two lymph node phantoms, and a liver phantom. The total inventory of the phantom library currently stands at seven whole body phantoms, one torso (chest) phantom, 21 lung sets, five liver phantoms, and two lymph node phantoms.

3.3.2 Child BOMAB Phantom Intercomparison

A four-year-old-child BOMAB phantom was measured at the IVRRF as part of a joint U.S./Canadian intercomparison study of in vivo bioassay laboratories. The results of the measurements indicated that the IVRRF could determine the activity of ^{137}Cs in children within 20% of the known activity, without having to develop a separate calibration for the much smaller size. Calibration of both ^{137}Cs and ^{88}Y radionuclides were performed from the phantom results to improve the performance of in vivo measurements for children to within $\pm 5\%$. The BOMAB phantom had been fabricated here at PNL as part of the DOE-HQ DOELAP program.

3.3.3 U.S. Transuranium Registry Support

Collaboration with the Washington State University (WSU) United States Transuranium/Uranium Registries (USTR/USUR) was continued in 1993. Measurements of a thorotrast cadaver were completed as part of an in-depth study into retention and distribution of the ^{232}Th , ^{230}Th , and ^{228}Th radionuclides in the body. Other measurements were performed on USTR/USUR registered donors in 1993 as part of the ongoing agreement with WSU.

3.3.4 Calibration Intercomparisons

The IVRRF participated in a calibration intercomparison program sponsored by Oak Ridge National Laboratory during 1993. This quarterly evaluation program is designed to allow participants to perform measurements of radioactivity in bottles in a block phantom and

intercompare the accuracy and precision of these on a quarterly basis with other in vivo bioassay facilities. The IVRRF results for 1993 are shown in Figure 3.5. These results indicate that the IVRRF can repeatedly measure unknown quantities of high-energy fission and activation products in the block phantom with an average bias of <3.5%. Figure 3.5 presents the IVRRF performance for bias over the 1993 quarterly testing program.

Quarter	Isotope	Actual	Measured	% Bias
Quarter 1	^{60}Co	174.7 ± 8.7	165.0 ± 18.2	-5.6%
	^{137}Cs	89.0 ± 4.5	89.5 ± 9.9	0.6%
Quarter 2	^{60}Co	18.3 ± 0.9	17.9 ± 2.0	-2.2%
	^{137}Cs	28.0 ± 1.4	28.9 ± 3.2	3.2%
Quarter 3	^{60}Co	65.1 ± 7.3	66.2 ± 7.3	1.7%
	^{137}Cs	42.6 ± 2.1	40.3 ± 4.4	-5.4%
Quarter 4	^{60}Co	106.3 ± 5.3	101.0 ± 11.1	-5.0%
	^{137}Cs	150.3 ± 7.5	155.0 ± 17.1	3.2%

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Figure 3.5. Bias Results of the IVRRF Participation in the ORNL Intercomparison Study

When the IVRRF was compared to other national in vivo bioassay laboratories, the results for 1993 indicated that the precision of the facility was as good or better than any other laboratory involved in the program. Figure 3.6 depicts the performance of the IVRRF when compared to other in vivo bioassay laboratories. The program will continue to participate in this and other intercomparison studies in the future.

Figure 3.6. ORNL Intercomparison Performance Study Results for 1993
(Note: IVRRF is indicated by letter I)

3.4 PROGRAM-RELATED PROFESSIONAL ACTIVITIES

Staff presentations, publications, and professional memberships during 1993 are listed in this section.

3.4.1 Presentations

Lynch, T. P., J. C. McDonald, and R. M. Loesch (USDOE EH-411). "The Department of Energy Phantom Library Loan Program." Presented at the 38th Annual Health Physics Society Meeting, July 13, 1993, Atlanta, Georgia.

Olsen, P. C., T. P. Lynch, J. C. McDonald, and R. M. Loesch (USDOE EH-411). "The DOE Phantom Library Program." PNL-SA-22145-A. Presented at the USDOE Radiation Protection Workshop, March 1993, Las Vegas, Nevada. The paper will be published in the proceedings.

Selby, J. M., M. M. Lardy, E. H. Carbaugh, T. P. Lynch, and D. J. Strom. "Internal Dosimetry Monitoring Equipment, Present and Future." PNL-SA-22263. Presented at the Workshop on Intakes of Radionuclides, September 1993, in Bath, United Kingdom.

3.4.2 Publications

Olsen, P. C., and D. E. Bihl. 1993. *Hanford Internal Contamination Incidence Response Plan*. Chapter in *Hanford Internal Dosimetry Program Manual*. PNL-7001, Pacific Northwest Laboratory, Richland, Washington.

Hui, T. E., L. L. Nichols, P. C. Olsen, and J. C. McDonald. 1993. "Measurement of Activity in Anthropomorphic Organ Phantoms." *Health Physics* 64(3):311-317.

3.4.3 Professional Memberships

Lynch, T. P. Chairman of ANSI N13.35 Working Group, which is writing the ANSI Standard *BOMAB Calibration Phantoms*.

Lynch, T. P. Member of ASTM Task Group E-10.04.27, which is writing the standard *Estimation of Low Energy Photon Emitters in a Wound*.

Olsen, P. C. Member of ANSI N13.35 Working Group, which is writing the ANSI Standard *BOMAB Calibration Phantoms*.

4.0 HANFORD EXTERNAL DOSIMETRY PROJECT

The Hanford External Dosimetry Project is a multifaceted effort involving all Hanford contractors. Dose-of-record information from external radiation for Hanford personnel is provided by this program in compliance with the requirements of DOE as set forth in the *Hanford Site Radiological Control Manual* (RL 1992), DOE 5480.11 (1988a), and DOE 5480.15 (1987). Project dosimeter results provide the means used by contractor personnel to project, control and measure radiation doses received by workers. Project staff also provide site-wide nuclear accident dosimetry in compliance with DOE 5480.11 requirements and environmental dosimetry in support of PNL and WHC Environmental Surveillance Programs.

4.1 EXTERNAL PERFORMANCE TESTING EVALUATIONS

Three external reviews of the Hanford External Dosimetry Project were conducted during 1993 as discussed in the following sections.

4.1.1 DOELAP ACCREDITATION

The RL operations office communicated receipt of the DOE Laboratory Accreditation Program (DOELAP) Certificate of Accreditation to the Director of PNL on November 17, 1993. Hanford Contractors were formally notified during the HPDAC meeting^(a) of December 15, 1993. This certificate recognized the program's successful completion of the DOELAP performance testing and onsite technical appraisal required by DOE 5480.15 (1987). Program accreditation is effective until November 1, 1995.

Three concerns, one deficiency, and five observations were noted during the DOELAP onsite technical appraisal on June 15-16, 1993. A formal program response was required for the one deficiency and each of the concerns. This was completed during July, 1993, with the adoption of program practices and documentation which addressed all of the issues. None of the issues questioned the quality of Hanford personnel dose estimates, but were directed at improving quality assurance documentation, training, and security of the Hanford External Dosimetry system. Table 4.1 summarizes the results of the DOELAP onsite appraisal. No routine program practices were changed; however, one new practice was adopted as follows:

(a) Fix, J.J. 1993. "Minutes of Hanford Personnel Dosimetry Advisory Committee Meeting on December 15, 1993." Letter to Distribution, dated December 17, 1993. Copy in the Hanford Radiation Protection Historical Files, Pacific Northwest Laboratory, Richland, Washington.

Table 4.1. Summary of DOELAP Onsite Technical Appraisal

DOELAP Category	Description
Personnel	<p><u>Observation #1.</u> The entire staff including administrative, technician, and professional demonstrated a commitment to the dosimetry program. They were enthusiastic about their program and their individual responsibilities. Their cooperation contributed to the effectiveness of the assessment.</p> <p><u>Observation #2.</u> The PNL <i>Quality Assurance Manual</i>, volume 1 states that competency reviews shall be performed every two years. This does not agree with the DOELAP requirement that they be performed annually. This was not considered a concern because of the limited turnover of the dosimetry staff; however, the manual should be revised to reflect the annual review requirement. This requirement will be included in the CY 1994 revised QA manual.</p> <p><u>Concern #1.</u> The job description outlined in the External Dosimetry Training Records for the Technical Leader of the External Dosimetry Group does not include a prime responsibility listed in the <i>Quality Assurance Manual</i>, volume 1 (i.e., identifying training requirements for the External Dosimetry Group's staff). Satisfied by letter to file dated June 17, 1993.</p>
Equipment and Facilities	<p><u>Observation #3.</u> No posting or procedural restrictions were identified to restrict annealing only for dosimeters. This observation was initially a concern, but because this item was corrected during the assessment, no written response is required.</p> <p><u>Observation #4.</u> Backup equipment is maintained in a separate room from the primary processing area; however, the reader should be moved to a different area to preclude the loss of all processing equipment in the event of a major disaster. This will be satisfied upon implementation of commercial dosimetry system.</p>
Quality Assurance	<p><u>Concern #2.</u> There is a notable lack of formality in the Dosimetry Quality Assurance Program consistent with the requirements of DOE Order 5700.6C. Examples include the absence of adequate document and records control procedures, no independent internal audit program, no clear means of identifying training on procedural revisions because the procedures do not contain revision numbers, no QA review of procedures (organizational). The elements of a QA program exist and represent the highest technical excellence with a notable absence of complimentary formality. Actions are underway during 1994 to resolve this concern.</p> <p><u>Concern #3.</u> The assessors believe that the Dosimetry Program should be classified as an Impact Level 2. The current classification (Level 3) does not support a graded approach to the implementation of 5700.6C; rather, it discourages the need for necessary Quality Assurance Program formality. Actions are underway during 1994 to resolve this concern.</p>

Table 4.1. (continued)

DOELAP Category	Description
Equipment Maintenance and Calibration	<u>Deficiency #1.</u> Dosimetry processing areas are not routinely surveyed for contamination. No historical documentation was available for review. No procedure is in place establishing contamination control requirements. The finding has been identified as a deficiency because the same finding was identified during the last DOELAP assessment (December 12-14, 1989). Prior to the assessment close-out briefing, the External Dosimetry organization facilitated a radiological survey of all processing areas. No detectable contamination was identified and the results were documented and filed. Satisfied by program change effective August 1, 1993, to maintain all survey records in project files.
Processing Procedures	Nothing noted.
Dosimeters	<u>Observation #5.</u> A notable practice was identified in that the dosimetry processing technicians independently developed a color-coded dosimeter posting/tracking system.
Reports and Recordkeeping	Nothing noted.

- Effective August 1, 1993, records of radiological surveys of External Dosimetry Project processing and dosimeter exchange laboratory facilities will be maintained in the project files.

This change was considered necessary to assure satisfaction of the one deficiency noted in which radiological surveys were being conducted, but not properly documented.

4.1.2 Westinghouse Hanford Company Blind Audit Dosimeters

Westinghouse Hanford Company routinely submits several audit dosimeters to be processed along with their personnel dosimeters. The PNL External Dosimetry Project successfully passed each monthly blind audit dosimeter evaluation conducted by WHC during 1993. The program also passed each of the quarterly evaluations conducted by WHC using the DOELAP methodology and criteria. During the entire year, no personnel dosimeter results exceeded established tolerance limits for the DOELAP accredited testing categories. The results of these audits are provided by WHC to the Hanford Radiation Protection Historical Files.

4.1.3 Tenth International Environmental Dosimeter Intercomparison Test

Pacific Northwest Laboratory participated in the 10th International Environmental Dosimeter Intercomparison Study during 1993. This study involved over 100 laboratories throughout the world. Table 4.2 summarizes the performance of Hanford in this study. Hanford's performance is acceptable although the cause of the apparent negative bias is being examined. Performance testing covered a period equivalent to a routine quarterly exchange as used at Hanford. The relative performance of Hanford compares favorably with the other laboratories involved in the study.

Table 4.2. Hanford Performance in 10th International Environmental Dosimeter Intercomparison Study (units in mrem)

Description	Given Dose	Reported Dose	Percent Error
Field Test	23.7	23.6	-0.4
Low Dose	22.7	21.2	-6.6
High Dose	63.7	59.5	-6.6

4.3 ROUTINE TASKS

During 1994, PNL reported 94,103 official personnel dose results. This is an increase of approximately 5% from the previous year's total of 90,302 and maintains the continued increase observed during recent years. This is illustrated in Figure 4.1 for the last five years.

The total dosimeters processed amounted to 214,422. This total vastly exceeds the 94,103 official dose results reported because of QC practices used to ensure the accuracy of the reported personnel dose as follows:

- processing a minimum of two QC dosimeters with every 50 personnel dosimeters and every 25 dosimeters when determining chip sensitivity factors
- reprocessing, prior to issue, any personnel dosimeter which has been stored more than 75 days to minimize environmental dose buildup
- reprocessing any dosimeter with an observed reader count greater than 650 counts in any dosimeter position

Figure 4.1. Trend in Reported Hanford Personnel Dosimeter Results

- conducting acceptance testing of new dosimeter inserts and holders
- updating chip sensitivity factors for dosimeters (i.e., requires two processings: before irradiation and after).

Each year numerous internal audit dosimeters are processed to ensure the integrity of dosimeter processing. During 1993, a total of 2190 internal audit dosimeters were processed. A breakdown of the internal audit dosimeters is shown in Table 4.3. Control charts are utilized 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 (e.g., every month plus annual) conducted each year as described in the report *Quality Control Program for the Hanford External Dosimetry Thermoluminescent Processing System* (Baumgartner et al. 1992). A QC 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. Three changes in routine program practices occurred during 1993 as discussed in the following sections.

Table 4.3. Number of Audit Dosimeters Processed During 1993

Dosimeter	Dose Category ^(a)			
	Shallow	Deep	Deep Neutron	Blank
Basic	N/A	400	N/A	180
Beta/Photon	130	64	N/A	N/A
Multipurpose	419	498	549	686
Rings	N/A	330	N/A	N/A

(a) N/A = Not applicable.

4.3.1 Hanford Practice for Reporting Dosimeters in Excess of Administrative Dose Control Levels

At the October 20, 1993, meeting^(a) of the Hanford Personnel Dosimetry Advisory Committee, it was agreed that External Dosimetry Project codes would be changed to automatically flag doses for reporting which exceed any of the following values:

Dose Component	Dose Threshold(mrem)	
	Previous Limit	New Limit
Shallow	2000	2000
Eye	n/a	1000
Deep	1000	500
Neutron	200	200
Whole Body (deep + neutron)	n/a	500
Extremity	3000	3000

(a) Bihl, D. E. 1993. "Minutes of Hanford Personnel Dosimetry Advisory Committee Meeting on October 20, 1993." Letter to Distribution, dated October 26, 1993. Copy in the Hanford Radiation Protection Historical Files, Pacific Northwest Laboratory, Richland, Washington.

Dosimeter records where one or more of the dose components exceed these values will be identified as a "high dose" by External Dosimetry and be reported to the Hanford Radiological Records Project. The HRRP then reports the "high dose" to the applicable contractor. Changes from previous practices include lowering the deep dose to 500 mrem from 1000 mrem and introducing criteria for the eye and whole body dose components.

4.3.2 Hanford Practice for Assigning Multiple Dosimeters

At the September 15, 1993, meeting^(a) of the Hanford Personnel Dosimetry Advisory Committee, it was agreed the preferred Hanford practice would involve 1) processing the assigned compliance dosimeter, 2) assigning the multiple dosimeter packet, and 3) re-assigning a compliance dosimeter following the use of the multiple dosimeter packet. In this manner, there should be no confusion regarding the proper use of multiple dosimeters. This practice was preferred because 1) it would ensure there was a documented review of all cases where multiple dosimeters were assigned and 2) there is not an acceptable place to hold the compliance dosimeter in the work environment while the multiple dosimeter packet is worn. This practice would also eliminate any confusion by the worker as to which dosimeters should be worn.

4.3.3 Hanford Practice for Basic Dosimeter Lower Limit of Detection

In the past, the reporting threshold for Hanford doses did not utilize a reporting threshold based on the detection level of the dosimetry system. The recent practice to report all dosimeter doses regardless of level has resulted in false positive reporting of low doses to visitors. This occurs infrequently compared to the volume of dosimeters processed; however, substantial staff time has been spent validating these low doses. At the December 15, 1993, meeting of the Hanford Personnel Dosimetry Advisory Committee,^(b) it was agreed that a lower reporting threshold of 15 mrem would be implemented for the single-chip, basic dosimeter effective with the December monthly and 1993 year-end processings. This reporting threshold was determined by analyzing results for dosimeters assigned to visitors where no occupational dose was received. By comparison, the 15-mrem dose is approximately twice the calculated detection level for background control dosimeter inserts kept at the dosimetry processing laboratory with minimal potential for exposure to chemical contaminants (i.e., hand cream, perspiration, etc.) or light.

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- (a) Fix, J. J. 1993. "Minutes of Hanford Personnel Dosimetry Advisory Committee Meeting on September 15, 1993." Letter to Distribution, dated September 20, 1993. Copy in the Hanford Radiation Protection Historical Files, Pacific Northwest Laboratory, Richland, Washington.
 - (b) Fix, J. J. 1993. "Minutes of Hanford Personnel Dosimetry Advisory Committee Meeting on December 15, 1993." Letter to Distribution, dated December 17, 1993. Copy in the Hanford Radiation Protection Historical Files, Pacific Northwest Laboratory, Richland, Washington.

4.4 SUPPORTING EVALUATIONS

Several supporting studies were conducted during 1993 as described in the following sections.

4.4.1 New Hanford Thermoluminescent/Track-Etch Personnel Dosimetry System

Nearly all procured items of the new Hanford Thermoluminescent (TL)/Track-Etch (TE) Dosimetry system were received during 1993. The new TL dosimetry system consists of four Harshaw 8800 hot-gas reader systems, two Harshaw 6600 hot-gas reader systems, and approximately 80,000 personnel, environmental, and extremity dosimeters. The TE dosimetry system is being fabricated by PNL. Numerous studies have been conducted concerning the performance of this equipment including dose response, light sensitivity, readout protocol, etc. These studies will be completed during 1994 along with DOELAP performance testing. The scheduled implementation date for the new system is January 1, 1995.

4.4.2 Prototype Combination TL/TE Personnel Neutron Dosimeters

Efforts continued during 1993 to evaluate the performance of a Hanford prototype combination TL/TE personnel neutron dosimeter. These studies support development of the dose algorithm to be used with the new dosimetry system. This effort began during December 1990 when combination dosimeters were assigned to seven to ten personnel working in neutron field environments. Elements of this effort were discussed in previous annual reports (Lyon et al. 1992, 1993). Dosimeters were exchanged monthly for all employees. The results obtained during 1993 further confirmed previous results. The thermoluminescent dosimetry (TLD) system results continue to be significantly greater than the track-etch dosimetry (TED) system results. The work environment where these dosimeters are used contains extensive shielding resulting in highly-scattered neutron radiation; the majority of the neutrons have an energy level less than 150 keV. Data from field measurements conducted during 1991 should be used in the interpretation of this data (Brackenbush et al. 1991). For these work environments, the TL dosimeter overestimates the dose and the CR-39 dosimeter underestimates the dose.

4.4.3 Evaluation of Personnel Neutron Dose from an AmBe Neutron Source

A technical evaluation of the dose received and the accuracy of routine measurements during well logging operations was conducted. The Hanford Multipurpose Personnel Dosimeter (HMPD) and an AmBe neutron source were used. Several personnel involved in this work wore multiple dosimeter packets consisting of additional HMPDs located at various locations on the body. Along with each HMPD, two TE foils were also used. Four specific steps of the well-logging operation were evaluated as follows:

1. Removal and return of the AmBe source to the Source Storage Cask.
2. Attaching and detaching the source to the well-logging probe.

3. Recording personnel dose while transporting source stored in shipping cask.
4. Recording personnel dose while moving the source from the shipping cask to the well and return.

The following conclusions were made upon completing the technical evaluation:

1. The site-specific neutron calibration factor is not warranted for the AmBe source without special verification.
2. Time spent in step 3 is very long compared to the relatively short period of time conducting steps 1, 2 and 4.
3. Any significant personnel neutron dose will be detected by the HMPD because of the substantial shielding (dosimeter holder filters), resulting in lower energy-scattered neutrons which are involved in all steps.
4. Historically, the dose received by all employees involved in this operation, as measured by the HMPD, is less than 100 mrem per year.
5. Track-etch foil data confirmed that very little personnel dose occurred from this operation when normal procedures were used.

4.5 DOCUMENTATION

Documentation for the Hanford External Dosimetry Project is maintained in two formal manuals:

1. PNL-MA-568. *Hanford External Dosimetry Project*. Pacific Northwest Laboratory, Richland, Washington, 1992.
2. PNL-MA-583. *Location of Criticality Alarms and Nuclear Accident Dosimeters at Hanford*. Pacific Northwest Laboratory, Richland, Washington, 1992.

In addition to these documents, project staff maintain eight internal technical documents describing various aspects of the project:

Volume I, *Quality Assurance*, 1992, W. V. Baumgartner
 Volume II, *Personnel Dosimeter Features, Calibration and Dose Assessment*, 1991,
 A. W. Endres
 Volume III, *Data Processing*, 1992, J. A. Schur
 Volume IV, *Nuclear Accident Dosimetry*, 1992, J. J. Fix
 Volume V, *Dosimeter Reader Systems*, 1991, W. V. Baumgartner

Volume VI, *Field Measurements*, 1991, A. W. Endres
Volume VII, *Environmental Dosimetry*, 1992, A. W. Endres
Volume VIII, *Laboratory Procedures*, 1992, J. D. Peters

These documents are used to administer the External Dosimetry Project. In addition, letter reports are prepared and submitted to the Hanford Personnel Dosimetry Advisory Committee for review and comment for significant program issues. Copies are included in the minutes of these committee meetings and provided to the Hanford Radiation Protection Historical File maintained by the Hanford Radiological Records Project.

4.6 PROGRAM-RELATED PROFESSIONAL ACTIVITIES

Staff presentations and professional memberships during 1993 are listed in this section.

4.6.1 Presentations

Fix, J. J. 1993. "Dose Variables for Radiation Protection and Epidemiology." PNL-SA-22240. Presented at the DOE Radiation Protection Workshop, Las Vegas, Nevada, April 13-15, 1993. The paper will be published in the proceedings.

Fix, J. J. 1993. "Personnel Dosimeter Assignment." PNL-SA-22241. Presented at the Radiation Protection Workshop, Las Vegas, Nevada, April 13-15, 1993. The paper will be published in the proceedings.

Fix, J. J. 1993. "Dose Variables for Radiation Protection and Epidemiologic Needs." Presented at the Nuclear Engineering and Health Physics Seminar, University of Cincinnati, Cincinnati, Ohio, October 1, 1993.

4.6.2 Professional Memberships

Endres, A. W. and J. J. Fix. Members of DOE ad hoc working group to develop extremity dosimeter performance standard.

Fix, J. J. Member of DOE Comprehensive Epidemiologic Data Resource (CEDR) provider working group.

Fix, J. J. Member of DOELAP Oversight Board identified in DOE Order 5480.15, "Department of Energy Laboratory Accreditation Program for Personnel Dosimetry."

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

Fix, J. J. Chairperson of International Agency for Research on Cancer (IARC) dosimetry committee to pool existing epidemiological studies from the U.S. (including Hanford), Canada and the United Kingdom.

5.0 INSTRUMENT CALIBRATION AND EVALUATION PROGRAM

The Instrument Calibration and Evaluation Program provides complete and reliable radiation protection instrument services for Hanford Site contractors to ensure personnel safety in the Hanford workplace. Specific tasks performed under this program during 1993 included conducting the routine instrument pool and the Hanford Test and Evaluation Project, supporting the HP-9000 Database which includes all instrument calibration records, providing technical reviews of instrument calibration procedures for Site contractors, maintaining the Site radiation protection instrument manual, and evaluating commercially available ion-chamber dose rate survey instruments to replace the Site Cutie-Pie. The Program provided an administrative mechanism for the equitable sharing of the cost to maintain the Hanford Site *Radiological Standards and Calibration Project* and the *Hanford Site Radiological Control Manual* (RL 1992) by proportioning contractor shares to instrument pool usage.

The Instrument Calibration and Evaluation Program provides complete instrument services, thereby providing the Hanford contractors with a quality, reliable, and accurate instrumentation pool capable of performing at the level necessary to ensure personnel safety as required by DOE 5480.11 (1990), DOE 5480.6 (1992), and the *Hanford Site Radiological Control Manual* (RL 1992). Calibrations are performed using the guidance in American National Standards Institute (ANSI) N323 (1978). The routine program activities fall under the base tasks that comprise the CY 1993:

1. management of the Routine Portable Instrument Pool
2. management of the Hanford Test and Evaluation Project
3. calibration and service of WHC, PNL and KEH non-pool radiation protection instruments
4. maintenance of a calibrations records database
5. maintenance of all the necessary radiological, electronic and mechanical standards traceable to NIST
6. continuing the update and revision of the site Instrument Manual.

In addition, the program provides for the equitable sharing of the cost of maintaining the *Hanford Site Radiological Control Manual* (RL 1992) among the site contractors by proportioning contractor share to instrument pool usage. These basic tasks and other important supporting tasks performed in CY 1993 are described in this chapter.

5.1 THE ROUTINE PROGRAM

The routine program provides for a complete radiological control portable instrument program. A pool of portable and semi-portable radiation protection instrumentation is maintained for contractor use. Maintaining this instrumentation pool involves the following:

- procuring new and replacement instruments
- overseeing an instrument pickup and delivery service
- maintaining calibration records
- surveying, decontaminating, maintaining, and calibrating instruments.

The routine program also includes the following tasks:

- maintaining traceability of radiological and electronic calibration systems to NIST
- operating a program to service radiation protection emergency kits
- modifying and updating written calibration procedures as new instruments are introduced and calibration techniques are improved
- procuring, acceptance testing, calibrating, and distributing pencil dosimeters
- performing specification development and acceptance testing on all instruments purchased for pool use and as required by Hanford contractors
- fabrication and certification of instrument performance check sources for Hanford contractors.

5.1.1 Routine Portable Instrument Pool

The use of portable instruments by contractors on the Hanford Site during CY 1993 is shown in Table 5.1. The instrument types are described in detail in the *Radiation Protection Instrument Manual*.^(a)

During the year, a number of new instruments were procured to replace instruments damaged or disposed of as a result of contamination. In addition, the continuing change in Site mission to restoration and remediation has required more contamination monitoring instruments and low level gamma field instruments. The following items were purchased in 1993:

- 125 count rate survey meters for portable alpha monitoring (PAM)
- 1520 Geiger-Mueller (GM) tubes for probe repairs and replacement parts

(a) Internal manual, PNL-MA-562, Pacific Northwest Laboratory, Richland, Washington.

Table 5.1. Portable Instrument Usage for CY93

Instrument Type	Kaiser		Westinghouse				300 & 400 Areas		PNL		Total
	Number of Instruments	% of Kaiser Total	Number of Instruments	% of 100 Area Total	Number of Instruments	% of 200 Area Total	Number of Instruments	% of 300 & 400 Area Total	Number of Instruments	% of PNL Total	
EBM					38	1%			28	0%	66
CP	9	5%	109	11%	1,096	16%	201	12%	524	12%	1,944
DAD/GAD/ FDPD	184	95%	91	9%	378	5%	138	8%	138	3%	929
EGM			302	30%	1,781	25%	364	21%	1,364	32%	3,820
TPC			7	1%	25	0%	17	1%	29	1%	78
LPC					3	0%					3
HPC			6	1%	38	1%	16	0%	4	0%	64
XCI			4	0%	26	0%	2	0%			32
SNOOPY			4	0%	71	1%	27	2%	38	1%	141
PAM	1	0%	135	13%	1,728	24%	321	19%	834	20%	3,030
LUD (a)			3	0%	194	3%	48	3%	131	3%	376
PANCAKE			222	22%	1,389	20%	312	18%	838	20%	2,795
HRCP									1	0%	1
LLM			18	2%	42	1%	18	1%	20	0%	98
BBCP					55	1%	24	1%	72	2%	151
PAC-6					38	1%			8	0%	46
BWCP					27	0%	4	0%	43	1%	74
SNM's (b)			3	0%			170	10%			173
HP210			16	2%	65	1%	33	2%	48	1%	163
RO2			64	6%	27	0%			9	0%	100
EXT			7	1%	18	0%	10	1%	21	0%	56
RO7			18	2%	9	0%			37	1%	64
<hr/>											
Total by Area/ Contractor	194		1,009		7,048		1,705		4,207		14,204
% of Total	1%		7%		50%		12%		30%		

(a) Includes Ludlum Models 21, 28, 177-8, 177, 177-36, 177-56, 177-52

(b) Includes HHD440, HHD470P, Ludlum Model 3, Ludlum Model 316

- 473 photomultiplier tubes for PAM probe manufacture and repairs
- 2120 low range (0-200 mR) and 200 medium range (0-500 mR) direct-reading pencil dosimeters.

As part of a complete portable instrument program, design and procurement continued for multirange checksource devices to verify the performance of instruments in the field as required in ANSI standards and DOE Orders. To complement these devices and the existing Site instrument checksources, the program to annually verify and recertify the checksources continued. The Program source calibration capabilities allow for the recertification of sources. Four counting systems provide this source certification service:

- a Nuclear Measurements Corporation (NMC) windowless proportional detector
- an Eberline proportional portal monitor detector
- a Berthold large area (8-inch diameter) flow-through proportional counting system
- a gamma spectroscopy germanium-lithium drifted (GeLi) system.

Late in the year, WHC discontinued certifying all sources except their own instrument calibration sources, which require traceability to NIST. New regulations on the shipment of sources from the field to the 318 Facility made annual certification of sources, other than calibration sources, too costly. The equipment and procedures are maintained for new source acceptance testing and calibration source certifications.

5.1.2 Hanford Instrument Test and Evaluation Project

The Hanford Instrument Evaluation Committee (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 onsite
- 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 are on this committee. During 1993, the committee developed a list of all radiation detection instruments used onsite and, based on the operating and calibration history, determined which were approved for use onsite and which required further evaluations. The "approved instrument list" was developed to meet *Hanford Site Radiological Control Manual* (RL 1992) requirements that only approved instruments may be used onsite. Several instruments identified as needing further evaluations before approval were tested and ultimately approved for use onsite during 1993. In addition to evaluating existing instruments, the committee evaluated a number of new instruments. The Eberline TCM-2 Tool Contamination Monitor, SAIC PD-4 electronic dosimeter, and Eberline AMS-3A-1 modular beta continuous air monitor (CAM) were evaluated and approved for use onsite. Other instruments or technologies evaluated by the committee, but not yet approved for use onsite, include dual alpha/beta detectors and instruments, ion chamber exposure rate meters, the Eberline AMS-4 beta CAM, and the Victoreen 325 high-range exposure rate meter. The committee also developed purchase specifications for alpha CAMs and ion chamber exposure rate meters.

5.2 SUPPORTING STUDIES

Special studies conducted by the Instrument Calibration and Evaluation Program are described in the following subsections.

5.2.1 Minimum Detectable Activity of Hanford Portable Radiation Detection Instruments

The MDA of Hanford portable radiation detection instruments was determined. The objective of the study was to determine if existing field instruments were capable of detecting surface contamination at or below the total contamination limits given in the *Hanford Site Radiological Control Manual* (RL 1992). A previous study documented the MDA for surveying point sources with Hanford portable instruments. During 1993, the study was expanded to include MDAs for surveying distributed (100-cm^2) sources. Empirical data was collected by having radiological control technicians listen to a count rate meter while a distributed source was passed beneath a radiation detector. The scan speed at which the source moved under the detector was regulated using a computer-controlled translation table. The technician then indicated whether or not a source was present. The probability of detecting the source was used to develop a minimum detectable count rate (MDCR). The MDCR and source efficiencies were used to determine the MDA. The report identified the activity that would be detected 95% of the time for isotopes given in Table 2.3 of the *Hanford Site Radiological Control Manual* (RL 1992).

5.2.2 Instrument Manual Update

The Instrument Calibration and Evaluation Program produces PNL-MA-562, *Radiation Protection Instrument Manual*,^(a) to provide the Site radiological control technologists with specific information for operating and using monitoring instruments available through the Hanford instrument pool. During 1993, procedure requirements on performance testing of portable pool instrumentation was added to the manual.

5.3 PUBLICATIONS AND PRESENTATIONS

Staff presentations, publications, and external professional activities are listed in this section.

5.3.1 Presentations

Froelich, T.J. 1993. "Effects of Environmental Conditions on Laboratory Measurements." Presented at the NIST Workshop on Measurement Quality Assurance for Ionizing Radiation, March 16-18, Gaithersburg, Maryland.

Johnson, M.L. 1993. "Methods for Calculating MDA of Portable Survey Instruments." Presented at the DOE Radiological Calibration Workshop, October 12-14, Estes Park, Colorado.

5.3.2 Publications

Johnson, M.L. 1993. *Evaluation of the Science Applications International Corporation PD-4 Electronic Dosimeter*. PNL-8959, Pacific Northwest Laboratory, Richland, Washington.

Johnson, M.L. 1993. *Evaluation of the Eberline TCM-2 Tool Contamination Monitor*. PNL-8923, Pacific Northwest Laboratory, Richland, Washington.

5.3.3 External Professional Activities

Johnson, M.L.-Chairperson of Working Group for ANSI N323B, *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 N323C, *Radiation Protection Instrumentation and Calibration - Fixed Instruments*.

(a) Internal manual, PNL-MA-562, Pacific Northwest Laboratory, Richland, Washington.

6.0 RADIATION STANDARDS AND CALIBRATIONS PROJECT

The primary function of the Radiation Standards and Calibrations (RS&C) Project is to maintain radiological standards necessary to facilitate appropriate characterizations and calibrations within the Hanford Instrument Calibration and External Dosimetry Projects. In support of this task, special instrument and dosimeter response-characterizing equipment and supplemental radiological reference fields are maintained, as necessary. This maintenance 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 the following:

- providing traceability of the calibration sources to the NIST
- maintaining basic radioactive sources and instruments that serve as radiological standards
- reviewing calibration standards, regulations, and handbooks
- ensuring that calibration procedures are in agreement with technically accepted methods.

Project activities conducted during CY 1993 are discussed in the following sections.

6.1 THE ROUTINE PROJECT

Activities in the routine project included maintaining 1) radiological standards and capabilities and 2) radiological reference fields traceable to national standards.

6.1.1 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 known and easily reproduced quantities of radiation dose or exposure to environmental or personnel dosimeters and instruments for providing NIST-traceable calibration and/or response characterization.

Gamma-Ray Photon Sources

Available photon sources include various activities of ^{137}Cs and ^{60}Co (configured in either collimated-beam, well or open field geometries) and a single ^{241}Am source (configured for irradiation in a 2π geometry) as listed in Table 6.1.

Table 6.1. Available Gamma-Ray Sources

Source	Geometry	Nominal Rate/Range [R(rem)/hr]	Location in Bldg. 318	Reference No.	Primary Photon Energy (MeV)
⁶⁰ Co	Well	0.006 - 2.000	Rm. 121	318-027	1.17/1.33
	Open	2 / 7	Rm. 106	318-164	1.17/1.33
	Beam	10 - 300	Rm. 8	318-037	1.17/1.33
	Beam	90 - 3000	Rm. 8	318-036	1.17/1.33
¹³⁷ Cs	Well	0.002 - 0.100	Rm. 121	318-031	0.662
	Well	0.040 - 10.000	Rm. 121	318-030	0.662
	Beam	0.100 - 30.000	Rm. 8	318-040	0.662
	Open	0.400 / 2.000	Rm. 106	318-001	0.662
	Beam	1 - 300	Rm. 8	318-044	0.662
	Open	1 / 8	Rm. 106	318-029	0.662
	Beam	3 / 30	Rm. 6	318-131	0.662
²⁴¹ Am	Open (2 π)	0.125	Rm. 6	318-184	0.060

The "open" sources listed in Table 6.1 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 target positioning stand located on a sliding rail system. Source 318-131 also includes a moveable target stand, but is typically characterized and used only at the 1- and 3-m 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-target distance is controlled by moving the sources on a trolley system up and down within the well (see Figure 6.1), via computer interface.

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Figure 6.1. Typical Calibration Well

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 produces Bremsstrahlung (broad) photon spectra (e.g., NIST techniques M30, S60, M150, H150, etc.) while the second is configured to facilitate production of K-fluorescence technique (narrow) secondary photon spectra (e.g., K17 and K59) within a shielded enclosure. Figures 6.2(a) and (b) show an example spectrum of each type of x-ray configuration and Table 6.2 provides a complete listing of available techniques and their characteristics. Both of these systems utilize a laser alignment system to aid in target (instrument/dosimeter) positioning.

Figure 6.2(a). Bremsstrahlung X-ray Spectrum (M30 Technique-20 keV Average [Effective] Energy)

Figure 6.2(b). K-Fluorescence X-ray Spectrum (K17 Technique-17.5 keV Photon Energy Peak)

Table 6.2. Available X-ray Photon Techniques^(a)

Style	Technique	Average/ Effective Energy (keV) ^(b)	Half-Value Layer (mm Al)	Homogeneity Coefficient	Exposure Rate/Range (R/hr) ^(b)
Bremsstrahlung	M20	12.8	0.150	0.790	2.9 - 288.6
	M30	20	0.354	0.634	3.2 - 326.1
	M50	29	0.976	0.650	3.4 - 350.9
	M100	51	4.86	0.720	1.5 - 305.0
	M150	70	9.90	0.862	3.8 - 391.4
	M200	84	N/A	N/A	4.3 - 431.0
	S60	36	2.72	0.760	0.6 - 119.6
	S75	39	1.81	0.610	4.6 - 472.2
	H50	38	N/A	N/A	0.05 - 9.40
	H100	70	13.47	0.964	0.02 - 3.07
K-Fluorescence	H150	120	16.71	0.980	0.12 - 16.5
	H200	167	20.22	0.994	0.09 - 9.22
	H250	210	22.48	0.987	0.09 - 8.50
	H300	252	23.87	0.898	0.06 - 5.63
	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.
(b) Nominal

Neutron Sources

Two configurations of ^{252}Cf neutron sources are available. The first configuration allows the use of 1.47-mg and 82- μg sources (at original assay) within the pneumatic transfer system in 318 Building, Room 106. During use, these sources are placed roughly in the geometric center of a room 10 meters in width, 14 meters in length and 8.8 meters in height, such that a low-scatter environment is established. Both 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 centimeter of cadmium. These moderated sources 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* (1986), and ANSI N13.11, *American National Standard for Dosimetry-Personnel Dosimetry Performance-Criteria for Testing* (1983).

The second configuration involves a ^{252}Cf source placed in a well to facilitate easy access for instrument calibration. This source provides a fission spectrum partially degraded by the significant scattering of neutrons from the sides of the well.

Beta Particle Sources

Beta particle sources (^{204}Tl , ^{147}Pm , and $^{90}\text{Sr}/^{90}\text{Y}$) are maintained primarily for dosimetry characterization. Available sources include those manufactured by Amersham-Buchler and calibrated directly by the Physikalisch-Technische Bundesanstalt (PTB), Germany's national physical standards organization, and those manufactured in the United States by Amersham and Isotope Products Laboratory. The absorbed dose rate for the ^{147}Pm source has decayed to a value which makes the reference field unusable for most purposes, including periodic constancy verifications. A suitable higher activity replacement is being investigated for procurement in 1994. Measurements have been made of all Amersham-Buchler sources and the Amersham-U.S. $^{90}\text{Sr}/^{90}\text{Y}$ sources to verify satisfactory compliance with ANSI N13.11 (1983), DOE/EH-0027 (1986), and International Standards Organization (ISO) 6980 (1984).

6.1.2 Traceability to National Standards

As stated, maintaining radiological reference fields traceable to national standards is one of the primary goals of the Radiation Standards and Calibrations Project. Although a pathway has been established over the history of this effort, it has not been discussed in previous reports. The method of traceability is often unclear and can vary periodically. Therefore, the current philosophy of traceability for PNL radiological reference fields is provided here.

Traceability means adopting some method of assuring that calibration fields are established and utilized so that they are consistent with national standards. There are two accepted types of consistency measurements which are commonly used to infer traceability: 1) implied consistency, which is established through the use of a laboratory standard submitted to NIST for

calibration within radiation fields applicable to the laboratory, and 2) demonstrated consistency, which is established through a measurement quality assurance (MQA) interaction with NIST. This latter method is akin to a performance test administered by NIST and is instrumental in verifying measurement traceability, as opposed to simply obtaining or maintaining a traceable source or reference instrument (i.e., artifact traceability). A disadvantage with traceability based only upon implied consistency is the lack of demonstration which indicates that measurements made of traceable sources or using traceable reference instruments are consistent with those made using national standards. Traceability based upon demonstrated consistency provides some 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.

The 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 requires a variance in the normal process. The following descriptions provide the traceability pathway for each of the radiation types applicable within this project.

Photon sources (i.e., gamma and x-ray sources) are maintained as 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. In January, 1984, a Capintec PM-30 air ionization chamber (s/n C1130.4277) was submitted to NIST for calibration to M100, M150, S60, and H150 x-ray techniques and ^{137}Cs and ^{60}Co gamma reference fields. In 1982, a Victoreen model 415A ion chamber (s/n 149), appropriate for low energy photon fields, was calibrated by NIST for the M30 and M50 x-ray techniques. More recently in 1992, a second Capintec PM-30 ion chamber (s/n C1130.7502) was submitted to NIST to obtain calibrations for M100, M150, S60 and H150 x-ray and ^{137}Cs and ^{60}Co gamma reference fields. By 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 6.3. To achieve demonstrated consistency, NIST has conducted measurement QA assessments of PNL photon reference fields since 1984, in most cases selecting a subset of the available sources and/or x-ray techniques. The most recent of these occurred in late 1992 during which time M30, M100 and M150 x-ray and ^{137}Cs reference fields were verified.

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 6.3, 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.

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Figure 6.3. Typical Traceability Pathway for PNL Photon Reference Fields

Neutron traceability for all irradiations and measurements performed using PNL sources is implied only. The primary pathway to NIST is through direct calibration of PNL ^{252}Cf sources, in terms of neutron emission rate, within the NIST manganous sulfate bath facility. Dose equivalent rates are calculated for these sources in their bare and moderated configuration based on NIST recommendations provided in National Bureau of Standards (NBS) Special Publication 633, *Procedures for Calibrating Neutron Personnel Dosimeters* (NBS 1982). A Nuclear Research Corporation (NRC) Model NP2 (SNOOPY) portable neutron monitor is maintained as a tertiary standard used to convey the dose equivalent rate in a low scatter environment to a calibration well equipped with a bare ^{252}Cf source. The well calibration range is currently established as a working standard specifically for use with SNOOPY 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 6.4.

During the past several years, numerous joint efforts have been made between the NIST and PNL to establish a suitable method for neutron MQA intercomparisons in order to demonstrate traceability. These efforts 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. With the experience gained from these prior attempts, a successful method of intercomparison is anticipated in the near future.

The NIST-traceability of beta reference fields is based upon both implied and demonstrated consistency. Of highest order in the reference field hierarchy are the Amersham-Buchler $^{90}\text{Sr}/^{90}\text{Y}$ (74 MBq and 1.85 GBq) and ^{204}Tl (18.5 MBq) beta point sources. The NIST maintains a similar set of sources at its facility which it has characterized/verified both quantitatively and qualitatively. Although the traceability of these sources is directly to the PTB in Germany, the adoption of this design by NIST as the national standard establishes the U.S. traceability path. The PNL laboratory predominantly uses an alternate (i.e., Amersham-U.S. and Isotope Products Laboratory) set of point sources of similar isotopic distribution, but with subtle differences in construction material and, in the case of the ^{204}Tl , a significantly larger activity (i.e., 1.85 GBq). The $^{90}\text{Sr}/^{90}\text{Y}$ sources of this alternate set, commonly referred to as the ANSI-N13.11 sources, were calibrated directly by NIST, the 74 MBq source in 1986 at the NIST and the 1.85 GBq source at PNL by an NIST scientist using a PNL extrapolation chamber. The NIST calibration places these sources as secondary standards in the calibration hierarchy. The PNL extrapolation chamber, used by the NIST scientist, is generally considered to be an absolute standard and is difficult to place in the laboratory traceability hierarchy. It is currently being utilized as a tertiary standard, since instead of being calibrated by NIST using primary standards, it is compared to the Amersham-Buchler sources which, through periodic MQA intercomparisons with NIST, are considered to be internal secondary standards. The traceability pathway for beta reference fields and the extrapolation chamber is shown in Figure 6.5.

Figure 6.4. Typical Traceability Pathway for PNL Neutron Reference Fields

The periodic MQA intercomparison NIST conducts with the PNL 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 PNL Amersham-Buchler sources. These sources were selected to preserve similar geometry, encapsulation, and activity since it is suspected that the transfer standard used for these measurements is sensitive to differences in these parameters.

6.1.3 Calibrations and Constancy Checks

Following initial calibration and between measurement quality assurance interactions with NIST for most radiation fields maintained by the RS&C Project, verification measurements are performed to assure constancy of field characteristics and magnitude. For beam and open geometry photon fields, this includes abbreviated quarterly checks and generally more rigorous annual verifications. X-ray reference fields are verified at the beginning of each calendar quarter. Low scatter room neutron sources are verified on a quarterly basis as a byproduct of the quarterly verification of the SNOOPY tertiary standard. Well sources (photon and neutron) are calibrated annually to provide additional data for modifying the computerized exposure rate calculational program which determines programmatic instrument calibration points. Beta source absorbed dose rates are verified annually using an extrapolation chamber at fixed distances to

Figure 6.5. Typical Traceability Pathway for PNL Beta Reference Fields

assure constancy with original calibration data. Instrument standards are intercompared annually, including verifying the calibration factors for photon ionization chambers, assuring the proper function of the Physikalisch-Technische Werkstätten (PTW) extrapolation chamber, and assuring accuracy and proper functioning of the reference SNOOPY detector (tertiary standard).

Annual calibrations of photon reference fields were completed as scheduled in 1993, with quarterly constancy verifications performed at approximately three-month intervals. The ^{241}Am and low scatter and shepherd ^{137}Cs annual source calibration data were compared to the originally established dose rates (corrected for decay) and were found to be within $\pm 1\%$ of the established values (see Table 6.3). Annual calibrations of the well sources and the high exposure facility gamma sources (318-027, -030, -031, -036, -037, -040 and -044) were used to formulate updated positioning equations used by the computer codes which control source placement. Quarterly constancy verifications of sources resulted in values within $\pm 5\%$ of anticipated exposure rates as required by procedure. Results above $\pm 2\%$ occurred for Well #1 (source no. 318-031) during the second quarter. This result was investigated and found to be attributed to the measurement method used for those particular quarters. This discrepancy, while of interest for refining the measurement technique, was not serious and posed no significant

Table 6.3. Photon Reference Fields - Calibration Performance Summary.
(Annual calibrations are shaded.)

		Percent Error of Reference Field Verification			
Source Number		Quarter 1	Quarter 2	Quarter 3	Quarter 4
¹³⁷ Cs	318-001	1.01	-0.65	-0.27	-0.33
	318-029	1.51	-0.83	-0.24	-0.74
	318-030	1.05	N/A	-0.03	-0.58
	318-031	-0.62	-4.14	N/A	-0.17
	318-040	-0.02	0.03	N/A	0.08
	318-044	0.20	0.03	N/A	0.02
	318-131	-0.58	1.33	-0.81	0.30
⁶⁰ Co	318-027	-0.54	N/A	-2.52	-2.52
	318-036	-0.12	-0.08	N/A	0.08
	318-037	-0.05	0.00	N/A	0.12
	318-164	0.23	Out of Service	Out of Service	Out of Service
²⁴¹ Am	318-184	1.14	0.57	0.97	0.65

consequence for the overall use of the facility. All x-ray calibration checks verified the reference fields to within $\pm 2\%$. Beta and neutron source measurements were performed and verified absorbed dose and dose equivalent rates.

Annual instrument standard verifications/calibrations were performed for a Capintec PM-30 ion chamber (secondary standard), a Far West Technologies 1000-cc pressurized ion chamber (working standard), a PTW extrapolation chamber (tertiary standard) and the NRC SNOOPY portable neutron monitor (tertiary standard).

6.1.4 Measurement Quality Assurance

No official MQA interactions were conducted during 1993; however, work continued toward developing a suitable method for neutron intercomparisons. This year, work was completed on the trial intercomparisons using a Far West Technologies REM-500 neutron survey instrument (employing a 6.3-cm diameter tissue equivalent proportional counter [TEPC]) and a Harwell Rem-Meter (survey instrument), which operates using a ³He detector. The data from these intercomparisons is still being reviewed by NIST, but in general indicates that neither instrument may be as suitable as necessary for such practices.

Investigative beta intercomparison measurements were conducted using passive "electret ion chambers." The NIST considers this device, previously employed for monitoring environmental radon, to be a valid replacement for the current beta intercomparison device, which, as previously stated, may have certain dependencies which detract from its usefulness. Two detector types (short term and long term) were used to assess the PNL 74-MBq Amersham-Buchler $^{90}\text{Sr}/^{90}\text{Y}$ source (318-013). Intercomparison results for the short-term (low dose) device were poor (approximately 12%); however, the long-term (moderate dose) devices agreed to within 2%, but with an uncertainty of 4-5%. This uncertainty is substantial and apparently associated with the electret, since the sources have been previously verified to be within $\pm 3\%$ using ionization chambers. This large uncertainty was observed at the NIST facility as well. The NIST intends to continue investigations into using this technique and will focus its efforts on the long-term device and the reduction of uncertainty in its use.

6.1.5 Improvements to Standards and Capabilities

The calibration of low-exposure-rate reference fields continues to be refined as experience is gained in measurement techniques. During 1993, Well #2 (source no. 318-030) was calibrated with and without a lead attenuator. Exposure rates for this well have been determined as low as 1.5 mR/hr through the attenuator with the source at the 9-meter position. Well #1 (source no. 318-031) was again calibrated into the micro-R/hr region using a modified drift adjustment technique which does not remove the effect of background or ceiling scatter at the detector location. This method, used predominantly for extrapolation chamber assessment of beta dose rates, involves collecting measurement data with both positive- and negative-biased voltage applied to the reference instrument. Adding the net values theoretically establishes the net system leakage/drift. This value, in terms of collected current (positive or negative), is subtracted or added, depending on the bias of the source measurement, to the net current evaluated at each source position. The primary difficulty in performing these measurements has been to 1) identify a suitable signal cable for the detector which does not induce a significant leakage/drift signal, 2) determine an appropriate "stabilization" time when switching the bias voltage to the chamber which facilitates a stable current during the leakage/drift measurement, and 3) determine a tolerable range of leakage/drift variation over the course of the measurements, some of which occupy several days. Some of these problems might be solved through the future procurement and use of a more sensitive electrometer (if one could be identified) or a pressurized ion chamber capable of pressurization up to several atmospheres. Using the present system, electrical current measurements in the region of 10^{-14} amps are typical at the lowest exposure rates.

Another significant improvement was made during 1993 in the assessment of the neutron source mounted within Well #3 (source no. 318-038). A procedure has been developed involving the use of a scaler device with the reference SNOOPY detector which allows the integration of counts during the measurement process. This procedure provides increased sensitivity and, consequently, accuracy when assessing low dose equivalent rates within the well. It also facilitates the measurement of more source positions within the well with little additional time spent. The number of source positions assessed is now similar to those assessed for the photon wells (i.e., more than 30 discrete positions). In addition, this process includes a more comprehensive calibration of the SNOOPY/scaler combination using the low scatter room neutron sources which cover a broader range of dose equivalent rates. This process provides more confidence to the entire well calibration.

A pilot quarterly measurement process using TLDs has been initiated for beta and neutron sources. When formalized, this process will be used to provide assurance of beta and Low Scatter Room neutron reference fields between annual instrument assessments. It could also be adapted to provide valuable qualitative measurements for characteristics such as field uniformity, scatter effects, and radiation energy.

6.2 SUPPORTING INVESTIGATIONS AND STUDIES

An assessment was made of the bare ^{252}Cf room return (scatter) effects within the Low Scatter Room for the SNOOPY reference instrument. This value is necessary in order to compensate the "known" dose equivalent rate during the instrument calibration process at increasing distance from the source (or closer proximity to the room walls). Measurements were performed from 1 to 3 meters for source 318-167 and from 0.5 to 2 meters for the smaller source 318-016. Figures 6.6(a) and (b) indicate the specific points measured and the linear fit used to establish correction factors.

In December of 1993, PNL was granted accreditation as a Secondary Calibration Laboratory for Ionizing Radiation (SCLIR) through the National Voluntary Laboratory Accreditation Program (NVLAP). This accreditation implies the concurrence by NIST that PNL can provide highly accurate instrument calibrations and dosimeter irradiations and that the laboratory complies with NIST Special Publication 812 (U.S. Department of Commerce/National Institute of Standards and Technology 1991). In addition to accurate performance, this document also requires SCLIR to

Figure 6.6(a). Snoopy Room Return Bare ^{252}Cf 318-167

Figure 6.6(b). Snoopy Room Return Bare ²⁵²Cf 318-016

have well qualified personnel, rigorous quality control and adequate procedures to assure continued high quality. The RS&C project has provided a significant portion of the basis for this accreditation in that it has driven PNL to maintain a high level of reference field agreement with NIST. Conversely, the Hanford Instrument Calibration and Evaluation Program and External Dosimetry Project reap the benefits of the additional QC, personnel qualification and procedures which accompany the accredited SCLIR. One of the eventual primary missions of the SCLIR will be to accredit "tertiary" instrument calibration facilities within the DOE via proficiency testing and onsite assessments.

6.3 PROGRAM-RELATED PROFESSIONAL ACTIVITIES

Project staff made the following presentations during 1993:

McDonald, J.C., G. Akabani, and R.M. Loesch. 1993. "Intercomparison of High Energy Neutron Personnel Dosimeters." Presented at the NIST Workshop on Measurement Quality Assurance for Ionizing Radiation, March 16-18, 1993, Gaithersburg, Maryland.

Piper, R.K., J.C. McDonald, R.A. Fox, and F.N. Eichner. 1993. "Quality Assurance Programs at the PNL Calibrations Laboratory." Presented at the NIST Workshop on Measurement Quality Assurance for Ionizing Radiation, March 16-18, 1993, Gaithersburg, Maryland.

7.0 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. The project is also responsible for maintaining the Hanford Radiation Protection Historical Files. Project 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 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 database was implemented in April of 1993. The REX system also includes all of the supporting exposure documentation on microfilm and laser optical 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 laser optical disk subsystem (called LaserREX) was implemented at the beginning of 1993. All exposure records starting with January 1, 1992, will be preserved on LaserREX.

The historical 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 ANSI N13.6, *American National Standard Practice for Occupational Radiation Exposure Records Systems* (1972), the *Hanford Site Radiological Control Manual* (RL 1992), as well as the following DOE Orders (as assigned by the *Hanford Site Services Handbook*^(a)): 1300.1, "Micrographic Management" (1980); 1324.2A, "Records Disposition" (1988b); 5480.11, "Radiation Protection for Occupational Workers" (1990); and 5484.1 Chg 3 "Environmental Protection, Safety, and Health Protection Information Reporting Requirements" (1987a). The program also complies with the applicable sections of the Privacy Act (1974) and the Freedom of Information Act (1966).

(a) U.S. Department of Energy Richland Operations Office (RL), 1993, RL 1400.1A, Richland, Washington (available online in HanInfo).

7.1 THE 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.

The database administration function performs system evaluations, troubleshooting, resolution of system and user problems, training of users, oversight of system security, liaison with the computer analysts, and initiation and testing of modifications to the database.

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 and RL. This function requires close contact with RL, the contractors, and other personnel dosimetry functions.

The library maintains individual exposure records that are not reducible to database elements as well as the Hanford Radiation Protection Historical Files. The library staff file and retrieve current 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 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 7.1 presents CY 1993 statistical information on many of the documents that are entered into the database and indexed into LaserREX.

Table 7.1. Records Activity for Calendar Year 1993

Document Type	Number
Personal Radiation Exposure History Form (used to document exposure history prior to Hanford and to initiate a record for a new employee)	5,513
Employee and Dosimetry Change Forms (used to document personnel or dosimetry changes)	6,165
Employee and Dosimetry Change Forms (used to document employee terminations)	3,415
Temporary Dosimeter Assignment Forms (used for visitors and sub-contractors as well as employees who forgot their dosimeters)	24,611
Investigation of Dosimeter Result Forms and Change Letters (used to estimate exposure for lost, damaged, or otherwise suspect dosimeter results)	2,843
Special Process Forms (used to document data for specially processed dosimeters)	3,698
Request for Special Excreta Sample Analyses (used to initiate the collection of samples for analysis)	1,526
Requests for Exposure Summaries (summaries requested for current and prior Hanford employees)	2,057
Letters Sent to Request Prior Exposure (to request summaries for new employees with prior exposure)	1,588

The major change to the routine activities was the implementation of the REX database and the LaserREX subsystem. LaserREX was implemented in January and the REX database was implemented in April. These systems are discussed below under Supporting Tasks.

7.2 SUPPORTING TASKS

The HRRP supportive tasks included implementing REX and the Laser Optical Disk Subsystem, as well as creating a one-point contact for Radiological Control Records.

7.2.1 Implementation of the REX System

The redevelopment of the ORE database was started in January 1990. The new system, renamed the REX System, was implemented on April 5, 1993. This included a 1-month delay from the implementation date scheduled during 1992. The history of the project has been recorded in the

previous Support Services Annual Reports for the years 1989 through 1992 (Lyon et al. 1990, 1991, 1992, 1993).

REX has several innovations that were not in the ORE database. A transaction log has been designed to log changes to the database which will replace some paper. The transaction log records, separately from the actual change,

- who made the change
- when the change was made (date and time)
- the type of change (e.g., name change, dose change, dosimeter or bioassay frequency change)
- the original value
- the new value.

The transaction log will be downloaded and stored on the laser optical disk system which is discussed below.

Because REX was being built using relational database management software (IBM's DB2 DBMS) that includes the Standard Query Language (SQL), ad hoc reports are easier to produce. A report writing software, Platinum Report Facility (PRF), was included to make the process even easier.

There are exposure records for individuals in the database with more than one social security number (SSN) and some early records that have no SSN. Because of this and other problems, REX generates a unique identification number for each individual in the database. This number has been called the REX ID. All of an individual's records will be incorporated under the REX ID.

An additional unique feature that was included in REX is a help function. There are over 50 different types of codes in the database. If the operators cannot remember the proper code to be entered, they can place the cursor on the code field, strike the F1 function key, and a table of all the applicable codes will appear. Each type of code has its own table.

The final system consisted of almost 200 screens, 72 reports/report screens, and 21 interfaces. Over 1.5-million pieces of data were converted from ORE into REX. Several screens were added during the year so that at year end there were 202 different screens.

The fiscal year (FY) 1993 costs for the development of REX significantly exceeded the budget. The final cost for the development was almost \$2 million. It took over three years to complete the development. In addition, due to changes in the billing structure for the new computer platform, the operational costs are much higher than expected.

The implementation of the REX System was considerably more difficult than expected. Even though all modules were tested and integration testing was performed, a number of problems occurred. Out of the greater than 1.5-million pieces of data that were converted, approximately 500 to 600 dosimeter tracking records did not convert properly. Unfortunately, these data were some of the records most needed right after the implementation. Several of the problems that occurred were very visible because reports were issued that had incorrect data on them. The incorrect data was due to problems with the report generation software or not setting the proper parameters when initiating the report; however, the data in the database is accurate. Other problems occurred due to the large number of edits programmed into the system and some of these had to be modified. Various other "bugs" were found in the system. At year end, the system had settled down and was functioning very well.

All changes to the database, whether software bugs, requested changes, or enhancements, are recorded on Software Change Request (SCR) forms. At year end, 363 SCRs had been issued and 16 remained open. A number of further changes have been requested that did not have SCRs written at the end of the year. Many of the changes were needed because the system did not operate as the users had expected it to when they detailed the design parameters. Enhancements are items not originally listed in the original requirements.

After the implementation, a lessons-learned study was completed. The problems that were identified and the lessons learned included the following:

1) Problem:

- Difficulties in estimating machine and labor costs significantly impacted PNL's budget for REX in FY 1993.

Lessons learned:

- "Alternative Analysis" and "Analysis of Benefits and Costs" should be reviewed during the development process any time a significant change in pricing occurs.
- Evaluation of machine processing requirements should be based on previous experience or benchmarking.
- A consistent development approach needs to be put in place so that labor estimated can be based on previous experience in similar technologies.

2) Problem:

- The approach of developing the entire REX system and implementing it all at once required too much change for the user community to absorb at one time.

Lessons learned:

- A large implementation should be broken into smaller more manageable pieces.
- "Lessons Learned" from releasing smaller portions first can be applied to subsequent releases.

3) Problem:

- User testing of screens and reports helped to certify the system, but did not adequately prepare the user community on the significant change in the way business was to be conducted.

Lessons learned:

- Representatives from the contractor organizations needed to be more involved in the design and certification of the REX system. Too much reliance on one person did not achieve the desired results. REX "experts" should have been developed in each of the contractor organizations to ensure ownership of the new system and to assist in end user training.

4) Problem:

- Although system acceptance was well defined between the PNL Records Project and Information Resource Management/Information and Scientific Systems (IRM/ISS), acceptance criteria were not clearly defined for acceptance by the Contractor organizations. End-user acceptance of the system was still a problem when the lessons learned were developed. (User acceptance had significantly improved by year end).

Lessons learned:

- On a system the size of REX, acceptance criteria established with the end-user community would have significantly improved the implementation process. An implementation readiness review would have clearly determined if all parties were satisfied as to the completion of the system.

5) Problem:

- Delays were encountered in preparing for the Site Data Administration (DA) Board hearings.
- The DA Board presentation requirements and success criteria were not clear and appeared to change. The project had to go through several revisions to prepare what the DA Board wanted.

- Appearance before the DA Board did not take place during the normal course of planned project work. That is, timing of the DA Board appearance was not opportune for the project, forcing the diversion of project focus and resources.

Lessons learned:

- External reviews by RL such as Site DA Board and Management Information Systems (MIS) Board reviews need to be planned as a work activity within the project plan for a development project. Improvements in the DA Board requirements and criteria had been incorporated by the time the lessons learned were prepared.

6) Problem:

- Insufficient developer resources were brought on to the REX project in FY 1992, causing some design activities to be delayed until FY 1993. Head-count restrictions and work priorities were contributors to this problem.

Lessons learned:

- Better means of dealing with staffing shortages need to be developed to allow planned support of project schedules to be accomplished.

7) Problem:

- Two key personnel assigned to the REX project were overloaded during FY 1993, which included the final stages of the development/construction phase and implementation phase. The IRM/ISS project manager was not relieved of non-REX responsibilities and the workload for the single REX user representative was too much.

Lessons learned:

- A full time project manager for a development the size of REX was required.
- Subject matter experts within the user community should have been assigned specific responsibilities during implementation to avoid overloading a single person.

8) Problem:

- The original REX Project Manager was operating as both project manager and system architect. After requirements and alternatives analyses were completed,

this project manager left the company. It was very difficult to replace both of these roles and the project was impacted.

Lessons learned:

- Separate the project manager and system architect positions. This provides a check and balance between system development and project tracking.

9) Problem:

- The External Dosimetry portion of the REX system was developed last, yet had the most impact on the user community and was the most complex piece to develop.

Lessons learned:

- Development scheduling should take in factors such as user impact and complexity in determining what modules should be developed first.

The BCSR software development groups have developed process improvement methodologies to assimilate these lessons learned into future projects. A principal action is the development of a new approach to software development called "PRODUCTIVITY +." PRODUCTIVITY + is a licensed software development process that BCSR is enhancing to fit into their system. It should standardize the development process and has features that will directly apply to correcting many of the problems listed.

7.2.2 Laser Optical Disk Subsystem

REX was designed around the use of electronic transaction records which will replace some of the paper records now used. Instead of storing these transaction records in the database, which can use considerable disk capacity and be costly, they will be stored on a laser optical disk (LOD) subsystem. Electronic records will be transferred regularly from the Large Scale Information System (LSIS) computer and recorded on write-once/read-many (WORM) laser optical disks. In addition, paper records will be scanned and recorded on laser optical disks. All records will be indexed into a database for automated retrieval.

Because the LOD storage system is non-magnetic, the disks should have a far longer storage capability with far less maintenance than required for magnetic tapes. Also, the images or computer data are in digital form. This allows documents or stored data to be viewed on a personal computer monitor, printed out on laser printers, or sent elsewhere by local area network or facsimile. The WORM type system creates a permanent record that cannot be erased from the disk or modified; therefore the records should be acceptable for litigation purposes.

The subsystem is Windows-based and has two interfaces with REX. One interface is for the downloading of the transaction log data discussed above. The second interface allows verification of individual identifiers against the REX identification tables during indexing of the hard copy documents.

The transaction log data will be automatically indexed to the individual involved. Retrieval will be by individual identifiers, record type, and date. When retrieved, the data will be inserted into a template so that the data is understandable and the items are identified.

The LOD subsystem was procured and installed during 1992. It was named LaserREX. Testing and training of the operators was in progress at the beginning of 1993. Although new system start-up problems occurred, the vendor response was very good and the problems were solved or other means were provided in a timely manner. The system was accepted in January. It was completed on schedule and below budget.

Because LaserREX is a totally new technology to the project, considerable trial and effort was required to develop efficient operating procedures. The retrieval of data significantly interfered with the indexing of scanned documents. A second retrieval station was installed which allowed retrieval while indexing continued.

The transaction log system in REX did not function as it was expected to. Because of more significant problems in REX, the corrections to the transaction log were put under a low priority. Although the download procedure to LaserREX was verified using test data, it could not be tested with production data until December. The transaction log data since implementation of REX had been downloaded and stored on magnetic tape. However, because the problems with the log caused some doubt about the accuracy of the data, it was decided that the transaction log would not be recorded officially until January 1, 1994. To prevent losing any data, the paper that was to be replaced with the transaction log was scanned and indexed into LaserREX.

Almost 74,000 documents were scanned and indexed into LaserREX during CY 1993. The Library Desk Procedures^(a) manual was revised to accommodate the new system.

7.2.3 One-point Contact for Radiological Control Records

The *Hanford Site Radiological Control Manual* (DOE 1992) charges the HRRP with serving as a one-point contact for locating the custodian of all Hanford Site radiological control records. The system will allow personnel needing particular radiological control records to call HRRP and obtain the appropriate references.

(a) Internal Manual - Dosimetry Records Library Desk Procedures, Pacific Northwest Laboratory, Richland, Washington.

A requirements analysis was performed to determine what type of equipment was needed. Because the demand for this service is expected to be light, it was decided that a rotary type card file would be sufficient to begin with. If the demand gets heavy, it would be a relatively easy task to create a database for use on the HRRP library personal computers. Meetings were held with contractor staff to determine what records were available and who the contacts were. The system will go operational in 1994.

7.3 PROGRAM-RELATED PROFESSIONAL ACTIVITIES

Staff presentations and professional memberships during 1993 are listed in this section.

7.3.1 Presentations

Berndt, V.L. 1992. "Can't Justify an Imaging System? How About a CAR?" Presented at the Inland Empire Chapter of the Association of Records Managers and Administrators, November 18, 1993, and at the Portland Chapter of the Association of Records Managers and Administrators, March 8, 1993, Portland, Oregon.

Berndt, V.L. 1993. "Lessons Learned in Procuring a Laser Optical Disk System." Presented at the Inland Empire Chapter of the Association of Records Managers and Administrators, November 18, 1993, Spokane, Washington, and at the Bellevue-Eastside Chapter of the Association of Records Managers and Administrators, May 11, 1993, Bellevue, Washington.

Lyon, M., V.L. Berndt, G.W. Trevino, and B.M. Oakley. 1993. "Development and Implementation of a New Radiation Exposure Record System." Presented at the 1993 DOE Radiation Protection Workshop, April 13-15, 1993, Las Vegas, Nevada. Paper will be published in the workshop proceedings.

7.3.2 Professional Memberships

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

8.0 REFERENCES

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