**Pacific Northwest Laboratory
Annual Report for 1989 to
the Assistant Secretary for
Environment, Safety, and Health**

17

**Part 5: Environment, Safety, Health, and Quality Assurance
April 1990**

**Prepared for the U.S. Department of Energy
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**Pacific Northwest Laboratory
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the Assistant Secretary for
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**Part 5: Environment, Safety, Health,
and Quality Assurance**

L. G. Faust, P. G. Doctor,
J. M. Selby, and Staff

April 1990

Prepared for
the U.S. Department of Energy
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Pacific Northwest Laboratory
Richland, Washington 99352

Preface

This 1989 Annual Report from Pacific Northwest Laboratory (PNL) to the U.S. Department of Energy (DOE) describes research in environment, safety, and health conducted during fiscal year 1989. The report again consists of five parts, each in a separate volume.

The five parts of the report are oriented to particular segments of the PNL program. Parts 1 to 4 report on research performed for the DOE Office of Health and Environmental Research in the Office of Energy Research. Part 5 reports progress on all research performed for the Assistant Secretary for Environment, Safety, and Health. In some instances, the volumes report on research funded by other DOE components or by other governmental entities under interagency agreements. Each part consists of project reports authored by scientists from several PNL research departments, reflecting the multidisciplinary nature of the research effort.

The parts of the 1989 Annual Report are:

Part 1: Biomedical Sciences

Program Manager: J. F. Park

J. F. Park, Report Coordinator
S. A. Kreml, Editor

Part 2: Environmental Sciences

Program Manager: R. E. Wildung

M. G. Hefty, Report Coordinator and Editor

Part 3: Atmospheric Sciences

Program Manager: C. E. Elderkin

C. E. Elderkin, Report Coordinator
E. L. Owczarski, Editor

Part 4: Physical Sciences

Program Manager: L. H. Toburen

L. H. Toburen, Report Coordinator
K. A. Parnell, Editor

**Part 5: Environment, Safety, Health,
and Quality Assurance**

Program Managers: L. G. Faust
P. G. Doctor
J. M. Selby

L. G. Faust, Report Coordinator
S. K. Ennor, Editor

Activities of the scientists whose work is described in this annual report are broader in scope than the articles indicate. PNL staff have responded to numerous requests from DOE during the year for planning, for service on various task groups, and for special assistance.

Credit for this annual report goes to the many scientists who performed the research and wrote the individual project reports, to the program managers who directed the research and coordinated the technical progress reports, to the editors who edited the individual project reports and assembled the five parts, and to Ray Baalman, editor in chief, who directed the total effort.

W. J. Bair and T. S. Tenforde
Environment, Health, and Safety
Research Program

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Annual Report for:

1951	HW-25021, HW-25709
1952	HW-27814, HW-28636
1953	HW-30437, HW-30464
1954	HW-30306, HW-33128, HW-35905, HW-35917
1955	HW-39558, HW-41315, HW-41500
1956	HW-47500
1957	HW-53500
1958	HW-59500
1959	HW-63824, HW-65500
1960	HW-69500, HW-70050
1961	HW-72500, HW-73337
1962	HW-76000, HW-77609
1963	HW-80500, HW-81746
1964	BNWL-122
1965	BNWL-280, BNWL 235, Vol. 1-4; BNWL-361
1966	BNWL-480, Vol. 1; BNWL-481, Vol. 2, Pt. 1-4
1967	BNWL-714, Vol. 1; BNWL-715, Vol. 2, Pt. 1-4
1968	BNWL-1050, Vol. 1, Pt. 1-2; BNWL-1051, Vol. 2, Pt. 1-3
1969	BNWL-1306, Vol. 1, Pt. 1-2; BNWL-1307, Vol. 2, Pt. 1-3
1970	BNWL-1550, Vol. 1, Pt. 1-2; BNWL-1551, Vol. 2, Pt. 1-2
1971	BNWL-1650, Vol. 1, Pt. 1-2; BNWL-1651, Vol. 2, Pt. 1-2
1972	BNWL-1750, Vol. 1, Pt. 1-2; BNWL-1751, Vol. 2, Pt. 1-2
1973	BNWL-1850, Pt. 1-4
1974	BNWL-1950, Pt. 1-4
1975	BNWL-2000, Pt. 1-4
1976	BNWL-2100, Pt. 1-5
1977	PNL-2500, Pt. 1-5
1978	PNL-2850, Pt. 1-5
1979	PNL-3300, Pt. 1-5
1980	PNL-3700, Pt. 1-5
1981	PNL-4100, Pt. 1-5
1982	PNL-4600, Pt. 1-5
1983	PNL-5000, Pt. 1-5
1984	PNL-5500, Pt. 1-5
1985	PNL-5750, Pt. 1-5
1986	PNL-6100, Pt. 1-5
1987	PNL-6500, Pt. 1-5
1988	PNL-6800, Pt. 1-5

Foreword

Part 5 of the 1989 Annual Report to the U.S. Department of Energy's Assistant Secretary for Environment, Safety, and Health presents Pacific Northwest Laboratory's progress on work performed for the Office of Environmental Guidance and Compliance, the Office of Environmental Audit, the Office of National Environmental Policy Act Project Assistance, the Office of Nuclear Safety, the Office of Safety Compliance, and the Office of Policy and Standards. For each project, as identified by the Field Work Proposal, there is an article describing progress made during fiscal year 1989. Authors of these articles represent a broad spectrum of capabilities derived from five of the seven technical centers of the Laboratory, reflecting the interdisciplinary nature of the work.

Contents

Preface	iii
Foreword	v
Deputy Assistant Secretary for Environment	1
Environmental Protection, Support, and Assistance	3
Technical Support During the Review of Proposed EPA Regulations, <i>K. A. Higley, S. M. Neuder, I. C. Nelson, K. C. Rhoads,</i> <i>and W. E. Kennedy, Jr.</i>	3
Technical Support to Criteria Development, <i>R. D. Stenner,</i> <i>K. A. Higley, W. E. Kennedy, Jr., W. L. Templeton, R. A. Peloquin,</i> <i>J. K. Soldat, and L. K. Grove</i>	3
Public Dose Evaluation from Operating DOE Nuclear Facilities, <i>E. E. Hickey, K. A. Higley, and W. E. Kennedy, Jr.</i>	4
Atmospheric Emergency Consequence Assessment, <i>J. V. Ramsdell and W. D. McCormack</i>	4
Other Technical Assistance, <i>W. E. Kennedy, Jr., R. D. Stenner,</i> <i>J. K. Soldat, P. E. Bramson, and I. C. Nelson</i>	4
Environmental/Hazardous Waste Risk Assessment	5
Remedial Action Assessment System, <i>J. L. Buelt, G. Whelan,</i> <i>and J. G. Droppo, Jr.</i>	5
Development of the Multimedia Environmental Pollutant Assessment System (MEPAS) Methodology, <i>J. G. Droppo, Jr., D. L. Strenge,</i> <i>J. W. Buck, B. L. Hoopes, G. Whelan, and M. B. Walter</i>	6
Environmental Guidance Technical Support Project	9
Analysis and Investigation of Environmental Policy and Guidance Issues, <i>J. F. Keller, D. M. Beck, R. E. Gephart, R. S. Myers,</i> <i>and M. B. Triplett</i>	9
Reviewing Key Environmental Regulations and Associated Documents, <i>J. F. Keller, M. R. Siegel, and R. D. Stenner</i>	10
Environmental Compliance Technical Support Project	11
Development of Compliance Methodologies and Supporting Technical Analyses, <i>J. F. Keller, C. A. Geffen, R. E. Gephart, E. E. Hickey</i> <i>K. H. Humphries, M. R. Siegel, S. J. Veitenheimer, W. K. Waller, and M. G. Woodruff</i>	11
Reviewing Key DOE Compliance and Policy Documents, <i>J. F. Keller, R. M. Smith,</i> <i>R. E. Gephart, T. L. Stewart, W. E. Kennedy, Jr., M. R. Siegel, T. D. Van Epp,</i> <i>S. J. Giarti, J. A. Van Deven, G. M. Kelly, R. Rodensky, and J. D. Longstreth</i>	12
Long-Range Planning and Assistance, <i>R. G. Schreckhise</i>	12
Long-Range Planning Assistance	13
Technical Evaluation, <i>R. G. Schreckhise, T. L. Anderson, D. A. Baker,</i> <i>D. P. Higby, B. V. Johnston, D. A. Lamar, D. A. McNeill, M. L. Rosbach,</i> <i>D. R. Simpson, R. D. Stenner, L. M. Valdez, and M. G. Woodruff</i>	13

National Environmental Policy Act Assistance	15
Interpretation and Enforcement of NEPA Regulations	15
NEPA Policy Development	15
Deputy Assistant Secretary for Safety, Health, and Quality Assurance	17
Neutron Dosimetry Evaluation and Upgrade	19
Field Neutron Spectrometer, <i>L. W. Brackenbush, R. I. Scherpelz, and J. L. Thorngate</i>	19
Combination Thermoluminescent/Track-Etch Dosimeter, <i>M. A. Parkhurst and D. E. Hankins</i>	20
Total Dose Meter, <i>L. W. Brackenbush</i>	20
Effective Dose Equivalent Task, <i>J. E. Tanner, R. J. Traub, and J. F. DiCello</i>	20
Optically Stimulated Luminescence, <i>S. D. Miller</i>	21
Superheated Drop Detector Evaluation, <i>D. R. Sisk, M. R. Tinker, and R. E. Apfel</i>	21
Beta Measurement Evaluation and Upgrade	23
Beta Dosimeter Development, <i>J. S. Durham, S. E. Merwin, G. G. Simons, and S. D. Miller</i>	23
Beta Survey Instrument Development, <i>D. R. Sisk and K. L. Swinth</i>	25
Beta Spectroscopy Instrument Development, <i>D. R. Sisk and K. L. Swinth</i>	25
Computational Studies, <i>R. E. Faw</i>	25
Health Physics Support and Assistance to the Department of Energy	27
Special Studies, <i>J. M. Selby and K. L. Swinth</i>	27
DOE 5480.11 Guidance, <i>J. M. Selby and K. L. Swinth</i>	29
Guidance for Implementation of DOE Orders for Internal Dosimetry, <i>J. M. Selby and D. R. Fisher</i>	29
Guidance for Implementation of DOE Orders for External Dosimetry, <i>L. G. Faust and J. E. Tanner</i>	30
Air Sampling and Monitoring Guidance, <i>T. P. Lynch</i>	30
Contamination Control Policy, <i>L. H. Munson</i>	30
Radiation Protection Review Program, <i>L. H. Munson</i>	31
Definitions from DOE Order 5480.11, <i>J. M. Selby and L. H. Munson</i>	31
Standards, <i>J. M. Selby</i>	31
Health Physics Guidance Documents, <i>K. L. Swinth</i>	32
Health Physics Review and Technical Assistance to OSPA, <i>J. M. Selby and L. H. Munson</i>	33
Laboratory Accreditation Support Program	35
Comprehensive DOELAP Objectives Plan, <i>J. M. Selby and J. C. McDonald</i>	35
External Dosimetry, <i>J. C. McDonald, N. E. Hertel, and R. Harty</i>	35
Calibration and Intercomparison, <i>J. C. McDonald, M. K. Murphy, J. F. DiCello, and H. E. Palmer</i>	36
Bioassay, <i>J. A. MacLellan, P. C. Olsen, and H. E. Palmer</i>	37
Instrumentation, <i>K. L. Swinth and J. M. Selby</i>	37
Internal and External Dosimetry Programs, <i>D. R. Fisher and J. C. McDonald</i>	37
Environmental Dosimetry Programs, <i>J. C. McDonald</i>	38

Internal Dosimetry Evaluation and Upgrade	39
Software Package for Occupational Internal Dosimetry, <i>J. R. Johnson, R. A. Peloquin, M. J. Sula, D. R. Fisher, and D. L. Strenge</i>	39
Ultrasound Measurement Techniques, <i>A. L. Anderson and D. Kruchten</i>	40
Internal Dosimeter Based on Optically Stimulated Luminescence, <i>S. D. Miller and J. S. Durham</i>	40
Correlation of Bioassay Data with Radionuclide Intake, <i>R. J. Traub and D. E. Bihl</i>	40
Low-Level Bioassay Measurements by Laser Spectroscopy, <i>G. K. Gerke and B. A. Bushaw</i>	41
 Radiation Protection Support to the Department of Energy for Technical Safety Appraisals	43
 Publications and Presentations	
Publications	45
Presentations	47
 Author Index	51
Distribution	Distr.1

Environment

Deputy Assistant Secretary for Environment

The U.S. Department of Energy (DOE) Deputy Assistant Secretary for Environment ensures that activities and installations of the DOE and its contractors are in full compliance with DOE environmental protection policies and applicable Federal, State, and local environmental standards and regulations. The Deputy Assistant Secretary for Environment provides technical support and oversight to DOE programs and ensures that all DOE-controlled activities are conducted in an environmentally responsible manner. Pacific Northwest Laboratory (PNL) has established the following six projects in support of the Deputy Assistant Secretary for Environment's mission:

- **Environmental Protection, Support, and Assistance**
- **Environmental/Hazardous Waste Risk Assessment**
- **Environmental Guidance Technical Support Project**
- **Environmental Compliance Technical Support Project**
- **National Environmental Policy Act Assistance**
- **Long-Range Planning Assistance.**

Environmental Protection, Support, and Assistance

Project Manager: *W. E. Kennedy, Jr.*

Pacific Northwest Laboratory (PNL) continued to provide technical assistance to the U.S. Department of Energy (DOE) Deputy Assistant Secretary for Environment through a project with the Office of Environmental Guidance and Compliance (OEG&C). Assistance from PNL included 1) technical support during the development of comments on proposed draft Environmental Protection Agency (EPA) revisions to the regulations implementing the Clean Air Act and regulations on the treatment, storage, and disposal of high-level and low-level radioactive waste, 2) the development and revision of draft technical requirements to support the revised DOE Orders concerning environmental protection, 3) development of draft annual summary reports containing the public radiation exposures for operating DOE facilities, 4) technical support during the development of a revised DOE Order for assessing atmospheric release consequences during emergencies at DOE nuclear facilities, and 5) additional support efforts concerning technical reviews and comments on draft public radiation exposure standards and regulations. The following subsections describe progress made during fiscal year 1989.

Technical Support During the Review of Proposed EPA Regulations

K. A. Higley,^(a) S. M. Neuder, I. C. Nelson, K. C. Rhoads, and W. E. Kennedy, Jr.

Proposed changes to environmental regulations implementing the Clean Air Act, regulating high-level radioactive waste disposal, and regulating low-level radioactive waste disposal are being developed by the EPA. These regulations can potentially have a major impact on the operation of DOE nuclear facilities. In response to EPA requests for comments, DOE OEG&C coordinated the development of comments on these draft regulations by establishing DOE Headquarters Steering Groups and Technical Resource Groups consisting of contractor technical representatives. To further support DOE in this effort, PNL assigned two staff members through the PNL Washington, D.C. Office as part of this project. The two staff members, K. A. Higley and S. M. Neuder, were able to provide daily support in the development and review of the comments from the DOE Operations and Programs Office representatives. The technical comments included information on the potential economic costs of alternative radiation protection standards and estimates of the potential health impacts of the proposed regulations. The interaction of the DOE Steering Groups with the Technical Resource Groups provided technically

credible and detailed comments consistent with DOE policy. The resulting comments have been provided to EPA and are currently being considered through an open dialogue process.

Technical Support to Criteria Development

R. D. Stenner, K. A. Higley,^(a) W. E. Kennedy, Jr., W. L. Templeton, R. A. Peloquin, J. K. Soldat, and L. K. Grove

In support of DOE's development of the revised environmental radiological protection Order "Radiation Protection of the Public and the Environment," PNL staff continued to contribute by developing technical criteria in a number of areas. Some of these criteria are included as draft requirements or guidance for effluent monitoring and environmental surveillance in the draft revised DOE environmental Orders. The technical criteria are those identified in other DOE Orders (for consistency within the DOE system), those identified in other established or pending Federal regulations, or those from other sources that represent sound technical practice. PNL technical experts also produced draft technical documents providing guidance on 1) establishing environmental programs to maintain public radiation doses "As Low As Reasonably Achievable" (ALARA) and 2) determining the "Best Available Technology" (BAT) for treating liquid radioactive effluents. In addition, PNL technical experts participated in criteria development efforts with the International Atomic

(a) Current address: Department of Radiology and Radiation Biology, Colorado State University, Fort Collins, CO 80523.

Energy Agency (IAEA) concerning 1) model validation studies using the Chernobyl data, 2) the estimation of radiation doses to biota from radioactive effluents from operating nuclear facilities, and 3) the determination of exempt quantities for recycle or reuse of slightly radioactive materials recovered from operating nuclear facilities. These international support efforts will continue through 1990.

Public Dose Evaluation from Operating DOE Nuclear Facilities

E. E. Hickey, K. A. Higley, and W. E. Kennedy, Jr.

Draft summaries of the reported public radiation doses from operating DOE nuclear facilities for the years 1984 through 1987 were prepared. The information included the reported maximum individual and population doses from 29 operating DOE nuclear sites. The reports also contain a summary of the quantities of radioactive materials, by radionuclide, released from different types of DOE facilities. This information will be completed during 1990 with the publication of the 1987 summary report. Summary papers on public exposures from DOE facilities were presented at the annual meeting of the American Nuclear Society and the annual meeting of the Health Physics Society (Kennedy and Hickey 1989; Hickey and Kennedy 1989). The papers contained information about the current levels of effluents and population dose impacts, and included information concerning the trends of these data over the last several years. Additional efforts to prepare annual dose summary reports, expanded to include the summary information on the nonradioactive hazardous material effluents, will continue during 1990 under a separate OEG&C-sponsored program.

Atmospheric Emergency Consequence Assessment

J. V. Ramsdell and W. D. McCormack^(a)

Technical assistance was provided to DOE-HQ during the revision of the environmental consequence assessment methods supporting the DOE environmental emergency response Orders. The

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methods focus on meteorological monitoring and consequence prediction following accident situations that may result in releases of radioactive material to the atmosphere. This task includes an analysis of the impact of proposed EPA Protective Action Guides on the development of environmental emergency response plans for DOE facilities. Contributors from PNL worked closely with DOE representatives from three separate organizations in developing the review draft information. This task is scheduled to continue during 1990.

Other Technical Assistance

W. E. Kennedy, Jr., R. D. Stenner, J. K. Soldat, P. E. Bramson, and I. C. Nelson

Through a technical assistance task, PNL further supports OEG&C by providing rapid-turnaround technical responses or reviews to priority requests. These requests typically are in areas that fall outside the scope of the identified tasks but have an urgency to DOE and its operations. During 1989, these special assistance tasks included: 1) participation in a special group to develop a Data Verification Plan for DOE site environmental data as required by DOE Orders, 2) conducting comparative radiation dose assessments used to determine the potential impacts from selected historical DOE operations, 3) participation in a DOE working group to evaluate unrestricted release and recycle/reuse criteria, 4) support to individuals contributing to the development of a new lung model for the International Commission on Radiological Protection, and 5) preparation of review comments on various draft or final technical reports and standards from national and international authorities.

References

- Hickey, E. E., and W. E. Kennedy, Jr. 1989. "A Review of Environmental Radiological Data from U.S. Department of Energy Nuclear Sites." Paper presented at the Health Physics Society Annual Meeting, June 25-29, 1989, Albuquerque, New Mexico.
- Kennedy, W. E., Jr., and E. E. Hickey. 1989. "Estimated Collective Exposures from U.S. Department of Energy Operations." Paper presented at the American Nuclear Society Annual Meeting, June 4-8, 1989, Atlanta, Georgia.

Environmental/Hazardous Waste Risk Assessment

Project Manager: *J. G. Droppo, Jr.*

Pacific Northwest Laboratory (PNL) continues to provide technical guidance and support to the U.S. Department of Energy (DOE) in the environmental/hazardous waste risk assessment area. During fiscal year (FY) 1989, PNL worked with the Office of Environmental Audit (OEA) in the area of environmental risk assessment, surveys, and evaluations of environmental problems related to hazardous and radioactive materials. The overall objective of PNL's efforts was to assist DOE in developing technical methods in support of guidance for its operations and to ensure compliance of these operations with applicable environmental regulations and standards. Major efforts during FY 1989 included the completion of the documentation of the Multimedia Environmental Survey, and technical support to the DOE Environmental Survey.

Remedial Action Assessment System

J. L. Buel, G. Whelan, and J. G. Droppo, Jr.

The Remedial Action Assessment System (RAAS) is being developed to help meet the requirements of the Remedial Investigation/Feasibility Study (RI/FS) process required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). RAAS will be a computer-based methodology that mimics Phases I and II of the feasibility study. It will screen established technologies for the remediation of waste sites and link them into remedial alternatives for individual waste sites (operable units). The methodology will then evaluate the various remedial alternatives on the basis of effectiveness, implementation, capability, and cost.

The objective of the RAAS project in FY 1989 was to initiate the development of the RAAS methodology by 1) initiating the development of a database that correlates waste and site characteristics with selected treatment processes from past feasibility studies, and 2) developing a limited demonstration model of the methodology. The results of each of these efforts are summarized below.

The review of past feasibility studies was conducted to identify those remedial alternatives that are currently being suggested as acceptable options for cleaning up waste sites. The information from the reviews is collected in a format designed to condense the information that is relevant to the RAAS methodology as follows:

- **Background Information on the Site** - This section provides historical background for the waste site.
- **Overview of Suggested Treatment Technologies** - This section identifies the unit processes initially considered for the cleanup action at the site.
- **Environmental and Contaminant Information** - This section documents the primary constituents of interest, which determine the type of remedial alternatives being considered for cleaning up the waste site.
- **Summary of Suggested Remedial Alternatives** - This section presents the remedial alternatives that were considered during the final review process and identifies the alternative that was finally suggested for cleaning up the site.

Eight feasibility studies were reviewed and condensed in this format. The reviews covered various site conditions including contaminated soils, sediments, groundwater, and surface water. Contaminants included a host of organic compounds and heavy metals. Remediation technologies identified in the review include biological treatment, such as biotreatment of groundwaters; chemical treatment, such as organic destruction by potassium hydroxide and polyethylene glycols; physical treatment, such as the introduction of slurry walls for groundwater diversion; and thermal treatment, such as rotary kiln incineration. The results of these studies help define the magnitude of the RAAS

development activity and provide an initial suite of technologies with which to begin prototype development.

A demonstration model using one technology for one set of waste conditions was received from PNL's subcontractor, Utah State University. The demonstration model provides an example of how a portion of the RAAS methodology will be used. It asks the user for the type and concentration of contaminant at the waste site and for some operational parameters. The demonstration model then calculates the time and cost necessary to complete the remediation to the desired cleanup condition. This model will be extremely useful in defining the parameters for the object-oriented modules that will be developed for the RAAS methodology to describe individual technology behavior. During FY 1990, technical activities will include 1) organizing and convening an external oversight committee, which will provide feedback and guidance on the RAAS development activities, 2) providing a graphic description of computer modules and logical interconnections of the RAAS methodology, 3) developing a comprehensive list of technologies to be included in the RAAS methodology, 4) completing the first phase technology database, 5) completing the development of object-oriented modules for one treatment technology and one disposal technology, 6) completing development of the first prototype module for acquiring specific operable unit data from the user, and 7) completing the development of a technology database access program.

Development of the Multimedia Environmental Pollutant Assessment System (MEPAS) Methodology

J. G. Droppo, Jr., D. L. Strenge, J. W. Buck, B. L. Hoopes, G. Whelan, and M. B. Walter

The Multimedia Environmental Pollutant Assessment System (MEPAS) is a methodology for assessing relative health impacts from the release of hazardous chemical and radioactive materials. MEPAS is an enhanced version of the Remedial Action Priority System (RAPS), which was expanded in 1987 to meet the needs of the environmental survey for a ranking tool that could evaluate active as well as inactive sites.

MEPAS uses environmental contaminant concentrations to estimate potential health impacts based

on an assessment of major pathways. The health impacts provide a metric for ranking and screening applications. Concentrations may either be entered as model inputs or computed using MEPAS transport pathway evaluation components. MEPAS mathematical pathway algorithms are based on standard modeling approaches such as recommended by the U.S. Environmental Protection Agency (EPA 1988). These components use site-specific characteristics to estimate both emission and contaminant migration from a site to receptors. Groundwater, overland, surface water, and atmospheric pathway components are used to simulate multimedia contaminant migration.

The first operational integrated MEPAS code was delivered to DOE in September 1987. The results of a preliminary prioritization effort for 16 DOE defense program sites using this first version was released in 1988 (DOE 1988). The second version of MEPAS code with a user-friendly interface (MEPAS shell) was delivered to DOE in September 1988. All versions of MEPAS are implemented for operation on a personal computer. The MEPAS shell guides the user in problem definition, data collection and entry, data review and documentation, and running applications.

Technical support was provided in FY 1989 for the application of MEPAS to 18 additional DOE facilities. During the year, PNL provided updates to the MEPAS code and databases as needed.

The major effort in FY 1989 was the preparation of MEPAS documentation. This documentation consists of seven reports, including a supplemental formulation, a constituent database report,^(a) a testing results report, a user's guide, a report containing guidelines for MEPAS applications,^(b) and input parameter guidance report.^(c)

(a) Droppo, J. G., G. Whelan, J. W. Buck, D. L. Strenge, B. L. Hoopes, and M. B. Walter. 1989. *Supplemental Mathematical Formulations: The Multimedia Environmental Pollutant Assessment System (MEPAS)*. Pacific Northwest Laboratory, Richland, Washington. (Draft)

(b) Droppo, J. G., D. L. Strenge, J. W. Buck, B. L. Hoopes, R. D. Brockhaus, M. B. Walter, and G. Whelan. 1989. *Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance Volume 1 - User's Guide*. Pacific Northwest Laboratory, Richland, Washington. (Draft)

(c) Droppo, J. G., D. L. Strenge, J. W. Buck, B. L. Hoopes, and G. Whelan. 1989. *Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance Volume 2 - Guidelines for Evaluating MEPAS Input Parameters*. Pacific Northwest Laboratory, Richland, Washington. (Draft)

The supplemental formulation report documents the MEPAS updates to the original RAPS formulation report (Whelan et al. 1987). Enhancements to the groundwater, surface water, overland, atmospheric, and exposure components are documented. These enhancements include a revision of the integration method for the waterborne pathway, a wetland component, a gaseous emission (volatilization) component, an atmospheric complex terrain component, mass budget formulations, and environmental decay. Several new exposure components are described along with enhancements to the exposure pathways computations.

To assure consistency in the environmental survey application to DOE sites, a MEPAS constituent database was used to define values of physical, chemical, and toxicological parameters at all sites. The constituent database report was written to document magnitudes and sources of these data. Currently, 394 chemicals are contained in this database.

A sensitivity study on the September 1988 version of the MEPAS code was conducted during FY 1989. A draft report is to be submitted to DOE in FY 1990. This study will quantify the sensitivity of MEPAS output ranking parameter values to variations in the input parameters.

During FY 1990, PNL will provide technical assistance in external reviews of the RAPS/MEPAS methodology. PNL will also provide assistance to DOE in the completion of the Environmental Survey Final Summary Report.

References

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Public Law 96-510, December 11, 1980. 94 Stat. 2767:42 USC 9601 et seq., as amended.

U.S. Department of Energy (DOE). 1988. *Environmental Survey Preliminary Summary Report of the Defense Production Facilities*. DOE/EH-0072, U.S. Department of Energy, Environment, Safety, and Health, Office of Environmental Audit, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1988. *Superfund Exposure Assessment Manual*. OSWER Directive 9285.5-1, Office of Remedial Response, Office of Solid Waste and Emergency Response, Washington, D.C.

Whelan, G., D. L. Strenge, J. G. Droppo, Jr., and B. L. Steelman. 1987. *The Remedial Action Priority System (RAPS): Mathematical Formulations*. PNL-6200, Pacific Northwest Laboratory, Richland, Washington.

Environmental Guidance Technical Support Project

Project Manager: *J. F. Keller*

The Environmental Guidance Technical Support Project provides technical assistance to the U.S. Department of Energy's (DOE's) Environmental Guidance Division (EGD) in fulfilling its responsibilities for providing guidance and policy information to the DOE complex. This project is currently focused on the complicated regulatory requirements for managing hazardous and radioactive mixed wastes, and also supports other environmental regulatory compliance activities.

Under this project, Pacific Northwest Laboratory (PNL) assists DOE in assessing the policy needs and developing the necessary guidance and policies to ensure that DOE's facilities are operated in a manner that protects human health and the environment. PNL provides support in the following areas: 1) identifying and prioritizing issues requiring guidance or policy statements; 2) focusing on and assessing specific policy needs and issues; 3) developing guidance manuals, workshops, and reports in support of DOE policies; 4) investigating environmental policy and guidance issues; 5) providing critical analyses of guidance and policy documents important to DOE's environmental activities; 6) analyzing and reviewing federal, state, and local regulations and guidance; and 7) providing recommendations and alternatives regarding environmental guidance activities. EGD has requested a continuation of the current support. Progress made on this project during fiscal year (FY) 1989 is discussed in the following subsections.

Analysis and Investigation of Environmental Policy and Guidance Issues

*J. F. Keller, D. M. Beck, R. E. Gephart,
R. S. Myers, and M. B. Triplett*

Technical highlights during FY 1989 included analyzing and investigating environmental policy and guidance issues. For example, based on U.S. Environmental Protection Agency (EPA) guidance for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA 1980) process, PNL developed guidance information on the Remedial Investigation/Feasibility Study (RI/FS) and Record of Decision process. Information on schedules, critical path, and costs for reaching a Record of Decision at DOE sites was prepared. This information has been used by the DOE field offices in their planning activities.

PNL and its subcontractor CH2M Hill are also assisting DOE in developing an outline of the implementation issues, questions, and processes involved in using the "observational approach" for site remediation at DOE hazardous and radioactive mixed waste sites. As being developed, the observational approach is a method for achieving site remediation that will favor action over study and that will incorporate an explicit recognition of the

uncertainties associated with site characterization and the implementation of a remedial alternative. During FY 1989, several workshops were held with DOE, subcontractors, and PNL staff for a panel review of the observational approach to identify benefits and its primary implementation issues. Subsequently, primary implementation issues were discussed and work was initiated to develop a formal presentation on this approach to site remediation to be given to DOE-Headquarters (HQ) program managers. Using the contingency planning elements of the observational approach, DOE may streamline the RI/FS process.

Efforts during FY 1989 also included the development of guidance and model language to assist DOE facilities in preparing treatment variance petitions for relief from Land Disposal Restriction (LDR) treatment standards for radioactive mixed wastes. PNL (and CH2M Hill) submitted a draft guidance document to DOE summarizing the LDR standards to provide a context for the treatability variance. Guidance was provided on information to be gathered, evaluation criteria, and the format for the variance petition. This guidance manual will be used by DOE-HQ and the field offices in preparing treatment variance petitions for approval by EPA.

PNL also assisted in the preparation of a report on DOE's LDR compliance strategy for mixed-waste

operations (DOE 1989). Several data packages were prepared to support the Best Demonstrated Available Technology (BDAT) determinations made by EPA. As a result of this and other activities, EPA has granted a 2-year national capacity variance for some radioactive mixed wastes.

Working closely with DOE-HQ staff, PNL (and CH2M Hill) assisted in planning, organizing, and conducting a 2-day Resource Conservation and Recovery Act (RCRA 1976) closure workshop. The workshop was designed to present DOE and DOE-contractor personnel with information regarding EPA's current regulations, policies, and approaches to the closing of RCRA regulated facilities, and to assist the DOE in setting priorities for topics to be included in the DOE guidance manual on RCRA closure. PNL has also assisted in the preparation of the comprehensive guidance manual, tailored to DOE's activities and needs. This manual is expected to be finalized in February 1990 and will be used to guide field offices in their closure activities.

Project staff (PNL and ICF, Inc.) also supported DOE in its development of a guidance manual on implementing a DOE community relations program under Superfund Amendments and Reauthorization Act of 1986 (SARA), as required by the National Contingency Plan (NCP; FR 50[224] 47933-47934, 47973). As part of this support, two workshops were planned on community relations and public involvement. The workshops provided participants with an understanding of DOE's philosophy and policies related to community relations/public involvement; an overview of the community relations/public involvement requirements; identification of successful strategies and "lessons learned" for implementing community relations/public involvement programs; and development of information networks for individuals responsible for implementing DOE community relations/public involvement programs.

Reviewing Key Environmental Regulations and Associated Documents

J. F. Keller, M. R. Siegel, and R. D. Stenner

PNL conducted a comparative review of the revised Hazard Ranking System (HRS), as

presented in the 53 FR (247) 511962-52081, and the original HRS. The purpose of this review was to identify the differences between the two systems and provide insight into the potential impacts on DOE that may be associated with the revised HRS. PNL also reviewed and commented on EPA's *Field Test of the Proposed Revised Hazard Ranking System (HRS)* report (EPA 1989).

References

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Public Law 96-510, December 11, 1980. 94 Stat. 2767; 42 USC 9601 et seq., as amended.

Resource Conservation Recovery Act (RCRA) of 1976. Public Law 94-580, October 31, 1976; 90 Stat. 95, 42 USC 6901 et seq., as amended.

Superfund Amendments and Reauthorization Act (SARA) of 1986. Public Law 99-499, October 17, 1986; 100 STAT. 1613, Title 10 §12701 et seq.

U.S. Department of Energy (DOE) 1989. DOE Land Disposal Restrictions Strategy Report for Radioactive Mixed Waste. DOE/EH-231, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1989. Field Test of the Proposed Revised Hazard Ranking System (HRS). Washington, D.C.

50 FR (224) 47933-47934, 47973. November 20, 1985. "National Oil and Hazardous Substances Pollution Contingency Plan." *Federal Register*.

53 FR (247) 51962-52081. December 23, 1988. "Hazard Ranking System (HRS) for Uncontrolled Hazardous Substance Releases: Appendix A of the National Oil and Hazardous Substances Contingency Plan." *Federal Register*.

Environmental Compliance Technical Support Project

Project Manager: *J. F. Keller*

The Environmental Compliance Technical Support Project provides technical assistance to the U.S. Department of Energy's (DOE's) Environmental Compliance Division (ECD) in fulfilling its oversight and technical assistance responsibilities to ensure that DOE facilities and operations are in compliance with DOE environmental Orders and other federal, state, and local environmental requirements. This project is currently focused on the complicated regulatory requirements for managing hazardous and radioactive-mixed wastes and also supports DOE's compliance activities with other environmental requirements. Under this project, Pacific Northwest Laboratory (PNL) assists DOE by providing technical support in two major areas: 1) technical support to DOE in developing compliance methodologies and the supporting technical analyses to be used by DOE for ensuring compliance and consistency across the DOE complex; and 2) technical support in reviewing and commenting on compliance and policy documents important to DOE's environmental activities. ECD has requested a continuation of the current support.

Progress made on this project during fiscal year (FY) 1989 is discussed in the following sections.

Development of Compliance Methodologies and Supporting Technical Analyses

J. F. Keller, C. A. Geffen, R. E. Gephart, E. E. Hickey, K. H. Humphries, M. R. Siegel, S. J. Veitenheimer, W. K. Waller, and M. G. Woodruff

Technical highlights during FY 1989 included analyzing and investigating environmental compliance. For example, PNL assisted the ECD in reviewing and summarizing current and prospective Resource Conservation and Recovery Act (RCRA) violations at the eight main field operations offices. Two types of violations were reviewed: 1) the violations identified and cited by Federal or State regulatory agencies, and 2) the potential RCRA violations that exist but have not been cited by regulatory agencies. As a result of this activity, current and prospective Clean Water Act, Clean Air Act, Safe Drinking Water Act, and Toxic Substances Control Act violations will be summarized.

Another major accomplishment during FY 1989 was PNL's development of a draft guidance manual for reviewing all RCRA and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA 1980) documentation submitted for ECD review. The manual provides guidance on the level of review and key elements to focus on from the ECD perspective. In addition to providing a mechanism for the consistent review

of RCRA and CERCLA documentation, the manual also provides a framework within which contractors can understand what ECD reviewers are looking for.

PNL conducted a comparative analysis of the three signed Federal Facility Agreements (FFA) entered into by DOE, EPA, and the respective states. The principal purpose of this analysis was to develop a report to serve as a guide to those preparing FFAs for other DOE facilities or for those responsible for reviewing those FFAs. By comparing the Lawrence Livermore National Laboratory, Monticello, and Hanford FFAs, the report also provides information on the similarities and differences in these agreements.

As required under DOE 5400.1 (DOE 1988a), each DOE site submits an environmental report each year. While the reports focus on environmental monitoring, other environmental program information is also included. Each year, DOE combines the data from the individual site reports to provide a summary of radionuclide emissions and radiation doses associated with DOE facilities. The focus in FY 1990 will be to expand the treatment of nonradiological emissions and to provide an indication of trends relating to DOE's environmental compliance activities. To support this need, PNL initiated work on summarizing the recommendations from the sites regarding format and usefulness of the reports, as well as developing options for displaying DOE-wide monitoring data.

PNL provided the Office of Environmental Guidance and Compliance (OEG&C), with follow-on support to the December 1988 report entitled, *Environment, Safety, and Health Needs of the U.S. Department of Energy* (DOE 1988b). Site-specific information packages detailing the information provided by the field offices in support of the "Needs" report were prepared. In addition, PNL reviewed and edited briefing packages relating to the report for OEG&C management, Defense Program management and staff, Congress, and others.

During FY 1989, PNL initiated work on developing a standard format of information to be reported monthly in order to adequately comply with the requirements of SEN-7-89, "Policy on Line Management's Responsibility to Achieve Environmental Compliance" (DOE 1989). A set of monthly reports provided by DOE-HQ will be used to compile the compliance items that should be included in the standard format. Examples of items to be included are issues associated with unplanned releases and reportable quantities, audit/appraisal findings, grey areas in interpreting the regulations, and permit violations, lawsuits, and management/operator performance. This standard format will facilitate the ease and consistency of reporting and review.

PNL also provided a comparative analysis of the CERCLA Remedial Investigation/Feasibility Study (RI/FS) to RCRA Remedial Feasibility Investigation/Corrective Measures Study (RFI/CMS) requirements. This review helped determine which requirements to follow during the review of compliance documents that subsequently satisfy both RCRA and CERCLA.

PNL developed a system for tracking ECD reviews of the various compliance reports. PNL also provided direct staff support to the OEG&C to assist in the editing/writing needs of DOE-HQ staff, and to provide liaison with PNL Richland staff in the review of compliance and guidance documentation.

Reviewing Key DOE Compliance and Policy Documents

J. F. Keller, R. M. Smith, R. E. Gephart, T. L. Stewart, W. E. Kennedy, Jr., M. R. Siegel, T. D. Van Epp, S. J. Gianti, J. A. Van Deven (CH2M Hill); G. M. Kelly, R. Rodensky, and J. D. Longstreth (ICF, Inc.)

PNL reviewed and commented on approximately 25 compliance reports written in accordance with RCRA and CERCLA requirements. These reports included the Waste Isolation Pilot Project (WIPP) no-migration petition, CERCLA documentation for the Weldon Spring Remedial Action Project, CERCLA and RCRA documentation for the Mound Laboratory, and RCRA documentation for the Rocky Flats Plant.

Long-Range Planning and Assistance

R. G. Schreckhise

In addition to the previously cited FY 1989 accomplishments, PNL's long-range planning assistance activities were reassigned in June 1989 to be conducted as part of the Environmental Compliance Technical Support Project for the remainder of FY 1989 and in future years. (See the Long-Range Planning Assistance section of this report.)

References

U.S. Department of Energy (DOE). 1988a. *General Environmental Protection Program*. DOE 5400.1, Washington, D.C.

U.S. Department of Energy (DOE). 1988b. *Environment, Safety, and Health Needs of the U.S. Department of Energy, Vol 1: Assessment of Needs; Vol 2: Site Summaries*, DOE/EH-0079, Washington, D.C.

U.S. Department of Energy (DOE). 1989. *Policy on Line Management's Responsibility to Achieve Environmental Compliance*. SEN-7-89, Washington, D.C.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Public Law 96-510, December 11, 1980; 94 Stat. 2767:42 USC 9601 et seq., as amended.

Resource Conservation Recovery Act (RCRA) of 1976. Public Law 94-580, October 31, 1976; 90 Stat. 95, 42 USC 6901 et seq., as amended.

Long-Range Planning Assistance

Project Manager: R. G. Schreckhise

Pacific Northwest Laboratory (PNL) continued to provide technical assistance to the U.S. Department of Energy (DOE) Headquarter's Environment, Safety, and Health (EH) organization. During late fiscal year (FY) 1988 and early FY 1989, PNL, along with Argonne National Laboratory (ANL), provided technical support to EH during the development of a DOE report entitled, *Environment, Safety and Health Needs of the U.S. Department of Energy* (DOE 1988). The PNL staff were primarily responsible for developing the database and compiling and evaluating the projected resource needs provided by the 49 different DOE sites, facilities, and/or operations. PNL staff analyzed the projected resource needs information and associated documents provided by the field operations and developed supporting materials to be used by EH for Congressional briefings and hearings. The purpose of the study was to help EH identify and assess the activities and projected resources that will be needed by all the DOE sites, facilities, and/or operations to achieve and maintain compliance with all applicable environmental, safety, and health-related rules and regulations. The various ongoing functions that were associated with this project were transferred to the EH Environmental Compliance project during FY 1989. Technical assistance provided during FY 1989 is described below.

Technical Evaluation

R. G. Schreckhise, T. L. Anderson, D. A. Baker,
D. P. Higby, B. V. Johnston, D. A. Lamar,
D. A. McNeill, M. L. Rosbach, D. R. Simpson,
R. D. Stenner, L. M. Valdez, and M. G. Woodruff

Pacific Northwest Laboratory, along with personnel from ANL, provided technical support to DOE during preparation of the December 1988 two-volume report entitled, *Environment, Safety, and Health Needs of the U.S. Department of Energy* (DOE 1988). PNL had lead responsibility for:

- developing Volume 2 (*Site Summaries*) of the report
- developing the database system used to summarize the projected needs of the 49 different DOE sites facilities and/or operations
- sharing editorial support with ANL for Volume 1 (*Assessment of Needs*).

Following publication of the report, PNL continued to provide technical support by:

- analyzing the data and associated documents provided by the field to prepare supporting information

- providing editorial support
- helping to prepare segments of Congressional briefing and hearing packages
- providing technical, editorial, and word processing support during the preparation of briefing packages that outline the mission, history, and pertinent environmental compliance concern at 17 DOE sites and facilities
- providing a comparison of the results of the Needs Assessment and the Five-Year Plan reports (DOE 1988; 1989).

References

U.S. Department of Energy (DOE). 1988. *Environment, Safety, and Health Needs of the U.S. Department of Energy, Vol 1: Assessment of Needs; Vol 2: Site Summaries*, DOE/EH-0079, Washington, D.C.

U.S. Department of Energy (DOE). 1989. *Environmental Restoration and Waste Management Five-Year Plan*. DOE/S-0070, Washington, D.C.

National Environmental Policy Act Assistance

Project Managers: *D. G. Huizenga and T. L. Anderson*

The National Environmental Policy Act (NEPA) Assistance Project provides onsite technical support for several major projects being reviewed by the Department of Energy's (DOE's) Office of NEPA Project Assistance. The projects currently under review are supported by several DOE Offices, such as Defense Programs, Environmental Restoration and Waste Management, Nuclear Energy, Radioactive Waste Management, New Production Reactors, and other agencies, such as the U.S. Department of Defense, and National Aeronautics and Space Administration. The projects include the Waste Isolation Pilot Project in Carlsbad, New Mexico; the Plutonium Recovery Modification Project at Rocky Flats, Colorado; the Special Nuclear Materials Research and Development Laboratory at Los Alamos National Laboratory; the Engineering Demonstration System for the Special Isotope Separation Project (SIS) at Lawrence Livermore National Laboratories; the Galileo Mission to Jupiter, launched in the fall of 1989; the testing of Army Depleted Uranium Munitions at the Nevada Test Site; the Advanced Photon Source at Argonne National Laboratory; the New Production Reactor Project; the Uranium Atomic Vapor Laser Isotope Separation (AVLIS) Project; and several other projects supporting the DOE plan to modernize the nuclear weapons production complex.

More specifically, tasks include 1) providing guidance to DOE Program and Field Office personnel regarding the interpretation and implementation of the regulations for implementing the procedural provisions of NEPA, and 2) development of overall NEPA policy and guidance. The scope of Pacific Northwest Laboratory's (PNL's) support continues to expand to include an even broader range of projects such as technical support to the NEPA activities of the DOE Tiger Teams. Project staff will assist DOE in the formulation of new policies that will be necessary to implement the recent decision, by the Secretary of Energy, to prioritize Environment, Safety, and Health over production of nuclear materials. Progress made on the two tasks during fiscal year (FY) 1989 is discussed in the following subsections.

Interpretation and Enforcement of NEPA Regulations

During FY 1989, PNL continued to provide guidance to DOE Headquarters and Field Office personnel to better interpret and enforce regulations for implementing NEPA. Guidance is based on regulations issued by the Council on Environmental Quality, 40 CFR 1500-1508 (as amended), the DOE NEPA guidelines, 52 FR 47662-47670, and legal case history. The project staff work closely with personnel in the Office of General Counsel, Office of Safety, Health, and Quality Assurance, Office of Environmental Guidance and Compliance, and in some instances the Secretary's Tiger Teams to ensure that all applicable federal, state, and local regulations are adequately addressed in the NEPA documentation.

NEPA Policy Development

In addition to providing technical input to specific projects, PNL staff support the development of DOE NEPA policy. Recent FY 1989 efforts in this

area include: 1) developing a strategy to interface the requirements of NEPA, the Resource Conservation and Recovery Act, the Comprehensive Environmental Response, Compensation, and Liability Act, and the Superfund Amendments and Reauthorization Act; 2) issuing guidance on the treatment of occupational impacts in DOE's NEPA documents; 3) developing guidance regarding the treatment of accident analysis; and 4) establishing the role of DOE in National Aeronautics and Space Administration missions using DOE-manufactured radioisotope thermoelectric heaters and generators.

The support efforts of staff involved on this project will continue to be needed by DOE for the foreseeable future. With the added emphasis and priority established by the Secretary of Energy for NEPA compliance, the importance and visibility of PNL's support has and will continue to increase. The Office of NEPA Project Assistance is currently expecting the support of two full-time employees during FY 1990.

References

40 CFR 1500-1517. 1985. Council on Environmental Quality, Executive Office of the President, "Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act." U.S. Code of Federal Regulations.

52 FR 47662-47670. December 15, 1987. U.S. Department of Energy, "Compliance with the National Environmental Policy Act (NEPA); Amendments to the DOE NEPA Guidelines." *Federal Register*.

**Safety, Health
and Quality
Assurance**

Deputy Assistant Secretary for Safety, Health, and Quality Assurance

To establish and maintain an effective radiation protection program, the U.S. Department of Energy (DOE) Deputy Assistant Secretary for Safety, Health, and Quality Assurance has assigned to the Office of Safety Compliance (OSC) and the Office of Safety Policy and Standards (OSPS) the responsibility for developing an effective applied research and development program and developing and promulgating nuclear safety policy, standards, and guidance. These offices are also responsible for the conduct of DOE-wide independent overview, support, and counsel in radiation protection. The objectives of these programs are to aid DOE in ensuring that the activities of DOE and its contractors are in full compliance with applicable nuclear safety, health, and emergency preparedness standards and regulations, and to provide technical support to the DOE Assistant Secretary for Environment, Safety, and Health. To accomplish this, Pacific Northwest Laboratory (PNL) was established as a lead laboratory in health physics to conduct the following six projects to assist DOE in achieving its radiation protection mission:

- **Neutron Dosimetry Evaluation and Upgrade**
- **Beta Measurement Evaluation and Upgrade**
- **Health Physics Support and Assistance to the Department of Energy**
- **Laboratory Accreditation Support Program**
- **Internal Dosimetry Evaluation and Upgrade**
- **Radiation Protection Support to the Department of Energy for Technical Safety Appraisals.**

Neutron Dosimetry Evaluation and Upgrade

Project Managers: *L. G. Faust and C. M. Stroud*

The U.S. Department of Energy (DOE) Neutron Dosimetry Evaluation and Upgrade Project has two primary objectives: 1) to assess current personnel neutron dosimeter capabilities, and 2) to develop improved personnel neutron dosimeters and instrument systems. The project provides DOE with an assessment of the current status of personnel neutron dosimetry capabilities at DOE facilities, develops improved near-term personnel neutron dosimetry techniques, and develops concepts with the potential for a significant technical breakthrough in state-of-the-art personnel neutron dosimetry and instrumentation. Technology transfer meetings and workshops are conducted to make any advances available to DOE contractors and private industry. Research and development activities are conducted at Pacific Northwest Laboratory (PNL) and several supporting DOE laboratories, universities, and private companies in order to involve the expertise of the most appropriate organizations and individuals on the task of improving operational neutron dosimetry and radiation protection in the field.

The project has identified significant problems in the field determination of personnel neutron dose and dose equivalent and in the ability to comply with applicable DOE Orders and regulations. Where appropriate, improved dosimetry techniques are developed for implementation at DOE facilities. The following subsections describe progress made during fiscal-year (FY) 1989 on selected tasks.

Field Neutron Spectrometer

*L. W. Brackenbush, R. I. Scherpelz, and
J. L. Thorngate (LLNL)*

About 50,000 workers at DOE facilities have a potential for exposure to neutrons. Because all existing neutron personnel dosimeters and survey instruments have an energy dependence, it is desirable to know the neutron energy spectrum. Both PNL and Lawrence Livermore National Laboratory (LLNL) are developing portable neutron spectrometers to measure the neutron energy spectrum in the workplace so that the various neutron dosimeters used at DOE facilities can be more accurately interpreted.

The existing field neutron spectrometer developed at PNL was designed to measure neutrons with energies below 5 MeV, which is adequate for plutonium workers. A number of DOE contractors have expressed interest in spectral measurements made with a highly portable spectrometer, such as the PNL field spectrometer. During FY 1989, the technology was transferred to private industry to produce a "suitcase" spectrometer incorporating many of the improvements suggested by field testing. The most significant of these is the addition of

uninterruptible power supplies, so that data will not be lost in the event of power line transients. Because of delays in obtaining capital funding during FY 1989, the improved field spectrometer has not been tested yet. A second improvement made during FY 1989 was the addition of a multisphere spectrometer to the field spectrometer. The use of the multisphere allows for rapid and accurate determination of neutron spectra. During FY 1990, the range of the field spectrometer will be extended to about 100 MeV, so that it can be used at DOE high-energy accelerator facilities.

Work at LLNL has progressed on developing a truly portable, battery-operated spectrometer based on a liquid scintillator. During FY 1989, a pulse shape discriminator circuit was designed and tested. This design functions over a wider range of pulse heights than most commercially available units, which are much larger and consume significantly more power. A green light pulser was developed and tested. With this light pulser, it is possible to calibrate the system and eliminate the need for radioactive calibration sources, which pose a problem for transport and use. During FY 1990, work will continue on integrating the breadboarded circuits into a practical, battery-powered instrument.

Combination Thermoluminescent/ Track-Etch Dosimeter

M. A. Parkhurst and D. E. Hankins

The main tasks under this project during FY 1989 were: 1) improving the response of the track detector component of the combination dosimeter to the low-energy range of fast neutrons, 2) reducing its angular dependence of detector response through the development of a new badge holder design, and 3) completing an automated readout system that is capable of providing track size distributions from track detectors. Radiators for track detectors that use various boron concentrations were fabricated by the University of Connecticut to determine the optimum boron concentration for improving neutron track detector sensitivity in the energy range from 1 keV to 100 keV. These radiators were applied to the track detector surface and exposed to monoenergetic neutrons of various energies at PNL. The results show that the use of boron radiators greatly enhances the track detection capability of low-energy neutron interactions from thermal to 150 keV. Additionally, the presence of boron in the radiator does not appear to reduce the neutron response of the dosimeter to energies above 150 keV.

A dosimeter holder has been designed to reduce the effect of angular dependence associated with the current badge holders. A significant drop in the dosimeter response occurs as the exposure angle changes with incident angle. This new theoretical design consists of a hemisphere of polyethylene that has two track detectors placed at strategic angles to improve its interaction frequency with incoming neutrons. Computer modeling was used to identify the optimum placement of the track detectors within the hemisphere that best reduces the angular response of the dosimeter.

An automated readout system capable of providing track size distributions has been developed through a contract with LLNL. The instrumentation incorporated into the overall system includes a microscope, a programmable stage, and a sample feeder. The software, which is run by an AT-compatible computer, automatically counts the tracks from the processed samples and displays histograms of track size distributions. The track size analyses are used to identify possible exposure energies or sources and can also be used to identify background track anomalies.

Total Dose Meter

L. W. Brackenbush

During FY 1989, work progressed on improving the total dose meter to facilitate technology transfer. The total dose meter is one of the few instruments available that can determine the dose equivalent from any type of ionizing radiation, although it was primarily developed to measure the neutron dose accumulated by a radiation worker. Improvements included reducing the power consumption, so that the existing design only requires about 60% of the current of the original design. The microphonics of the detector were reduced by reversing the polarity of the high voltage on the detector. However, this created an unexpected problem with the failure of a transformer. A larger transformer has been tested and found to be satisfactory, but the larger size necessitated the redesign of the printed circuit boards. In the original design, it was found that the printed circuit boards were also microphonic, which contributed to noise in the electronic system. This was reduced by mounting the first stage of the pre-amplifier directly on the tissue-equivalent proportional counter (TEPC), which is shock-mounted to significantly reduce microphonic noise.

There has been some interest from commercial instrument manufacturers in the total dose meter concept. Two firms have signed nondisclosure agreements and may incorporate part of the total dose meter circuitry in their instruments.

Considerable interest in the total dose meter was developed by a modified version of the total dose meter being flown aboard the Space Shuttle by the National Aeronautics and Space Administration (NASA). The DOE program may benefit from some of the technology developed for NASA. It is expected that an improved instrument will be fabricated and tested during FY 1990 and that the technology will be transferred to private industry.

Effective Dose Equivalent Task

J. E. Tanner, R. J. Traub, and J. F. Dicello

In FY 1988, preliminary calculations of the effective dose equivalent for various incident neutron energies and geometries were completed. In FY 1989, these calculations were further refined and tested. As computer space and speed became less of a constraint, computer models of the

female and male phantoms were expanded to include more detailed anatomical descriptions. A more complete system of mathematical phantom models, based on the MIRD-V phantom,^(a) was developed at Oak Ridge National Laboratory (ORNL) and consists of a newborn, 1-year-old, 5-year-old, 10-year-old, 15-year-old, and full-grown adult. The ORNL system of phantom models was implemented on the computer for future calculations of the sensitivity of effective dose equivalent to phantom size and possibly to differences occurring in pregnant female radiation workers.

The quality factors used to estimate the organ dose equivalents from the neutron fluence incident upon organs estimated by the transport calculations were also updated. The quality factors now reflect the actual quality of the radiation at the organ rather than a position of a dose equivalent maximum. The transport calculations were tested by comparing organ dose calculations using Version 3 of the Monte Carlo Code for Neutron and Photon Transport (MCNP) on the Hewlett Packard-9000 computer and MCNP Version 3A and 3B on the Hanford Cray computer. The comparisons indicated that differences exist between Versions 3 and 3B of the code, primarily in the treatment of thermal neutrons, given the same input to the code. These differences were resolved by appropriate changes to the input data.

Because consistency between calculated and measured neutron dose equivalent rates is essential, a set of experiments was initiated to verify the MCNP calculations. The first verification experiment included a comparison of the calculated and measured neutron dose equivalent rates from bare ²⁵²Cf at depth within a cylindrical phantom of A-150 tissue-equivalent plastic. The second experiment involved the comparison of measured dose equivalents from a ⁶⁰Co source in a Rando® phantom with the calculated dose equivalent in the MIRD-5 phantom. The verifying measurements for these experiments were conducted with thermoluminescent dosimeters, CR-39 dosimeters, and TEPCs.

(a) MIRD = Medical Internal Radiation Dose Committee.

® Rando is a registered trademark of Alderson Research Laboratories, Inc., Stamford, Connecticut.

Optically Stimulated Luminescence

S. D. Miller

During FY 1989, work centered on the phenomenon known as M-center luminescence. A blue light laser, emitting at 442 nm, produces a red light emission in LiF single crystals that have been exposed to ionizing radiation. An M-center luminescence reader was completed during this fiscal year to specifically measure the light output that results when LiF is stimulated by a laser within this absorption band.

This dosimetry technique has advantages over current technologies. The M-center luminescence technique can be read out in a fraction of a second, which will allow for fast, cost-effective processing. Unlike conventional thermoluminescent techniques, the M-center luminescence technique does not require heating the material. The non-heating aspect will provide more accurate results with a longer dosimeter lifetime by eliminating thermal degradation. In addition, M-center luminescence is not erased significantly by the readout process. This allows for a repeat measurement, and provides the basis for a viable lifetime dosimeter. The M-center in LiF is very sensitive to thermal neutrons because lithium can be easily enriched in ⁶Li, thereby enhancing measurement sensitivity. Because this technique is so innovative, a DOE invention disclosure has been filed. This technique, which was demonstrated to be feasible this fiscal year, is now ready for development into a practical dosimetry system that promises to be extremely fast and cost-effective.

Superheated Drop Detector Evaluation

D. R. Sisk, M. R. Tinker, and R. E. Apfel (Apfel Enterprises, Inc.)

During FY 1989, the environmental sensitivity and radiation response of the latest configuration of the Superheated Drop Detector/Active Personnel Dosimeter (SDD/APD) was evaluated. The results of the evaluations were sent to Apfel Enterprises, Inc., for incorporation with Apfel's test results into a draft final report on the SDD/APD. The draft report was reviewed by PNL and returned to Apfel with comments. Apfel incorporated the comments by PNL into the draft and returned the draft to PNL for final review.

Beta Measurement Evaluation and Upgrade

Project Managers: *L. G. Faust and K. L. Swinth*

The Beta Measurement Evaluation and Upgrade Project is designed to provide continuing identification and resolution of significant problems that affect field measurement of beta dose and to ensure that U.S. Department of Energy (DOE) facilities can comply with applicable standards. The objective of this project is to investigate and upgrade beta radiation measurements by developing improved personnel beta dosimeters and instruments used in DOE facilities.

The work performed during fiscal year (FY) 1989 can be classified into four major areas: 1) dosimeter development, 2) survey instrument development, 3) spectrometer development, and 4) theoretical considerations. Progress made in these four areas during FY 1989 is discussed in the following subsections. Pacific Northwest Laboratory (PNL) staff and universities contributed to the total effort.

Beta Dosimeter Development

J. S. Durham, S. E. Merwin, G. G. Simons (KSU), and S. D. Miller

The objectives of this task are to identify and develop new and innovative beta dosimeters for assessing beta dose and for estimating beta spectra. Three types of dosimetry being further developed, tested, and evaluated are discussed in the following subsections.

Thermoluminescent Dosimetry

Personnel dosimetry that uses thin thermoluminescent chip technology can achieve an acceptable accuracy for determining shallow (7 mg/cm^2) dose from radiation fields with mixed energies and of mixed radiation types. This was shown during earlier laboratory evaluation of the thin (approximately 17 mg/cm^2) LiF chip backed by graphite, which was developed by Kansas State University (KSU) under subcontract to PNL. PNL evaluations have shown that, although thin dosimeters improve accuracy, there is a concomitant degradation in the lower detection level of the dosimeters. This is due to the decrease in sensitive volume of thermoluminescent dosimeter (TLD) material.

Studies have been performed at KSU to evaluate TLD materials and identify a material that will perform acceptably at low beta energies. Tests indicated that the sensitivity of an 11-mg/cm^2 TLD (LiF:Mg,Ti) has one forty-sixth of the sensitivity of a conventional 235-mg/cm^2 TLD when irradiated with ^{90}Y beta particles. KSU fabricated and tested a variety of state-of-the-art beta-particle

dosimeters, with each dosimeter containing a thin layer of either LiF, CaF_2 , or $\text{Li}_2\text{B}_4\text{O}_7$ TLD material. None of the dosimeters had permanently attached covers. TLD thicknesses ranged from a maximum of 235 mg/cm^2 (for the single element TLDs) to less than 10 mg/cm^2 (for the composite dosimeters). For all dosimeters having a TLD layer thinner than 100 mg/cm^2 , composite devices were formed by attaching the TLD wafers to nominal 200-mg/cm^2 -thick backing materials.

Many combinations of composite dosimeters were fabricated. All composite dosimeters consisted of one thin layer of TLD material, a high-temperature bonding agent, and a backing support that had a low atomic number. Bonding techniques tested included: high temperature epoxies, Teflon,[®] and Kapton.[®] Backing materials included: CaF_2 crystal, LiF crystal, Teflon, graphite, aluminum, and LiF TLD-100. Beta-particle and gamma-ray radiation responses of these new dosimeters were compared with the responses of the KSU-patented graphite-backed thin-LiF dosimeters and/or the responses of thick-LiF TLDs. Characterization also included measuring thermoluminescent emissions above 100°C for each bonding agent and backing material.

Of the many combinations tested, several potentially useful ones were discovered. $\text{CaF}_2\text{:Mn}$ dosimeters in thin configurations have three

[®] Teflon is a registered trademark of E. I. duPont de Nemours and Company, Wilmington, Delaware.

[®] Kapton is a registered trademark of E. I. duPont de Nemours and Company, Wilmington, Delaware.

times the sensitivity of LiF. To further expand the potential of thin-element dosimetry, experiments were performed to test the degree to which residual thermoluminescence could be removed following a high radiation exposure. An annealing chamber was constructed that allowed simultaneous treatment by ultraviolet light and hot nitrogen gas. The maximum temperature of the hot nitrogen gas was chosen to be much less than 400°C, so as to reduce thermal damage to the bonding agents.

Laser-Heated Thermoluminescent Dosimetry

The concept of using an infrared (IR) laser to provide the necessary heating for readout of TLDs was evaluated previously. It is apparent the laser TLD reader concept is fast, accurate, reproducible, and highly sensitive when used with a thin TLD design. The results obtained by using IR laser heating of thin TLDs can be expected to be superior to the results obtained by conventional readout methods. Laser heating of thin TLDs can provide the ability to measure very low doses, even in a high-background environment. Of the three thin TLD designs evaluated previously, $\text{CaSO}_4:\text{Dy}$ appears to be the best, followed closely by $\text{MgB}_4\text{O}_7:\text{Dy}$. Both of these thin TLDs have a very flat energy response and both have the potential to measure doses on the order of 1 mrad. Based on the KSU findings, additional materials such as $\text{CaF}_2:\text{Mn}$ must be studied.

Efforts this year were hampered by deficiencies in the reader. The dynamic range of the reader is limited, thus making readout difficult without prior knowledge of the approximate exposure of the dosimeter. The required modifications were identified and included replacement of the processor board, and modification of the stabilizing system, the input/output electronics, and the software. The required changes are being implemented.

Exoelectron Dosimetry

Efforts during FY 1989 continued on the development of a personnel dosimeter that can meet U.S. Department of Energy Laboratory Accreditation Program (DOELAP) criteria for both beta and photon radiation. The first dosimeter design contained only two elements, one to measure the shallow dose at a depth of 7 mg/cm² and one to measure the deep dose at a depth of 1000 mg/cm². Although this dosimeter easily met DOELAP criteria for both beta and gamma radia-

tion, it under-responded to low-energy x rays. As a result, a third element was added to the dosimeter. Initially, this element was similar to the deep-dose element except for a thin layer of aluminum between the dosimeter and the 1000-mg/cm² Teflon cover. The presence of the aluminum causes an over-response to low-energy photons, which allows for the determination of the low-energy photon component of the incident radiation and a correction of the response of the shallow- and deep-dose elements. Testing of several designs of this third element resulted in an exoelectron dosimeter that can meet DOELAP criteria for all beta energies and other photons, with a maximum 23% error for the worst-case mixture.

Eventually the third element was changed to a 1000-mg/cm² layer of aluminum with a 60-mg/cm² layer of Teflon covering the dosimeter. This provides significant attenuation of the low-energy photons for comparison with the deep-dose element, which permits a correction of readings on the first and second elements. The new dosimeter meets DOELAP criteria with a maximum bias of 19%. With a standard deviation of readings typically between 6% and 10%, the dosimeter meets DOELAP criteria for all photon, beta, and mixtures of radiation tested. Results of the evaluation were published in *Radiation Protection Dosimetry* (Merwin 1989).

Although it has been demonstrated that a three-element exoelectron dosimeter is satisfactory for measuring beta particles and photons under controlled conditions, it has not yet been demonstrated that the dosimeters are acceptable for measuring doses in the workplace. Studies now under way include angular dependence testing and side-by-side field testing with other types of dosimeters. Studies on fading and dose response have been completed and have indicated satisfactory performance. Because exoelectron dosimeters are fundamentally superior to TLDs for measuring beta doses, it is hoped that the dosimeters will prove acceptable for measurements in the workplace. Ultimately, the dosimeters could be used for specialized measurements, such as beta field characterization, or as personnel dosimeters for workers exposed to significant beta doses. In the latter application, the dosimeter could be used either alone or in conjunction with a TLD.

A new reader with a multianode counter was ordered. The counter will improve the dynamic

range and the precision of the readout. The reader is set up in the laboratory and is in the process of being commissioned.

Beta Survey Instrument Development

D. R. Sisk and K. L. Swinth

This task is dedicated to the development of instrumentation to enable the accurate measurement of both penetrating and nonpenetrating radiations.

Information from programmatic studies on beta survey instruments (source geometry response, response calculations, comparisons, etc.) was used to develop specifications for a prototype beta survey instrument. The specifications were the basis for a competitive bid resulting in the commercial manufacture of a prototype instrument. Delays in software development by the manufacturer delayed delivery of the unit, but the prototype was evaluated prior to yearend. The unit has a thin ionization chamber (2.7 cm wide) and is microprocessor-based, permitting semi-automated correction of readings for geometry effects. Energy response for beta radiations is excellent, but the system has a marked over-response at low photon energies, is affected by magnetic fields, and has poor linearity at high dose rates. In addition, radiation overloads cause the instrument to "blank out." Such deficiencies are not unexpected in a first prototype, and tests are under way to identify corrections to be incorporated into a new model.

Beta Spectroscopy Instrument Development

D. R. Sisk and K. L. Swinth

This task is dedicated to the development of spectrometers for the characterization of beta fields in the workplace. Optimization, fine-tuning, and field testing of the beta-gamma field spectrometer continued during FY 1989.

The spectrometer uses a coincidence technique that employs two detectors to separate the beta and gamma components from a mixed-radiation field. The instrument consists of a gas-flow proportional counter attached to the front of a plastic scintillator detector. Beta particles entering the system generate a signal as they pass through the proportional counter and deposit their

remaining energy in the scintillator. Conversely, the low thickness density of the proportional counter decreases gamma sensitivity. Gamma radiation is detected by interactions in the plastic scintillator. Gating circuitry selectively routes a beta or gamma scintillator pulse to a multichannel analyzer (MCA) that collects the energy pulses to produce a spectrum. A computer is used to calculate dose rates from spectra collected using the spectrometer system.

A system of electronics and a detector was procured along with a new MCA. The electronics improved the overall system performance, and with the new MCA it was possible to reduce the number of units that comprise the system for easier transport during field measurements. Tests showed that new detectors did not improve system performance and the original detector system is now being used.

Computational Studies

R. E. Faw (KSU)

The purpose of this task is to conduct basic studies that affect beta dosimetry and to develop methods of calculating energy deposition from beta radiation.

A Monte Carlo simulation study and supporting experiments were undertaken to provide users of the Physikalisch-Technische Bundesanstalt (PTB) Beta Secondary Standard beta source set with information such as angular and energy distributions of the beta-particle fields delivered. The Standard set uses filtered ^{147}Pm , ^{204}Tl , and $^{90}\text{Sr}/^{90}\text{Y}$ beta-particle sources to provide radiation fields with well-known depth-dose distributions in tissue.

The Monte Carlo simulation study was conducted in two phases. First, energy and angular distributions of beta-particles were calculated, not only at the emergence from source encapsulation, but also in the plane of emergence from "beam-flattening" filters. These calculations fully accounted for the significant backscattering from the source support material. Second, the energy and angular distributions at the emergence from source encapsulation were used to represent effective sources in calculations of absorbed-dose distributions in skin and TLD devices, and in examination of the effects of beam-flattening filters

on the off-axis variation of dose rates delivered by the sources. A companion experimental study was completed on the study of filter effects.

The use of effective sources greatly reduces the computational effort in the simulation of the PTB Standard. For a TLD device of prescribed configuration to be calibrated using one of the Standard sources, one may readily compute the dosimeter response factor (the ratio of the average absorbed dose in the active region of the TLD to the skin dose under the same exposure conditions). Such

evaluations were described in a KSU letter report to PNL and the results were compared with measurements. The computational results were used to calculate the response of the beta spectrometer.

Reference

Merwin, S. E., and K. L. Swinth. 1989. "Performance of an Exoelectron Dosimeter Badge for Personnel Beta Dosimetry." *Radiat. Prot. Dosim.* 28(3):219-222.

Health Physics Support and Assistance to the Department of Energy

Project Managers: *J. M. Selby and K. L. Swinth*

This project focuses on identifying needed improvements in occupational radiation programs and measurement technologies, and on analyzing the applicability and impact of standards, regulations, and engineering or administrative actions on the U.S. Department of Energy's (DOE's) occupational radiation protection programs. This is accomplished by means of special technical studies. Technical assistance is provided in developing guidelines for implementing standards and regulations and in conducting and preparing technical reports as requested by the sponsor. This assistance also includes transferring laboratory-developed techniques to the field by means of DOE-sponsored workshops. Project objectives are achieved using the capabilities and expertise of Pacific Northwest Laboratory (PNL), other DOE laboratories, universities, and private industry. Progress made during fiscal year (FY) 1989 on the Health Physics Support and Assistance (HPS&A) tasks is discussed in the following subsections.

Special Studies

J. M. Selby and K. L. Swinth

The objectives of this task are to 1) provide technical assistance with development of guidelines for the implementation of standards and regulations, and 2) prepare technical reports and conduct special studies for the Office of Safety Policy and Standards (OSPS), as requested by the sponsor. Work and special studies performed in FY 1989 are described in the following subsections.

Neutron Quality Factor: *L. G. Faust*

The status of the neutron quality factor (Q) has been under continuous review by many countries for approximately the past 10 years. During that time, changes varying from a factor of 2 to a factor of 50 have been proposed. However, no changes have been officially adopted except for Japan, which increased the Q from 10 to 20. Others, including the United States, have similar actions under consideration. For DOE, two issues are of importance. Report 91 of the National Council on Radiation Protection and Measurements (NCRP 1987), *Recommendations on Limits for Exposure to Ionizing Radiation*, which recommends an increase in Q for fast neutrons of a factor of 2, is being redrafted. The other issue is what the International Commission on Radiological Protection (ICRP) and the International Commission on Radiation Units and Measurements (ICRU) eventually adopt. Currently, they are recommending a factor of

2 increase. However, their recommendation incorporates a value of 20 for fast neutrons with no adjustment for energy distribution. That is the basic difference between the ICRP/ICRU and the NCRP recommendations.

Annual Radiation Exposure Report:

S. E. Merwin

The data for the 1987 exposure year, which became available in January 1989, were incorporated into the 20th annual report, and a draft was sent to DOE-Headquarters (HQ) for comment on March 10, 1989. The report included several changes from the previous report. These changes reflected the fact that actual data, rather than summarized data, were used to calculate collective dose equivalents. A reduction in the collective dose for all DOE activities from 7340 rem to 6353 rem resulted from using actual data for each exposure category rather than using the midpoint of each range.

A meeting was held with DOE-HQ's Environment, Safety, and Health (EH) organization, the System Safety Development Center (SSDC), and PNL staff to discuss revisions to DOE Order 5484.1 (DOE 1981) and the annual exposure report. The 21st annual report, which will report 1988 exposure data, will be completely revised and expanded and will include detailed exposure data that are now available as a result of the revised exposure reporting format. This report will report increased statistical analyses of exposure by age, sex, and job classification. A lifetime dose analysis will be

provided from one site and there will be discussions on limits and generic exposure scenarios.

Demographic Analysis of Lifetime Occupational Exposure: R. J. Traub

Personnel exposure data have been analyzed for the historical dosimetry data file at Hanford. The data file consists of dosimetry records from 1945 to 1985 on 30,352 individuals. Of these records, 14,394 were complete and 15,958 were missing information like date of birth and work location. The missing data were obtained but were not merged into the data file in time for analysis. The work conditions associated with the doses received were also identified as follows: reactor operators, fuel fabrication, fuel reprocessing, general research, and plutonium workers.

The initial analyses of the data indicated the following:

- Only one individual has had a cumulative recorded dose in excess of 100 rem (this individual has worked at Hanford for 37 years).
- For those individuals who have worked at Hanford for more than 10 years, the maximum cumulative lifetime doses are consistent with a rate of accumulation of about 2.5 rem/yr.
- The average lifetime dose for all workers at Hanford is about 0.3 rem (total).
- Ninety-nine percent of all workers have a cumulative lifetime dose of less than 42 rem.

Missed Dose Study: R. J. Traub

A report summarizing the current state of personnel dosimetry and that of radiation monitoring systems is being prepared for issuance in FY 1990. The extent to which an individual may have received a radiation dose that is not recorded in his/her dose history file will be estimated and reported. All aspects of personnel dosimetry (internal, external, extremity, and skin dosimetry) will be reviewed in the report, along with the monitoring instrumentation, which includes air monitors, area radiation monitors, and portable survey instruments.

Four mechanisms can cause an individual's dose history to contain unreliable information: 1) true missed dose, 2) unnoticed dose, 3) under-recorded dose, and 4) unreliable dose. A radiation

dose will be completely missed when the radiation dose received by an individual is completely unrecorded and there is no theoretical limit to the radiation dose that may have gone unrecorded. There are procedural and technical reasons for missed dose. A procedural missed dose results when an individual is not issued a dosimeter (and thus has no measured dose) because the applicable radiation protection program contains procedures that identify persons who should not be enrolled in the dosimetry program.

Technical missed doses are those radiation doses that are completely missed because of limitations of the dosimetry system. In such cases, the individual has been issued a dosimeter that either cannot or does not record a dose because of technical problems such as energy response, angular response, or insensitivity to the particular type of radiation. This category also includes radiation doses that are not recorded because of the dosimeter was placed in the incorrect position.

Computation of examples of missed doses for various work conditions identified as exposure scenarios in a separate task have begun, but were not completed in FY 1989.

ALARA Engineering: J. W. Baum, BNL

Six out of the ten scheduled DOE/U.S. Department of Defense (DOD) contractor facilities have been visited by Brookhaven National Laboratory (BNL) ALARA Center personnel to collect information regarding ALARA Engineering and Programs.

A draft outline for the ALARA Engineering report and draft agenda for a DOE ALARA Workshop were transmitted to K. P. Ferlic on September 15, 1989.

The "International Workshop on New Developments in Occupational Dose Control and ALARA Implementation at Nuclear Power Plants and Similar Facilities" was held at BNL from September 18 through 21, 1989, and was attended by 14 individuals from the DOE community. Copies of the proceedings are being sent to those DOE facilities being visited by BNL, whose representatives were unable to attend the workshop.

The first formal report, entitled *ALARA Engineering at Department of Energy Facilities: Bibliography of Selected Readings in Radiation Protection and*

ALARA, was published in September 1989 (Daniels et al. 1989). Copies were distributed at the September 1989 workshop described above and will be sent to the DOE facilities involved in this project under a separate cover letter.

Assistance on EPA-PAG Studies: *M. P. Moeller*

A review of proposed U.S. Environmental Protection Agency (EPA) Protective Action Guides (PAGs) was performed at DOE's request. The issues identified by DOE prompted EPA to provide an extended comment period, thus permitting other Federal agencies to analyze the impact of the new PAGs in depth and consider the issues raised in the initial review. A program in support of continued study on the issues was developed and initiated. The purpose of the ongoing program will be to assist DOE-HQ in responding to EPA's request for information in support of its efforts to develop PAGs and guidance applicable to DOE sites and facilities.

DOE-Requested Special Studies: *J. M. Selby and K. L. Swinth*

Several special studies were undertaken at DOE request. These included:

- Review of PAGs for the Galileo Space Shot - A report on PAGs was given a critical review and important issues were identified.
- Review of the Proposed Release of Activated Copper - A proposal for the unrestricted release of slightly radioactive copper from accelerators was reviewed.
- Analysis of Comments on DOE Orders 5480.11 and 5484.1 - Comments received on DOE Orders 5480.11 (1989) and 5484.1 (1981) were compiled and subjected to technical analysis.
- Review of DOE Order 5480.4 - A detailed review of DOE Order 5480.4 (DOE 1984) was performed to identify changes in standards cited, assure that reference to the latest standards were included, and to identify new standards that should be included.
- Exposure Scenarios - Descriptions have been prepared of the dose distributions received at typical DOE facilities, including a tritium facility, a plutonium processing facility, a fuel reprocessing facility, and an accelerator facility. The information obtained for each facility included the age distribution of the workers and the internal and external dose distributions.

- Review Procedures for the Waste Isolation Pilot Project (WIPP) - Procedures for external dosimetry, internal dosimetry, and training at the WIPP site were reviewed to assist the WIPP operational readiness review. A detailed review was performed and comments were transmitted to DOE for their action.

Miscellaneous Studies

Several additional special studies were performed including:

- Information on dosimetry data collection
- Review of DOE records schedule
- Review of 8 DAC-hr^(a) guidance
- Development of accident scenarios.

DOE 5480.11 Guidance

J. M. Selby and K. L. Swinth

The purpose of this task is to help develop guidance to interpret various aspects of operational health physics programs and to aid in the implementation of requirements in DOE Order 5480.11 (1989). This Order represents the first substantial change in DOE (and predecessor) directives since 1975. The new DOE 5480.11 represents substantial changes not only in the limits but also in many administrative requirements. The use of the effective dose equivalent concept, as set forth in Publication 26 of the International Commission on Radiological Protection (ICRP 1977) and as clarified by the Presidential Guidance (52 FR [17]2822-2834), required adding external dose to internal dose using weighting factors for various organs. Workplace monitoring for external and committed effective internal dose is now required to be compared against a limit.

Guidance for Implementation of DOE Orders for Internal Dosimetry

J. M. Selby and D. R. Fisher

An Internal Dosimetry Expert Group was formed in 1987 to develop guidance for implementation of the new internal dosimetry requirements of DOE

(a) DAC-hr = derived air concentration per hour.

Order 5480.11. This group consists of R. M. Hall, Jr. (Chair) and T. R. LaBone (Savannah River Plant), D. R. Fisher, M. J. Sula, and D. E. Bihl (PNL), J. S. Bogard (Oak Ridge National Laboratory), W. D. Fairman (Argonne National Laboratory), R. B. Falk (Rocky Flats Plant), J. D. Foulke and D. R. Nelson (DOE), J.N.P. Lawrence (Los Alamos National Laboratory), E. T. Lessard (BNL), and A. N. Tschaeché (Westinghouse Idaho Nuclear Company). The new Order requires a complete revision of previous methods used for internal dose assessment, the summing of internal and external doses, more extensive recording and reporting, and adoption of new dosimetric quantities.

During 1989, DOE changed the work scope of the Expert Group from development of a guidance document to development of a performance standard to prepare for implementation of an internal dosimetry performance testing and accreditation program. In early May 1989, the Expert Group began to extensively revise the working document in response to this change in scope.

Version 7.0 of the draft Performance Standard for Internal Dosimetry Programs was prepared, reviewed, and revised, as most of the major technical issues were resolved. A workshop was held in May 1989 at DOE-HQ (Germantown) for persons at DOE and DOE-contractor facilities to discuss issues pertaining to the revised Orders, the performance standard, and the proposed internal dosimetry accreditation program.

The Expert Group recommended 1) performance criteria for evaluating the "acceptability" of internal dosimetry programs, and 2) new methods for evaluating the "correctness" of internal dose estimates for workers with inadvertent intakes of radioactive materials. Yet to be incorporated in the performance standard are a description of the proposed accreditation program, a section dealing with technologically enhanced natural radiation at DOE facilities, and consensus methods for bioassay monitoring programs, the interpretation of air monitoring data, and internal dose assessments. Scientific committees will be formed to prepare "school solutions" to test dose assessment problems for accreditation testing purposes.

Guidance for Implementation of DOE Orders for External Dosimetry

L. G. Faust and J. E. Tanner

The purpose of this task is to develop a companion document for External Dosimetry similar to *The Performance Standard for Performance Testing of Internal Dosimetry Programs*. A bibliography of relevant standards and guidance documents was developed and the outline was revised to reflect a performance standard rather than the initially planned manual of good practice. More explanatory material was also added. A draft of the standard will be available early in 1990.

Air Sampling and Monitoring Guidance

T. P. Lynch

The purpose of this task is to develop a manual that contains practical information that can be used to design and implement an effective workplace air sampling program. An initial outline, with summaries and references for each chapter, was completed. A draft of a workplace air sampling manual being developed for the U.S. Nuclear Regulatory Commission (NRC) was reviewed for application to this project. The manual will include chapters on representative sampling, air monitoring, sample volume measurement, quality control for analytical results, and data analysis.

Contamination Control Policy

L. H. Munson

The purpose of this task is to provide consistent and comprehensive contamination control guidance for DOE facilities. As a result of new DOE Orders, findings of Technical Safety Appraisals (TSAs) and the absence of existing DOE guidance similar to that found in NRC Regulatory Guides, DOE requested the development of documents to provide the needed guidance. An annotated outline was prepared for DOE-HQ review. Using Institute of Nuclear Power Operations (INPO) contamination control guidance documents as a pattern, a DOE "Search for Excellence" document was prepared. Further direction from DOE-HQ resulted in the preparation of a "Performance Standard for Contamination Control at DOE Sites" document.

This document will provide detailed information for contamination control in DOE facilities to support the generic Radiological Protection Guidelines for Operation of DOE Facilities (RPGODF). The RPGODF document provides the basic contamination control guidance for first-line management and the performance standards document provides the health physics guidance for its implementation.

Radiation Protection Review Program

L. H. Munson

The objective of this task is to provide a single, comprehensive program document that will be used for conducting appraisals of radiation protection programs in DOE facilities. The document will be designed to be used for TSAs, radiation protection functional appraisals, DOE Tiger Team assessments, and specific topic appraisals by both DOE-HQ and Field Office personnel. The use of a single set of objectives and performance criteria for appraisals will ensure more consistent conduct of the required appraisals. Several revisions of the document have been prepared for internal and DOE review and field-use testing. Incorporation of the latest round of comments is in progress and a final draft will be available in early 1990.

Definitions from DOE Order 5480.11

J. M. Selby and L. H. Munson

The purpose of this task is to provide clarification and specific application of selected definitions from DOE 5480.11 to ensure their consistent use in the field. A working group, consisting of staff from the local DOE Field Office and DOE contractors, was convened to develop clarification of the definitions from the new DOE 5480.11 and to verify their applicability to field situations. A definitions document was prepared for review and consideration by DOE-HQ staff for use throughout the DOE complex in the preparation and implementation of contamination control programs.

Standards

J. M. Selby

The purpose of this task is to provide a timely, technical evaluation of national and international occupational radiation exposure recommendations, standards, and regulations to determine

their technical applicability, compatibility with DOE operations and Orders, and impact on DOE operations. As appropriate, technical expertise is drawn from other DOE contractor laboratories to assist in the evaluations. Progress made under this task during FY 1989 is discussed in the following subsections.

Reference Man Database: R. J. Traub

The Reference Man database is a fundamental starting point for internal dose calculations; it contains generic anatomical and physiological data for the human species. This task provides funding to Oak Ridge National Laboratory (ORNL) staff working on revisions to ICRP 23 on Reference Man (ICRP 1974). Approval for this work was received from DOE and supplemental funding has been provided to ORNL.

Internal Dosimetry Standards: D. R. Fisher, J. R. Johnson, A. C. James, and F. T. Cross

The purpose of this task is to achieve the following: 1) contribute to and monitor the progress of national and international scientific committees dealing with occupational internal dosimetry methods, models, and biokinetic parameters, 2) ensure that recommended or "state-of-the-art" biokinetic models for major human organs are incorporated into computer codes used for internal dosimetry at DOE facilities, 3) provide a bridge between developments in biological research on internal emitters and applications to worker protection at DOE facilities, 4) provide review of ICRP and NCRP internal emitter standards for DOE-HQ personnel, and 5) apprise DOE of the impact of changes on operations at DOE facilities.

The current progress of NCRP Scientific Committee 57 on internal emitter standards for respiratory tract and skeletal models for internal dose calculations, on gastrointestinal tract models, and on uranium metabolism were reviewed. The new respiratory tract models proposed by NCRP Scientific Committee 57-2 and the ICRP Task Group on Lung Dynamics were also reviewed.

PNL staff played a major role in current work on revision of the ICRP lung model, including 1) extraction of data on lung morphology and physiology, 2) development of a structural model and mathematical clearance model of the human lung, 3) selection of parameters for age-dependent deposition of aerosols as functions of particle size

and breathing patterns, and 4) calculation of absorbed fractions of alpha- and beta-particle energies in various regions of the respiratory tract.

Proposed changes in respiratory tract models will have significant impacts on internal dose assessment at DOE facilities in the near future. The similarities and differences between the proposed ICRP and NCRP respiratory tract models for dosimetry have been analyzed. The proposed ICRP respiratory tract model is being incorporated into the software package CINDY (Code for Internal Dosimetry) for internal dosimetry at DOE facilities. (CINDY is being developed under the Applied Research Program.) Contributions were also made to the working scope of a new NCRP Scientific Committee 46-10 on assessment of occupational dose from internal emitters.

Review and Analysis of Proposed Standards:

J. M. Selby and K. L. Swinth

Several national and international standards were reviewed in terms of DOE needs and their potential impact on DOE. This included standards on x-ray and sealed sources, pocket dosimeters, calibration sources, instrument testing, contamination evaluation, etc. A set of reference standards was maintained and copies were provided to DOE-HQ as requested.

Health Physics Guidance Documents

K. L. Swinth

The objective of this subtask is to identify and develop guidance to be used by DOE facilities to enhance radiation protection practices in the workplace and support the new DOE Order 5480.11 (1989). Changes in technology, DOE Orders, standards, and regulations, together with the need for more uniformity in health physics practice, are the driving forces behind these guidance documents.

Guide to Good Practices at DOE Tritium

Facilities: *H. Anderson (Mound Laboratory) and J. B. Martin*

The peer review group for the health physics chapter of the Tritium Guide met on June 26 during the Health Physics Society meeting in Albuquerque, New Mexico. The group discussed Revision 2 of the health physics chapter. In

response to the comments received from the peer review group, Revision 3 of the chapter on health physics and properties of tritium was prepared and forwarded to Mound Laboratory. Revision 3 was incorporated with the other chapters of the tritium guide and the completed guide was sent to DOE Field Offices and contractors for review.

Handbook for Health Physics: K. L. Swinth and P. C. Olsen

A general outline was developed for a handbook to assist operational health physics staff. The handbook is a needed source of current technical health physics and radiological health data that pertain to the DOE community. It will be developed for use by both the professional health physicist and for the field technical person or student. Available materials that encompass the various technical aspects of health physics are out-of-date and are not specific to a DOE contractor's needs. A technical reference that includes necessary data, tables, rules of thumb, and calculational methodology for the health physics specialist in the unique operating environment of DOE is a necessary tool. A shorter field guide that includes elements of the above reference with emphasis on immediate response actions and information is also envisioned.

As currently planned, two documents will be developed. One will be an extensive technical document with detailed reference information needed in administering and planning health physics programs at DOE facilities. The various sections included will cover needed aspects of radiation protection, pertinent rules and regulations, shielding, dosimetry, radionuclide data, and operational health physics. The second document will be an abbreviated version of the first in a format useful for field work, such as a pocket guide. It is envisioned that this pocket guide will be versatile in that it may be tailored to each individual facility or professional. This will contain rules of thumb and technical references needed for quick decision-making in health physics incidents and on-the-job activities that don't allow the user access to specific procedures manuals.

The initial outline was submitted for DOE comment and has been revised and prepared for internal comment and resubmission.

Health Physics Performance Requirements for X-Ray Devices and Sources at DOE Facilities:

J. M. Selby and J. G. Stephan

This performance guide is being prepared because of the need to provide up-to-date and uniform guidance for the use of x-ray generating devices and sources that are being used in DOE and DOE contractor facilities. In accordance with DOE Orders, it will include requirements for limiting radiation exposure to the lowest technical and economical practical levels within applicable standards.

The implementation of the Presidential Guidance on radiation protection for occupational exposure (52 FR [17]2822-2834) requires the standardization of radiation protection programs. Because site-specific requirements, facilities, and equipment vary in the DOE complex, no single set of detailed criteria for the use of x-ray generating devices and sources is currently available, and no uniform radiation protection program can be readily defined. The performance guide will address requirements and guidance on devices and sources used for non-medical and medical applications at DOE sites (if used in non-medical applications), and will include such topics as facility design, modification of existing facilities, selection of devices and sources, device storage and disposal, shielding requirements, radiation alarms and access control devices, radiation protection surveys and inspections, and emergency action planning and others.

A detailed outline of the performance guide has been reviewed and approved by DOE-HQ.

Training Guidance Document: *P. C. Olsen*

The purpose of this task has been to develop specific radiation safety training guidance for DOE and subcontractor personnel pursuant to revised provisions of DOE Order 5480.11. Based on DOE/EH review, the scope and format of this document have been altered significantly to be more in keeping with other documents on radiological protection and health physics that are under development.

Two separate documents will be developed, one directed toward a radiation safety orientation of DOE and contractor non-radiation workers and non-badged employees, and a second for the radiation worker. Concurrently, clarifications of

certain definitions have been necessary for proper distinction between each type of training. A draft outline for each document has been developed and subsequently reviewed by DOE-HQ. Continuing work based on these reviews is under way.

Calibration Guidance Documents: *K. L. Swirth*

PNL staff worked closely with the National Institute of Standards and Technology (formerly the National Bureau of Standards) to develop comprehensive calibration accreditation documentation. These documents will provide the basis for a technically excellent calibration program for both instruments and dosimeters at Federal facilities. As staff become available, the material in these documents will be used to develop guidance for DOE facilities.

An outline for a short course to train DOE staff in calibrations was developed. This was planned as a 2-week course with 1 week of classroom work and 1 week of hands-on training.

Near Source Corrections: *D. R. Sisk*

The purpose of this study is to develop appropriate techniques for correcting instrument response to non-uniform radiation fields. The techniques will be described in a guidance document on near-source measurement. During FY 1989, a draft annotated outline for the Near Source Guidance Document was completed and sent to DOE-EH for review. The revised draft outline will provide the basis for the study.

Health Physics Review and Technical Assistance to OSPA

J. M. Selby and L. H. Munson

The objective of this task is to provide technical support to the OSPA in performing health physics reviews, analyzing weaknesses and strengths in DOE radiation programs, identifying changes or additions to Orders, and identifying guidance documents to strengthen or further enhance the programs. Progress made under this task during FY 1989 is discussed in the following subsections.

Health Physics Reviews: *L. H. Munson*

One operations office contamination control policy was generally critiqued for its applicability as a site-specific document as well as a DOE-wide document. Two DOE facilities were visited to

evaluate their proposed action for contamination control, including items that might have been missed and any proposed structural changes that should have been considered. Contamination control action plans were reviewed, discussions were held with plant staff, and the facilities were inspected.

Technical Assistance to OSPs: J. M. Selby and L. H. Munson

An assessment of the status of the radiation safety program at the Waste Isolation Pilot Plant was conducted during a 3-day site visit. This work was in support of the DOE Advisory Committee on Nuclear Facility Safety.

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Laboratory Accreditation Support Program

Project Managers: *J. M. Selby and J. C. McDonald*

The Department of Energy Laboratory Accreditation Program (DOELAP) provides for verification and documentation of the correct performance of certain radiation protection activities. The measurements taken as part of these activities are also examined to verify their traceability to national standards. In support of DOELAP, the Laboratory Accreditation Support Program at Pacific Northwest Laboratory (PNL) develops new methods for calibration and accreditation of radiation protection activities, and recently it was expanded to include: extremity dosimetry, bioassay (in vitro and in vivo), calibration and intercomparison, instrumentation, external and internal dosimetry programs, and environmental dosimetry programs. Previously, DOELAP accredited only whole body personnel dosimeters, but it will soon accredit nearly all aspects of DOE radiation protection programs.

During the last year, PNL staff and Northwest Organization for Colleges and Universities for Science (NORCUS) researchers contributed to the support program at PNL. The project developed several new proficiency testing methods and evaluated the potential impact of an entirely new method for the evaluation of personnel dose equivalent as described by the International Commission on Radiological Units and Measurements in Reports 39 and 43 (ICRU 1985; 1988). Progress made during fiscal year (FY) 1989 under this program is discussed in the following subsections.

Comprehensive DOELAP Objectives Plan

J. M. Selby and J. C. McDonald

The DOELAP operation is administered by the Radiological and Environmental Sciences Laboratory (RESL) at Idaho National Engineering Laboratory. Because it is necessary to coordinate the new developments at PNL with the operational concerns of RESL, a long-term plan for the developmental efforts of the DOELAP project was developed in FY 1989. As planned, the overall accreditation program will have major activities in several areas. The first of these is the implementation of an extremity dosimetry accreditation program. A draft standard has been written and initial feasibility testing of the techniques described in the standard has been completed. The initial stages of operational proficiency testing are expected to take place at RESL in late FY 1990. The bioassay testing program will continue to develop documents to guide participants, and a DOE draft standard has been written. Intercomparisons will be expanded to include methods of evaluating the uniformity of in vivo bioassay (whole body counting techniques as well as the present radiological calibrations intercomparison), which has been carried out by PNL for the last 4 years. PNL will develop methods for the accreditation of

radiological instrument calibration programs as well as for external and internal dosimetry programs. These last two tasks will require the development of techniques for accreditation of all of the aspects of these dosimetry programs. Accreditation of the environmental dosimetry programs at DOE facilities will also be pursued under DOELAP.

External Dosimetry

J. C. McDonald, N. E. Hertel (NORCUS), and R. Harty

The present DOELAP standard recognizes the need for additional testing categories that would reflect new requirements and advances in the state of the art. The external dosimetry testing development work that was accomplished this year included writing a draft standard for testing extremity dosimeters and performing a feasibility study to evaluate the testing techniques using actual field dosimeters from other DOE facilities. The standard will be reviewed by DOE dosimetry experts and RESL personnel, and it is expected that a pilot test round will be initiated at RESL at the end of FY 1990.

Additional development in dosimetry accreditation and testing is required in the area of personnel dosimetry for high-energy accelerator facilities. The

present DOELAP testing categories are more appropriate for the lower-energy photons and neutrons associated with more conventional facilities. Some of the large DOE accelerators can generate neutrons and charged particles with energies of several gigaelectron volts. Heavy shielding moderates these high-energy particles so that their mean energy is usually several tens of million electron volts in the area where personnel may be exposed. The problem addressed by this task is to identify an appropriate neutron calibration source in this energy region. Work on this task has just been started this fiscal year, and it is expected that input will be obtained from field personnel at a calibrations workshop planned for the second quarter of FY 1990.

To keep current with new developments in calibration standards, ICRU Reports 39 and 43 were reviewed (ICRU 1985; 1988). These reports describe a new method of evaluating dose equivalent, and they include new quantities and units. These new quantities are defined at positions within a 30-cm-diameter spherical phantom known as the ICRU sphere. Presently, the DOELAP testing program uses a rectangular polymethylmethacrylate phantom upon which dosimeters are mounted for irradiation. If the new ICRU quantities are adopted, it will be necessary to relate dose equivalent on the rectangular phantom to dose equivalent within the ICRU sphere and to dose equivalent within the human body. During FY 1989, a special session at the annual Health Physics Society meeting was organized to bring together several international experts on the evaluation of dose equivalent to discuss the impact of the new ICRU quantities. The conclusion of these experts was that the new quantities would not soon be adopted in Europe and that when they are adopted, they will have minimal impact. In addition, Monte Carlo computer calculations of the relationships between dose equivalents for photons and neutrons were carried out at PNL. These calculations also indicated that the impact of the new quantities may not be large. In fact, a personnel dosimeter of the type used at Hanford would actually measure a value in closer agreement with the expected dose equivalent when

irradiated on the present DOELAP phantom than when irradiated on the ICRU sphere.

Calibration and Intercomparison

J. C. McDonald, M. K. Murphy, J. F. Dicello (NORCUS), and H. E. Palmer

Not all aspects of radiation protection programs are amenable to proficiency testing and accreditation. In some cases it is more productive to intercompare measurements performed by DOE personnel at other sites. This type of program provides a measure of the uniformity of performance. Two such intercomparison projects are presently under way. The first of these involves the use of a set of instruments and radiation sources that are used by participants to measure specified doses of radiation from a variety of sources. This project has been under way for a number of years, and the results to date are fairly typical of intercomparison programs. During the first few years, agreement was poor, but as people continued to participate, their results quickly became more uniform. This may be due to increased familiarity with the equipment and the procedures. In FY 1989 most participants reported results that are within a band of about 5% to 6%. Results were detailed in a draft annual report for this task. This program helps to evaluate not only the consistency of the instruments and sources, but also the ability of the personnel using the devices to correctly operate them and interpret the results they obtain.

A similar intercomparison, being initiated this year, will test the uniformity of *in vivo* bioassay measurements. This will be accomplished through the use of a "library" of phantoms that will contain known amounts of radionuclides. One or more of these phantoms will be circulated to other DOE facilities, and replicate measurements will be made. It is anticipated that there will be several types of phantoms that will be used to study various types of problems that might actually occur in field conditions at whole body counters. During the last year, progress was made on characterizing a phantom that contains parts of the skeleton of a former DOE worker who was contaminated with americium.

Bioassay

J. A. MacLellan, P. C. Olsen, and H. E. Palmer

This work is directed toward developing and implementing a bioassay performance test standard and a proficiency testing program. This effort is following the same general outline as the external dosimetry program. Draft American National Standards Institute (ANSI) Standard N13.30 (ANSI 1989) was reviewed and analyzed for its applicability to DOE operations. It was found that ANSI N13.30 would not be adequate for the more complex nature of DOE problems. Therefore, a new draft standard was written and a feasibility study was conducted to evaluate some of the testing techniques given in the draft standard. In addition, a testing procedure manual was written, including sections on quality assurance and sample preparation. During FY 1990, PNL personnel will work with RESL personnel to help implement the operational proficiency testing and accreditation portion of the work, which will take place routinely at RESL.

Instrumentation

K. L. Swinth and J. M. Selby

Several PNL studies have shown that the level of performance of radiation protection instrumentation is below what is expected by many national and international standards. Because instruments and instrument calibration programs cannot be tested and accredited in exactly the same manner as personnel dosimeters, it was necessary to develop new methods for this task. Methods of approach include acceptance testing and type testing. Acceptance testing requires that any instruments purchased for a DOE facility must pass a series of tests that qualify it for use. Type testing requires that a particular type of instrument (survey meter, contamination monitor, etc.) must pass certain tests, and when testing is successfully completed for a single instrument, others of the same type can be used.

The tests that must be performed are given in ANSI Standards N323 (ANSI 1978) and draft N42.17.^(a) These tests are extensive, and many DOE facilities do not have the resources or the personnel to carry out such tests. These tests could be carried out by a few DOE regional calibration laboratories that may be accredited as

secondary laboratories to the National Institute of Standards and Technology (NIST).

PNL has developed extensive capabilities for the automated testing of instruments. This capability includes a wide range of radiation sources of photons, neutrons, and beta particles. The response of instruments to environmental factors such as inertial shocks, radiofrequency (r-f) interference, temperature variations, and pressure changes can all be tested. In FY 1989, several newly developed instruments have been put through all of the tests outlined in ANSI N42.17.^(a) These tests determined that a new alpha particle survey meter showed an extreme susceptibility to r-f interference. A prototype beta particle survey meter demonstrated superior performance for beta surveys, but a larger than expected low-energy photon response and a susceptibility to magnetic fields limited its performance.

The plans for FY 1990 include developing procedure manuals for instrument testing and preparing for accreditation as a secondary laboratory with the NIST.

Internal and External Dosimetry Programs

D. R. Fisher and J. C. McDonald

These two new tasks have just been initiated. They will serve to develop methods for the testing and accreditation of the entire operation of dosimetry programs. The present testing and accreditation programs only concentrate on the measurement process. These tasks will develop methods to evaluate such things as procedures, personnel, record-keeping, quality assurance, and documentation of traceability to national standards. The

(a) American National Standards Institute (ANSI). *Performance Specifications for Health Physics Instrumentation, Part A - Portable Instrumentation for Use in Normal Environmental Conditions*, Draft ANSI N42.17, at press.

American National Standards Institute (ANSI). *Performance Specifications for Health Physics Instrumentation, Part B - Occupational Airborne Radioactivity Monitoring Instrumentation*, Draft ANSI N42.17, at press.

American National Standards Institute (ANSI). *Performance Specifications for Health Physics Instrumentation, Part C - Portable Instrumentation for Use in Extreme Environmental Conditions*, Draft ANSI N42.17, at press.

techniques used will necessarily be different from the proficiency testing techniques used in the personnel dosimetry DOELAP program. These tests will require staff to evaluate doses in a number of idealized situations that will be given to all participants. Responses to these "scenarios" will then be evaluated for accuracy and uniformity. During FY 1990, outlines for the evaluations procedures will be developed.

Environmental Dosimetry Programs

J. C. McDonald

One of the areas of increasing concern is the dose that would be received via environmental pathways. Programs are in place at all DOE facilities to evaluate such doses. However, it is necessary to develop a program that will provide verification of the accuracy and traceability to national standards for environmental dosimetry programs. RESL currently holds an informal intercomparison of environmental dosimeters on a semi-regular basis in cooperation with the Environmental Measurements Laboratory (EML) in New York. This new task is planned, but has not started in FY 1989. PNL will

work with RESL and EML to establish a more formal accreditation program through DOELAP. It is expected that this will be initiated in FY 1990 and be completed in FY 1991.

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Internal Dosimetry Evaluation and Upgrade

Project Managers: *L. G. Faust and D. R. Fisher*

The Internal Dosimetry Evaluation and Upgrade Project is a multilaboratory research effort to improve internal dose assessment at U.S. Department of Energy (DOE) and DOE-contractor laboratories. Internal dosimetry is the science of determining radiation doses to organs and tissues from internally deposited radioactive materials. This includes the analysis of inadvertent intakes of radioactive materials by workers, the redistribution of radionuclides in body fluids, tissues, and organs, and their excretion from the body. Estimating intake also involves measurement of radionuclides in the body by external counting and measurement of radionuclides in bioassay samples.

Studies to improve the methods of internal dose assessment are in progress at the Pacific Northwest Laboratory (PNL) and at other supporting DOE laboratories and universities. The following subsections describe progress made during fiscal year (FY) 1989 on selected tasks.

Software Package for Occupational Internal Dosimetry

*J. R. Johnson, R. A. Peloquin, M. J. Sula,
D. R. Fisher, and D. L. Stenge*

A software package for occupational internal dosimetry is being prepared to assist dosimetrists in meeting the requirements of DOE Order 5480.11 (DOE 1989). The Code for Internal Dosimetry (CINDY) will provide a tool for improving the quality and uniformity of internal dose assessments at DOE and DOE-contractor facilities. It will also aid in the design of bioassay monitoring programs. Development of the software was begun in FY 1989 and much of the programming was completed during FY 1989.

Included in the software package are the computer code, user interface, data libraries, and user manual. The software will provide the capability to interpret bioassay data, execute complex calculations, and provide annual and committed organ and effective dose equivalent estimates.

The software package incorporates the current biokinetic models and model parameters of the International Commission on Radiological Protection (ICRP) and National Council on Radiation Protection and Measurements (NCRP) for radionuclides encountered in the workplace. It also contains other scientific models for specific radionuclides and chemical compounds, and it provides the user with the option of using an ICRP model or other specified models.

The output format will be customized to the specific requirements set forth by each user facility's internal dosimetry program. PNL will provide code quality assurance, quality testing, maintenance, and revision and update services for all users. The code will meet the requirements of American National Standards Institute (ANSI) Standard ANSI/NQA-1 (ANSI 1983). Future respiratory tract models and other changes necessitated by scientific development will be incorporated as required to serve the needs of the DOE community.

Potential users at DOE facilities have been involved in the design and implementation of CINDY. Twenty-nine field participants reviewed the third pre-release (Version 0.53) during September 1989. The response from field participants has been helpful in customizing the code to meet user needs, for identifying software limitations and coding bugs, and for making general improvements to the code. Technical aspects, such as correct interpretation of bioassay measurements, compartment modeling and parameters, database quality, and mathematical execution of the code, have also been improved.

Peer review and scientific validation of the code are proceeding. The release of Version 1.0 is scheduled for January 1990. Future revisions of the code will be issued as biokinetic models, dose factors, and user requirements are revised.

Ultrasound Measurement Techniques

A. L. Anderson and D. Kruchten (LLNL)

The tissue thickness and fat content of the chest wall greatly affect the determination of plutonium and other low-photon-energy transuranics in the lungs. A computer system was developed at Lawrence Livermore National Laboratory (LLNL) that more accurately measures the fat, muscle, and bone content of the chest wall over the lungs using ultrasonic imaging of workers. This system has made it possible to determine the chest-wall thickness within ± 1.5 mm, compared with the usual error of ± 3 mm to ± 6 mm using biometric equations or ruler measurements on ultrasonic images.

The new system developed at LLNL involves an ultrasound transducer, image analysis software, and computer and data storage components. Analog images of the chest wall are transferred by computer from the ultrasound unit to a "frame-grabber" board inside a 286-class personal computer. Two programs are used to digitize and save the images to disk and to analyze the images. These menu-driven programs allow the user to store, retrieve, and analyze images. The user may also edit the database in which the information is maintained. The software package, user manual, and a list of additional software and hardware requirements for system operation are available from LLNL.

Internal Dosimeter Based on Optically Stimulated Luminescence

S. D. Miller and J. S. Durham

The purpose of this task is to determine the feasibility of an internal dosimeter for direct measurement of beta radiation inside the body from internal emitters. The dosimeter concept is based on the measurement of optically stimulated luminescence (OSL) emitted from a natural LiF crystal after exposure to ionizing radiation.

During FY 1989, a system design was chosen that uses a bifurcated fiber optic. One channel delivers the stimulating light from a laser to trigger the OSL effect, while the second channel collects the light emitted from the stimulated crystal. The two-channel design was chosen to eliminate luminescence within the fiber optic. The amount of light

emitted from the stimulated crystal indicates the dose absorbed by the crystal. The fiber optic design allows for continuous measurement of light emissions from excitation of the electron traps produced by ionizing radiation, and allows the crystal to operate as a continuous-readout dosimeter. It can also be used as an integrating dosimeter. Procurement difficulties have delayed testing of the preliminary design until early FY 1990.

Correlation of Bioassay Data with Radionuclide Intake

R. J. Traub and D. E. Bihl

The purpose of this task is to develop a statistically reliable method for estimating intakes of radionuclides in workers using bioassay measurement results. A major uncertainty in occupational dose assessment for internally deposited radionuclides relates to our inability to accurately correlate bioassay results with actual intakes. Potential methods of analysis and difficulties associated with interpretation were studied.

A common approach to bioassay (excreta) interpretation is to compare the results of the bioassay measurement with the prediction of a mathematical model, such as those employed by the code CINDY. If there are multiple estimates of the intake, then an average of the estimates may be employed as the best estimate of the intake. When employing this method the user should be aware that outliers may exist in the data. The presence of these nonrepresentative samples may be determined by the test described by Dixon (1953). Algorithms for dealing with outlying observations have been described by the American Society for Testing and Materials (1980).

A second method for interpretation of excretion bioassay data is described as the least-squares method and is suggested in NUREG/CR-4884 (Lessard et al. 1987). Although not explicitly stated, the least-squares bioassay interpretation equation is that for the slope of a line that passes through the origin. Because this equation is the regression equation for a straight line it is straightforward to apply those tests that are common to regression analysis. These analyses include confidence intervals for the regression coefficients and the F-test to determine the value of the derived equation. Irrespective of the method

employed, it is imperative to test the assumption of this equation, namely that the data describe a straight line that passes through the origin.

An important item that is overlooked by some individuals is that either method described above will provide a good estimate of the intake only if the excretion model, against which the actual excretion is compared, is appropriate for the inhaled material. Work was initiated in 1989 to determine how the excretion data may be employed as a guide to the correct excretion model. No conclusions are yet available for these investigations, but it is hoped that analysis of the residuals between observed and model excretion rates may be useful.

Low-Level Bioassay Measurements by Laser Spectroscopy

G. K. Gerke and B. A. Bushaw

This project involved development of technologies for measuring extremely small quantities of radionuclides in biological samples. The goal of this project was to reduce the limit of detection for analysis of plutonium and other transuranics in bioassay samples using new methods of resonance ionization spectroscopy (RIS) that do not rely on radioactive decay.

Two methods of analysis for trace levels of uranium or plutonium were developed (see Figure 1). The first is called "resonantly enhanced collisional ionization" (RECI). It involves laser excitation of two resonant transitions in the element of interest to produce a high-lying Rydberg state. Collisions of the Rydberg state atom with a buffer gas atom or molecule causes ionization, which is then measured by conventional ion-detection methods. The resonant optical transitions may be obtained with relatively simple and inexpensive low-power lasers. The use of a buffer gas for collisional ionization slowed the passage of atoms through the laser interaction region, thus increasing the sensitivity of the process by allowing more atoms to undergo the excitation and detection process.

The second method is called "double resonance autoionization with mass analysis" (DRAMA). It involves two resonant transitions to selectively excite plutonium to an autoionizing state. Measurements are made in high vacuum using simple time-of-flight mass analysis. The second autoionizing resonance increased the measurement sensitivity by a factor of 50 over RECI. Spectral lines for both ^{238}U and ^{239}Pu were determined.

FIGURE 1. Laser-induced ionization pathways studied under this program. RECI uses a double resonance excitation to a highly excited state, which is then ionized by collisions with buffer gas species. DRAMA uses a double resonance excitation to autoionizing levels.

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Radiation Protection Support to the Department of Energy for Technical Safety Appraisals

Project Manager: *L. G. Faust*

The purpose of the Radiation Protection Support for Technical Safety Appraisals project is to provide technical support in radiation protection, personnel protection, and emergency readiness to the U.S. Department of Energy (DOE) Headquarter's Environment, Safety, and Quality Assurance organization for its contractor safety oversight program. The contractor safety oversight program supports the DOE Environment, Safety, and Health (EH) Division's responsibility for the health and safety standards related to the operation of DOE facilities. Key elements of this program are the Technical Safety Appraisals (TSAs), Tiger Teams (TTs), and other functional appraisals of DOE contractor-operated sites and facilities.

The Radiation Protection Support project provides professional staff with varied specialized technical expertise and experience, whose areas of expertise are matched with the case-specific needs of the particular facility to be reviewed. The reviews include design, operational, organizational, and managerial aspects related to the operation of reactors; critical facilities; uranium, plutonium, and tritium processing facilities; as well as other supporting facilities.

TSAs address radiation protection aspects in 13 different areas, emergency preparedness and security/safety interfaces in 7 areas, and personnel protection in 7 areas. Tiger Teams cover the same areas but usually not as in depth, whereas functional appraisals are directed to a single element, i.e., fire protection, radiation protection.

Assigned staff accomplish their assignment by reviewing records and procedures, directly observing facility operations, and interviewing facility personnel. All projects are integrated by and conducted under the direction of a DOE team leader who is responsible for the specific appraisal. However, other activities, such as follow-up appraisals, quick response assistance, in-depth technical investigations, and independent analyses of specific topics, are included as appropriate, on a case-specific case basis and as agreed upon by the team leader or the DOE and Pacific Northwest Laboratory (PNL) program managers.

In order to be able to respond quickly and comprehensively, Battelle^(a) has established subcontracts with other DOE laboratories and private consultants currently totalling 25 organizations. The expertise represented by the organizations under these subcontracts covers all aspects of the radiation protection, emergency readiness, and personnel protection portion of the appraisal program.

Subcontracting efforts are accomplished by the Subcontracts Section of PNL's Contract Department. PNL's procurement and subcontracts functions successfully passed the DOE-conducted Contractor Procurement System Review in December 1984. As a result, PNL procurement and contracting authority levels have been substantially increased and the procurement lead times have been dramatically reduced.

During FY 1989, PNL participated in eight follow-up appraisals, six TSAs, three TTs, two large functional appraisals, and several other reviews of action plans, performance objectives, and other related activities.

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

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Author Index

Author Index

- Anderson, A. L., 40
 Anderson, H. (Mound Laboratory), 32
 Anderson, T. L., 13, 15
 Apfel, R. E. (Apfel Enterprises, Inc.), 21
 Baker, D. A., 13
 Baum, J. W. (BNL), 28
 Beck, D. M., 9
 Bihl, D. E., 40
 Brackenbush, L. W., 19, 20
 Bramson, P. E., 4
 Buck, J. W., 6
 Buelt, J. L., 5
 Bushaw, B. A., 41
 Cross, F. T., 31
 Dicello, J. F. (NORCUS), 20, 36
 Droppo, J. G., 5
 Droppo, J. G., Jr., 5, 6
 Durham, J. S., 23, 40
 Faust, L. G., 19, 23, 27, 30, 39, 43
 Faw, R. E. (KSU), 25
 Fisher, D. R., 29, 31, 37, 39
 Geffen, C. A., 11
 Gephart, R. E., 9, 11, 12
 Gerke, G. K., 41
 Gianti, S. J. (CH2M Hill), 12
 Grove, L. K., 3
 Hankins, D. E., 20
 Harty, R., 35
 Hertel, N. E. (NORCUS), 35
 Hickey, E. E., 4, 11
 Higby, D. P., 13
 Higley, K. A., 3, 4
 Hoopes, B. L., 6
 Huizenga, D. G., 15
 Humphries, K. H., 11
 James, A. C., 31
 Johnson, J. R., 31, 39
 Johnston, B. V., 13
 Keller, J. F., 9-12
 Kelly, G. M. (ICF, Inc.), 12
 Kennedy, W. E., Jr., 3, 4, 12
 Kruchten, D., 40
 Lamar, D. A., 13
 Longstreth, J. D. (ICF, Inc.), 12
 Lynch, T. P., 30
 MacLellan, J. A., 37
 Martin, J. B., 32
 McCormack, W. D., 4
 McDonald, J. C., 35-38
 McNeill, D. A., 13
 Merwin, S. E., 23, 27
 Miller, S. D., 21, 23, 40
 Moeller, M. P., 29
 Munson, L. H., 30, 31, 33, 34
 Murphy, M. K., 36
 Myers, R. S., 9
 Nelson, I. C., 3, 4
 Neuder, S. M., 3
 Olsen, P. C., 32, 33, 37
 Palmer, H. E., 36, 37
 Parkhurst, M. A., 20
 Peloquin, R. A., 3, 39
 Ramsdell, J. V., 4
 Rhoads, K. C., 3
 Rodensky, R. (ICF, Inc.), 12
 Rosbach, M. L., 13
 Scherpelz, R. I., 19
 Schreckhise, R. G., 12, 13
 Selby, J. M., 27, 29, 31-35, 37
 Siegel, M. R., 10-12
 Simons, G. G. (KSU), 23
 Simpson, D. R., 13
 Sisk, D. R., 21, 25, 33
 Smith, R. M., 12
 Soldat, J. K., 3, 4
 Stenner, R. D., 3, 4, 10, 13
 Stephan, J. G., 33
 Stewart, T. L., 12
 Streng, D. L., 6, 39
 Stroud, C. M., 19
 Sula, M. J., 39
 Swinth, K. L., 23, 25, 27, 29, 32, 33, 37
 Tanner, J. E., 20, 30
 Templeton, W. L., 3
 Thorngate, J. L. (LLNL), 19
 Tinker, M. R., 21
 Traub, R. J., 20, 28, 31, 40
 Triplett, M. B., 9
 Valdez, L. M., 13
 Van Deven, J. A. (CH2M Hill), 12
 Van Epp, T. D. (CH2M Hill), 12
 Veitenheimer, S. J., 11
 Waller, W. K., 11
 Walter, M. B., 6
 Whelan, G., 5, 6
 Woodruff, M. G., 11, 13

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G. Whelan K6-96
T. J. Whitaker K2-21
R. E. Wildung P7-50
W. R. Wiley K1-46
L. D. Williams K1-41

M. G. Woodruff K6-55
J. D. Zimbrick P7-50
Health Physics Department
Library
Life Sciences Library (2)
Publishing Coordination
Technical Report Files (5)