**Pacific Northwest Laboratory
Annual Report for 1984 to the
Assistant Secretary for Policy
Safety and Environment**

**Part 5 Overview and Assessment
February 1985**

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

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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W. J. Bair and Staff Members
of Pacific Northwest Laboratory

February 1985

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Pacific Northwest Laboratory
Richland, Washington 99352

PREFACE

This 1984 annual report from Pacific Northwest Laboratory (PNL) to the Department of Energy (DOE) describes research in environment, health, and safety conducted during fiscal year 1984. The report again consists of five parts, each in a separate volume.

The five parts of the report are oriented to particular segments of our 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 Policy, Safety, and Environment. 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 1984 Annual Report are:

Part 1: Biomedical Sciences Program Manager - J. F. Park	D. L. Felton, Report Coordinator and Editor
Part 2: Environmental Sciences Program Manager - B. E. Vaughan	B. E. Vaughan, Report Coordinator C. M. Novich, Editor
Part 3: Atmospheric Sciences Program Manager - C. E. Elderkin	N. S. Laulainen, Report Coordinator E. L. Owczarski, Editor
Part 4: Physical Sciences Program Manager - J. M. Nielsen	R. M. Garcia, Report Coordinator J. E. Danko, Editor
Part 5: Overview and Assessment Program Manager - W. A. Glass	R. W. Baalman, Report Coordinator and 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 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, Manager
S. Marks, Associate Manager
Environment, Health and Safety
Research Program

Previous reports in this series:

Annual Report for

1951	W-25021, HW-25709
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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
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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
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1978	PNL-2850, Pt. 1-5
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1980	PNL-3700, Pt. 1-5
1981	PNL-4100, Pt. 1-5
1982	PNL-4600, Pt. 1-5
1983	PNL-5000, Pt. 1-5

FOREWORD

Part 5 of the 1984 Annual Report to the Department of Energy's Assistant Secretary for Environmental Protection, Safety and Emergency Preparedness presents Pacific Northwest Laboratory's progress on work performed for the Office of Nuclear Safety, the Office of Operational Safety, and for the Office of Environmental Analysis. For each project, as identified by the Field Task Proposal/Agreement, articles describe progress made during FY 1984. Authors of these articles represent a broad spectrum of capabilities derived from various segments of the Laboratory, reflecting the interdisciplinary nature of the work.

For additional information on any of the projects reported in Part 5, contact the authors of the articles.

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Environmental
Analysis

ENVIRONMENTAL ANALYSIS

- **Uncertainties in Modeling Source/Receptor Relations for Acidic Deposition**

The Office of Environmental Analysis represents the Department of Energy's interests in the Federal regulatory development process, maintains comprehensive environmental data bases, conducts anticipatory analyses for early identification and scoping of emerging regulatory issues, and provides environmental technical support and guidance to Departmental programs.

• Uncertainties in Modeling Source/Receptor Relations for Acidic Deposition

Contributions of various processes related to modeling source/receptor relations in long-range transport were examined. Initial results are presented.

MODELING SOURCE/RECEPTOR RELATIONS--ACID DEPOSITION

C. Berkowitz

The purpose of this study is to quantify uncertainty in model/observation relations in the areas of (1) atmospheric chemistry, (2) trajectories based on single and multiple layer methods, and (3) interannual variability in meteorology. Extensive use has been made of residual analysis (Daniel and Wood 1980), examination of frequency diagrams, and response surface functions (Draper and Smith 1981). The Regional Air Pollutant Transport Model (McNaughton, Powell, and Berkowitz 1981), a multi-layer version of RAPT, and a statistical model (Sheih 1977) are the basic tools of this study.

A set of experiments in which input parameters to RAPT were varied by a hypercube sampling method demonstrated that the deposition velocity of SO_2 strongly governs the root mean square fit between model predictions and the corresponding observations. Such a result is not surprising; this deposition velocity effectively reduces or increases the resulting emission field in a model with linear chemistry (such as RAPT has).

In another set of experiments, assorted measures of "goodness of fit" were calculated as functions of different areas over which the observations and predictions were combined. It was found that there is a significant improvement in model performance for areas greater than $14 \times 10^5 \text{ km}^2$; below this area, the model performs significantly worse.

References

- Daniel, C and F. S. Wood. 1980. Fitting Equations to Data. Wiley and Sons. 2nd Ed.
- Draper, N. and H. Smith. 1981. Applied Regression Analysis. Wiley and Sons.
- McNaughton, D. J., D. C. Powell and C. M. Berkowitz. 1981. RAPT-The Pacific Northwest Laboratory Regional Air Pollutant Transport Model. PNL-3390. Prepared for U.S. EPA under a Related Services Agreement with DOE.
- Sheih, C. M. 1977. Application of a Statistical Trajectory Model to the Simulation of Sulfur Pollution Over Northeastern United States. Atmospheric Environment Vol II, pp. 173-178.

Nuclear
Safety

NUCLEAR SAFETY

- **Health Physics Support and Assistance to the Department of Energy**
- **Technical Guidelines for Personnel Dosimetry Calibrations**
- **Personnel Neutron Dosimeter Evaluation and Upgrade**
- **Beta Measurement Evaluation and Upgrade**
- **DOE Laboratory Accreditation Program for Occupational Exposure Measurements**

To establish and maintain an effective nuclear safety program, DOE has assigned to the Office of Nuclear Safety responsibility for developing and promulgating nuclear safety policy, standards, and guidance and for DOE-wide independent overview, support, and counsel. The objective of the Nuclear Safety Program is to assure that the activities of the Department of Energy (DOE) and its contractors are in full compliance with DOE and other applicable nuclear safety, health, and emergency preparedness standards and regulations and to provide technical support to the DOE Office of Nuclear Safety.

The major emphasis at Pacific Northwest Laboratory continues to be on developing criteria, instruments, and methods to assure that radiation exposure to occupational personnel and to people in the environs of nuclear facilities is maintained as low as reasonably achievable. Particular emphasis has been placed on improving basic personnel exposure measurement and recording programs and on improving reporting systems

-
- Bullets denote Field Task Proposal/Agreement (FTPAs) titles.

• Health Physics Support and Assistance to the Department of Energy

Pacific Northwest Laboratory functions as the lead laboratory providing health physics support and assistance to the DOE Division of Operational Safety on special studies principally associated with the analysis of impact of standards, regulations, and engineering and administrative actions on occupational and environmental exposure. Support and assistance are also provided for other specific tasks or special studies identified by DOE as priorities. The designation of lead laboratory in health physics, with an agreement and budget in place, provides the Division with the additional expertise necessary to respond to the many questions and situations that arise during the operation of their numerous nuclear energy research, development, and demonstration facilities.

TECHNICAL EVALUATION OF THE CAPABILITY OF PRESENT INSTRUMENTATION TO MEET THE DRAFT ANSI STANDARD (N42.17) ON PERFORMANCE SPECIFICATIONS FOR RADIATION PROTECTION SURVEY INSTRUMENTATION*

J. L. Kenoyer, K. L. Swinth

This study was established to evaluate the applicability and practicality of the proposed American National Standards Institute (ANSI) Standard "Performance Specifications for Radiation Protection Survey Instrumentation (N42.17);" to determine the degree of conformance to the proposed standard of selected currently available commercial instruments; to develop a formal test and evaluation protocol and specific procedures; and to lay the ground work for establishing a permanent testing laboratory.

During the past year, a total of ninety-nine portable health physics instruments were evaluated with the testing procedures based on the requirements in ANSI N42.17D3. These included forty Geiger-Mueller (GM) detectors, twenty-one ion chambers (IC), twenty-seven alpha survey meters, nine neutron monitors, and two scintillation-type low-level gamma survey meters.

These instruments have been procured through three methods: purchase directly from the manufacturers, loan from instrument manufacturers, and loan from Department of Energy (DOE) laboratories and Nuclear Regulatory Commission (NRC) licensees. Instruments have been borrowed from nine commercial vendors as well as six DOE laboratories and one nuclear power station.

Modifications were made in several of the testing procedures in order to incorporate changes in the draft standard that were made

during a January meeting of the ANSI working group. These procedures were then reverified before being implemented in the testing program.

Data have been obtained with the following testing procedures for "normal" environments: inspection, battery lifetime, stability, geotropism, response time, accuracy, precision, IER energy dependence, beta energy dependence, angular dependence, temperature, humidity, ambient pressure, AC power, radiation overloads, nonionizing electromagnetic radiations, electrostatic fields, extracamera response, magnetic fields, interfering ionizing radiations, alarm threshold drift, alarm reset, vibration shock, and temperature shock. Selected results from these tests are listed in Table I for GM detectors, IC, alpha survey meters, and neutron dose equivalent survey instruments. During the last year, over 250 tests were performed with these instruments.

Data have also been obtained with procedures for use under extreme environmental conditions, including temperature shock, condensing atmosphere, and exposure to high-energy photons. A limited number of instruments have been tested with the extreme range temperature shock procedure. Results for the condensing atmosphere test are listed in Table I. All of the instruments exposed to high-energy photons from ^{16}N (i.e., 6.12 and 7.11 MeV photons) overresponded when compared to the response to ^{137}Cs (i.e., 0.66 MeV photons). The ratio of the response to ^{16}N radiations to the response to ^{137}Cs radiations after normalization to the conventionally true values of each source ranged from 1.1 to 3.9. For five ICs, this overresponse ratio ranged from 1.1 to 2.2. For eighteen GM detectors, the ratio ranged from 1.4 to 3.9; five of these instruments overresponded by factors of 1.4 to 2.0, ten instruments overresponded by factors of 2.1 to 2.9, and the three remaining instruments overresponded by factors of 3.3 to 3.9.

*This task is jointly sponsored by the Department of Energy and the Nuclear Regulatory Commission.

TABLE 1. Selected Testing Results

Test	No. of Failures/No. Tested			
	Ion Chamber	GM Detector	Alpha Detector	Neutron
AC power	NT	0/4	NT	NA
Battery lifetime	1/5	7/19	1/5	NT
Alarm reset	NT	1/3	NT	NA
Alarm threshold drift	NT	0/3	NT	NA
Stability	1/9	3/35	6/15	3/4
Geotropism	3/9	4/20	9/14	NT
Response time	8/13	13/22	0/7	3/3
Precision	0/15	18/23	7/8	0/3
Accuracy	1/4	6/12	NT	NT
IER energy dependence	4/14	18/23	NA	NA
Radiation overloads	LNT	1/4	NT	NT
Angular dependence	8/9	19/20	NA	0/2
Temperature	9/17	0/22	10/13	0/3
Temperature shock	1/3	0/2	3/5	3/5
Humidity	1/7	4/18	10/15	0/6
Ambient pressure	0/7	0/5	12/13	1/6
Magnetic fields	0/6	0/13	NT	NT
RF fields	2/7	2/11	0/5	0/5
Electrostatic fields	0/7	0/13	NT	NT
Extracameral	NA	0/12	NA	NT
Vibration	1/4	1/7	0/7	NT
Shock	0/3	0/8	0/7	NT
Condensing atmosphere	1/7	0/5	4/7	0/3
Microwave fields	4/5	3/7	2/3	NT

NT - None tested
 NA - Not applicable
 LNT - Limited number tested

The following conclusions on instrument performance can be made from the results of the testing program:

- A large variability in performance is observed among instruments of the same type from different manufacturers.
- Variability in performance is observed between same manufacturer/same model instruments.
- Performance data supplied by many manufacturers are incomplete, unsatisfactory, and at times inaccurate.
- Temperature dependence can be quite severe for ion chambers.
- Most GM instruments currently available are highly IER energy dependent.
- High humidity can affect instrument performance; IC and GM instruments tend to recover when returned to low humidity.
- Air proportional alpha-detection instruments are very sensitive to humidity and pressure changes.

- The rate of pressure drop affects the response of scintillation detectors.

TECHNICAL EVALUATION OF DRAFT ANSI STANDARD M13.30 PERFORMANCE CRITERIA FOR RADIOBIOASSAY*

D. R. Fisher, A. V. Robinson, R. T. Hadley

The purpose of this study is to evaluate the adequacy of draft ANSI Standard 13.30 performance criteria by conducting a nationwide bioassay intercomparison test. The study involves two rounds of performance testing of laboratories making in in-vitro (excreta analysis) or in-vivo (external counting) measurements. The performance of bioassay laboratories is judged against criteria specified in the draft Standard for bias, precision, and minimum detectable activity.

During the past year, the first round of in-vivo testing was completed, and the second round was begun. In addition, the second round of in-vitro testing was completed with

*This study is jointly sponsored by the Department of Energy and the Nuclear Regulatory Commission.

the exception of final data analysis. A large number of laboratories voluntarily participated in these tests, including commercial testing laboratories, DOE/DOE-contractor laboratories, universities and medical institutions, and commercial nuclear power facilities.

In-vivo testing involved the measurement of radioactivity in the lungs of a torso phantom, in the thyroid of a neck phantom, and in the composite mass of a whole-body bottle phantom. Three interchangeable polyurethane lung sets, each tagged with a different nuclide (^{235}U , ^{241}Am , or ^{60}Co), were employed. A point source of enriched ^{40}K was imbedded into the heart cavity of the torso phantom to provide a natural ^{40}K background interference.

To test whole-body measurement capabilities, a bottle phantom, filled with a gelatinous matrix containing precisely known quantities of ^{137}Cs , ^{144}Ce , and ^{60}Co along with the background interference radionuclides of ^{90}Sr and ^{40}K , was used. Thyroid counting capabilities were tested using capsules containing ^{131}I . All radioactive source materials were provided by the National Bureau of Standards. In-vivo laboratories were tested for Minimum Significant Photon Activity (MSPA), bias and precision for several radionuclides. A summary of round one in-vivo test results is given in Table 1. In general, in-vivo counting facilities had bias and precision difficulties measuring whole-body distributions of ^{144}Ce in the presence of ^{60}Co and ^{137}Cs . A high bias failure rate was also observed for ^{60}Co in the lung and whole body.

In-vitro measurement capability testing involved preparation of approximately 560 carefully spiked artificial urine samples for round one and 1300 samples for round two. The round two samples, containing known amounts of ^{241}Am + ^{238}Pu , ^{89}Sr + ^{90}Sr , ^3H , ^{60}Co + ^{137}Cs , or natural uranium, were shipped to participating bioassay laboratories for analysis. A third-party cross-check laboratory verified that the intended activity levels were present in the test samples. A preliminary summary of round two in-vitro test results is given in Table 2.

For in-vitro laboratories, failures in gamma spectrometry, alpha spectrometry, and uranium determinations were observed due to unacceptable minimum detectable activities (MDAs) and bias. Failures in beta measurements for ^{89}Sr were due to difficulties in meeting bias and precision criteria. These results were comparable to those observed in round one testing.

The intercomparison test results show that both in-vivo and in-vitro laboratories had difficulties meeting the draft Standard performance criteria in several categories. The causes of test failures varied markedly. The test results indicate a need for laboratory accreditation to ensure accurate bioassay results. The present testing program provides an opportunity for laboratories to assess their performance in light of industry standards and to identify areas of weakness; it also reinforces the need for continual quality assurance.

TABLE 1. Summary of Round One In-Vivo Test Results

Category	Nuclide	Number of Participants	Responding Facilities	Percent Failure			MSPA, Bias, or Precision
				MSPA	Bias	Precision	
Lung	^{241}Am	6	4	0	0	0	0
Lung	^{235}U	7	5	20	20	0	40
Lung	^{60}Co	15	13	0	62	0	62
Whole body	^{60}Co	16	14	29	36	7	57
Whole body	^{137}Cs	15	13	46	15	0	62
Whole body	^{144}Ce	14	12	58	58	50	92
Thyroid	^{131}I	28	25	24	20	0	36

TABLE 2. Preliminary Summary of Round Two In-Vitro Test Results^(a)

Category	Nuclide	Number of Participants	Responding Facilities	Percent Failure			AMDA, Bias, or Precision
				AMDA	Bias	Precision	
Liquid scintillation	³ H	35	27	7	26	11	33
Gamma spectrometry	¹³⁷ Cs	27	19	53	21	5	58
	⁶⁰ Co	17	11	50	33	17	61
Beta measurements	⁸⁹ Sr	17	6	17	50	33	67
	⁹⁰ Sr	16	8	11	11	0	22
Alpha spectrometry	²⁴¹ Am	16	4	50	75	0	75
	²³⁸ Pu	16	6	67	0	0	67
Fluorescence measurements	U-nat	20	13	38	46	0	62

(a) As of September 29, 1984

CHARACTERIZATION OF DOE FACILITY EMERGENCY PREPAREDNESS

K. L. Swinth, J. A. MacLellan, J. M. Pisarcik, A. V. Robinson, B. L. Murphy, J. M. Selby

The purpose of the emergency preparedness task is to update and expand on the emergency instrument performance criteria published in the 1970s and to provide guidance on the proper elements of emergency instrument programs. The work will entail development of a generic document on emergency preparedness instrumentation followed by documents on emergency instrument performance criteria and requirements for specific categories of facilities.

In 1980, following the Three Mile Island incident, DOE requested Pacific Northwest Laboratory (PNL) to expand and update an earlier study on emergency instrumentation preparedness conducted in 1970. The 1970 survey study resulted in four reports on performance criteria for radiological emergency instrumentation. Three of these documents addressed criteria for emergency instrumentation at 1) reactors, (2) mixed oxide fuel fabrication plants, and (3) fuel reprocessing plants. The fourth document addressed evaluation testing and calibration methodology for these instruments.

The update of this earlier study has included a survey of thirty DOE contractors to assess current emergency preparedness capabilities. This survey showed that in approximately one-half of the criteria surveyed in both 1970 and 1980 there was a significant improvement. Approximately 30% of the criteria that were in-

cluded in both surveys showed some improvement, and 20% indicated a decline in emergency response capabilities.

A draft report covering the results of the survey was completed in FY 1983. Following an extensive review, the draft report was revised to facilitate the comparison of data with the earlier report and to improve the presentation of results. This included a reanalysis of some of the earlier data. The report was completed and published during FY 1984.

The review has also shown that the earlier instrument performance criteria should be updated to reflect the current state-of-the-art. Refinements have been made in models for atmospheric transport, and new and improved instruments have become available, including the current trend toward digital instruments. Several standards have been written or are in preparation covering instrument performance under a variety of conditions. Recommendations on emergency preparedness instrumentation will be updated to reflect changes in DOE facility types and instrument performance criteria as reflected in standards and state-of-the-art instrumentation.

Updating of the reports was started in FY 1983 with preparation of sections of a draft document on generic requirements for emergency instrument preparedness at DOE facilities. These sections were edited and reorganized during FY 1984, but most of the effort was directed toward completion of the survey report.

During FY 1985, efforts will be directed toward onsite evaluation of emergency instrument preparedness at selected DOE facilities. This will provide a basis for reassessment of data in the survey report, will provide a realistic assessment of emergency instrumentation capabilities, and will form a basis for recommendations in the generic document. This will also assist in identification of requirements at specific facility types.

DOE PROGRAM FOR IMPROVING AIR SAMPLING AND MONITORING

J. L. Kenoyer, B. L. Murphy, A. V. Robinson

The objective of this task is to provide a continuing effort to identify and resolve problems with work environment air sampling and monitoring at DOE and DOE contractor facilities. Workplace air sampling and monitoring are commonly used as indications of the effectiveness of engineered controls on dispersible radioactive materials. Less commonly, air sampling and monitoring results are used to estimate personnel exposure to airborne radionuclides. Although the accuracy and precision of existing air sampling and monitoring techniques are typically not adequate for this purpose, changes in the recommendations of the International Commission on Radiological Protection (ICRP) may place increased emphasis on the use of air sampling to assess internal dose.

During FY 1984, a draft standard was developed in association with the ANSI N42.17 evaluation work being performed for DOE and NRC. This draft standard entitled "Performance Specifications for Airborne Radioactivity Monitoring Instrumentation" includes testing criteria and procedures that are directly related to the needs of this project. Areas discussed in this standard include general, environmental, electronic, radiological, and airflow requirements. The draft standard has been reviewed once by members of the ANSI working group and by other interested manufacturers, users, and regulators not on the committee. The changes recommended by these reviewers will be incorporated into the text, and the draft standard will be reviewed again by the working group early in FY 1985. A technical evaluation of the standard is planned in FY 1985.

A detailed air sampling and monitoring questionnaire was sent to DOE contractors through the respective field offices in FY 1984. This questionnaire covered eight aspects of workplace air sampling and monitoring:

- Documentation
- General Practices
- Continuous Sampling
- Personnel Air Sampling
- Sample Handling and Analysis
- Air Monitoring Practices

- Air Monitor Calibration
- Development Needs

The results of the project were developed into a draft report entitled "DOE Workplace Air Sampling and Monitoring Practices." The report, which will be published in FY 1985, summarizes current air monitoring/sampling practices from twenty DOE or DOE contractor facilities. Areas identified for improvement and/or closer inspection include derivation of MPC-hr limits; particle size and solubility determination; effect of humidity, pressure, and temperature on air monitoring instruments; and improved capability for real-time alpha and tritium monitoring.

A subcontract with Lawrence Livermore National Laboratory to develop a highly sensitive transuranic aerosol monitor for use in the workplace environment is in place. The system may have the capability of measuring airborne levels of ^{239}Pu under quasi-real-time conditions with a sensitivity level of ≤ 0.5 MPC-hr. The concepts have been developed, and effort is under way to build the prototype that will be field tested. The development of the collection system, the control circuitry, and software is presently under way.

DOE ALARA (As Low As Reasonably Achievable) UPGRADE

L. H. Munson, D. P. Higby, R. L. Kathren

This task was initiated in FY 1983 with the objective to review and upgrade DOE guidance on ALARA. The existing manual is being revised, including the development of additional detailed guidance as necessary. A draft revision of the manual, emphasizing the application of ALARA and providing decision trees for development of ALARA programs, was completed in FY 1984 and transmitted to the sponsor. Following a review of the manual, it was decided to expand the scope of each of the sections with the ultimate goal of a single definitive document describing the elements necessary for an effective ALARA program and methods for implementation. Future efforts will center on expansion and completion of the sections on Administration, Goal Setting and Program Evaluation, and Conduct of Operations. In addition, the format and basis information for an in-depth treatment on radiological design for ALARA will be developed for expansion of the Radiological Design Section.

EVALUATION AND UPGRADE OF DOE INTERNAL DOSIMETRY PRACTICES

B. L. Murphy, K. R. Heid, R. J. Traub, A. V. Robinson

The objectives of this program are to (1) evaluate significant problems that affect internal

dosimetry practices at DOE/DOE contractor facilities, (2) provide recommendations for improvements in internal dosimetry programs, and (3) develop improved analytical (e.g., bioassay) and dose evaluation techniques. Reports will be prepared on current status of internal dosimetry, dose evaluation techniques, improvements in analytical capabilities, application of new promising concepts for internal dosimetry, and recommended internal dosimetry practices.

During FY 1984, a questionnaire concerning the internal dosimetry practices at DOE facilities sent to all DOE/DOE contractor facilities was analyzed, and a report has been drafted. A preliminary report on the findings was presented at the Twenty-Ninth Annual Meeting of the Health Physics Society.

The responses to the questionnaire indicated that the individuals responsible for internal dosimetry at DOE facilities are concerned about the accuracy and reliability of the methods used to estimate uptakes of radioactive materials and the radiation doses resulting from the uptakes. Specifically, the radiation detection methods do not have the spatial resolution needed to quantify radioactive materials in individual body organs, except for a few instances such as iodine in the thyroid. In addition, the mathematical models that describe the distribution of radioactive material within the body are not sufficiently accurate to predict the organ depositions in specific individuals. A final concern is that the method used to assign a date of intake when the actual date is unknown will result in large errors.

Three literature searches were conducted and documented in FY 1984 via letter reports. First, review of the available literature was conducted in order to estimate the magnitude of the error associated with internal dosimetry. The sources of errors were placed into seven categories: bioassay, uptake models, organ masses, energy distributions, time of uptake, nonuniform distribution of activity within body organs, and the undetected annual dose commitment due to bioassay interval. The magnitude of the errors for each error source was estimated based upon estimates from the scientific literature. The individual errors ranged from 10% to greater than 100%. The total error associated with internal dosimetry was not estimated because it was not known to what extent the individual errors were independent, random events.

Second, the effectiveness of fecal analysis in a bioassay program was reviewed. It was concluded that, for some isotopes, fecal analysis provided better sensitivity than other techniques, but careful attention to exposure history, metabolic parameters, and physical form of the isotopes is necessary to enhance the utilization of the technique.

Third, the correlation between personal air samplers and internal dose estimations was investigated. The error associated with personal air samplers was found to be significant. Considerable improvements in the interpretation of sampling results and the correlation with biological deposition are required before the data can be effectively used for internal dosimetry practices.

STANDARDS EVALUATION

J. M. Selby, B. L. Murphy, K. R. Heid, J. P. Corley

The objective of this task is to provide a timely technical evaluation of national and international occupational exposure recommendations, standards, and regulations to determine in particular their technical accuracy, their impact on DOE operations, and compatibility with DOE operations and orders. As appropriate, technical expertise is drawn from other DOE contractor laboratories to assist in the evaluation. In FY 1984, evaluations were performed of ICRP Publication 26; proposed NRC revision to 10 CFR 20; proposed EPA revision to Guidance to the Federal Agencies on Occupational Radiation Protection Transuranium Elements in the General Environment (EPA); Clean Air Act (EPA); draft NCRP committee report; draft HHS Radioepidemiological tables and numerous ISO, IAEA, NEA, and ANSI standards. A Technical Advisory Committee consisting of representatives from several DOE contractor laboratories was formed to assist with evaluations that specifically affected occupational exposure regulations.

HEALTH PHYSICS TECHNICIAN TRAINING CHARACTERIZATION FOR DOE CONTRACTORS

J. A. MacLellan, J. M. Selby, B. L. Murphy

The health physics technician plays an essential role in the control of radiological hazards at DOE facilities. Recent staff reductions at contractor-operated DOE facilities raise the possibility of a corresponding reduction in radiological control abilities. With this in mind, the DOE Office of Nuclear Safety requested a survey of the current status and trends in technician-level radiation safety manpower and training among DOE contractors. A detailed questionnaire was sent to DOE field offices for transmittal to appropriate DOE contractors. The responses to the questionnaire, along with other requested supplemental material, were analyzed and reported in two phases.

Phase I ended with the completion of the ORAU report "Manpower Trends and Training Requirements for Radiation Protection Personnel in the DOE Contractor System." The "Phase II" report, which describes recommendations con-

cerning training requirements, has been completed and is currently with the sponsor. Jay MacLellan presented the findings of this survey to the Training Resources and Data Exchange meeting in Las Vegas, July 9-10, 1984.

RADIATION RECORDS SYSTEMS AT DOE FACILITIES

R. J. Traub, B. L. Murphy

Two surveys were performed to determine the present status of radiation records systems at DOE/DOE contractor facilities. A questionnaire was sent to all DOE facilities through DOE/HQ and the respective field offices. The questionnaire dealt with the extent to which computer data bases were used for radiation exposure records and the time required to obtain certain types of information concerning radiation exposure histories. The responses to the questionnaire indicated that, of the thirty-six facilities who responded, twenty-three used computer systems to assist in maintaining the records. Most of the computer systems were described as having been developed in-house. The time required to retrieve information from the records systems varies from facility to facility; the variation among facilities exists because not all facilities have completed entering their data into computer files.

A telephone survey was also conducted to determine the impact upon the records personnel of increasing the frequency of reporting dose summary data from annually to quarterly. The responses received indicate that, in addition to increased costs due to more frequent reporting, there may be substantial costs associated with changes in external and internal dosimetry programs. The changes in the programs would be required in order to provide the data for the more frequent reports.

EXTREMITY DOSE MEASUREMENTS EVALUATION AND UPGRADING

B. L. Murphy, P. L. Roberson, J. A. MacLellan

The objective of this program is to evaluate proposed regulations. New extremity dosime-

try dosimeters and instruments in current use at DOE laboratories for monitoring personnel extremity exposure and report on (1) current status of extremity dosimetry systems, including response characteristics; (2) development of calibration systems and procedures for instruments and dosimeters; (3) application of new promising concepts for extremity measurements; (4) status of occupational protection standards related to extremity dosimetry and evaluation of needs for new or improved guidance and impact on DOE operations; and (5) preparation of operations manuals for recommended systems.

This program will evaluate the significant problems that affect field measurement of extremity dose due to beta, gamma, and neutron radiation. Particular attention will be given to difficulties in complying with present or psystems will be designed for possible implementation at DOE facilities.

During FY 1984, a questionnaire sent to DOE/DOE contractor facilities concerning the current status of extremity dosimetry was evaluated. This evaluation indicated a need to improve dosimeters for the measurement of the shallow dose equivalent for extremities and to provide guidance on the selection, use, and placement of extremity dosimeters; the results of the study will be published in FY 1985.

Studies to determine an appropriate phantom for the performance testing of extremity dosimeters were initiated in FY 1984. These studies will also provide data to determine the significance of C_x factor for extremity dosimetry. Data from these studies will be utilized in draft HPSSC/ANSI 13.32 "Standard for the Performance Testing of Personnel Dosimetry Systems."

• Technical Guidelines for Radiological Calibrations

This program continues to provide technical guidelines for personnel dosimetry calibration procedures at DOE laboratories. This information and guidance will help to optimize equipment and procedures for radiological calibrations. The current tasks include developing a performance data base for radiation protection instruments and preparing guidelines for their calibration. In addition, an intercomparison program for laboratory calibrations is under way.

TECHNICAL GUIDELINES FOR RADIOLOGICAL CALIBRATIONS

J. C. McDonald, P. L. Roberson, K. L. Swinth

The objectives of this program are to establish guidelines for the calibration of personnel dosimeters and radiation protection instruments. This guidance will help DOE laboratories institute optimum techniques for radiological calibrations in a cost effective and prompt manner. It will also establish a more uniform approach to dosimetry by reducing site-dependent differences in reported personnel doses that may arise from calibration differences. The accomplishments of the program are described below.

A data base is being developed to characterize the calibration techniques, the types, and the performance of instruments currently used at DOE facilities. A survey of DOE facilities and a compilation of data available from Hanford experience and data from related projects have been completed. Site visits to several major DOE laboratories and use of related data from the laboratories are planned.

Experience gained from the ongoing evaluation of ANSI N42.17D2 and additional evaluations deemed necessary will be used to determine instrument performance. Information has been tabulated on typical instrument performance, existing calibration capabilities, and calibration requirements. The frequency of calibration, type of radiation, dose, and energy have been investigated.

When new or more rigorous calibration requirements are established for instruments, tests

will be performed to assure that they are practical. Uniform calibration requirements have not been established for many instruments. When they are established, the entire range of influencing parameters must be considered, such as energy response, temperature response, and environmental influences.

At the request of the DOE Office of Nuclear Safety, Health Physics Group, PNL is conducting an intercomparison study of radiological calibration standards. The intent of the program is to identify and eliminate sources of variation in calibration procedures and techniques. This study, similar to one conducted in Europe, is expected to encourage greater communication between laboratories regarding field-tested procedures to be used to solve calibration problems specific to DOE facilities. Further, the program will provide DOE laboratories an opportunity to obtain independent checks of calibration standards.

The intercomparison program involves cross-checks of both instrument and dosimeter calibrations. Laboratories have the opportunity to participate in the following four categories of testing: high energy photon, low energy photon, beta, and fast neutron. Laboratories participating in the study have been shipped a set of instruments and dosimeters and have been requested to expose the devices to their calibration sources at specified doses. The laboratories have been reporting the instrument response and returning the dosimeters to PNL for readout. Preliminary results are available. When the study is complete, the intercomparison procedure will be integrated into the DOE Laboratory Accreditation Program.

• Personnel Neutron Dosimeter Evaluation and Upgrade Program

A program was initiated during FY 1981 with Pacific Northwest Laboratory as the lead laboratory to: (1) evaluate response characteristics of personnel neutron dosimeter systems in current use at several DOE laboratories; (2) develop improved neutron detection for use as personnel neutron dosimeters and/or portable instruments; (3) provide technical coordination of work being conducted by various laboratories, universities, and private companies; and (4) maintain program quality and timeliness.

PERSONNEL NEUTRON DOSIMETER EVALUATION AND UPGRADE PROGRAM

L. G. Faust, D. E. Hadlock, L. W. Brackenbush, M. A. Parkhurst, J. C. McDonald, R. I. Scherpelz, D. L. Haggard, G. W. R. Endres

The objective of this program is to provide a continuing effort to resolve problems of assessing personnel neutron dose at DOE facilities. Progress during FY 1981, FY 1982, and FY 1983 included: an assessment of the current status of personnel neutron dosimeter systems at DOE facilities; recommendations on methods of calibrating personnel neutron dosimeters; and continuing development of several concepts that show promise of upgrading the state-of-the-art in personnel neutron dosimetry. The program is continuing tasks to improve personnel neutron dosimetry and dosimetry systems for DOE and its contractors. Program accomplishments are publicized, and commercial vendors are encouraged to participate through technology transfers, which could lead to commercialization of dosimeters and/or instruments.

During FY 1984, PNL and its subcontractors conducted neutron dosimetry research and development or other activities in nine principal areas: (1) technology transfer, (2) prototype evaluation, (3) field measurements, (4) CR-39 (Columbia Resin-39) plastic technology, (5) combination thermoluminescent dosimeter (TLD)/ track etch dosimeter (TED) concepts, (6) total dosimeter dosimetry, (7) high energy neutron (>5 MeV) dosimetry, (8) neutron depth dose characterization, and (9) resonance ionization spectroscopy dosimetry.

Transfer of program developments to field operations is being continued through the use of contractor meetings and workshops. Prototype dosimeters and instruments are being developed from proof-of-principle concepts and are being evaluated to determine their potential for improving existing capability.

Field measurements of neutron dose and spectra are being conducted at several DOE laboratories and commercial power reactors. This information, along with the measured responses of new devices, will allow determination of

the accuracy of field neutron measurements and is published as it becomes available.

Field implementation of a superior neutron dosimeter that uses TLDs in combination with TEDs is being accomplished. Of all the track etch materials now available, the one with the trade name CR-39 is one of the best for neutron dosimetry purposes. During the last year, the uniformity, long-term stability, and radiation response characteristics of CR-39 have been established to a great extent. In particular, the energy response from approximately 25 keV to 18 MeV has been completed, and certain unexpected responses resulting from carbon breakup due to neutrons with energies around 16 MeV have been identified. Work is currently under way on investigating the lower limits of neutron sensitivity, both in dose and energy. In addition, the University of California at Berkeley, the University of Connecticut at Storrs, Lawrence Livermore National Laboratory, and PNL have worked together to: (1) produce a chemical processing system that can handle large numbers of TEDs during any one processing period; (2) improve the manufacturing process to make dosimetry grade CR-39; (3) evaluate the long-term properties (fading, change in sensitivity) of CR-39; and (4) develop improved CR-39 monomers.

Development of total dose meter (rem-meter) concepts is continuing through the use of tissue equivalent proportional counter (TEPC) technology. During the last year, PNL has demonstrated the feasibility of making simultaneous neutron and gamma dose measurements with a single cylindrical TEPC. Simple algorithms have been derived to determine quality factors and dose equivalent from spherical counters and are currently being developed for cylindrical detectors. This is being accomplished by making a series of exposures to monoenergetic neutrons with energies ranging from 100 keV to 20 MeV. Once this relationship is known, an inexpensive micro-computer will be programmed to determine dose and dose equivalent for mixed radiation fields. In addition, a breadboard device was designed, built, and connected to the detector(s) to prove the feasibility of the concept. During FY 1985, EG&G/Santa Barbara, will be working closely with PNL to develop an operational prototype to fit DOE's needs.

Other selected concepts potentially capable of state-of-the-art improvements in personnel neutron dosimetry were also investigated during the year.

- A tissue-equivalent phantom was exposed to beams of neutrons, and the depth-dose profile inside the phantom was measured using several small TEPCs. The exposures were performed using monoenergetic neutrons generated by a Van de Graaff positive ion accelerator. Improvements to the commonly-used tabulations of flux-to-dose conversion factors were then calculated by PNL using profiles of neutron flux, dose, and dose equivalent profiles in tissue-equivalent phantoms exposed to the beams of monoenergetic neutrons.
- PNL continued to improve the accuracy and efficiency of personnel dosimetry for DOE laboratory workers who may be exposed to high energy neutrons (greater than 5 MeV). Few techniques are available for the measurement of such high energy neutrons. However, the response of several dosimeter types (track etch dosimeters, TLDs, portable rem-meters, etc.) for both monoenergetic neutrons and neutron spectra encountered at DOE facilities, such as the Bevalac accelerator at Lawrence Berkeley Laboratory, was determined during FY 1984.
- The measurement of low levels of neutron exposure is a matter of renewed concern, especially at low neutron energies where no suitable method currently exists. New

information on relative biological effectiveness calls for reduction of the minimum measurable limit in monitoring the neutron exposures received by personnel in the nuclear industry. To achieve the desired limits, in turn, requires the development of a new type of neutron dosimeter. Atom Sciences, Inc., Oak Ridge, Tennessee, is investigating a system to count xenon atoms released from a solid matrix material by collision events which correlate with neutron dose. The xenon atoms released during the period of exposure to neutrons would be counted in a laboratory "reader" using resonance ionization spectroscopy.

To date PNL and its subcontractors have:

- recommended personnel neutron dosimeter calibration procedures
- measured response characteristics of current personnel neutron dosimeters at DOE facilities
- developed a combination thermoluminescent/track etch dosimeter
- developed a new dose meter using tissue-equivalent proportional detector technology.

Future accomplishments include evaluation of new neutron dosimeter prototypes, implementation of new dosimetry systems and programs, field measurements of dose equivalent and spectra including accelerators, and technology transfer to commercial vendors.

• Beta Measurement Evaluation and Upgrade

This program focuses on the resolution of problems associated with the field measurement of the beta dose component at DOE facilities. Little attention has been paid to improving beta measurements during the past fifteen years. The change in DOE programs, including increased efforts in improved waste management and D&D facilities, coupled with beta measurement problems identified at Three Mile Island, has heightened DOE's awareness for the need to improve beta measurements. In FY 1982, work was initiated to provide a continuing effort to identify problems associated with beta dose assessment at DOE facilities. The problems identified resulted in the development of this program. The investigation includes (1) an assessment of measurement systems now in use, (2) development of improved calibration systems and procedures, (3) application of innovative beta dosimetry concepts, (4) investigation of new instruments or concepts for monitoring and spectroscopy, and (5) development of recommendations to assure an adequate beta measurement program within DOE facilities.

BETA MEASUREMENT EVALUATION AND UPGRADE

K. L. Swinth, L. A. Rathbun, P. L. Roberson,
G. W. R. Endres

The Beta Measurement Evaluation and Upgrade program was initiated to review the problems associated with beta dosimetry practices and to develop improved procedures and measurements. The work performed in FY 1984 can be classified into four major areas: (1) current practices, (2) field measurements, (3) dosimeter development, and (4) instrument development.

During the past year, a survey of current beta measurement practices at DOE facilities was analyzed and put into report format. The draft report is currently under review with publication expected early in FY 1985. The report shows that a wide variety of beta sources exist at DOE facilities and that:

- Programs for calibration, performance testing, and quality assurance are inadequate.
- Instruments and dosimeters are not appropriately designed for beta measurement in some instances.
- Nonpenetrating dose is not uniformly defined.
- Calibration sources do not exhibit one step traceability to a NBS standard and often have significantly different energy from the energy of the beta radiation measured in the field.

To date, field measurements have been performed at three DOE facilities, and measurements have shown that significant beta dose rates can occur. Beta spectral analyses were performed at the sites using scintillation and solid state detectors calibrated at Pacific Northwest Laboratory (PNL).

Multielement thermoluminescent dosimeters (TLDs) were used to perform reference dose-rate measurements. The response of the instruments and dosimeters currently in use at the facility were compared with the measurements made using the PNL systems. Data have been analyzed and, following additional measurements during FY 1985, a report on the results will be completed.

Prototype badges were prepared under subcontract with Kansas State University using their prototype thin graphite-backed TLDs. Tests showed that the badges have a beta energy response that is relatively independent of beta energy and performed better than commonly used commercial badges. Additional evaluation of prototype badges is planned for FY 1985.

A second dosimetry system is being developed under a subcontract with International Sensor Technology (IST). This system uses an infrared laser system to heat the TLD material and leads to selected area read-out and an improved signal-to-noise ratio. A prototype system was completed during the year and delivered to PNL; however, full evaluation of the system has been delayed until acquisition and installation of a suitable computer system can be completed. Under subcontract, IST has continued to refine this read-out technique. This has included improved laser read-out stability and an improved beam profile to permit read-out of a larger area of the TLD. It will enhance reproducibility and lower the detection level; it will be incorporated into our read-out system in the coming year.

The use of photoacoustic read-out fiber optics was investigated for beta dosimetry. Tests showed some promise, but results were ambiguous. Initial experiments were also performed on optically stimulated read-out of TLDs; further tests on both photoacoustic read-out and optically stimulated read-out are planned during the coming fiscal year.

thick depletion region free of charge traps. Under subcontract with Lawrence Livermore National Laboratory, the use of silicon detectors as a solid-state analog of the extrapolation chamber was investigated. The results were partially successful, but the high purity of currently available detectors provides a

ping centers with low bias voltages. A strong dependence on collection region thickness with bias voltage is required for successful implementation of this concept. To successfully develop such a detector would require an expensive material development project.

- **Department of Energy Laboratory Accreditation Program for Occupational Exposure Measurements**

This program provides research support for the Department of Energy Laboratory Accreditation Program (DOELAP) for personnel dosimetry services. The research effort encompasses development of improved accreditation methods and operation of calibration intercomparison and measurement assurance programs for DOE laboratories. The effort for FY 1984 was primarily directed toward development of the documents required for the operation of the performance testing laboratory used in the accreditation process. These documents included the "DOE Standard for the Performance Testing of Personnel Dosimetry Systems," the "DOELAP Handbook" for program participants seeking accreditation, and the "Quality Assurance Manual" for the DOE performance testing laboratory.

DEPARTMENT OF ENERGY LABORATORY ACCREDITATION PROGRAM FOR OCCUPATIONAL EXPOSURE MEASUREMENTS

P. L. Roberson, R. A. Fox, C. D. Hooker, B. L. Murphy

A national approach to the quality assurance and accreditation of radiological calibrations of personnel dosimetry services is being developed through the DOE Laboratory Accreditation Program (DOELAP). This program provides research support for the continuing DOELAP for personnel dosimetry services. The DOELAP research effort encompasses: (1) research into improved accreditation methods, (2) intercomparison of DOE radiological calibration standards using round-robin shipment of transport standards (instruments and sources), and (3) measurement assurance relationships with DOE calibration laboratories through irradiation of generic dosimeters and instruments.

The FY-1984 effort concentrated primarily on the preparation of the documents required for the operation of the performance testing laboratory. These documents were the "DOE Standard for the Performance Testing of Personnel Dosimetry Systems," the "DOELAP Handbook" and the "Quality Assurance Manual" for the DOE performance testing laboratory. All documents underwent a peer review performed by representatives of major DOE laboratories. The documents were updated in response to the review comments.

The DOE standard specifies test exposure sources and techniques for the performance evaluation of personnel dosimeters. It was based on the American National Standard, Criteria for Testing Personnel Dosimetry Performance, ANSI N13.11-1983 (ANSI-1983), and the recommendations in Guidelines for the Calibration of Personnel Dosimeters, PNL-4515 (Roberson and Holbrook, 1984). The recommendations in PNL-4515 resulted from an analysis of ANSI N13.11 performed during the de-

velopment of a data base on the performance of DOE dosimetry processors.

The participant's handbook for DOELAP was designed to be sent to DOE facilities undergoing the DOE accreditation process. It provides a short history of the development of the program, a scope of accreditation, a description of the administrative structure, and a description of the accreditation process.

The Quality Assurance Manual provides guidance for dosimeter handling, exposure sequencing, radiation field standardization, dosimeter uncertainty analysis, and quality assurance procedures. The quality assurance procedures detail classification of laboratory equipment, calibration frequencies, documentation, and relationship of laboratory standards to national standards.

Calibration laboratory upgrades were performed to prepare for research irradiations to develop improved accreditation methods and for irradiation assistance to the DOELAP performance testing laboratory. The tube for the 320-kVp x-ray machine was replaced. Monitor ionization chamber systems were installed for the beta and x-ray irradiation systems. A process-control system was installed for the x-ray laboratory. The process-control system will record irradiation parameters for dosimeter exposures and is an integral part of the quality assurance effort for DOELAP.

References

- American National Standards Institute (ANSI). 1983. American National Standard, Criteria for Testing Personnel Dosimetry Performance. ANSI N13.11-1983, New York, New York.
- Roberson, P. L. and K. L. Holbrook. 1984. Guidelines for the Calibration of Personnel Dosimeters. PNL-4515, Pacific Northwest Laboratory, Richland, Washington.

Operational
Safety

OPERATIONAL SAFETY

- **Assurance Program for Remedial Action**
- **Environmental Protection, Support and Assistance**
- **Hazardous Waste Risk Assessment**
- **Policy Studies—Radiation**

The responsibility of the Department of Energy (DOE) Office of Operational Safety is to assure that activities and installations of the Department and its contractors are in full compliance with DOE environmental protection, safety and health protection policies and applicable federal, state, and local environmental, safety and health (ES&H) standards and regulations; to provide technical support to DOE ES&H programs and assurance systems; and to ensure that all DOE-controlled activities are conducted in a manner that will maintain risks to the safety and health of the public and employees at acceptably low levels, and that will provide for adequate protection of property and the environment.

• Assurance Program for Remedial Action

This project was initiated in the first quarter of FY 1984 to provide technical assistance to the DOE Office of Operational Safety (OOS) in developing and implementing its Assurance Program for Remedial Action (APRA), i.e., overview of the DOE remedial action programs. During this first year of the project, the technical assistance included report and procedure reviews, and preparation of the technical content for a draft DOE Order on APRA. Information-gathering visits were made to three of the DOE Remedial Action program offices. Pacific Northwest Laboratory (PNL) developed criteria for generic program guidance review and a bibliographic data base. Draft reports were prepared on: reviews of the Formerly Utilized Sites Remedial Action Program (FUSRAP) guidance documents; radiological survey protocols with respect to risk assessment; radiological assessment methodologies at uranium mill tailings vicinity properties; radiological standards and guidelines pertinent to DOE's remedial action programs. PNL also provided technical support and assistance to OOS in the APRA appraisal of the FUSRAP office (DOE/OR), including participation in preappraisal visits to four FUSRAP sites in New York and New Jersey.

TECHNICAL ASSISTANCE TO DOE/OOS ASSURANCE PROGRAM FOR REMEDIAL ACTION (APRA)

D. H. Denham; F. T. Cross; W. E. Kennedy, Jr.; S. Marks; J. K. Soldat; R. D. Stenner

The objective of this project is to assist the Department of Energy (DOE) Office of Operational Safety (OOS) in developing and implementing its Assurance Program for Remedial Action (APRA). The intent is to provide technical support to OOS in its role of overviewing to assure, by review and appraisal, the successful implementation and completion of DOE's four remedial action programs:

- Formerly Utilized Sites Remedial Action Program (FUSRAP)
- Surplus Facilities Management Program (SFMP)
- Uranium Mill Tailings Remedial Action Program (UMTRAP)
- Grand Junction Remedial Action Program (GJRAP)

OOS recognizes that the APRA support contractors may also have input to individual remedial action projects. To avoid any potential conflicts with respect to these services, OOS makes adjustments accordingly in requesting support from certain APRA contractors on specific remedial action projects. For this reason, this project has not provided assistance in the overview of SFMP.

The project includes five tasks: general technical support and assistance, assistance in conducting ES&H reviews and appraisals, review of existing and proposed radiological standards, evaluation of risk assessment methodologies, and overall project management. Specific task areas addressed in FY 1984 included:

- reviews and comments on proposed project direction in consultation with OOS and other support contractors;
- assistance with developing a DOE Order on APRA;
- assistance with planning and conducting the first OOS (APRA) appraisal of a DOE remedial action program office;
- reviews of existing and proposed radiological standards and guidelines for use in DOE's remedial action programs;
- reviews of risk assessment practices with respect to remedial action programs, including reviews of existing radiological survey protocols; and,
- preparation of generic program guidance review criteria.

APRA PROJECT DIRECTION

D. H. Denham

As major input to the direction of this project in FY 1984, PNL provided OOS with an overall project plan; a topical outline for procedural, operational, and verificational overview; and draft material for a DOE Order.

ES&H REVIEWS AND APPRAISALS

R. D. Stenner

The major activity of this task was the development of generic program guidance review criteria. Based on these criteria, reviews were completed of the program plan documents for UMTRAP and all of the program guidance documents for FUSRAP. In addition to these re-

views, PNL also provided support for the OOS appraisal (including preappraisal visits to specific FUSRAP remedial action sites) of the FUSRAP office.

RADIOLOGICAL STANDARDS REVIEW

J. K. Soldat

This task has involved active participation in residual contamination criteria workshops sponsored by DOE/DP (DOE Headquarters, January 17-19), and DOE/NE (Gaithersburg, Maryland, February 21-23; Argonne, Illinois, June 26-27). Preliminary results of the standards reviews were summarized in a series of tables, and a brief narrative was provided to OOS in the summer.

RISK ASSESSMENT REVIEWS

S. Marks

Two draft technical reports were prepared under this task during the fiscal year: "A Review of Radiological Assessment Methodologies for Uranium Mill Tailings at Vicinity Properties" and "A Review of Radiological Survey Techniques from DOE's Remedial Action Programs Relative to Performing Risk Assessments." Other activities of this task included responding to Congressional inquiries regarding risk assessment and providing ad hoc reviews of risk assessment practices for OOS staff upon request.

• Environmental Protection Support and Assistance

The Pacific Northwest Laboratory continued to provide technical assistance to DOE's Office of Operational Safety (OOS) in the area of environmental protection. PNL's technical support included extensive planning and assistance in preparing for the Fifth DOE Environmental Protection Information Meeting and assistance in preparing and reviewing interim DOE guidance for estimating public radiation doses. A data evaluation report was prepared and published concerning the DOE Quality Assessment Program for environmental monitoring, and a report summarizing the radioactive effluents from DOE facilities was prepared.

ENVIRONMENTAL PROTECTION SUPPORT AND ASSISTANCE TO DOE/OOS

W. E. Kennedy, Jr.; R. E. Jaquish; J. P. Corley; R. C. Adams; K. A. Hawley; K. L. Imhoff; R. R. Kinnison; E. B. Moore, Jr.; J. R. Raymond; J. K. Soldat; E. C. Watson

The Environmental Protection Support and Assistance Project provides the Department of Energy's Office of Operational Safety (OOS) with technical support to assist OOS in accomplishing its environmental protection objectives. Several ongoing tasks are funded concurrently, at the request of OOS, to provide flexibility in response to management priorities as they evolve. Task areas addressed during 1984 included:

- participation in the DOE Remedial Action Criteria Workshops to determine DOE remedial action criteria for application to DOE's formerly utilized sites and remote surplus facilities
- participation in Advisory Group meetings of the International Atomic Energy Agency (IAEA) concerning assessments in relation to limiting releases of radioactive effluents to the environment
- assistance to OOS in support of the Fifth DOE Environmental Protection Information meeting
- initial development of revised sections of the updated Effluent and Environmental Monitoring Guide
- assistance in preparing and reviewing interim DOE guidance for estimating public radiation doses
- development of guidelines for a DOE ground-water protection program
- development of a ground-water monitoring handbook
- completion and publication of an annual summary of environmental effluents from operating DOE sites

- publication of a DOE quality assessment program data evaluation for environmental monitoring data

EFFLUENT AND ENVIRONMENTAL MONITORING GUIDES

J. P. Corley, J. K. Soldat, E. C. Watson

The environmental monitoring guide, a companion document to the effluent guide, is in the process of being revised and updated. This guide was written to promote greater uniformity in DOE environmental radiological monitoring programs. Additional modifications resulting from proposed revisions to DOE guidance for estimating public radiation doses were under consideration.

QUALITY ASSURANCE FOR DOE ENVIRONMENTAL AND EFFLUENT MONITORING

R. E. Jaquish, R. R. Kinnison

PNL continued to support the DOE Environmental and Effluent Monitoring Quality Assessment Program by continuing ongoing discussions with the Environmental Measurements Laboratory in New York. A document entitled "U.S. Department of Energy Quality Assessment Program Data Evaluation Report" was issued. Information for the next QA Steering Committee meeting, to occur during the Fifth DOE Environmental Protection Information meeting, was prepared.

ENVIRONMENTAL DOSE ASSESSMENT METHODOLOGY

J. P. Corley

Initial efforts to produce a draft document concerning interim guidance for conducting public dose evaluations for environmental effluents from DOE sites were begun. These efforts combined contributions from PNL and Los Alamos National Laboratory in considering a change to the ICRP 30 dosimetry system for public dose estimates. Final interim guidance is scheduled to be completed early in 1985.

ANNUAL ENVIRONMENTAL SUMMARY REPORT

K. A. Hawley

Each year, PNL provides for DOE management a summary of the information contained in the annual environmental reports generated by the DOE nuclear facility contractors. The 1983 summary (based on contractor documents received in May of 1984) was completed in draft form and issued for field review. Initial comments were collected from the DOE field organizations.

ENVIRONMENTAL DATA REPORTING

E. B. Moore, Jr.

Data collection efforts for three DOE nuclear sites began in support of the development of a series of Environmental Summary Profiles and Environmental Profile data bases. A detailed outline for the data base was prepared and reviewed. This effort is intended to ultimately provide DOE/OOS with current information about the environmental status of each DOE site. The information will be stored in a data base that will permit easy access and modification by both PNL and OOS staff.

GROUNDWATER PROTECTION PROGRAM

J. R. Raymond

A draft groundwater protection report was developed and reviewed by OOS staff. This report is entitled "Guidelines for a U.S. Department of Energy Ground-Water Protection Program." A second document entitled "Guidelines for Ground-Water Monitoring Programs at U.S. Department of Energy Facilities" was revised after initial review comments were received. Both of these documents will be completed during 1985.

FIFTH DOE ENVIRONMENTAL PROTECTION INFORMATION MEETING

J. P. Corley; W. E. Kennedy, Jr.

A Program Committee was established for reviewing the abstracts submitted in response to the call for papers for the Fifth DOE Environmental Protection Information Meeting. Registration packages were mailed to all meeting participants and initial arrangements were made for producing the camera-ready copy of the meeting proceedings. PNL staff provided additional administrative and support assistance to OOS in preparing for this important meeting.

RISK VALUE METHODOLOGY DEVELOPMENT

R. C. Adams, K. L. Imhoff

A risk value methodology was developed and modified to fit the needs of DOE in determining a priority ranking of proposed Environmental Safety and Health upgrade projects. This methodology was applied to the FY 1986 budget requests and the resulting ranking was used by DOE in determining the final budget. Future tasks include providing formal documentation of the computerized methodology.

SPECIAL ASSISTANCE

W. E. Kennedy, Jr.; J. P. Corley

This special assistance task provides for quick responses to issues that may fall outside the scope of other established tasks. Technical support is given on an ad hoc basis as requested. During 1984, the activities conducted under this task included: participation in the DOE Remedial Action Criteria Workshops to determine DOE remedial action criteria for application to DOE's formerly utilized sites and remote surplus facilities, participation in Advisory Group meetings of the International Atomic Energy Agency (IAEA) concerning assessments in relation to limiting releases of radioactive effluents to the environment, and continued reviews of proposed regulatory changes that may affect DOE operations.

• Hazardous Waste Risk Assessment

Pacific Northwest Laboratory continued to provide technical assistance to the DOE Office of Operational Safety (OOS) in the area of risk assessment for hazardous and radioactive mixed waste management. The overall objective of this work is to provide technical assistance to OOS in developing strategies for bringing DOE facilities into compliance with the technical intent of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Major efforts during FY 1984 included: (1) completion of an effort to develop and conduct a workshop on groundwater monitoring under RCRA; (2) selection and assembly of a team of experts to conduct a technical review of DOE field office groundwater monitoring plans; (3) provision of technical input for developing DOE guidance on CERCLA; (4) initiation of work to modify the EPA Hazard Ranking System to include assessment of radiological hazards; (5) initiation of work to develop an objective, scientifically based methodology for DOE management to use in establishing priorities for conducting site assessments and possibly remediation; and (6) initiation of an open literature technical review of documented contamination of groundwater by organics.

GROUNDWATER MONITORING WORKSHOP

B. L. Steelman, R. Schalla, J. M. Meuser,
D. A. Myers

During the early part of FY 1984, DOE field offices began earnest efforts to prepare implementation plans for bringing their facilities into compliance with DOE Order 5480.2 (Hazardous and Radioactive Mixed Waste Management within the framework of RCRA). While DOE field offices have extensive experience in monitoring groundwater for radiological parameters and some other inorganics, their experience in monitoring techniques for organics in groundwater is more limited. Therefore, to assist DOE field offices in developing plans for groundwater monitoring under DOE Order 5480.2, Pacific Northwest Laboratory (PNL) prepared and conducted a workshop to provide technical guidance in this area.

REVIEW OF DOE FIELD OFFICE GROUNDWATER MONITORING PLANS

B. L. Steelman, D. A. Myers, G. L. McKown,
P. VanVorhis, S. R. Peterson

To assist the Office of Operational Safety in reviewing and commenting on DOE field office groundwater monitoring plans, PNL, in concert with OOS, assembled a team of five technical experts. Actual efforts for reviewing and commenting on the field office plans are expected to begin in the early part of fiscal year 1985.

TECHNICAL GUIDANCE ON CERCLA

B. L. Steelman

Pacific Northwest Laboratory provided OOS with draft technical guidance on Comprehensive Environmental Response, Compensation and Liability Act. This guidance was then used by OOS as input to the draft DOE Order 5480.14

(Department of Energy Program Guidance for Comprehensive Environmental Response, Compensation, and Liability Act of 1980). A final version of this order is expected to be available in the early part of FY 1985.

MODIFICATION OF THE EPA HAZARD RANKING SYSTEM

B. A. Napier, K. A. Hawley

The EPA Hazard Ranking System (HRS) is a simplified methodology for determining which uncontrolled hazardous waste sites may pose a high enough risk to warrant further investigation and possible remediation. However, the HRS is unable to explicitly evaluate the potential risks of radioactive material, and, therefore, its applicability to DOE sites is debatable. Without changing the basic philosophy of the HRS, PNL has initiated an effort to modify the methodology so that it can evaluate the risks of radioactive materials. A final report on this effort is expected in the early part of FY 1985, and meetings are planned to discuss the proposed modifications with EPA.

METHODOLOGY FOR ESTABLISHING PRIORITY OF INACTIVE WASTE SITES

G. Whelan, B. L. Steelman, J. V. Ramsdell,
D. L. Strenge, B. A. Napier

Pacific Northwest Laboratory has initiated an effort to develop an objective, scientifically based management tool for DOE to use in setting priorities among the potential risks of their inactive hazardous and radioactive mixed waste disposal facilities. The EPA Hazard Ranking System (HRS) was developed several years ago, and, while the modified HRS will be useful in comparing the calculated priorities of DOE sites to non-DOE sites, it tends to be more subjective than necessary. The state-of-the-art in risk assessment tools is advancing rapidly, and it

is now possible to develop a more objective, scientifically based risk assessment methodology that will provide a better measure of the potential relative risks that sites may pose. This improved methodology, the Remedial Action Priority System, will serve as a valuable tool for DOE management to use in making funding allocations for further site investigations and possible remediations. Initial development efforts are expected to be completed in the early part of FY 1986.

ORGANICS CONTAMINATION OF GROUNDWATER

R. M. Ecker, B. L. Steelman

Because of recent public awareness and regulatory activity, the scientific and engineer-

ing community has given considerable attention to contamination of groundwater by organics. At the request of OOS, PNL conducted a review of the open literature on contamination of groundwater by organics and provided a brief summary of the available field data on (1) the behavior of organics in groundwater (e.g., transport and transformation mechanisms); and (2) the extent of documented migration by organics from the source of contamination. A draft report has been given to OOS; a final report is expected in the early part of FY 1985.

• Policy Studies—Radiation

The purpose of this project is to provide the Department of Energy with responsive reviews, studies, and analysis of contemporary radiation issues of a diverse nature.

POLICY ANALYSIS

W. J. Bair

During FY 1984, several staff members from Pacific Northwest Laboratory (PNL) met with a representative of the DOE Office of General Counsel to inform him of the biological effects of radon and radon decay products, the interpretation of pathology in the lungs of smokers who also inhaled radon, and measurements of radon and radon decay products. PNL also made available to the DOE legal staff who are involved in the Nevada and Utah litigations information from our research programs that would help them make effective use of several of their consultants.

The EPA draft document, "Interim Recommendations on Doses to Persons Exposed to Transuranium Elements in the General Environment" was reviewed. An appendix to the EPA document summarizing DOE's Enewetak experience was also reviewed.

A request from the Nevada Operations Office led to a meeting at PNL to discuss the dosimetric data from the Marshall Islands. Participants included staff from several national laboratories and DOE. The purpose of the meeting was to review the current status of predicted and actual radiation exposures of Marshall Islanders, particularly as these relate to potential resettlement of Eneu Island

in the Bikini Atoll. Comparisons presented of radiation doses based on in-vivo counting measurements versus doses predicted from radionuclide intake models for Marshall Islanders at Utrik and the southern islands of Rongelap showed excellent agreement. This agreement between measured and predicted levels constitutes an important overall validation of models employed in the predictions--including physical, biological, and cultural aspects of these models. An area of remaining uncertainty relates to the transuranic elements, principally plutonium and americium, where very limited bioassay data on plutonium excretion yielded much higher radiation dose values than predicted by models. This is not considered a serious complication because the transuranics are not predicted to contribute importantly to the total radiation dose, and analytical problems involving natural polonium in the urine samples seem to offer a plausible explanation of the bioassay results. Based on the best current evidence, it still seems unlikely that an Eneu resident, consuming a mix of local and imported foods (but no significant quantity from Bikini Island) would exceed an exposure of 500 mrem per year.

Also under this project, two papers were prepared for presentations at meetings abroad. Both were published in the proceedings and are included in the Publications and Presentations at the end of this volume.

Publications
and
Presentations

PUBLICATIONS

- Alvarez, J. L. 1984. "Beta Measurements in a Photon Field." Proceedings of the International Beta Dosimetry Symposium. NUREG/CP-0050, p. 187.
- Braunlich, P., S. C. Jones, A. Abtahi, and M. deMurcia. 1984. "Heating of Continuous Thermoluminescent Layers With Localized Laser Beams." Proceedings of the Seventh International Conference on Solid State Dosimetry, Radiation Protection Dosimetry, 6, p. 83.
- Braunlich, P., W. Tetzlaff, J. Gasiot, and S. C. Jones. 1984. "Development of a Laser-Heated TLD Reader." Proceedings of the International Beta Dosimetry Symposium. NUREG/CP-0050, p. 471.
- Fisher, D. R., A. V. Robinson, and R. T. Hadley. 1984. "Preliminary Results of Testing Bioassay Analytical Performance Standards." PNL-SA-11656. Proceedings of the Eleventh Light Water Reactor Research Information Meeting, October 24-28, 1983, Gaithersburg, Maryland. NUREG/CP-0048, Vol. 6, pp. 140-147.
- Fix, J. J., K. L. Soldat, and K. L. Holbrook. 1984. "Beta and Low Energy Photon Irradiation of Several Commercial Phosphors." Proceedings of the International Beta Dosimetry Symposium. NUREG/CP-0050, p. 411.
- Gillings, J. C., B. L. Murphy, C. D. Corbit, J. A. MacLellan, T. H. Essig, D. P. Higby, C. D. Hooker, G. J. Laughlin, G. A. Stoetzel, K. L. Swin, J. M. Selby, E. J. Vallario. 1984. Characterization of Emergency Preparedness at DOE Contractor Facilities. PNL-4198.
- Roberson, P. L., and K. L. Holbrook. 1984. Guidelines for the Calibration of Personnel
- Roberson, P. L., and K. L. Holbrook. 1984. Guidelines for the Calibration of Personnel Dosimeters. PNL-4515, Pacific Northwest Laboratory, Richland, Washington.
- Robinson, A. V., D. R. Fisher, and R. T. Hadley. 1983. "Results of Round One Test of Draft ANSI Standard N13.30: Performance Criteria for Radiobioassay." Proceedings of the Twenty-Ninth Annual Conference on Bioassay, Analytical and Environmental Chemistry, October 12-13, Seattle, Washington.
- Robinson, A. V., D. R. Fisher, and R. T. Hadley. 1984. Performance Testing of Radiobioassay Laboratories, Pilot Study Report, Part I: In-Vitro Measurement Testing. DOE/NBM-1071, PNL-5107, Pacific Northwest Laboratory, Richland, Washington.
- Scherpelz, R. I., G. W. R. Endres, and P. L. Roberson. 1984. "The Application of a Multi-Element Beta Dosimeter." Proceedings of the International Beta Dosimetry Symposium. NUREG/CP-0050, p. 209.
- Selby, J. M., K. L. Swin, C. D. Hooker, and J. L. Kenoyer. 1984. "Field Measurements and Interpretation of Beta Doses and Dose Rates." Proceedings of the International Beta Dosimetry Symposium. NUREG/CP-0050, p. 157.
- Simons, G. G., R. B. Stuewe, T. M. Derby, and K. D. Stansbury. 1984. "Application of Beta Spectroscopy to Beta Dosimetry Research." Proceedings of the International Beta Dosimetry Symposium. NUREG/CP-0050, p. 201.
- Swin, K. L. 1984. "Beta Problems in Uranium Mining, Milling, Enrichment and Fabrication." Proceedings of the International Beta Dosimetry Symposium. NUREG/CP-0050, p. 641.

PRESENTATIONS

Bair, W. J., "All Smokers at Greater Risk from Radiation Exposure Than Nonsmokers?" 6th International Radiation Protection Association, Berlin, Federal Republic of Germany, May 7-12, 1984.

Brackenbush, L. A., "A Pocket Total Dose Meter," PNL-SA-12409. Conference on the Application of Accelerators in Residential and Industry, Denton, Texas, November 12-14, 1984.

Brackenbush, L. W., "A Pocket TEPC to Measure Dose Equivalent from Penetrating Ionizing Radiation," PNL-SA-11961. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Brackenbush, L. W., and G. W. R. Endres. "Personnel Monitors Utilizing Tissue Equivalent Proportional Counters," PNL-SA-12460. Fifth Symposium on Neutron Dosimetry in Neuherberg, Germany, September 1984.

Braunlich, P., and W. Tetzlaff. "Laser Heating Techniques in Beta Thermoluminescence Dosimetry." 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Cross, F. T. and W. J. Bair, "Mean Dose Versus Local Dose to the Respiratory Tract--Implications for Radiological Protection." Lung Modeling Workshop in Oxford, England sponsored by Commission of European Communities and the National Radiation Protection Board. March 26-28, 1984.

Faust, L. G., D. E. Hadlock, and E. J. Vallario. "DOE Personnel Neutron Dosimetry Evaluation and Upgrade Program," PNL-SA-12546. Fifth Symposium on Neutron Dosimetry in Neuherberg, Federal Republic of Germany, September 17-21, 1984.

Fleming, D. M., P. L. Roberson, G. L. Carter, R. A. Fox, C. D. Hooker, J. C. McDonald, F. E. Owens, J. L. Pappin, "An Integrated Calibration Facility for Radiological Health Physics." 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Hadley, R. T., M. A. Parkhurst, D. L. Haggard, D. E. Hadlock, "A Computerized Management System for Neutron Track Etch Dosimetry Data," PNL-SA-11949. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Hadlock, D. E., M. A. Parkhurst, D. L. Haggard, L. W. Brackenbush, L. G. Faust, "High Energy (10 MeV) Neutrons: CR-39 Track Detector Revelations," PNL-SA-11957. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Haggard, D. L., D. E. Hadlock, M. A. Parkhurst, "Neutron Energy Response Charac-

teristics of CR-39 Using Monoenergetic Neutrons," PNL-SA-11958. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Hooker, C. D., B. L. Murphy, J. A. MacLellan, E. J. Vallario, "Extremity Dosimetry Evaluation and Upgrade Program," PNL-SA-11992. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Kathren, R. L., L. H. Munson, D. P. Higby, "Application of Risk-Cost Benefit Techniques to ALARA and De Minimis," PNL-SA-12106. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Kenoyer, J. L., K. L. Swinth, K. R. Mashburn, J. M. Selby, "Evaluation of a Draft Standard on Performance Specifications for Health Physics Instrumentation - Environmental Tests," PNL-SA-11481. Spring Conference of the American Society for Nondestructive Testing in Denver, May 21-24, 1984.

Kenoyer, J. L., K. L. Swinth, K. R. Mashburn, J. M. Selby, E. J. Vallario, M. V. Federline, "Evaluation of a Draft Standard on Performance Specifications for Health Physics Instrumentation - Environmental Tests," PNL-SA-11931. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Kenoyer, J. L., K. L. Swinth, R. L. Kathren, D. M. Fleming, J. M. Selby, E. J. Vallario, and M. V. Federline, "Results of Testing and Evaluating a Health Physics Instrument Performance Standard," PNL-SA-10985. IRPA meeting in West Berlin, May 7-12, 1984.

MacLellan, J. A., "Health Physics Technician Training Characterization for DOE Contractors," PNL-SA-12413. Invited paper at the TRADE meeting at Las Vegas, Nevada, July 9-10, 1984.

McDonald, J. C., and F. M. Cummings, Results of High-Energy Neutron Measurements at LBL presented at European Workshop on Proportional Counter Measurements in Health Physics, May 16-18, 1984 in Homburg, West Germany by K. L. Swinth.

Murphy, B. L., J. M. Pisarcik, K. L. Swinth, and E. J. Vallario. "An Evaluation of Current Practices in Beta Dosimetry at DOE Facilities," PNL-SA-11945. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

Parkhurst, M. A., D. L. Haggard, P. L. Tomeraasen, D. E. Hadlock, "Trials and Tribulations of Processing CR-39 for Neutron Dosimetry," PNL-SA-11957. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

- Pisarcik, J. M., A. V. Robinson, K. L. Swinth, and B. L. Murphy. "Selection and Use of Radiation-Measuring Instruments for Emergency Preparedness Programs," PNL-SA-11944. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.
- Roberson, P. L., C. D. Hooker, J. C. McDonald, J. L. Pappin, "Experience with the Buchler Secondary Beta Standards," PNL-SA-11945. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.
- Roberson, P. L., C. D. Hooker, J. C. McDonald, J. M. Selby, and E. J. Vallario, "Department of Energy Laboratory Accreditation Program," PNL-SA-12029. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.
- Robinson, A. V., D. R. Fisher, and R. T. Hadley. 1984. "A Radiobioassay Intercomparison Program for Evaluation of Draft ANSI Standard N13.30 Performance Criteria for Radiobioassay," PNL-SA-10655. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.
- Selby, J. M., "Criteria for Assessment and Recording Worker Doses Using ICRP-26 Recommendations as a Base," PNL-SA-12060. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.
- Selby, J. M., "Draft American National Standard N42.17." National Bureau of Standards Workshop on Radiation Survey Instruments and Calibrations, Gaithersburg, Maryland, July 10-12, 1984.
- Simons, G. G. "Thin TLD's for Beta Dose Measurements." 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.
- Stoetzel, G. A., J. L. Kenoyer, K. L. Swinth, K. R. Mashburn, "Evaluation of the Performance of Alpha Survey Instrumentation Against Requirements in a Draft Performance Standard," PNL-SA-11943. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.
- Swinth, K. L., "Assessment of the Beta Dosimetry Problem and Status of Present Programs." Interagency Committee on Occupational Radiation Protection Measurements, Washington, D.C., December 13, 1983.
- Swinth, K. L., "The DOE Contractor Perspective." National Bureau of Standards Workshop on Radiation Survey Instruments and Calibrations, Gaithersburg, Maryland, July 10-12, 1984.
- Swinth, K. L., and J. L. Kenoyer, "Evaluation of Draft Standard N42.17 by Testing," PNL-SA-12011. National Bureau of Standards Workshop on Radiation Survey Instruments and Calibrations, Gaithersburg, Maryland, July 10-12, 1984.
- Swinth, K. L., and J. L. Kenoyer, "Evaluation of a Draft Standard on Performance Specifications for Health Physics Instrumentation," PNL-SA-11625. Invited paper at the Second DOE Workshop on Portable Instrumentation and Dosimeters in Knoxville, Tennessee, April 9-11, 1984.
- Swinth, K. L., J. L. Kenoyer, K. R. Mashburn, J. M. Selby, "Evaluation of a Draft Standard on Performance Specifications for Health Physics Instrumentation - Radiological Performance," PNL-SA-12611. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.
- Swinth, K. L., J. L. Kenoyer, K. R. Mashburn, J. M. Selby, "Evaluation of a Draft Standard on Performance Specifications for Health Physics Instrumentation - Radiological Performance," Spring Conference of the American Society for Nondestructive Testing in Denver, May 21-24, 1984.
- Swinth, K. L., P. J. McGoe, and K. K. Rhoads, "The Role of Non-Uniform Distributions in Determination of Lung Depositions of Transuranics," PNL-SA-11000. IRPA Meeting in West Berlin, May 7-12, 1984.
- Tomeraasen, P. L., D. L. Haggard, M. A. Parkhurst, D. E. Hadlock, "Personnel Neutron Dosimetry Using Track Etch Techniques," PNL-SA-11953. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.
- Traub, R. J., B. L. Murphy, J. M. Selby, E. J. Vallario, "Characterization of Internal Dosimetry Practices at DOE Facilities," PNL-SA-11962. 29th Annual Meeting of the Health Physics Society, New Orleans, Louisiana, June 3-7, 1984.

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