**Pacific Northwest Laboratory
Annual Report for 1985 to
The Assistant Secretary for
Environment, Safety and Health**

**Part 5 Overview and Assessment
February 1986**

**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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**Pacific Northwest Laboratory
Annual Report for 1985 to the
DOE Office of the Assistant Secretary
for Environment, Safety and Health**

Part 5 Overview and Assessment

L. G. Faust and Staff Members
of Pacific Northwest Laboratory

February 1986

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

Pacific Northwest Laboratory
Richland, Washington 99352

PREFACE

This 1985 annual report from Pacific Northwest Laboratory (PNL) to the Department of Energy (DOE) describes research in environment, health, and safety conducted during fiscal year 1985. 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 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 1985 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 - R. E. Wildung	R. E. Wildung, Report Coordinator C. M. Novich, 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 J. E. Danko, Editor
Part 5: Overview and Assessment	
Program Manager - L. G. Faust	L. G. Faust, Report Coordinator R. W. Baalman, 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.

A highlight this past year was the appointment of a Scientific Advisory Committee. Honoring us by accepting our invitation to serve on the committee are:

Dr. Franklin I. Badgley	University of Washington
Dr. Leo K. Bustad	Washington State University
Dr. Franklin Hutchinson	Yale University
Dr. Albert W. Johnson	San Diego State University
Dr. J. Newell Stannard	University of Rochester
	University of California, San Diego
	W. J. Bair, Manager
	S. Marks, Associate Manager
	Environment, Health and Safety
	Research Program

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Annual Report for

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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
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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

FOREWORD

Part 5 of the 1985 Annual Report to the Department of Energy's Assistant Secretary for Environment, Safety and Health 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 1985. Authors of these articles represent a broad spectrum of capabilities derived from four of the seven research departments 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

- **Effect of Areal Averaging on Performance of a Long-Range 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.

• Bullets denote Field Task Proposal/Agreement (FTP) titles.

• Effect of Areal Averaging on Performance of a Long-Range Acidic Deposition

The effect of areal averaging on the performance of a long-range acidic deposition was examined. Initial results are presented.

AN INTERMODEL COMPARISON OF LINEAR SOURCE RECEPTOR RELATIONSHIPS FOR SEVEN LONG-RANGE ACID DEPOSITION MODELS

C. M. Berkowitz and S. K. Heflick

Relationships between emissions and deposition mass are often estimated by use of detailed meteorological models. These models simulate the release of a puff of specified composition and reduce the amount of primary pollutants in such puffs via deposition, scavenging, and chemistry. Chemical transformations result in a simulated increase in the amount of secondary pollutants. The final value to be estimated in such models is the amount of deposited mass at a given receptor site, which depends only in part on the initial release. Other major factors include the meteorology associated with the particular simulation period and parameterizations of the component processes.

For linear models, a transfer matrix can be used to empirically relate the initial emissions with the amount of deposited mass finally estimated. Elements of such a matrix are defined by

$$T_{ij} = d_{ij}^m / E_j$$

where E_j is the total mass emitted in region j and d_{ij}^m is the portion of E_j predicted by model m to be deposited at receptor region i . The total mass predicted to occur at region i by linear model m is thus given by

$$D_i^m = \sum_{j=1}^J d_{ij}^m$$

This is the quantity used in most model evaluation studies; it would correspond to the final predicted value of deposited mass at site i .^(a) In this study, both D_i^m and d_{ij}^m from 9 MOI (Ferguson and Machta 1981) models were compared.

(a) No comparisons were made in this study of D_i^m with the corresponding observations (results of such a study are in Ferguson and Machta, 1981).

The results show that not only was there considerable variability in the total predicted deposited mass at a number of receptor locations, but also that there was considerable variability in the individual source receptor relations, d_{ij}^m , among each of the models.

The basis for comparing these two quantities for each model were the average values, calculated for all models, of D_i^m and d_{ij}^m :

$$\langle D_i \rangle = (1/7) \sum_{m=1}^7 D_i^m$$

$$\langle d_{ij} \rangle = (1/7) \sum_{m=1}^7 d_{ij}^m$$

A simple regression analysis was done on the paired values of D_i^m and $\langle D_i \rangle$, and on the set of paired values of d_{ij}^m and $\langle d_{ij} \rangle$. Results for these comparisons showed that there was a wide range in the prediction tendencies for the models. This disparity was measured by (1) scatter plots, (2) regression coefficients, and (3) mean square error calculations between the model's specific value and the corresponding average value. This range in prediction was found for both the total deposited mass, D_i^m , and the term d_{ij}^m . Not only did these tendencies for over- and under-prediction (as indicated by the slopes of the regression line) vary between the models, but the tendencies for any one model varied according to the species (SO_2 or SO_4^{2-}) and form of the deposited material (wet or dry).

A SCALING ESTIMATE OF LONG-TERM DRY DEPOSITION DOWNWIND OF A POINT SOURCE

C. M. Berkowitz

There are two main removal mechanisms for pollutants in the atmosphere: wet and dry deposition. Wet deposition refers to the incorporation of compounds within cloud particles and their subsequent removal by falling precipitation. Dry deposition re-

fers to the removal of particles or gases by direct settling on land or water surfaces.

Early studies suggested that dry deposition might be as important as wet deposition (Thomas 1943). More recent theoretical work (Garland 1978) suggests that about half of the SO_2 emitted to the atmosphere is removed by dry deposition (the remainder being oxidized to sulfate and removed by precipitation).

Establishing the relative magnitude of these two processes is complicated by the variability shown in field data. The reasons for this variability in wet deposition are numerous but can be grouped according to the variability associated with (1) experimental error, (2) storm features, and (3) source characteristics (Hales and Dana 1979). Estimates of dry deposition are even more difficult to interpret, there being no practical and widely accepted measurement method for dry deposition (Durham et al. 1983).

To obtain estimates of the efficiency of removal by dry deposition for time periods greater than the 24 hours to one month that typify such estimates (Dolske and Gatz 1985), an analysis was made of predicted air concentration values which in turn were based on five years of meteorological records. Details of the source depletion Gaussian plume model used to derive these values is given by Vaughan et al. (1975). For this overview report, we would only note that

1. Under most conditions, the model employed tended to overestimate surface air concentrations relative to a more realistic surface depletion model (Horst 1974).
2. Rather than actual hourly data, normally employed in Gaussian plume model, a statistical data set from the National Climatic Center was employed. This data set presents wind distribution as a function of Pasquill stability class, wind direction, and speed. Rainfall rates (necessary for wet removal calculations) are not explicitly included in this data set. Vaughan et al. (1975) assumed that rain occurred 2% of the time when the wind speed was less than 16 knots and when the direction was within the SE-SW sector (implying wet deposition within the NW-NE sector).

3. The specific data set used was for St. Louis, Missouri and was based on five years of records (1960 through 1964).
4. A deposition velocity of 1 cm/s, and a scavenging coefficient of $10^{-4}/\text{s}$ were used.

Average air concentrations estimated from this five-year data set were presented for radial distances out to 50 km at 16 direction sectors. The simulated source had an emission rate of 1 g/s. Results were presented for a summer and winter low stack (30 m) and a winter tall stack (300 m).

The azimuthally averaged, dry-deposited mass, $\langle D \rangle$, at a given distance from the source was calculated from the air concentration values, C , by

$$\langle D \rangle = (1/16) \times \sum C \times V_d \times \Delta t$$

where the sum is over sixteen direction sectors, V_d = the deposition velocity, and Δt = 3 months. It was found that to a good approximation, $\langle D \rangle = aX^b$, where X is the radial distance from the stack, and 'a' and 'b' were derived from a standard regression statistics package. The total dry-deposited mass could thus be evaluated from

$$2\pi \int_r^R r' \langle D \rangle dr' = 2\pi a [R^{b+2} - r^{b+2}] / (b+2)$$

where R and r represent the inner and outer radii of disks over which we want to estimate the total deposited mass.

The results in Vaughan et al. (1975) limited this analysis to only (1) a summer climatology with a 30-m stack, (2) a winter climatology with a 30-m stack, and (3) a winter climatology with a 300-m stack.

Little variation was seen in the total dry deposited mass as a function of distance for the two short stack cases (see Table 1). For both cases, dry deposition removed in excess of 50% of the emitted mass by 50 km. In contrast, the tall stack data implied deposition removal values that were an order of magnitude less.

A winter situation would be associated with more stable atmospheric conditions. Limited vertical mixing and the presence of low-level temperature inversions in the atmosphere can likely explain this order-of-magnitude reduction in dry-deposited mass for the tall stack.

TABLE 1. Percentage of Dry Deposited Mass (Relative to Emissions), as a Function of Distance from Source.

distance from stack, m	% dry deposited (relative to total emissions)		
	30-m stack (summer)	30-m stack (winter)	300-m stack (winter)
1,000	11	14	0
2,000	15	18	0
5,000	23	25	0
10,000	30	33	0.5
20,000	42	44	1.5
30,000	51	51	1.5
50,000	63	63	5

While we would caution against extrapolating these results beyond the admitted limitations of this study, it may be concluded that in the winter, dry deposition is inconsequential for near-field (<50 km) regions in the vicinity of tall stacks.

THE EFFECT OF AREAL AVERAGING ON THE PERFORMANCE OF A LONG-RANGE ACIDIC DEPOSITION MODEL

C. M. Berkowitz

Many factors affect the performance of models that simulate long-range transport and the associated chemical and scavenging processes. In this study, we consider the impact of spatially averaging the values to come out of a typical long-range acid deposition model. This is of interest in order to define the optimal spatial scale at which such a model performs.

The Regional Air Pollutant Transport (RAPT) model (McNaughton, Powell, and Berkowitz 1981) was used to simulate results applicable to the July 1978 Sulfur Regional Experiment (SURE) intensive period (Perhac 1978). Because RAPT is linear in its method of simulating the conversion of SO_2 to $\text{SO}_4^{=}$, results from individual grid cells can be summed to produce analogous results over larger areas. This was done over areas ranging from 33-km x 33-km to 50-km x 50-km regions.

Those model predictions were compared with the analogous July 1978 SURE data. Values from the SURE stations were averaged together when the station locations were within the same averaging area as the cor-

responding model averaging space. Thus, the results for this study are (fundamentally) a set of paired statistics between SO_2 and $\text{SO}_4^{=}$ air concentration observations and their corresponding predictions. Each set of paired values differed from the other sets in the area over which the averaging was done.

A mean square error (MSE) statistic was used to quantify model performance. Letting O_n = the observed value for a given region, and P_n = the associated predicted value, we define

$$\text{MSE} = \frac{1}{N} \sum_{n=1}^N |P_n - O_n|^2 \quad (1)$$

By defining model bias, $\langle \epsilon \rangle$, as

$$\langle \epsilon \rangle = \frac{1}{N} \sum_{n=1}^N [O_n - P_n] \quad (2)$$

and variance of a scalar ϕ as

$$\text{Var}(\phi) = \frac{1}{N} \sum_{n=1}^N |\phi_n - \langle \phi \rangle|^2 \quad (3)$$

with an average value of

$$\langle \phi \rangle = \frac{1}{N} \sum_{n=1}^N \phi_n \quad (4)$$

we can write

$$\text{MSE} = \frac{N-1}{N} [\text{Var}(O) + \text{Var}(P)] + \langle \epsilon \rangle^2 - 2 \frac{N-2}{N} \text{Cov}(O, P) \quad (5)$$

where $\text{Cov}(O, P)$ is the covariance between the observed and predicted values.

By examining the three component terms of the MSE (variance, bias, and covariance) as functions of area, we found the following for the RAPT model and July 1978 air quality data:

1. There is an optimal area for model predictions of SO_2 air concentrations. This area corresponded to combining ten to twenty-five 33-km x 33-km grids: (a) below this optimal area,

the combined variability of SO₂ observations and predictions produced poor performance, as measured by Eq (5); (b) above this optimal area, there was a significant increase in model bias (Eq [2]). As the degree of areal averaging increases, more model predictions applicable to clean-air regions would come into the computation of <P>, with no such addition of values to <O> because of the limited number of observing sites. For this reason, the increase in bias is thought to result from a decrease in the mean predicted value with increased aggregation.

2. No such optimal area was found for predicting SO₄⁼ air concentrations in RAPT. This is somewhat surprising since modeled SO₂ and SO₄ are inter-related via two coupled, linear ordinary differential equations of the form

$$\frac{d[SO_2]}{dt} = -[K_1 + T][SO_2]$$

$$\frac{d[SO_4^=]}{dt} = -K[SO_4^=] + 1.5 T [SO_2]$$

where [] indicates mass per volume,
 K₁, K₂ = linear rate constants
 T = conversion rate of SO₂ to
 SO₄⁼ (for a linear system).

Because no such optimal area was found for SO₄⁼, nor were the variance, bias or covariance found to be sensitive to area of averaging, the postulated linearity of the SO₂-SO₄⁼ system will require reconsideration. As a primary pollutant, the results of SO₂ require little chemistry. SO₄⁼ though, is largely a secondary pollutant; predictions are more sensitive to the assumed chemical mechanism.

References

- Dolske, D. A., and D. F. Gatz. 1985. "A Field Intercomparison of Methods for the Measurement of Particle and Gas Dry Deposition." *J. Geophysical Research*, 90 (01):2076-2084.
- Durham, J. L., B. B. Hicks, M. L. Wesley, R. G. dePena and D. R. Thomson. 1983. Status of research to develop acidic dry deposition monitoring capability. Rep. EPA-600/D-83-093. USEPA Sci. Res. Lab., Research Triangle Park, N.C.
- Ferguson, H. and L. Machta. 1981. Modeling Subgroup Report of Work Group 2, Atmospheric Sciences and Analysis. Report No. 2-13, July 10, 1981. Under the Memorandum of Intent on Transboundary Air Pollution Signed by the United States and Canada on August 5, 1980.
- Garland, J. A. 1978. "Dry and Wet Removal of Sulphur from the Atmosphere." *Atmos. Environ.* 12:349-362.
- Hales, J. M. and M. T. Dana. 1979. "Precipitation Scavenging of Urban Pollutants by Convective Storm Systems." *Journal of Applied Meteorology* 18(3):294-316.
- Horst, T. W. 1974. "A Surface Flux Model for Deposition and Resuspension." In Pacific Northwest Laboratory Annual Report for 1973. Vol. 2, Part 1, pp. 63-67.
- McNaughton, D. J., D. C. Powell, and C. M. Berkowitz. 1981. RAPT The Pacific Northwest Laboratory Regional Air Pollutant Transport Model. PNL-3390. Pacific Northwest Laboratory, Richland, Washington.
- Perhac, R. M. 1978. "Sulfate Regional Experiment in the Northeastern U.S.: The SURE Program." *Atmos. Environ.* 12:641-648.
- Thomas, M. D., R. H. Hendricks, T. R. Collier, and G. R. Hills. 1983. "The Utilization of Sulphate and Sulphur Dioxide for the Sulphur Nutrition of Alfalfa." *Pl. Physiol.* 18:345-371.
- Vaughan, B. E., K. H. Abel, D. A. Cataldo, J. M. Hales, C. E. Hane, L. A. Rancitelli, R. C. Routson, R. E. Wildung and E. G. Wolf. 1975. Review of Potential Impact on Health and Environmental Quality from Metals Entering the Environment as A Result of Coal Utilization. A Battelle Energy Program Report, PB-289658, Battelle Memorial Institute, Columbus, Ohio.

NUCLEAR SAFETY

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

To establish and maintain an effective nuclear safety program, the Department of Energy (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 DOE's activities and those of 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 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.

• 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 Division of Operational and Environmental Safety, Department of Energy (DOE), 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 DRAFT ANSI STANDARD N13.30 PERFORMANCE CRITERIA FOR RADIOBIO-ASSAY

J. A. MacLellan, R. J. Traub, A. V. Robinson, W. D. Reece

The purpose of this study is to evaluate the adequacy of draft ANSI Standard N13.30 performance criteria by conducting a nationwide bioassay intercomparison test. The study involves two rounds of performance testing of laboratories involved in both in-vitro (excreta analysis) and/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 in-vivo report was completed, data analysis for the second round of in-vitro testing was completed, preparation began for the second round of in-vivo testing as well as the artificial versus natural urine matrix study. The In-Vivo Pilot Study Report was reedited to incorporate all comments, and revised camera-ready mats were submitted for clearance and publishing as a PNL document. A large number of laboratories are voluntarily participating in these tests, including commercial testing laboratories, DOE/DOE-contractor laboratories, universities and medical institutions, and commercial nuclear power facilities.

Table 1 summarizes the results for Round I of the in-vivo testing and shows that the Minimum Detectable Activity (MDA) criterion is most limiting to the laboratories. In recognition of this fact, future work will include investigation into the most appropriate way to determine the MDA for an analysis. It has been suggested by the ANSI N13.30 committee that a site visit by the evaluating team may be more appropriate than simple evaluation of reported data.

Round II in-vivo testing will involve 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, will be employed. The nuclides to be used in the study are ^{235}U , ^{238}Pu , ^{60}Co , ^{134}Cs , and ^{137}Cs . Point sources of cesium isotopes and ^{40}K will be imbedded into the heart cavity of the torso phantom to provide natural background interference.

Additionally, six non-DOE facilities have expressed their willingness to participate in Round II in-vivo testing on a cost recovery basis since Nuclear Regulatory Commission (NRC) is no longer providing their share of support for the program.

In-vitro measurement capability testing involved preparation of approximately 560 carefully spiked artificial urine samples for Round I and 1,300 samples for Round II. The Round II 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. The report entitled "Performance Testing of Radiobioassay Laboratories: In-Vitro Measurements, Pilot Study Report," NUREG/CR-3809, DOE/NMB 1071, Vol. 1, was published in December 1984. A preliminary summary of Round II in-vitro test results is given in Table 2. Results were comparable to those observed in Round I testing with MDAs and bias causing the most failures.

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 testing program continues to highlight the need for laboratory accreditation to ensure accurate bioassay results. The present testing program provides an opportu-

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

Category	Nuclide	Number of Participants	Responding Facilities	Number of Laboratories Passing		
				Bias	Criteria Precision	MDA
Lung	²⁴¹ Am	6	4	4	4	1
Lung	²³⁵ U	7	5	4	5	1
Lung	⁶⁰ Co	15	13	5	13	4
Whole Body	⁶⁰ Co	16	14	8	12	4
Whole Body	¹³⁷ Cs	15	13	11	13	4
Whole Body	¹⁴⁴ Ce	14	12	5	7	1
Thyroid	¹³¹ I	28	22	16	22	25

TABLE 2. Preliminary Summary of Round II In-Vitro Test Results

Nuclide	Responding Facilities	Number of Laboratories Passing		
		Bias	Criteria Precision	MDA ^(a)
³ H	28	27	26	23
¹³⁷ Cs	19	15	17	10
⁶⁰ Co	19	15	17	8
⁸⁹ Sr	6	4	5	3
⁹⁰ Sr	9	6	9	8
²⁴¹ Am	4	2	3	0
²⁴⁸ Pu	6	6	6	2
U-nat	15	12	14	5

(a) Not all laboratories provided sufficient information to estimate the MDA.

ity 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.

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

J. L. Kenoyer and K. L. Swinth

Technical Assistance: M. R. Tinker

The objectives of this task can be divided into two areas: those related to the origi-

nal draft ANSI N42.17 standard (i.e., ANSI N42.17A), and those related to the two companion standards on air monitors (ANSI N42.17B) and extreme environmental conditions (ANSI N42.17C). Objectives in the first area include the following: (1) to evaluate the applicability and practicality of the proposed ANSI Standard "Performance Specifications for Health Physics Instrumentation"; (2) to determine the degree of conformance to the proposed standard of selected currently available commercial instruments; (3) to develop a formal test and evaluation protocol and specific procedures; and (4) to lay the ground work for establishing a permanent testing laboratory. Development of procedures includes procedures for a measurement assurance (MA) program to define the continuing technical relationship between the National Bureau of Standards (NBS) and laboratories that test health physics instruments. This will assure that measurements are consistent with national standards and provide techniques to control the measurement process during testing against performance criteria in ANSI N42.17. Objectives in the second category covering the companion standards are essentially identical; however, the testing will not be as extensive, and future testing is expected to be limited.

Approximately 60 portable health physics instruments are still available for evaluation using testing procedures based on draft ANSI N42.17A and ANSI N42.17C. Four CAM-type air monitors are currently being evaluated using procedures based on ANSI N42.17B; others are to be procured during FY 1986.

An ANSI working group meeting was held in Santa Fe, New Mexico on December 11-13, 1984. J. M. Selby chaired the sessions; J. L. Kenoyer and K. L. Swinth attended the meeting as consultants. The revised ver-

TABLE 1. Selected Testing Results to Date (9/30/85)

Test	Number of Failures/Number Tested							
	Ion Chamber		GM Detector		Alpha Detector		Neutron Detector	
	Instruments	Models	Instruments	Models	Instruments	Models	Instruments	Models
Stability	1/9	0/6	3/35	3/20	6/15	2/8	3/4	2/3
Geotropism	0/10	0/7	1/24	0/12	9/14	5/7	NT	
Response Time	8/15	4/9	10/22	6/13	0/7	0/4	3/3	1/1
Accuracy	1/9	1/6	7/19	3/11	NT		4/6	4/6
Coefficient of Variation	1/20	0/10	11/21	5/13	7/10	3/5	0/3	0/1
Photon Radiation Energy Dependence	3/9	2/7	12/20	9/14	NA		NA	
Photon Radiation Overload	7/9	4/6	1/16	1/13	NA		NA	
Radio Frequency Field Susceptibility	3/8	2/7	2/13	2/11	0/5	0/5	1/5	1/5
Microwave Field Susceptibility	4/5	4/5	3/7	3/7	2/3	2/3	NT	
Temperature	9/17	3/7	0/23	0/12	10/13	4/6	0/4	0/3
Temperature Shock	2/7	1/6	3/9	3/9	3/5	2/3	2/5	2/5
Humidity	1/7	1/5	4/18	3/14	10/15	2/4	0/6	0/3
Vibration	1/4	1/4	0/7	0/7	3/7	2/6	NT	

NT: None Tested
 NA: Not Applicable

FIGURE 1. Instrument Performance and Testing **FIGURE 2.** Instruments tested

sion of ANSI N42.17A was sent to E. J. Vallario in May for submission to the N42.1 Committee. Recommended changes have been made to ANSI N42.17B during FY 1985, and the updated version is scheduled to be sent to the working group members early in CY 1986 for comment. Some changes have been made in ANSI N42.17C, but the revision is not complete. Another meeting of the ANSI working group will be scheduled for early CY 1986 to discuss these three draft standards.

During FY 1985, data were obtained from instruments following test procedures for inspection, alarm reset, alarm threshold drift, alarm activation delay, accuracy, response time, stability, extracamerall response, mechanical shock, vibration, coefficient of variation, temperature, temperature shock, humidity, ambient pressure, radiation overload, beta and photon energy dependence, beta and photon angular dependence, radio frequency fields, brief immersion, flowrate meter accuracy, and flowrate stability.

The data obtained to date with portable instruments under normal environmental conditions have been reevaluated against the requirements in the latest draft of ANSI N42.17A. Table 1 summarizes selected testing results. Data are listed in terms of the number of failures observed and the total number tested for instruments and models of instruments. The number of failures per number of instruments and models tested have changed slightly from those seen with earlier versions of the draft standard. The same major conclusions are still applicable including the following: (1) most of the currently available GM detectors are highly energy dependent and should not be used as dose-rate type instruments; (2) the statistical fluctuations observed with GM detectors and alpha survey instruments ranged to 20% on the most sensitive ranges; (3) alpha survey meters are much more susceptible to effects of environmental changes than ion chambers, GM detectors, and neutron monitors; (4) ion chambers can be very temperature dependent; and (5) many of the neutron monitors show a high level of statistical fluctuations, as well as very long response times. Figure 1 depicts some of the testing equipment and devices used in this program; Figure 2 depicts the variety of instruments tested.

A draft of Part I (i.e., Testing Procedures) of the final report related to testing under normal environmental conditions was sent to the sponsors on July 31, 1985. A draft of Part II (i.e., Testing Results) of the final is currently being reviewed by PNL personnel and is scheduled to be sent to the sponsors early in FY 1986.

During the last year, work has been performed on the development of measurement assurance procedures and the determination of required recalibration frequencies for laboratory standards. Elmer Eisenhower at NBS has been examining the role of NBS in a measurement assurance program for testing of instruments and has completed a draft report which is currently under peer review. The statistical basis for internal control of measurements was discussed with NBS personnel and has been used to prepare a report on quality assurance procedures for the testing lab. The general control of measurements and comparison of multiple standards for temperature, pressure, humidity, force, etc. was considered in addition to the control of radiation measurements.

DOE PROGRAM FOR IMPROVING AIR SAMPLING AND MONITORING

J. L. Kenoyer, J. Mishima, K. L. Swinth

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.

Work was performed on three PNL publications during FY 1985. The report "Effects of Particle Size and Velocity on Burial of Airborne Particles in Glass Fiber Filters," PNL-5278, by D. P. Higby was published during this period. Two draft reports have also been submitted to the sponsor for comment: PNL-5286, "U.S. Department of Energy Workplace Air-Sampling and Air-Monitoring Practices" and PNL-5287, "Problems Involved in Assessing Committed Dose Equivalent with Personal Air Samplers in Relationship to Department of Energy Programs."

Work has been performed in the ANSI N42.17 evaluation study that supports the air monitoring efforts in this program. The development of draft ANSI Standard N42.17B and related testing procedures will certainly enhance the efforts in this program. Additional sampling and analysis capabilities are currently being developed for this program. These include the following

systems: cascade-impactor sampling and analysis system, electrostatic precipitation sampling and analysis systems, real-time particle size measurement system using a laser spectrometer, aerodynamic particle size analyzer, air dilution system, and aerosol generation systems. The aerosol exposure system that has been received will allow for uniform exposure of air monitors and samplers to tracer or test aerosols.

The subcontract with Lawrence Livermore National Laboratory (LLNL) to develop a highly sensitive transuranic aerosol monitor for use in the workplace environment is currently in place. The system may have the capability of measuring airborne levels of Pu-239 under quasi-real-time conditions with a sensitivity level of ≤ 0.5 MPC-hr. During FY 1985, work was performed in the aerosol testing of the system, software development and debugging, system electronics development, fabrication and testing, interface development, and transport modification and testing. The aerosol testing of the unit showed that particle collection across the filter is uniform, and very little particle impaction on the detector is observed. An additional \$40K for the manufacture of a second Workplace Transuranic Aerosol Measurement System (WOTAMS) prototype was authorized during FY 1985. Currently, the work on the first and second prototypes is slightly behind schedule, but the work is progressing well. The first prototype should be operating by the end of October and be ready for evaluation by PNL personnel in November. The second prototype is approximately a month behind schedule; the funding for this system was delayed, and the design took longer than was planned. The complete mechanical assembly of this unit should be ready by mid-November; the electronics will then be installed, the system tested, and the complete unit should be delivered to Rocky Flats for evaluation by January 15, 1986.

A meeting was held at DOE Headquarters on April 10, 1985 to discuss the DOE/ONS air monitoring program. Attendees included Edward Vallario, Group Leader Health Physics; Robert Barber, Acting Director Office of Nuclear Safety; Joseph Fitzgerald, Health Physicist Office of Nuclear Safety (DOE Headquarters); Jack Selby, Bette Murphy, Ken Swinth, Leo Faust, Judson Kenoyer (PNL); Paul Phelps, Bob Kaifer, Chuck Prevo, Dick Griffith (LLNL); Bill Tyree, George Campbell, Bob Yoder (Rocky Flats Plant); Joe Graff (LANL). The meeting was opened by Mr. Robert Barber who emphasized the need for improvements in air monitoring programs. Following his remarks, Mr. Edward Vallario described the purpose of the meeting as follows: to discuss ambient and workplace monitors current-

ly in use and/or development, and to discuss and develop specific criteria for workplace or breathing-zone air monitors that could be developed. The importance of air monitoring programs was described as being the initial "warning system" for the protection of personnel from unnecessary exposure to airborne radioactive materials. Air monitoring appears to be a neglected area of work; small advances have been made in recent years in the increase in sensitivity or the change in design for the systems in use. Several areas of discussion were covered during the meeting with excellent presentations on topics that included the new LLNL plutonium air monitor, breathing-zone monitors being designed and fabricated by personnel at Rocky Flats, criteria for working area and breathing zone monitors, and possible miniaturization of currently used air monitoring systems. A workshop on air monitoring is now scheduled to be held on October 28-30, 1985. This workshop will be hosted by personnel at LLNL. Personnel from other DOE facilities have been invited to discuss aspects of the ongoing air monitoring programs at those facilities. Instrumentation, analysis techniques, program management, and problems and needs as seen by the DOE personnel will be discussed at the workshop. Editing and publication of the proceedings of the workshop will be coordinated by PNL personnel.

EXTREMITY DOSE MEASUREMENTS EVALUATION AND UPGRADING

B. L. Murphy,^(a) P. L. Roberson, R. Harty

A draft of the report, "Extremity Dosimetry at U.S. Department of Energy Facilities" has been written. This report contains the information obtained from a questionnaire distributed to DOE/DOE contractor facilities in the fall of 1983 to determine the general characteristics of their extremity monitoring programs. Technical background pertaining to extremity dosimetry is also contained in the report as a basis for understanding the survey results. The background information includes regulations, recommendations from advisory groups, a description of the types of extremity dosimeters available, and the current problems and areas for improvement in extremity dosimetry.

After the draft report had been written, it was realized that some key information required to completely characterize extremity

^(a) No longer employed by Pacific Northwest Laboratory.

dosimetry at DOE facilities was missing. During the time since the survey was conducted, the interest in extremity dosimetry has increased considerably along with our understanding and expertise. Additional information, such as the criteria used by the facility to determine when extremity monitoring is required, is being obtained from DOE facilities and will be included in the final report.

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, improvement in analytical capabilities, application of new promising concepts for internal dosimetry, and recommended internal dosimetry practices.

Internal Dosimetry

K. R. Heid and R. J. Traub

A method has been devised that will allow internal dosimetry experts to relate cancer induction risk to bioassay data. The method consists of a three-step approach. The first step consists of estimating the radiation dose that will result in a defined level of risk to the worker. This first step is accomplished by utilizing the cancer risk information published in ICRP Publication 26, BEIR-III, and the National Institutes of Health (NIH) Radioepidemiological Tables. The second step is to relate the radiation dose derived in the first step to a rate of (inhalation) intake that occurs continuously over a period of time. The final step is to relate the rate of intake to excretion rates. The excretion rates are obtained by combining the ICRP Task Group Lung Model, metabolism models specific to the radionuclide of interest, and excretion models, such as those that appear in ICRP Publications 10 and 10A.

The method will allow estimation of required detection levels for bioassay procedures. Work has begun on utilizing this method for estimating the level of detection required at various times following

initiation of continuous intakes. The method has not yet been used to determine required detection levels. The advantage of this method is that upper bounds of the cancer risks to the workers can be estimated based upon excretion data.

Plans were completed and an agenda prepared for the first Radiobioassay and Internal Dosimetry Workshop to be held in Albuquerque, New Mexico, January 20-22, 1986.

Manuals of Good Practice for Internal Dosimetry Programs

K. R. Heid and R. J. Traub

A rough draft of a Manual of Good Practice for Routine Surveillance Programs for Plutonium has been prepared. The manual discusses routine monitoring of the workplace for airborne radioactive contamination. The manual also discusses monitoring the radiation worker for contamination, including the types of bioassay required and criteria for determining the frequency for bioassay examinations. The final section of the manual identifies action levels that warrant follow-up action and the appropriate follow-up response based on the indicative potential severity of an intake of plutonium.

Radionuclide Measurements Using Resonantly Enhanced Collisional Ionization (RECI)

T. J. Whitaker, B. A. Bushaw, G. K. Gerke

The objective of this program is to develop and evaluate a laser-based method for radionuclide measurements. The technique being developed uses two nitrogen-laser pumped dye lasers to selectively excite the target isotope to an electronic state near the ionization threshold. Previous work has shown that such excited atoms are efficiently ionized by collisions with argon or krypton. The resulting ions can be detected by conventional methods. The attributes of this approach include highly sensitive isotope analysis with relatively inexpensive lasers and greatly reduced pumping requirements. The narrow laser line widths also provide isotopic selectivity.

The project was begun in March of 1985, and initial work involved design of the dye lasers and vacuum chamber. One dye laser has been assembled, and initial characterization studies show a bandwidth of 0.15 wavenumbers. The bandwidth is comprised of several modes. Stable single-mode operation (less than 500 MHz drift in three minutes) was achieved near threshold, but continuous scanning of a single mode will require insertion of a Brewster plate in the

cavity. We plan to increase mode resolution by replacing the current 2400-lines/mm grating with a 3600-lines/mm grazing incidence holographic grating. Several detection methods have been investigated to determine the best method of ion detection, and a proportional counter was chosen. This will allow single ion detection at high pressures (approximately 200 torr) but still permit operation at reduced pressures (with reduced detection efficiency) to minimize collisional broadening. The optimum operating pressure will be a trade-off between minimum line broadening (i.e., maximum isotopic selectivity) and gain in the detector.

Assembly of the vacuum chamber has been hampered by procurement delays. At the end of the fiscal year, all parts for the chamber had been delivered, and initial assembly was in progress.

EFFLUENT MONITORING SYSTEMS AT DOE FACILITIES

C. M. Unruh

This project is currently funded by the Department of Energy Office of Nuclear Safety and the Office of Operational Safety. Progress on this project is reported in the section entitled Operational Safety (page 41).

ALARA ENGINEERING

L. H. Munson, et al.

Improvement of DOE ALARA Guidance

In early 1980, a manual, Guide to Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA), was published as DOE/EV 1830-T5. This manual has since been specified by DOE as "mandatory." Since its publication, existing standards have been revised and upgraded, and increasingly detailed interpretations of ICRP and NCRP recommendations have been promulgated. Thus, revision and upgrading of guidance documents is necessary to maintain DOE leadership in the application of ALARA in radiation protection.

This program is designed to provide a long-range plan to upgrade the DOE guidance to its operators and contractors in maintaining radiation doses as low as reasonably achievable.

Initial efforts were directed at revision and upgrade of the manual DOE/EV 1830/T5. A draft of the revised manual was prepared and submitted for review in FY 1983. Additional guidance was received requiring ex-

tensive reorganization and editing of the draft. A revised draft of the manual, emphasizing the application of ALARA and providing decision trees for development of ALARA programs, was completed in FY 1984.

Continuing work is directed to developing more complete guidance for DOE operations handling specific radionuclides, such as plutonium and uranium. Existing manuals are being revised, and new documents are being developed to provide detailed guidance in these areas and to incorporate recent recommendations from the ICRP in developing and implementing the optimization process in the design of new facilities and on the modification and operation of existing facilities.

The current program will provide a revised and upgraded DOE ALARA manual, a revised and upgraded manual, "A Guide to Good Practices at Plutonium Facilities," and a newly developed manual, "A Guide to Good Practices at Uranium Facilities." Work in progress on these guidance documents includes: properties of specific materials, design criteria, radiation protection criteria and techniques, emergency preparedness, decontamination, decommissioning and dismantling, and diagnostic evaluation of internal deposition.

SPECIAL STUDIES

J. M. Selby and L. G. Faust

Occupational Radiation and Exposure Information System

K. R. Heid and R. J. Traub

Assistance was provided to DOE Headquarters in responding to technical comments received on the proposed revision to DOE Order - 5484.1A on radiation protection reporting requirements. K. R. Heid chaired a DOE Expert Group on Internal Dosimetry at a meeting in Colorado Springs on January 10, 1985 to prepare technical review of internal dosimetry requirements to provide a basis for the development by DOE of DOE Order 5484.1A on Reporting Internal Exposure. The consensus paper, which was sent to DOE-HQ, incorporated terminology and symbols agreed to by the Interagency Task Group discussing revisions to EPA and dose limitation guidance.

Lifetime Dose Assessment

R. J. Traub

A new project was begun to assist in assessing the impact of proposed changes in dose assessment and recording procedures on

DOE programs. This project will analyze the radiation doses received by workers at major DOE facilities to: (1) provide a body of radiation protection data; (2) use the data to analyze the lifetime exposures as well as the rates at which they were received; and (3) utilize these data to estimate the impacts of proposed legislation and proposed recommendations of national and internal advisory groups (e.g., lifetime dose limits, rate of receipt of doses, etc.), which may have an impact upon DOE and its contractors.

Health Physics Appraisal Program

L. G. Faust, J. M. Selby, et al.

A technical health physics appraisal was conducted at selected DOE Albuquerque field office contractor sites as part of the Office of Nuclear Safety's functional appraisal of the Albuquerque Operations Office. The appraisal was conducted using three teams, each visiting three sites and each team being led by a Headquarters staff member. Individual reports were compiled for each site and later compiled into a final report to be used by DOE Headquarters.

Quality Factors

L. G. Faust

A special committee was appointed by DOE to perform an independent review of the technical basis to support a proposed change in neutron quality factor. The committee is composed of Harvey Drucker, Bill Loewe, George Kerr, Frank Masse, Dick McCall, Gene Saenger, Jim Smathers, and is chaired by Leo Faust. Several meetings were held including one in which Drs. Harald Rossi and Warren Sinclair addressed the group. There appear to be many inconsistencies associated with the existing current values of Q, most of which do not disappear with the new proposed values. It is, however, the general consensus of the committee that a change will be implemented. The change is expected to be about a factor of 2 for all neutrons with energies in excess of thermal. A draft with recommended actions for DOE, including recommendations to accommodate expected additional changes some time in the future, will be available in mid-November. Final recommendations should be available in March or April, 1986.

Nonequilibrium Effects on Dose to the Basal Layer of the Skin from Gamma-Emitting Contamination

W. D. Reece and S. D. Miller

In the calculation of dose to the skin arising from contamination, attention us-

ually is given to the effect of beta particles. Although beta particles will deposit large amounts of energy in the basal layer compared to gamma rays, the gamma rays can be important during certain situations. During work in contaminated areas, often the worker will be protected from the beta particles emitted from radioactive contamination by protective clothing, but the gamma rays will penetrate and expose the basal layer of the skin.

The calculation of the dose to the basal layer from gamma rays is not straightforward. Implicit in the assumption relating gamma energy fluence to dose is the concept of electronic equilibrium. The reactions of the gamma rays with electrons in a small area near the dose point actually deposit little energy in the volume because the electrons spread the energy that they have received from the gamma ray over their entire range. The simplifying assumption underlying normal dose calculations is that the energy carried out of a small volume near the dose points is replaced by electrons carrying energy in from interactions happening nearby with other gamma rays. This concept is formally called electronic equilibrium.

For dose points near the surface of the skin, and in particular the basal layer of the skin, electronic equilibrium will not be assured. If the gamma rays must travel some distance in air before impinging on the skin, they often will arrive in electronic equilibrium by virtue of interactions with air. For sources lying directly on the skin, this is not the case.

To investigate this effect, computer programs were written to integrate formal expressions for the double differential Compton scatter cross section (the Klein-Nishina formula) coupled with electron range-energy relations (the Berger formulas). The results to date are very encouraging. At depths in tissue comparable to the range of the Compton scattered electrons, the dose rates predicted by the code agree with normal dose calculation methods. For depths similar to the location of the basal layer, the code predicts decreasing electronic equilibrium with increasing gamma ray energy, as is the case. For point sources of cobalt-60, assuming shielding from the beta rays, the code predicts that the dose to the basal layer is only 10% or less of what would be predicted using electronic equilibrium.

Further work is necessary to assure that the code is working correctly and to modify the code to include sources other than point sources.

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.

During FY 1985, K. R. Heid chaired a meeting of Health Physics Society Standards Committee (HPSSC) Working Group 2.5 (which is responsible for Draft ANSI N13.50 Stan-

dard, "Performance Criteria for Radiobio-assay"), which met in Seattle, Washington, April 16-18, 1985 to work on draft standard ANSI N13.30. A consensus agreement was reached on the accuracy and precision needed, and the revised and new portions of the standard were reviewed in depth.

Members of the DOE Office of Nuclear Safety Technical Advisory Committee on Occupational Exposure Standards provided evaluation and comments on the draft NCRP Committee 1 Report and EPA proposed federal radiation protection guidance. The EPA has formally transmitted the guidance document to the federal agencies.

A new procedure for the coordination of standards review was developed. Technical reviews of twelve ISO, IEC, and ANSI Standards were performed during FY 1985.

- **Technical Guidelines for Radiological Calibrations**

This program continues to provide technical guidelines for personnel dosimetry calibration procedures at Department of Energy 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, showing the performance of portable radiation protection instruments currently in use at Department of Energy

(DOE) facilities, was assembled. These data served to provide input for the draft guidelines document on the calibration of portable instruments. The guidelines for calibration of portable instruments will provide techniques that can be adopted throughout DOE facilities. This will help to promote more uniformity in the calibration of radiation protection instrumentation.

The intercomparison of radiological calibration sources has provided us with several pieces of information. The facilities compared so far have shown reasonably good consistency, but some have performed better than others. It is our intention to establish the intercomparison as part of our DOE Laboratory Accreditation Program (DOELAP) performance testing. The experience to date will be written up to document the procedures necessary for regular performance testing.

• 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 personnel neutron dosimeters, dosimetry systems, and portable instruments; (3) provide technical coordination of work being conducted by various laboratories, universities, and private companies in support of the development efforts; and (4) advance general state-of-the-art of overall neutron dosimetry field.

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, F. M. Cummings, G. W. R. Endres, W. D. Reece, P. L. Roberson

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 1984 included: the completion of 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 its projects 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 eventually lead to commercialization of the devices.

During FY 1985, PNL and its subcontractors conducted neutron dosimetry research and development or other activities in thirteen principal areas: (1) prototype evaluation, (2) field measurements, (3) CR-39 plastic technology, (4) combination TLD/track etch dosimeter development and implementation, (5) development of a device for total dose measurement, (6) high-energy neutron (greater than 5 MeV) dosimetry, (7) neutron depth dose characterization, (8) optical fiber dosimetry, (9) semiconductor dosimetry, (10) resonance ionization spectroscopy dosimetry, (11) radiation protection practices at accelerators, (12) neutron quality factor data evaluation, and (13) technology transfer.

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 in 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 (which uses thermoluminescent dosimeters [TLDs] in combination with track etch dosimeters [TEDs]) is being conducted. The useful energy range of the combination system is from thermal to greater than 20 MeV. Of all the track etch materials now available, the one with the trade name CR-39 (Columbia Resin-39) seems to be preferred for neutron dosimetry purposes. During the last year, the uniformity, long-term stability, and radiation response characteristics of CR-39 have been established. Work is currently under way on investigating and improving 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 (e.g., fading, change in sensitivity, etc.) of CR-39, (4) develop improved CR-39 monomers, CR-39 copolymers, and other track etch polymers. The technology transfer of the combination TLD/TED system is being conducted through participation of eleven DOE sites, one DoD component, and several vendors in a field demonstration.

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 built several pocket-sized prototypes that are capable 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 for cylindrical detectors. These have been

programmed into an inexpensive microcomputer to determine dose and dose equivalent for mixed radiation fields. The total dose meter is a product of improvements developed by PNL in the state-of-the-art in electronic circuits. EG&G, Santa Barbara has developed more sensitive detectors to be incorporated into this system. The device is shown in Figure 1.

FIGURE 1. Total Dose Meter

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

- 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). The response of several dosimeter types (track etch dosimeters, TLDs, portable rem meters, etc.) for both monoenergetic neutrons and neutron spectra encountered at DOE accelerator facilities was determined during FY 1985. Information on high-energy neutron dosimetry was also obtained for inclusion in the DOE Laboratory Accreditation Program (DOELAP).
- The neutron depth-dose profile inside a tissue-equivalent phantom was measured with both monoenergetic and continuous neutron energy spectra. 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. In addition, an anthropomorphic tissue-equivalent phantom was constructed at the end of FY 1985 and will be used in conjunction with beams of monoenergetic neutrons in FY 1986 to continue this work.
- Recent findings about the sensitivity of fiber optic light pipes have shown promise in detection of fast and thermal neutrons. PNL and the University of Connecticut at Storrs have conducted preliminary investigations into the feasibility of using optical fibers as the detecting elements in a personnel neutron dosimeter.
- Tri-Cities University Center staff conducted studies to prove the feasibility of using the change in electrical and magnetic properties of a semiconductor when irradiated by neutrons to produce both active and passive dosimeters.
- Atom Sciences, Inc., Oak Ridge, Tennessee, completed preliminary investigations of 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. The results of this work are being evaluated to determine the potential for continuation of research efforts in this area.
- Argonne National Laboratory staff initiated efforts to develop a systematic methodology for the assay of induced radioactivity in various materials and equipment from accelerators designated for disposal or reuse. Stanford Linear Accelerator staff initiated efforts to upgrade and standardize the level of performance of health physics programs at DOE accelerator facilities.
- 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. In response, DOE has formed a committee to review neutron quality factor data and make recommendations for future research efforts. PNL chairs this committee and is currently preparing the committee's recommendations, including the identification of research and development needs.

Major accomplishments to date by PNL through this program have been: recommend-

ations for personnel neutron dosimeter calibration procedures; measurement of response characteristics of current personnel neutron dosimeters; development of a combination thermoluminescent/track etch dosimeter; and development of a new dose meter using tissue-equivalent proportional detector technology.

Future accomplishments are expected to 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 Department of Energy (DOE) facilities. The change in DOE programs, including increased efforts in improved waste management and decontamination and decommissioning (D&D) of facilities, coupled with beta measurement problems identified at Three Mile Island has increased 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 1985 can be classified into five major areas: (1) current practices, (2) field measurements, (3) dosimeter development, (4) instrument development, and (5) beta calibrations. Progress has been made on several subtasks in the above areas and includes efforts by subcontractors (universities, private companies, DOE laboratories) in addition to efforts by PNL staff.

The report on the survey of current practices at DOE facilities has undergone internal review and major revisions. It appears that the survey results should be supplemented by additional contact with the facilities to clarify responses and supply missing information prior to publication.

To date, field measurements have been performed at six DOE facilities and have shown that significant beta dose rates can occur. This year, more emphasis was placed on comparison of measurement techniques during the site visits. Field measurements have shown that beta/gamma dose ratios approaching 100:1 are possible, with typical dose ratios in the neighborhood of 20-40:1. Beta dose rates vary significantly over short distances, which complicates the interpretation of multielement dosimeters and large volume detectors. Dose rates at several of the sites have ranged from 45-790, mrad/hr with many of the dose rates over 100 mrad/hr. A final report incorporating the results of field measurements is in preparation.

Thin thermoluminescent dosimeters (TLDs) with a graphite backing were developed and evaluated by Kansas State University (KSU) in FY 1984. Several of these dosimeters were procured by PNL and put into experimental two-element badges for evaluation during field measurements. The results are superior to conventional badges.

International Sensor Technology (IST) has developed an advanced laser-heated TLD reader with specialized optical and electronics circuitry to improve beam uniformity and stability of readout. The system will now provide enhanced sensitivity and stability, which make its use for routine dosimetry feasible. In addition, a "reflection" readout is provided for opaque dosimeters.

The prototype laser TLD reader was interfaced to a micro-computer on an interim basis. Operation will be transferred to the recently installed mini-computer in the near future. The micro-computer can automatically position the beam and analyze the signal from the photomultiplier. Data plotting and analysis software are still under development.

Thermally stimulated exo-electron readout of dosimeters was studied. Because it is a surface phenomenon, it has excellent promise for beta dosimetry, and a system was ordered for evaluation. Parts of the system have arrived, and assembly and testing are scheduled for FY 1986. Tests on photoacoustic readout and optically stimulated readout of TLDs are continuing. The potential for annealing dosimeters optically has been demonstrated. This may lead to new, more consistent methods for dosimeter readout.

An experimental system to measure the response of beta measurement instruments to an array of point sources is being devel-

oped. This will permit the evaluation of the geometrical response of beta detectors. For beta measurements, geometrical corrections as large as a factor of 100 can be required, and an understanding of these responses is essential for accurate dose determination.

Measurements were made on three prototype instruments to determine angular response, energy response and sensitivity (correction factor). Tests on a modified commercial ionization chamber (shallow chamber) show a response closer to conventionally true values from the calibration sources and a more correct response as a function of energy. Results of tests on EG&G Idaho's thick scintillator show that the unit provides good spectral reconstruction. However, the unit is severely dose-rate limited. Results of the evaluation of the EG&G Idaho prototype tissue-equivalent survey instrument are promising.

KSU has developed a proportional counter-scintillation counter system that provides excellent discrimination against photons in a mixed beta-gamma field. KSU studies on this concept are nearing completion, and PNL will evaluate the system next year.

In the area of calibrations, spectra for all of the beta sources were documented, and new sources have been ordered to reduce the time necessary for ^{147}Pm and ^{204}Tl irradiations.

A system was designed and hardware ordered to provide the capability for large area low dose rate (≈ 100 mrad/hr) irradiations with monoenergetic electrons at the electron Van de Graaff. This will provide a capability unique in the U.S., covering an important energy range (500-1500 keV) not available elsewhere. This capability will increase our understanding of dosimeters, instruments, and the materials used for beta shielding or measurements.

- **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 intercomparison and measurement assurance programs for DOE laboratories. Major accomplishments for FY 1985 included an upgrade in performance of dosimetry measurements to help improve beta-source standardization criteria, preparation of a source intercomparison capability for beta particles, quality assurance procedures and hardware, and the updating of documents required for the operation of the performance testing laboratory used in the accreditation process.

DEPARTMENT OF ENERGY LABORATORY ACCREDITATION PROGRAM FOR OCCUPATIONAL EXPOSURE MEASUREMENTS

P. L. Roberson, F. M. Cummings, R. A. Fox, C. D. Hooker

A national approach to the quality assurance and accreditation of personnel dosimetry services for DOE laboratories is being implemented through the DOE Laboratory Accreditation Program (DOELAP). This effort provides research support for DOELAP, encompassing: (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-1985 effort included: the dosimetry measurements to improve the beta source standardization specifications; the development of source intercomparison techniques and the procurement of sources; the fabrication of standard dosimeters to be used for dosimeter calibration intercomparison measurements; upgrading of the quality assurance program for dosimeter irradiations; and the editing of the documents required to operate the dosimetry system performance evaluation program.

The DOE Standard for the Performance Testing of Personnel Dosimetry Systems specifies dosimetry parameters to help standardize source specifications. The parameter specified for the uranium slab sources is the ratio of the dose rate at a depth of 100 mg/cm² to the dose rate at 7 mg/cm². The values specified in the standard were taken from dose-rate measurements reported in the literature. Measurements were performed on uranium slab sources to verify the literature values. Small differences were found requiring some adjustment in the values.

The use of radioactive sources for an intercomparison program among DOE laboratories was investigated. Areas in which sources may be useful include beta and neutron dosimetry. The capability for the transport of beta sources was achieved by purchasing a secondary standard beta source set that meets the specifications in the international beta standard (ISO 6980) for series 1 sources. A shipping container was designed and manufactured, and procedures were prepared for the handling and use of the sources.

The quality of source calibrations was improved by entering into measurement assurance programs with the National Bureau of Standards (NBS). Participation for beta, x-ray, and gamma sources has been initiated. Similar services for neutron sources are not available.

Improved calibration traceability of the k-fluorescence x-ray sources has resulted from discussions with and recommendations made by NBS personnel. Transfer standard ionization chambers with slowly varying energy responses are used for calibration measurements. Because NBS does not directly offer monoenergetic x-ray calibrations, confirmation of the calibration factors will be sought through an international intercomparison using two different chamber designs. Personnel from NBS are assisting in the arrangements.

Technical specifications for a dosimetry-quality x-ray machine were developed. The purchase of a Phillips machine was awarded using the competitive bid process. The new x-ray machine is scheduled to be installed in early FY 1986.

The documents required for the operation of the DOELAP performance testing laboratory were updated as required. These 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.

Reference

International Organization for Standardization (ISO). 1981. Reference Beta Radia-

tions for Calibrating Dosimeters and Doseratemeters and for Determining Their Response as a Function of Beta Radiation Energy. ISO/DP 6980. UDC 535-34 : 539.165 : 53.089.6. Geneva, Switzerland.

Operational
Safety

OPERATIONAL SAFETY

- **Assurance Program for Remedial Action**
- **Environmental Protection, Support and Assistance**
- **Hazardous Waste Risk Assessment**
- **Effluent Monitoring Systems at Department of Energy Facilities**

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 FY 1984 to provide technical assistance to the Department of Energy (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 second year of the project, the technical assistance included report and procedure reviews, and assistance with conducting the Uranium Mill Tailings Remedial Action Program (UMTRAP) Office (DOE/AL) appraisal. This included participation in preappraisal visits to UMTRAP sites in Canonsburg, Pennsylvania; Grand Junction, Colorado; and Salt Lake City, Utah. Pacific Northwest Laboratory (PNL) also transferred the PNL-developed document review software to the Oak Ridge Associated Universities (ORAU) staff in Grand Junction, Colorado, in anticipation of future document reviews by the ORAU staff. Other accomplishments have included publication of two formal documents and three project reports, preparation and presentation of five topical reports at national and international meetings, two foreign trip reports, and comments on proposed draft standards of the Environmental Protection Agency (40 CFR 193). The project manager has also participated on National Council on Radiation Protection and Measurements (NCRP) and American Society for Testing and Materials (ASTM) subcommittees developing decommissioning standards, as well as International Atomic Energy Agency (IAEA) advisory groups developing environmental monitoring guidelines.

TECHNICAL ASSISTANCE TO DEPARTMENT OF ENERGY/OFFICE OF OPERATIONAL SAFETY ASSURANCE PROGRAM FOR REMEDIAL ACTION

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

This project provided the Department of Energy (DOE) Office of Operational Safety (OOS) technical support in implementing its Assurance Program for Remedial Action (APRA). The support during this second year of the project involved three tasks: general technical support and assistance; document reviews; and remedial action program appraisals. Specific items addressed in FY 1985 included:

- comments on project direction in consultation with OOS and other support contractors;
- assistance with reviewing and withdrawing a proposed DOE Order for APRA;
- reviews and comments on program guidance documents for proper attention to Environment, Safety and Health (ES&H) matters;
- documentation of a review of standards and guidelines pertinent to DOE's remedial action programs;
- assistance in planning for and conducting appraisals of DOE remedial action program offices;
- individual (D. H. Denham) technical support to the International Atomic Energy Agency (IAEA) in developing draft reports on "principles" and "methods" for monitoring for the

radiation protection of the public at two advisory group meetings in Vienna, Austria (travel paid by IAEA);

- documentation of APRA bibliography data base management system;
- documentation of radiological survey protocols and risk assessment practices within DOE's remedial action program;
- reviews of Environmental Protection Agency Proposed Low-Level Radioactive Waste Standards (40 CFR 193) Background Information Document;
- preparation of a series of information packets for DOE to use in planning for and conducting future remedial action program appraisals.

TECHNICAL SUPPORT

D. H. Denham

This task involved many trips to DOE Headquarters to review and advise on timely topics related to APRA as well as the documentation for the radiological standards and risk assessment reviews initiated in the previous fiscal year. Several papers were prepared and presented within the technical support task, as identified below:

- "Review of Standards and Guidelines Pertinent to DOE's Remedial Action Programs," by J. K. Soldat and D. H. Denham at the Fifth DOE Environmental Protection Information meeting, November 6-8, 1984.

- "DOE's Assurance Program for Remedial Action," by D. H. Denham, R. D. Stenner, C. G. Welty, Jr., and T. S. Needels at the Fifth DOE Environmental Protection Information meeting in Albuquerque.
- "DOE's Remedial Action Assurance Program," by C. G. Welty, Jr., T. S. Needels, and D. H. Denham at the American Nuclear Society/European Nuclear Society International Conference in Washington, D.C., November 12-16, 1984.
- "Estimation of Health Effects Due to Elevated Radiation Exposure Levels in Structures," by S. Marks, F. T. Cross, D. H. Denham, and W. E. Kennedy, Jr. at the Seminar on Exposure to Enhanced Natural Radiation and Its Regulatory Implications in Maastricht, The Netherlands, March 25-27, 1985.

Foreign Trip Reports were prepared and distributed following Mr. Denham's participation in the IAEA Advisory Group meetings:

- Foreign Trip Report, D. H. Denham, March 22-April 20, 1985 for participation in the Seminar on Exposure to Enhanced Natural Radiation and Its Regulatory Implications, Maastricht, The Netherlands; scientific discussions of decommissioning/environmental monitoring criteria with specialists at the Central Electricity Generating Board Nuclear Laboratories - Berkeley, England; National Radiological Protection Board - Didcot, England; and the IAEA Advisory Group Meeting on Principles of Monitoring for the Radiation Protection of the Public - Vienna, Austria.
- Foreign Trip Report, D. H. Denham, August 17-25, 1985 for participation in IAEA Advisory Group Meeting on Methodology for Source and Individual Related Environmental Monitoring and for Effluent Monitoring - Vienna, Austria.

The following reports were prepared, documenting progress within the context of the Technical Support task:

- Soldat, J. K. and D. H. Denham. 1984. Review of Standards and Guidelines Pertinent to DOE's Remedial Action Programs, PNL-SA-12441. Pacific Northwest Laboratory, Richland, Washington.
- Marks, S.; F. T. Cross; D. H. Denham; W. E. Kennedy, Jr.; and R. D. Stenner. 1985. Risk Assessment in the DOE

Assurance Program for Remedial Action, PNL-5541. Pacific Northwest Laboratory, Richland, Washington.

ES&H REVIEWS

R. D. Stenner

This task involved the continuation of the review of generic remedial action program guidance documents based on the review criteria established in the previous fiscal year, presentation of a poster session at the Health Physics Society Midyear Meeting, and documentation of the APRA bibliography data management system.

The following APRA reports, paper, and document concerning the PNL ES&H reviews were issued during the year:

- "Review of FUSRAP Guidance Documents," March 1985.
- "Review of UMTRAP Guidance Documents," August 1985.
- "Criteria for Overviewing Environmental, Safety, and Health Issues Pertaining to Remedial Action Project Plans," by R. D. Stenner and D. H. Denham, presented at the Health Physics Society Midyear Meeting in Colorado Springs, Colorado, January 7-10, 1985.
- Stenner, R. D., D. K. Washburn, and D. H. Denham. 1985. Assurance Program for Remedial Action (APRA) Microcomputer-Operated Bibliography Management System, PNL-5527. Pacific Northwest Laboratory, Richland, Washington.

APPRAISALS

R. D. Stenner

The activities of this task were associated with planning and conducting the UMTRAP appraisal and preappraisal site visits in March-April and planning for the Surplus Facilities Management Program (SFMP) appraisal, tentatively scheduled for FY 1986. This included preappraisal site visits to Grand Junction, Colorado, and Salt Lake City, Utah, as well as the UMTRAP Office appraisal in Albuquerque, New Mexico.

In planning for the SFMP appraisal, the following materials were assembled by the PNL team (who will not be involved in the appraisal itself) and transmitted to DOE/OOS on August 5, 1985:

- Comparison of Paraphrased Findings in Draft FUSRAP and UMTRAP Appraisal Reports

- Comparison of Types of Findings from FY 1984-1985 FUSRAP and UMTRAP Appraisal Reports with Proposed "Lines of Inquiry for SFMP Appraisal - FY 1986"
- DOE Surplus Facilities Decommissioning/Remedial Action Programs Organizational Structure and Interfaces
- (charts) with Alphabetical Contacts List
- SFMP FY 1985 (4th Qtr.) and FY 1986 Site Projects (Civilian) and FY 1985-89 Budget Summaries (Civilian/Defense Projects)

• Environmental Protection Support and Assistance

The Pacific Northwest Laboratory (PNL) continued to provide technical assistance to the Department of Energy (DOE) Office of Operational Safety (OOS) in the area of environmental protection. PNL's technical assistance included development of revised DOE guidance for estimating population doses from exposures to radioactive materials, preparation of the annual DOE environmental summary, initial development of a standardized environmental protection information system, and development of a draft budgetary priority ranking method for identified ES&H upgrade projects. As part of the PNL ad hoc efforts, an independent evaluation was provided to OOS of the potential radiation doses to the public for the historical (1953-1984) uranium effluents to air and water resulting from operations at the Feed Materials Production Center (FMPC) located near Fernald, Ohio. PNL also supported OOS by providing extensive planning, local arrangements, and coordination of the published proceedings for the Fifth DOE Environmental Protection Information Meeting, which was held in Albuquerque, New Mexico November 6-8, 1984.

ENVIRONMENTAL PROTECTION SUPPORT AND ASSISTANCE

W. E. Kennedy, Jr.; J. P. Corley; T. J. McLaughlin; R. E. Jaquish; K. A. Hawley; D. K. Washburn; R. A. Peloquin; R. D. Stenner; N. C. Van Houten; R. C. Adams; K. L. Imhoff; J. R. Raymond; M. J. Graham; D. A. Myers; P. J. Mitchell; M. D. Freshley

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 and assurance objectives. Several ongoing tasks as well as quick turn-around ad hoc tasks are funded concurrently to provide flexibility in response to DOE management priorities as they evolve. Task areas addressed during 1985 included:

- an independent evaluation of the potential maximally exposed individual doses for the historical (1953-1984) uranium effluents to air and water resulting from operations of the Feed Materials Production Center (FMPC) near Fernald, Ohio
- development of a draft standardized environmental protection information system that includes both a compliance module and an environmental appraisal module
- support during the environmental protection program appraisal of the Portsmouth Gaseous Diffusion Plant
- development of a draft priority ranking method for identified ES&H facility upgrade projects
- development of a document containing the DOE tables for estimating population doses from inhalation or ingestion of radioactive materials

- development of draft documents concerning the DOE ground-water monitoring and ground-water protection programs
- completion of the annual summary of environmental effluents from operating DOE sites
- assistance in conducting the Fifth DOE Environmental Protection Information Meeting held in Albuquerque, New Mexico November 6-8, 1984 and coordination of the publication of the meeting's proceedings
- assistance during the development of DOE remedial action guidelines for the Formerly Utilized Sites and Remote Surplus Facilities Management Programs
- technical reviews and evaluations of proposed EPA regulations on high-level radioactive waste, low-level radioactive waste, remedial action, and the Clean Air Act amendments
- participation in an International Atomic Energy Agency (IAEA) Advisory Group on "Assessing the Reliability of Radionuclide Environmental Transfer Model Predictions."

Environmental Profiles and Assurance

W. E. Kennedy, Jr.; R. A. Peloquin; R. D. Stenner; T. J. McLaughlin; N. C. Van Houten

An iterative design process was used in the initial design and development of a standardized environmental protection information system for DOE operations. PNL began this task by evaluating existing environmental information systems, developing the draft Environmental Profile Data Retrieval System (EPDRS), providing initial design structure for a Performance (or compliance) Module, providing an overall conceptual system de-

sign that includes Lines of Inquiry for site appraisals, and considering the development of a standardized reporting format. Four design review meetings were held in the DOE Germantown, Maryland offices, and four letter reports reviewing various phases of progress were produced.

Environmental Pathway and Dosimetry Methodology

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

A camera-ready document entitled "Committed Dose Equivalent Tables for U.S. Department of Energy Population Dose Calculations" was prepared and sent to DOE for publication and distribution. This document was jointly developed by PNL and Jack Healy of Los Alamos National Laboratory. Additional efforts included assistance in the development of revised public radiation protection standards, preliminary revisions to the radiological environmental surveillance guideline document, and an initial evaluation of the mathematical models used by the U.S. Environmental Protection Agency in support of the amendments to the Clean Air Act. Future efforts will include the development of standardized environmental pathway analysis models for evaluating public radiation doses.

Quality Assurance for DOE Environmental and Effluent Monitoring

R. E. Jaquish

PNL supported the DOE Environmental and Effluent Monitoring Quality Assessment Program by continuing ongoing activities with the Environmental Measurements Laboratory (EML) in New York. A meeting of the DOE QA Steering Committee was held, and the formal minutes were sent to DOE. A joint document was produced with EML concerning recommendations for inclusion of nonradioactive samples in the QA program.

Environmental Summaries

K. A. Hawley and D. K. Washburn

Each year, PNL develops a summary of the information contained in the annual environmental reports generated by the DOE facility contractors for use by DOE management. The camera-ready 1983 summary, including comments from the facility contractors and DOE field and program offices, was sent to DOE for publication and distribution. In addition, the draft 1984 environmental summary was prepared and distributed for review. Major revisions were made to the format and content of the 1984 report based on comments from DOE/OOS.

Ground-Water Program

J. R. Raymond, M. J. Graham, M. D. Freshley, T. J. McLaughlin, P. J. Mitchell, D. A. Myers

The camera-ready copies of two documents concerning ground-water monitoring and ground-water protection were completed and sent to DOE/OOS. These documents will be issued for field use and comment. Additional draft documents concerning reviews of ground-water models and ground-water restoration technologies were completed. As part of the ground-water restoration technology review, PNL developed an idea that resulted in a patent application. In addition, PNL assisted OOS in the development of onsite liquid radioactive discharge criteria for DOE operations. These criteria will be included in revised DOE Orders.

Fifth DOE Environmental Protection Information Meeting

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

The Fifth DOE Environmental Protection Information Meeting was held November 6-8, 1984 in Albuquerque, New Mexico. PNL participated in the Program Committee and assisted in establishing the meeting's program and agenda. In addition, PNL coordinated the local meeting arrangements and compiled the contributed papers into the official proceedings, which were sent to DOE in camera-ready form for publication and distribution.

Assistance to DOE in the Management of Identified ES&H Deficiencies

R. C. Adams and K. L. Imhoff

A priority ranking method for evaluating identified ES&H deficiencies was developed and modified. This method was applied by DOE to both the FY-1986 and FY-1987 facility upgrade projects identified in the budgetary process. Additional efforts included a verification of the criteria weights used in the ranking process, the development of integrated cost considerations, and the development of a software and formal documentation package for the method. An extended review and application of this method is planned for the coming year.

Special Assistance

W. E. Kennedy, Jr.; J. P. Corley; K. A. Hawley; R. A. Peloquin

Through a special assistance task, PNL further supports OOS by providing quick

turn-around technical responses to priority questions, which are typically in areas that fall outside the scope of the identified tasks. During 1985, the activities conducted as part of this special assistance task included: (1) an independent evaluation of the potential doses to the maximally exposed member of the public from the historical (1953-1984) uranium effluents to air and water from the Feed Materials Production Center (FMPC) located near Fernald, Ohio; (2) assistance during the development of DOE remedial action guidelines for the Formerly Utilized Sites and

Remote Surplus Facilities Management Programs; (3) technical reviews and evaluations of proposed EPA regulations on high-level radioactive waste, low-level radioactive waste, remedial action, and the Clean Air Act amendments; (4) assistance in the development of tolerance dose limits for aquatic biota exposed to onsite liquid radioactive liquid discharges; and (5) participation in an International Atomic Energy Agency (IAEA) Advisory Group on "Assessing the Reliability of Radionuclide Environmental Transfer Model Predictions."

• Hazardous Waste Risk Assessment

Pacific Northwest Laboratory continued to provide technical assistance to the Department of Energy (DOE) Office of Operational Safety (OOS) in the area of risk assessment for hazardous and radioactive-mixed waste management. The overall objective is to provide technical assistance to OOS in developing cost-effective risk assessment tools and strategies for bringing DOE facilities into compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) and the Resource Conservation and Recovery Act (RCRA). Major efforts during FY 1985 included (1) completing the modification of the Environmental Protection Agency (EPA) Hazard Ranking System (HRS) and developing training manuals and courses to assist in field office implementation of the modified Hazard Ranking System (mHRS); (2) initiating the development of a system for reviewing field office HRS/mHRS evaluations for appropriate use of data and appropriate application of the methodology; (3) initiating the development of a data base management system to maintain all field office HRS/mHRS scoring sheets and to support the master OOS environmental data base system; (4) developing implementation guidance for Phase I of the DOE CERCLA Program, Installation Assessment; (5) continuing to develop an objective, scientifically based methodology for DOE management to use in establishing priorities for conducting site assessments under Phase II of the DOE CERCLA Program, Confirmation; and (6) participating in developing the DOE response to EPA on the proposed listing of three sites on the National Priorities List.

MODIFIED HAZARD RANKING SYSTEM (mHRS) DEVELOPMENT

K. A. Hawley and B. A. Napier

Pacific Northwest Laboratory completed the development effort to modify the Environmental Protection Agency (EPA) Hazard Ranking System (HRS), which is a simplified methodology for determining those inactive hazardous waste sites that may pose a significant risk to human health and/or the environment. Because the HRS is unable to explicitly evaluate the potential risks of radioactive wastes relative to chemical wastes, DOE has challenged EPA on the applicability of the HRS to sites containing radionuclides. The new modified system, called the modified Hazard Ranking System (mHRS), is capable of evaluating the potential hazard in inactive waste sites containing radionuclides in the same way that HRS already evaluates chemical waste (non-radioactive) sites. Pacific Northwest Laboratory has completed documentation of the mHRS development effort, a user's manual for the system, and the development of a computerized spreadsheet for HRS/mHRS scorings. During FY 1985, PNL has also supported OOS in several meetings with EPA to discuss the mHRS.

FIELD OFFICE TRAINING AND EVALUATION OF DOE HRS/mHRS SCORING

K. A. Hawley, B. L. Steelman, R. D. Stenner
R. A. Peloquin

Available HRS/mHRS documentation provides guidance on applying the methods; however, numerous ambiguities exist in the basic HRS philosophy. To help ensure consistent application of the methods across DOE field

offices, PNL is working with OOS in scheduling EPA training courses on the HRS and is developing a supplemental training course on the mHRS. Even with proper training, the possibility is great for misinterpretation/misuse of the systems and for simple human error in recording data. Therefore, PNL has begun to develop a system similar to the one used by EPA to review HRS/mHRS score sheets and their supporting documentation for (1) appropriate use of data, (2) correct and consistent application of the method, and (3) computational accuracy.

HRS/mHRS DATA-BASE MANAGEMENT SYSTEM

K. A. Hawley, R. D. Stenner, R. A. Peloquin

Field offices have been asked to prepare their HRS/mHRS evaluations using the computerized spreadsheet format developed by PNL. After receiving the electronic score sheets and reviewing them for accuracy, the score sheets will be finalized and permanently archived in a data-base management system (DBMS) being developed by PNL. This DBMS can be used to obtain detailed statistical information on DOE HRS/mHRS scores; it will provide direct input to the more comprehensive DOE CERCLA DBMS being developed by another OOS contractor.

IMPLEMENTATION GUIDANCE FOR PHASE I OF THE DOE CERCLA PROGRAM

B. L. Steelman

In support of DOE Order 5480.14 (Comprehensive Environmental Response, Compensation, and Liability Act Program), PNL prepared more detailed guidance for field

office implementation of Phase I, Installation Assessment. This information will be attached to a future letter on CERCLA guidance from the Assistant Secretary's office to the field offices.

REMEDIAL ACTION PRIORITY SYSTEM (RAPS) DEVELOPMENT

G. Whelan, D. L. Strenge, J. G. Droppo, B. L. Steelman

Pacific Northwest Laboratory has nearly completed the initial development of an objective, scientifically based management tool for DDE management called the Remedial Action Priority System (RAPS). It will be used to prioritize resource allocations for additional site investigations and possible remediations. DDE views the application of the HRS and mHRS to its sites as an initial screening effort to discriminate between waste sites that have a definite potential to pose significant risk to health, safety, and/or the environment and those that are essentially innocuous. DOE believes and EPA has concurred verbally that the HRS/mHRS methods were not developed to quantify the relative risks of sites or to set priorities for sites requiring further investigation. RAPS uses empirically, analy-

tically, and semianalytically based mathematical algorithms to predict the potential for contaminant migration from a waste site to receptors of concern using pathways analyses. Using the pathways analyses results, simplified exposure assessments are performed for important receptors, and the risks associated with the sites are then calculated relative to other sites for each pathway and for all pathways combined. RAPS is expected to be operational during the first quarter of CY 1986.

PROPOSED LISTING OF DOE SITES ON THE NATIONAL PRIORITIES LIST

B. L. Steelman, K. A. Hawley, R. G. Schreckhise

Pacific Northwest Laboratory provided technical support to OOS in drafting the DOE response to EPA concerning the nomination of three DOE sites (Rocky Flats Plant, Weldon Spring Quarry, and Lawrence Livermore Laboratory) to the National Priorities List. The primary PNL contributions involved (1) discussing HRS limitations, (2) describing the mHRS, (3) identifying and discussing inappropriate application of HRS to the sites, and (4) recalculating the site scores using mHRS.

- **Effluent Monitoring Systems at Department of Energy Facilities**

The purpose of this task is to: (1) evaluate the system design, procedures, and performance of Department of Energy effluent monitoring for both routine and accidental releases; (2) identify significant deficiencies or problem areas; (3) provide technical assistance as requested; (4) verify performance of selected systems by direct independent measurements (to be accomplished by a subcontract to EG&G-Idaho); and (5) provide a mechanism to facilitate exchange of information between facilities.

EFFLUENT MONITORING SYSTEM AT DOE FACILITIES^(a)

C. M. Unruh

The progress this year consisted of detailed planning for performance of the field work. An effluent monitoring system analysis matrix was developed to assure consistent review of the appropriate components of each effluent system at each DOE facility visited. The protocols for the visits were developed. A previsit data collection questionnaire was designed. A QA plan was developed and approved. A contract with EG&G-Idaho was executed for the

independent verification measurement part of the task. A suggested schedule of facility evaluations was prepared. Details of the task planning were reviewed with DOE-HQ staff. Pacific Northwest Laboratory is ready to commence the actual field work as soon as DOE-HQ completes arrangements for access to the various field office facilities.

^(a)This project is currently funded by the DOE Office of Nuclear Safety and the Office of Operational Safety.

PUBLICATIONS

Brackenbush, L. W., and G. W. R. Endres. 1985. "Personnel Monitors Utilizing Tissue Equivalent Proportional Counters," PNL-SA-12460. Proceedings of the 5th Symposium on Neutron Dosimetry, pp. 359-368. Published by Commission of European Communities, EUR-9762EN.

Faust, L. G., D. E. Hadlock, and E. J. Vallario. 1985. "DOE Personnel Neutron Dosimetry Evaluation and Upgrade Program," PNL-SA-12546. Proceedings of the 5th Symposium on Neutron Dosimetry, pp. 547-552. Published by Commission of European Communities, EUR-9762EN.

Hawley, K. A., and B. A. Napier. 1985. "A Ranking System for Mixed Radioactive and Hazardous Waste Sites," PNL-SA-12489. In Fifth DOE Environmental Protection Information Meeting, Albuquerque, New Mexico, November 6-8, 1984.

Hawley, K. A., and D. K. Washburn. 1985. A Summary of Annual Site Environmental Monitoring Reports - U.S. Department of Energy - January-December 1983, DOE/EP. U.S. Department of Energy, Washington, D.C.

Hawley, K. A., and D. K. Washburn. 1985. "Current Practices in Environmental Radiological Surveillance at U.S. Department of Energy Nuclear Facilities," PNL-SA-12439. In Fifth DOE Environmental Protection Information Meeting, Albuquerque, New Mexico, November 6-8, 1984.

Higby, D. P. 1984. Effects of Particle Size and Velocity on Burial of Airborne Particles in Glass Fiber Filters, PNL-5278. Pacific Northwest Laboratory, Richland, Washington.

Marks, S., F. T. Cross, D. H. Denham, and W. E. Kennedy, Jr. 1985. "Estimation of Health Effects Due to Elevated Radiation Exposure Levels in Structures." The Science of the Total Environment, Vol. 45:543-550.

Marks, S., F. T. Cross, D. H. Denham, W. E. Kennedy, Jr., and R. D. Stenner. 1985.

Risk Assessment in the DOE Assurance Program for Remedial Action, PNL-5541. Pacific Northwest Laboratory, Richland, Washington.

Murphy, B. L., J. M. Selby, and E. J. Vallario. 1985. Proceedings of the Workshop on Radiation Survey Instruments and Calibrations, PNL-SA-13346. Pacific Northwest Laboratory, Richland, Washington.

Parkhurst, M. A., D. E. Hadlock and D. L. Haggard. 1985. DNA Annual Report, FY-1984 - Combination TLD/TED Neutron Dosimetry.

Selby, J. M., K. L. Swinth, and J. L. Kenoyer. 1985. "Health Physics Instrumentation Needs." IEEE Trans. Nuc. Sci., MS-32, p. 912.

Spitz, H. 1985. "Monitoring Internal Exposure by Analysis of Radioactivity in Urine." PNL 1830 Education Pamphlet, PNL-SA-13295A. Pacific Northwest Laboratory, Richland, Washington.

Stenner, R. D., D. K. Washburn, and D. H. Denham. 1985. Assurance Program for Remedial Action (APRA) Microcomputer-Operated Bibliography Management System, PNL-5527. Pacific Northwest Laboratory, Richland, Washington.

Swinth, K. L. 1985. "DOE Beta Measurement Evaluation and Upgrade Program." Health Physics Newsletter, Vol. XIII, Issue 5, May 1985.

Swinth, K. L., and J. L. Kenoyer. 1985. "Evaluation of Health Physics Instrument Performance." IEEE Trans. Nuc. Sci., MS-32, p. 923.

Swinth, K. L., R. J. Traub, B. L. Murphy, and H. E. Palmer. 1985. "Factors Affecting the Assessment of Lung Depositions of Transuranics," PNL-SA-13453. In Proceedings from Second International Workshop on Lung Dosimetry, Cambridge, UK, September 2-6, 1985.

PRESENTATIONS

Carbaugh, E. H., M. J. Sula, T. L. Aldridge, and H. B. Spitz. 1985. "The Impact of Upgraded In-Vivo Lung Measurement Capability in an Internal Dosimetry Program," PNL-SA-12650. Second International Workshop on Lung Dosimetry, Cambridge, UK September 4, 1985.

Denham, D. H., R. D. Stenner, C. G. Welty, Jr., and T. S. Needels. 1984. "DOE's Assurance Program for Remedial Action," PNL-SA-12443. Fifth DOE Environmental Protection Information Meeting, Albuquerque, New Mexico, November 6-8, 1984.

Endres, G. W. R., and K. L. Swinth. 1985. "Thermoluminescent Phosphor Selection," PNL-SA-13439. Symposium of Baltimore-Washington Chapter Health Physics Society Meeting, Gaithersburg, Maryland, September 28, 1985.

Faust, L. G. 1985. "Uncertainties in Existing and Future Dosimetry for Neutrons." Workshop on Radiobiological Effectiveness of Neutrons. Informal presentation compiled by G. E. Stapleton, R. G. Thomas, and J. W. Thiessen. USDOE CONF-8504162, National Technical Information Service.

Hadlock, D. E., M. P. Parkhurst, and D. L. Haggard. 1985. "High-Energy Neutrons Interact with Air! Does CR-39 Respond?" PNL-SA-12885-A. Annual Health Physics Society Meeting, Chicago, Illinois, May 26-31, 1985.

Hadlock, D. E., M. A. Parkhurst, C. S. Yang, J. Groeber, J. F. Johnson, and S. J. Huang. 1985. "Electrochemical Development of Particle Tracks in CR-39 Polymer Dosimeters," PNL-SA-13388. Thirteenth International Conference on Solid State Nuclear Track Detectors, Rome, Italy, September 23, 1985.

Hawley, K. A. and B. A. Napier, "A Ranking System for Mixed Radioactive and Hazardous Waste Sites." Hanford Technical Exchange, Richland, Washington, June 5, 1985.

Hawley, K. A., and B. A. Napier. 1984. "A Ranking System for Mixed Radioactive and Hazardous Waste Sites," PNL-SA-12489. Fifth DOE Environmental Protection Information Meeting, Albuquerque, New Mexico, November 6-8, 1984.

Hawley, K. A., and B. A. Napier, "Evaluating Mixed Radioactive and Hazardous Waste Sites: Test Applications of the Modified Hazard Ranking System," PNL-SA-12874. Annual Health Physics Society Meeting, Chicago, Illinois May 26-30, 1985.

Hawley, K. A., and D. K. Washburn. 1984. "Current Practices in Environmental Radiological Surveillance at U.S. Department of Energy Nuclear Facilities," PNL-SA-12439. Fifth DOE Environmental Protection Information Meeting, Albuquerque, New Mexico, November 6-8, 1984.

Heid, K. R. 1985. "Estimations of Plutonium Deposited Systemically Based on Bioassay Data," PNL-SA-13207A. Annual Health Physics Society Meeting, Chicago, Illinois, May 26-31, 1985.

Heid, K. R., J. J. Jech, R. L. Kathren, and M. J. Sula. 1985. "A Comparison of Long-Term Retention of Plutonium Oxide in Lung Based on Excretion Data with Observed Lung Burdens at Autopsy." Sixth International Symposium on Inhaled Particles, Cambridge, UK, September 4, 1985.

Huang, S. J., C. S. Yang, J. Groeger, J. F. Johnson, D. E. Hadlock, and M. A. Parkhurst. 1985. "Structure Property Correlation for CR-39 Polycarbonate in Dosimetry," PNL-SA-13388. Thirteenth International Conference on Solid State Nuclear Track Detectors, Rome, Italy, September 23, 1985.

Jaquish, R. E., R. R. Kinnison, S. P. Mathur, and R. Sastry. 1984. "Evaluation of Analytical Results on DOE Quality Assessment Program Samples," PNL-SA-12418. Fifth DOE Environmental Protection Information Meeting, Albuquerque, New Mexico, November 6-8, 1984. Also, Winter Meeting of the American Nuclear Society, Washington, D.C., November 12, 1984.

Kennedy, W. E., Jr. and B. A. Napier. 1984. "Allowable Residual Contamination Levels for Decommissioning, Part 2: A Summary of Example Results," PNL-SA-12053. Fifth DOE Environmental Protection Information Meeting, Albuquerque, New Mexico, November 6-8, 1984.

Kenoyer, J. L., A. V. Robinson, B. L. Murphy, and K. L. Swinth. 1985. "Occupational Air Monitoring and Sampling Instrumentation and Practices at DOE Facilities," PNL-SA-12857. Annual Health Physics Society Meeting, Chicago, Illinois, May 26-31, 1985.

Kenoyer, J. L., and K. L. Swinth. 1985. "Control of Measurement Quality During Instrument Testing." Columbia Chapter of the Health Physics Society Topical Symposium on Quality Assurance in Ionizing Radiation Measurements, Kennewick, Washington, March 14-15, 1985.

Kenoyer, J. L., and K. L. Swinth. 1985. "Performance of Portable Radiation Protection Instruments," PNL-SA-12737. Annual American Industrial Hygiene Conference, Las Vegas, Nevada, May 19-24, 1985.

Marks, S., F. T. Cross, D. H. Denham, and W. E. Kennedy, Jr. 1985. "Estimation of Health Effects Due to Elevated Radiation Exposure Levels in Structures," Seminar on Exposure to Enhanced Natural Radiation and Its Regulatory Implications. Maastricht, The Netherlands, March 25-27, 1985.

McDonald, J. C. 1985. "New Radiation Measurement and Calibration Technologies," PNL-SA-12960. Region X Conference of Radiation Control Program Directors, Seattle, Washington, February 20, 1985.

McDonald, J. C. 1985. "Quality Assurance in Health Physics Instrument Calibrations." Moderated panel discussion at the Health Physics Society Chapter Meeting, Kennewick, Washington, March 14-15, 1985. Participants included W. Howell (Westinghouse Hanford Company), K. L. Soldat (PNL), M. Lardy (U.S. Testing), and K. L. Swinth (PNL).

McDonald, J. C., W. D. Reece, P. L. Roberson, and R. J. Traub. 1985. "Radiation Dose Calibrations at the Battelle Pacific Northwest Laboratory." Annual Meeting of the American Nuclear Society, Boston, Massachusetts, June 9-13, 1985.

Napier, B. A., and K. A. Hawley. "The Modified Hazard Ranking System: A Method for Evaluating Mixed Radioactive and Hazardous Waste Sites," PNL-SA-12875. Annual Meeting of the Health Physics Society, Chicago, Illinois, May 25-30, 1985.

Napier, B. A., and W. E. Kennedy, Jr. 1984. "Allowable Residual Contamination Levels for Decommissioning, Part 1: A Description of the Method," PNL-SA-12052. Fifth DOE Environmental Protection Information Meeting, Albuquerque, New Mexico, November 6-8, 1984.

Parkhurst, M. A., D. E. Hadlock, and L. W. Brackenbush. 1985. "Track Formation Mechanisms in CR-39 and Their Relevance to Personnel Neutron Dosimetry," PNL-SA-12886-A. Annual Health Physics Society Meeting, Chicago, Illinois, May 26-31, 1985.

Parkhurst, M. A., D. E. Hadlock, and L. G. Faust. 1985. "Semi-Empirical Model of Neutron and Charged Particle Interactions

with CR-39," PNL-SA-13388. Thirteenth International Conference on Solid State Nuclear Track Detectors, Rome, Italy, September 23, 1985.

Rathbun, L. A., K. L. Swinth, D. L. Haggard, and R. A. Fox. 1985. "Beta Field Measurements at DOE Facilities," PNL-SA-12887. Annual Health Physics Society Meeting, Chicago, Illinois, May 26-31, 1985.

Roberson, P. L., and C. D. Hooker. 1985. "Quality Assurance Requirements for the DOE LAP Performance Testing Laboratory," PNL-SA-13052. Columbia Chapter of the Health Physics Society Topical Symposium on Quality Assurance in Ionizing Radiation Measurements, Kennewick, Washington, March 14-15, 1985.

Robinson, A. V. 1985. "Quality Assurance During Performance Testing of Radiobioassay Laboratories." Columbia Chapter of the Health Physics Society Topical Symposium on Quality Assurance in Ionizing Radiation Measurements, Kennewick, Washington, March 14-15, 1985.

Scherpelz, R. I., and L. W. Brackenbush. 1985. "Determining a Physically Appropriate Neutron Spectrum from Multi-sphere Data," PNL-SA-12888. Annual Health Physics Society Meeting, Chicago, Illinois, May 26-31, 1985.

Selby, J. M. 1985. "Draft American National Standard N42.17A - Performance Specifications for Health Physics Instrumentation," PNL-SA-13271. Workshop on Radiation Survey Instruments and Calibration, Gaithersburg, Maryland, July 10-12, 1985.

Selby, J. M., and K. L. Swinth. 1985. "The Role of Standards in Improving Health Physics Measurements." Columbia Chapter of the Health Physics Society Topical Symposium on Quality Assurance in Ionizing Radiation Measurements, Kennewick, Washington, March 14-15, 1985.

Selby, J. M., K. L. Swinth, and J. L. Kenoyer. 1984. "Health Physics Instrumentation Needs." Annual Nuclear Science Symposium, Orlando, Florida, October 31 - November 2, 1984.

Soldat, J. K., and D. H. Denham. 1984. "Review of Standards and Guidelines Pertinent to DOE's Remedial Action Programs," PNL-SA-12441. Fifth DOE Environmental Protection Information Meeting, Albuquerque, New Mexico, November 6-8, 1984.

Stenner, R. D., and D. H. Denham. 1985. "Criteria for Overlooking Environmental, Safety, and Health Issues Pertaining to Remedial Action Project Plans." Health Physics Society Midyear Meeting in Colorado Springs, Colorado, January 7-10, 1985.

Swinth, K. L. 1985. "Emergency Assessment Instrumentation - Status and Outlook." Harvard University Short Course on "Planning for Nuclear Emergencies," Boston, Massachusetts, June 11, 1985.

Swinth, K. L. 1985. "Instrument Performance and Testing," PNL-SA-12737. Invited paper, Region X Conference of Radiation Control Program Directors, Seattle, Washington, February 20, 1985.

Swinth, K. L. 1985. "Instrument Performance and Testing," PNL-SA-12969. Tri-Services Radiac Meeting, Oak Ridge, Tennessee, June 12-14, 1985.

Swinth, K. L. 1985. "Instrument Performance Testing." Harvard University Short Course on "Radiation Protection Instrumentation," Boston, Massachusetts, April 15-19, 1985.

Swinth, K. L. 1985. "Portable Instruments for Emergency Response," PNL-SA-13225. Short Course at the 1985 Annual Health Physics Society Meeting, Chicago, Illinois, May 26-31, 1985.

Swinth, K. L., and G. W. R. Endres. 1985. "Thermoluminescent Dosimeters for Beta Dosimetry," PNL-SA-13434. Symposium of Baltimore-Washington Chapter Health Physics Society Meeting, Gaithersburg, Maryland, September 28, 1985.

Swinth, K. L., and J. L. Kenoyer. 1984. "Evaluation of Health Physics Instrument Performance." Annual Nuclear Science Symposium, Orlando, Florida, October 31 - November 2, 1984.

Swinth, K. L., and J. L. Kenoyer. 1985. "Testing of Health Physics Instruments to

Improve Measurement Quality." Columbia Chapter of the Health Physics Society Topical Symposium on Quality Assurance in Ionizing Radiation Measurements, Kennewick, Washington, March 14-15, 1985.

Swinth, K. L., L. A. Rathbun, and L. W. Brackenbush. 1985. "Beta Fields and Measurement Practices at DOE Facilities," PNL-SA-13458. Workshop on Dosimetry of Beta Particles and Low-Energy X-Ray. Paris, France, October 7-9, 1985.

Swinth, K. L., L. A. Rathbun, C. D. Hooker, P. L. Roberson, and J. L. Kenoyer. 1985. "The Beta Response of Selected Instruments," PNL-SA-12901. Annual Health Physics Society Meeting, Chicago, Illinois, May 26-31, 1985.

Vallario, E. J. 1985. "SL-1 Accident," (K. L. Swinth, presenter). Harvard University Short Course on "Planning for Nuclear Emergencies," Boston, Massachusetts, June 11, 1985.

Welty, C. G., Jr., T. S. Needels, and D. H. Denham. 1984. "DOE's Remedial Action Assurance Program," PNL-SA-12416. ANS/ENS International Conference, Washington, D.C., November 12-16, 1984.

Whelan, G., D. L. Strenge, B. L. Steelman, and K. A. Hawley, "Development of the Remedial Action Priority System: An Improved Risk Assessment Tool for Prioritizing Hazardous and Radioactive-Mixed Waste Disposal Sites." Sixth National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D.C., November 4-6, 1985.

Yang, C. S., S. J. Huang, J. F. Johnson, D. E. Hadlock, and M. A. Parkhurst. 1985. "Structure Property Correlation for CR-39 Polycarbonate in Dosimetry" (presented by J. F. Johnson, University of Connecticut). Annual Health Physics Society Meeting, Chicago, Illinois, May 26-31, 1985.

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