**Pacific Northwest Laboratory
Annual Report for 1982 to the DOE
Office of the Assistant Secretary for
Environmental Protection, Safety
and Emergency Preparedness**

**Part 5 Environmental and Occupational
Protection, Assessment and Engineering**

February 1983

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

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

February 1983

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Pacific Northwest Laboratory
Richland, Washington 99352

PREFACE

This 1982 annual report from Pacific Northwest Laboratory (PNL) to the Department of Energy (DOE) describes research in environment, health, and safety conducted during fiscal year 1982. 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 Office of the Assistant Secretary for Environmental Protection, Safety and Emergency Preparedness. Each part consists of project reports authored by scientists from several PNL research departments, reflecting the interdisciplinary nature of the research effort.

The parts of the 1982 Annual Report are:

Part 1: Biomedical Sciences

Program Manager - H. Drucker

D. L. Felton, Editor

Part 2: Environmental Sciences

Program Manager - B. E. Vaughan

B. E. Vaughan, Report Coordinator
C. M. Novich, Editor

Part 3: Atmospheric Sciences

Program Manager - C. E. Elderkin

N. S. Laulainen, Report Coordinator
E. L. Owczarski, Editor

Part 4: Physical Sciences

Program Manager - J. M. Nielsen

J. M. Nielsen, Report Coordinator
J. E. Danko, E. M. Toomey, Editors

**Part 5: Environmental and Occupational
Protection, Assessment, and
Engineering**

Program Managers - S. Marks
W. A. Glass

W. J. Bair, 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.

W. J. Bair, Manager
S. Marks, Associate Manager
Environment, Health and Safety Research
Program

Previous reports in this series:

Annual Report for

1951	W-25021, HW-25709
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1953	HW-30437, HW-30464
1954	HW-30306, HW-33128, HW-35905, HW-35917
1955	HW-39558, HW-41315, HW-41500
1956	HW-47500
1957	HW-53500
1958	HW-59500
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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
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1972	BNWL-1750, Vol. 1, Pt. 1-2; BNWL-1751, Vol. 2, Pt. 1-2
1973	BNWL-1850, Pt. 1-4
1974	BNWL-1950, Pt. 1-4
1975	BNWL-2000, Pt. 1-4
1976	BNWL-2100, Pt. 1-5
1977	PNL-2500, Pt. 1-5
1978	PNL-2850, Pt. 1-5
1979	PNL-3300, Pt. 1-5
1980	PNL-3700, Pt. 1-5
1981	PNL-4100, Pt. 1-5

FOREWORD

Part 5 of the 1982 Annual Report to the Department of Energy's Office of Environmental Protection, Safety and Emergency Preparedness presents Pacific Northwest Laboratory's progress on work performed for the Office of Environmental Programs, Office of Operational Safety, and the Office of Nuclear Safety. The report is in three sections, introduced by blue divider pages, corresponding to the program elements: Technology Impacts, Environmental and Safety Engineering, Operational and Environmental Safety.

In each section, articles describe progress made during FY 1982 on individual projects, as identified by the Field Task Proposal/Agreement. Authors of these articles represent a broad spectrum of capabilities derived from various segments of the Laboratory, reflecting the interdisciplinary nature of the work.

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

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Technology
Impacts

TECHNOLOGY IMPACTS

- **Acid Deposition Assessment***

The integrated technology overview program, funded by the Department of Energy, Office of Environmental Assessment, is a mechanism by which health, environmental, social, economic, and institutional factors are combined into a form useful for energy planning and decision making. This program selectively combines information about the potential effects of alternative energy technologies (such as waste releases, land and water use, and social effects) and about constraints on the development and use of these technologies to produce broad-based assessments of the advantages and disadvantages of energy and conservation policy options. As a corollary, needs for further research, development, and technology transfer are identified.

*Bullets denote Field Task Proposal/Agreement (FTPA) titles.

• Acid Deposition Assessment

The purpose of the work done under this program was to examine the magnitude of the discrepancy in trajectory calculations that can be expected when using a single-layer wind value to characterize the full spectrum of values that usually occur in a baroclinic atmosphere. Wind data over a four-month period from seven stations east of the Appalachian Mountains were selected for analysis.

ACID DEPOSITION ASSESSMENT (Uncertainties Associated with Layering Winds for Use in Trajectory Calculation)

C. M. Berkowitz, W. E. Davis

This project analyzed wind data (1) to compare mean wind speeds/direction for four layers of 450-m thickness with the one value of wind speed/direction of a single column going from the ground to 1800-m (the top of the layer); (2) to compare the second moments of these layer values against the second moment of the wind which would characterize the column for a single-layer calculation; (3) to examine the extent of spatial coupling and decoupling between winds observed at the stations; and (4) to examine the variability of layered winds about the column values.

It was found that the layered values of the 450- to 900-m layer come very close to reproducing the wind speed that would be used in a single-layer model. If directional differences were 180° between layered and column values, then a total error of about 324 miles over 24 h could result, based on average conditions. A worst-case scenario could develop that would produce differences between a multilayer trajectory and a single-layer trajectory of up to 1500 miles. However, such a scenario is not very likely based on the distributions of the deviations in wind speed between the layered values and the single-column values; such distributions were found to be approximately normal.

Whether or not one of the layers examined in this study could be used to characterize the directional component of a trajectory calculation for a single-layer model was not clear. The same type of normal distribution characterizing the speed differences was found to apply to the directional differences. In a worst-case scenario for discrepancies between a column value and a number of layer values, winds could be 180° apart, resulting in an error that would be directionally proportional to the corresponding wind speeds.

Small linear correlation coefficients ($r < .5$) were found to result between the wind speeds at the different stations during July and August, suggesting that there is only a minimal amount of interdependence for this specific case. More generally though, a stronger correlation was found for wind speeds (winter months) and wind direction. The summer analysis for wind speed suggests that a knowledge of wind speed at a given station carries little weight in estimating the speed anywhere else. Stations separated by the spatial scales of this study appear to be too related to assume independence, except under special conditions. But the weak coupling does not warrant extensive trajectory calculations for summertime conditions when wind speeds are almost totally independent.

Environmental
and Safety
Engineering

ENVIRONMENTAL AND SAFETY ENGINEERING

- **Liquefied Gaseous Fuels Safety Studies**
- **Compressed Air Energy Storage (CAES) Environmental Concerns**
- **Former Nuclear Site Risk Estimation**

The objective of the Environmental and Safety Engineering Program is to assure that the environmental control capability for each DOE energy technology is complete, practical, cost-effective, and available in a timely manner as the energy source is developed. Program activities are oriented to identifying control technology status and needs for emerging energy systems, then developing methods and equipment for meeting these needs.

Pacific Northwest Laboratory's effort in this program, which grew rapidly through 1981, was greatly reduced in 1982 with the completion of a number of projects.

• Liquefied Gaseous Fuels (LGF) Safety Studies

The LGF Safety Studies Project, started in FY 1977 with work on liquefied natural gas (LNG), was completed at the end of FY 1982. Objectives of this project were to (1) conduct research on LGF release prevention and control in support of the DOE Liquefied Gaseous Fuels (LGF) Safety and Environmental Control Assessment Program and (2) to provide assistance to the DOE/EP Environmental and Safety Engineering Division in the planning, implementation and technical surveillance of the DOE Program.

Several task and milestone reports were completed and published in FY 1982 including (1) the Third DOE Program Status Report; (2) an assessment of R&D needs in liquefied petroleum gas (LPG) Safety and environmental control; (3) an overview study of LNG release prevention and control systems; (4) a study of human factors engineering applications to LNG release prevention and control; (5) analyses of release prevention systems at LNG import terminals and peakshaving facilities; (6) a review of LNG fire and vapor control technologies; and (7) a comparative safety analysis of LNG storage tanks. A task was initiated to evaluate the use of liquid nitrogen as a method for reducing the vapor concentration and generation rate of spilled LNG. Literature surveillance and development of the LNG library were continued. A final LNG Annotated Bibliography that summarizes all the literature reviews developed during the project was also published.

LIQUEFIED GASEOUS FUELS (LGF) SAFETY STUDIES

LGF Safety Studies

J. G. DeSteese, E. G. Baker, H. J. Bomelburg, C. A. Counts, C. E. Cowan, W. E. Davis, A. L. Franklin, T. E. Gates, G. M. Holter, G. J. Konzek, G. D. Marr, K. O. Nelson, P. J. Pelto, T. B. Powers, W. L. Rankin, T. B. Rideout, R. Shikier, K. M. Yasutake

The Environmental and Safety Engineering Division of the Department of Energy, Office of Environmental Protection, Safety and Emergency Preparedness (DOE/EP), conducted the DOE Liquefied Gaseous Fuels (LGF) Safety and Environmental Control Assessment Program. The objective was to gather, analyze and disseminate technical information that will aid future decisions made by industry, regulatory agencies, and the general public relating to facility siting, systems operations, and accident prevention and mitigation. The DOE program was coordinated with the efforts of other agencies and supported by research at national laboratories and technical institutions and by private contractors. The LGF Safety Studies Project, conducted by Pacific Northwest Laboratory (PNL), provided research on LNG release prevention and control, planning assistance, and technical surveillance in support of the DOE/EP program. Many of the safety and environmental issues identified for liquid natural gas (LNG) apply also to the handling of other liquefied gaseous fuels such as liquefied petroleum gas (LPG) and ammonia. As part of the FY 1982 project, PNL completed a safety and environmental control assessment of LPG.

The FY-1982 PNL project was structured around eight major tasks, summarized below:

1. LNG Advanced Release Control Studies

H. J. Bomelburg

The concept of introducing liquid nitrogen (LN_2) into an accidental LNG spill was studied as an advanced release control method. The LN_2 would both cool the LNG and provide an inert cover gas that could maintain a nonflammable vapor mixture above the evaporating liquid pool for some time after the spill occurred. Depending on the design of the facility and on the circumstances of an accident, the formation of combustible vapor clouds may be prevented for at least an hour by mixing LN_2 at about one-tenth of the rate that LNG is released. While this approach may be feasible for land-based facilities, the practicality and economics of providing similar shipboard protection are questionable.

2. LNG Technical Surveillance

H. J. Bomelburg, C. A. Counts, C. E. Cowan, W. E. Davis, J. G. DeSteese, P. J. Pelto

The objective of the LNG Technical Surveillance Task was to assist the DOE in establishing and maintaining technical surveillance of research and development activities related to LNG safety and environmental control. Literature surveillance and development of an LNG library continued. Three quarterly supplements to the "LNG Annotated Bibliography" and additions to the "LNG Safety and Control Literature and Research

Updates" were distributed to the sponsor and other contractors. The fourth quarterly supplement for FY 1982 was combined with previous literature reviews and published in September 1982 as a final task report entitled LNG Annotated Bibliography (Bomelberg et al. 1982). This bibliography contained a survey of European LNG literature contributed by Battelle-Institut e. V. in Frankfurt, West Germany.

3. Status Report Preparation

C. A. Counts, J. G. DeSteeze

A third status report was compiled as an account of DOE program activities and progress for the period FY 1980-1981. This effort included collecting information from other contributing contractors, preparing an executive summary, minor editing, and assembling the report for printing. The final version of the third status report (Pacific Northwest Laboratory 1982) was published in March 1982.

4. Human Factors (HF) Analysis

W. L. Rankin, T. B. Rideout, R. Shikiar

The overall goal of this research was to analyze the need for applying human factors (HF) principles in LNG facility design and operations. Specifically, this study focused on HF needs with regard to the release prevention and control systems used in the LNG industry. This goal was accomplished by focusing on four objectives: (1) identify applications of HF engineering in other industries that might relate to applications in the LNG industry; (2) identify the extent of current HF applications in the LNG industry; (3) define general research needs and knowledge gaps in the application of HF principles to the LNG industry; and (4) investigate further the potential human error contributions to LNG release scenarios.

During the course of the research, the task team made a total of eight site visits to six different LNG peakshaving facilities, spoke to numerous individuals in the LNG Industry, and visited an HF engineering group at an aerospace company. In addition, an extensive search of the LNG literature and a selective search of the HF literature were undertaken and a final report (Shikiar, Rankin, and Rideout 1982) was published.

5. LPG Assessment

H. T. Bomelburg, C. A. Counts, J. G. DeSteeze, P. J. Pelto

The purpose of this task was to provide the sponsor with background information and a data base on research and development (R&D) needs in LPG safety and environmental control for use in planning and implementing LPG subprogram activities in the DOE program. In FY 1982, PNL completed the final assessment report (DeSteeze et al. 1982), which included additional information provided under subcontract by Applied Technology Corporation.

6. PNL Report Preparation

E. G. Baker, C. A. Counts, B. A. Fecht, A. L. Franklin, T. E. Gates, G. M. Holter, G. J. Konzek, G. D. Marr, K. O. Nelson, P. J. Pelto, T. B. Powers, K. M. Yasutake

Several final reports on LNG study tasks completed in FY 1981 were submitted for sponsor review. In FY 1982, this task was directed toward incorporating reviewers' comments and preparing these documents for publication. They are included in the publication list at the end of this article.

7. LGF Program Overview

J. G. DeSteeze

The goal of this task was to provide an assessment of the objectives, approach, and achievements of the DOE program. Effort was to be directed toward evaluating the extent to which the DOE program has addressed gaps in knowledge about LGF safety and environmental control. It was intended that this task would contribute to the Program Overview and Recommendations Section of a Final DOE Status Report planned for publication in FY 1983. Work in this task was not completed because the project was terminated at the end of FY 1982. However, the results of initial efforts were published in a paper presented at the Second Symposium on Heavy Gases and Risk Assessment sponsored by Battelle-Institut e.V. in Frankfurt, West Germany, May 25-26, 1982 (DeSteeze and Rhoads 1982). This paper, entitled "R&D Needs and Opportunities in LGF Safety and Environmental Control," presented the highlights of PNL's perspectives on remaining LGF research needs given the accomplishments of the DOE Program and other recent R&D activities in this area.

8. Special Studies

J. G. DeSteeze

At DOE's request, the PNL project manager attended the Eighth International LNG/LPG Conference and Exhibition (GASTECH 81) held in Hamburg, West Germany October 20-23,

1981, to fulfill some of the objectives of the surveillance and technical review tasks in the PNL project. A large volume of information was gathered on the latest technology, developments, and operational practices of the LNG and LPG industries. This information was summarized and reviewed on the basis of its potential use as background information for the DOE program.

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• Compressed Air Energy Storage (CAES)

The objectives of this project are to identify potential environmental problem areas associated with the implementation of Compressed Air Energy Storage technology, to ensure that technology development proceeds in conjunction with environmental concerns, and to assist in the environmental and regulatory aspects of bringing this technology to commercial application. Research efforts in FY 1982 consisted of preparing reports and assessments on CAES environmental studies completed during this period, interfacing on the siting work for the first U.S. commercial CAES plant, assisting in the design and installation of the geologic monitoring systems for an aquifer air storage field test, and assisting the Illinois Environmental Protection Agency in interpretation of UIC rules with respect to permitting that test. The project has assessed and evaluated CAES environmental concerns, applied those conclusions in real-world regulatory situations, and assisted in actual siting and permitting operations for working facilities.

COMPRESSED AIR ENERGY STORAGE (CAES) ENVIRONMENTAL AND REGULATORY CONCERNS

T. J. Doherty

M. A. Beckwith*

Compressed Air Energy Storage (CAES) is a technology for storing excess off-peak electrical energy in the form of compressed air for later use generating peak-load electricity. During periods of low electricity demand, excess base-load generating capacity is used to power an air compressor at the CAES facility. The compressed air is then stored underground in the pore space within aquifers; in caverns solution-mined in salt formation; or in caverns mined in air-tight hard rock. During peak demand periods, the compressed air is withdrawn, reheated with fuel, and expanded through a modified gas turbine to generate electricity.

As the lead laboratory for research in CAES sponsored by the Department of Energy, Pacific Northwest Laboratory (PNL) established the Environmental Concerns Program to parallel the technology development efforts elsewhere in the laboratory. The objectives of the program are to (1) identify the environmental and regulatory issues associated with the implementation of CAES technology and make that information available to the industrial community; (2) ensure coordinated development of the technology and its environmental constraints through definition, analysis and evaluation of work on both fronts; and (3) assist industry and technical development efforts in regulatory, permitting and siting activities to establish consistent and comprehensive precedents for the environmental basis under which this technology is to be implemented.

During FY 1982, the objectives of the program were met by activity on three fronts: (1) assembly, evaluation and dissemination of information on generic issues of concern; (2) involvement in the siting of the first U.S. CAES plant by the Soyland Power Cooperative of Decatur, Illinois; and (3) participation in the design of monitoring systems and state environmental permitting for the Pittsfield aquifer field test in west-central Illinois.

Information on the environmental, legal and regulatory aspects of CAES technology has been prepared within this program. A summary of the legal and regulatory aspects was published early in FY 1982 (Hendrickson 1981). A second document will describe the impact of environmental and siting considerations on the feasibility of CAES systems. This document was based on the work of the DOE/EPRI demonstration projects carried out by the Potomac Electric Power Co., Middle South Services, and the Public Service of Indiana, as well as the siting and technology assessment studies performed by DOE through PNL for the Soyland Power Cooperative.

Soyland Power Cooperative, in conjunction with this program and the DOE Utility Applications Project, carried out a technology assessment and a siting selection study as the initial activity in their plan to construct the first U.S. CAES plant. PNL contributed to and coordinated some of the tasks within that work, represented DOE's interests, and reviewed and published the ensuing reports to ensure free access to this precedent-setting work (Environmental Science and Engineering 1982a, 1982b).

As part of the CAES project, PNL is conducting a small-scale field test to investigate the response of an aquifer structure to cyclic air storage at a site near Pittsfield, Illinois. The test, while intended to evaluate operational concerns, is a unique op-

*Beckwith & Associates

portunity to acquire data defining subsurface environmental impacts; therefore, PNL has contributed to the design and installation of the subsurface monitoring system to ensure the adequacy of environmental data gathering. The system is installed and is being checked as this reporting period ends (Hostettler, Childs and Phillips 1982). In addition, close coordination has been maintained with the Illinois Environmental Protection Agency (IEPA) regarding the permits needed for this test. Illinois is a primary state for implementation of Underground Injection Code (U.I.C.), and has ruled that this CAES application falls under those regulations. As CAES does not fit into the standard U.I.C. categories, PNL assisted IEPA in defining requirements, prepared supporting environmental documentation for the test facility operations permit, and functioned as intermediary between the project's operational staff and the IEPA.

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• Former Nuclear Site Risk Estimation

During FY 1982, the project was initiated to estimate health effects at formerly utilized MED/AEC nuclear sites or inactive uranium mill tailing sites. This activity complements radiological survey programs that are also sponsored by the Office of Operational Safety. During FY 1982, the general outlines of the methodology to be used in health effects estimation were developed, and initial estimates were calculated for twelve vicinity properties in the Salt Lake City area.

HEALTH EFFECTS ESTIMATION FOR VICINITY PROPERTIES AT URANIUM MILL TAILING SITES

S. Marks, F. T. Cross, D. H. Denham, W. E. Kennedy, Jr., K. A. Hawley and R. E. Jaquish

Work on this project, dating from February 1, 1982, has been directed principally to the development of procedures to be followed in calculating estimates of projected health effects at formerly utilized MED/AEC nuclear facilities or in the vicinity of inactive uranium mill tailings sites. During the period from the start of the study until the end of FY 1982, twelve vicinity properties in the Salt Lake City area were assigned by the DOE Office of Operational Safety (OOS) for the calculation of effects. These are properties immediately adjacent to the deactivated Vitro uranium mill tailing pile or at a greater distance. In the latter case, tailings material had been transported to the properties at some past time for use as landfill.

Tasks under the project include characterization of the source term for each property, selection of an appropriate set of health risk coefficients, evaluation of risk from environmental pathways, calculation of estimated health effects, and suggestions for the revision of radiological survey procedures to improve the achievement of objectives under this project.

The radiological source term was described in a report for each property in which we summarized radiological survey data compiled by Oak Ridge National Laboratory (ORNL) and Mound Laboratory. The reports briefly identified the nature of activities conducted at each property, the physical characteristics of the site and structures upon it, and the presence of various types of land cover, either in or outside the structures, that may modify radiological exposure levels. Contour lines were mapped on diagrams of the properties to reflect the isopleths for gamma exposure rates when taken at 1 meter above ground. When necessary, building diagrams were incorporated in the property reports.

The source-term section described the basis for selection of gamma-ray and radon daughter exposure values that were used in the health effect calculations. The gamma-ray values were usually the arithmetic means of measurement in buildings or in areas of differing exposure within a building. Guidelines were developed for the selection of grab or continuous radon gas measurements or of grab radon daughter measurements for use in the health effect calculations. The basis for acceptance of a calculated equilibrium factor or use of a default factor of 30% was also discussed for each property.

In the vicinity properties considered to date, three types of exposure have entered into the calculation of projected health effects. These are gamma-ray exposure rates at 1 meter, radon daughter concentrations, and exposure through the food pathway for two residential properties. The latter assumed the existence of home gardens on these properties that would provide a portion of the diet to the residents. In calculating health effects resulting from gamma exposure, the end point was cancer, and the currently accepted lifetime risk coefficient of 100×10^{-6} cancer cases per rem of exposure was employed. In the case of radon daughter exposure, a risk coefficient developed by the Task Group for Radon and Daughters of NCRP Scientific Committee 57 was used. The risk coefficient is 5.6×10^{-3} /WLM/yr for lifetime risk and lifetime environmental exposure for populations having a mixture of ages similar to that of the U.S. population. This risk coefficient was then adjusted for various values of the equilibrium factor.

Three expressions for health risk were employed. One is a lifetime cancer or lung cancer risk per individual for gamma or radon daughter exposure, respectively. The second measure is the percent increase in cancer relative to the individual's normal cancer or risk. The latter is obtained by dividing the probability of death from cancer or lung cancer as a result of the radiation exposure incurred during occupancy of the property by the

population lifetime risk of mortality for the corresponding disease category. Finally, the number of projected excess cancer deaths due to the radiation exposure was calculated for each property as the sum of risks due to gamma-ray exposure, radon daughters and, for the single family residences, ingestion of food products for the total number of occupants. The number of projected cancer deaths can then be related to the cost of cleanup, thereby establishing a cost-benefit basis for assigning priorities for remedial action on various properties.

In calculating excess cancer deaths, occupancy data furnished by OOS were used, and assumptions were made with respect to the assignment of persons to various areas within a building. These must be considered hypothetical and should be either verified or replaced by more detailed occupancy data later. If the pattern of occupancy is included in the development of estimates of projected cancer deaths, the estimates become more realistic in reflecting the variation of exposure levels that do in fact occur within many properties.

Finally, in accordance with a task assigned to the project by our OOS sponsor, recom-

mendations for modification of radiological survey protocols were developed. These were directed to improvement of the data base for calculating estimated health effects. The suggestions included improvement in the quality of occupancy data, including the typical distribution of persons within buildings; the simultaneous grab measurement of radon gas and daughters so that equilibrium factors could be estimated; and the use of distributed track-etch devices for radon gas measurement so that the pattern of exposure levels within different areas of the building could be more accurately characterized.

A report was submitted to OOS that included a summary description of procedures used in the project with detailed appendices relating to environmental pathway calculations and the scientific basis for the radon daughter exposure risk coefficients; suggestions for improvement of radiological survey procedures from the standpoint of health effects estimation; individual property reports for the twelve properties under consideration; and a set of tables incorporating the calculated health effect estimates in a form that permits ready comparison of values for the individual properties.

Operational Safety
and Environmental
Protection

OPERATIONAL SAFETY AND ENVIRONMENTAL PROTECTION

- **Criteria Development for DOE Decommissioning**
- **Environmental Protection Support and Assistance**
- **Technical Guidelines for Personnel Dosimetry Calibrations**
- **Health Physics Support and Assistance to the Department of Energy**
- **Personnel Neutron Dosimeter Evaluation and Upgrade Program**
- **Assessment of Criticality Safety**

The responsibility of the Department of Energy (DOE) Office of Environmental Protection, Safety, and Emergency Preparedness (EP) is to assure that DOE-controlled activities are conducted in a manner that will minimize risks to the public and employees and will provide protection for property and the environment. The program supports the various energy technologies by identifying and resolving safety problems; developing and issuing safety policies, standards, and criteria; assuring compliance with DOE, federal, and state safety regulations; and establishing procedures for reporting and investigating accidents in DOE operations.

The Pacific Northwest Laboratory's Operational Safety and Environmental Protection Program contributes to these objectives through projects in the nuclear area. During 1981, the major emphasis continued 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 improved reporting systems.

• Criteria Development for DOE Decommissioning

This project was initiated in the third quarter of FY 1979 to prepare guidance for DOE staff and contractors in the planning and implementation of decommissioning operations and in the certification of decommissioned DOE sites. A working draft of a radiological guide was prepared and forwarded for sponsor review in FY 1980. During FY 1981, the guide was completed and all comments were incorporated early in FY 1982. Although the Guide had been expected to be published in FY 1982, DOE management had not yet authorized its publication prior to the end of the fiscal year.

This effort was extended to nonradiological hazardous materials in the last quarter of FY 1980, by developing a questionnaire for DOE contractor sites to identify and quantify nonradiological waste inventories. Although the effort for FY 1981 was to have involved collecting data on DOE sites using that questionnaire, start-up of this work was delayed because of possible overlap with the EPA Superfund Questionnaire issued at about the same time. As a result, only a limited data-gathering effort was completed in FY 1981 using available DOE Annual Environmental Monitoring Reports and Environmental Impact Statements. The major effort in FY 1982 involved preparation of an assessment methodology and applying that methodology to assessing the inventory of chemical wastes and disposal sites on the Hanford Reservation.

CRITERIA DEVELOPMENT FOR DOE DECOMMISSIONING OPERATIONS

D. H. Denham, C. J. English, Jr.

The primary objective of this project is to prepare guidance for DOE and its contractors in assessing the need for and evaluating the performance of decommissioning operations. This guidance is intended to provide a uniform basis for (1) assessing residual radioactive and hazardous waste inventories at DOE excess facilities, (2) developing environmental risk analyses, (3) making decommissioning decisions, and (4) monitoring for compliance with federal standards and certifying that decommissioned sites meet applicable standards. While this study initially addressed radioactive contaminants, it has been expanded to include other hazardous materials. Both of these areas are described below.

- Radiological Decontamination and Decommissioning

"A Guide for Radiological Characterization and Measurements for Decommissioning of U.S. Department of Energy Excess Facilities," (Denham et al. 1982) was prepared under the radiological task of this project. Although not yet published, the guide describes the elements of radiological characterization at DOE excess facilities in preparation for, during, and subsequent to decommissioning operations. The guide's purpose is to provide the user with sufficient information to carry out the decommissioning tasks with a minimum of confusion and to provide a uniform basis for

evaluating site conditions and verifying that decommissioning operations are conducted according to a specific plan. The guide emphasizes:

- the need for and suggested methods of radiological site characterization including historical surveys, environmental pathway analyses, statistical sampling design, and appropriate instrumentation and measurement choices;
- the need for quality assurance, documentation, and records retention;
- the establishment of a design objective approach to setting site-specific contamination limits based on the ALARA philosophy;
- the assignment of numerical values to a "de minimis" or minimum dose level for decommissioning operations.

We anticipate DOE approval of the Guide for publication and distribution to field offices and contractor staffs in FY 1983.

As part of this project, PNL continued to participate in ongoing decommissioning projects and to inform DOE of those activities. In particular, PNL continued to serve on the American Society for Testing and Materials (ASTM) Subcommittee (E10.03) developing decommissioning standards for nuclear facilities and participated in the Third International Symposium of the Society for Radiological Protection in Inverness, Scotland, June 6-11, 1982.

- Nonradiological Decontamination and Decommissioning

Available data on inactive hazardous waste sites at DOE facilities were collected early in FY 1982. The primary sources of these data were questionnaires submitted to the Environmental Protection Agency (EPA) by the DOE field offices in compliance with Superfund legislation. These and other data were summarized and submitted to the DOE Office of Operational Safety (OOS). The results of this summary indicate that there is a continuing need to collect and evaluate data from the respective sites to assess the nature of inactive hazardous waste sites at DOE facilities.

To help correct this data shortage, efforts were begun to develop a method that could be used to obtain chemical waste inventory data at DOE sites. Similar efforts currently under way by EPA and other government

agencies were reviewed. Sources of chemical waste data at DOE sites were also identified. Based on this information, a draft chemical waste inventory method was developed and submitted to OOS during the third quarter of FY 1982.

To further refine this method, it was applied to the Hanford Site. During the third and fourth quarter of FY 1982, chemical waste inventory data were collected at Hanford. As a result, improvements and changes were made to the inventory method. In addition, an inventory was prepared of Hanford's chemical waste sites and their estimated contents.

While applying this methodology to other sites had been an option for FY 1982, the PNL and DOE staffs agreed to postpone that effort until review of the Hanford data could be completed.

• Environmental Protection Support and Assistance

Technical assistance continued to DOE's Office of Operational Safety (OOS) in the general area of environmental protection. Workshops were held to review the draft documents on dose assessment models and the effluent monitoring guide. Reports for final sponsor review covering these technological areas were completed after inclusion of suggestions from the workshop attendees. A prototype system to handle noncompliance information was completed, and reports defining the scope and content of the proposed environmental data reporting system were prepared. Criteria for selecting significant commitments in DOE environmental impact statements (EIS) were completed. Options for developing a tracking system were provided. Site visits were conducted to follow up on the information obtained in the ground-water questionnaire. A report summarizing the ground-water monitoring practices at DOE facilities was prepared.

ENVIRONMENTAL PROTECTION SUPPORT AND ASSISTANCE TO DOE/OOS

J. P. Corley, J. C. Bower, C. D. Corbit, P. J. Cowley, P. A. Eddy, K. A. Hawley, R. E. Jaquish, W. E. Kennedy, I. C. Nelson, L. S. Prater, D. L. Strenge, D. G. Watson

The objective of this program is to provide the Department of Energy's Office of Operational Safety (OOS) with technical support as needed in accomplishing its environmental protection objectives. The intent is to support a number of separate tasks, as requested by the sponsor, and to have the capability and flexibility to respond quickly to new problem areas and changing priorities as they develop. Task areas addressed during FY 1982 included:

- reviews and comments on proposed regulation, draft DOE Orders, and other potential operational impacts;
- assistance with planning and conducting OOS-sponsored information meetings, workshops, and conferences;
- reviews of existing practices and recommendations for environmental and effluent data reporting systems, including annual summaries;
- reviews of existing practices and recommendations for environmental dose assessment;
- reviews and analyses of existing quality assurance practices in effluent and environmental programs;
- assessment of need and feasibility of a follow-up program for DOE environmental impact statement commitments;
- reviews of existing practices and recommendations for ground-water monitoring programs;

- preparation of an effluent monitoring guide to supplement DOE Orders.

DOE Information Meetings and Conferences

J. P. Corley

The fourth DOE Environmental Protection Information Meeting was planned and organized. Technical support for the meeting included participating in the program development and selection of papers, communicating with authors, selecting facilities, and providing all local arrangements. The meeting is scheduled to be held in December 1982 in Denver, Colorado.

Effluent Guide

J. P. Corley

The guide for effluent monitoring is expected to be published in 1983. The objective of the guide is to promote greater uniformity in DOE environmental protection and to provide an additional tool to DOE management for assessing their effluent monitoring programs. The draft report was reviewed at a workshop attended by DOE and contractor personnel responsible for conducting effluent monitoring. Their suggestions were incorporated in the final version of the guide. Areas the guide addresses include: evaluation criteria and applicable standards, methods of evaluation, monitoring program design, equipment specifications, detection levels and action guides, sampling and measurement variability, appropriate statistical applications, quality assurance, and report formats.

Quality Assurance Requirements for Effluent and Environmental Monitoring

R. E. Jaquish

The major activity of this task was provid-

ing staff support for re-establishing the DOE Quality Assessment Program (QAP). Several options for obtaining this service were pursued and recommendations provided. A Quality Assurance Steering Committee, to provide advice and consultation to OOS on quality assurance, was established. This task provided technical support and recommendations on quality assurance as applied to environmental monitoring, including participation in the steering committee.

Environmental Dose Assessment Methodology.

D. L. Streng

The purpose of this task was to evaluate and make recommendations on methods for assessing population radiation doses from normal operations at DOE facilities. The work was performed by reviewing assessment methods used during 1979 (as reported in the 1979 annual environmental monitoring reports prepared by DOE contractors), identifying state-of-the-art methods, and reaching consensus with DOE and its contractors on acceptable methods for population dose assessments.

A preliminary review of current practices was completed during FY 1981. A draft report on the review results and recommended methods was the subject of a workshop held during June 1982 for DOE and contractor personnel. As a result of comments received during the workshop, the draft report was divided into two reports: one contains results of the review of the 1979 contractor practices (Kennedy and Mueller 1982); the other presents the recommended methods for assessing population exposures (Streng, Kennedy and Corley 1982). This task was completed during FY 1982 with publication of these reports.

Environmental Data Reporting System

R. E. Jaquish

During 1982 the effort continued to define and develop a reporting system for DOE environmental protection information. A data base was developed that contained information on noncompliance with environmental regulations at DOE facilities in 1981 and 1982. A prototype system was completed to enter, store, and produce reports on these data. A review was prepared of the environmental legislation applicable to DOE facilities, and the scope and objectives of the environmental data system were defined. Specifications for the components of the system were also prepared. Development ef-

forts were coordinated with the DOE contractor who will implement these systems when specifications are completed.

Environmental Impact Statement (EIS) Follow-Up

I. C. Nelson

Development of a method for selecting and tracking commitments contained in DOE EISs continued. A set of criteria was developed to determine, in EISs or Records of Decision (ROD), those commitments made for the protection and enhancement of the environment that warrant tracking. Two additional EISs, together with their respective RODs, were examined for commitments according to the selecting criteria. It was concluded that listing all comments followed by those warranting tracking would provide an appropriate basis for a recorded tracking system. A review was made of the NEPA and CEQ regulations, and a proposed level of EIS follow-up together with alternative levels was drafted for DOE management consideration. A collection of RODs that have been prepared to the present was provided to the sponsor as was an updated year-end list of agency EISs.

Ground-Water Monitoring Review

P. A. Eddy

A summary report of the ground-water monitoring practices at various DOE facilities was prepared based on a questionnaire and site visits. The report presents what the sites are presently doing but does not make judgments on the applicability of their procedures. A report containing conclusions and recommendations for the monitoring of ground water at the various DOE facilities is being prepared and should be available by the end fiscal year 1983.

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Streng, D. L., W. E. Kennedy, Jr., and J. P. Corley. 1982. Environmental Dose Assessment Methods for Normal Operations at DOE Nuclear Sites. PNL-4410, Pacific Northwest Laboratory, Richland, Washington.

• Technical Guidelines for Personnel Dosimetry Calibrations

A base of technical information has been acquired and used to evaluate the calibration, design, and performance of selected personnel dosimetry systems in use at Department of Energy (DOE) facilities. A technical document was prepared to guide DOE and DOE contractors in selecting and evaluating personnel dosimetry systems and calibrations. A parallel effort was initiated to intercompare the radiological calibrations standards used to calibrate DOE personnel dosimeters.

TECHNICAL GUIDELINES FOR PERSONNEL DOSIMETRY CALIBRATIONS

P. L. Roberson, R. A. Fox, R. T. Hadley, K. L. Holbrook, C. D. Hooker, J. C. McDonald

The purpose of this project is to assemble information to guide DOE and DOE contractors in selecting personnel dosimetry systems and calibrations and to initiate an intercomparison of calibration standards among DOE laboratories. Personnel dosimetry performance is strongly influenced by dosimeter calibration techniques. Proper calibration assures that the response of a personnel dosimeter correlates with the radiation dose equivalent received by an individual. Errors and uncertainties arising in the calibration are propagated through the entire personnel dosimetry system, often causing incorrect assessments of radiation dose equivalents to personnel. The design of the dosimeter influences its performance at energies far from the chosen calibration points. The correct interpretation of the dosimeter response is important for an accurate assignment of dose equivalent for exposures received in the work environment.

This project is divided into three tasks. The first task was to compile a data base on the performance of personnel dosimetry systems currently used by DOE laboratories. The second task was to prepare a set of guidelines for the performance, design and calibration of personnel dosimetry systems. The third task was to prepare for the intercomparison of calibration standards scheduled to begin in early FY 1983.

- The Performance of DOE Personnel Dosimetry Systems

A set of tests was performed based on those specified in the American National Draft Standard, Criteria for Testing Personnel Dosimetry Performance, ANSI N13.11 (ANSI 1978). Tests in addition to those specified were performed to provide information on energy response and radiation mixture response of the dosimeters. Eleven DOE laboratories participated in the tests.

Dosimeters were shipped to PNL for exposures to random levels and returned for

readout. In phase I, the tests were patterned after those specified in ANSI N13.11 (ANSI 1978), using participant calibrations. Calibration information from PNL was supplied for Phase II, and the data were re-evaluated. Additional testing not specified in ANSI N13.11 was performed in Phase III. The results for Phases I and II were included in the annual report for FY 1981. Below we discuss results for Phase III.

Irradiation categories for x rays ranged in effective energy from 16 keV (k-fluorescent technique) to 167 keV (heavily-filtered technique). In Figure 1 the fractional difference between the reported and the given doses (bias) is plotted versus the x-ray technique in ascending order of effective energy for dosimeters using thermoluminescent (TLD) material. The open squares represent calibration points provided by PNL. The closed circles represent the response for systems that use one fixed calibration constant for all photon energies. The open circles represent the response of dosimetry systems using variable-response functions. Variable-response systems use ratios of element responses as a basis for adjusting reported dose. The variable-response techniques provided superior performance

FIGURE 1. X-Ray Shallow-Dose Performance of TLD Dosimeters. The dosimetry systems were calibrated using PNL irradiations.

characteristics. The fixed-response technique did not have the flexibility to improve performance at x-ray energies without compromising performance for beta and ^{137}Cs categories. The performance of 16-keV x-ray irradiations was poor, varied widely, and was not related to dosimeter type. Processors with both fixed and variable calibration TLD dosimeters had difficulty interpreting the shallow-dose response to 16-keV x rays.

Performance of the film dosimeters is shown in Figure 2. Interpretation of dose

FIGURE 2. X-Ray Shallow-Dose Performance of Film Dosimeters. The dosimetry systems were calibrated using PNL irradiations.

from film is more difficult than for TLDs because film density varies with both photon energy and magnitude of delivered dose. The usefulness of the calibration irradiations provided by PNL was limited because only one dose level was provided for each energy. The x-ray performance for the film dosimeters was generally poorer than for both fixed and variable dosimeters was difficult to control because of the energy and dose-level dependence of the film.

The low-energy beta response for each dosimeter was determined from exposures to ^{85}Kr (0.67 MeV maximum energy) and $^{90}\text{Sr}/^{90}\text{Y}$ (2.3 MeV maximum energy) sources. The response per unit delivered dose of ^{85}Kr was divided by the response per unit dose of ^{90}Sr and plotted as a function of open window thickness (Figure 3). The lowest response was observed for TLD elements 230 mg/cm^2 in mass thickness (0.9 mm). Dosimeter response decreased with increasing filtration over the "shallow dose" TLD. The best response, 70%, was achieved for a TLD element 15 mg/cm^2 in mass thickness using minimal filtration.

FIGURE 3. Low-Energy Beta Response [$^{85}\text{Kr}/^{90}\text{Sr}-^{90}\text{Y}$].

Film data were sparse; however, the low-energy beta response was superior to the response of thick TLDs.

The effect of neutron calibration facility size on TLD-albedo dosimeter response was investigated. The effective room radius for each facility was calculated based on room dimensions. When the facility provided only one scatter surface (e.g., an outdoor calibration range or metal building with concrete floor), the effective room radius that would yield the same amount of scatter in an enclosed room was estimated. The relative scatter component increases with the source-to-phantom distance, so that all room radii were normalized to represent the scatter conditions for an irradiation distance of 50 cm. Formulas for room scatter are found in NBS Special Publication 633 (Schwartz and Eisenhauer 1982). The room return calculations are only a general guideline, since the scatter conditions are influenced by other factors not taken into account. Results are shown in Figure 4. In general, the bias approaches zero for large room radii (low scatter). High-scatter facilities result in low dosimeter response.

In summary, the performance data indicated that:

- the best performance at x-ray energies was achieved by TLD dosimeters using response algorithms dependent on a measured estimation of mean energy (variable-response dosimeters);
- the response of dosimeters using film packets was difficult to calibrate and control at x-ray energies;
- thinner sensitive elements are required for adequate response to low-energy beta sources;

FIGURE 4. TLD-Albedo Dosimeter Performance as a Function of Effective Irradiation Room Radius. The effective room radii were adjusted to represent relative scatter contribution at 50 cm.

- the calibration of TLD albedo dosimeters varies widely and depends on the size of the calibration facility.
- Guidelines for the Calibration of Personnel Dosimeters

A set of guidelines was prepared for the performance, design and calibration of personnel dosimetry systems using the dosimetry performance data base developed in Phase I. The guidelines are closely related to ANSI N13.11 (ANSI 1978); however, instead of specifying test arrangements they list recommended performance criteria, dosimeter design parameters and calibration techniques. The performance criteria are based on recommendations by the International Commission on Radiation Units and Measurements and the National Council on Radiation Protection and Measurements. The irradiation categories include those specified in ANSI N13.11. Important additions address the problems observed in the development of the data base on dosimeter performance. Additional x-ray, beta-particle and neutron categories were added. The guidelines for dosimeter design stressed avoidance of poor performance due to design limitations.

The guidelines for dosimeter calibrations specified a set of radiation fields and geometries intended to standardize reference calibrations. They follow ANSI N13.11 where practical.

- Intercomparison of Radiological Calibration Standards

A program for dosimetry intercomparisons among major DOE laboratories has been initiated to demonstrate the capabilities of putting into place improved and more uniform calibration methods. This program will also help stimulate communications between the laboratories.

The method for this intercomparison will be to ship a set of instruments calibrated at PNL to participating DOE laboratories. Each laboratory will report the instruments' response per unit exposure or dose delivered by x-ray source(s), a ¹³⁷Cs or ⁶⁰Co source, beta source(s), and neutron source(s). The responses measured at each laboratory will be compared to those measured at PNL. The instruments will include ionization chambers, a G-M counter, cables, and an electrometer with built-in power supply. The calibration of these systems is ongoing and will be completed within the first quarter of FY 1983.

In addition to the above, a set of TLDs will be shipped to the DOE laboratories, exposed, and returned to PNL for evaluation.

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American National Standards Institute (ANSI). 1978. Draft American National Standard Criteria for Testing Personnel Dosimetry Performance. ANSI N13.11, New York, New York.

Schwartz, R. B., and C. M. Eisenhauer. 1982. "Procedures for Calibrating Neutron Personnel Dosimeters." NBS Special Publication 633, National Bureau of Standards, Washington, D.C.

• 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.

HEALTH PHYSICS SUPPORT AND ASSISTANCE TO THE DEPARTMENT OF ENERGY

L. G. Faust, J. M. Selby

Characterization of Internal Dosimetry Practices

R. J. Traub, K. R. Heid, J. C. Mann

The purpose of this task is to characterize current practices in internal dosimetry at DOE facilities and evaluate those practices with respect to consistency among DOE Contractors. This task is multifaceted in that all aspects of an internal dosimetry program are addressed. Items considered include, but are not necessarily limited to, record systems and ease of information retrieval; ease of integrating internal dose and external dose; modeling systems employed, including ability to modify models depending on excretion data, and verification of computer codes utilized; bioassay procedures, including quality control; and ability to relate air concentration data to individual workers and bioassay data. This task will also identify collective and individual strengths and weaknesses in the assessment of internal dose by DOE contractors. Furthermore, it will serve as a basis by which these practices can be improved. This past year a draft questionnaire has been written and should be distributed early next fiscal year.

This task has also supported work that has demonstrated the feasibility of uranium analysis in solution by laser fluorescence excitation at uranium concentrations of one part per billion. This is less than the background concentration of uranium in urine samples. Improvements in laser stability may increase the sensitivity to allow measurements at one part per trillion. This would allow the dilution of the sample by at least 1000-fold prior to analyses and should therefore ensure the dilution of interfering substances to insignificant levels.

Technical Evaluation of the Capability of Present Instrumentation to Meet the Draft ANSI Standard on Performance Specifications for Radiation Protection Survey Instrumentation

J. L. Kenoyer, K. L. Swinth, R. L. Kathren

The objectives of this project are to evaluate the applicability and practicability of the proposed ANSI standard "Performance Specifications for Health Physics Instrumentation;" to determine the degree of conformance to the proposed standard of selected currently available commercial instruments; to develop a formal test and evaluation protocol and specific procedures; and to lay the ground work for establishing a permanent testing and certification laboratory.

Early in the fiscal year, existing standards and guides were reviewed to determine what criteria are currently used with instrumentation. In addition, a survey of commercially available instruments was performed to determine information on types of instruments available and the specifications claimed by the manufacturers. Direct contact with instrument users provided information regarding instrument preference and desired capability. Based on the above information and statistical criteria, procurement of representative instrumentation was initiated. An estimated 50 instruments will be procured by loan or purchase for test and evaluation.

Instrument test and evaluation procedures are being developed that follow the existing, proposed, or draft standards and guides. Drafts of the required test procedures have been prepared, and several of the procedures have been tested. A manual giving detailed operational and administrative guidance will result.

Testing of the instrumentation will include tests to evaluate each of the performance specifications in the ANSI standards ap-

plicable to the instrument type. New facilities for temperature, humidity, vibration, pressure/vacuum and radio frequency field testing are in the process of installation and characterization. With the exception of a few highly specialized tests, PNL has the facilities for all the required testing. Arrangements have been investigated for specialized testing at other laboratories where required by the standard.

In the testing phase of the program, a semi-random sample of production health physics surveillance instruments will be evaluated. Tests are assumed to apply to all instruments of a particular class and will thus permit evaluation of performance specifications in the applicable ANSI standards.

High Efficiency Particulate Air Filter Experience Survey

E. H. Carbaugh

A FY-1981 study of high efficiency particulate air (HEPA) filter experience at DOE sites was concluded with the presentation of summary results at the Seventeenth DOE Nuclear Air Cleaning Conference (Carbaugh 1982). The study evaluated causes and magnitude of HEPA filter changeouts and failures at DOE sites for the years 1977-1979. Several conclusions were inferred from the data including:

- HEPA filters have been generally performing the task they were designed for.
- Most changeouts have been made because of filter plugging, preventive maintenance, or precautionary reasons rather than evidence of filter failure.
- Where failures have been experienced, records generally have not been adequate to determine the cause of failure.
- Where cause of failure has been determined, damage attributed to personnel handling and installation has been substantially more prevalent than that from filter environmental exposure. Some respondents indicated the need for improved personnel training in handling and installation.
- Some reduction in filter failure frequency can be achieved by improving the acid and moisture resistance of filters, and providing adequate pretreatment of air prior to HEPA filtration.

Characterization of Emergency Preparedness at Department of Energy Contractor Facilities

E. H. Carbaugh, C. D. Corbit, T. H. Essig, D. P. Higby, G. J. Laughlin, J. C. Mann, B. L. Murphy, J. M. Selby, G. A. Stoetzel

In 1980 a study was initiated at the request of DOE to expand and upgrade the information/data base contained in a series of five reports (Selby and Unruh 1971; Selby et al. 1972; Andersen, Selby et al. 1974; Anderson, Selby et al. 1976; Bramson, Selby et al. 1976) that characterized DOE facility emergency preparedness in the early 1970s. These earlier studies focused on radiation protection instrumentation used for emergency assessment purposes.

To characterize emergency preparedness in the 1980s, a detailed emergency preparedness questionnaire was sent to DOE field offices in August 1980 for transmittal to appropriate DOE contractors. This questionnaire consisted of 15 information modules for nine subject areas:

- administration
- security
- transportation accidents
- emergency medical capability
- effluent monitoring
- environmental surveillance
- meteorological monitoring
- communications
- quality assurance/control

Data were received from 30 DOE contractors, and the first computer-assisted tabulation of responses was completed in August 1981. A second tabulation of responses was completed in February 1982 and used a facility classification system identical to that used in the 1971 report (Selby and Unruh 1971). Using this system, all facilities were categorized into high-, medium- or low-hazard classifications based upon the severity of potential accidents (keyed to the radioactive materials inventory).

The analysis of this data is being performed and includes an in-depth look at the present state of emergency preparedness at DOE facilities; a review of the 1970s documents to determine their applicability to state of the art instrumentation, and a comparison between the 1970 and 1980 state of emergency preparedness at DOE facilities. In addition, a comparative analysis was made between NRC and DOE emergency preparedness requirements and similarities noted.

Neutron Spectrometers in Direct Dose Equivalence Measurements

L. W. Brackenbush

Since all existing personnel neutron dosimeters are highly energy dependent, some knowledge of the neutron energy spectra they are exposed to is necessary to properly interpret dosimeter results. The purpose of this task is to fabricate three types of neutron spectrometers from commercially available equipment and calibrate them to derive dose equivalent from the relation

$$H = \int_{E_{\min}}^{E_{\max}} h(E) \phi(E) dE$$

where H is the dose equivalent, h(E) are the fluence to dose equivalent conversion factors recommended by the National Council on Radiation Protection and Measurements (NCRP 1971), $\phi(E)$ is the measured neutron fluence, and the quantities are integrated over all neutron energies, E. Three types of neutron spectrometers were developed: multisphere, helium-3 and NE-213 liquid scintillator.

The multisphere system has been calibrated at Lawrence Livermore National Laboratory. The dose equivalent rates from californium neutron sources have been measured with reasonable accuracy using the computer code LOUHI to unfold the measured spectra. The results obtained using the computer code YOGI are not as accurate; however, it runs faster and can be used with mini computers. The multisphere spectrometer covers the range of energies (thermal to 20 MeV), but unfortunately has very poor resolution.

A new computer code has been written to analyze the data from measurements made with ^3He proportional counters. This code incorporates response functions derived from monoenergetic neutrons in the 50-keV and 1-MeV range produced by the PNL Van de Graaff accelerator.

The third spectrometer uses a NE-213 liquid scintillation to measure neutron spectra and determine dose equivalent. Using the British Link Systems pulse shape discriminator, we were able to differentiate 100-keV neutrons from gamma rays. Unfortunately, it is not possible to accurately analyze data below about 1 MeV using state-of-the-art computer codes (such as FORIST) to analyze the data. It is hoped that a new methodology to analyze such data (presently in the conceptual stage) can be developed.

Procedures have been written so that technicians set up and calibrate the spectrometer systems. Instructions relative to analysis of the data using the various computer codes will be completed in the near future.

REFERENCE

National Council on Radiation Protection and Measurements (NCRP) 1971. Protection Against Neutron Radiation. NCRP-38, Washington, D.C.

Technical Evaluation of Draft ANSI Standard N13.30 Performance Criteria for Radiobioassay

D. R. Fisher, A. V. Robinson, H. E. Palmer

This study was established to evaluate the appropriateness of draft ANSI Standard N13.30 by conducting a nationwide bioassay intercomparison test. The study will evaluate the performance of in vivo and in vitro bioassay laboratories against criteria specified in the standard.

During the past fiscal year, testing procedures were developed and reviewed by the National Bureau of Standards (NBS). Laboratory equipment and supplies needed for preparation and distribution of test samples and phantoms were procured. NBS also supplied certified radionuclide standards for use in the intercomparison program.

Two rounds of in vivo and in vitro testing are planned. A torso phantom with interchangeable sets of radioactively labeled lungs and a whole-body bottle phantom filled with precise amounts of selected radionuclides in a gelatinous matrix will be shipped to participating in vivo counting facilities. Natural or artificial urine samples spiked with carefully controlled amounts of radionuclides will be shipped to participating in vitro bioassay laboratories for analysis. Procedures to be tested include liquid scintillation counting, alpha spectrometry, beta measurements, fluorescence measurements, and gamma spectrometry.

Arrangements were made with six in vivo and twenty-one in vitro measurement laboratories to participate in the first round of the study. Approximately half of these laboratories are affiliated with DOE. In addition, arrangements will be made with four commercial nuclear power plants to participate in the first round in vivo test.

An artificial urine matrix was developed for the in vitro testing program.

Advantages in using artificial urine include: biological and chemical stability over long time periods, ease of replication, and elimination of costly and bothersome sample collection. The recipe contains most of the major components in natural urine.

We collaborated with NBS to ensure the quality of dilution procedures and the accuracy of activity levels in test samples and phantoms. In addition, we provided review and analysis of the draft ANSI Standard, which is being written by an expert working group of the Health Physics Society.

Test results will be compiled and analyzed statistically. Sources of error will be determined, and suggestions will be offered for ways that laboratories may improve their accuracy and precision. Recommendations, based upon findings of the intercomparison study, will be provided to the standard-writing group. A procedures manual will be written for a future testing laboratory to follow in conducting an ongoing performance testing program for laboratory accreditation.

As a result of these efforts, it is expected that improvements will result in the accuracy and precision of analytical measurements performed by or for DOE facilities.

Development of a Standard Neutron Instrument

L. W. Brackenbush

The objective of this task is to investigate the use of tissue equivalent proportional counters (TEPC) as a standard instrument to increase the accuracy of measurements characterizing neutron fields. These devices are widely used in medical physics applications for measuring absorbed neutron dose and kerma but are seldom used by health physicists. Interest in tissue equivalent proportional counters has been revived by the issuance of the "NCRP Statement on Dose Limits for Neutrons" by the National Council on Radiation Protection and Measurements in 1980. References in this statement indicate that the NCRP may be considering changing quality factors and may redefine quality factor on the basis of lineal energy* rather than linear energy

*Lineal energy, y , is defined as the quotient E/ℓ , where E is the energy imparted to matter in a volume of interest which has a mean chord length, ℓ . Lineal energy is a stochastic quantity; i.e., its value changes owing to statistical fluctuations in microscopic irradiated volumes.

transfer, LET. Linear energy is directly measured by the tissue equivalent proportional counter. Tissue equivalent proportional counters offer several advantages:

- They are self calibrating, using an internal alpha check source or the so-called proton drop point.
- They provide an absolute measure of absorbed dose in a tissue-like material.
- With TEPCs, it is possible to derive quality factors and dose equivalent using the appropriate algorithm.

We have demonstrated that it is possible to build a single instrument to measure gamma rays, neutrons, or any charged particle that penetrates the tissue-equivalent walls. Because of the wide energy range of the events from the TEPC, it is necessary to use two amplifiers operating at gains with a counter filled with propane-based tissue-equivalent gas.

Before the TEPC can be used as a practical "rem-meter" it will be necessary to develop better, simplified algorithms for determining quality factors and dose equivalent. Figure 1 shows one possible simplified algorithm. This figure demonstrates a simple linear relationship between the effective quality factor as determined by the Rossi algorithm (Rossi 1968) and the average event size (or pulse height) in the absorbed dose distribution measured by a tissue equivalent proportional counter.

FIGURE 1. Quality Factors Calculated from Tissue Equivalent Proportional Counter Data Using the Rossi Algorithm

The average event size was determined from experimental data for event sizes less than 115 keV/micrometer for monoenergetic neutrons with energies ranging from 100 keV to 17 MeV. With this simple algorithm, the quality factor can be determined from the average pulse size (or event size) from a spherical tissue equivalent proportional counter.

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Neutron Depth Dose

R. I. Scherpelz

Many methods of determining personnel doses due to exposure to a field of neutron radiation first determine energy-dependent neutron flux distributions at the body surface and then use flux-to-dose conversion factors to convert the fluxes to dose.

Some of the commonly used tabulations of these conversion factors are based on calculations performed at widely-spaced energy points, and different interpolating schemes can lead to widely varying values for energy points not explicitly included in the tabulation. This study is adding improvements to the tabulations of neutron flux-to-dose conversion factors by calculating neutron flux, dose and dose-equivalent profiles in a tissue-equivalent phantom exposed to beams of monoenergetic neutrons. Flux-to-dose conversion factors will be derived from these profiles. These calculations are being performed for a number of energies, some chosen to allow comparison with previously-published tabulations of conversion factors, and some energies chosen to fill in the gaps in published values.

The computer code BMC-MG (Battelle Monte Carlo Multigroup) was chosen to perform the depth dose calculations. This code is a sophisticated neutron transport code that uses the Monte Carlo methodology, and is well suited to the calculation of depth-dose profiles. This computer code has been implemented on the UNIVAC 1100/44 computer at the Hanford Site; a simplified trial case was run to ensure the correct operation of the code.

The original code package included a 27-group neutron cross section library. Limiting the calculations to neutron transport, however, ignores the photons produced by neutron collisions, which may

contribute significantly to the dose in the low-energy region. Thus, a coupled neutron-gamma calculation was considered to be more appropriate for determining doses inside the phantom. A coupled neutron-gamma library with 22 neutron groups and 21 gamma groups has been obtained from the Radiation Shielding Information Center, and this library is now being used with BMC-MG.

BMC-MG directly calculates neutron and gamma fluxes at a number of points interior to the phantom. In order to convert these flux profiles into dose and dose-equivalent profiles, localized conversion factors must be chosen. A set of local flux-to-kerma factors has already been implemented (kerma is a first-collision approximation to dose), and the local flux-to-dose factors are being developed.

Several sample cases have been run for code debugging, input verification and optimal code parameter. With the final selection of local flux-to-dose factors, the study will proceed with calculations of neutron flux, dose and dose-equivalent profiles for a number of different monoenergetic beams of neutrons.

Beta Measurement, Evaluation and Upgrade

D. W. Murphy, G. W. R. Endres, K. L. Swinth

The Beta Measurement Evaluation and Upgrade task was initiated to review the problems associated with beta dosimetry practices. The work performed under this task can be classified into three major areas: (1) current practices, (2) dosimeter development, and (3) instrument development.

The review of current practices associated with beta dosimetry will be performed by the use of a survey to be sent to various sites and through the field measurements. The development of the questionnaire to be used for the survey was initiated and will be finalized in the first quarter of FY 1983. A report will be produced that discusses the current practices at the DOE sites in relationship to beta dosimeters, beta instrumentation, and the calibration practices associated with each. The report will summarize the weaknesses, strengths, and problem areas that are identified by the various facilities.

In the area of dosimeter development, two studies were initiated. The first was the development of a multi-element beta dosimeter. The multi-element beta dosimeter developed at PNL consists of one element covered by aluminized mylar and 6 elements covered by aluminum filters ranging in thickness from 34 to 860 mg/cm². Each ele-

ment contains three lithium fluoride (TLD-700) chips. After exposure of the dosimeter, the TLD chips are analyzed, and the results are used to determine a quantitative beta dose and a quantitative gamma dose for the exposure period. The reading under the thickest aluminum filter (860 mg/cm²) is assumed to result from gammas only, and this is subtracted from the other elements to provide the general shape of the beta energy spectrum. The resulting spectral shape is then used to determine the applicable calibration factor for the calculation of the beta dose.

The second study, involving the development of laser heating techniques in beta thermoluminescent dosimetry, was performed under subcontract with International Sensor Technology (IST). A new type of reader for thermoluminescent dosimetry has been developed that utilizes the transfer of energy from a CO₂ laser beam to layers of TLD powder on a glass substrate. With a 10.6-μg photon beam of less than 8 watts power, small amounts (less than 200 μg) of TLD material can be heated from room temperature to about 400°C in less than 10 msec. Such heating rates can increase signal-to-noise ratio, thus improving sensitivities. The preliminary feasibility studies using calcium sulfate dysprosium (CaSO₄:Dy), lithium borate (Li₂B₄O₇:Cu,Ag) and using a polyethylene step-type filter were performed. Figure 1 illustrates one of the advantages of the use of laser readout in thin layer TLDs.

The development of a compact beta spectrometer was performed by EG&G, Idaho Inc. A prototype spectrometer was built using a Ne-102 scintillator with the capabilities to measure, record, and analyze beta spectra both in the laboratory and in the field. The spectrometer responded well to beta sources of various energies and its linearity and stability were found to be acceptable. However, a problem of assessing the gamma response in the mixed-gamma field has not yet been resolved.

A study in beta dosimetry and spectroscopy was performed by Kansas State University (KSU). Beta particle doses and energy distributions were measured in beta fields with end point energies up to 2.3 MeV. A new technique was developed to produce TLD dosimeters of varying thickness. This technique involves developing a capability to uniformly slice TLD materials and mount them on a graphite matrix. The response of TLDs with thicknesses ranging from 0.02 to 0.89 mm were obtained. The emphasis was placed on characterizing the newly developed graphite-backed thin TLD. These TLDs showed a linear dose response and good

energy response for beta particles over a wide energy range. This new technique appears to be an extremely important breakthrough for many dosimetry purposes.

Additionally, two beta spectrometers were developed by KSU. One system was based on the use of plastic scintillators with thicknesses of 5.08 to 20.32 mm and diameters of 50.8 mm. The second system utilized a high purity germanium detector of 5-mm thickness. The results indicated that the plastic scintillators yielded accurate end point and average energy measurements when calibrated using the end point energies of known beta spectra. The high purity germanium detector data were most useful for end point determination, because backscatter-induced distortion limited the direct measurement of the average energies.

These studies will continue, and new study areas will be developed in FY 1983.

Radiation Exposure Information Record System

D. W. Murphy, J. J. Fix, B. L. Murphy

The third and final report, "Proposed Alternatives for a DOE-Wide Occupational Radiation Exposure Information System," was written and distributed to the field for comment. This proposed alternative was developed from the information that was reported in the previous two reports, "Overview of DOE Radiation Exposure Information Reporting System, REIRS," and "Current Personnel Dosimetry Practices at DOE Facilities." An ad hoc committee on Occupation Exposure Registry Upgrade consisting of twelve members was assembled to provide guidance and review for the document.

The proposed alternative would provide DOE with a radiation exposure data base that could be used to assess the impacts of proposed changes in radiation protection practices and regulations. Although the data base would contain dose information on all DOE employees who are monitored for compliance, no personal identifiers would be maintained with this information.

In order to facilitate the request for dose information on a given individual, the proposed system includes a DOE employee locator file and a badged visitor file. The primary purpose of the locator file is to provide an up-to-date list of all current employees at DOE and DOE contractor sites. This file would be developed prospectively; thus, information on employees who worked prior to the system's

initiation may not be available. However, the sites would be encouraged to provide as much of this historical information as is readily obtainable.

The report, Proposed Alternatives for a DOE-Wide Occupational Radiation Exposure Information System (PNL-3715) will be issued in the first quarter of FY 1983.

Characterization of Health Physics Technician Manpower Supply and Training Programs

R. L. Kathren, J. C. Mann

The purpose of this study is twofold: (1) to determine the current status and recent trends in radiation safety manpower supply and demand among DOE contractors; and (2) to document the scope of radiation safety training activities within the DOE contractor system.

A questionnaire has been developed in conjunction with Oak Ridge Associated Universities to gather data in these two areas. The questionnaire will be sent to DOE field offices in the first quarter of FY 1983. Responses will be received and tabulated in the second quarter of FY 1983.

Conclusions and recommendations regarding manpower supply and demand and training practices will be drawn.

Annual Exposure Report

B. L. Murphy, J. C. Mann

All DOE facilities annually submit occupational radiation exposure data to a central repository. The data include a summary of whole-body exposures, a summary of internal depositions of radioactive materials above specified limits, and occupational exposure reports for terminating employees. The 1981 data were received in August 1982 and have been incorporated into a report format, established in 1980, that includes technical discussions and data illustrations. The report was sent to DOE for publication in October 1982 (Murphy 1982).

REFERENCE

B. L. Murphy. 1982. 14th Annual Report Radiation Exposure for DOE and DOE Contractor Employees - 1981. PNL 4421, Pacific Northwest Laboratory, Richland, Washington. (The report will be published by DOE with a DOE document number).

• Personnel Neutron Dosimeter Evaluation and Upgrade Program

A program was initiated during FY 1981 with PNL as the lead laboratory to: (1) evaluate response characteristics of personnel neutron dosimeter systems in current use at several DOE laboratories, and (2) to develop improved neutron detection techniques for use as personnel neutron dosimeters and/or portable instruments. Evaluation of neutron dosimeters from twelve DOE laboratories was completed during FY 1982.

PERSONNEL NEUTRON DOSIMETER EVALUATION AND UPGRADE PROGRAM

J. J. Fix, L. W. Brackenbush, J. C. McDonald, P. L. Roberson, K. L. Holbrook, G. W. R. Endres, L. G. Faust

Evaluation of neutron dosimeters from twelve DOE laboratories involved about 2500 dosimeter irradiations at both PNL and the National Bureau of Standards (NBS) using neutrons of several energies and doses and several irradiations for good statistical analysis. The data and their analyses will be published at a later date. The information is not associated with individual laboratories or dosimeters, but it is an evaluation of dosimeter results observed for accuracy, precision, lower dose detection, and energy response.

During FY 1982, approximately \$550K were provided to fund ten tasks within other DOE laboratories as well as universities and private companies. Many of the results of these studies were presented at the Ninth DOE Workshop on Personnel Neutron

Dosimetry held in Las Vegas, Nevada June 24-25, 1982 and are included in the proceedings (Parkhurst 1982). Prototype dosimeters and instruments are being evaluated to determine their potential for upgrading the existing capability. Commercial manufacturers are involved in this phase of the program and are being encouraged to market these devices by participating in an active technology transfer program. Field measurements of neutron dose and spectra are being conducted at several DOE laboratories. This information, along with the measured responses of new devices, will allow determination of the accuracy of field neutron measurements and will be published at a later date.

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● Assessment of Criticality Safety

A study was undertaken to determine concerns and possible trends in nuclear criticality safety in DOE facilities. The information gathered from specialists in the field did not indicate that serious concerns or trends exist. The program was terminated before completion.

ASSESSMENT OF CRITICALITY SAFETY

E. D. Clayton

Criticality Safety Trends

The purpose of this program was to obtain an improved view of current trends in nuclear criticality safety and control throughout DOE facilities so that corrective actions could be proposed in advance of the consequences of adverse trends. Analyses of the data routinely collected by means of fault tree methodology would also contribute to the trend analysis. Data on safety experience were collected and categorized. The Office of Nuclear Safety subsequently distributed these data to interested users to foster improved communications between DOE contractors in the area of criticality safety and to improve uniformity in reporting and evaluating infractions.

Plans were made to collect infraction data on criticality safety from DOE contractors through DOE Headquarters. Though the program was terminated before data could be formally collected, information gathered

on an informal basis while planning this program showed active interest in safety among the DOE contractors. For example, infraction data and the Assessment of Criticality Safety in DOE Facilities (Lloyd et al. 1981) have been used in training and safety programs. One area of concern was the loss of experienced people from the field of criticality safety through retirement and other attrition. The importance of experience is underscored by noting that, despite excellent training programs, many of the criticality safety infractions could be attributed to persons with less than one year's experience on their present job. Awareness of this condition should help keep minor infractions from leading to more serious events.

This study was terminated before completion. Further study in criticality safety to determine trends would be of value.

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