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Pacific Northwest Laboratory Annual Report for 1979 to the DOE Assistant Secretary for Environment

Part 5 Environmental Assessment, Control, Health and Safety February 1980

Prepared for the U.S. Department of Energy
under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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NOTICE

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Part 5 Environmental Assessment, Control, Health, and Safety

W. J. Bair and Staff Members
of Pacific Northwest Laboratory

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Pacific Northwest Laboratory
Richland, Washington 99352

PREFACE

Pacific Northwest Laboratory's (PNL) 1979 Annual Report to the Department of Energy (DOE) Assistant Secretary for Environment describes research in environment, health, and safety conducted during fiscal year 1979. 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 1-4 report on research performed for the DOE Office of Health and Environmental Research. Part 5 reports progress on all other research performed for the Assistant Secretary for Environment, including the Office of Technology Impacts and the Office of Environmental Compliance and Overview. Each part consists of project reports authored by scientists from several PNL research departments, reflecting the interdisciplinary nature of the research effort. Parts 1-4 are organized primarily by energy technology.

The parts of the 1979 Annual Report are:

Part 1: Biomedical Sciences
Program Manager - H. Drucker — D. L. Felton, Editor

Part 2: Ecological Sciences
Program Manager - B. E. Vaughan — B. E. Vaughan, Report Coordinator; C. H. Connally, Editor

Part 3: Atmospheric Sciences
Program Manager - C. E. Elderkin — R. L. Drake, Report Coordinator; G. B. Long, Editor

Part 4: Physical Sciences
Program Manager - J. M. Nielsen — J. M. Nielsen, Report Coordinator; J. L. Hooper, Editor

Part 5: Environmental Assessment, Control, Health and Safety.
Program Managers - D. L. Hessel, S. Marks, C. M. Unruh — W. J. Bair, Report Coordinator; R. W. Baalman, C. W. Dotson, Editors

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 Dr. 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:

<u>Annual-Report for</u>

1951	W-25021, HW-25709
1952	HW-27814, HW-28636
1353	HW-30437, HW-30464
1954	HW-30306, HW-33128, HW-35905, HW-35917
1955	HW-39558, HW-41315, HW-41500
1956	HW-47500
1957	HW-53500
1958	HW-59500
1959	HW-63824, HW-65500
1960	HW-69500, HW-70050
1961	HW-72500, HW-73337
1962	HW-76000, HW-77609
1963	HW-80500, HW-81746
1964	BNWL-122
1965	BNWL-280, BNWL-235, Vol. 1-4, BNWL-361
1966	BNWL-480, Vol. 1, BNWL-481, Vol. 2, Pt. 1-4
1967	BNWL-714, Vol. 1, BNWL-715, Vol 2, Pt. 1-4
1968	BNWL-1050, Vol. 1, Pt. 1-2, BNWL-1051, Vol. 2, Pt. 1-3
1969	BNWL-1306, Vol. 1, Pt. 1-2, BNWL-1307, Vol. 2, Pt. 1-3
1970	BNWL-1550, Vol. 1, Pt. 1-2, BNWL-1551, Vol. 2, Pt. 1-2
1971	BNWL-1650, Vol. 1, Pt. 1-2, BNWL-1651, Vol. 2, Pt. 1-2
1972	BNWL-1750, Vol. 1, Pt. 1-2, BNWL-1751, Vol. 2, Pt. 1-2
1973	BNWL-1850, Pt. 1-4
1974	BNWL-1950, Pt. 1-4
1975	BNWL-2000, Pt. 1-4
1976	BNWL-2100, Pt. 1-5
1977	PNL-2500, Pt. 1-5
1978	PNL-2850, Pt. 1-5

FOREWORD

Part 5 of the 1979 Annual Report to the Department of Energy Assistant Secretary for the Environment presents Pacific Northwest Laboratory's progress on work performed for the Office of Technology Impacts, the Office of Environmental Compliance and Overview, and the Office of Health and Environmental Research. The report is in four sections, introduced by blue divider pages, corresponding to the program elements: Technology Impacts, Environmental Control Engineering, Operational and Environmental Compliance, and Human Health Studies.

Projects such as those dealing with decontaniination and decommissioning of nuclear facilities that were transferred to Energy Technology from the Environment Program this past year are not included in this report.

In each section, articles describe progress made during FY 1979 on individual projects, as identified by the Work Package Proposal and Authorization System. 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 this Part, contact the authors of the articles.

CONTENTS

ENVIRONMENTAL CONTROL ENGINEERING

Technology Impacts

TECHNOLOGY IMPACTS

- **Policy Analysis**
- **Technology Assessment**
- **Environmental Impacts**
- **Regional Assessment**

The integrated technology overview program, funded by the Department of Energy (DOE) Office of Technology Impacts, 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.

The Office of Technology Impacts is organized into four divisions which are named after their respective roles as listed above. The program at the Pacific Northwest Laboratory (PNL) is similarly divided.

Projects conducted for the Division of Policy Analysis are typically aimed at reviews of specific policy actions outside of DOE which are expected to affect DOE programs. Technology Assessment projects focus on respective energy production technologies. These projects evaluate the readiness of these technologies for commercial application and the likely consequences of their deployment under appropriate national energy and environmental policy assumptions.

The projects of the Division of Environmental Impacts are designed to improve analytical methodologies; facilitate the collection, storage, and transmission of energy and environmental information; and project gross national and regional environmental effects associated with national policy options. Regional Assessment considers in some detail the consequences of various national energy policy alternatives as represented by scenarios in which a portfolio of energy technologies is considered to be deployed in the region. At PNL these assessments are directed at the four Pacific Northwest states—Alaska, Washington, Oregon and Idaho. The regional work includes characterization of the region as it is now, identification and assessment of regional issues, and possible approaches to mitigation of regional problems interfering with implementation of national policy.

Policy Analysis

Pacific Northwest Laboratory supported the Division of Policy Analysis in the review of some proposed radiation protection regulations. However, the principal effort conducted under this part of the program concerned transuranics in the environment on Enewetak Atoll.

Transuranics in the Environment--Enewetak Atoll

W. J. Bair, J. W. Healy,[a] B. W. Wachholz.[b]

The purpose of this project was to write a document to support a Department of Energy presentation to the people of Enewetak Atoll in the Marshall Islands. The document describes the current radiological conditions resulting from the nuclear weapons tests conducted on Enewetak Atoll between 1948 and 1958. The document provides dose assessments for various living conditions and also discusses the possible health risks the people might face should they decide to return to live on the Atoll.

This dual-language document was drafted in English and translated into Marshallese using a dynamic equivalent translation method. The English text is a modified literal translation of the Marshallese. The text was translated by A. Buck, M. Jelke, and K. Sam from the Marshall Islands. Special graphics were created by H. E. Krueger with assistance from M. P. Hutton, M. C. Sheets, and P. A. Andersen, all from Pacific Northwest Laboratory (PNL). The document was edited by R. W. Baalman, PNL. J. Iaman, from the Marshall Islands, acted as medical consultant.

(a) Los Alamos Scientific Laboratory.
(b) Department of Energy.

• Technology Assessment

Work in Technology Assessment considered a variety of energy technologies. Some of it was directed toward the preparation or revision of brief Environmental Development Plans and Environmental Readiness Documents. Other work focused on the conduct of technology assessments. The products of both types of efforts are used by the Assistant Secretary for Environment as a basis for adopting a position on further development and application of respective energy technologies and on other energy policy matters.

Environmental Development Plans and Environmental Readiness Documents

The Environmental Development Plans (EDPs) are prepared by the Technology Assessment Division jointly with appropriate energy technology divisions. The objective of this part of the Technology Assessment program is to prepare and, as necessary, revise an EDP for technologies of interest. The EDP provides a mechanism to identify areas of potential environmental concern, to evaluate the current status of the environmental research studies relevant to the respective technologies, and to identify research programs needed in areas not receiving adequate attention in current studies. The EDPs include compilations of known pertinent research programs with summaries of the results of these efforts, as appropriate. They also identify areas where further research and development programs are required.

Environmental Readiness Documents (ERDs) are prepared by the Technology Assessment Division as statements of the Assistant Secretary for Environment's evaluation of the prospects for the respective technologies. EDPs and ERDs are updated every year or two to keep them abreast of changes in the status of the technologies and of knowledge about the potential effects of these technologies.

One EDP on which Pacific Northwest Laboratory (PNL) performed substantial work in 1979 concerns Nuclear Fuel Cycle Material Transportation. It was found that the transportation of nuclear material entails risks, however small, of accidental releases of radionuclides into the environment. The activity also imposes a number of other potential impacts upon the environment. Most of these impacts are typical of transportation activities generally, although some are unique to the transportation of radioactive materials. Consequently, environmental research programs are required which provide information on the kinds and extent of potential impacts and measures for mitigating them. Since many governmental agencies and private groups are involved in identifying and handling potential environmental problems associated with transportation of nuclear materials, coordination and assessment of the ongoing research activities are critical.

Other EDPs to which PNL made substantial inputs concerned magnetic fusion, coal liquefaction, and coal gasification. Reviews were conducted on others, especially those on gas recovery from unconventional sources, enhanced oil recovery, and oil shale.

Late in the year, PNL undertook an ERD on magnetic fusion. ERDs are especially important at key transition phases of an emerging technology. Magnetic fusion technology is in transition from the basic research phase to the developmental research phase; it is appropriate at this time to consider the status of the environmental issues in preparation for the transition. The Magnetic Fusion ERD is a joint effort including PNL, Teknekron, and Aerospace Corporation. The contributing organizations have defined the project scope, objective, technical approach, and division of responsibilities.

Technology Assessment of Environmental and Safety Aspects for the Enhanced Recovery of Natural Gas from Unconventional Geologic Sources

E. F. Riedel

Efforts to find more natural gas have intensified over the past decade. As conventional sources have become depleted, newer unconventional sources are receiving greater attention. However, before these unconventional sources can add significantly to our nation's supply of natural gas, the public health and safety, environmental, social, economic, and legal/political consequences and constraints that might be associated with these technologies must be examined. This assessment is limited to the examination of the potential public health and safety problems and the potential environmental impacts.

The objective of this project is to identify and evaluate known, potential, and heretofore unknown environmental and safety concerns associated with the recovery of natural gas from unconventional sources. Results of this study will be used to evaluate the commercialization of four resources:

- tight western sands
- methane from coal seams
- Devonian Age shales
- methane from geopressured aquifiers.

In FY 1979, Pacific Northwest Laboratory focused primarily on the resource of tight western sands with a limited amount of work on the resource of methane from coal seams. In FY 1980, the remaining two resources will be examined with the assistance of Lawrence Berkeley Laboratory. Results from these assessments along with results from the study of methane from coal seams will be included in a final report that the Department of Energy will use for ranking the commercialization effort for these natural gas resources.

Technology Assessment of Oil Shale

D. L. Hessel

Oil shale is a resource of great potential significance to the United States. The major oil shale deposit in the country, the Green River Formation of Colorado, Wyoming, and Utah, contains the equivalent of two trillion bbl of oil. That portion of the resource with greatest economic potential, averaging 25 or more gal per ton of rock, contains the equivalent of some 600 billion bbl. By comparison, the U.S. domestic petroleum reserves were estimated at about 30 billion bbl in January 1978. However, the shale oil potential is tempered by physical limitations on the rate of production, long technical development lead time, and high costs.

No shale oil production method has been demonstrated beyond the scale of 100 bbl/day. Numerous uncertainties exist about the physical and economic suitability for development of the current processes to commercial sized plants of 10,000 to 50,000 bbl/day. As with other energy technologies based on fossil fuels, shale oil production and use pose controversial questions about possible undesirable effects on the natural environment, agriculture, and human health and safety.

The oil shale assessment described here was undertaken:

1. to provide a comprehensive, objective review of shale oil technologies as a means of supplying domestically produced fuels within acceptable limits for environmental, social, economic, and legal/institutional impacts;
2. to examine the major points of uncertainty regarding potential impacts in light of all reasonably available data, analyses, and experienced judgment;
3. to resolve issues when data and analyses are compelling or where conclusions can be reached on judgmental grounds; and
4. to specify issues which cannot be resolved using only the data, analyses, and experienced judgment currently available.

Since most of the rich oil shale lies in northwestern Colorado, northeastern Utah, and southwestern Wyoming, this assessment is focused on development of the resource in that area. A wide variety of above-ground and modified in-situ retorting processes are incorporated into a hypothetical, but realistic, technological mix as a basis for analysis. This mix is designed to produce 300,000 bbl/day when fully implemented, assumed to be about 1990 or 1995. Rigorous consideration of these technologies at this scale should result in recognition of most of the potentially significant impacts of a mature shale oil production industry. The assessment considers these impacts in the categories of effects on media (air, surface water, ground water, and land); ecosystems and agriculture; human health and safety (primarily occupational); social and economic systems; and legal/institutional systems.

The approach for the assessment involves two major and interrelated thrusts. One of these is a series of technical tasks designed to assemble and examine available field and laboratory data and to carry out systematic data analyses. The other is structured workshops for representatives of private and governmental organizations interested in oil shale development.

The assessment is being conducted by an interdisciplinary team of scientists and recognized oil shale authorities. These individuals are drawn from Pacific Northwest Laboratory, several other national Department of Energy laboratories, from universities, and consulting firms.

Technology Assessment of In-Situ Uranium Production

C.E. Cowan

As the uranium mining industry expands to meet the needs of the nuclear industry and develop deposits that are smaller and less accessible by conventional methods, the costs of conventional methods per unit of ore recovered are increasing. Also as public environmental awareness and concern about the potential impacts of uranium mining increase, conventional uranium mining methods are encountering public opposition and licensing difficulties in some areas of the country. New techniques are therefore being developed, tested, and applied on pilot and commercial scales to improve uranium extraction and recovery. In particular, the in-situ leaching of uranium ore is receiving increased attention, especially in mining smaller- or lower-grade uranium deposits. Currently, commercial operations exist in Texas and Wyoming with plans for future operations in other parts of the Western Plateau.

The objective of this project is to prepare a report assessing the environmental, health, and safety impacts of the in-situ uranium leaching technology. The technology assessment (TA) describes the current state of the art for in-situ leaching and summarizes what is known about the environmental impacts; thus **it** can serve as an important tool to the regulators. In addition, the TA will identify areas of incomplete data for assessing impacts and unresolved issues which can provide a basis for evaluating the need for future research or regulation.

The focus of the tasks in this project are two-fold. The first phase includes a review of available literature, including licensing documents, and discussions with persons involved in the in-situ industry to determine the recognized impact areas and still unresolved issues relating to future development of the industry. **It** also involves analyses of this information to produce quantitative estimates of impacts. The second phase of the project consists of building on this framework by conducting a workshop. The workshop participants will represent government, environmental, and industry groups. The workshop will focus on clarification and discussion of the major issues and identification of positions on the issues. The results of these two phases will be integrated into a final report discussing the technology, identifying impacts and issues, and presenting recommendations and conclusions.

The project started in April 1979 and in the remainder of FY 1979 concentrated on phase one. This effort is still continuing and should be conipleted by the middle of FY 1980. A workshop has been scheduled for early FY 1980, and participants have been chosen. The project is scheduled for completion at the end of FY 1980.

Technology Assessment of Advanced Isotope Separation

P. J. Mellinger

Additional nuclear fuel is retrievable by recovering uranium (U-235) from uranium fluoride (UF_6) tails. This potential has led to the establishment of the Advanced Isotope Separation (AIS) 'program in the Department of Energy. The goals of the AIS program are to develop environmentally acceptable technologies that will (1) provide the means to recover U-235 from the depleted tails of the current gaseous diffusion and planned gas centrifuge uranium enrichment plants and (2) achieve primary enrichment directly from uranium oxide (U_3O_8) to reactor-grade material. Three candidate AIS processes have been identified which meet these objectives. These candidate processes (two use lasers and one uses supermagnetic plasmas) are currently in the applied research stage.

The AIS technology assessment (TA) was started late in FY 1979. **It** will examine the potential environmental, health, and safety considerations of the conversion (head end), reconversion (back end), and tails utilization alternatives surrounding candidate AIS processes. This TA will be used in the FY-1981 selection of one of the AIS technologies for further evaluation in an Engineering Demonstration Facility. The production plant is scheduled for construction beginning in 1989 and operation in 1995.

Preliminary Technology Assessment of Energy Conservation Measures

E. Edelson, M. Olsen[(a)]

Energy conservation measures have become a key technology in the nation's attempt to meet its energy needs, but this has been by necessity and not choice. As a result, many of the questions about impacts of nuclear and coal energy technologies have not been applied to energy conservation. This project was undertaken in conjunction with Brookhaven National Laboratory (BNL) to help the Assistant Secretary for Environment establish a research agenda for the impact of energy conservation. Three different approaches were used to identify research areas.

In April, a workshop was conducted to recomnend priorities for nineteen energy conservation measures. Participants came from business, labor, environmental groups, utilities, local government, and the federal government. They were asked to rank each measure for eight desirability criteria and four feasibility criteria. Those measures that were ranked the highest were building performance standards, small cars, retrofit, appliance performance standards, and redesign of the automobile.

Based on the rankings and discussion at the workshop, several measures were selected for further environmental and institutional impact analysis. An energy model based on BNL's Regional Reference Energy System was modified to consider changes in the environmental pollutants in the Pacific and Middle Atlantic regions when specific energy conservation measures were applied. Because of the difficulty in adapting the model, outputs were available but not analyzed by the end of the year.

For the institutional impact analysis, researchers interviewed about twenty representative citizens from selected cornunities for their impressions on the impacts on their cornunities if specific conservation measures were implemented. Two communities were chosen in Pennsylvania (Philadelphia and Erie) and two in Washington (Seattle and Yakima). Comparisons between the two Washington communities show an interesting contrast in the perceived impacts. In Seattle, a large metropolitan center, respondents saw conservation as a highly desirable policy that should be promoted as fully as possible. In Yakima, a moderate sized agricultural center, energy conservation was viewed as less important than policies that increase energy availability. No one felt that the impacts of energy conservation were so undesirable that conservation measures should not be applied. However, one area of mutual concern was the question of social equity. More work was recommended in this area.

(a) Human Affairs Research Centers, Seattle, Washington.

Technology Assessment of Solar Energy

E. Edelson, W. Sandusky, A. Chockie, J. Allwine, W. J. Eadie

Pacific Northwest Laboratory (PNL) is one of six national laboratories involved in the multiyear assessment of the regional, subregional, and community environmental and socioeconomic impacts resulting from maximum practical use of solar technologies in the year 2000. The project has examined alternative combinations of solar technologies in each region and is evaluating one highly beneficial combination.

A presidential domestic policy review has determined that the maximum practical deployment of solar energy is 14.2 quadrillion Btu. However, that analysis only assumed environmental benefits. To evaluate the benefits more thoroughly, the national projection was disaggregated to the state and county levels using the Strategic Environmental Assessment System (SEAS). The SEAS was programmed to quantify the changes in benefits resulting from high solar utilization.

PNL is responsible for analyzing impacts from changes in particulate level using an existing long-range transport model and for analyzing the significance of the changes in all pollutants in the Pacific Northwest Region. Substantive results are expected to be generated in FY 1980.

Special Study of Coal-Related Air Impacts of the Beluga Development

D. J. McNaughton

The objective of this task was to evaluate air quality impacts associated with possible construction of a 500-MWe coal-fired power plant at Beluga, Alaska. Air quality simulations were performed during FY 1979 for a generic plant located at Beluga, and maximum concentrations of three pollutants--sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and total suspended particulates (TSP)--were compared to applicable Alaska and national air quality standards and regulations for the prevention of significant deterioration (PSD) of air quality. Preliminary assessments of visihility degradation and sulfate formation were also made.

Because of the undeveloped state of the west shore of the Cook Inlet, there is a lack of meteorological data for air quality assessment. New source permitting procedures developed by the Environmental Protection Agency in response to the 1977 Clean Air Act Amendment suggest that a survey or "screening" analysis can be performed. This analysis can use best available meteorological data and conservative dispersion models such as the VALLEY model used in this study. Meteorological data used for long-term pollutant concentrations included a stability wind rose for Anchorage with wind direction frequencies modified to reflect the terrain at Beluga. Short-term pollutant concentrations were calculated assuming typical worst-case dispersion conditions for elevated point sources. The influence of terrain was included in simulations.

The generic power plant parameters assumed for Beluga studies are typical of plants currently under construction. Emissions for oxides of nitrogen and particles were assumed to be the maximum allowable under New Source Performance Standards (NSPS). Two emission scenarios were examined; the first simulated uncontrolled SO_2 emissions and the second assumed a 70% control efficiency for wet SO_2 scrubbers. All emission rates were below upper limits set in the NSPS.

Table 1 shows the fraction of the standards represented by maximum simulated concentrations for the controlled and uncontrolled SO_2 cases. Background pollutant concentrations are not significant in the analysis except for levels of total suspended particulates that are currently above standards because of fugitive dust. The highest concentrations in all cases were predicted for the mountains west and north of Beluga. Table 1 illustrates conipliance for all pollutants except when concentrations resulting from uncontrolled SO_2 emissions are conipared to PSD standards. Changes in plume rise associated with SO_2 scrubbing caused higher NO_2 and TSP concentrations when SO_2 was controlled.

TABLE 1. Comparison of Simulation Results to Ambient Air Quality Standards

Pollutant Averaging Period	Fraction of Standard (%)			
	SO_2 Controlled		SO2 Uncontrolled	
	AAQS	PSD	AAQS	PSD
SO_2 3-hr	30	77	56	142
24-hr	18	73	50	200
Annual	6	24	17	67
TSP 24-hr	7(4)[a]	29	6(3)	24
Annual	17(14)	54	1(1)	5
NO2 Annual	16	(b)	14	(b)

(a) National Ambient Air Quality Standard comparison given in parenthesis
(b) No PSD increment

Several important conclusions can be drawn:

- Air quality impacts of a 500-MWe power plant at Beluga show a high potential for compliance to standards and PSD increments at the screening level of analysis **if** the plant were properly sited and NSPS, including SO_2 scrubbing, were enforced.

- More sophisticated modeling and meteorological monitoring might show compliance to the PSD increments without scrubbing.

- Sensitivities in results suggest that plant siting nearer mountainous terrain could potentially cause air pollutant concentrations to exceed standards, as could changes in effective plume rise. Reanalysis at the screening level or a more sophisticated level would be required after actual plant design and siting.

- Firing low sulfur Beluga coal would have a small impact on sulfate levels and visibility in the Upper Cook Inlet.

• Environmental Impacts

Pacific Northwest Laboratory's work in support of the Environmental Impact Division in FY 1979 consisted principally of improvements in the use of long-range transport of air pollutants from the application of energy technologies.

Interregional Transfer Matrix for Atmospheric Pollutants

W. F. Sandusky, W. J. Eadie, W. E. Davis

Pacific Northwest Laboratory (PNL) has prepared an interregional transfer matrix that describes air quality impacts of pollutants over the continental United States. The elements of the matrix represent impacts on Air Quality Control Regions (AQCRs). The matrix allows the prediction of impacts in any AQCR from emissions in all other AQCRs. The matrix can be used to evaluate a variety of emission scenarios according to the National Energy Plan since, for purposes of the model, all emissions sources for each AQCR were aggregated into one and the source strength was normalized to one source.

This study concentrated on respirable particles. These particles were removed from the atmosphere by wet and dry deposition. For the transfer matrix, respirable particles were removed by dry deposition at a constant rate except in areas of complex terrain. In those regions, the removal rate was increased up to a factor of five, depending on the type of terrain encountered during plume travel. Wet removal of particles was based on climatological rainfall events. For both these removal processes, the plume in the model was depleted according to a surface depletion parameterization technique.

Concentration values of particles were predicted according to the established PNL long-range trarsport model. However, to handle a large number of emission sources, a new technique that uses an emission grid in the model calculations was developed. The value of this technique is that by using the emission grid, instead of a costly extrapolation to the actual emission source location, the pollutant concentration field can be predicted.

Matrices were generated' for four months of meteorological data: January, April, July, and October 1974. Comparative studies were made against concentration fields generated by the long-range transport model that predicted plume travel that originated from the actual emission location. Agreement was found at all distances from the emission source.

• Regional Assessments

The principal work conducted by Pacific Northwest Laboratory for the Regional Assessment Division in Fy 1979 was analysis of the consequences from and constraints applicable to the possible use of a specified mix of energy technologies in Federal Region X (Alaska, Washington, Oregon, and Idaho). The mix of technologies considered was reflective of the National Energy Plan as that plan was proposed by the President of the United States in 1977. This analysis was conducted in cooperation with other national laboratories, each of which focused on one or more of the other Federal Regions. The aggregate national analysis comprised the Regional Issues Identification and Assessment program.

Regional Issues Identification and Assessment

G. L. Wilfert, M. A. Beckwith

Significant changes in the national pattern of energy production and consumption are necessary during the remainder of this century. At the national level, energy policy and priorities are being considered that will affect historic production and consumption patterns. The purpose of this research is to help improve the effectiveness of federal energy policy by identifying areas where policy changes may be necessary. Pacific Northwest Laboratory has completed a study of the impacts of a national energy scenario. The study is reported in one of ten companion volumes, one for each of the Federal Regions in the nation, prepared by six national Department of Energy (DOE) laboratories. This set of reports presents a comprehensive, consistent description of the regional environmental impacts and implications of future national energy development.

The scenario used in this evaluation is the Projection C--the TRENDLONG MID-MID scenario, one of six possible energy futures predicted bv the Energy Information Administration of the Department of Energy for the DOE 1977 Annual Report to Congress. The TRENDLONG MID-MID scenario is representative of the official DOE national energy projections. Detailed analyses of air, water, ecology, land use, solid waste, health and safety, and socioeconomic and institutional factors show that impediments to implementing the national scenario in Region X are primarily institutional and technical rather than environmental. Although socioeconomic impacts may be significant because of the location of energy facilities in rural areas, the region is somewhat accustomed to rapid growth, and identified socioeconomic impacts should be mitigated.

The national scenario disaggregated to the regional level contains some values that are inconsistent with current regional plans, particularly in the rate that regional natural gas usage will be reduced and in the rate that regional geothermal resources will be developed for electrical energy production. In the area of projected nuclear, coal, and hydroelectric facility expansion, regional plans and the scenario-specified developments were similar.

Institutional Analysis Lead Laboratory

F. A. Morris[(a)]

In the identification and assessment of national energy technology impacts, institutional considerations have assumed increasing importance. Although engineering, economic, environmental, and socioeconomic models can reveal much about the consequences of alternative energy policy, the effect of institutional factors is often missing.

The purpose of this project was to develop and disseminate methods for incorporating institutional factors--defined to include legal, organizational, and political factors--into regional assessments conducted by national laboratory personnel. The specific results of this project were a workshop for national laboratory personnel and a report presenting five basic forms of institutional analysis. These forms are:

- institutional mapping (a systematic presentation of the participants, activities, and the connections among them for a specific policy problem);

(a) Human Affairs Research Centers, Seattle, Washington.

- institutional constraints analysis (the identification of legal, organizational, and political barriers to the achievement of desired policy outcomes);
- institutional impacts analysis (the identification of legal, organizational, and political consequences of government actions);
- institutional design (the specification of new institutional arrangements to achieve desired objectives);
- integration of institutional analysis into policy analysis (delineation of the relationship between institutional and technical factors in analyzing alternative policies).

Long-Range Transport of Atmospheric Pollutants

W. F. Sandusky, W. J. Eadie, D. R. Drewes

One of Pacific Northwest Laboratory's (PNL) lead laboratory responsibilities in the Regional Assessment Program is modeling the long-range transport of pollutants over the western United States. For the Regional Issues and Identificaton Assessment program during FY 1979, this modeling responsibility involved predicting incremental air quality impacts resulting from energy-technology emissions from industries and utilities that, under the scenario studied, would be operating in the western United States in 1985 and 1990.

The pollutants modeled were sulfur oxides (SO_2 and SO_4) and particulate emissions. The predicted incremental concentrations were then compared to the prevention of significant deterioration (PSD) limits to determine if any constraints to future energy technology siting would occur.

The PNL long-range transport model accounts for the transformation of emitted SO_2 to SO_4 aerosol and also accounts for wet and dry removal mechanisms. The sampling grid, from which the concentrations are computed, is compatible to the grid used by the Brookhaven National Laboratory in its long-range transport modeling of pollutant emissions in the eastern United States.

During the study, the emission sources varied according to pollutant type and amount of discharge. This variation occurred because more efficient controls for particles exist in certain areas of the western United States than in others, and thus some emission sources are small. These small emissions sources (<1 kiloton/yr) were not included in the analyses. Figure 1 shows SO_2 emission locations for the 1990 siting pattern. Figures 2 and 3 show the predicted incremental concentrations of SO_2 and particulates for both industrial and utility

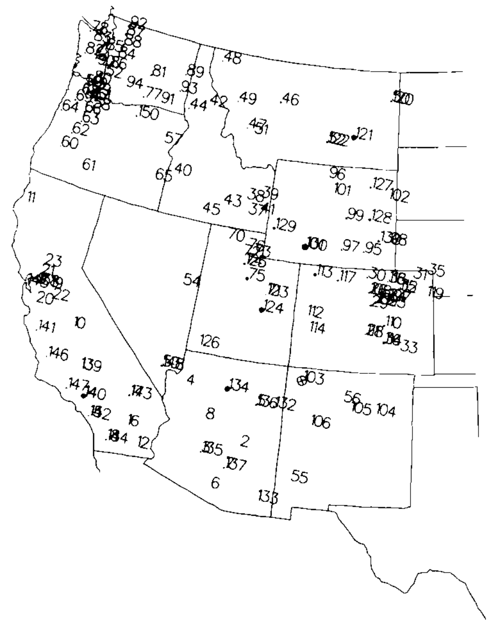

FIGURE 1. 1990 Regional Issues and Identification Assessment—Utility and Industrial Source Locations and Strengths

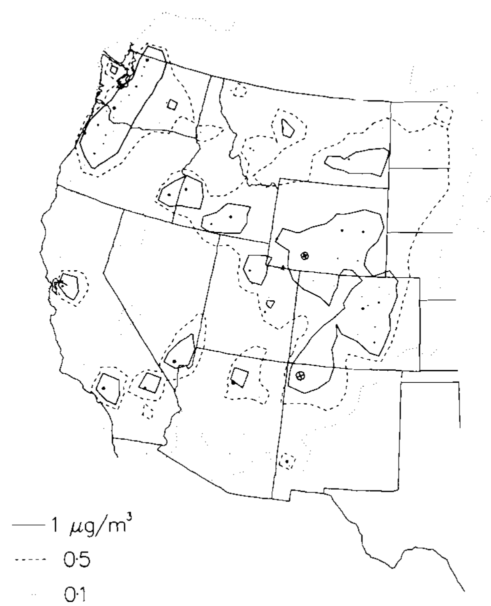

FIGURE 2. 1990 Regional Issues and Identification Assessment—Utility and Industrial SO_2 Air Concentrations

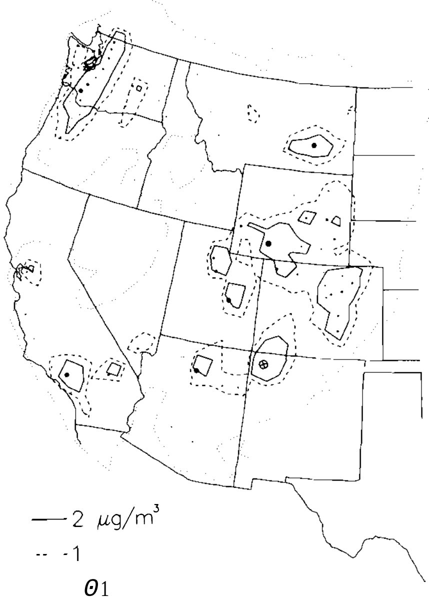

FIGURE 3. 1990 Regional Issues and Identification Assessment – Utility and Industrial Particulate Air Concentrations

emissions. The maximum incremental SO_2 and particulate concentrations on the figures are 10.9 and 11.4 $\mu g/m^3$, respectively. Thus, the PSD limits for Class II areas, as outlined in the Clean Air Act Amendments of 1977, are not exceeded. The western United States, however, contains a large amount of land area designated to be mandatory Class I (Figure 4), where allowable SO_2 and particulate increments are limited to 2 $\mu g/m^3$ and 5 $\mu g/m^3$, respectively. Therefore, SO_2 concentrations may constrain future energy technology development in southern California, the Portland-Seattle area, the Four Corners area, and the Rocky Mountain region of Colorado.

The predicted incremental particulate concentrations may also constrain future energy technology development in these same areas. However, the effect of fugitive dust emission has not been factored in this analysis. Incremental concentrations of dust emissions would, for some regions, contribute to a reduction in existing visibility.

Regional-scale sulfate concentrations are smaller than SO_2 concentrations. The maximum predicted incremental concentration was 1.1 $\mu g/m^3$. No federal PSD limits for sulfates have been established, although some states have established their own standards. Both Montana and North Dakota allow a maximum annual average sulfate concentration of 4 $\mu g/m^3$, and California has a 24-hr sulfate standard of 25 $\mu g/m^3$. Based on the analysis of these allowable concentrations, incremental sulfate concentrations would not limit future energy technology siting.

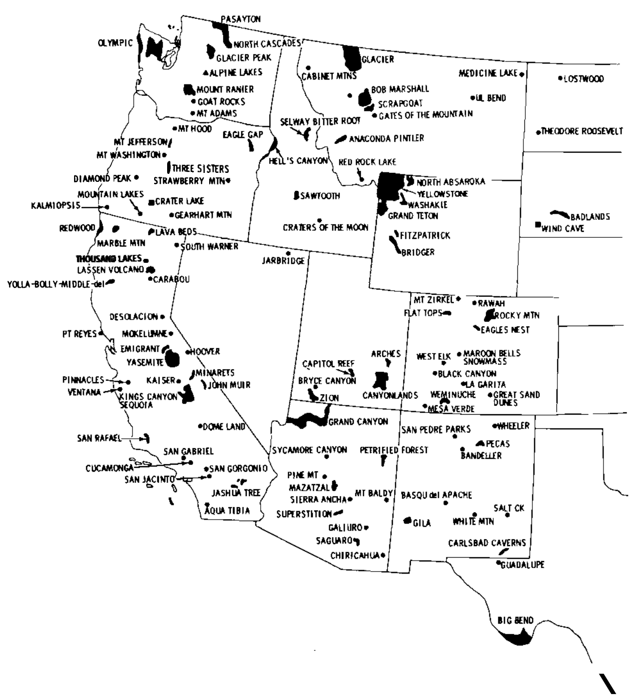

FIGURE 4. Mandatory Class I Areas in the Western United States

Environmental
Control
Engineering

ENVIRONMENTAL CONTROL ENGINEERING

- Energy Material Transport, Now Through 2000
- Dry/Wet Cooling Towers
- Liquefied Natural Gas (LNG) Safety Studies
- Liquefied Petroleum Gas (LPG) Safety and Environmental Research and Development (R&D)
- Burning of Oil Spills
- Environmental Control Technology for Shale Oil Waste Waters
- Compressed Air Energy Storage (CAES)
- Assessment of Energy-Conserving Industrial Waste Treatment
- Analysis of Nuclear Fuel Cycles
- Transportation Safety Study
- Assessment of Environmental Control Technologies for Koppers-Totzek, Texaco, and Winkler Coal Gasification Systems

The objective of the overall Environmental Control 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 is growing rapidly. During 1979 we conducted studies in support of both nonnuclear and nuclear technologies, with programs in oil shale, oil, coal, gas, energy materials transport, compressed air energy, and nuclear fuel cycle analysis.

● Energy Material Transport, Now Through 2000

The overall objectives of this project are to assess potential problems which may inhibit the safe and environmentally acceptable development of nuclear and fossil energy material transportation systems from now to the year 2000 and to recommend research, development, and other necessary action to mitigate the potential adverse impact of these problems. Effort in FY 1979 addressed the domestic transportation of petroleum, synfuels, nuclear fuel cycle materials, and legal and regulatory concerns. Results of the studies on petroleum, synfuels, and legal and regulatory concerns were published. Research continued on spent fuel cask productivity, coal sludge transportation, the Northern Tier Pipeline, and joint utility corridors.

Energy Material Transport, Now Through 2000: System Characteristics and Potential Problems

J. G. DeSteese, D. W. Faletti, A. L. Franklin, C. A. Geffen, C. R. Schuller, W. Wakamiya

Primary objectives of this study are to provide early recognition and assess priorities of future problems in energy material transportation. Other objectives are to identify possible gaos in the coverage of related programs and recommend action to minimize the potential impact of these problems. The purpose of the project is to provide information and perspective to government and industry that assist the development of problem-mitigation strategies. Final task reports containing system characterization and potential problem assessments of petroleum and synfuel transportation were completed and published in FY 1979. A final report on legal and regulatory problems was also published. Some concerns in previous overview studies were evaluated in more detail. Assessments were made of potential problems associated with spent nuclear fuel transportation, the possible need to transport flue-gas desulferization sludges, and the Northern Tier Pipeline proposal. The implications of institutional barriers that prevent the development of multipurpose utility corridors were also evaluated. The results of these studies are discussed below in more detail.

Petroleuni Transportation Assessment Task

J. G. DeSteese, C. A. Geffen

The final report was published containing a summary characterization of petroleum transportation systems and an assessment of potential problems that may affect domestic petroleum transportation during the balance of the century. The system characterization included a review of petroleum product movements, modal operations and comparisons, and transportation regulations and safety. This system overview also summarized domestic production and consumption'scenarios to the year 2000.

Potential problenis in petroleum transportation were identified by the analysis of current issues and establishing priorities for them. The priorities were judged on the basis of their overall impact on the system and the immediacy of the potential impact. The concerns were grouped in the following four categories: (1) environmental effects and management of oil spills; (2) transportation system safety; (3) transportation logistics; and (4) legal, regulatory, and institutional problems. Recommendations were made for actions that address specific concerns and their consequences in each of these categories.

Synfuel Transportation Assessment Task

W. Wakamiya

The final task report considered the future transportation needs of shale oil, synthetic gas from coal, coal syncrude, and methanol from coal and hydrogen. The study concluded that since most synfuel production will involve new facilities, many problems of existing energy material transportation systems can be avoided by proper design and system planning. Technical problems, such as whether synfuels may be compatible with current technology materials and equipment, should be readily solved on a case-by-case basis. However, potential institutional, legal, regulatory, and social problems may discourage the production and transportation of synfuels. Such problems include the cost of compliance with environmental regulations, the impacts of litigation, and public acceptance of transportation systems and plant siting.

Nuclear Materials Transportation Assessment

D. W. Faletti

The focus of this effort was the transportation of spent reactor fuel. Improved cask productivity is one of the approaches available to address the current concern that spent fuel transportation may become inadequate during the next decade. This concern has been expressed by representatives of industry and government and is based on the expectation of a future cask and vehicle shortage. The study determined that cask productivity (cask trips per year) can be increased up to about 60% in some cases if in-plant loading and unloading (turnaround time) is reduced. Significant reductions in turnaround times can he achieved by innovations and modifications in cask design and handling, facility operation, and system development. Specific recommendations include the use of overpacks on casks containing long-cooled fuel, improved and automated decontamination procedures, and facility and logistic planning that minimize turnaround times.

Assessment of the State of Preparedness to Transport Sludge from Coal Plants

A. L. Franklin

Large increases in the quantities of solid waste produced by coal-fired plants are expected to occur over the next twenty years as a result of the greater dependence on coal-fired power plants and the increasing use of sludge-producing flue gas desulfurization (FGD) processes required to meet air pollution standards. The purpose of this study was to determine whether significant long distance transportation of FGD sludge may he required in the future. It was concluded that utility planning is currently adequate for obtaining disposal sites that meet current regulations and that are at or near plant sites.

The Environmental Protection Agency, in carrying out its responsibilities under the Resource Conservation and Recovery Act of 1976, is in the process of setting new standards for the disposal of solid wastes. Fly ash, bottom ash, and FGD sludges have been placed in a category called "Special Wastes." It was recommended that the Department of Energy keep this situation under scrutinv because if these wastes are declared to be hazardous, industry may not be prepared for the possible need to transport sludge from existing plant sites.

Legal, Regulatory, and Institutional Concerns

C. R. Schuller

Some legal, regulatory, and institutional concerns considered previously in this project have developed new implications, and similar concerns have evolved from recent events. Detailed assessment of eight specific legal and regulatory concerns were published as a final report in this task. The concerns included state authority to regulate the transportation of nuclear materials, petroleum pipeline divestiture, natural gas transportation, and the adequacy of energy transportation systems in emergencies. This report also contained assessments of coal pipeline legislation, railroad problems, and the possible impacts of the Panama Canal Treaty. In addition, topical reports were completed on the Northern Tier Pipeline and institutional barriers that prevent the development of energy materials transportation corridors.

• Dry/Wet Cooling Towers

The dry/wet cooling tower program is assessing the prospects and environmental impact of large-scale advanced dry/wet heat rejection systems. Experimental studies reported the heat transfer efficiencies of dry/wet heat exchangers and corrosion-deposition aspects. These studies showed heat exchange increase by factors of two or more when running wet; however, they also showed significant quantities of deposition whose chemical control and heat exchange effect were not assessed. The market incentives of dry cooling in advanced energy systems such as solar and geothermal, were examined. A possible dry cooling use of about 2.5 GW by the year 2000 in these new power generation methods was projected.

Dry/Wet Cooling Towers Program

R. T. Allemann

The objective of the Department of Energy/ Environmental Control Technology Dry/Wet Cooling Towers Program is to obtain information about the prospects and environmental impact of large-scale use of dry/wet heat rejection systems for power generating plants. The information can be applied to conserve water resources and increase power plant siting flexibility. Work during FY 1979 was directed at three tasks: (1) completion of a report (Parry et al. 1979) of experiments on the use of water deluge for enhancing dry cooling, (2) tests on corrosion-deposition and environmental constraints on the use of aluminum in dry/ wet towers, and (3) a study of the incentives for use of dry cooling in support of advanced energy generation systems.

Water Deluge Tests

The water augmented test apparatus (WATA) used in the tests is shown in Figures 1 to 3. One of the primary results of the

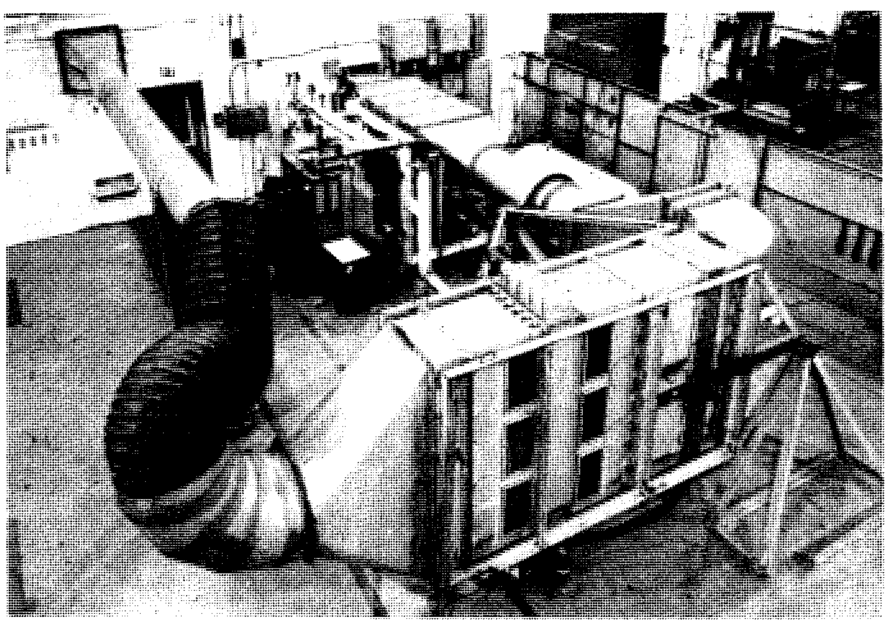

FIGURE 1. Water Augmentation Test Apparatus (WATA) Used to Measure Wet/Dry Heat Transfer

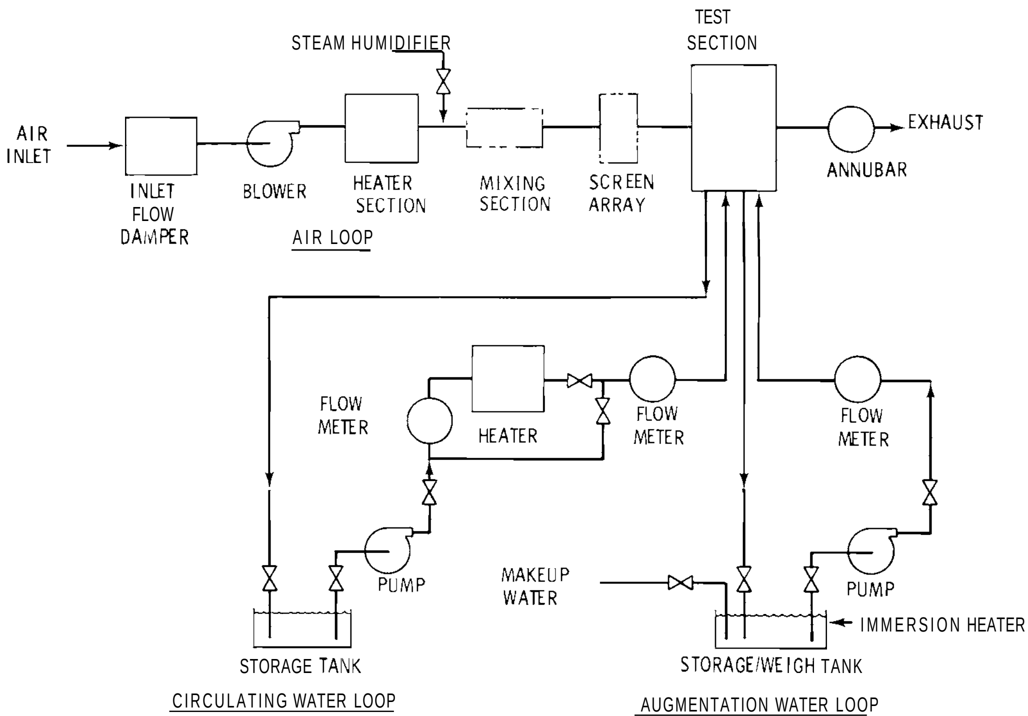

FIGURE 2. Water Augmentation Test Apparatus (WATA) Schematic

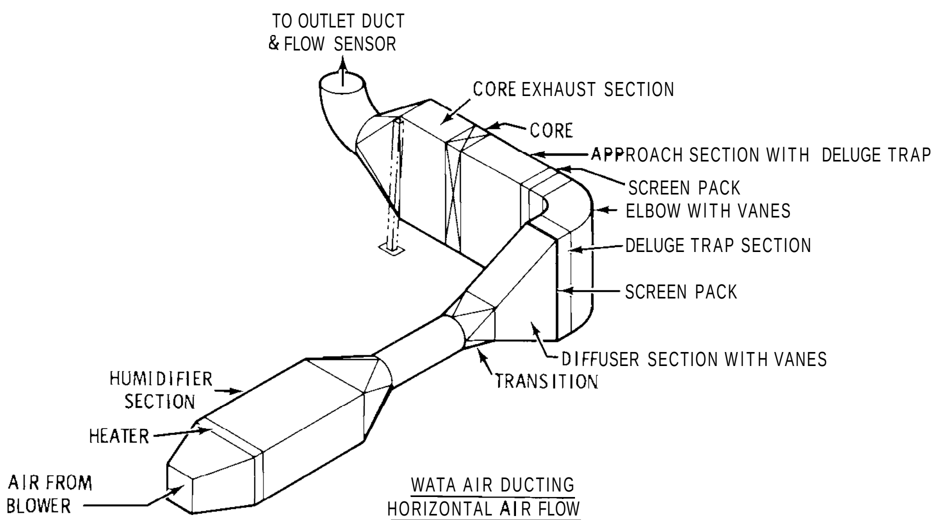

FIGURE 3. Water Augmentation Test Apparatus (WATA) Air Ducting — Horizontal Airflow

WATA nieasurements was the rate of heat transfer from a deluged surface. Figure 4 illustrates that the heat transfer coefficient can be increased by a factor of 2 to 6 depending on run conditions above that for a dry surface.

Use of Aluminum

Since aluminum is a leading candidate construction material for the advanced concept dry/wet cooling towers, the possible environmental constraints on its use were a concern. Industrial users of aluminum surfaces were contacted, and tests were done on aluminum heat exchangers to evaluate the extent to which aluminum would interact with the environment and require cleanup and/or slow-down of augmentation water. Results indicate that with proper design, aluminum can be used as proposed for steam condenser tubes. Environmental constraints on use of aluminum cooling towers will be influenced by the amount of hlowdown required to keep augmentation water in a noncorroding, non-depositing condition.

In the case of deluge cooling, where the air-cooled, extended surface heat exchanger is covered with a film of water to promote evaporative (supplemental) cooling, the level of contaminants and dissolved solids may markedly affect corrosion and scale deposition on the finned surfaces. Data were obtained with the corrosion-deposition loop (CDL), Figure 5, which is a test bed for accelerating the deposition of solids on heat exchanger surfaces through cycles of on/off, wet/dry operation.

A larger (106-R) deluge reservoir was installed early in FY 1979 to increase and stabilize the ion inventory available for deposition in a given time interval. Since

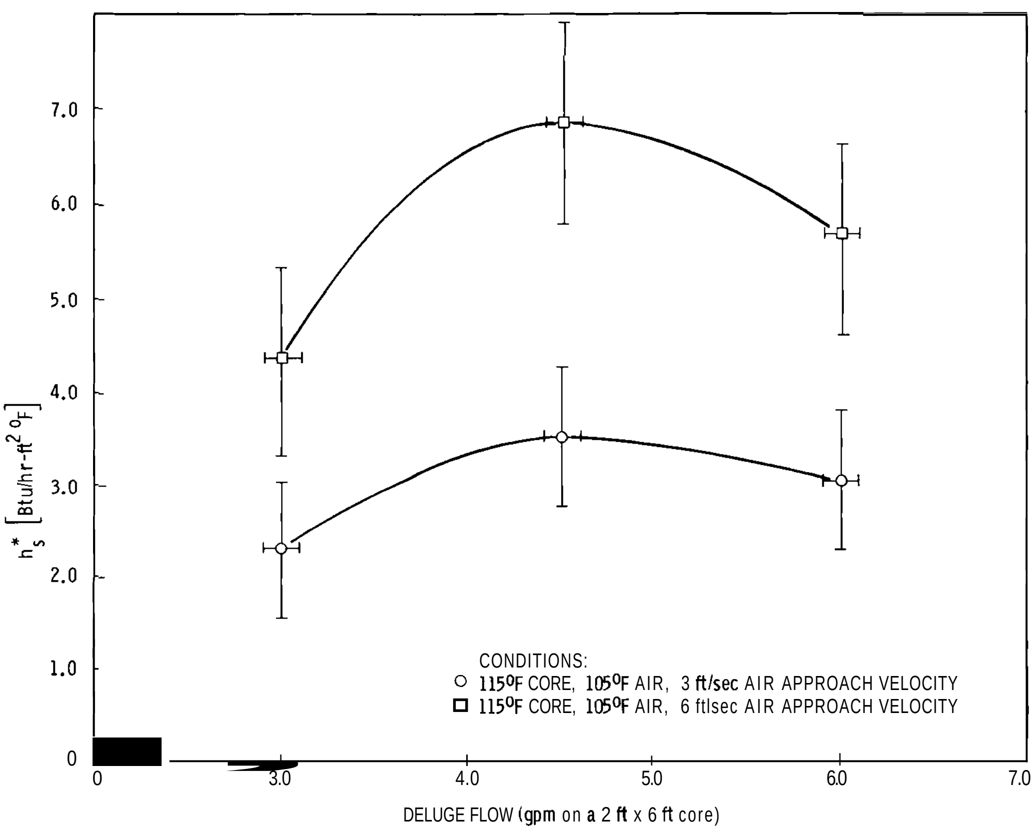

FIGURE 4. Wet/Dry Cooling: The Effect of Deluge Flow on Effective Deluge Surface Coefficient, h_s*

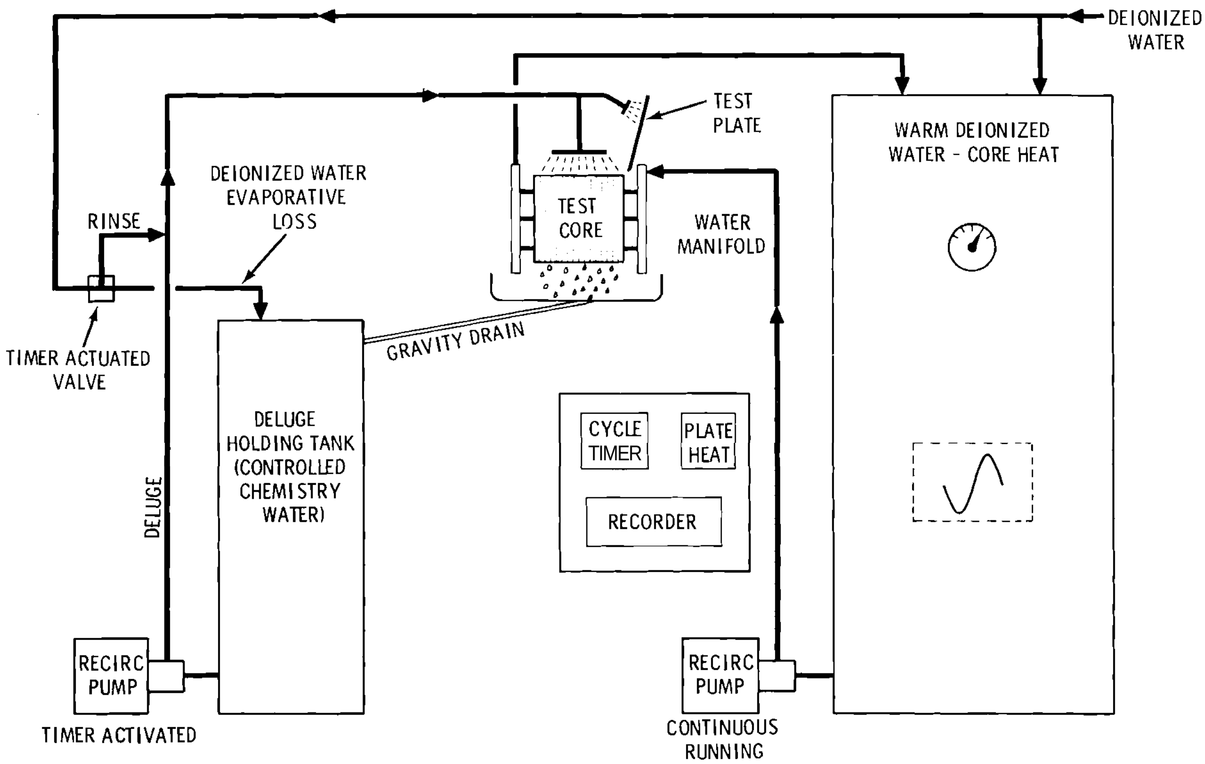

FIGURE 5. Corrosion-Deposition Loop (CDL)

scaling associated with alternate wet/dry cycling had been examined in some depth during FY 1878, the FY 1979 effort examined the scaling occurring only during deluging, exclusive of any deposit resulting from water film drying. Most experimental runs in the CDL were made with deluge equivalent to 4 times Kern well[(a)] water concentration. Reducing blowdown frequency by permitting tower operation to a water concentration factor of four (4X) helps achieve environmental conservation goals as well as reduce operating cost. Table 1 shows results of continuous wet deposition tests. Previous tests had shown nearly double the deposition when 250 cvcles of wet-rinse-dry operation were compared to a continuous wetting of the same duration. Even so, the deposition from continuous wet operation may be an important scaling mode for wet/dry towers and may require chemical and pH control. Work in progress is directed toward the chemical nature and control of the deposition process.

(a) A large test of a wet/dry cooling tower is being designed for operation in Kern County, California, under the auspices of Electric Power Research Institute and Pacific Gas and Electric.

TABLE 1. Deposition on Aluminum Fins

Run	Water Conc.	Core Cycles	Wet Time (hr)	Core Wet Temp (°F)	Wt. Gain (mg/dm^2)
14	2X	1	125	126	-13.3
15	4X	1	120	125	47

Advanced Energy Generation Systems

A previous study estimated that some degree of dry cooling, in conjunction with supplemental evaporative cooling, will be needed to provide waste heat rejection from 20 to 30 GWe of power-generating capability by the year 1995. This projection is based on the present practice of water allocation. There are indications that the political climate may change, making water availability for industrial use even more critical and increasing the need for dry/wet cooling. Therefore, an updated study was prepared on the incentives for using dry cooling in advanced energy generation systems. The preliminary conclusions are that energy generation systems using solar central tower (except geothermal, coal gasification, coal liquefaction, and coal solvent and refining) have market potential for dry cooling towers; hence their environmental effects may he influenced by the choice of dry cooling.

Table 2 shows a summary of energy use and projected waste heat generation for various energy subtypes. The central solar and geothermal production of electrical energy is expected to be 0.3 quads (10 GWe) by the year 2000. Previous studies indicated that dry cooling would capture about 5% of the cooling duty for fossil and nuclear power plants. Assuming central solar is used largely in the arid Southwest, perhaps 50% central solar would be dry cooled. Siting restrictions on geothermal suggest that perhaps 10% of geothermal power production would be dry cooled. The sum of these projections gives about 2.5 GWe of solar and geothermal to be dry cooled by the year 2000, compared to projections of 11 to 44 GWe of nuclear and fossil plants to be dry cooled by the year 2000. Hence, advanced energy generation technologies offer a 6% to 23% increase in the projected use of dry cooling in the power industry.

TABLE 2. Summary of Energy and Waste Heat Generation/Intermediate Growth (Quads)

	Year								
	1985			2000			2025		
Energy Type	Eout[a]	QD[b]	QI[c]	Eout	QD	QI	Eout	QD	QI
Coal Syn. Liquids	0.2	0.017	0.059	6	0.501	1.775	10	0.834	2.959
Coal Syn. Gas, High Btu	0	0	0	2	0.332	0.631	3	0.498	0.946
Coal Syn. Gas, Low and Intermediate Btu	0.3	0.023	0.053	12	0.900	2.100	16	1.200	2.800
Coal Clean Fuel	0.1	0.011	0.018	3	0.322	0.549	4	0.430	0.732
Oil Shale Syn. Liquids	0	0	0	7	1.156	2.697	15	2.477	5.779
Solar[d]	0	0	0	0.546 (0.113)[e]	0.052 (0.010)	0.995 (0.199)	2.785 (0.279)	0.259 (0.026)	4.914 (0.491)
Geothermal	0.01	0.003	0.064	0.93 (0.186)	0.311 (0.062)	5.913 (1.183)	7.1 (0.71)	2.376 (0.238)	45.140 (4.514)
Fossil Fueled[f] Power Plants	8.9	2.09	11.83	11.3 (11.9)	2.65 (2.79)	15.02 (15.82)	11.3 (15.7)	2.65 (3.68)	15.02 (20.87)
Nuclear Fueled[f] Power Plants	3.7	0.38	7.30	3.9 (4.5)	0.41 (0.47)	7.70 (8.88)	2.6 (7.05)	0.27 (0.73)	5.13 (13.91)

(a) Eout Useful work energy taken from power plant
(b) QD Direct energy loss to environment (stack losses, etc.)
(c) QI Thermodynamic cycle heat exchange energy rejection
(d) Contribution from central tower plants only
(e) Parenthetical values are based on a more conservative DOE study
(f) Eout corrected for efficiencies

● Liquefied Natural Gas (LNG) Safety Studies

The objectives of this project are (1) to conduct research and development in specific areas of the Department of Energy (DOE) Integrated Liquefied Natural Gas (LNG) Safety and Environmental Control Program and (2) to provide assistance to the DOE Environmental Control Technology Division in planning and technical surveillance of the program. Scoping assessments in the release prevention and control task were completed. The model comparison and evaluation task progressed in the areas of analysis procedure development and selection of test cases. Literature surveillance and the development of an LNG library continued. In addition, assistance was provided in the preparation of the DOE Liquefied Gaseous Fuels Program Status Report and in the planning of the Ammonia Safety and Environmental Control Assessment Program.

Liquefied Natural Gas (LNG) Safety Studies

J. G. DeSteese, D. J. McNaughton, P. J. Pelto

The Department of Energy Environmental Control Technology Division (DOE-ECT) is conducting a multicontractor program to develop liquefied natural gas (LNG) safety and environmental control information needed by industry, regulatory agencies, and the general public for decision making. In support of this goal, the objectives of the LNG Safety Studies Project are (1) to conduct research and development in specific areas, principally in LNG release prevention and release control, and (2) to provide assistance to the DOE-ECT in planning and technical surveillance of the program.

Research continued on the scope assessment for release prevention and control for the following LNG facilities: export terminal, marine vessel, import terminal, peak-shaving plant, and satellite plant. This research included a preliminary hazards analysis (PHA) and analysis of a generic system and representative release scenarios; The initial emphasis of the assessment was release prevention. The system descriptions outlined basic process flows, plant layouts, and process descriptions. The PHA identified critical release prevention components and operations. The representative release scenarios provided a format for discussing potential initiating events, effects of the release prevention and control systems, information needs, and possible design changes to prevent or reduce the consequences of a potential release.

The LNG vapor generation and dispersion model evaluation task has the following objectives: (1) to identify LNG dense gas models and differences among models and (2) to examine the sensitivity of these models to various input parameters for setting priorities for future research. The development of analytical procedures progressed, and the preliminary test case selection was completed. Preliminary tests were selected for three cases: (1) instantaneous unconfined water spills, (2) continuous unconfined water spills, and (3) continuous confined land spills. The selection of the preliminary test cases were based on (1) choice of parameters that can be traced through all model components, (2) choice of input parameters suspected of being critical to the prediction of LNG hazards, and (3) choice of the minimum number of cases required to show main parameter effects and interactions.

Literature surveillance and the development of an LNG library continued. Quarterly supplements to the "LNG Annotated Bibliography" and additions to the "LNG Safety and Control Literature and Research Updates" were completed.

Assistance was provided in the preparation of the DOE publication "Liquefied Gaseous Fuels Safety and Environmental Control

Assessment Program: A Status Report," (DOE/EV-0036). This effort included the collection of input from other contractors, minor editing, reproduction quality enhancement, the preparation of an introduction, and the incorporation of five status reports on project activities. The camera-ready report was assembled and sent to DOE Headquarters for printing.

Many of the safety and environmental issues identified for LNG appear to apply to the handling of other liquefied gaseous fuels and energy materials. Assistance was provided in planning the DOE Ammonia Safety and Environmental Control Assessment Program.

● Liquefied Petroleum Gas (LPG) Safety and Environmental Research and Development (R&D)

The project's objective is to assist the Department of Energy Environmental Control Technology Division in developing a program plan that addresses safety and environmental concerns relating to the production, transportation, and storage of Liquefied Petroleum Gas (LPG). Contributions to the preliminary report included descriptions of production, import/export, and peakshaving plants, together with pipeline, barge, ship, rail, and truck transportation systems. Summaries of the current status of LPG Safety Research and Development were provided in vapor generation and dispersion, fire hazards, release prevention, and release control.

Liquefied Petroleum Gas (LPG) Safety and Environmental Research and Development

J. G. DeSteese

The overall objective of the project is to evaluate safety and environmental control issues relating to the production, transportation, and storage of Liquefied Petroleum Gas (LPG). The resulting information will support the Department of Energy Environmental Control Technology Division in developing a research and development (R&D) program plan for LPG safety and environmental concerns. Objectives of this project in FY 1979 were to characterize the LPG industry and to summarize the status of current LPG safety and environmental R&D activities.

As used by industry, the term "Liquefied Petroleum Gas" includes propane, butane, and various propane-butane mixtures. LPG is grouped with natural gasoline, ethane, and other materials under the term "Natural Gas Liquids (NGL)." About 75% of these products are obtained from domestic natural gas sources. The remainder is represented by "Liquefied Refinery Gases," produced from petroleum sources and foreign imports.

Data from the Gas Processors Association (GPA) indicate that the total production of NGL has declined slightly since a peak in 1972, but overall has been quite stable since 1974. The GPA also reports that underground storage of light hydrocarbons (such as LPG) has been increasing at about 8% per year and reached an estimated capacity of 375 million hbls by the end of 1977.

Because about 75% of the LPG conies from natural gas sources, its production is very closely related to natural gas production. The GPA expects a growing deficit between consumption and domestic production with a resulting growth in LPG imports. Therefore, the principal growth in LPG is expected in large volume transportation and storage.

Started in July 1978, this project has involved the efforts of two subcontractors. Battelle Columbus Laboratories (BCL) has supplied system descriptions of LPG transportation by pipelines, rail, and trucks. In addition, BCL provided assessments of the R&D state of the art in LPG vapor generation, dispersion, fires and explosions, and release prevention and control. The Institute of Gas Technology contributed descriptions of production, import/export, and peakshaving plants, together with barge and ship transportation systems.

• Burning of Oil Spills

The purpose of this feasibility assessment project is to provide scientific data and guidelines on oil spill combustion that are useful to those who must make decisions on employing the technology or allowing research directors to establish needs and priorities. A 700-page report, which includes more than 60 figures and nearly 50 tables, has been prepared; the report also includes detailed appendices and an annotated bibliography. The report has been reviewed and critiqued by specialists in the United States and abroad, and the final form is in publication. Areas for future investigation include radiant heat enhancement theory applied to oil slicks, proposed oil combustion classification verification studies, and oil spill mitigation by prevention evaluation. The project is expected to continue through FY 1980 with the majority of the technology review work being reported early in FY 1981.

Combustion: An Oil Spill Mitigation Tool

C. H. Thompson, G. W. Dawson, J. L. Goodier

The use of combustion as a tool for mitigating pollution from oil spills has been rarely employed, and the success of the application has been reported by few but questioned by many. Pollution control literature is limited in its scientific content explaining the oil combustion mechanisms and providing explanations of success or failure of oil burning attempts. Fire research literature is primarily directed toward control, not promotion, of fire, and to structural surfaces behavior, not the fuel source, e.g., the petroleum pool. The scope of our studies covers the application of combustion to the oil cargo of a stranded or wrecked tanker, oil released into or upon water, and oil-contaminated debris requiring disposal.

The objective of our report is to meet needs established by the Department of Energy (DOE) and the U.S. Coast Guard (USCG). DOE defined the objectives as follows: to gather existing information on actual experiences in the use of combustion as an oil spill mitigation tool, to examine the technical feasibility of using the technique based upon reviews of existing response tools and experience, to investigate the combustion phenomena and explain why the technique is reported with variable success, to prepare a reference text including an annotated bibliography of relevant work, and to identify significant issues that must be considered in using the technology. USCG defined the objectives as follows: to develop a mathematic model for the burning of oil on water that addresses all environmental and thermodynamic factors as well as the properties of the oil, to identify types of oils amenable to spill response by combustion, to determine conditions favorable to using combustion, to develop limitations or precautions for using existing technology, and to provide practical guidance on how to use combustion technology. Both DOE and USCG set as objectives: to determine what related research was being conducted, to identify gaps in existing research and development, and to explore the ethical basis of using such technology.

The report has been prepared in two parts: (1) Practical Guidance and (2) Theory and Evaluations. The second part serves as the detailed reference for the Guidance. Spill incident and case history data are provided in Part 2 to establish a magnitude and context for considering the use of combustion. Theoretical explanations are offered that allow a classification of oils by their combustibility potential and provide a quantitative assessment of the amount of energy necessary to ignite and sustain a given oil pool fire under various weather conditions. The technology available to employ combustion is documented, and these tools are evaluated in comparison to other nonburning spill responses. To assist the responsible on-scene official in making the evaluation to use combustion as an oil spill mitigation tool, three situations were considered. Pertinent information is presented in decision-tree format for (1) information elements for in-situ tanker oil burning, (2) burning oil released upon water, and (3) burning oil-contaminated debris.

Oil spill slick movement has received much more modeling attention than combustion. A review of oil spill movement models indicated major advances in predicting the movement of slicks but little quantitative work on the mechanisms of weathering. The factors of movement and environmental interactions are important for combustibility of oils because combustibility is inversely proportional to degree of weathering. With the principal factors identified from modeling attempts, the combustion process is expressed in a simplified relationship:

$$H_{comb} \propto H_{evap} + H_{sens}$$

where

H_{comb} = the heat released upon combustion of a unit of fuel,

H_{evap} = the latent heat of vaporization for that unit of fuel, and

H_{sens} = heat required to raise the temperature of the liquid fuel from ambient to its boiling point.

Based on evaluation of empirical data from pool fires, the above relationship was refined to provide a means for theoretical evaluation of combustibility of individual hydrocarbon mixtures. The equation is

$$0.02 \times H_{comb} = H_{evap} + C_p (B_p - T_a)$$

where

C_p = the specific heat of the fuel,

B_p = the boiling point of the fuel, and

T_a = the ambient temperature.

This relationship was used to propose an oil classification system to evaluate the potential success of initiating and sustaining an oil burn under a variety of conditions and to identify various concepts which may enhance the oil combustion process. The following categories of oils were defined:

Cat. No. 1 - those fuels from which ample excess heat is generated to easily meet heat requirements,

Cat. No. 2 - those fuels whose radiant heat back to the pool roughly equals the heat requirements, and

Cat. No. 3 - those fuels which, unaided, produce insufficient heat to meet the requirements for burning.

A detailed analysis of crude oil fractions allowed the proposal of a "break-even point" where the heat required equals the heat generated for the fractions remaining in the crude oil. This analysis indicated that oils with break-even points at 20% to 30% of fraction remaining are unlikely to sustain combustion, while oils with break-even points at 80% to 90% should readily burn.

Radiant heat transfer to oil slicks is shown to be more significant than conduction or convection and appears to have received minimal attention by manufacturers and practitioners of oil burning. It is suggested that if an increase of 1% or 2% in the radiant heat transfer could be accomplished, most, if not all, oils could be burned.

Losses due to volatilization are a prime factor in the weathering process. Vaporization theory was employed to determine changes in the combustibility of an oil over time, considering interactive factors such as wind speed. The ignition of Arabian light crude oil was evaluated as an example. Between 0.012 and 0.06 $cal/sec\text{-}cm^2$ of pool surface is required during the ignition phase along with a pulse input of 72 to 714 cal/cm^2 to account for initial heat losses.

The technical feasibility assessment in this study considered the probability of using burning technology compared to other nonburning alternatives. Case history experience was also used to assess usefulness, and it becomes evident that there will be major incidents where the combustion tool should be carefully considered and employed.

As a result of this study, it appears that oils may be grouped into the following general categories. Oils that:

- are easily amenable to burning (Category 1)
  - ..refined cuts having positive net heat available throughout their boiling temperature range
  - ..crude oil having a break-even point at greater than 67% by volume;

- are amenable to burning depending upon circumstances and some limited use of combustion promoters (Category 2)
  ..refined cuts having at least a positive net heat available at the upper boiling point of the fraction
  ..crude oil having a break-even point at greater than 40%, less than 67%;

- require considerable effort and repeated use of combustion promoters to burn (Category 3)
  ..refined cuts having a negative heat available throughout the fraction boiling range
  ..crude oil having a break-even point at 40% or less.

The technical feasibility of burning oil in-situ in tankers, on water, and as contaminated debris was prepared by listing conditions and circumstances most favorable to burning and then comparing the burning technique to other response techniques in a relative ranking matrix. The feasibility of burning oil in-situ tanker is a promising concept which is yet to be fully demonstrated and requires investments to be included as a viable oil spill mitigation tool. Burning oil on water is a technically justified concept for categories of oil under certain environmental conditions. Hardware and systems need refinement and demonstration. Burning oil-contaminated debris is proven feasible and its use is limited not by technology but by local environmental policy makers.

It appears that combustion as an oil spill mitigation tool becomes feasible considering social and economic factors if:

- The subject oil classifies in the first or possibly second category.

- Response action is taken within hours after oil is released.

- Such imminent and substantiated danger exists that intervention is justified.

- The burning site is remotely located from population.

- Weather is expected to change for the worse precluding time required for successful completion of other spill response alternatives.

- The volume of oil is beyond the capacity and capability of other response methods.

- Salvage operations are questionable or abandoned.

- Groundwater is too high to permit land fill burial of debris.

- Quantities and bulky characteristics of debris make land farming too costly.

- Local authorities will permit burning debris.

- Personnel experienced in oil burning and necessary equipment and material are on scene or available within hours.

- Because of age or damage the vessel is expected to be lost or at best scrapped.

- Vessel stability, weather, and cargo pose an unreasonable risk to responding personnel.

The ethics of using combustion as an oil spill mitigation tool have been described by examining concerns of responsible officials, economic considerations, and significant issues. The thirteen concerns raised by these officials plus other considerations have been reduced to eight issues on the use of combustion. Considerations both for and against burning provide the necessary framework upon which a decision-maker can be prepared to make rational determinations and predictable acceptance.

The prevailing attitude is that the technology is yet to be proven and therefore reluctance in its use can be anticipated. Experience cannot be gained and this attitude modified until there has been a sufficient investment of resources and reported success. The negative attitudes toward use of burning can be overcome if assurances can be given of the advantages and limitations of the technique for a specific incident. A good example of this is the concern for air quality, as expressed by officials, which would be temporarily relaxed if the technique works and results in a benefit to the local populous and the environment.

• Environmental Control Technology for Shale Oil Wastewaters

The capabilities and limitations of conventional treatment and disposal technology are being evaluated for shale oil wastewaters. Bench-scale treatability studies are being conducted to assess the effectiveness of alternative physical, chemical, and biological processes for removing pollutants from shale oil wastewaters. Toxicity problems previously experienced with aerobic biological treatment of in-situ retort water have been overcome through careful control of pH in the activated sludge aeration units and by a prolonged acclimation period to allow the biological sludge to adjust to the relatively harsh chemical nature of the retort water. Adding powdered activated carbon to the activated sludge units also helped promote biological degradation of both organic and inorganic constituents of the retort water samples tested.

Analysis, Screening, and Evaluation of Control Technology for Wastewater Generated in Shale Oil Development

B. W. Mercer, W. Wakamiya

Several different types of wastewaters may be generated in the mining and processing steps leading to the recovery of oil from shale. Retort water, produced during pyrolysis of oil shale, is generally the most heavily polluted waste stream; others, such as cooling water, may have a relatively low pollution potential. Most, or all, of these wastewaters can be used to moisturize spent shale from surface retorts, but disposal or reuse must be practiced for in-situ operations. The primary objective of this program is to assess the capabilities of state-of-the-art technology for the treatment and disposal of wastewaters generated in shale oil development.

Biological Treatment

Initial flow-through bench-scale biological treatment experiments were unsuccessful in achieving effective total organic carbon (TOC) removal hy activated sludge from retort water that had been steam stripped for ammonia removal. Toxicity problems were evident when attempts were made to acclimate the activated sludge units to mixtures of simulated and actual retort water. Removal of TOC fell off sharply as the concentration of actual retort water exceeded 50%. Anaerobic digestion of retort water also appeared to be adversely affected by toxicants in the retort water; however, a sample of retort water from a simulated retort was successfully treated by adding 2000 mg/ℓ of powdered activated carbon to the digester. High levels of sulfur (mostly thiosulfate) are believed to contribute to the toxicity problem with anaerobic digestion.

Subsequent fill-and-draw bench-scale studies on activated sludge demonstrated effective removal of TOC after a long acclimation period. For these experiments, mixtures of activated-carbon-treated retort water were used with untreated steam-stripped retort water and an activated sludge seed obtained from a petroleum refinery wastewater treatment plant. In addition, the pH was controlled within a range of 6.5 to 7.5 to facilitate the biodegradation of thiosulfate. Removal of TOC and chemical oxygen demand (COD) was about 45% and 65%, respectively, without powdered activated carbon addition to the activated sludge units. Addition of 300 mg/ℓ of powdered activated carbon increased TOC and COD removals to about 55% and 75%, respectively. Removal of thiocyanate (a good indicator of the "health" of the activated sludge) was increased from 67% to 99% by the addition of activated carbon. Ammonia levels increased by about 50 mg/ℓ through the activated sludge process (believed to result from biodegradation of nitrogenous organics and thiocyanate).

Activated Carbon Sorption

Bench-scale studies were conducted with effluent from the fill-and-draw activated sludge units to determine removal levels of residual refractory organics by granular activated carbon columns. The carbon columns consisted of a 1.8-cm diameter by 10-cm-high bed of 50 x 120 mesh Filtrasorb® 500 carbon and were operated at a flow rate of 3.9 mℓ per minute. Figures 6 and 7 illustrate TOC and COD removals, respectively, from both bio-treated and untreated steam-stripped retort water (SS effluent) with activated carbon. Treatment by activated sludge effectively complements activated carbon adsorption for removal of highly soluble organics that are not adsorbed well by activated carbon. The organics include salts of the lower aliphatic acids (e.g., acetate, propionate) prevalent in retort waters. Removal of COD is especially poor without biological treatment because thiosulfate is not adsorbed by activated carbon.

Treatment Studies

Bench-scale studies to evaluate steam stripping as a means of removing ammonia from retort water were continued with the 5-cm ID glass pipe packed to a depth of 61 cm with either 0.64- or 1.27-cm ceramic saddles. Feed to the stripper is introduced at the top of the column of saddles and is counter-currently contacted with steam generated by a reboiler at the bottom of the column. Steam, containing volatile constituents stripped from the feed, is removed from the top of the column, condensed, and collected in a condensate receiver. The condensate receiver is vented to a water trap and an acid trap in series to adsorb ammonia vapor carried over with noncondensable gases. The steam-stripped feed collects in the reboiler and is drawn off continuously to maintain the desired liquid level in the reboiler. Two operational modes were evaluated, one with recycle of the condensate and one without recycle. In the condensate recycle mode, the condensate is recycled by injecting it into the feed stream to the stripping column. Recycle of the condensate eliminates the necessity of a separate wastewater stream, but also reduces the efficiency of ammonia removal in the stripping column by increasing the ammonia concentration in the feed streams. The alternative of no condensate recycle results in an aqueous ammonia solution that contains volatile organic matter stripped from the retort water.

The results of studies with the 5-cm diameter stripper with several different process waters are presented in Table 3. The major difference between the two runs made with simulated in-situ process water is the addition of alkalinity in the case of condensate recycle. This alkalinity accounts for the higher effluent pH, which is critical to maintaining ammonia as free NH_3. Without the alkalinity addition, the

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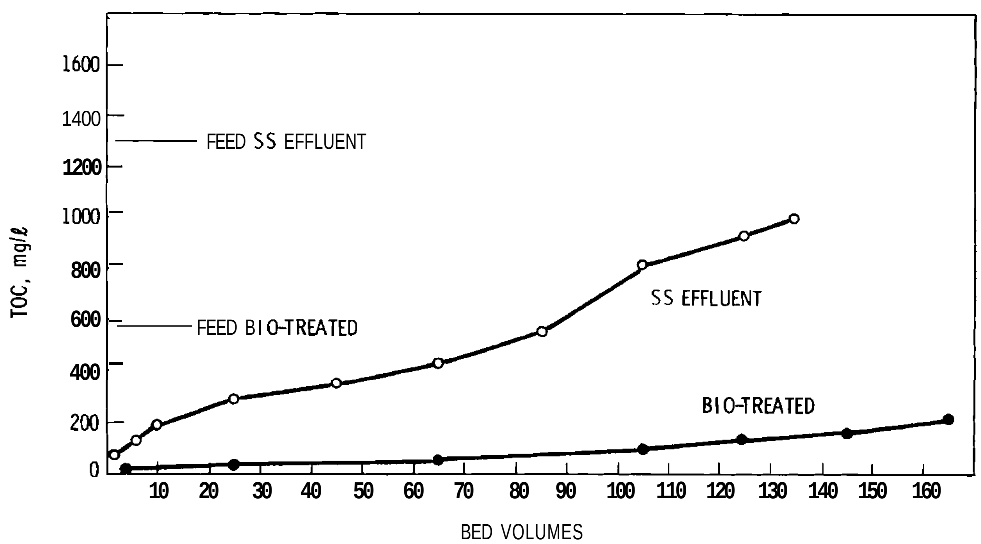

FIGURE 6. Activated Carbon Treatment Total Organic Carbon (TOC) Removal

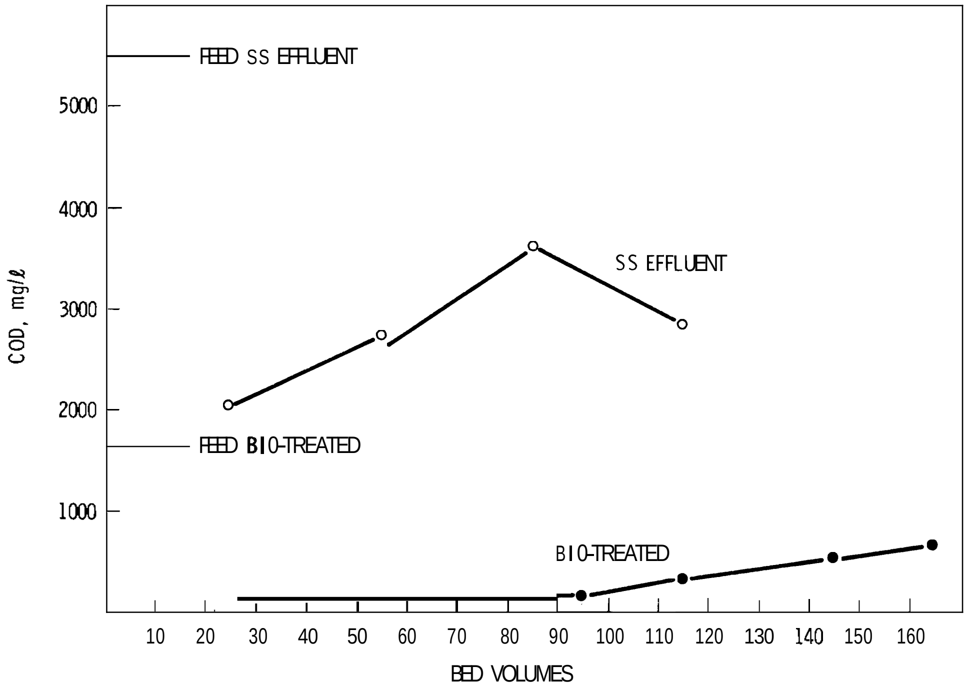

FIGURE 7. Activated Carbon Treatment Chemical Oxygen Demand (COD) Removal

performance with recycle and lower boiloff rate would have resulted in ammonia removal levels below 98%. With the alkalinity addition, it was possible to achieve 99.95% removal. The effect of alkalinity addition on steam stripping of simulated in-situ process water is illustrated in Figure 8. Without the addition of NaOH, the pH drops to 7.9, where some of the ammonia is in the fixed form and is not available for stripping. On the other hand, nearly all of the amnonia is availabie as free NH_3 above pH 9.5 and can be more effectively removed by stripping.

Steam stripping data in Table 3 for Utah in-situ No. 2 show the effect of recycle of the condensate at low boiloff rates. Ammonia removal was only 83% with recycle at a boiloff rate of 5%. Reducing the packing size for Utah in-situ No. 3 appeared instrumental in increasing the ammonia removal. Additional factors which may have contributed to the higher ammonia removal rate are the lower flow rate and a different composition of process water, although the primary controlling factor of pH was essentially the same for each wastewater. The stripper performance for Utah in-situ No. 4 was much improved over No. 3. This improvement is apparently due to small increases in the boiloff rate and pH. The pH from feed to effluent increases owing to the stripping of CO_2 from the $NaHCO_3$ present in Utah in-situ process water. Ammonia removal for the above-ground retort water was very poor since most of the ammonia is in the fixed form (NH_4^+) without sufficient carbonate

TABLE 3. Steam Stripping Results with 5-cm Column

Process Water	Stripper Packing Diameter[a] (cm)	Feed Rate (mℓ/min)	Boiloff Rate[b] (%)	Condensate Recycle	Feed pH	Effluent pH	Total Organic Removal (%)	Ammonia Removal (%)
Simulated in-situ	0.64	55	14	No	9.4	7.9	—	98
Simulated in-situ	0.64	45	11	Yes	9.5	10.2	18	99.95
Utah in-situ No. 2	1.28	100	8	No	8.8	9.7	—	99.5
Utah in-situ No. 2	1.28	110	5	Yes	8.8	9.7	—	83
Utah in-situ No. 3	0.64	57	5	Yes	8.7	9.6	19	96
Utah in-situ No. 4	0.64	51	6	Yes	8.6	10.0	17	99.5
Above-ground retort	0.64	27	30	Yes	8.5	6.2	—	38

[a] Intalox saddles
[b] Percent of feed

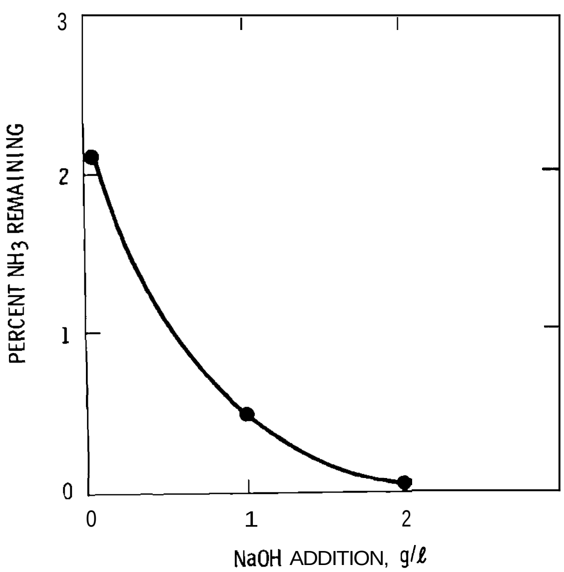

FIGURE 8. Effect of Alkalinity Addition on Ammonia Removal from Simulated In-Situ Process Water by Steam Stripping

alkalinity. Addition of inexpensive alkalinity in the form of lime to this water creates a large amount of calcium carbonate sludge. The formation of this sludge can be avoided and lime use minimized by removing the free ammonia first in a separate stripper or stripper section (which also removes CO_2), then adding lime to remove the fixed ammonia in another stripper or section of the stripper. Thus, removal of free and fixed ammonia from coking liquor is accomplished.

Evaporation of Retort Water

Feasibility tests on evaporation of retort water were initiated through a subcontract with Resources Conservation Company of Seattle, Washington. Evaporation of retort water appears to offer the best chance of recovering high-quality water in reasonable volumes for reuse. The high salinity of the in-situ retort waters studied renders these waters unsuitable for membrane processes such as reverse osmosis or electrodialysis.

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 (CAES) technology, to assess the potential impacts of these concerns, and to identify or highlight the need for technologies to prevent or control adverse impacts. Research efforts in FY 1979 concentrated on two waste disposal problems: (1) the disposal of brines produced when a salt cavern is solution mined for compressed air storage and (2) the disposal of waste rock produced when the storage cavern is mined from hard rock. Research in FY 1980 will focus on the effects of CAES facilities on surface and groundwater systems.

Compressed Air Energy Storage (CAES) Environmental Control Concerns

R. A. Craig, G. R. Keizur

Compressed air energy storage (CAES) is a technology for storing excess off-peak electrical energy in thermo-mechanical form and recovering it later for peak-demand period generation of electricity. During periods of low electricity demand, the excess capacity of a baseload generating plant would be used to power an air compressor train at the CAES facility. The compressed air would then be stored underground in porous media, such as aquifers, or in caverns mined from hard rock or solution mined in salt formations. During daily peak-load periods, the compressed air would be extracted, mixed with fuel, and burned in a combustion chamber. The hot combustion products would then be expanded through turbines for power.

As lead laboratory for research sponsored by the Department of Energy in compressed air energy storage, Pacific Northwest Laboratory established the Environmental Control Concerns Program. The objectives of the program include identification of the environmental factors (air- and water-borne releases, effects on geologic stability, and aesthetic and land-use considerations) associated with the use of CAES; quantification of the environmental impacts of these factors and establishment of a data resource useful for planning and siting CAES facilities; and identification of environmental control practices or areas of research leading to improved control practices.

During FY 1979, the full range of potential environmental concerns was surveyed, and a management plan was prepared. Research efforts concentrated on the characterization, handling, and disposal of waste materials generated in the construction of CAES reservoirs. Two waste disposal problems were investigated: the disposal of brines produced when a salt cavern is solution mined for compressed air storage and the disposal of waste rock when the storage cavern is mined from hard rock.

In analyzing the feasibility of brine disposal in underground formation, several factors were considered. First, suitable geologic formations were identified for use as injection sites, and possible effects of injection on the stability of these formations were assessed. Next, brine injection methods were investigated, and systems for monitoring the injected brine mass were discussed. Finally, legal/institutional factors (including the proposed Environmental Protection Agency Underground Injection Control Program [40 CFR Part 146]) were studied.

The analysis of environmental impacts of mined waste rock included identification of the rock formations that could be encountered in developing CAES facilities. Potential pollutants (including sulfides, radionuclides, asbestiforms, and suspended and dissolved solids) and their environmental impacts were assessed. Finally, control strategies were identified that could be used to mitigate these impacts.

Research efforts in FY 1980 will focus on the effects of CAES facilities on aquifers and surface waters, including possible contamination of aquifers in which CAES facilities are located and possible contamination of surface waters used in pressure-compensated systems. Also to be studied is the possibility of increased seismic activity from artificial increases and decreases of pore pressures.

Assessment of Energy-Conserving Industrial Waste Treatment Technology

The Water Pollution Control Acts Amendments (PL 92-500) require substantial treatment of industrial wastes. Most waste treatment processes have been developed with little regard for energy use. The objectives of this program are to provide an overview of current industrial pollution control practices, assess Department of Energy activities in this area, and prepare a plan on recommended alternative possibilities of energy-conserving industrial waste treatment processes. A comprehensive literature review was undertaken to establish an industrial priority list, develop industrial process diagrams, determine industrial pollutant discharges, and identify current study areas. Published data and information or data collected from industrial trade groups were used to develop the necessary data base. Possible industrial waste treatment areas were identified where additional research in energy-conserving processes is needed. In addition, the report examined the impact the Federal Water Pollution Control Act of 1977, the Clean Air Act of 1977, and the Toxic Substances Control Act of 1976 will have on industry.

Assessment of Energy-Conserving Industrial Waste Treatment Processes

B. W. Mercer, S. E. Petty

The energy required by industry to meet government regulations for pollution control during 1977 represents approximately 3% of the total energy consumed by industry. Although this currently amounts to only 1.3% of the total U.S. energy requirements, efforts are under way to implement energy-conserving technology into the industrial pollution control field. Energy consumption has not characteristically been a key parameter considered by industry for deciding the type of pollution control strategy to implement. Instead, the decision has been based on factors such as total cost, maintenance requirements, ease of operation, and dependability in controlling the pollutant. However, as the cost of energy increases in the future, energy consumption will play a major role in making decisions about pollution control and in determining operating costs. By developing and implementing energy-conserving pollution control alternatives now, the cost to industry and the related energy requirement can be maintained at a minimum as discharge standards become more stringent.

Many industries are currently involved in reviewing total in-plant use. This review shows that plant process modification and waste recovery can conserve significant quantities of energy. The potential energy savings through development and implementation of more energy-efficient pollution control systems are less significant. However, a general lack of hard data relative to pollution control energy requirements for the various industrial processes makes this analysis difficult to quantifv.

Prior to identifying specific areas of suggested Department of Energy involvement, the resultant energy savings must be placed in proper perspective by making industrial pollution control processes more energy-conserving. The total energy required by industry to meet government regulations for pollution control during 1977 represented approximately 2% of the total U.S. energy requirement. This amounts to a nominal value of 1.7 x 10^{15} Btu. Conservation efforts resulting in a 20% reduction in energy consumed for pollution control would save approximately the amount of energy required to produce about 5.5% of the steel produced in the U.S. during 1977.

Energy-conserving pollution control practices will not make available a large quantity of energy. Industrial process modifications and general housekeeping techniques would be much more productive. However, efforts to implement energy-conserving technology into the pollution control field will maintain energy consumption for pollution control at a minimum while discharge standards become increasingly more strict.

Therefore, further study is recommended. In order to achieve more energy conservation in the industrial pollution control field, the following steps should be taken: develop the capability to view the many pollution control alternatives on a comparative basis and modify or develop new energy-conserving pollution control technologies that offer an economic advantage to the user. Areas immediately amenable to such research efforts include sulfur oxide control, NO_x control, advanced wastewater treatment processes, high-temperature particulate collection, and collection of fine particulate matter.

Prior to FY 1979, the initial objective of the Energy-Conserving Industrial Waste Treatment research was to examine ten industries using significant amounts of energy for pollution control and to identify effluents produced by each of these industries and the most energy-effective methods available to reduce these effluents. FY-1979 research reflected recent enactments covering discharge of air and water pollutants by industry. In addition, an industrial survey was performed to gain insight into industry's impressions of recent Environmental Protection Agency regulations, to ascertain the degree to which industry would comply with these regulations, and to locate areas within the industries where research is needed for feasible methods of pollution control.

Analysis of Nuclear Fuel Cycles

The operation of nuclear fuel cycle facilities will introduce noxious materials, both radiological and chemical, into the environment through routine discharges of both liquid and airborne effluents. The environmental control implications of continuing to develop existing nuclear fuel cycles and implementing new fuel cycles must be systematically determined so technologies that control or eliminate the discharge of noxious materials to the environment can be quickly developed and demonstrated. The objective of this program is to identify areas in developing nuclear fuel cycles where (1) inadequate consideration is being given to environmental controls, (2) inconsistencies and conflicts exist in environmental policy, and (3) environmental control improvements can be justified on a cost/risk/benefit basis to ensure that funds are not expended for control in instances where neither the potential effects nor public concerns warrant such expenditures.

Alternative Fuel Cycles

M. A. Lewallen, A. M. Nolan

The objective of this task was to compare the environmental effects of effluents from reprocessing and fabrication of alternative light water reactor (LWR) and liquid nietal fast hreeder reactor (LMFBR) fuels. This task included a comparison of the environmental hazards of potential releases from a deep geologic repository for storage of wastes generated by fuel cycle facility operations.

Effluent quantities were estimated for a generic reprocessing plant and three different generic fuel fabrication/refabrication plants. Fifty-year dose commitments per MTHM resulting from a one-year release were determined for total body and four organs. Comparisons of the total body and bone dose commitments for the various fuel types are shown in Table 4 and Table 5, respectively; Table 6 shows the contents of the various fuel types.

The variations in dose commitnients for the reprocessing and ^{233}U fuel refabrication plants are a result of the differing quantities of ^{232}U in the fresh and spent fuels. This nuclide results from the irradiation of thorium and is present in spent thorium-based fuels and in uranium obtained from reprocessing these fuels. Variations in dose commitments for the fuel fabrication and plutonium fuel refahrication plants can be attributed to the quantity of ^{233}Th in each applicable fuel type. The LMFBR blankets produce lower reprocessing dose commitments because they are exposed in the reactor to a much lower burnup than the core regions.

Radionuclide groundwater concentrations as a function of time were estimated for the leaching of repository wastes from a bedded salt site. The concentrations were used to generate a biohazard index for comparison of potential environmental effects of the storage of fuel cycle waste resulting from the various fuel types. The waste considered in this task included high-level vitrified wastes and transuranic- (TRU) contaminated hulls and hardware from the fuel reprocessing plant, as well as TRU wastes from the fuel fabrication and refabrication plants. The results of the comparison of biohazards are shown in Table 7.

The variations in biohazard index at 2100 years are due to the quantity of ^{129}I in the wastes from each fuel type. At 37,000 years, the variations can be attributed to differing amounts of ^{233}U and ^{234}U in the waste, while ^{237}Np is the relevant nuclide at 230,000 years.

TABLE 4. Relative Fifty-Year Total Body Dose Commitments Per MTHM For a One-Year Release

Fuel Cycle Facility	LWR Fuel Type[a]							
	LEU	ReLEU	DU-Th	ReDU-Th	HEU-Th	ReHEU-Th	Pu-U	Pu-Th
Reprocessing Plant	1.0[b]	11	0.97	1.1	0.98	1.1	1.1	1.0
Fuel Fabrication Plant[c]	1.8	NA[d]	6.6	NA	7.6	NA	NA	NA
Fuel Refabrication Plant—Pu Fuels	NA	NA	NA	NA	NA	NA	1.0[b]	1.8
Fuel Refabrication Plant—^{233}U Fuels	NA	1.0[b]	NA	2.6	NA	3.0	NA	NA

Fuel Cycle Facility	LMFBR Fuel Type[e]				
	Inner Core	Outer Core	U Radial Blanket	U Axial Blanket	Th Radial Blanket
Reprocessing Plant	0.73	0.60	0.061	0.041	0.030
Fuel Fabrication Plant[c]	NA	NA	0.18	NA	6.8
Fuel Refabrication Plant-Pu Fuels	1.0	1.4	NA	2.8x10^{-8}[f]	NA
Fuel Refabrication Plant—^{233}U Fuels	NA	NA	NA	NA	NA

(a) Alternative LWR Fuels
- LEU is low enriched uranium oxide fuel containing some recycled uranium
- ReLEU is low enriched uranium oxide fuel containing high-activity recycled uranium
- DU-Th is denatured uranium-thorium oxide fuel
- ReDU-Th is denatured uranium-thorium oxide fuel containing high-activity recycled branium
- HEU-Th is highly enriched uranium-thorium oxide fuel
- ReHEU-Th is highly enriched uranium-thorium fuel containing high-activity recycled uranium
- Pu-U is plutonium-uranium oxide fuel
- Pu-Th is plutonium-thorium oxide fuel

(b) Reference fuel type for comparison. All comparisons are for equivalent control technologies.

(c) Reference fuel type for comparison is once-through (no recycle) LEU.

(d) NA means that this fuel type is not fabricated at this plant,

(e) Alternative LMFBR Fuels
- Inner Core is plutonium-uranium oxide fuel
- Outer Core is plutonium-uranium oxide fuel
- U Radial Blanket is depleted uranium oxide
- U Axial Blanket is depleted uranium oxide
- Th Radial Blanket is thorium oxide

(f) This fuel type is fabricated as an integral part of the core fuel elements.

TABLE 5. Relative 50-Year Bone Dose Commitments Per MTHM for a One-Year Release

Fuel Cycle Facility	LWR Fuel Type[a]							
	LEU	ReLEU	Du-Th	ReDU-Th	HEU-Th	ReHEU-Th	Pu-U	Pu-Th
Reprocessing Plant	1.0[b]	31.	79.	133.	96.	209.	1.8	37.
Fuel Fabrication Plant[c]	1.9	NA[d]	11.	NA	13.	NA	NA	NA
Fuel Refabrication Plant—Pu Fuels	NA	NA	NA	NA	NA	NA	1.0	1.7
Fuel Refabrication Plant—^{233}U Fuels	NA	1.0	NA	2.6	NA	3.1	NA	NA

Fuel Cycle Facility	LMFBR Fuel Type[e]				
	Inner Core	Outer Core	U Radial Blanket	U Axial Blanket	Th Radial Blanket
Reprocessing Plant	1.9	2.2	0.10	0.076	16.
Fuel Fabrication Plant[e]	NA	NA	0.20	NA	12.
Fuel Refabrication Plant—Pu Fuels	0.97	1.3	NA	1.6×10^{-8}[f]	NA
Fuel Refabrication Plant—^{233}U Fuels	NA	NA	NA	NA	NA

(a) Alternative LWR Fuels
- LEU is low enriched uranium oxide fuel containing some recycled uranium
- ReLEU is low enriched uranium oxide fuel containing high-activity recycled uranium
- DU-Th is denatured uranium-thorium oxide fuel
- ReDU-Th is denatured uranium-thorium oxide fuel containing high-activity recycled uranium
- HEU-Th is highly enriched uranium-thorium oxide fuel
- ReHEU-Th is highly enriched uranium-thorium fuel containing high-activity recycled uranium
- Pu-U is plutonium-uranium oxide fuel
- Pu-Th is plutonium-thorium oxide fuel

(b) Reference fuel type for comparison. All comparisons are for equivalent control technologies

(c) Reference fuel type for comparison is once-through (no recycle) LEU.

(d) NA means that this fuel type is not fabricated at this plant.

(e) Alternative LMFBR Fuels
- Inner Core is plutonium-uranium oxide fuel
- Outer Core is plutonium-uranium oxide fuel
- U Radial Blanket is depleted uranium oxide
- U Axial Blanket is depleted uranium oxide
- Th Radial Blanket is thorium oxide

(f) This fuel type is fabricated as an integral part of the core fuel elements.

TABLE 6. Relative Biohazard Indices for Waste Repository Effluents Per MTHM Charged to Reactor

Time After Generation of Waste (yr)	LWR Fuel Type[a]							
	LEU	ReLEU	DU-Th	ReDU-Th	HEU-Th	ReHEU-Th	Pu-U	Pu-Th
2,100	1.0 [b]	1.6	1.2	1.6	1.2	1.7	1.3	1.4
37,000	1.0 [b]	22.	10.	46.	1.1	41.	11.	32.
230,000	1.0 [b]	0.40	0.57	2.2	0.39	1.9	3.7	6.5

Time After Generation of Waste (yr)	LMFBR Fuel Type[c]				
	Inner Core	Outer Core	U Radial Blanket	U Axial Blanket	Th Radial Blanket
2,100	5.3	4.0	1.5	0.60	0.55
37,000	2.7	2.9	0.25	0.24	20.
230,000	3.4	4.8	0.65	0.082	0.0051

(a) Alternative LWR Fuels
LEU is low enriched uranium oxide fuel containing some recycled uranium
ReLEU is low enriched uranium oxide fuel containing high-activity recycled uranium
DU-Th is denatured uranium-thorium oxide fuel
ReDU-Th is denatured uranium-thorium oxide fuel containing high-activity recycled uranium
HEU-Th is highly enriched uranium-thorium oxide fuel
ReHEU-Th is highly enriched uranium-thorium fuel containing high-activity recycled uranium
Pu-U is plutonium-uranium oxide fuel
Pu-Th is plutonium-thorium oxide fuel

(b) Reference fuel type for comparison. All comparisons are for equivalent control technologies.

(c) Alternative LMFBR Fuels
Inner Core is plutonium-uranium oxide fuel
Outer Core is plutonium-uranium oxide fuel
U Radial Blanket is depleted uranium oxide
U Axial Blanket is depleted uranium oxide
Th Radial Blanket is thorium oxide

Light Water Reactor (LWR) Analysis

M. A. Lewallen, C. M. Heeb

An analysis of radioactive and nonradioactive substances projected to be released to the environment from the operation of all facilities in the light water reactor (LWR) nuclear fuel cycle from 1977 to 2076 was completed. Annual releases for some 250 nonradioactive substances and 175 radioisotopes were computed. Three nuclear generation scenarios were chosen, including the once-through, reprocessing without recycle, and reprocessing for full uranium and plutonium recycle options.

The entire set of substances was ranked according to a ranking criterion based on the 100-year sum of releases. The twenty highest radioactive and twenty highest non-radioactive substances were selected for more detailed analysis. The analysis includes a description of the present method of controlling each release and an assessment of available alternative methods for reducing effluents and, when cost information is available, the cost of implementing the alternative system.

Table 7 lists the twenty highest ranking radioactive effluents for the full recycle scenario. Table 8 shows the twenty highest ranking nonradioactive effluents. The analysis of the control of these effluents is contained in Heeb et al. (1979). In general, the most serious radioactive effluents came from the reactors and reprocessing plants, while the most serious nonradioactive effluents came from the head end of the fuel cycle, i.e., mining, milling, and enrichment.

TABLE 7. Twenty Highest Dose Nuclides for Full U and Pu Recycle

Order	Nuclide	Plant	Relative Ranking Factor For Total Body
1	^{3}H	FRP	2.07×10^{6}
2	^{138}Xe	BWR	5.01×10^{5}
3	^{85}Kr	FRP	1.73×10^{5}
4	^{14}C	FRP	1.18×10^{5}
5	^{88}Kr	BWR	1.02×10^{5}
6	^{135}Xe	BWR	7.93×10^{4}
7	^{3}H	PWR	6.59×10^{4}
8	^{87}Kr	BWR	5.42×10^{4}
9	^{134}Cs	PWR	4.25×10^{4}
10	^{90}Sr	FRP	3.90×10^{4}
11	^{135m}Xe	BWR	2.89×10^{4}
12	^{133}Xe	PWR	2.74×10^{4}
13	^{244}Cm	FRP	2.60×10^{4}
14	^{14}C	PWR	2.28×10^{4}
15	^{137}Cs	PWR	1.76×10^{4}
16	^{232}U	FRP	1.41×10^{4}
17	^{14}C	BWR	1.35×10^{4}
18	^{133}Xe	BWR	1.33×10^{4}
19	^{3}H	BWR	8.45×10^{3}
20	^{238}Pu	FRP	6.21×10^{3}

TABLE 8. Ranking of Dilution Factors for Nonradioactive Airborne Effluent: Full U and Pu Recycle

Rank	Dilution Factor (m^3)	Chemical Name	Plant
1	3.268×10^{15}	Ammonia	Uranium fuel fabrication
2	3.266×10^{15}	Sulfur oxides	Enrichment cascade
3	2.533×10^{15}	Nitrogen oxides	Reprocessing
4	1.950×10^{15}	Nitrogen oxides	Enrichment cascade
5	1.609×10^{15}	Uranium	Acid leach mill
6	1.257×10^{15}	Sulfur oxides	BWR
7	1.139×10^{15}	Rock dust	Surface mine
8	1.193×10^{15}	Rock dust	Underground mine
9	8.442×10^{14}	Sulfur oxides	Reprocessing
10	6.179×10^{14}	Nitrogen oxides	Aqueous conversion
11	5.029×10^{14}	Nitrogen oxides	BWR
12	4.555×10^{14}	Aldehydes	Surface mine
13	3.862×10^{14}	Nitrogen oxides	Acid leach mill
14	3.282×10^{14}	Hexane	Aqueous conversion
15	3.080×10^{14}	Aldehydes	Acid leach mill
16	2.953×10^{14}	Nitric acid	Uranium fuel fabrication
17	2.809×10^{14}	Hydrogen fluoride	Aqueous conversion
18	2.648×10^{14}	Aldehydes	Underground mine
19	2.875×10^{14}	Sulfur oxides	Aqueous conversion
20	2.277×10^{14}	Nitrogen oxides	Surface mine

Thorium/Uranium Environmental Control Technology

M. A. Lewallen, C. H. Bloomster

The objectives of the thorium/uranium Environmental Control Technology project are to (1) identify the major waste effluents associated with the mining, milling, and refining of thorium and low-grade uranium; (2) identify existing environmental control technologies for these effluents and determine their costs and the current levels of control; and (3) identify environmental control technologies that could be used to meet more stringent control standards and determine their costs as a function of the level of control. All three of these objectives are completed for thorium, and a summary report is being issued. The cost results are presented in Table 9. The lower cost figures are for state-of-the-art environmental control technology at each site.

The uranium part of the project is now focused on the first objective. The deposits to be included in the study are listed in Table 10. At this time, no representative site has been selected for phosphate rock; this work will be conipleted during FY 1981.

TABLE 9. Cost Range of Environmental Control for the Mining, Milling, and Refining of Thorium Resources

Location	Approximate Cost Range Cost/lb Thoria Produced[a,b]
Lemhi Pass	$0.63 - $40.65
Hall Mountain	0.28 - 16.35
Wet Mountain	0.34 - 18.96
Palmer, Michigan	0.46 - 2.13
Bald Mountain	4.29 - 26.22
Conway Granite	0.43 - 4.56
Stockpile Refinery[c]	0.15 - 1.98

(a) Minimum costs represent the base technology which is usually the most available, lowest cost, and simplest to employ (e.g., equipment constructed of mild steel, easy-to-move soil, good onsite availability of construction materials, no special protection from the environment, low contingency).

(b) Maximum cost is for the more effective, but usually more complex methods and includes up to 200% contingency on estimates.

(c) Does not include mining and milling environmental control costs.

TABLE 10. Low-Grade Uranium Deposits

Deposit	Type
Chattanooga, Tennessee	Black shale
Bokan Mt., Alaska	Peralkaline granite
Thomas Caldera, Utah	Volcanic rock
	Phosphate rock

REFERENCE

Heeb, C. M., et al. 1979. Analysis is in A Survey of LWR ECT Performance and Cost. PNL-2287, Pacific Northwest Laboratory, Richland, Washington.

Fusion Materials Cycle

M. A. Lewallen, V. L. Teofilo

The objective of this task is to evaluate environmental effluents released by the generation of fusion power. Early investigation of these effluents will reveal ways of not only controlling but also reducing the consequences of such effluent release. This task will identify the environmental control technology (ECT) requirements associated with all aspects of the fusion materials and resource cycle (fusion fuel cycle) of tokamak magnetic fusion power plants using deuterium and tritium fuel. Requirements for fusion power plant materials have been determined for two different tokarnak magnetic fusion reactor designs. Design 1 incorporates a liquid lithium-cooled blanket with no neutron multiplier, and design 2 uses a helium-cooled blanket with solid lithium aluminate breeding material and beryllium multiplier. The material requirements of these designs for initial inventory as well as periodic replacement have been determined for the principal fusion reactor materials: niobium, lithium, beryllium, helium, deuterium, and tritium. These requirements are summarized in Table 11.

The evaluation of the impact of supplying the materials in Table 11 to the fusion fuel cycle and the assessment of the adequacy of the presence of planned environmental control technology for reducing the associated effluents have been performed. The resource production facilities operate under existing standards for liquid, solid, and airborne effluent releases. The major effluents of any significance are airborne effluents. An estimate of the effluent concentrations corresponding to annual fusion power plant requirements are shown in Table 12. When compared to the maximum ambient air concentration levels allowed under current regulations or recommendations as shown in Table 13, the present or planned ECT appears to be adequate.

TABLE 11. Fusion Material Balance

Material	Design Option 1 Inventory (MT/1000 MWe)	Design Option 1 Replacement (MT/1000 MWe-yr)	Design Option 2 Inventory (MT/1000 MWe)	Design Option 2 Replacement (MT/1000 MWe yr)
Nb	45	0	45	0
Li	730	1	500	22
Be	0	0	235	12
He	50	0.086	60	0.270
	(kg/1000 MWe)	(kg/1000 MWe-yr)	(kg/1000 MWe)	(kg/1000 MWe-yr)
D	8	92	4.8	92
T	∿16	∿140	∿10	∿140

TABLE 12. Effluent Concentrations Corresponding to Annual Fusion Requirements

Effluent	Air Concentration ($\mu g/m^3$)
$LiAlSi_2O_6$ dust	2×10^{-5}
Li_2CO_3 dust	2×10^{-5}
Li_2NaPO_4 dust	3×10^{-6}
Particulates	0.18
CO_2	0.13
SO_2	1×10^{-5} (a) 1.3×10^{-2} (b)
Nb dust	6.3×10^{-6}
HF	1.2×10^{-3}
NH3	2.6×10^{-2}
Be ore dust	4.1×10^{-6}
$Be(OH)_2$ dust	5.6×10^{-4}
D	3.0×10^{-6}
H_2S	$<<10^{-5}$
NOx	4.4×10^{-3}
T (gaseous)	$<<10^{-10}$ $\mu Ci/cm^3$
(water)	$<<10^{-6}$ $\mu Ci/cm^3$

(a) Li production
(b) D_2O production

TABLE 13. Maximum Ambient Environmental (Air) Concentrations Allowed Under Current Regulations(a)

Li(LiH)	25 $\mu gr/m^3$ (b)
Nb	.05 mg/m^3
Be	.01 $\mu g/m^3$
T	4×10^{-5} $\mu Ci/m\ell$
D	No standard
Particulates	75 $\mu gr/m^3$ (c)
SO2	80 $\mu gr/m^3$ (c)
CO_2	9000 mg/m^3
NOx	100 $\mu gr/m^3$ (c)
HF	3 ppm
NH_3	18 mg/m^3
H_2S	15 mg/m^3

(a) Annual average
(b) Eight-hour, time-weighted average, occupational number only
(c) Particulates, SO_2, and NOx standards vary according to state or region

• Transportation Safety Studies

In order to ensure adequate protection of man and the environment in the transportation of energy materials, it is neceessary to understand the safety and potential environmental effects of the shipments of energy materials, both in normal transport and under accident conditions. The objective of the Transportation Safety Studies Project is to assess these potential effects in terms of risk. The initial objective of this program was to develop and use a model to assess the risk associated with the shipment of radioactive materials, although the scope of the program has since been expanded to include transport of non-nuclear energy-related materials. The technique of risk analysis was chosen for assessing the safety of transporting energy materials. Risk is defined as the probability that an undesirable event will occur, multiplied by the type and degree of consequence. Final reports were published this fiscal year on the risk of shipping gasoline by truck, the risk of shipping spent fuel by truck, and a conceptual design of a rail cask for shipping solidified high-level wastes. Studies were also conducted on the risk of transporting spent fuel by train, the risk of shipping chlorine by train, the risk of shipping propane by truck and train, documentation of the Transportation Risk Evaluation Code (TRECII), and the risk of shipping uranium ore concentrates by truck. Studies were also undertaken to assess the risk of shipping Department of Energy transuranic wastes, to assess the risk of shipping low-level reactor wastes, and to characterize the transportation requirements for the nuclear fuel cycle.

Safety Aspects of Transporting Potentially Hazardous Energy Materials

R. E. Rhoads, W. B. Andrews, H. K. Elder, C. A. Geffen-Fowler, A. L. Franklin, J. Greenborg, J. M. Olyear

Work was conducted on eleven transportation safety studies during FY 1979: (1) the risk of transporting gasoline by truck, (2) the risk of shipping spent fuel by truck, (3) the risk of shipping spent fuel by train, (4) the risk of shipping propane by truck and train, (5) the risk of transporting chlorine by train, (6) a conceptual design of a shipping container for transporting high-level waste by rail, (7) documentation of the Transportation Risk Evaluation Code (TRECII), (8) the risk of shipping uranium ore concentrates, (9) the risk of transporting low-level reactor wastes, (10) the risk of transporting Department of Energy transuranic wastes, and (11) characterization of the transportation systems in the nuclear fuel cycle. A brief summary of each analysis follows.

An Assessment of the Risk of Transporting Gasoline by Truck

R. E. Rhoads

The peer review of the draft report was completed, necessary revisions were made, and the final report was published. The analysis predicted that about 28 fatalities per year would result from gasoline tank truck shipments in the mid-1980s. This risk level was found to be lower than many other risks in society from man-caused and natural events. This analysis used the detailed fault-tree analysis methodology employed in previous studies in this project. The results were in agreement with available historical data.

An Assessment of the Risk of Shipping Spent Fuel by Truck

H. K. Elder

Peer review of the draft report was completed and the final report was published.

The risk to the public in the mid-1980s from spent fuel shipments was found to be much lower than risk from many other man-caused or natural events.

An Assessment of the Risk of Shipping Spent Fuel by Train

H. K. Elder

The analysis of the risk from train shipments of spent fuel in the mid-1980s was completed. The results showed that the risks from train shipments of spent fuel were comparable to the risks from truck shipments, although larger consequences are possible because of the larger spent fuel inventories in the train cask.

An Assessment of the Risk of Shipping Propane by Truck and Train

C. A. Geffen-Fowler

The analysis of the risk of transporting propane by truck and train was completed. The analysis predicted about nine fatalities per year from propane shipments in the mid-1980s. This risk level was found to be less than the risks from many other man-caused and natural events.

An Assessment of the Risk of Transporting Chlorine by Train

W. B. Andrews

The analysis of the risk of shipping chlorine by train was completed. The analysis predicted that about eleven fatalities per year would occur from chlorine rail shipments in the mid-1980s.

Conceptual Design of a Shipping Container for Transporting Solidified High-Level Waste by Rail

R. E. Rhoads

Reviews of the draft report were completed and the final report was published in December as PNL-2244 (Peterson and Rhoads 1978).

Documentation of the Transportation Risk Evaluation Code (TRECII)

A. L. Franklin

Modifications were made to the Transportation Risk Evaluation Code (TRECII) to improve user interfaces and running efficiency and to make the code compatible with new computing equipment at Hanford. The code is used to perform consequence evaluations and final risk calculations for risk assessments of radioactive material transportation systems.

An Assessment of the Risk of Transporting Uranium Ore Concentrates

C. A. Geffen-Fowler

An assessment of the risk of transporting uranium ore concentrates was completed. This analysis used a less detailed risk assessment methodology, permitting overview-type risk studies to be performed in less time than our previous methodology required.

An Assessment of the Risk of Transporting Low-Level Reactor Wastes

J. Greenborg

The analysis of the risk of transporting low-level reactor wastes was completed. This analysis also used the revised transportation risk assessment methodology.

An Assessment of the Risk of Transporting DOE Transuranic Wastes

W. B. Andrews

The analysis of the risk of transporting contact-handled DOE transuranic wastes was completed. The analysis was based on transportation using existing shipping systems.

Characterization of Nuclear Fuel Cycle Transportation Systems

J. M. Olyear

This task developed basic system description information needed to perform risk assessments of nuclear fuel cycle transportation systems.

Plans for Next Period

All tasks currently in progress will be completed, and final reports of the results of research in these tasks will be published. This will complete research in this project.

REFERENCE

Peterson, P. L., and R. E. Rhoads. 1978. Conceptual Design of a Shipping Container for Transporting High-Level Waste by Railroad. PNL-2244, Pacific Northwest Laboratory, Richland, Washington.

● Assessment of Environmental Control Technologies for Koppers-Totzek, Texaco, and Winkler Coal Gasification Systems

Commercial coal conversion processes employing Koppers-Totzek (K-T), Texaco, and Winkler gasifiers were reviewed to determine the availability of environmental control technologies for meeting current release standards. Information on material and energy flows in the conversion processes was obtained from manufacturers of the gasifiers and from the literature. Technologies for control of releases to air, land, and water are commercially available and are adequate for meeting current environmental release standards. The behavior of trace elements in the coal feed has not been adequately characterized. A final report has been completed that defines areas where improvements of technology would benefit the conversion processes. Construction of a demonstration plant employing these technologies for ammonia production is recommended.

Data Search on Gasifiers to Generate Synthesis Gases

L. K. Mudge, L. J. Sealock

Data on material and energy flows in commercial plants that use Winkler, Texaco, or Koppers-Totzek (K-T) gasifiers to generate synthesis gas were obtained by contacting manufacturers of these gasifiers and by searching the literature. The objectives of the study were (1) to determine if environmental control technologies in commercial use are adequate relative to existing and proposed standards, (2) to identify areas where improved control technologies are needed, and (3) to rank research and development programs in terms of their potential benefit.

The project is now completed and is available (Mudge and Sealock 1979).

REFERENCE

Mudge, L. K., and L. J. Sealock. 1979. Assessment of Environmental Control Technologies for Koppers-Totzek, Winkler, and Texaco Coal Gasification Systems. PNL-3104, Pacific Northwest Laboratory, Richland, Washington.

Operational and Environmental

Compliance

OPERATIONAL AND ENVIRONMENTAL COMPLIANCE

- **Guidelines for Radiation Exposure—ALARA**
- **Environmental, Safety, and Health Standards for Geothermal Energy**
- **Personnel Dosimetry Calibrations**
- **DOE Decommissioning Criteria**
- **Analysis of Criticality Safety**
- **Handbooks on Effluent and Environmental Monitoring**
- **Health Physics Lead Laboratory**

The responsibility of the Department of Energy (DOE) Office of Operational and Environmental Compliance 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 Operational and Environmental Compliance Program contributes to these objectives through projects in the nuclear and nonnuclear areas. Nonnuclear research and development is assuming growing significance and in the future will constitute a major portion of the program. During 1979 the major emphasis was on developing criteria, instruments, and methods to assure that radiation exposure to occupational personnel and to people in the environs of nuclear-related facilities is maintained at the lowest level technically and economically practicable.

• Guidelines for Radiation Exposure — ALARA

A three-phase project was planned to assist the nuclear industry in ensuring that radiation doses to personnel shall be maintained "as low as reasonably achievable (ALARA)." Phase one (identification and characterization of radiation exposure activities) was completed in FY 1977. FY 1978 focused on the second phase of the project, a published summary of ALARA efforts at Department of Energy (DOE) facilities. The third and final phase of this project was completed during FY 1979, the preparation and publication of a comprehensive document entitled Guidelines for Reducing Radiation Exposures *to As Low As Reasonably Achievable (ALARA),* suitable for direct application by DOE contractors and other industrial users of radioactivity and radiation generating machines. The document provides direct guidance in program development and management, radiological engineering and operations, and program evaluation.

Technical Guidelines for Maintaining Radiation Exposures As Low As Reasonably Achievable (ALARA)

R. L. Kathren, J. M. Selby

The objective of this project was to provide comprehensive guidelines applicable to maintaining radiation exposures at Department of Energy (DOE) contractor facilities as low as reasonably achievable (ALARA). The first phase of the study, completed in FY 1977, identified and characterized radiation exposure activities at DOE sites. Phase two, carried out in FY 1978, was a published summary of ALARA activities at the sites. The final phase of the project was preparation and publication of comprehensive guidelines suitable for use by DOE management and field personnel, as well as contractor management and health physics personnel.

The guidelines are presented in the form of recommendations following an underlying discussion of risk, cost, and benefit in which general guidelines for optimizing radiation exposures using cost-benefit are given. For planning purposes, a minimum value of $2000 per cumulative dose-equivalent is given as the level or cost below which radiation protection measures are always ALARA. Appropriate organizational structures are suggested, and the need for commitment is stressed in the section on management and organization. To facilitate communication, and to further the achievement of personnel exposure goals, an ALARA coordinator or committee may be necessary.

Guidelines are also offered for education and training of both professional and technical personnel to meet the goals of ALARA. Technical sections of the document include radiological design, measurement of radiation in the field, operational health physics, and environmental protection. For design, criteria other than monetary (e.g. dollars per man-reni) are presented to assist design personnel in achieving maximum dose reductions with minimum cost. Recommended instrument specifications are given along with an operational health physics checklist to enable field personnel to rapidly evaluate whether a particular task has been adequately considered from a basic radiation-protection standpoint. The document also provides the application of ALARA guidelines to emergency preparedness and planning. Finally, the document can be used to evaluate radiological protection programs, including the setting of ALARA goals, and it gives 17 specific measures of ALARA and discusses the applications and limitations of each. While most of the program evaluation measures are based on dose-equivalent, new concepts, such as the physical area of radiation and contamination zones and radiation concentration-volume product, are developed as means of determining progress toward ALARA goals.

● Environmental, Safety, and Health Standards for Geothermal Energy

Environmental, Safety, and Health (ES&H) Standards have been identified and evaluated for their potential application to geothermal energy development. For this evaluation, the ES&H problem areas were subdivided into 14 topics: airborne emissions, liquid waste disposal and water pollution, blow-out/hot water and steam releases, subsidence and induced seismicity, noise, heat stress, sampling and analyses, falling hazards, electrical hazards, heavy equipment operations, soil effects and land-use planning, fire hazards, construction, and hazardous substances.

Environmental, Safety, and Health Standards Identification for Geothermal Energy

J. B. Martin, A. Brandstetter,
F. L. Thompson, R. A. Walter,
W. R. McSpadden, D. G. Quilici,
T. N. Bishop, D. C. Christensen,
N. E. Maguire, R. G. Anderson,
A. E. Desrosiers, B. D. Robertson,
P. A. Wright

The objective of this project is to identify and assess existing environmental, safety, and health (ES&H) standards that may be applicable to geothermal energy development. The standards were identified by reviewing applicable Environmental Protection Agency documents and the National Bureau of Standards publication, Index of U.S. Voluntary Engineering Standards.

These standards were assessed after a comprehensive evaluation of ES&H problems that have been encountered by the geothermal industry. In most cases, recommendations were made that either existing standards or modified standards should be applied to solve these problems. For specialized areas in which standards were found to be non-existent or inappropriate, research was recomnended to provide a suitable data base for the development of ES&H standards.

The problem areas have been subdivided into 14 topics, as shown in Table 1. Each report includes a detailed discussion of problems, an evaluation of the need for standards, an evaluation of the existing standards, and recommendations for application of the standards. Report Nos. 1, 2, 3, 4, 5, 6, and 11 were completed during FY 1978 and were summarized in last year's annual report. A brief summary of the remaining reports follows.

TABLE 1. Reports on EH&S Standards for Geothermal Energy

Report No.	Title	Code[a]
1	Airborne Emissions	E & O
2	Liquid Waste Disposal and Water Pollution	E
3	Blowouts/Hot Water and Steam Releases	E & O
4	Subsidence and Induced Seismicity	E
5	Noise	E & O
6	Heat Stress	O
7	Sampling and Analyses	E & O
8	Falling Hazards	O
9	Electrical Hazards	O
10	Heavy Equipment Operation	O
11	Soil Effects and Land-Use Planning	E
12	Fire Hazards	O
13	Construction	O
14	Hazardous Substances	O

(a) E = Environmental topics
O = Occupational safety and health topics

Report 7 - Sampling and Analyses

Several of the reports in this series deal with environmental and occupational health hazards that require sampling and analysis for their assessment. Since this was noted at the outset, it was decided to separate the sampling and analyses aspects of all the topics listed in Table 1 and summarize them in a single report. The report is divided into two major sections (environmental and occupational health) which identify the elemental, chemical, and physical parameters of concern in typical fluids and gases at a geothermal site. Each section discusses the rationale for sampling and analyses and develops a methodology for determining appropriate measurements, sensitivities, frequencies, and procedures.

Existing standards for analysis of fluids and gases were found to be adequate for the most part. However, standard sampling methods were not considered adequate for some of the unique sampling situations encountered in the geothermal industry, such as downhole or well-head sampling at elevated temperatures and pressures. Some of these unresolved problems are being addressed by another Pacific Northwest Laboratory study for the Department of Energy (Watson 1978).

Report 8 - Falling Hazards

Climbing and falling hazards are given special consideration in this series because they are the second largest category of compensation cases in industry. Every phase of geothermal energy development will include some types of climbing tasks and falling hazards that could disable or kill personnel. This report considered falls from heights, at ground level, and below ground level and falling objects that may occur during drilling, construction, and power plant operation and maintenance.

Existing standards were found to be well established and adequate for most geothermal operations. The remaining problem is the need for diligent application and enforcement of these standards. The geothermal industry can benefit from the experience and information gained from other industries; however, this is a new industry and some unique falling hazards may require development of special protective equipment or safety standards. For example, we recommended that a standard for drill rigs be modified to provide for working at heights during windy conditions.

Report 9 - Electrical Hazards

The frequency of electrical accidents is not particularly high, but they are often very severe. Since the major objective of the geothermal industry is to generate electricity, the potential for electrical accidents is significant. Construction operations are perhaps the most hazardous for personnel, equipment damage, and fire potential.

Electrical safety standards are well established and comprehensive. No deficiencies were identified in the existing body of standards. Recommendations were made that existing standards be applied to the geothermal industry with a strong implementation and enforcement program.

Report 10 - Heavy Equipment Operations

Serious accidents involving heavy equipment could occur during all phases of geothermal development. This report concluded that present standards are adequate if supplemented with safe practice guides. However, unless the standards are applied by management to strictly enforce safe practices and adequate equipment maintenance, the accident frequency and severity will probably be no better than the current accident experience in the construction and oil drilling industries.

Report 12 - Fire Hazards

The drilling and construction phases of geothermal development involve numerous flammable materials and sources of ignition. These hazards are generally well recognized and controlled by existing standards. Most codes and standards are directed toward the protection of property rather than life. However, these principles are effective in protecting personnel since early detection and suppression of fires reduce overall risk. No deficiencies were found in the existing body of fire codes and standards.

Report 13 - Construction

This report was designed to include all other occupational health aspects of construction that were not discussed in Report Nos. 1, 3, 5, 6, 7, 8, 9, 10, 12, and 14. Report No. 13 considers welding and cutting, hand tools, power tools, and material handling equipment. It also discusses personal protective equipment, sanitation, warning signs and barricades, illumination, first-aid, employee selection, training, and safety management. Existing standards for these topics were evaluated and found to be generally adequate for application to the geothermal industry. The major need is for a dedicated safety management program to implement and enforce the standards.

Report 14 - Hazardous Substances

A large number of substances used and generated in developing geothermal resources are potential occupational health and safety hazards. These hazards are increased by the high temperatures of geothermal and drilling fluids. One major problem is the hazard of potential skin contact and inhalation during handling of large quantities of materials, including highly toxic cheniicals, in drilling and geothermal fluid treatment operations. Another major problem is the hazard of exposure during handling and disposal of large amounts of chemical waste from geothermal operations. Additional possibilities for exposures occur in more conventional construction and maintenance operations, such as welding, sandblasting, and insulating operations.

Based on a review of the chemicals and their sources, the potential hazards from occupational skin exposure, ingestion, and inhalation were estimated, and the applicable standards and guides were identified. This study concluded that Occupational Safety and Health Administration (OSHA) standards are not completely adequate for the control of these potential hazards and recommended supplementing OSHA standards with existing standards and guides to prevent excessive exposures.

Although general information is available on many hazardous substances generated or used in the geothermal industry, data on the actual exposures of workers have not been published. Evaluations of employee exposures during geothermal development should be conducted to determine control requirements.

REFERENCE

Watson, J. C.. 1978. Sampling and Analysis Methods for Geothermal Fluids and Gases. PNL-MA-572. Pacific Northwest Laboratory. Richland, Washington.

• Personnel Dosimetry Calibrations

A data base of technical information will be developed for evaluating the calibration, design, and performance of dosimeters used at Department of Energy (DOE) facilities. A technical document will be prepared to provide guidance to DOE and DOE contractors in establishing personnel dosimetry calibration procedures. The American National Standards Institute, Inc. (ANSI 1978) will be used as a guide in establishing appropriate dosimeter calibration procedures.

Technical Guidelines for Personnel Dosimetry Calibrations

W. T. Bartlett, C. D. Hooker, J. W. Courtney, R. A. Fox, R. T. Hogan, J. P. Holland, R. C. Yoder, J. M. Selby

The objectives of the project are to improve dosimeter calibration methodologies, to evaluate the performance of dosimeters used by all Department of Energy (DOE) contractors, and to publish a guide for performing dosimeter calibrations. The radiation calibration techniques will be modified to conform with the ANSI N13.11 standard. These new techniques will incorporate several concepts that have not been used routinely in calibrations laboratories. First, a Dose Equivalent Index (DEI) must be assigned to each irradiated dosimeter; therefore, the irradiation procedure must provide for measurement of all the variables necessary for a dose assignment rem. In the past, only assignment of exposure in roentgens was required. Second, dosimeters must be backed by a tissue equivalent (T.E.) material rather than exposed in air. T.E. material backing of dosimeters more closely simulates the actual conditions of occupational radiation exposures. Finally, the DEI assignment must be accurate to within 5%, and certain sources and instruments must be calibrated by the National Bureau of Standards. The accuracy and intercomparison requirements necessitate an error analysis and quality control program.

The project has been divided into three phases to be completed over a three-year period. Phase I, Optimization of Calibration Techniques, was initiated in January of FY 1979 and will be complete in mid-FY 1979. Phase II, Development of a Dosimeter Performance Data Base, will begin late in FY 1980 and will be followed in FY 1981 by Phase III, Preparation of a Calibration Manual.

Optimization of Calibration Techniques

The requirements of the ANSI N13.11 standard necessitate the use of four radiation sources: gamma-ray, x-ray, beta, and fast neutron. In order to assign a DEI, the radiation emissions from each source must be characterized, and the contribution of radiation scatter from the exposure room area must be quantified. Correction factors for beam monitoring instruments, environmental conditions, and beam quality must be measured continuously. A process control system will be interfaced with each of the required sources. Without a process control system, the accuracy and quality control requirements of the standard could not be achieved. The characterization of the radiation fields and automation of the irradiation process will be completed before test dosimeters are received from DOE contractors

Developnient of a Dosimeter Performance Data Base

All DOE laboratories that process dosimeters will be requested to send dosimeters to be evaluated in accordance with the standard. A primary calibration of each dosimeter will be provided for the dosimeter processor before evaluation. The performance data will allow analysis of the ability of each dosimeter processor to provide an accurate assessment of DEI under specified conditions.

Preparation of a Calibration Procedure Manual

The irradiation techniques used in the study will be documented for review and publication. The resulting information will permit a uniform approach to radiation calibrations by DOE laboratories.

REFERENCE

The American National Standards Institute (ANSI), Inc. 1978. ANSI N13.11.

• DOE Decommissioning Criteria

This project was launched in the last quarter of FY 1979 to prepare a Guide for use by Department of Energy (DOE) staff and contractors in the planning and implementation of decontamination operations and the certification of decommissioned DOE facilities and sites. "Proposed Numerical Guidance," a listing of basic radiation standards to be met for all release conditions, was prepared and work began on the proposed Guide.

Criteria Development for DOE Decommissioning Operations

D. H. Denham, J. P. Corley, E. C. Watson

The primary objective of this project is to prepare a Guide for use by the Department of Energy (DOE) and its contractors in conducting decommissioning operations. This Guide will provide a uniform basis for assessing hazard inventories, developing cost/benefit ratios and risk analyses, decision making, monitoring for compliance, and certifying of decommissioning activities. While initially addressed to radioactive contaminants, this work will, in all likelihood, be expanded to address other contaminants. The work to be performed at Pacific Northwest Laboratory (PNL) will include (1) a listing of basic radiation standards to be met (as agreed upon with the sponsor); (2) recommendations for appropriate records generation and maintenance; (3) selection and evaluation of methods for estimating occupational radiation exposures during decommissioning operations and for estimating environmental exposures prior to, during, and subsequent to decommissioning operations, including unplanned releases; (4) review and evaluation of methods derived by Oak Ridge National Laboratory under Nuclear Regulatory Commission (NRC) contract for confirming radioactivity levels, including statistical design, sampling techniques, and instrumentation performance criteria; (5) simplified methods for determining specific numerical guidance for decontamination and/or release, for both exterior and interior surfaces and for bulk materials; (6) application of recommended methods to an example site; and (7) incorporation of above tasks into a Radiological Guide for DOE Decommissioning Operations.

The initial phase has involved review and evaluation of previous and ongoing efforts in decontamination and decommissioning, especially the DOE/EV-0005 series of reports on "Formerly Utilized MED/AEC Sites Remedial Action Program" and the NRC-sponsored studies PNL currently has in progress on the "Technology, Safety and Costs of Decommissioning Reference . . .(PWR, fuel fabrication, and reprocessing) Plants."

The PNL team for this project reviewed and provided comments to the authors and sponsor of Los Alamos Scientific Laboratory's recent draft, "Interim Soil Limits for D&D Projects," and helped prepare recommendations for decontamination criteria and instrument survey techniques for the old New Brunswick Laboratory site based on those interim limits.

• Analysis of Criticality Safety

The results of a previous study on 100 violations of criticality safety specifications covering a ten-year period in the operations of a fuels reprocessing plant were summarized (Lloyd, Heaberlin and Clayton 1979). The previous data collection was broadly expanded during the year to include over 400 violations covering various other operations within Department of Energy facilities. With this broader, more complete data base, a more definitive result of the status of overall criticality safety will be possible. The additional data collected during the year are being used in a fault-tree analysis in which causes are assigned frequency values. On completion of the analysis, the most frequent causes of violations can be identified and suggestions made to effect further improvements in criticality safety control.

Analysis of Criticality Safety

R. C. Lloyd, E. D. Clayton, W. E. Converse

The objective of this program is to develop and apply a systematic method to analyze the criticality safety program in Department of Energy (DOE) facilities. An analysis of past data on criticality safety violations, in terms of criticality safety philosophy and the human and mechanical factors involved, permits judgments that may help reduce the number of future violations. Furthermore, these data may be used in a fault-tree analysis in which causes are assigned frequency values. Thus, when the most frequent causes of violations are identified, corrective action can be taken to eliminate them.

Fault-tree analysis is a form of risk assessment in which the pathways to the failure of a system are identified (failure is the occurrence of a criticality accident). The fault-tree is developed from the various conditions, events, and components leading to an accident, even though there may be little experience with complete failure of the system. This risk-assessment technique is well suited for analyzing criticality safety. A study is being conducted on the overall criticality safety at DOE facilities. The sites have been visited and discussions held with criticality safety experts in the field. The data accumulated on 400 criticality safety violations are currently being analyzed for inclusion in the fault tree. Two reports on a similar but less comprehensive study have been made to date (Lloyd, Heaberlin and Clayton 1979, and Lloyd et al. 1977). The collected data will be analyzed with the ACORN and MFAULT computer codes (Carter 1977 and Pelto and Purcell 1977). From these analyses, the probability of the inadvertent occurrence of criticality can be estimated and the most likely contributing events identified. With this knowledge, suggestions can be made to effect further improvements in criticality safety control.

REFERENCES

Lloyd, R. C., S. W. Heaberlin and E. D. Clayton. 1979. "Assessment of Criticality Safety." Nuclear Technology 42.

Lloyd, R. C., et al. 1977. "Criticality Safety Assessment." Trans. Nuc. Soc. 427:404-405.

Carter, J. L. 1977. ACORN: A Computer Program for Plotting Fault Trees. BNWL-2144, Pacific Northwest Laboratory, Richland, Washington.

Pelto, P. J., and W. L. Purcell. 1977. MFAULT: A Computer Program for Analyzing Fault Trees. BNWL-2145, Pacific Northwest Laboratory, Richland, Washington.

• Handbooks on Effluent and Environmental Monitoring

Issue of the draft *Guide* for Effluent Monitoring at DOE Installations was postponed pending resolution of further regulatory requirements. Analysis and evaluation of CY-1978 annual environmental surveillance reports from Department of Energy (DOE) nuclear sites was approximately 50% completed. A draft Executive Summary of 1977 environmental impacts from all DOE nuclear sites was completed.

Handbooks of Recommended Practices for Environmental and Effluent Monitoring and Reporting

J. P. Corley, D. H. Denham, B. V. Andersen, G. W. Schwendiman

The objectives of this program are to provide

1. suggested methods and procedures to bring greater uniformity and comparability to Department of Energy (DOE) contractor systems for environmental and effluent radiological monitoring and reporting, and

2. guidelines of suggested environmental and effluent radiological monitoring practices for the Office of Operational and Environmental Safety.

Effluent Guide

Continuing uncertainty as to eventual regulatory requirements stemming from the 1977 amendments to the Federal Water Pollution Control Act and Clean Air Act caused further delay in issuing the Draft Guide. Sections on criteria and on specific monitoring methods may require revision. By agreement with the sponsor, further draft revisions and a workshop for Department of Energy field office and contractor staff were postponed to FY 1980.

Environmental Guide

Analysis of the CY-1978 annual environmental reports and supporting surveillance programs for the 29 DOE nuclear sites that reported was approximately 50% completed. Evaluations and comparisons were made against both the requirements of former Energy Research and Development Administration (ERDA) Manual Chapter 0513 (being reissued as DOE Orders Chapter XVIII) and the Environmental Surveillance Guide ERDA-77-24. Usefulness of the Environmental Surveillance Guide, previously prepared under this project, continued to be demonstrated by requests for the document and referencing. Comments and suggestions for use in a FY-1980 revision of ERDA-77-24 continued to be solicited.

DOE Executive Summary of Environmental Impacts

A draft executive summary of CY-1977 environmental impacts from all 29 DOE nuclear sites was prepared for issuance as a DOE document. It included site maps, brief site and operations descriptions, tabulations of radiation doses to individuals and the population (within an 80 km radius), and quantities released for both radioactive and nonradioactive pollutants.

• Health Physics Lead Laboratory

Pacific Northwest Laboratory functions as the lead laboratory providing health physics support and assistance to the Division of Operational & 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

Analysis of Impact on Department of Energy (DOE) Facilities and Programs Resulting From a Reduction in the Dose Equivalent (DE) Limits

J. M, Selby, G. E. Backman, K. R. Heid, J. B. Martin, I. C. Nelson, E. E. Oscarson, H. L. Wedlick, Ad Hoc Headquarters Committee

The Department of Energy (DOE) conducted a study of the impact of reducing the occupational radiation exposure limit from 5 rem/yr to 2.5, 1.0, and 0.5 rem/yr, respectively. Many years of radiation exposure experience in all phases of nuclear energy applications were surveyed to evaluate the impact of reducing the present DOE limit of 5 rem/yr.

Since DOE programs involve a large and diverse portion of all work involving radiation in the United States, it was assumed that reduction of exposure limits might be felt most keenly within DOE. As a result of the response by the Environmental Protection Agency to the Natural Resources Defense Council petition and the impending response by the Nuclear Regulatory Commission, as well as mounting Congressional interest in the problem of occupational exposure, DOE decided that a review should be undertaken to delineate the impact of lowered occupational radiation exposure limits on DOE personnel, programs, and facilities. To establish a basis for assessing the potential impact of lower exposure limits among DOE contractors, a list of questions was sent to DOE Field Office contractors.

Selected contractor representatives were appointed to an ad hoc committee through DOE Field Offices. These members were assigned responsibility for coordinating replies to the questions from various contractors within their Field Office. A meeting of the ad hoc committee was held, the data from all of the contractors were reviewed, and initial summaries were prepared. The following set of basic assumptions and decisions were made:

- No discussion or evaluation of dose effects would be undertaken; however, some health effects would be assumed even at low dose.
- Total worker population dose would be considered along with individual worker's dose.
- No attempt would be made to assess the value of a program or facility to DOE, the industry, or the United States.
- The same radiation protection control and reporting philosophy would be continued if lower limits were adopted.
- The committee would not recommend any change in limits.
- No attempt would be made to identify or quantify the delay or curtailment of programs.

- For the purpose of developing cost and manpower estimates, it would be assumed that programs and facilities could be operated at the proposed limits (this may not be a viable assumption at the 0.5 rem/yr limit).

The basic design of the report (U.S. Department of Energy 1979) was developed with a list of important points to be discussed. Note that this report was limited to a presentation of exposure experience and anticipated economic and exposure impact of the reduction of occupational exposure limits and did not address the alleged need for dose limit reduction. The ad hoc committee concluded that the results of this study satisfactorily project the effects and problems associated with the proposed reduction of the dose limits. The following conclusions were reached:

1. Reduction of the occupational exposure limit would result in significant increase in total accumulated exposure to the current radiation worker population and could require an increase in the work force with subsequent personnel and administrative problems.

2. Important programs and/or facilities would have to be abandoned at a planned exposure limit of 0.5 rem/yr.

3. Some engineering technology is not sufficiently developed to design or operate at the 0.5 rem/yr limit.

4. Even a factor-of-2 reduction, so all planned exposures would be less than 2.5 remlyr, would significantly increase costs and would result in an increase, perhaps not an important increase, in total exposure to the work force.

5. In addition to a significant one-time initial capital cost resulting from a 0.5 rem/yr limit, there would be a significant increase in annual costs.

6. The major emphasis in controlling occupational exposure should be on continued work toward further reduction of total man-rem. This should involve continued development of As Low As Practicable (ALAP) programs along with improvements in dose measurement and recording methods; better containment, handling, and remote maintenance techniques; and development of more sophisticated exposure records.

7. Radiation protection practices at DOE facilities have maintained exposures of the bulk of the nuclear work force substantially below current limits for many years. The exposure experience presented in this report documents the effectiveness of a continuing exposure reduction effort.

8. The current standard of 5 rem/yr is used only as a limit. For example, 97% of the employees receive less than 0.5 rem/yr. This is possibly due to the flexibility permitting a few radiation workers to receive exposures above 0.5 rem/yr but below the limit of 5 rem/yr in an effort to maintain total worker exposure ALAP.

REFERENCE

U.S. Department of Energy. 1979. Study of Anticipated Impact on DOE Program From Proposed Reductions to the External Occupational Radiation Exposure limit. DOE/EV-0045. Washington, D.C.

Evaluation of Impact of ICRP-26 Recommendations

J. P. Corley, A. E. Desrosiers, K. R. Heid, C. E. Newton, Jr.

The recornendations contained in the International Commission on Radiological Protection (ICRP) Publication 26 were reviewed for their effects on occupational and environmental exposure limits and the resultant modifications to each of the evaluation and control programs. Using the Hanford Site programs as a base, changes to accommodate the significant differences defined previously are identified along with the feasibility and approximate cost where applicable or reasonable to develop. Where proven technology does not exist or where apparent cost of implementation appears excessive, those program changes are identified. Although thorough analysis was not possible, approximations of parallel efforts required at Department of Energy (DOE) sites with other record-keeping systems were attempted. Suggested changes in the DOE Manual Chapter (or the equivalent) and health and safety requirements are to be provided in the final summary report.

In some cases, amplification or explanation of Publication 26 was taken from subsequent publications of the ICRP or its committees. Otherwise the effect of compliance with the verbatim recommendations of Publication 26 was analyzed.

Where the recommendations differ significantly from current practice, the Hanford Site's programs were used as a base to identify the feasibility and cost of effecting changes. Impractical changes are identified. In general, the ICRP's recommendations would significantly affect operational monitoring of internal emitters and subsequent reporting of radiation dose. In the near term, however, changes in radiation standards and methods of calculating and reporting doses would have a transient effect on schedules and budgets for both occupational and environmental radiation protection programs. Suggested changes in the appropriate DOE Manual Chapters and health and safety requirements are to be provided in the final summary report.

A portion of the effort on this project was directed toward studying the indirect impact of incorporating ICRP's recommendations into the Environmental Protection Agency's (EPA) forthcoming federal radiation protection guidance for limiting exposure of workers to ionizing radiation. EPA's guidance for occupational protection can be expected to have different impacts from those relating to Publication 26 itself because the EPA may modify several of ICRP's recommendations, resulting in guidance that blends ICRP's innovative concepts with presently established radiation limits. Analyses of EPA's proposed guidance were prepared for use by DOE in interagency discussions of the proposed guidance.

Assessment, Analysis, and Recommendations for Personnel Neutron Dosimetry

L. W. Brackenbush, G. W. R. Endres, L. G. Faust

The objective of this task was to assess the state of the art of personnel neutron dosimetry. The work included reviewing neutron dosimetry literature, surveying dosimetry systems at Department of Energy (DOE) facilities, contacting principal investigators throughout the world who are involved in neutron dosimetry research, and identifying techniques to help improve dosimetry at DOE facilities. The literature search produced more than 1200 citations on neutron dosimetry and detectors; only about 200 were found to be pertinent.

The literature search revealed one new type of neutron dosimeter, the Superheated Drop Detector, invented by Dr. R. Apfel of Yale University. This dosimeter consists of small drops of a superheated liquid placed in a viscous gel that stabilizes the superheated liquid. It is possible to determine the energy of the incident neutrons by using several Superheated Drop Detectors with mixtures of superheated liquids having different degrees of superheat and hence different neutron energy thresholds. There are, however, many practical problems which need to be solved before the Superheated Drop Detector could be used as a personnel neutron dosimeter.

Contacts were made with several foreign dosimetry experts. Neutron dosimeters were obtained from Karlsruhe, Germany, and Windscale, England, for evaluation. The German albedo dosimeter has six lithium fluoride thermoluminescent dosimeter (TLD) chips in a boron carbide holder. The English dosimeter is also a TLD albedo dosimeter with lithium borate as the thermoluminescent material.

Three commercial neutron dosimeter services were contacted: one provides Nuclear Track Emulsion (NTA) film, track etch, and TLD albedo dosimeters; the second provides TLD albedo dosimeters; and the third provides TLD albedo and NTA film dosimeters. Two of these firms provide neutron dosimeters to DOE contractors. One offers a plastic track etch dosimeter which may be of interest because it has a lower energy threshold than previous track etch dosimeters.

A personnel neutron dosimetry survey form was distributed to dosimetry experts at major DOE facilities. This survey seeks information about the type of dosimeter used at a given DOE site, the method by which neutron dose is determined by the dosimeter, the energy and angular response of the dosimeter, the, lower detection limit of the dosimeter, the method by which the dosimeter is calibrated, the type of facilities (nuclear reactors, accelerators, etc.) in which the dosimeters are used, and the number of people exposed to neutrons in each type of facility.

Neutron dosimetry systems and their problems were discussed at six major DOE sites. Five of the sites employ TLD albedo personnel neutron dosimeters; only one, an accelerator laboratory, uses NTA film. The energy sensitivity and calibration problems of the TLD albedo dosimeters are well recognized at all five sites. Most sites use a single calibration factor for interpreting their dosimeter results. All of the sites using a single calibration factor tend to be conservative, which results in overestimation of the neutron dose. In situations where the dosimeter is calibrated with an unmoderated neutron source and exposed in the field to a moderated source, the neutron dose may be overestimated by a factor of 2 or more. At two sites there is an attempt made to compensate for differences in the neutron spectra in which the TLD albedo dosimeters are exposed. Correction factors are determined by crude neutron spectrum measurements made at work locations from the ratio of response of thermal neutron detectors inside 9- and 3-inch spheres of polyethylene.

It was concluded that accurate neutron spectrum measurements need to be made in work locations and in calibration facilities to improve neutron dosimeter responses. No dosimeter was found to be completely satisfactory in measuring personnel neutron exposures under field conditions.

Characterization of DOE Facility Emergency Preparedness

E. E. Oscarson, A. E. Desrosiers, R. A. Fox, D. E. Friar, W. M. Harty, J. S. Kent, W. D. McCormack, M. L. Smith.

The study involves eight subtasks, including evaluation of source terms data gathered during a review of Department of Energy (DOE) onsite emergency preparedness capabilities, preparation of an updated emergency preparedness questionnaire, evaluation of instrument malfunction and performance data, evaluation of data from the first two subtasks, a comparison of the magnitude of the impact of postulated accidents to the instrumentation and other resource capabilities to deal with the accidents, and a reassessment and update of the previous reports. The task was initiated in FY 1979 and will be completed by the end of FY 1981.

Responses from the Field Offices at four major DOE sites were reviewed to gather source terms and other release and dose-rate data. These responses were found to be inadequate for the type of analysis being performed. Consequently, further information is being requested from the participating Field Offices.

A new draft questionnaire was prepared on the "Technological Consideration in Emergency Instrumentation Preparedness." Further efforts under the expanded scope will center on preparing a questionaire which will include training programs, audit systems, and emergency plans and procedures.

Emergency instrumentation performance data for the Hanford Site is being gathered and analyzed. When completed, it should be possible to prepare recommendations on instrument design, construction, and quality assurance and control.

Human Health Studies

HUMAN HEALTH STUDIES

- **Statistical Health Effects**
- **Urinary Excretion of Metals and DTPA Salts**
- **Radioisotope Customer List**

A program of accumulation of data on the mortality of workers at the Hanford plant has been in progress for 15 years. Since 1975, this epidemiologic data set has been analyzed here by statistical procedures alternative to those used by other investigators. The Pacific Northwest Laboratory (PNL) analyses indicated that the general health of Hanford employees is favorable with respect to cancer generally and to other diseases. The study disclosed possibilities that warrant additional follow-up in two cancer types. The Hanford Environmental Health Foundation is associated with PNL in this continuing study.

PNL analyzed urine samples from a person accidentally exposed to americium-241 and treated with Ca and Zn DTPA. These analyses demonstrated that Zn was the only essential element excreted more rapidly than normal becuase of the chelation therapy. The excretion of Zn was compensated adequately by the use of Zn DTPA instead of the calcium salt or by the administration of $ZnSO_4$. This information has important implications for the long-term use of DTPA in the decorporation of deposited radionuclides.

• Statistical Health Effects Study

The main purpose of this program is to analyze the mortality of Hanford workers and to determine the effects of radiation exposure in this population. A secondary objective is the development of improved methodology for assessing health effects of chronic low-level exposure to harmful agents or substances, particularly in an occupational setting. In the past year, we have published a paper describing the results of our analyses, made a number of informal presentations, and updated our files and mortality analyses.

Statistical Health Effects Study

E. S. Gilbert

Our primary objective is an adequate analysis of Hanford mortality and exposure data, using the most appropriate and sensitive methods available. The mortality analysis has now been updated to include several hundred additional deaths that occurred up to May 1, 1977 (instead of April 1, 1974, as in previous analyses). Results of the new analysis are presented in Table 1. Although there are three new deaths from cancer of the stomach in the highest exposure group (15+ rem), results are not changed in any important way from earlier analyses.

The working master file at Pacific Northwest Laboratory is being updated to include workers employed after 1974, as well as the most recent exposure and mortality data on all workers. This task involves editing and resolving discrepancies among three major files, as well as summarizing extensive occupational histories.

Support in the design and implementation of the data collection system for the study is provided to staff of the Hanford Environmental Health Foundation, who are responsible for the data collection and are our joint investigators. Efforts are under way to evaluate the potential usefulness of data now in the file or under consideration for future acquisition, the adequacy of quality control procedures, and methods of maintaining files for greatest utility and accessibility. Other questions that are being explored are the completeness of Social Security Administration ascertainment and the quality of death certificate diagnosis.

Current research efforts include an investigation of methods of estimating the potential of occupational exposure data for assessing risks from radiation exposure, using data from the Hanford population for illustration. Questions of interest concern the advantages and disadvantages of using an external population for comparison, developing expressions for confidence limits for risks and for the power of various procedures, and the relative merits of various analytical techniques and approaches to handling the dosimetry data.

During the past year, a paper describing the results of our analyses was published in Radiation Research (Gilbert and Marks 1979), and several oral presentations were made.

REFERENCE

Gilbert, E.S., and S. Marks. 1979. "An Analysis of the Mortality of Workers in a Nuclear Facility." Rad. Res. 79:122-248.

TABLE 1. Observed and Expected Deaths Due to Selected Causes by Exposure Category for Monitored White Males Employed at Least Two-Years. Exposures are lagged for two years (includes deaths up to May 1, 1977, see text).[a]

	Exposure Category										
	0-2 rem		2-5 rem		5-15 rem		15+ rcm		Exposure Score for Trend Test		Probability of Trend Arising Due to Chance[c]
Person Years	173.254		32.653		21.609		11,159				
Cause of Death	Obs.	Exp.[b]	Obr.	Exp.	Obs.	Exp.	Obs	Exp.	Obs.	Exp.	
All causes	1719	1707.7	263	261 3	144	1478	90	99.2	2.4	2.5	0.88
All malignant neoplasms (140-209)[d]	342	344.6	66	56.1	29	32.8	20	23.5	2.5	2.7	0.81
M N of buccal cavity (140-149)	15	13.2	0	1.9	2	1.0	0	0.8	1.5	2.5	0.81
M N of stomach (151)	21	21.8	4	3.0	0	1.9	3	1.3	3.6	2.6	0.13
M N of large intestine (153)	34	34.9	7	4.7	1	2.1	1	1.3	1.8	2.0	0.66
M N of pancreas (1571	21	22.9	6	4.5	1	2.9	4	1.8	4.4	3.0	>0.06
M.N. of other digestive organs (150, 152, 155-6)	30	27.5	3	3.0	0	1.5	0	1.0	0.8	1.9	>0.95
M.N. of lung (162)	91	98.4	24	18.6	16	11.9	7	9.1	3.2	3.3	0.54
M.N. of prostate (185)	26	24.0	6	4.6	2	3.0	0	2.5	1.5	3.4	>0.97
M.N. of brain (191-2)	10	12.2	4	2.1	2	1.1	0	0.6	2.2	2.4	0.56
Lymphosarcoma and reticulum cell sarcoma (200)	12	11.6	2	1.6	1	1.1	0	0.7	1.5	2.6	0.83
Hodgkins disease (201)	4	4.8	2	0.8	0	0.4	0	0.1	1.4	1.7	0.59
Myeloid leukemia (205)	7	5.7	0	1.5	1	0.6	0	0.3	1.6	2.5	0.71
Other leukemia (204, 206-7)	6	5.2	0	0.5	0	0.2	0	0.1	0.6	1.5	0.75
Multiple myeloma (203)	4	5.1	0	0.8	0	0.6	3	0.5	11.2	3.3	0.006[e]
Other M.N. of lymphatic and hematopoietic tissue (202, 208-9)	5	4.5	0	0.4	0	0.1	0	0.0	0.6	1.0	0.68
All other M.N.	56	52.9	8	8.2	3	4.4	2	3.5	1.9	2.7	0.88
All noncancer causes	1377	1363.1	197	205.1	115	115.1	70	75.7	2.4	2.5	0.80

(a) See Radiation Research 79:122 for complete details. Table I above is an updated version of Table VIII from this paper.

(b) Expected deaths are calculated from the experience of all workers in the exposure study, allowing for calendar year, occupation, and employment status.

(c) The significance levels are for a one-tailed test and are calculated using a normal approximation. For M.N. of the pancreas, other digestive organs, and prostate, the true levels are somewhat larger than those given.

(d) ICD codes.

(e) This probability calculated exactly.

Urinary Excretion of Metals and DTPA

Urine samples from a person treated intravenously with diethylenetriaminepentaacetic acid (DTPA) salts to promote the excretion of ^{241}Am were assayed for metals and DTPA. Zinc was the only essential body metal excreted faster than normal. Use of either $Na_3ZnDTPA$ or $Na_3CaDTPA$ combined with oral dosages of $ZnSO_4$ appeared to completely compensate for this rapid loss. Many urine samples were assayed for DTPA by the sensitive method developed last year, but bacterial degradation obscured any DTPA-excretion patterns.

Urine Analysis for Essential Body Metals and DTPA Salts

D. R. Kalkwarf, V. W. Thomas, K. K. Nielson, M. L. Mauch, R. A. Gelman, V. Smith

Treatment of a person with both calcium and zinc salts of diethylenetriamine-pentaacetic acid (DTPA) to enhance his excretion of ingested ^{241}Am provided a rare opportunity to test for side effects of this therapeutic method in man. The purposes of this project were (1) to test for enhanced urinary excretion of essential body metals during the various DTPA-injection schedules and (2) to determine the relationship between the injected amounts of DTPA and those excreted in the urine. This information is needed to guide physicians in regulating the dosage of DTPA salts during the treatment of patients contaminated with radionuclides and to judge the adequacy of animal models for predicting the effects of DTPA salts in man.

Analysis of 568 urine specimens by energy-dispersive, x-ray fluorescence and selective-ion electrode measurements showed that zinc was the only essential metal excreted faster than normal in the course of six different DTPA injection schedules. Use of either $Na_3ZnDTPA$ or $Na_3CaDTPA$ combined with oral dosages of $ZnSO_4$ appeared to completely compensate for this loss. A substantial number of urine samples were assayed for total DTPA species by the procedure developed last year, and although the sensitivity of the method was adequate, there appeared to be no quantitative correlation between the amounts of DTPA injected and those excreted. It was concluded that bacterial degradation obscured any DTPA-excretion patterns.

The urine samples were prepared and analyzed by the methods described in last year's report (Kalkwarf et al. 1979, p. 4.3). The ranges of values that were found are shown in Table 2, together with those for urine specimens from 14 healthy male volunteers, measured by the same procedures, and

TABLE 2. Concentration Ranges for Elements in Normal Urine, Volunteer's Urine, and Patient's Urine in Mg/ℓ

Element	Normal Range[a]	Volunteers' Range	Patient's Range
As*	(0.2-2) x 10^{-1}	(<0.1-0.6) x•10^{-1}	(<0.1-0.03) x 10^{-1}
Br	1-7	1-8	0.02-4
Ca*	(0.5-5) x 10^{-2}	(1-7) x 10^{-2}	(0.1-7) x 10^{-2}
Cl*	(4-7) x 10'	(2-12) x 10'	(2-12) x 10^{3}
Cr	(0.07-1) x 10^{-2}	(<1-22) x 10^{-2}	(1-27) x 10^{-2}
Co	(0.01-3) x 10^{-1}	(<0.01-1) x 10^{-1}	(0.03-7) x 10^{-1}
Cu*	0.01-0.3	0.06-0.4	0 01-0.6
F*	0.4-4	0.1-1	0 04-2
Ga	0.04	<0.1	<0.1-0.4
Fe*	0.1-1	0.1-1	0.03-6
Pb	(0.1-1) x 10^{-1}	(0.4-9) x 10^{-1}	(0.03-10) x 10^{-1}
Mn*	0.0002-2	<0.01-0.2	0.007-0 2
Hg	(0.01-1) x 10^{-1}	(0.1-0.3) x 10^{-1}	(0.04-3) x 10^{-1}
Ni*	(0 02-9) x 10^{-1}	CO.2-1) x 10^{-1}	(0.02-1) x 10^{-1}
P*	(0.5-1) x 10^{3}	(0.2-2) x 10'	(0.03-1) x 10'
K*	(1-3) x 10^{3}	(0.4-5) x 10'	(0.9-3) x 10^{3}
Rb	1-3	0.4-2	0.03-2
Se*	(0.2-2) x 10^{-1}	(0.1-0.3) x 10^{-1}	(0.007-0.2) x 10^{-1}
Si*	(4-6) x 10^{3}	(<0.1) x 10'	(0.01-0.7) x 10^{3}
Na*	(3-5) x 10^{3}	(1-20) x 10^{3}	(0.3-7) x 10^{3}
Sr*	(1-4) x 10^{-1}	(<0.2-0.5) x 10^{-1}	(0.05-3) x 10^{-1}
S*	(0.8-2) x 10^{3}	(0.2-2) x 10'	(0.01-0.6) x 10^{3}
Ti *	(0.1-5) x 10^{-1}	(3-40) x 10^{-1}	(0.5-90) x 10^{-1}
V*	(0.i-3) x 10^{-2}	(<1) x 10^{-2}	(2-50) x 10^{-2}
Zn*	0.04-1	0.1-1	0.25-450

[a] Iyengen, Kollmer and Bowen, 1978
* Essential for normal metabolism

ranges reported in a recent evaluation of normal urine composition (Iyenger, Kollmer and Bowen 1978). Elements shown with an asterisk are considered essential for normal metabolism (Iyenger, Kollmer and Bowen 1978). For most elements, the concentration range in urine covers an order of magnitude in values. Generally, concentrations found in volunteers' urine fell within these ranges, but the upper limits to the ranges for chromium, lead, sodium, and titanium were more than double those for the normal ranges. These differences may be due to biases in the analytical methods used, but they are more likely due to dietary factors or sample contamination.

During the three-year treatment period, zinc was the only essential body metal excreted by the patient at rates that were consistently more than twice the upper limits for both the literature and volunteer-assay ranges. Six injection schedules were used: 1 g $Na_3CaDTPA$/12 hr, 0.5 g $Na_3CaDTPA$/12 hr, 1 g $Na_3CaDTPA$/24 hr, 1 g $Na_3ZnDTPA$/12 hr, 1 g $Na_3ZnDTPA$/24 hr, and 1 g $Na_3ZnDTPA$/72 hr. A correlation between the concentration of zinc excreted and the amount of $Na_3CaDTPA$ injected during the first week of treatment is shown in Figure 1. Occasionally, cobalt, gallium, iron, mercury, titanium, and vanadium were excreted at concentrations that were more than twice the upper limits for both the literature and volunteer-assay ranges. However, no correlation was seen between their excretion rates and the DTPA injections, so the occasional high values were attributed to dietary changes or sample contamination.

Since increased excretion of zinc had been anticipated, two methods were used to counteract this loss. Soon after the $Na_3CaDTPA$ was injected, zinc sulfate was

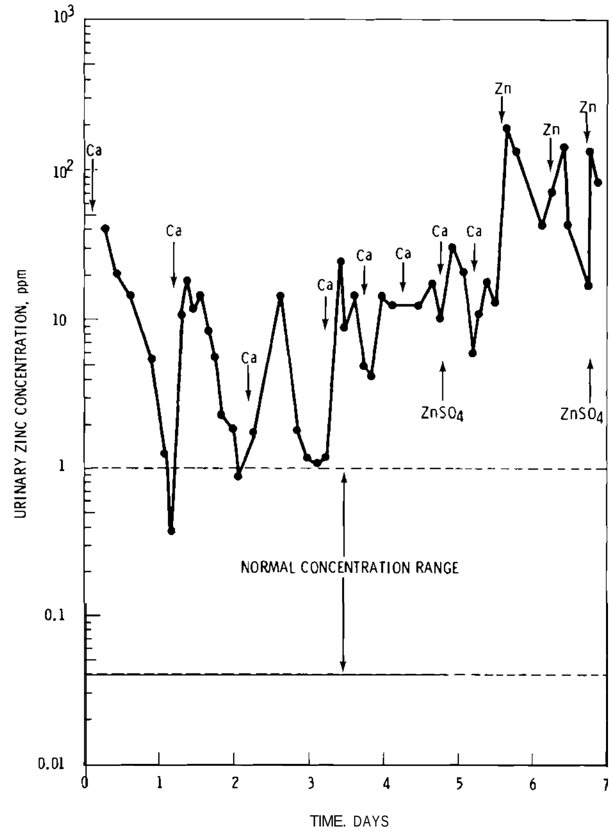

FIGURE 1. Variation in the Patient's Urinary Zinc Concentration with Time and Treatment. Downward-pointing arrows indicate times for l-gram injections of either $Na_3CaDTPA$ (Ca) or $Na_3ZnDTPA$ (Zn). Upward-pointing arrows indicate times for oral administration of 220-mg zinc sulfate capsules.

administered orally at the rate of 220 mg/day (89 mg zinc/day). Excretion data obtained before these supplements were used showed that 1 g $Na_3CaDTPA$/24 hr increased the urinary loss of zinc by 25 mg/day, and 1 g $Na_3CaDTPA$/12 hr increased the loss by 30 mg/day. Thus, the zinc supplement appeared adequate to completely compensate for this loss. Zinc loss was also counteracted by the use of $Na_3ZnDTPA$, and since 1 g of this compound contains 125 mg zinc, it should have also completely compensated for any zinc loss.

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• Radioisotope Customer List

Radioisotope Customer List
J. S. Burlison

The purpose of this program is to prepare and distribute the annual document entitled List of DOE Radioisotope Customers with Summary of Radioisotope Shipments FY-1978. This document lists the FY-1978 commercial radioisotope production and distribution activities of the Department of Energy (DOE) facilities at Argonne National Laboratory, Brookhaven National Laboratory, Hanford Engineering Development Laboratory, Idaho Operations Office/Aerojet Nuclear Co., Los Alamos Scientific Laboratory, Mound Facility, Pacific Northwest Laboratory, Oak Ridge National Laboratory, Savannah River Plant/DOE, and United Nuclear Industries, Inc. The report was distributed in May 1979.

Presentations and Publications

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Beck, C. A., et al. "Compressed Air Energy Storage (CAES) Environmental Control Concerns." PNL-SA-7365. Presented at the Department of Energy/Environmental Control Technology Symposium, Washington, D.C., November 1978.

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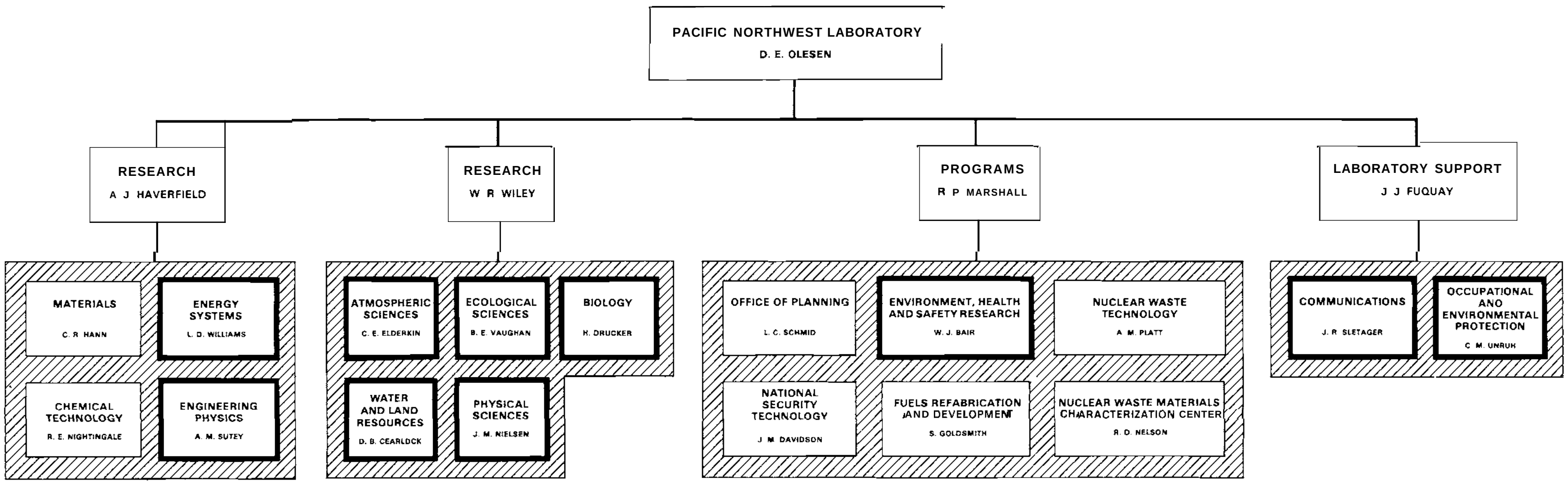

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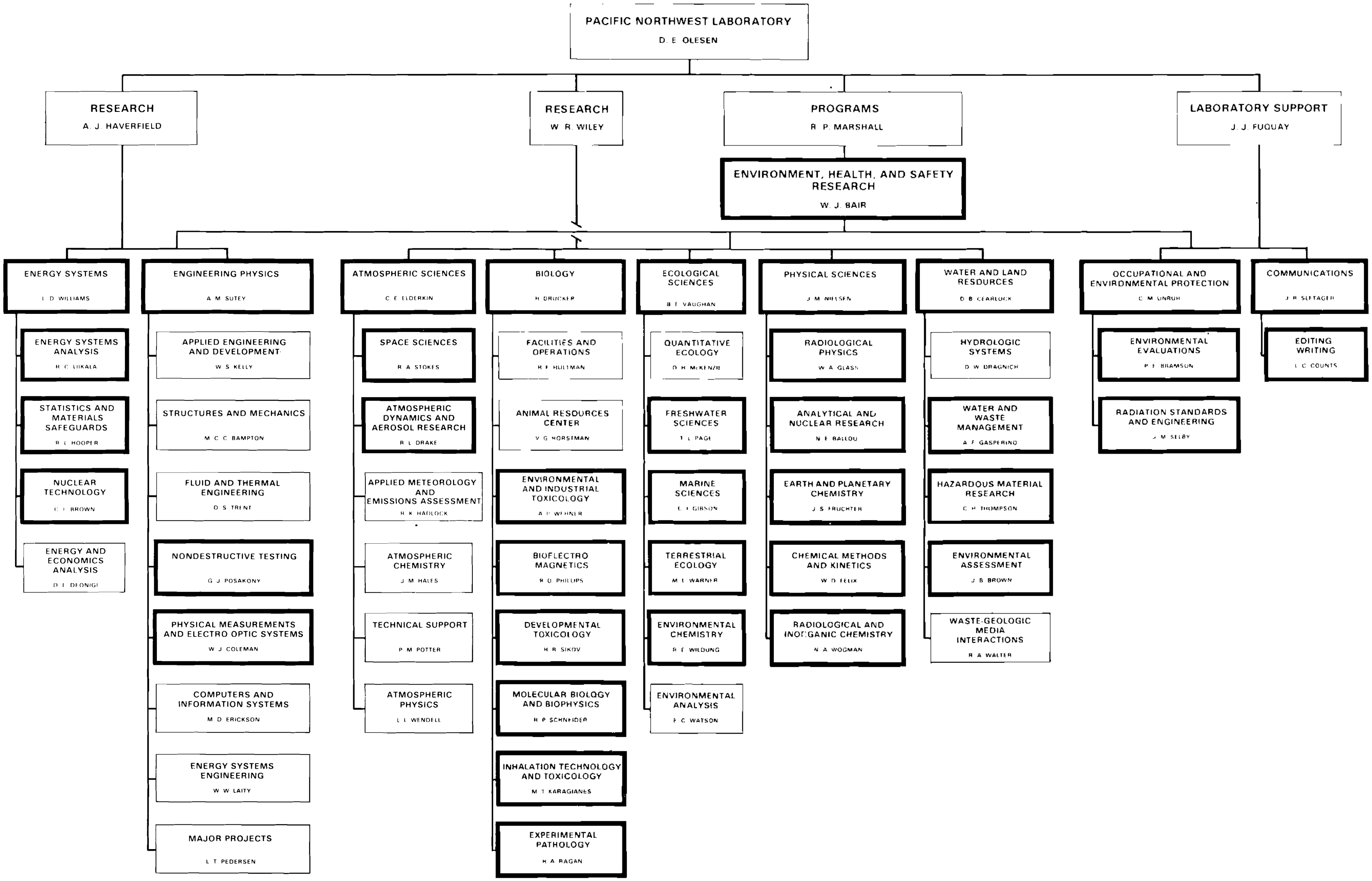

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