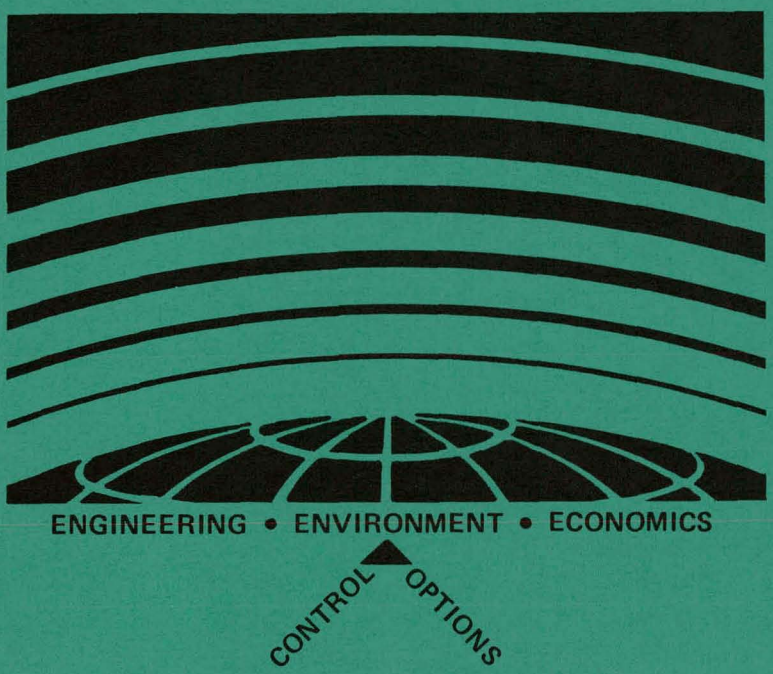
DOE/EV-0128

Division of Environmental Control Technology Program-1979

JUNE 1980



U.S. Department of Energy
Assistant Secretary for Environment
Office of Environmental Compliance and Overview
Division of Environmental Control Technology

DISCLAIMER

Printed in the United States of America

Available from

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes

Printed Copy:	$15.00
Microfiche Copy:	$ 3.50

Master

DOE/EV-0128
UC-11

Division of Environmental Control Technology Program-1979

JUNE 1980

U.S. Department of Energy
Assistant Secretary for Environment
Office of Environmental Compliance and Overview
Division of Environmental Control Technology
Washington, D.C. 20585

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

PREFACE

This report covers the Environmental Control Technology Division* projects in progress during fiscal 1979, within the Office of the Assistant Secretary for Environment, Department of Energy. It is the third in a series of annual reports. The first report, covering fiscal 1977 projects, was published as DOE/EV-0015, "Division of Environmental Control Technology Program -- 1977," June 1978; the second, fiscal 1978 projects, was published as DOE/EV-0042, "Division of Environmental Control Technology Program -- 1978," June 1979.

* Future reports will use the revised divisional title, Environmental and Safety Engineering Division, under the Office of Environmental Compliance and Overview.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

FOREWORD

The Environmental Control Technology Division continues to support the Assistant Secretary for Environment in discharging two primary responsibilities: (1) under the Environmental Engineering Program, the independent overview and assessment of the environmental control aspects of both the U.S. Department of Energy's research, development, and demonstration programs and the Nation's energy policies, and (2) under the Decontamination and Decommissioning Program, the reduction of potential environmental hazards at the radioactively contaminated sites that are presently owned or were formerly used by the Government.

ENVIRONMENTAL ENGINEERING

Policy decisions and effective research, development, and demonstration planning for the environmental control aspects of energy technologies demand not only raw technical data on control capability but the engineering expertise to systematically evaluate, interpret, and apply the data to the complex issues being addressed. In the Office of the Assistant Secretary for Environment, the primary source of this essential capability resides in the Environmental Control Technology Division's Environmental Engineering Program.

The philosophy guiding Environmental Engineering Program activities is embodied in three postulates: First, environmental controls are of great importance because they represent one of the primary mechanisms that allow energy systems to operate in the commercial sector. Second, an organizational capability for independent, objective overview and assessment is required to ensure that environmental control issues receive proper emphasis for timely resolution. Third, the development of environmental control hardware and systems is best conducted as an integral part of the developing energy systems themselves. In fiscal 1979, the Department of Energy dedicated approximately $422 million (5.0 percent of the Department's total budget) to environmental control activities, as reported in DOE/EV-0084, "Environmental Control Technology Activities of the Department of Energy in FY 1979," June 1980. This is approximately a $127 million increase in funding from fiscal 1978, with the major increase in the area of nuclear waste management.

An important feature of the Environmental Engineering Program's independent overview and assessment viewpoint is that environmental control options are treated as an integral part of an overall energy-producing system. Hence, judgments on cost and control effectiveness are based on a systems orientation that reflects a host of parameters, including multimedia impacts, parasitic energy demands, and potential trade-offs provided by alternative environmental controls, all of which affect the countless operations within the total fuel cycle. This systems orientation is necessary to ensure that optimization of environmental control operations does not, in fact, create concomitant adverse environmental situations (for example, unacceptable byproduct formation or excessive water use) in other parts of the energy cycle.

In summary, the programs supported by the Environmental Engineering Program continue to nurture the development of an environmental control assessment capability that has been used to

- Make judgments on the environmental control aspects of National Environmental Policy Act documents;
- Provide input to and make judgments on environmental control requirements and options for Environmental Development Plans, Environmental Readiness Documents, Project Environmental Plans, and Energy Systems Acquisition Project Plans;
- Provide a sound basis for staff participation on interagency task forces;
- Provide environmental control input to Department of Energy policies and Federal regulatory activities;
- Evaluate the availability of control options for compliance of Department of Energy operations with environmental, health, and safety requirements; and
- Broaden the focus of environmental control research, development, and demonstration activities within other entities of the Department of Energy.

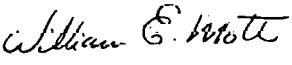
DECONTAMINATION AND DECOMMISSIONING

In the rapid pace of technical development that has characterized the establishment of nuclear defense and energy programs, many sites and facilities have become obsolete or otherwise rendered of no further use in their intended function. These sites and facilities, when contaminated with radioactive material, present a unique management problem of ensuring that the latent hazard of radioactivity is controlled and does not pose a threat to man nor a burden to the environment. In many cases, the responsibility for this management has passed from programmatic sponsorship -- the facilities are remnants of former programs -- and has become a general program in the interest of environmental stewardship.

The overall objective of this program is to reduce the potential environmental hazards associated with sites and facilities no longer required or used in the Nation's nuclear programs. Such facilities currently include both surplus Government-owned property and private property where nuclear activities were conducted under contract but where the decontamination was not sufficient to allow an unrestricted alternative use or where residual radioactivity poses a potential environmental or health concern as viewed in the light of current standards. Decontamination and decommissioning actions are being conducted with the goal of minimizing potential risks and restoring sites and facilities to allow beneficial use without radiological restrictions. The residual radioactive materials that remain at these sites and facilities must be properly contained and stabilized or removed and disposed of so that all potential impacts to the health, safety, and welfare of the Nation are reduced to a level equal to or lower than the existing or proposed guidelines and criteria.

On this basis, the Environmental Control Technology Division, during most of fiscal 1979, continued to conduct the Decontamination and Decommissioning Program of the Department of Energy. In late fiscal 1979, the Department of Energy consolidated nuclear waste management projects in the Office of the Assistant Secretary for Nuclear Energy, which is now responsible for the actual conduct of surveillance, decontamination, decommissioning, and remedial actions. The Environmental Control Technology Division, under the Office of the Assistant Secretary for Environment, is now responsible for independently providing and documenting assurance for the Department that potential health hazards at these sites and facilities are identified and controlled or eliminated by remedial action projects.

This report of work sponsored in fiscal 1979 is the third in an annual series. The first report was published in June 1978 as DOE/EV-0015, "Division of Environmental Control Technology Program -- 1977"; the second was published in June 1979 as DOE/EV-0042, "Division of Environmental Control Technology Program -- 1978." In continuing the annual series, this report presents a short summary of objectives, approach, progress and results, future plans, and a reference bibliography for each research, development, or assessment project within the program areas described above.



William E. Mott
Director, Environmental and
Safety Engineering Division
Office of the Assistant Secretary
for Environment
U.S. Department of Energy

CONTENTS

ENVIRONMENTAL ENGINEERING

Environmental control technology provides a necessary bridge that allows energy systems to operate acceptably in the commercial world. Independent judgments on the efficacy and practicability of environmental control procedures, processes, strategies, and systems by the Environmental Control Technology Division within the Office of the Assistant Secretary for Environment provide an objective input to U.S. Department of Energy policies and evaluations that serve to ensure the general public of the commitment of the Department on environmental control matters. Major program areas include

- Nonnuclear energy, which critically examines the environmental control aspects of coal, petroleum and gas, oil shale, solar, and geothermal energy technologies, as well as energy conservation applications, and

- Nuclear energy, which assesses the adequacy of environmental controls for all phases of the nuclear fuel cycle, including shipment of energy materials and wastes, and evaluates alternative waste disposal techniques.

Although the Department of Energy's technology research, development, and demonstration programs are generally relatively large, homogenous programs of several years' duration, Environmental Control Technology Division projects are comparatively small, diverse, and targeted to individual environmental control and safety issues or requirements earmarked by the energy technologies, Environmental Development Plans, independent identification within the Office of the Assistant Secretary for Environment, or the Environmental Control Technology Division. In fiscal 1979, a major focus of the Division's Environmental Engineering Program was fossil energy development. Within this area, assessment of the environmental control implications of generating electric power from coal, environmental assessment of gasifiers in industry, and determination of the safety and control measures required for liquefied gaseous fuels predominated. Emphasis was also placed on related coal cycle issues such as environmental control capability and needs in strip mining, trace element releases, wastewater cleanup systems, and waste heat management for the near, mid, and far terms (year 2000), with emphasis on the near to mid terms. Additionally, the Environmental Engineering Program supported projects to assess the environmental control requirements for all phases of the nuclear fuel cycle.

To achieve the objectives of the Environmental Engineering Program, studies and assessments are sponsored at Department of Energy laboratories and research centers, as well as at selected industrial and academic facilities. Environmental Engineering Program activities sponsored in fiscal 1979 are described in the following sections.

SURVEY OF ENVIRONMENTAL CONTROL TECHNOLOGY ACTIVITIES

ORGANIZATION AND CONTRACT NUMBER

The Aerospace Corporation
DE-AM03-76SF01101

PRINCIPAL INVESTIGATOR

J.S. Dock

OBJECTIVE

The objective of this project is to provide support to the Environmental Control Technology Division in the organization, conduct, and documentation of the third annual Department of Energy internal survey of all fiscal 1979 projects having environmental control technology aspects.

APPROACH

For the fiscal 1979 environmental control technology survey, input requirements (including definitions, criteria, documentation forms, and examples) will be developed. The survey is to be initiated by a letter from the Assistant Secretary for Environment to all of the Department of Energy energy technology offices requesting their assistance in completing the survey. An initial meeting will then be scheduled to brief the offices participating in the survey. Following this meeting, panel sessions and information transfer meetings and discussions are to take place to completely and concisely define all Department activities having environmental control aspects as well as the associated funding.

PROGRESS AND RESULTS

A letter was transmitted from the Assistant Secretary for Environment to all energy technology offices calling for inputs to define the fiscal 1979 projects having environmental control aspects and the portion of funding devoted to environmental control technology efforts. A plan and the structure for implementation were prepared, including criteria and applicability to environmental controls, schedules, energy category, structural breakdown, and guidelines, and were presented to the energy technology representatives at a meeting chaired by the Environmental Control Technology Division. Inputs from the energy technologies were compiled and integrated into a report on all projects, including their funding (Table 1). The distribution of the total fiscal 1979 funding related to environmental control activities within the Department of Energy is depicted in Figure 1.

Table 1. Total Department of Energy Environmental Control Activities Funding Allocation

Energy-Related Activities	FY 1979 Budget Outlays[a] Related to Environmental Control Activities ($ in thousands)	Percent of Total FY 1979 Budget Related to Environmental Control Activities
Conservation	11,598 (444)	3.3
Fossil Energy	85,700 (9,182)	11.7
Nuclear Energy	301,254 (4,856)	8.3
Solar	3,308 (216)	0.8
Geothermal	12,362 (207)	9.7
Supporting Research	4,716	2.2
Magnetic Fusion Energy	2,595	0.7
Total	421,533[b]	5.0[b]
	Total DOE FY 1979 Outlays:	$8,437,471,000

a FY 1979 funding within the Office of the Assistant Secretary for Environment is included in the individual rows and allocated as shown in parentheses.

b FY 1977 values were $184,683,000 and 3.4%.
FY 1978 values were $294,066,000 and 3.3%.

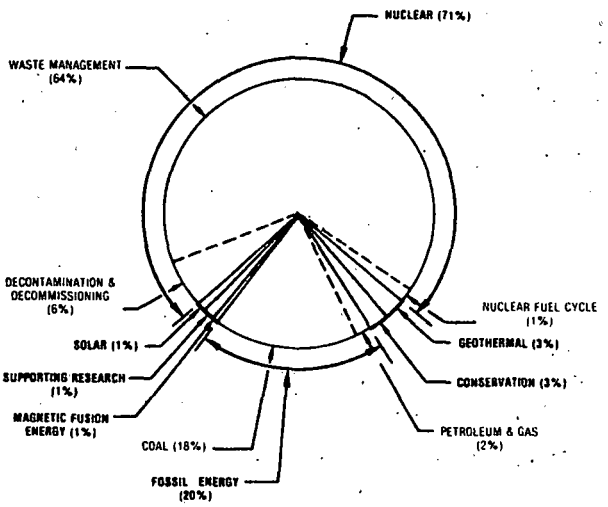


Figure 1. Distribution of Total Department of Energy Environmental Control Activities Related to Fiscal 1979 Funding by Energy Categorgy

PLANS FOR NEXT PERIOD

The plans and preparation necessary to conduct and document the total Department of Energy fiscal 1980 projects having environmental control aspects will be initiated.

REPORTS PUBLISHED

Documented and prepared inputs to the third annual report, "Environmental Control Technology Activities of the Department of Energy in FY 1979," DOE/EV-0084, Division of Environmental Control Technology, June 1980.

PROJECTED MILESTONES

- Fourth quarter fiscal 1980 -- Initiate fiscal 1980 environmental control technology survey
- First quarter fiscal 1981 -- Complete survey and initiate final report
- Second quarter fiscal 1981 -- Document and prepare annual report

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

COAL

In view of the increasing role that coal plays in the Nation's energy future, an important aspect of the Environmental Control Technology Division activity in fiscal 1979 was the continuous focus on evaluating the efficacy and practicability of environmental control options within the coal energy cycle. The need to prepare and update control assessments is necessary to ensure that

- The scope of the Department of Energy's research, development, and demonstration programs includes proper emphasis on environmental control issues and the need for confirmatory performance data on environmental control options is satisfied in concert with the demonstration of coal technologies ready for commercialization.

- The Department's input to national energy policies and regulatory initiatives is based on up-to-date evaluations of environmental control capabilities and costs along with the effect that existing and proposed regulations might have on new and improved controls.

A major fiscal 1979 activity directed at coal is the continued systematic evaluation of the environmental control implications of alternative systems for generating electricity from coal, with special emphasis on the industrial sector. The following near-term issues relating to coal combustion are addressed through data acquisition and assessment studies to establish the data base for an independent judgment:

- The efficacy and practicability of options for controlling sulfur dioxide and other coal derivations (i.e., sulfates, nitrogen oxide, respirable particulates, and hazardous hydrocarbons).

- The management of wastes produced by state-of-the-art control processes (e.g., ash management and disposal of flue gas desulfurization sludges).

- The potential for simultaneous control of emissions and effluents (e.g., simultaneous control of sulfur and nitrogen oxides).

- The "nonprocess" energy requirements of various control options, which, in many cases, may be appreciable.

These studies will yield detailed multimedia evaluation of the economic, engineering, and environmental trade-offs associated with various industrial coal utilization options, including conventional combustion with stack gas cleaning, physical and chemical coal cleaning, fluidized bed combustion, combustion of coal/oil mixtures, advanced power systems, and conversion of coal to an intermediary clean-burning gas or liquid fuel.

Field studies designed to develop confirmatory and/or complementary data required to support independent judgments have been used, with emphasis on acquiring new data needed to fill information gaps. These studies benefit from and rely heavily on concurrent utility coal combustion studies that are used to provide input to the Department of Energy position on utility New Source Performance Standards and to provide guidance to the environmental control program being established within the Department's Office of Fossil Energy.

An additional product of the Division's assessments in fiscal 1979 has been the development of operability and cost data that established the feasibility of potentially enhanced environmental control options meriting interest and additional research by energy developers. An example is the "impregnated" sulfur scavenger in coal, which may be especially promising for industrial gasification applications by allowing the processing of sulfur, prior to combustion, at large, centralized facilities. This may be a cost-effective dilute hydrocarbon emission control option for Lurgi gasification to avoid the need for combustion with premium methane (as proposed by the Environmental Protection Agency in a draft background document on enhanced wastewater treatability options). It is also an improved option for fine particulate control.

Examples of additional activities completed in the area of coal utilization during fiscal 1979 include

- Development of a set of unit operation-oriented assessments of the environmental controls available for conventional coal electric generation systems;

- Evaluation of wastewater control systems for coal conversion, which culminated in a contractor workshop in June 1979;
- Contributions to the comprehensive Office of Environment/Office of Fossil Energy Gasifiers in Industry Program; and
- Continued determination of subsidence and aquifer environmental control needs for in situ coal gasification.

The information generated and the expertise developed in the Environmental Control Technology Division have been and will continue to be used to review the environmental control aspects of a host of internal and external documents, including Environmental Impact Statements, Environmental Assessments, Environmental Development Plans, Environmental Readiness Documents, other Federal agency documents, Federal regulatory initiatives, and correspondence with other Federal agencies and the private sector.

ENVIRONMENTAL CONTROL IMPLICATIONS OF GENERATING ELECTRICAL POWER FROM COAL

ORGANIZATION AND CONTRACT NUMBER

Argonne National Laboratory
W-31-190-ENG-38

PRINCIPAL INVESTIGATOR

K.E. Wilzbach

OBJECTIVE

The program is a continuing effort to provide the Environmental Control Technology Division with indepth evaluations of the technical, environmental, and economic aspects of control technologies for coal-based energy systems and with comparative evaluations of alternative control technologies and strategies. Both current and developing technologies are being investigated in the program. This effort is intended to assist the Office of Environment staff in fulfilling its responsibility of ensuring the adequacy of environmental control systems for energy extraction, conversion, and utilization technologies. The core group of experts maintained by the program is available for consultation with the Department of Energy staff as needed and can provide quick-response reviews of topical issues.

APPROACH

Information on the costs, reliability, availability, resource consumption, and environmental effluents of power generation processes and the associated pollution control systems is being compiled from reports and discussions with manufacturers, users, and developers of these processes and control technologies. The Argonne National Laboratory staff is responsible for evaluating this information and resolving any discrepancies and inaccuracies that arise. The capabilities of the in-house staff are supplemented by subcontractors and consultants with special capabilities and expertise.

A systems analysis methodology for comparing alternative control technologies on the basis of their capabilities for cost-effective control of environmental impacts is used. The methodology is being computerized with the development of economic and performance models of the various technologies.

PROGRESS AND RESULTS

During fiscal 1979, the program funding was $750,000. About 35 percent was distributed to subcontractors and consultants, using universities and small businesses whenever possible. The program core group at Argonne was maintained at an average level equivalent to about 6.5 staff years. Four technical reports were issued, bringing the project total to 11. In addition, 10 reports were in various stages of preparation at the end of the year. Six papers were prepared for technical conferences by members of the project staff, and two presentations were made by subcontractor personnel on work supported by the project.

Several subcontracted studies were completed during fiscal 1979, including an extensive economic and environmental evaluation of alternative low-Btu gasification/combined-cycle systems and a review of progress in combustion modification techniques for nitrogen oxide control. In addition, the initial and second phases of a major systems study of industrial boiler environmental controls were completed. This effort was designed to provide a coherent basis for a policy on industrial boiler standards. Another completed study involved the status assessment of fluidized bed combustion technology as well as the development of a useful methodology for deriving such an assessment from the proceedings of a major conference. Work was initiated by the Argonne staff to provide additional material for this assessment.

A number of in-house studies were begun by the project staff. An evaluation of environmental considerations in the production and use of solvent refined coal was initiated, as was an assessment of particulate control systems for industrial boilers. Also started were an update of a previous study on the status of flue gas desulfurization technology and the development of background information for the assessment of magnetohydrodynamics for power generation.

Early in the year, several previously developed models were used in developing an economic comparison of advanced power generation technologies. Computer modeling capabilities were expanded by the implementation on the Argonne computer of a power system model developed by Carnegie-Mellon University. Work was started to add models of advanced technologies to the system. An advanced particulates control model was under development at

Argonne, supported by both this project and the Morgantown Energy Technology Center.

In a quite different area, the project was given responsibility for assisting the Department of Energy with the organization of environmental control symposia. The first of these was held in November 1978. The proceedings of that conference were prepared for publication at Argonne. The second symposium will be held in March 1980.

Overall, the dominant theme in fiscal 1979 was the analysis of environmental controls in the context of proposed New Source Performance Standards. Argonne staff members made substantial contributions to the dialogue between the Department of Energy and the Environmental Protection Agency on the utility standards and began developing information necessary for a sound approach to industrial regulations.

PLANS FOR NEXT PERIOD

Many of the activities noted above will carry over into this period. Several studies will be completed, including the solvent refined coal assessment, the industrial particulates control evaluation, the flue-gas desulfurization technology update, and the fluidized bed combustion status assessment. Modeling work will continue with the addition of gasification/combined-cycle and fluidized bed combustor models to the systems program, as well as completion of the advanced particulates control model. Completion of the industrial boiler environmental control study with a Phase III effort is also planned. This work will expand the range of boiler sizes, fuels, controls, and capacity factors that are analyzed.

New efforts will involve an updated report on utility particulates control technology, an environmental evaluation of magnetohydrodynamics technology, and a status assessment of coal-oil-mixture preparation and use. Technology comparisons will be continued with a detailed look at the trade-offs between the use of solvent refined coal and the use of conventional coal for electric power generation. Monitoring of developments in all areas relevant to the project will continue, and topical studies will be initiated if warranted.

Publication of about 10 more technical reports can be expected, and several conference presentations have been planned. Organization of the Second Environmental Control Symposium and preparation of the proceedings will be important staff activities for this period.

REPORTS PUBLISHED

The following reports have been published under the generic title "Environmental Control Implications of Generating Electric Power From Coal":

Foster Wheeler Energy Corp., "Assessment of Low-Btu Gas Combined Cycle Power Generation, ANL/ECT-3, Appendix C of Technology Status Report, Argonne National Laboratory, in press.

KVB, Inc., "Current and Advanced NO_x-Control Technology for Coal-Fired Industrial Boilers," ANL/ECT-4, Argonne National Laboratory, 1978.

Manhattan College, "Control Technology for Fine-Particulate Emissions," ANL/ECT-5, Argonne National Laboratory, 1978.

PROJECTED MILESTONES

Reports resulting from work completed in fiscal 1979 will be issued by June 1980. The third and final phase of the industrial boiler study will be completed in June 1980 in time to serve as the basis for informed comments on the New Source Performance Standards scheduled to be proposed by the Environmental Protection Agency in October 1980. Completion of the cost/performance models under development will permit the computerized comparisons of conventional and advanced (fluidized bed combustion and low-Btu gasification/combined-cycle) power systems by July 1980.

ENVIRONMENTAL CONTROL TECHNOLOGY FOR ATMOSPHERIC CARBON DIOXIDE

ORGANIZATION AND CONTRACT NUMBER

Brookhaven National Laboratory
EY-76-C-02-0016

PRINCIPAL INVESTIGATORS

A.S. Albanese
M. Steinberg

OBJECTIVE

The objective of this study is to assess the applicability of state-of-the-art control processes for controlling the level of atmospheric carbon dioxide.

APPROACH

The approach is to (1) survey alternative environmental control technologies for application to atmospheric carbon dioxide control; (2) develop conceptual process schemes for removal, recovery, and disposal (or reuse) of carbon dioxide from primary emission sources and reservoirs; and (3) assess and evaluate the control systems in terms of energy efficiency and economic costs.

PROGRESS AND RESULTS

The impact of fossil fuel use in the United States on worldwide carbon dioxide emissions and the impact of increased coal use on carbon dioxide emission rates were assessed. The aspects of carbon dioxide control were examined, as were the available carbon dioxide control points (removal sites). The primary factor affecting the practicability of a carbon dioxide control system is the energy it requires. Of the three potential control points, removal from the stacks of fossil fuel powerplants appears to require the least amount of energy. Estimates of the energy required to capture and recover carbon dioxide from coal-fired powerplant stacks by various processes were made. Although capture and recovery of carbon dioxide is an important consideration in the overall control scheme, the disposal or reuse of recovered carbon dioxide may be the weakest link in the control chain. Of the several options considered, deep ocean storage appears the most promising.

Two control scenarios were evaluated: one based on the absorption, by seawater, of carbon dioxide contained in powerplant flue gas, the other based on the absorption of carbon dioxide by monoethanolamine. Captured carbon dioxide is injected into the deep ocean in both cases. Analyses indicate that capture and disposal by seawater is not feasible, whereas capture and disposal using monoethanolamine is a possibility. However, the economic penalties of carbon dioxide control are significant; for example, at a carbon dioxide removal efficiency of 50 percent, it is estimated that the power generation efficiency of a conventional coal-fired powerplant would be reduced from 34 to about 25 percent. The cost of power generation would be expected to double. For 90-percent carbon dioxide removal, power generation efficiency is reduced to between 15 and 6 percent, and the cost of power generation increases by factors of 4 to 7.

The use of nonfossil energy sources such as nuclear or solar energy to control the carbon dioxide emissions resulting from fossil energy usage was not considered in this study.

PLANS FOR NEXT PERIOD

The study was completed as of September 30, 1979.

REPORTS PUBLISHED

Albanese, A.S., and M. Steinberg, "Environmental Control Technology for Atmospheric Carbon Dioxide," Final Report, BNL 51116, Brookhaven National Laboratory, September 1979.

PROJECTED MILESTONES

None

ASSESSMENT OF RADIOACTIVE EMISSIONS FROM COAL MINING, PROCESSING, AND COMBUSTION

ORGANIZATION AND CONTRACT NUMBER

Los Alamos Scientific Laboratory
W-7405-ENG-36

PRINCIPAL INVESTIGATOR

P. Wagner

OBJECTIVES

The objectives of this program are to (1) determine the degree of enrichment of naturally occurring radionuclides in coals and residues from coal mining, processing, and combustion; (2) identify the potential for the release of these radioactive contaminants into airborne or waterborne pathways; and (3) define environmental control technologies for those emissions or effluents having sufficiently high concentrations of radioactive substances to be of environmental concern.

APPROACH

There are three basic parts to the research required to achieve the stated technical objectives: (1) resolution of the distribution(s) of

radionuclides in the various sectors of the coal utilization cycle, (2) analysis of the nature and magnitude of radionuclide releases associated with coal use, and (3) identification of control technologies to counter environmental problem areas that are uncovered, if any. The first task included the measurement of certain radionuclides in coals, coal wastes, bottom ashes, fly ashes, and scrubber sludges from several coal-fired electric generating stations and coal-cleaning plants that use high-sulfur coals. The radionuclides analyzed included uranium-238, radium-226, bismuth-214, lead-210, and polonium-210 in the uranium-238 decay series and thorium-232 and thallium-208 in the thorium-232 decay series.

Leaching experiments have been initiated to determine the aqueous mobility of these radionuclides in a variety of coals and residues. The results of these experiments will allow us to assess the magnitude of the release of radionuclides from coal storage areas, refuse dumps, ash disposal sites, and scrubber sludge ponds. In the event that environmentally hazardous radionuclide release pathways are identified, research on appropriate environmental controls will be initiated. Identification of such hazards will require a knowledge of radionuclide enrichment as well as environmental mobility. An understanding of the environmental behavior of these contaminants is a natural precursor to development of control technologies.

PROGRESS AND RESULTS

Coals and powerplant residues from seven coal-fired electric generating stations have been analyzed for radionuclide content. The majority of these samples were provided through the Environmental Protection Agency's Office of Radiation Programs powerplant sampling program. In general, Los Alamos Scientific Laboratory's research in this area deals with some of the high-sulfur coals being sampled by the Environmental Protection Agency. Some preliminary results are as follows:

	Uranium-238 Activity (pCi/gram)	Thorium-232 Activity (pCi/gram)
Average for coal samples	0.9 ± 0.5*	0.4 ± 0.2
Average for bottom ash samples	4.3 ± 2.1	1.8 ± 0.6
Average for fly ash samples	5.4 ± 2.7	2.4 ± 1.2
Average for scrubber sludge	2.3 ± 0.9	1.0 ± 0.4

* One standard deviation.

Radium-226 and bismuth-214 appear to be in secular equilibrium with the uranium-238 for the coals and residues. Lead-210 and polonium-210 are near secular equilibrium for coals, but they are depleted in the bottom ashes; lead-210 is apparently enriched in fly ashes. The volatilization of lead and polonium during combustion probably results in their condensation and subsequent enrichment on fine fly ash particles. Thallium-208 appears to be in secular equilibrium with thorium-232 for the coals and residues. The enrichment of uranium-238, radium-226, bismuth-214, thorium-232, and thallium-208 in the ashes is similar to that of aluminum and titanium and results from the loss of the organic coal constituents during combustion. Compounds of these radionuclides are not appreciably volatile.

The preliminary results from the leaching experiments have shown that the aqueous mobility of the radionuclides radium-226, lead-210, and polonium-210 is generally low. The maximum activity in any coal or waste extract was 8.8 picocuries/liter for radium-226, 8.1 for lead-210, and 0.8 for polonium-210. The maximum percentage extractable by leaching of coals or residues was 2.6 percent for radium-226, 10.7 for lead-210, and 1.1 for polonium-210.

PLANS FOR NEXT PERIOD

Leaching experiments will be performed on the coals and coal waste samples. When completed, these leaching data will provide an initial assessment of the potential aqueous mobility of naturally occurring radionuclides in coals, coal wastes, ashes, and scrubber sludges. Upon completion of analyses of the high-sulfur coals and residues, a determination of future directions will be made. If the waterborne pathway of radionuclide release appears to be of appreciable environmental concern, it will be investigated further. Attention will also be directed to the airborne pathways, including radon-222 emissions from coal storage or residue disposal sites.

Should mobile radionuclides that present hazards to health or to the environment be identified, control technology research will be initiated to ameliorate these problem areas.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

Monthly and annual reports will be submitted, and semiannual program reviews of results and research directions will be conducted with the Environmental Control Technology Division program manager.

AN ENVIRONMENTAL ASSESSMENT OF COGENERATION AS A DISTRICT HEATING SOURCE

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
Energy and Computer Sciences Division
W-7405-ENG-26

PRINCIPAL INVESTIGATORS

W.G. Stockdale
H.A. McLain
D.B. Murphy

OBJECTIVE

The objective of this study is to examine the environmental aspects of a district heating system supplied by cogenerated heat at electrical power generation stations. In large metropolitan areas, replacing a large number of individual heating systems that use fuels such as distillate and residual oil with district heating/cogeneration offers the potential of improving the air quality in those regions.

APPROACH

The twin cities of Minneapolis-St. Paul were selected as the study area because district heating/cogeneration is considered a viable project for implementation there in the 1980s and 1990s. Studsvik Energiteknik prepared the plan under subcontract to Oak Ridge National Laboratory for the Department of Energy. The annual averages of the ground-level sulfur dioxide concentrations in the Twin Cities area were selected as the measure of air quality. To assess the impact of this action, three scenarios were chosen: a base case (1976, the latest year data are available); a scenario in a future year with partial gas curtailment and no district heating/cogeneration; and the same year with district heating/cogeneration. Partial gas curtailment and substitute fuel information for the Twin Cities is available for 1987; the substitute fuel is primarily distillate and residual oil. The study therefore used 1987 as the future year for the last two scenarios, even though 2000 is a more realistic date for a district heating/cogeneration system to be fully implemented.

Emission source inventories based on review, update, and additions of the National Emission Data System file for the Twin Cities area were developed by the Minnesota Energy Agency and Lockheed-Huntsville Research and Engineering Center under subcontracts to Oak Ridge National Laboratory. Using these data, the ground-level sulfur dioxide concentrations were estimated using the Environmental Protection Agency Climatological Dispersion Model.

PROGRESS AND RESULTS

The emission source inventories were completed by the Minnesota Energy Agency and Lockheed and put in a format suitable for the Climatological Dispersion Model. This included evaluating the data and making estimates where data were missing or questionable. Projections were made of gas use by 11 priority classes from the area utility. Curtailments of gas to the different priority classes were projected for 1987. The mix of alternate fuels, mainly distillate and residual oil, was estimated for gas-curtailed customers.

The Climatological Dispersion Model was run for the three study scenarios to characterize the ground-level sulfur dioxide concentrations in the Twin Cities area. Typical results are shown in Figures 2 and 3. In 1987, without district heating/cogeneration, the maximum ground-level sulfur dioxide concentration exceeds 35 micrograms/cubic meter near the courthouse as well as the south part of the Twin Cities, which has a large number of refineries. The concentration exceeds 30 micrograms/cubic meter in a substantial portion of the urban areas. With district heating/cogeneration, the concentrations decrease sharply (except for the refinery area, which does not have district heating/cogeneration); maximum sulfur dioxide concentrations are predicted to be less than 30 micrograms/cubic meter; and the areas of the highest concentrations are decreased.

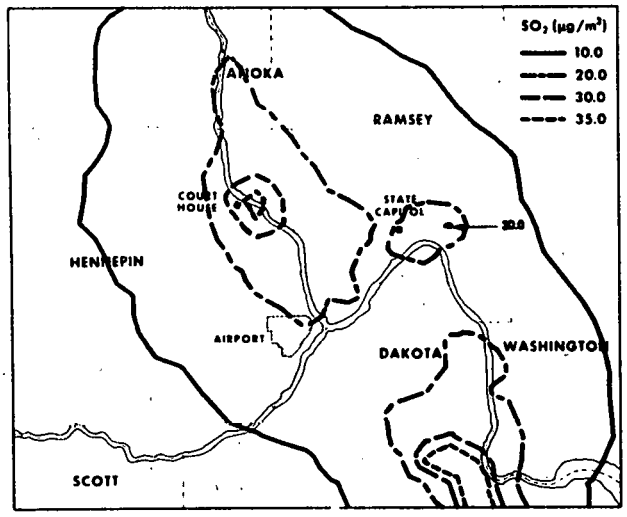


Figure 2. 1987 Ground-Level Air Concentrations of SO_2 Without Cogeneration

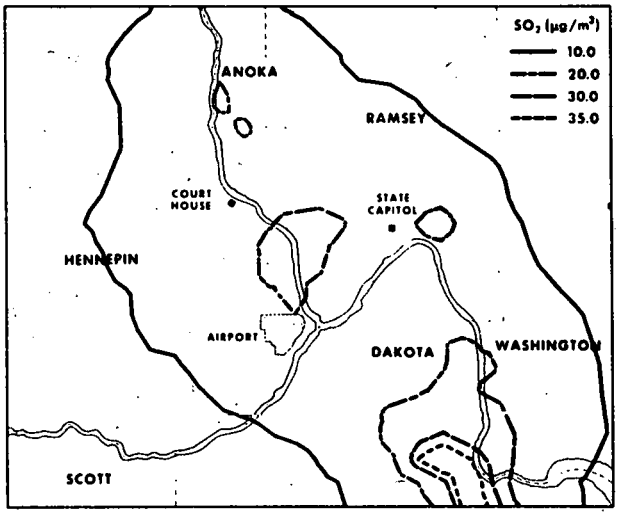


Figure 3. 1987 Ground-Level Air Concentrations of SO_2 With Cogeneration

PLANS FOR NEXT PERIOD

A report presenting the results of the study and the methodologies and assumptions used will be published.

REPORTS PUBLISHED

Murphy, B.D., et al., "The Effects of a District Heating System on Annual Urban Sulfur Dioxide Emissions," in District Heating/Cogeneration Symposium, April 2-3, 1979, Proceedings, CONF-790401, Oak Ridge National Laboratory, October 1979.

PROJECTED MILESTONES

- Second quarter of fiscal 1980 -- Issue final report.

ASSESSMENT OF ENVIRONMENTAL CONTROL OPTIONS FOR CONTROL OF CARBON DIOXIDE IN THE GLOBAL ATMOSPHERE

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATORS

C.F. Baes, Jr.
S.E. Beall
D.W. Lee
G. Marland

OBJECTIVE

The objective of this project has been to develop possible alternatives for the recovery and disposal of carbon dioxide from concentrated sources and to assess their feasibility for controlling carbon dioxide in the global atmosphere.

APPROACH

The approach has been to study (1) the possible methods of removing carbon dioxide from concentrated sources, such as the stack gases produced by electric power generating stations; (2) the characteristics of the various physical forms of carbon dioxide, such as compressed gas, concentrated aqueous solutions, the solid hydrate, and dry ice; and (3) the feasibility of disposing of carbon dioxide in the deep oceans or storing it in depleted gas and oil fields, as biomass, or at the South Pole.

PROGRESS AND RESULTS

A study was completed with the following conclusions:

- Scrubbing carbon dioxide from the stack gas of a coal-fired plant by the most efficient means presently available will require about 46 percent of the combustion energy of the coal.
- Although some improvement might be realized by burning the coal in pure oxygen, any method of recovery from stack gas will use a substantial fraction of the energy content of the fuel.
- The best option for disposal is in the ocean, in the form of a negatively buoyant plume of concentrated solution that would carry the carbon dioxide to deep water, giving retention times of many hundreds of years. Alternatively, liquid carbon dioxide could be injected into the ocean, but at much greater depths to achieve the needed density, or blocks of the solid hydrate or dry ice might be released at the ocean surface.
- The most efficient option for the future might be floating power stations that use cold, deep seawater both for condenser cooling and carbon dioxide disposal. One such attractive configuration would be to compress the flue gas directly and scrub the carbon dioxide (and sulfur dioxide) directly with seawater under sufficient pressure to form a negatively buoyant plume.
- Depleted oil and gas fields could be used as a near-term storage option, but storage as buried biomass or as a solid near the South Pole were the least attractive options considered.

PLANS FOR NEXT PERIOD

This program was terminated at the end of fiscal 1979.

REPORTS PUBLISHED

Baes, C.F., Jr., S.E. Beall, and G. Marland, "Options for Collection and Disposal of Carbon Dioxide From Concentrated Sources," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Baes, C.F., Jr., et al., "Options for the Collection and Disposal of Carbon Dixoide," Final Report, in preparation.

PROJECTED MILESTONES

None

WASTE HEAT AND WATER MANAGEMENT IN THE ELECTRIC POWER INDUSTRY

ORGANIZATION AND CONTRACT NUMBER

Massachusetts Institute of Technology
E(11-1)4114(EY-76-S-02-4114-A001)

PRINCIPAL INVESTIGATOR

D.R.F. Harleman

OBJECTIVE

The tremendous quantity of waste heat rejected by steam-electric powerplants represents both a substantial energy loss and a major environmental concern. The environmental impact of waste heat on natural water bodies can be greatly reduced by employing closed-cycle cooling systems such as cooling towers, ponds, or spray modules. However, these systems are generally more costly and involve greater fuel (and often freshwater) consumption than open-cycle systems due to greater capital costs, decreased net efficiency, reliance on evaporative cooling, and the requirement for greater backup capacity. Additionally, closed-cycle systems may have other environmental impacts of their own. The objectives in the initial phases of this project (fiscal 1977 and 1978) were to examine these trade-offs more closely as they relate to the choice, design, and operation of a cooling system for an individual plant and as they relate to national policies concerning fuel conservation goals, water pollution control, and so on. In the most recent phase (fiscal 1979), the focus was specifically on the water consumption of alternative closed-cycle cooling systems and on how the use of cooling reservoirs and wet/dry cooling towers equipped with onsite storage can be used most effectively to minimize conflicts with existing water demands in areas where water supply is scarce or intermittent.

APPROACH

The initial phases of the project were concerned with broad economic, environmental,

and resource consumption issues associated with the choice of cooling system. Analysis of different cooling systems was performed for a specific site and generalized to regional and national levels. The latter analysis allowed the prediction of increased cost, fuel consumption, and freshwater consumption incurred by the use of closed-cycle cooling, as opposed to open-cycle cooling, as a function of various scenarios of electricity demand and powerplant siting. In addition, a study was made of the Browns Ferry Nuclear Power Plant to identify the sensitivity of costs and fuel consumption to various modes of operating the plant's supplementary cooling system.

The most recent phase of the project involved a case study of cooling system design in the arid West, using a tributary of the Powder River in Wyoming. Historical flows, demand by existing users, and other water commitments (such as downstream flow constraints) were summarized to characterize the supply (availability and value as a function of time) of water that might be used for cooling purposes. Various sized cooling reservoirs and wet/dry towers were characterized by their cost and water demand characteristics (e.g., annual consumption, maximum storage time). Combining the characteristics of water supply and demand allows a multiobjective display of cooling system cost versus impact (opportunity cost) to existing and future water users.

PROGRESS AND RESULTS

Results of the initial phases are summarized in the Proceedings of the Environmental Control Symposium (November 1978) and in the reports listed herein. For the most recent phase, water demanded by existing agricultural users was identified, and a streamflow hydrograph was developed for a typical dry year. Based on this year, a cooling system comparison was made of cost versus volume of water denied to existing (agricultural) users.

PLANS FOR NEXT PERIOD

The analysis will be extended by treating water availability stochastically, refining the value placed on water by existing users, and allowing for greater flexibility in simulating cooling system operation.

REPORTS PUBLISHED

Adams, E.E., et al., "Mathematical Models for Cooling Lake Design, Part B: Users Manual for MITEMP, Part C: Development of Quasi-Steady Models," MIT Energy Laboratory Report No. MIT-EL 79-039, 1979.

Adams, E.E., and D.R.F. Harleman, "Summary Report of Waste Heat Management in the Electric Power Industry: Issues of Energy Conservation and Station Operation Under Environmental Constraints," MIT Energy Laboratory Report No. MIT-EL 79-040, 1979.

Choi, M.K.-W., and L.R. Glicksman, "Computer Optimization of Dry and Wet/Dry Cooling Tower Systems for Large Fossil and Nuclear Plants," MIT Energy Laboratory Report No. MIT-EL 79-034, 1979.

Choi, M.K.-W., and L.R. Glicksman, "Computer Optimization of the MIT Advanced Wet/Dry Cooling Tower Concept for Power Plants," MIT Energy Laboratory Report No. MIT-EL 79-035, 1979.

Najjar, K.F., et al., "An Environmental and Economic Comparison of Cooling System Designs for Steam-Electric Power Plants," MIT Energy Laboratory Report No. MIT-EL 79-037, 1979.

Shaw, J.J., et al., "Economic Implications of Open Versus Closed Cycle Cooling for New Steam-Electric Power Plants: A National and Regional Survey," MIT Energy Laboratory Report No. MIT-EL 79-038, 1979.

Stolzenbach, K.D., et al., "Operational Issues Involving Use of Supplementary Cooling Towers To Meet Stream Temperature Standards With Application to the Browns Ferry Nuclear Plant," MIT Energy Laboratory Report No. MIT-EL 79-036, 1979.

PROJECTED MILESTONES

None

ENVIRONMENTAL EFFECTS OF DRY/WET COOLING TOWERS

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATOR

R.T. Allemann

OBJECTIVE

The objective of this program is to evaluate the environmental effects of dry/wet cooling and to develop (in conjunction with utilities and the cooling tower industry) dry/wet systems that can be applied to conserve water resources, increase powerplant siting flexibility, and give efficient powerplant performance over a year's cycle, at costs (capital and operating) substantially below systems presently available from manufacturers.

The use of water for plant cooling has implied environmental effects from the standpoint of the amount of available water used, the identification of waste heat streams, and the possible environmental effect of using aluminum as a construction material. The deposition/corrosion of aluminum is of particular environmental consequence because it influences the allowable cycles of concentration, and hence blowdown, that can be tolerated. For plants constrained with "zero discharge" criteria, this becomes a crucial factor. It is these environmental effects that will be assessed in this study.

APPROACH

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 that heat exchange increased by factors of 2 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 gigawatts-electric by the year 2000 in these new power generation methods was projected.

PROGRESS AND RESULTS

Efforts were directed at three tasks: completing a report (Parry et al., 1979) on experiments using water deluge for enhancing dry cooling; testing corrosion-deposition and environmental constraints on the use of aluminum in dry/wet towers; and studying the incentives for Using dry cooling in support of advanced energy generation systems.

The report on water augmentation tests was issued. The data obtained from the water-augmented test apparatus (see Figures 4, 5, and 6) gave the rate of heat transfer from a water-deluged fin surface heat exchanger (Figure 7). These data showed that the rate of heat transfer can be increased by a factor of 2 to 6 (depending on run conditions) above that for a dry surface.

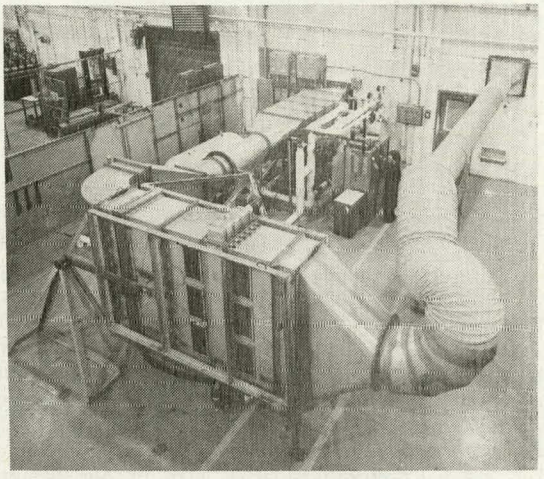


Figure 4. Water-Augmented Test Apparatus

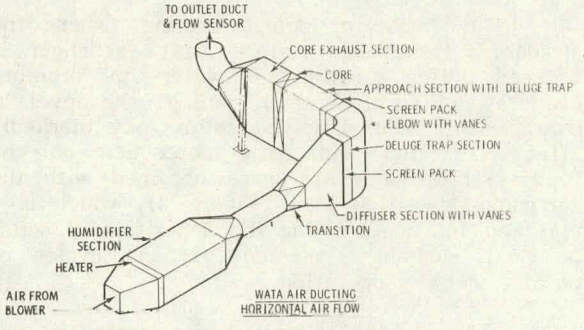


Figure 5. Water-Augmented Test Apparatus Air Ducting Horizontal Airflow

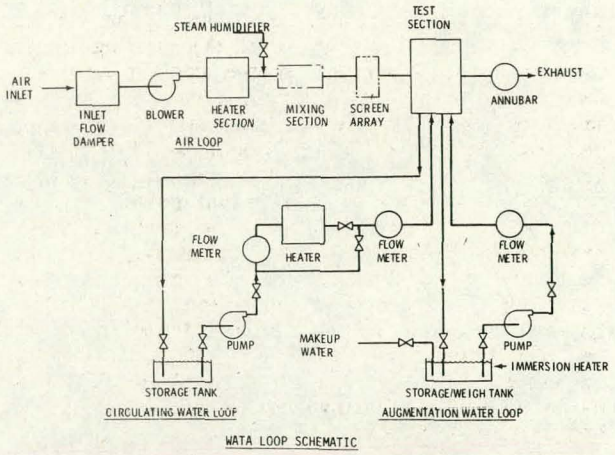


Figure 6. Water-Augmented Test Apparatus Loop Schematic

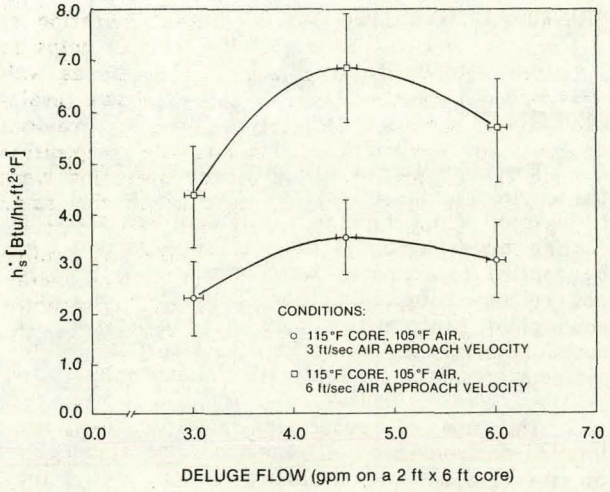


Figure 7. Effect of Deluge Flow on the Effective Deluge Surface Heat Transfer Coefficient

Because 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 or slowdown of augmentation water. Results indicate that with proper design, aluminum can be used as proposed for steam condenser tubes. Environmental constraints on the use of aluminum cooling towers will be influenced by the amount of blowdown required to keep augmentation water in a noncorroding, nodepositing 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 (Figure 8), 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-liter) deluge reservoir was installed early in fiscal 1979 to increase and stabilize the ion inventory available for deposition in a given time interval. Because scaling associated with alternate wet/dry cycling had been examined in some depth during fiscal

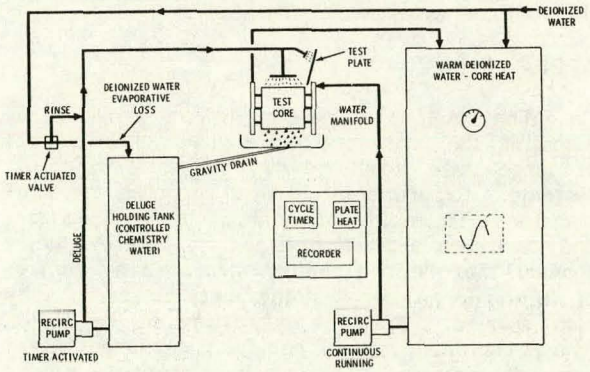


Figure 8. Corrosion-Deposition Loop

1978, the fiscal 1979 effort examined the scaling occurring only during deluging, exclusive of any deposit resulting from water film drying. Most experimental runs in the corrosion-deposition loop were made with deluge equivalent to four times Kern well* water concentration. Reducing blow-

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

down frequency by permitting tower operation to a water concentration factor of 4 (4X) helps to achieve environmental conservation goals as well as reduce operating cost. Table 2 shows results of continuous wet deposition tests. Previous tests had shown nearly double the deposition when 250 cycles 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.

Table 2. Deposition on Aluminum Fins

	Run 14	Run 15
Water Concentration	2X	4X
Core Cycles	1	1
Wet Time (Hour)	125	120
Core Wet Temperature (°F)	126	125
Weight Grain (milligrams/ square decimeter)	-13.3	47

The 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 gigawatts-electric 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 a 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 be influenced by the choice of dry cooling. Table 3 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 quad (10 gigawatts-electric) by the year 2000. Previous studies indicated that dry cooling would capture about 5 percent of the cooling duty for fossil and nuclear powerplants. Assuming central solar is used largely in the arid Southwest, perhaps 50 percent of it would be dry cooled. Siting restrictions on geothermal suggest that perhaps 10 percent of geothermal power production would be dry cooled. The sum of these projections gives about 2.5 gigawatts-electric of solar and geothermal to be dry cooled by the year 2000, compared to projections of 11 to 44 gigawatts-electric of nuclear and fossil plants to be dry cooled by the year 2000. Hence, advanced energy generation technologies offer a 6- to 23-percent increase in the projected use of dry cooling in the power industry.

PLANS FOR NEXT PERIOD

None

REPORTS PUBLISHED

Mayer, D.W., and E.M. Arnold, "Potential Use of Dry Cooling in Support of Advanced Energy Generation Systems," PNL-3149, Pacific Northwest Laboratory, Richland, Washington, 1979.

Parry, H.L., et al., "Augmented Dry Cooling Surface Test Program: Analysis and Experimental Results," PNL-2746, Pacific Northwest Laboratory, Richland, Washington, 1979.

PROJECTED MILESTONES

None

ASSESSMENT OF THE RADIOLOGICAL IMPACT OF COAL UTILIZATION: RADIONUCLIDES IN WESTERN COAL ASH

ORGANIZATION AND CONTRACT NUMBER

Mound Facility
DE-AC04-76-DP00053

PRINCIPAL INVESTIGATOR

C.E. Styron

OBJECTIVES

Objectives in this phase of the program are to (1) participate in an interlaboratory comparison of the results of radiochemical analysis of

Table 3. Summary of Energy and Waste Heat Generation/Intermediate Growth (Quads)

Energy Type	Year								
	1985			2000			2025		
	Eout[a]	QD[b]	Q1[c]	Eout	QD	Q1	Eout	QD	Q1
Coal, Synthetic Liquids	0.2	0.017	0.059	6	0.501	1.775	10	0.834	2.959
Coal, Synthetic Gas High Btu	0	0	0	2	0.332	0.631	3	0.498	0.946
Coal, Synthetic 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, Synthetic 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)	2.259 (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] Powerplants	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] Powerplants	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 powerplant.
b QD - Direct energy loss to environment (stack losses, etc.).
c Q1 - Thermodynamic cycle heat exchange energy rejection.
d Contribution from central tower plants only.
e Parenthetical values are based on a more conservative Department of Energy study.
f Eout corrected for efficiencies.

samples of coal, bottom ash, and fly ash; (2) evaluate partitioning coefficients for radionuclides in coal; (3) evaluate the potential for radiation doses from coal ash; and (4) evaluate the magnitude of leachate discharges of radionuclides from coal ash ponds to groundwaters and surface waters.

APPROACH

Experience in an earlier phase of this project confirmed the difficulty of analyzing coal and coal refuse for low levels of radionuclides. In the absence of standard methods for these determinations, an interlaboratory study was conducted to ensure comparability of results among participating laboratories. Samples of coal, bottom ash, and fly ash were split between the Mound Facility, the Los Alamos Scientific Laboratory, and the Environmental Protection Agency's Eastern Environmental Radiation Facility. Each laboratory applied its own analytical methods.

Partitioning coefficients were estimated for radionuclides in samples received from a separate Environmental Protection Agency project. These samples included coal, lignite, bottom ash, and fly ash. Emanation of radon-222, resuspension of fly ash, and leaching of uranium-238 and its radioactive progeny into groundwater and surface water were evaluated for a powerplant burning western coal.

PROGRESS AND RESULTS

Results from the three laboratories for radiochemical analysis of split samples were generally in very good agreement, with the exception of values for lead-210. Results from a commercial laboratory for analysis of radium-226 in coal were quite different from Mound's. Concentrations of radium-226 as measured by the commercial laboratory with the emanation method were two to seven times lower than concentrations as measured by Mound with emanation and with gamma spectroscopy. It is

possible that values determined by radon emanation can be biased low because of failure to completely solubilize the radium-226 in coal or ash samples. The American Society of Testing and Materials radon emanation method was developed for measuring radium in water, and the procedure has not been thoroughly tested on other sample matrices such as coal.

Additional samples shared by the Environmental Protection Agency and Mound included coal, lignite, bottom ash, and fly ash from powerplants in Colorado, Minnesota, Montana, and South Dakota. Concentration ratios for uranium and thorium as fly ash/coal and bottom ash/coal ranged from 7 to 17. Similar ratios for radium ranged from 5 to 20. Concentration ratios for lead-210 and polonium-210 as fly ash/coal were from 18 to 28; as bottom ash/coal, from 0.24 to 1.8. Partitioning coefficients and enrichment ratios for radionuclides in bottom ash and fly ash were determined for powerplants using coal and lignite and having stoker, cyclone, and pulverized coal furnaces. The bottom ash of stoker and pulverized coal furnaces was depleted of all radionuclides included in this analysis. Depletion of lead-210 and polonium-210 from bottom ash of a lignite-fueled cyclone furnace was also significant; radium-228, thorium-228, and uranium-235 were enriched in this bottom ash. Lead-210 and polonium-210 were enriched 1.5 to 2.6 times in fly ash from stoker, cyclone, and pulverized coal furnaces.

Continued studies at a powerplant burning western coal dealt with an assessment of potential radiation doses from coal ash ponds and the leachate discharges of radionuclides from coal ash ponds. Emanation of radon-222 is relatively low. Based on our studies, the predicted emanation of radon-222 from the ash pond (0.09 picocurie/square meter-second (pCi/m^2-s)) with a radium-226 concentration of 4.5 pCi/gram is roughly six times lower than the reported average emanation rate for soil in general (approximately 0.5 pCi/m^2-s). Emanation from ash containing a radium-226 concentration of 25 pCi/gram should be approximately equal to the average background value for soil. At 1000 meters from the center of the ash pond, radon-222 concentrations due to emanation from the ash ponds are predicted to be 1000 to 3000 times less than background (0.1 to 0.2 pCi/liter). Under worst case assumptions, if all the radon-222 formed from the decay of radium-226 escaped the ash particles and diffused upward through the ash with no holdup, the concentrations of radon-222 at 1000 meters due to emanation from the ash pond would be less than 30 percent of background. Pathways exist for transport of radionuclides leached from ash into an aquifer beneath the holding ponds, but concentrations of radionuclides in water leaving the ponds are less than concentrations in groundwater upgradient of the ponds. Leachability of the ash is quite low, on the order of 0.02 percent per year, and the flow of ash sluicing water (3 percent of the volume of the ponds each day) has actually diluted normal background concentrations of radionuclides.

PLANS FOR NEXT PERIOD

Similar studies will be performed at powerplants employing flue gas desulfurization systems in their emission control program.

REPORTS PUBLISHED

Styron, C.E., "A Radiological Impact Assessment of a Power Plant Utilizing Western Coal," MLM-2512(OP) Natural Radiation Environment III Symposium, Houston, Texas, April 23-28, 1978.

Styron, C.E., et al., "Assessment of the Radiological Impact of Coal Utilization. I. Preliminary Studies on Western Coal," MLM-2514, Mound Facility, Miamisburg, Ohio, February 12, 1979.

PROJECTED MILESTONES

- First quarter fiscal 1980 -- Collect samples from coal-fired powerplants having flue gas desulfurization systems
- Third quarter fiscal 1980 -- Complete analysis of radionuclides in coal, coal refuse, and flue gas desulfurization refuse

REMOVAL OF NITROGEN OXIDE AND SULFUR DIOXIDE FROM FLUE GAS THROUGH ELECTRON BEAM IRRADIATION

ORGANIZATION AND CONTRACT NUMBER

Research-Cottrell, Inc.
EP-78-C-02-4902.A000

PRINCIPAL INVESTIGATORS

J.R. Bush
L.N. Menegozzi

OBJECTIVE

A new technique for controlling nitrogen oxide and sulfur dioxide emissions from flue gases using electron beam irradiation has been under development in Japan for several years. The objective of this study is to assess the technical, economical, and environmental aspects of this new concept for coal-fired utility power-plants. This process has several advantages over conventional flue gas scrubbing processes:

- Nitrogen oxide and sulfur dioxide are removed simultaneously;
- The process is dry, which enhances operating reliability;
- With ammonia addition, marketable fertilizer byproducts can be produced; and
- The proccess lends itself to retrofit applications.

APPROACH

The project was divided into five subtasks:

- Critical study of the literature on irradiation of sulfur dioxide and nitrogen oxide systems
- Design of bench-scale experiments for typical conditions found in utility applications (Figures 9 and 10)
- Bench-scale experiments with both d.c. and pulsed electron beams

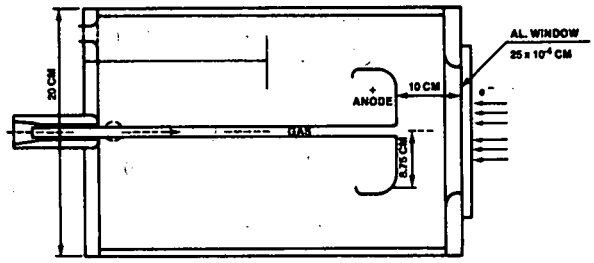


Figure 10. Reaction Chamber

- Development of a model based on experimental data to predict nitrogen oxide and sulfur dioxide removal as functions of irradiation dosage, operating conditions, and flue gas composition
- Technoeconomic evaluation of the process

PROGRESS AND RESULTS

The project has been completed and has established the feasibility of applying this technology to a coal-fired system with widely varying sulfur and fly ash contents.

Another important result has been the development of a phenomenological, mathematical model that fits the data obtained in this project, as well as the data previously published by Japanese authors. A computer version of the model can be used to predict removal rates of nitrogen oxide and sulfur dioxide under a range

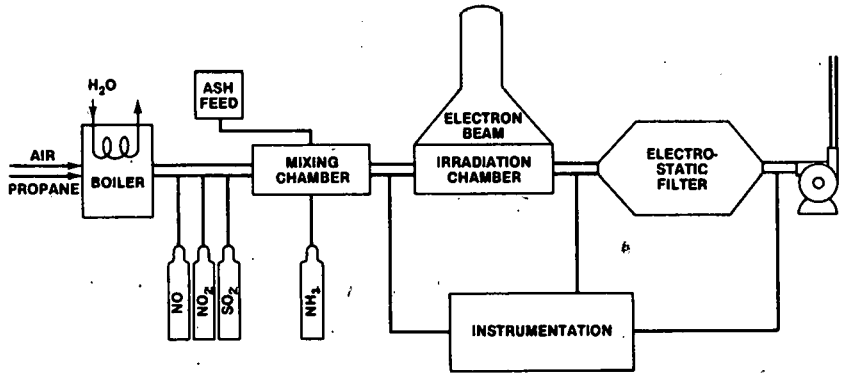


Figure 9. Bench-Scale Experimental System

of conditions, including electron beam dosage, temperature effects, moisture, oxygen, and ammonia addition.

A technoeconomic evaluation was made for several potential E-beam processes for sulfur dioxide removal with simultaneous high nitrogen oxide removal. The results show that the following processes have lower overall annual costs than existing commercial processes for sulfur dioxide and nitrogen oxide control:

- Spray dryer/electron beam/fabric filter
- Electron beam/electrostatic precipitators/fertilizer byproduct
- Electron beam/electrostatic precipitators/double alkali

Furthermore, the economic analyses indicate that the first two processes are lower in cost than the wet limestone flue gas desulfurization process for high-sulfur coals without the nitrogen oxide removal requirement.

PLANS FOR NEXT PERIOD

None, project completed

REPORTS PUBLISHED

"Removal of NO_x and SO_2 From Flue Gases Using Electron Beam Irradiation," report to the U.S. Department of Energy in compliance with contract EP-78-C-02-4902.

PROJECTED MILESTONES

None

ENVIRONMENTAL ASSESSMENT OF COAL WASTE DISPOSAL IN OCEAN WATERS

ORGANIZATION AND CONTRACT NUMBER

State University of New York at Buffalo, Marine Science Research Center
New York State Energy Research and Development Authority
EP-78-C-02-5029 (A000)

PRINCIPAL INVESTIGATORS

I.W. Duedall
P.M.J. Woodhead

OBJECTIVES

As a possible solution to the problem of the disposal of the calcium sulfate-sulfite sludge and fly ash that accompany the operation of coal-fired plants using scrubbers, stabilized scrubber sludge in the form of blocks is being placed in the ocean. The objective of this project is to determine the engineering and economic feasibility and environmental acceptability of disposing of these coal wastes in the form of a large-scale, artificial reef. Before establishing the entire reef structure, a baseline study at the project site and a laboratory study of the block material have been conducted.

APPROACH

A baseline study of the project site has determined the physical and chemical characteristics of the water column and bottom sediments. The biological community has also been sampled and identified. A sampling schedule has been established to detect any significant changes in these properties after the placement of the large reef blocks in the ocean. When the engineering aspects of the production and transport of the large blocks have been developed and cost analyses of the process have been determined, the feasibility of this disposal method will be ensured.

PROGRESS AND RESULTS

Laboratory characterization of scrubber block material similar to the composition of blocks to be used during this project has been conducted with funding from the New York State Energy Research and Development Authority, the Power Authority of the State of New York, the Electric Power Research Institute, and the Environmental Protection Agency. Data on the physical integrity and biological colonization of small scrubber blocks have been collected over 16 months at Conscience Bay and for the past 9 months at the ocean reef site.

The initial study of the engineering aspects of producing the blocks has been carried out by IU Conversion Systems, Inc., of Philadelphia and by the Marine Sciences Research Center. Sampling procedures for both above and below water have been devised. Baseline cruises have been performed to obtain data on the chemical and physical properties of the water column and bottom sediments as well as to collect samples of the phytoplankton, zooplankton, and benthic communities. A series of sample blocks (Figure 11) has been installed to determine

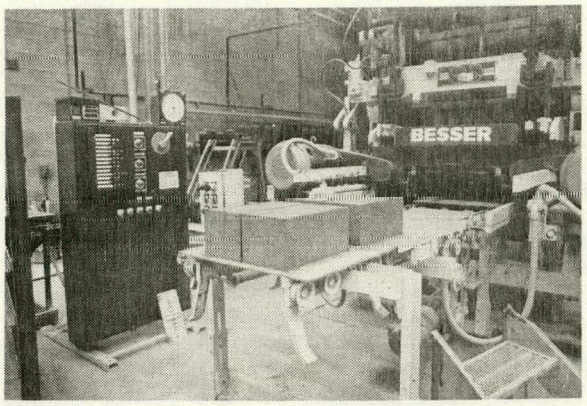


Figure 11. Sample Scrubber Blocks

environmental compatibility and susceptibility to weathering as a function of sludge fixation parameters.

PLANS FOR NEXT PERIOD

Work will continue on the laboratory characterization of the various compositions of the reef blocks. Leaching investigations will include elutriate, percolation, and tank leaching experiments. Concentrations of major and minor components in the dissolved and particulate phases will be determined in replicates using methods already developed at the Marine Science Research Center. Such components include Ca, SO_3, SO_4, Ni, As, Se, Cd, Hg, Pb, Fe, and other selected trace elements.

Another baseline cruise will be conducted at the project site. This cruise will collect data concerning the physical and chemical properties of the water column, including salinity, temperature, dissolved oxygen, chlorophyll *a*, suspended sediment, nutrients, and heavy metals, and will obtain samples to study the phytoplankton and zooplankton communities. Bottom grab samples will be taken to allow characterization of sediment properties, including metals composition. A study of the benthic community will also be accomplished with these samples. Divers will survey the project site for benthic organisms unobtainable by grab samples and will survey the existing artificial fishing reef nearby.

Production of several thousand coal waste blocks will begin in early spring with placement of the blocks in the Atlantic Ocean expected in late spring 1980. The physical integrity and chemical composition of the blocks will be monitored monthly. Colonization of the block surfaces will be documented on a monthly basis in two ways: using photographs taken by divers and by laboratory analyses on test blocks returned from the reef. Colonizing organisms, grazers and browsers, and local fish will be analyzed for possible uptake of reef block components. Bioassay analyses will be performed using approved Environmental Protection Agency procedures.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- March 1980 -- Complete placement of 7000 blocks of scrubber sludge and fly ash

EXPERIMENTAL INVESTIGATION OF ACOUSTIC AGGLOMERATION SYSTEMS FOR FINE PARTICLE CONTROL

ORGANIZATION AND CONTRACT NUMBER

State University of New York at Buffalo, Laboratory for Power and Environmental Studies
DE-AC02-79EV10013

PRINCIPAL INVESTIGATOR

D.T. Shaw

OBJECTIVE

The objective of the program is to determine the feasibility of using acoustic agglomeration as a preconditioner in the upstream of conventional devices such as electrostatic precipitators, scrubbers, filters, or cyclones. Under high acoustic intensity (> 160 decibels), fine particles agglomerate into coarser ones, making the fine particles easier to remove with conventional devices. Laboratory-scale experiments will be performed to determine the acoustic agglomeration rates under both standing-wave and traveling-wave modes of operation.

APPROACH

Hot-film anemometer and Fast Fourier Transform data-processing equipment will be used

to determine the origin and nature of acoustic turbulence. Simulated aerosol particles of NH_4Cl will be used to verify the analytical results on the acoustic agglomeration rate. A light-scattering technique will be used to monitor the total agglomeration rate, and the centrifuge mass spectrometer and cascading impactor will be used to measure the time-dependent size distribution changes. A computer program was developed for predicting such size distribution changes. The mechanisms included in the computer program are Brownian and gravitational coagulation and isokinetic, hydrodynamic, and turbulent interactions.

PROGRESS AND RESULTS

Turbulent interaction has been identified as the predominant acoustic agglomeration mechanism at relatively high intensities (160 decibels). The root mean square turbulence velocity, which is directly proportional to the acoustic agglomeration rate, is experimentally found to have a $I^{1/2}$ (I = acoustic intensity) dependence but is relatively independent of the acoustic frequency. This is contrary to the previous theory that isokinetic interaction is the most important acoustic agglomeration mechanism. The fact that the acoustic agglomeration rate is independent of acoustic frequency makes it possible to operate acoustic agglomerators at relatively low frequency (400 to 1000 hertz). Such low-frequency operation is desirable because of the low acoustic attenuation in the aerosol chamber and the high efficiency in sound generation.

PLANS FOR NEXT PERIOD

The primary emphasis will be on the experimental verification of acoustic agglomeration rates under various operating conditions. The data will be compared with the computer model, and the model will be modified as needed. In addition, the possible enhancement of acoustic agglomeration by precharging and preconditioning the particles will be investigated.

REPORTS PUBLISHED

Rajendran, N., et al., "Acoustic Precipitation of Aerosol Under Standing-Wave Condition," Journal of Aerosol Science, Vol. 10, No. 329, 1979.

Shaw, D.T., and N. Rajendran, "Application of Acoustic Agglomerators for Emergency Use in LMFBR Plants," Nuclear Science and Engineering, Vol. 70, No. 127, 1979.

Shaw, D.T., and K.Tu, "Acoustic Particle Agglomeration Due to Hydrodynamic Interaction Between Monodisperse Aerosols," Journal of Aerosol Science, Vol. 10, No. 317, 1979.

Wiley Interscience, "Acoustic Agglomeration of Aerosols," in Recent Developments in Aerosol Science," Chapter 13, New York, 1978.

PROJECTED MILESTONES

None

POROUS DIKE INTAKE EVALUATION

ORGANIZATION AND CONTRACT NUMBER

New England Power Company
Interagency Agreement With the Environmental Protection Agency and the Department of Energy

PRINCIPAL INVESTIGATORS

S.K. Batra
B.A. Ketschke

OBJECTIVE

The overall objective of this project is to install and monitor a new intake screening device for industrial cooling water systems. Industrial cooling systems are required by Section 316(b) of the Clean Water Act to be equipped with the best technology available to minimize adverse environmental impact. The porous dike is one possible system that could advance the state-of-the-art technology in intake design to minimize adverse environmental impact. The specific objectives of this project are to quantify

- Under natural conditions, the effectiveness of porous dikes of various compositions in excluding zooplankton, fish larvae, and post-larval to adult fish from powerplant cooling water intakes and
- The level and composition of fouling and/or clogging within the dike, continuously over time and in separate seasons.

APPROACH

The approach used was to build and test a small-scale porous dike structure. For this study, a 60 by 20 by 10 foot porous dike test facility was constructed. The structure is divided into three sections, two of which are equipped with porous dike stone gabions. Water is then drawn through the test gabions at 0.1 foot/second by a single axial flow pump. On a regular basis, the ability of zooplankton, fish larvae, and fish to avoid passage through the stone dike is measured. The hydraulic head loss, velocity, and degree of fouling will also be measured. Laboratory work on the swim speed and behavioral response of larval and juvenile fish will be conducted to investigate the behavioral avoidance capacity of these forms. This work will be correlated with field results collected during the fish and larval fish screening study. Laboratory work will be conducted in a specially designed T-shaped flume that allows for low-velocity tests simulating intake withdrawal.

PROGRESS AND RESULTS

The porous dike test facility (Figure 12) has been completed, and testing has been initiated. Laboratory work on larval and juvenile fish supports the idea that some species of larval and juvenile fish avoid entrainment through a stone dike. Early field testing has shown positive results for zooplankton, fish larvae, and adult and juvenile fish avoidance.

PLANS FOR NEXT YEAR

Field testing of zooplankton, fish larvae, and adult and juvenile fish entrainment avoidance will continue.

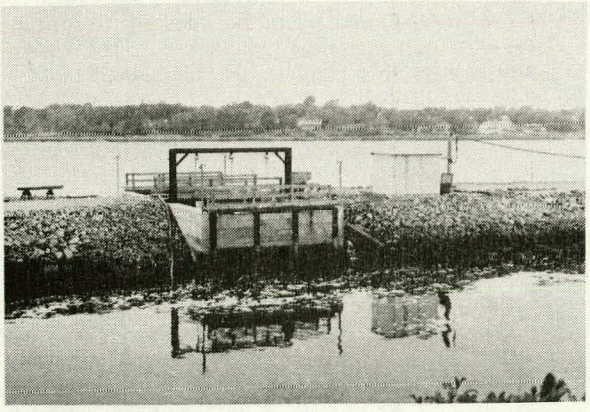


Figure 12. Porous Dike Test Facility

REPORTS PUBLISHED

Ketschke, B.A., and M.R. Anderson, "Use of a Porous Dike to Reduce Entrainment and Entrapment in Power Plant Cooling Water Intake Systems," Northeast Fish and Wildlife Conference, Providence, Rhode Island, April 1979.

PROJECTED MILESTONES

- Complete porous dike field test facility
- Initiate all field testing procedures
- Complete laboratory work on larval and juvenile fish swim speed and avoidance

NOVEL METHODS FOR RESPIRABLE DUST CONTROL

ORGANIZATION AND CONTRACT NUMBER

General Electric Company
DE-AC02-79EV10143

PRINCIPAL INVESTIGATORS

R.R. Boericke
P.W. Dietz

OBJECTIVES

The objectives of this program are to (1) determine the technical and economic feasibility of electrocyclone particulate control devices for the control of fine particulate matter contained in flue gas resulting from the combustion of coal and (2) evaluate the role acoustic agglomeration techniques may have in complementing and/or competing with the reference electrocyclone collectors to control fine particulates.

APPROACH

The program is organized into two tasks. Under Task 1, Extension of Bench Experiments, an experimental electrovortex apparatus (Figure 13) will be used to perform parametric studies of the combined effects of electrostatics, aerodynamics, and inertial behavior of small particles in the respirable dust range. An existing theoretical model will be refined to fit the observations on fine particles and then used to assess the potential of the electrocyclone to remove such particles.

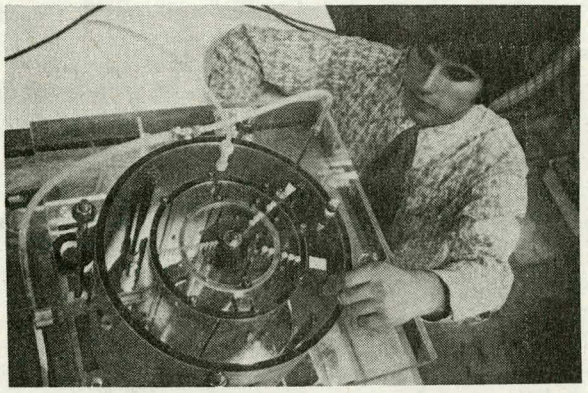


Figure 13. Laboratory Apparatus for Particulate Removal

Under Task 2, Applications Study, the potential roles of both the electrocyclone and the acoustic agglomerator for control of coal combustion particulate emissions will be investigated. Preferred particulate control systems will be identified for (1) a new pulverized coal boiler, (2) a retrofit pulverized coal boiler, and (3) a pressurized fluidized bed coal combustor, using appropriate combinations of conventional cyclones, conventional electrostatic precipitators, electrocyclones, and acoustic agglomerators.

PROGRESS AND RESULTS

This program was initiated in September 1979. Work to date has involved redesign and modification of the instrumentation on the electrovortex apparatus to accommodate the respirable particle size range (0.3 to 3 micrometers). An existing analytical model for electrocyclone performance is being modified to include effects of diffusion charging and fluid-particle slip.

PLANS FOR NEXT PERIOD

This project will be completed in fiscal 1980. A final report will be prepared delineating the applicability of electrocyclones for fine particle control and the role acoustical preagglomeration may have in this family of inertial collectors. Recommendations for future work will be made, stating both program objectives and resource requirements.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- May 1980 -- Complete bench experiments
- June 1980 -- Complete application study
- July 1980 -- Prepare final technical progress report

EVALUATION OF POLLUTANTS FROM FLASH HYDROPYROLYSIS

ORGANIZATION AND CONTRACT NUMBER

Brookhaven National Laboratory
EY-76-C-02-0016

PRINCIPAL INVESTIGATORS

M. Steinberg
A.S. Albanese

OBJECTIVE

The objective of this project is to assess the environmental factors and control technologies involved in the flash hydropyrolysis of coal and in related processes for the production of gaseous and liquid hydrocarbon fuels and feedstocks.

APPROACH

Laboratory analyses will be conducted on samples obtained from Brookhaven National Laboratory's experimental flash hydropyrolysis unit (Figure 14). Based on the experimental data and a literature survey of available environmental control technologies, conceptual flow diagrams and mass and energy balances of full-scale flash hydropyrolysis chemical and refinery complexes will be prepared. Available technologies will be assessed, and areas in which new technology is required will be identified. In addition, an attempt will be made to extend and generalize the findings and conclusions by reviewing and analyzing the available literature and data on processes related to flash hydropyrolysis, such as those under development at the Institute of Gas Technology, Rocketdyne, Cities Service, and City College of New York.

PROGRESS AND RESULTS

Product streams of the experimental flash hydropyrolysis unit have been analyzed, and

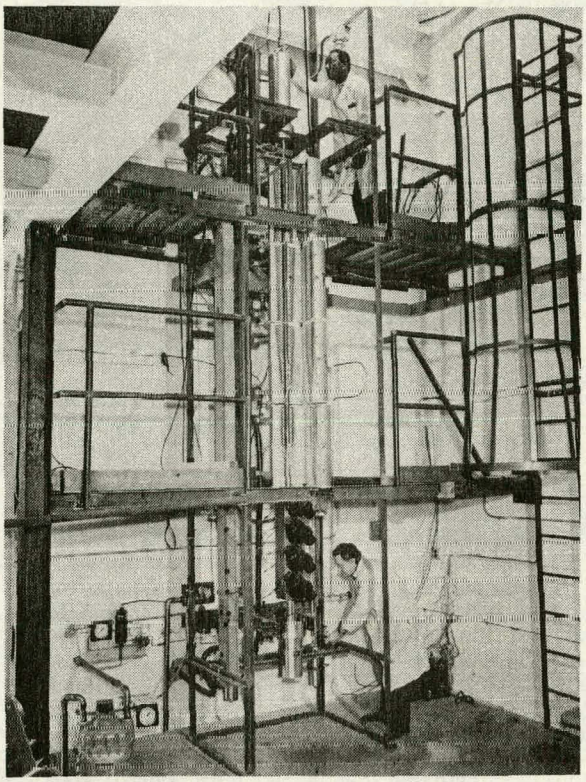


Figure 14. Brookhaven National Laboratory Bench-Scale Flash Hydropyrolysis Unit Used To Assist in Assessment of Environmental Control Requirements

potential pollutants, identified. On a weight percentage basis for a North Dakota lignite feed, the carbon and ash contained in the product char are higher than in the dry lignite feed, but the hydrogen, oxygen, nitrogen, moisture, and volatile matter contents are reduced. The same trends are indicated when processing New Mexico subbituminous coal. However, the two types of coal behave differently with respect to sulfur. In the case of lignite, the sulfur content of the char is about twice as great as that of the coal feed, increasing from about 0.6 percent by weight to about 1.1 percent by weight, on the average.

The liquid product of flash hydropyrolysis, which is formed on cooling the raw gaseous effluent of the unit, consists of two phases: an organic phase, containing benzene, toluene, xylene, and light oils, and an aqueous phase. The organic phase has been analyzed for carbon, hydrogen, nitrogen, sulfur, trace elements, and polynuclear aromatics; the aqueous phase has been analyzed for ammonia, phenols, cyanide, thiocyanate, and total carbon. The gas product of flash hydropyrolysis, consisting of those components that do not condense after a two-stage condensation at 55°F and -22°F, respectively, is principally composed of methane, ethane, and oxides of carbon.

Based on the experimental results and analytical studies, a preliminary environmental assessment of a conceptual, industrial-scale flash hydropyrolysis chemical complex producing pipeline gas, benzene, light oils, ethylene, and a number of byproducts has been made. Solid, liquid, and gaseous effluents of the complex have been evaluated, and required treatment facilities and potential problem areas, identified. A similar analysis on a flash hydropyrolysis refinery complex has been made for three modes of operation: (1) for the production of pipeline gas, (2) for the production of liquid hydrocarbons such as motor gasoline and liquefied petroleum gas, and (3) for the production of both liquid and gaseous products.

PLANS FOR THE NEXT PERIOD

The study was completed as of September 30, 1979.

REPORTS PUBLISHED

Albanese, A.S., and M. Steinberg, "Environmental Control Technology for the Flash Hydropyrolysis of Coal," Progress Report No. 3, BNL 50983, Brookhaven National Laboratory, February 1979.

PROJECTED MILESTONES

None

ENVIRONMENTAL CONTROL ASPECTS OF IN SITU COAL GASIFICATION: GROUNDWATER QUALITY CHANGES AND SUBSIDENCE EFFECTS

ORGANIZATION AND CONTRACT NUMBER

Lawrence Livermore Laboratory
W-7405-ENG-48

PRINCIPAL INVESTIGATOR

S.W. Mead

OBJECTIVES

Two important environmental concerns associated with in situ coal gasification (now generally called underground coal gasification) are (1) the possibility of groundwater contamination by reaction products that remain underground after gasification and (2) ground subsidence. The intermediate objectives of this project include (1) measurements and assessments of changes in groundwater quality and subsidence effects in the vicinity of specific experiments and (2) the development of a predictive capability with regard to these effects that is applicable to commercial-scale underground coal gasification. The ultimate objective is the identification of appropriate control technologies.

APPROACH

The investigation of groundwater quality effects of underground coal gasification includes groundwater sampling and analysis before, during, and after gasification; laboratory studies of ash-leaching and of contaminant sorption by coal and other media; and computer modeling of the evolving plume of contaminated groundwater.

The subsidence studies involve field investigations carried out in conjunction with specific experiments, triaxial strength measurements of core samples, and the application and validation of a finite element computer code for subsidence prediction. The field investigations include both surface and subsurface ground deformation measurements.

PROGRESS AND RESULTS

The effects of underground coal gasification on groundwater quality continued to be investigated during the past year by means of a groundwater monitoring program, laboratory experiments, and modeling studies. Water quality sampling is now in progress at the sites of three experiments conducted in northeastern Wyoming by the Lawrence Livermore Laboratory. Measurements near the first experiment (Hoe Creek I, 1976) showed that, in this instance, the largest group of organic contaminants consisted of phenolic materials. The phenols were concentrated in a shell-like layer just outside the burn boundary at an initial level of approximately 400 parts per million. These materials are effectively sorbed by the surrounding coal. Recent measurements show that in the first 25 months after gasification, the concentration of phenolic materials near the gasification cavity decreased by more than two orders of magnitude (Figure 15). However, the generality and ultimate effectiveness of sorption cleansing by the surrounding coal must be determined by further study.

Laboratory measurements have been conducted to evaluate the "distribution coefficients" (a measure of sorption effectiveness) for a broad range of residual underground contaminants associated with underground coal gasification. The species studied included 17 cations, 11 anions, aromatic hydrocarbons, phenolic compounds, and pyridine. Substances that were strongly sorbed by coal included phenolic compounds, heavy metal ions (atomic weight greater than 50), some anions (CN^-, S^{-2}, VO_3^-), aromatic hydrocarbons, and pyridine. Light metal ions and most anions were only weakly sorbed by coal. The weakly sorbed materials, boron for example, might be expected to persist for longer periods in the local groundwater.

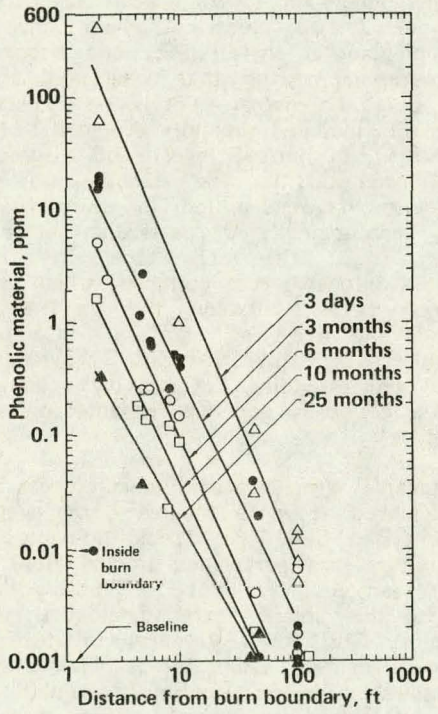


Figure 15. Concentration of Phenolic Materials in the Groundwater Near the Hoe Creek I Underground Coal Gasification Experiment. Distances Are Measured From the Nearest Cavity Boundary. Times Are Measured From the End of Gasification. The Sampling Wells Are Completed in the Gasified Coal Seam and Located in Various Directions From the Gasification Zone.

Ash leaching experiments have provided quantitative information concerning this mechanism of contaminant production. A computerized series solution of the 2-D transient convective dispersion equation was developed and used to study the evolution of the groundwater contaminants.

The ground movement and potential surface subsidence associated with the creation of a gasification cavity are also of significant environmental concern, partly because these phenomena may affect the dispersal of the reaction-product contaminants. Our continuing efforts to assess these effects have included triaxial strength tests of core samples obtained from the gasification site. The results have been used to improve our finite element modeling studies of ground movement and subsidence. We have also measured a variety of ground movement phenomena by means of an array of geotechnical instruments installed at the second gasification experiment (Hoe Creek II). The instruments included two 6-position borehole extensometers, two electrical shear strips, a multiple piezometer installation, and a borehole deflectometer apparatus that was used in six specially cased boreholes. Provisions for surface measurements included specially designed isolation bench marks, an optical level, and a precision tape extensometer. The results of these measurements have also led to more realistic modeling capabilities. Of particular interest is the fact that the subsurface instruments documented extensive roof collapse, which caused an interconnection between the gasified coal seam and two overlying aquifers. Completed post-burn coring investigations provided an improved understanding of cavity geometry, overburden collapse, and aquifer interconnection (Figure 16).

Extensive groundwater measurements have been conducted at more than a dozen wells in the vicinity of the Hoe Creek II experiment. Some analyses are performed in the field, and preserved samples are sent for more detailed analysis to the United States Geological Survey laboratories, Gulf South Research Institute, and Lawrence Livermore Laboratory. Measurements of groundwater levels (hydraulic heads) as a function of time confirm the fact that roof collapse caused the gasification cavity to be connected with overyling aquifers. Because the gasification site is a recharge region, water from

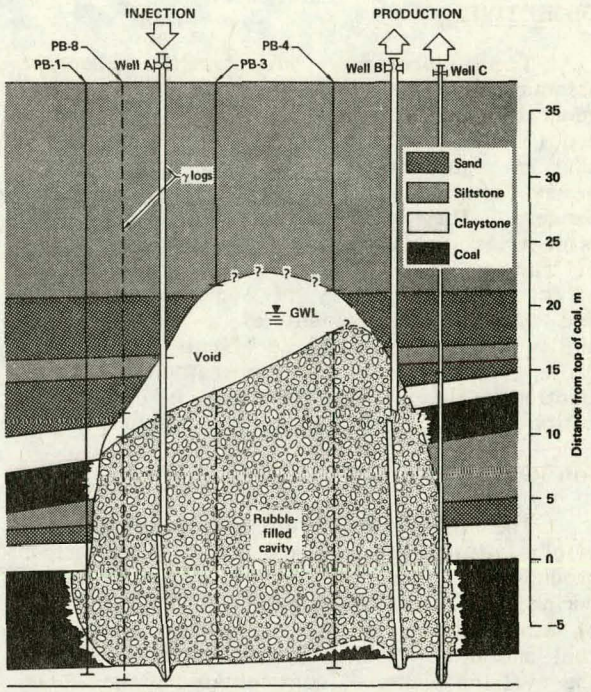


Figure 16. The Hoe Creek II Gasification Cavity. The Drawing Is Based Primarily on the Results of Post-Burn Logging and Coring Measurements (PB).

the overlying aquifers is flowing downward and then radially outward in the gasified coal seam. The environmental implications of this interconnection, including local hydrologic changes and the effects on contaminant dispersal, are being investigated. The outward movement of boron (Figure 17) is particularly interesting, because this contaminant is toxic to some plants at concentrations above 1 part per million and, as mentioned above, it may be less effectively sorbed by the surrounding coal than many other contaminants.

Recent field activities also involved the preparation and installation of groundwater sampling wells and an expanded array of geotechnical instruments (Figure 18) in the vicinity of the Hoe Creek III gasification experiment. Measurements with these facilities began in late fiscal 1979 and will be particularly important because extensive roof collapse, surface

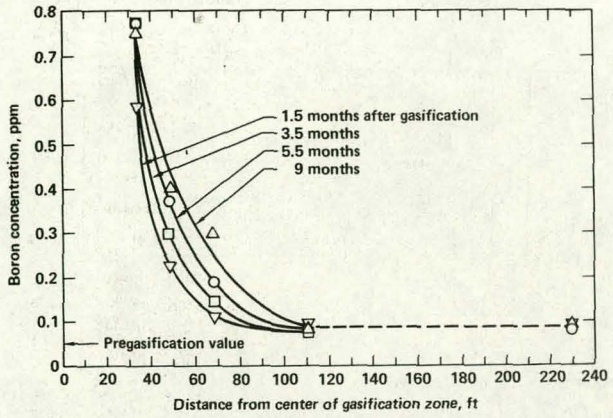


Figure 17. Changes in Groundwater Boron Concentrations Near the Hoe Creek II Experiment

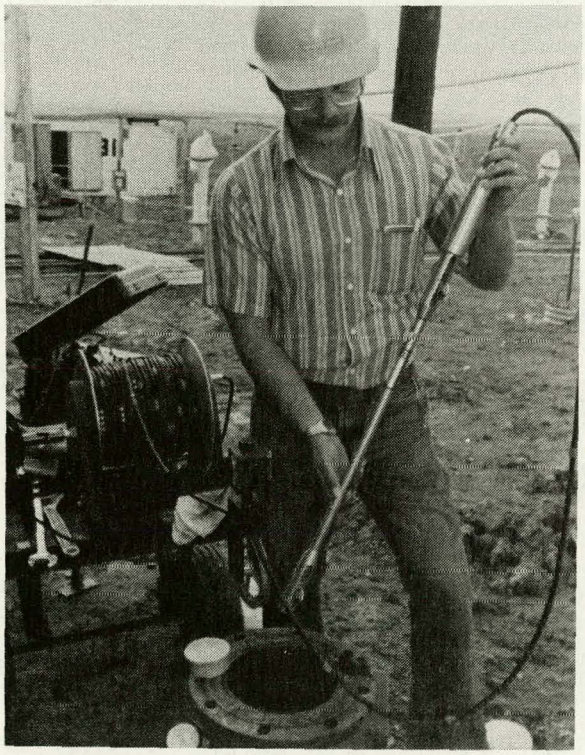


Figure 18. The Borehole Deflectometer Probe Ready for Insertion Into One of the Specially Cased Boreholes. The Device Measures Inclinations Referenced to Gravity That Are Interpreted in Terms of Lateral Displacements.

subsidence (Figures 19 and 20), and aquifer interconnection occurred as a result of the Hoe Creek III experiment. The sink in the foreground of Figure 20 is roughly 25 feet wide and has a maximum depth of about 12 feet. Horizontal displacements are being measured with a precision tape extensometer; vertical subsurface movement was measured with multiple-position borehole extensometers. The transducer head of one such instrument is shown at right center. The photo was made about 2 months after the end of the gasification experiment.

PLANS FOR NEXT PERIOD

Groundwater monitoring near the three Hoe Creek gasification experiments will be continued. A post-burn coring and logging investigation of the Hoe Creek III gasification site will be conducted. Laboratory studies of groundwater contaminants will continue and will include laboratory measurements of the sorptive properties of sandstone and clay. Subsidence modeling studies will include efforts to provide improved predictions of gasification cavity roof collapse. Efforts to identify suitable control and mitigation methods will continue with particular emphasis on specific methods of groundwater quality restoration.

During fiscal 1981, the Department of Energy expects to initiate a new series of underground coal gasification experiments at a site yet to be selected. These experiments will involve the gasification of deep coal -- 500 feet or more below the surface -- and will represent signficant steps toward an economically attractive process. It will be important to assess the environmental implications of this new hydrogeological setting. We expect to initiate preparations for the first deep-coal experiment in fiscal 1980.

REPORTS PUBLISHED

Campbell, J.H., et al., "Groundwater Quality Near an Underground Coal Gasification Experiment," Journal of Hydrology, Vol. 44, No. 241, 1979.

Ganow, H.C., "In Situ Coal Gasification at the Hoe Creek, Wyoming, Field Site -- An Overview," UCRL-82987, Lawrence Livermore Laboratory, 1979.

Homsy, R.V., "Two-Dimensional Transient Dispersion and Adsorption in Porous Media," in Proceedings of the 5th Underground Coal Conversion Symposium, Alexandria, Virginia, June 18-21, 1979, pp. 295-303.

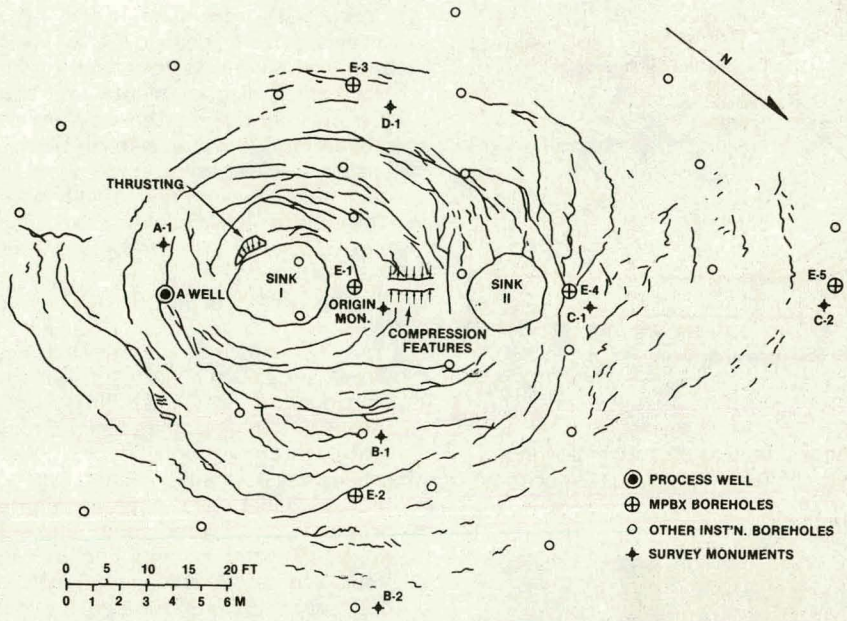


Figure 19. Surface Cracks and Subsidence Sinks at Hoe Creek III Site 28 Days After the End of Gasification

Also published as Lawrence Livermore Laboratory Report UCRL-81970, Rev. 1, 1979.

Mead, S.W., et al., "Environmental Studies of LLL's Hoe Creek II Underground Coal Gasification Experiment," UCRL-82409, Lawrence Livermore Laboratory, 1979. This paper was presented at the Fifth Annual Underground Coal Conversion Symposium, Alexandria, Virginia, June 18-21, 1979.

Mead, S.W., et al., "Ground-Water Effects of Underground Coal Gasification Experiments in Northeastern Wyoming," presented at the 54th Annual Fall Technical Conference and Exhibition of the Society of Petroleum Engineers of AIME, Las Vegas, Nevada, September 23-26, 1979.

Mead, S.W., F.T. Wang, and H.C. Ganow, "Control Aspects of Underground Coal Gasification: LLL Investigations of Ground-Water and Subsidence Effects, UCRL-81887, Lawrence Livermore Laboratory, 1978. Presented at the U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Wang, F.T., "A Comparison of Analytical Methods for Phenols, Cyanide and Sulfate as Applied to Ground-Water Samples From Underground Coal Gasification Sites," UCRL-82702, Lawrence Livermore Laboratory, 1979. To be published in the ASTM Symposium volume on Analysis of Waters Associated With Alternate Fuel Production.

Wang, F.T., "The Sorptive Property of Coal," in Proceedings of the 5th Underground Coal Conversion Symposium, Alexandria, Virginia, June 18-21, 1979, pp. 403-407. Also published as Lawrence Livermore Laboratory report UCRL-82703, 1979.

Wang, F.T., and H. Wasserman, "Transport of Metal Ions Through Coal," presented at the 1978 Fall Meeting of the American Geophysical Union.

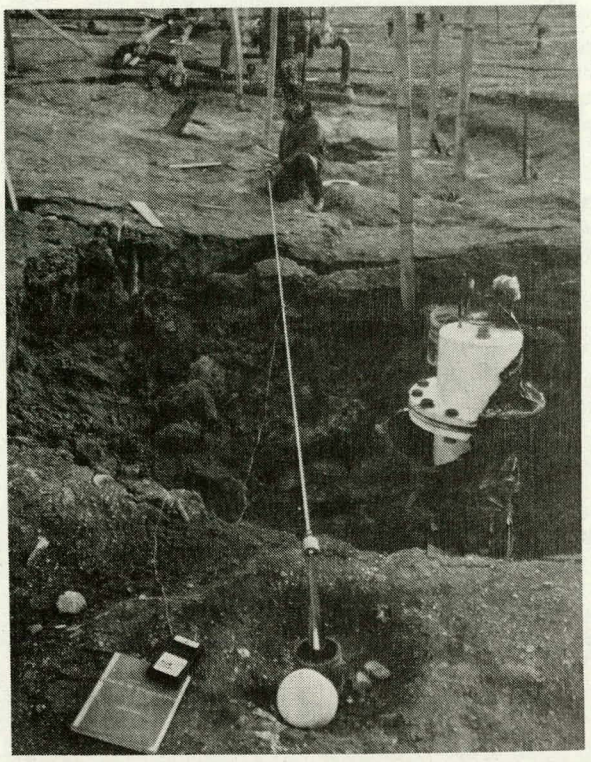


Figure 20. Surface Subsidence Above the Hoe Creek III Experiment

PROJECTED MILESTONES

- March 1981 -- Prepare fiscal 1980 annual report
- March 1982 -- Prepare fiscal 1981 annual report

ASSESSMENT OF ENVIRONMENTAL CONTROL TECHNOLOGY FOR COAL CONVERSION WASTEWATER SYSTEMS

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATORS

J.I. Brand
J.A. Klein

OBJECTIVE

The objective of this program is to investigate the applicability of various state-of-the-art and developing environmental control processes for treating aqueous coal conversion wastes. This information will, by no means, be the final word on the tractability of aqueous wastes from coal conversion processes but will provide the screening and engineering information required by the developers and designers of the developing coal conversion industry. This information must be obtained to ensure that water supply and quality are not adversely affected by the industry.

APPROACH

Experimental work for this period focused primarily on evaluating of sorption and ozonation as polishing steps for actual coal conversion wastes. However, to ensure the uniformity of wastes entering the tertiary polishing steps, some effort was devoted to standardizing primary stripping and secondary biotreatments. Monitoring of the mutagenicity and toxicity of waste during treatment was initiated, and monitoring of the levels of phenols, total carbon, polynuclear aromatics, and sulfur compounds processing was continued.

Modification of batch apparatus to continuous flow was begun before installation of an integrated wastewater system. On the left of Figure 21 is the stripping column used in primary treatment; on the right are the four parallel gravity-fed sorption columns used in polishing.

PROGRESS AND RESULTS

Screening tests of the sorption of organic carbon from the scrubber water at the Oak Ridge National Laboratory hydrocarbonization unit were carried out with inexpensive, plentiful materials. Batch contacting of samples of this wastewater after biological treatment and ozonation yielded equilibrium loadings of 0.2 milligram/gram for char from Wyodak subbituminous coal and 1.2 milligrams/gram for char from Texas Wilcox lignite. These equilibrium loadings were achieved after 4 to 5 days of contacting at 25°C. By comparison, a commercially available activated charcoal achieved a loading of 3.7 milligrams/gram in less than 2 hours of contact with the same water.

Ozonation evaluation focused on determining where in the polishing process the ozonation step should occur. Chromatographic analysis of biologically treated hydrocarbonization water

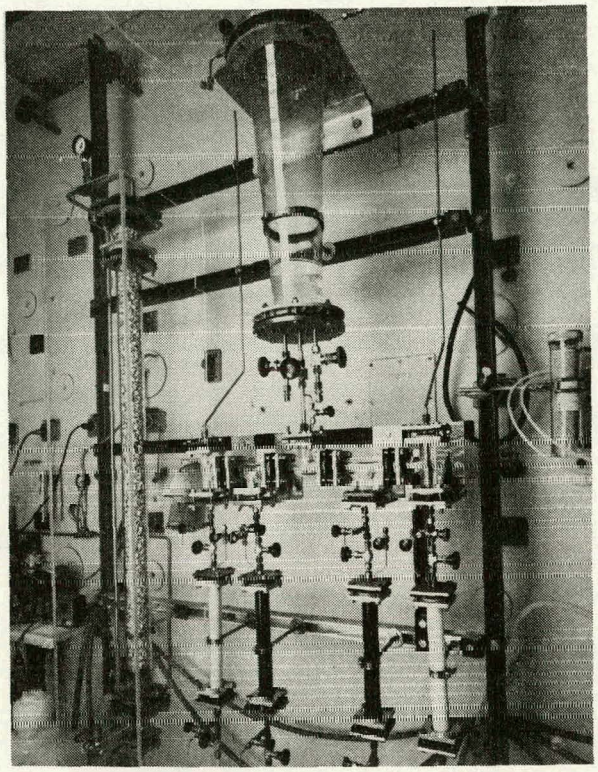


Figure 21. Steam Stripper (Left) and Gravity-Fed Parallel Sorption Columns (Right) for Assessment of Environmental Control Technology for Aqueous Coal Conversion Wastes.

showed that ozonation followed by carbon adsorption produced an effluent with no detectable fluorescence when excited at a wavelength of 272 nanometers and analyzed for emissions at wavelengths ≥ 320 nanometers. Neither ozonation or adsorption alone, nor adsorption followed by ozonation, could equal these results.

Biological treatment studies centered on two areas: acclimating a microbial population to obtain adequate phenol degradation in actual coal conversion wastes and investigating the effect of fluctuation of nonphenolic components of the waste. The acclimatization has yielded two 3.5-liter activated sludge units capable of reducing the phenol content of a steam-stripped diluted carbonized scrubber water from 500 to 10 parts per million with a residence time of 48 hours. The presence of thiocyanates appears to have no effect on the rate of phenol degradation: in batch tests using a culture unacclimated to thiocyanates, phenol was degraded from 400 to 130 parts per million consistently in 3-1/2 hours of contact time, although the thiocyanate concentration was varied from 0 to 1000 parts per million.

Short-term mutagenicity studies on the bench-scale hydrocarbonization unit scrubber water sampled at various steps of processing are summarized in Table 4. The significant reduction in mutagenicity during the early processing steps, accompanied by high concentrations of polynuclear aromatics in the sludges produced in these steps, indicates that future research focusing on these sludges is desirable. Daphnia toxicity studies on the same samples have been initiated.

Primary treatment in the conceptual integrated wastewater process consists of steam stripping to remove ammonia and hydrogen sulfide. During initial operation of the stripping column, which has a nominal diameter of 2 inches and is packed with 1.2 meters of 1/2-inch Berl saddles, 50 percent of the organic carbon in the carbonizer scrubber water that was fed to the column was carried over by the steam. This unexpected carryover was contrary to experience in the treatment of petroleum industry sour water often used as a guideline for coal conversion wastewaters. By raising the pH of stripping to 11, carryover was reduced to about 20 percent of the total carbon and 18 percent of the phenols present. This produces a stripper product amenable to biological degradation. However, the treatability of condensate from the steam carryover has not been investigated.

PLANS FOR NEXT PERIOD

Investigations of various treatment processes for coal conversion wastewater will continue. An integrated wastewater system including biological treatment, ozonation, and other advanced processes will be tested on a variety of coal effluent streams. For those treatment technologies that look promising, both toxicity and mutagenicity screening tests will be performed to determine the actual hazard level of both untreated and treated streams.

REPORTS PUBLISHED

Klein, J.A., C.H. Brown, and D.D. Lee, "Wastewater Treatment Technology for Coal Conversion Plants," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Table 4. Short-Term Mutagenicity (Salmonella Assay) of Bench-Scale Hydrocarbonization Unit Scrubber Water (Run No. HC-25)

Scrubber Water	Short-Term Mutagenicity	
	TA-98 Revertants	Contribution to Whole Effluent Mutagenicity (%)
Raw Wastewater		
Whole water	Negative results	
Acid fraction	Negative results	
Neutral fraction	5.2 rev/mg	55.6 with Ar S-9
Base fraction	830 rev/mg	44.4 with AR S-9
	3300 rev/mg	100 with øB S-9
Raffinate	Negative results	
Wastewater, pH Adjusted and Filtered		
Whole water	Negative results	
Acid fraction	Negative results	
Neutral fraction	Negative results	
Base fraction	470 rev/mg	100 with øB S-9
Bioreactor Feed	Negative results (all fractions)	
Biotreated Water	Negative results (all fractions)	
Ozonated Water	Negative results (all fractions)	
Ozonated and Charcoal Absorbed	Negative results (all fractions)	
Charcoal Absorbed and Ozonated	Negative results (all fractions)	

PROJECTED MILESTONES

- June 1980 -- Design and construct an integrated polishing process train for actual coal conversion wastewater
- Publish topical reports and open literature publications as appropriate

COAL CONVERSION -- HYDROCARBON AND CARBON MONOXIDE EFFLUENT CONTROL

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATORS

C.H. Brown, Jr.
J.A. Klein

OBJECTIVE

The objective of this investigation is to determine the feasibility of using catalytic incineration and coal-fired incineration as methods of controlling hydrocarbons and carbon monoxide emissions from coal conversion processes. Coal conversion processes will succeed in providing substitutes for natural gas and petroleum only if they can do so in an environmentally acceptable manner. All coal conversion processes will release waste gas streams to the environment that will need to be treated to control releases of hydrocarbons and carbon monoxide.

APPROACH

The following tasks are included as part of this project: The design, fabrication, and installation of the necessary experimental equipment for catalyst testing was completed. Baseline testing of eight commercially available incineration catalysts was initiated. The coal carbonizer was operated to generate simulated tail-gas for detailed chemical characterization. Arrangements for a subcontract to determine the feasibility of using coal-fired incineration to remove hydrocarbons and carbon monoxide from tail-gas have been made. Initiation of the subcontract is pending final appropriation of funds for the work.

PROGRESS AND RESULTS

All of the catalysts were tested using bottled feed gas (hydrocarbons, carbon monoxide, carbon dioxide, air) to determine reactant conversion versus catalyst bed temperature at constant space velocity and inlet reactant concentrations. Typical results are given in Figure 22. Using these data, the catalysts can be ranked as a function of the temperature required for 90-percent conversion. Typical preliminary results are given in Figure 23.

The coal carbonizer was operated with Wyodak subbituminous coal to generate simulated tail-gas for detailed analysis. Run conditions and online gas analyses are given in Table 5, and sulfur and nitrogen component analyses are given in Table 6. Trace element analyses were also performed, and most species were found in the low parts-per-million range.

PLANS FOR NEXT PERIOD

Testing of the incineration catalysts will be performed during this period. Sensitivity of catalysts to H_2S and COS poisoning will be measured. A completion report for the project will be prepared and issued. The thermal incineration contract will be let upon receipt of funds, with completion 6 months later.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- January 31, 1980 -- Complete experimental testing of catalysts
- March 16, 1980 -- Draft completion report for project
- June 1, 1980 -- Issue completion report
- Determine date to let thermal incineration contract
- Close thermal incineration project 6 months after contract is let

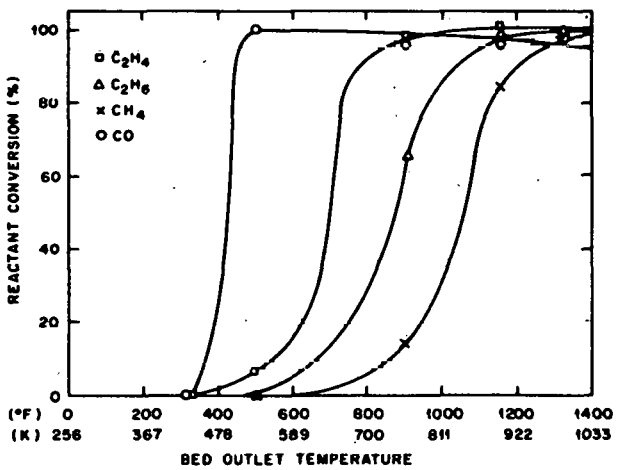


Figure 22. Measured Conversion vs. Bed Outlet Temperature for Run CI-A-8

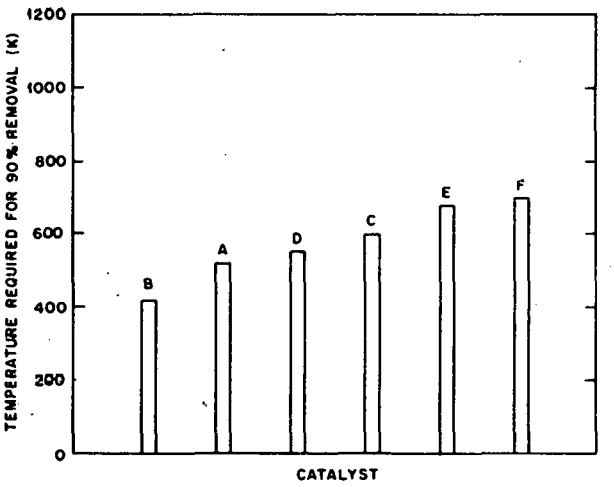


Figure 23. Carbon Monoxide Removal as a Function of Catalyst (Preliminary)

Table 5. Carbonizer Operating Conditions for Run CCI-A-4

Parameter	Value
Reactor Temperature	797K (975°F)
Coal Feed Rate	2.57×10^{-4} kg/s (2.04 lb/hr)
Plenum Gas Flow Rate[a]	1.75×10^{-4} m^3/s (0.37 scfm)
Transport Gas Flow Rate[a]	1.27×10^{-4} m^3/s (0.27 scfm)
Time of Feed	2.16×10^4 S (6.0 hr)
Exit Gas Composition[b] (volume %):	
$C_3H_6 + C_3H_8$	0.194
C_2H_4	0.209
C_2H_6	0.287
O_2	0.339
CH_4	1.71
CO	2.00

a At 294K and 1 atmosphere.
b By process gas chromatograph.

ENVIRONMENTAL ASSESSMENT FOR GASIFIERS IN INDUSTRY: UNIVERSITY OF MINNESOTA, DULUTH

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATORS

M.R. Guerin
J.A. Klein

OBJECTIVES

The objectives of this program are to (1) obtain the prerequisite data to make an evaluation of specific and overall health and environmental effects to be expected from the long-term operation of a gasifier of this type and (2) make an assessment based on the data obtained.

Table 6. Analysis of Run CCI-A-4 Carbonizer Effluent Grab Samples for Sulfur and Nitrogen Components

Table 6. Analysis of Run CCI-A-4 Carbonizer Effluent Grab Samples for Sulfur and Nitrogen Components

		Method		
Component	Sample No.	GC-FPD[a]	FT-IR[b]	CLA[c]
COS	3	47 ppm	40 ppm	
	4	44 ppm		
H_2S	3	820 ppm		
	4	860 ppm		
SO_2	3	.1 ppm	400 ppm[d]	
	4	.1 ppm		
HCN	3		50 ppm	
	4		10-20 ppm	
NO	3		60 ppm	66 ppm[e]
	4			
NO_x	3		25 ppm	26 ppm[e]
	4			

a Gas chromatograph, flame photometric detector.
b Fourier-transform infrared spectroscopy.
c Chemical-luminescent analyzer.
d Probable hydrocarbon interference.
e CO_2 interference.

APPROACH

The low-Btu gasifier at the University of Minnesota, Duluth, is operated to produce fuel for boilers that provide space heating for the entire campus. An "off-the-shelf" stoic gasifier design of South African development characterizes this gasifier, designed for continuous operation on about 75 tons of coal per day.

The gasifier project is scheduled for 3 years commencing approximately in June 1978. State-of-the-art methods are being emphasized for monitoring, sampling, analyzing, managing data, and making final assessments. Other governmental agencies such as the Environmental Protection Agency and the National Institute for Occupational Safety and Health are participants in various aspects of this project.

Details of the approaches are summarized in the report referenced in the bibliography

(Conserv, ed., January 23, 1978). The principal components of the monitoring and testing program are online analyses and measurements, occupational area monitoring, and collection of specified process samples for analysis at the Oak Ridge National Laboratory. Online data collection is handled with a dedicated computer that can monitor gas stream compositions, temperatures, pressures, etc. Software has been developed for handling other project data, such as industrial hygiene information. Data obtained online as well as the analytical data obtained on process samples become part of the data base for the assessment team. Other data, e.g., from remote atmospheric monitoring stations, are also added to the data base. One aspect of the assessment part of this project is to determine the efficiency, reliability, and maintenance requirements of environmental control equipment and to assess the adequacy of health and safety controls incorporated into the process streams.

PROGRESS AND RESULTS

Operation of the gasifier was intermittent during the first year. Online analysis equipment did not function properly, but most problems have been solved, and the equipment is presently performing satisfactorily. The computer system is interfaced with the online analyzers and several transducers. This system is functioning well, and data log tapes are being produced routinely.

A number of process samples were collected during the intermittent operating periods. Results are preliminary and do not represent a "lined-out" performance. Analyses have been performed principally on the feed coals, tars, ashes, chars, and ash pan water.

Industrial hygiene samples have been obtained as organics collected on activated carbon (personnel monitors) and hi-vol filter samples. None of the personnel monitors had detectable amounts (greater than 0.5 microgram) of any of the common Occupational Safety and Health Administration's designated organic volatiles. The hi-vol filter pads were extracted and analyzed; they collected little material and n-alkanes predominated (C_{20}-C_{35} range).

Sample collection details and data management functions have been worked out to the extent possible with limited operating time. Quality assurance practices have been established.

PLANS FOR NEXT PERIOD

Continuous gasifier operation will provide the opportunity to get all online equipment calibrated and operating smoothly. The collection of samples as outlined in the plan will generate sufficient data to begin the assessment process.

Particulate loadings of the top-gas and bottom-gas will be determined on the upstream and downstream sides of the control devices, i.e., the electrostatic precipitator (top gas) and the cyclone (bottom gas). These measurements will help evaluate the performance of these devices.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

ENVIRONMENTAL ASSESSMENT FOR GASIFIERS IN INDUSTRY: PIKE COUNTY, KENTUCKY

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATORS

M.R. Guerin
J.A. Klein

OBJECTIVES

The objectives of this program are to obtain process, environmental, and occupational health data from the low-Btu gasifier installation to be built at Pike County, Kentucky. This information will permit judgments to be made on the potential environmental and health impacts and consequent environmental acceptability of further commercialization of low-Btu gasification processes.

APPROACH

This project will use two 36-ton-per-day Wellman-Galusha gas producers operating on low-sulfur eastern Kentucky coal. The environmental and health program is expected to continue for 3 years, beginning with the initial startup of the facility. Present gasifier plans are presently in a state of flux due to the possibility of having to add a desulfurization unit to the facility.

State-of-the-art methods will be emphasized in monitoring and testing, and the interests and needs of other Government agencies, such as the Environmental Protection Agency and the National Institute for Occupational Safety and Health, will be integrated into the program.

The principal components of the monitoring and testing plan involve online studies, in-plant studies, and local area studies to be integrated through multidisciplinary assessments. This proposal includes the requirements for automatic gas stream analysis, as well as sample collection, preparation, characterization, and servicing of sampling equipment. These requirements relate to the characterization of process streams, effluents, and the working environment and to data collection for determining the efficiency, reliability, and maintenance requirements of environmental control equipment and assessing the adequacy of health and safety controls incorporated into the process stream.

PROGRESS AND RESULTS

Sample ports have been located and designed. Specifications for capital equipment, including a process gas chromatograph, sulfur dioxide and nitrogen oxide monitors, and a data logger, have been prepared.

PLANS FOR NEXT PERIOD

Depending on construction progress for the Pike County Coal Gasifier Facility, all capital equipment will be purchased, including in-plant and personnel monitoring equipment. An extensive sampling and analysis procedure described in the environmental and health program for the Pike County Gasification Facility will be implemented.

Monitored data, such as temperatures, pressures, flow rates, and gas stream compositions, will be analyzed onsite for overall process characterization. In addition, some 1000 samples will be acquired, analyzed, and tested. Results of the analysis of these samples, the online and in-plant monitoring data, and day-to-day operational experience will be used to assess the efficiency of the cyclones and the need, if any, to improve health and safety controls incorporated into the system to minimize fugitive emissions and other modes of operator exposures.

REPORTS PUBLISHED

Cowser, K.E., ed., "Environmental and Health Program for Pike County Coal Gasification Facility," Oak Ridge National Laboratory, August 1979.

PROJECTED MILESTONES

None

TREATMENT OF COAL CONVERSION WASTEWATERS

ORGANIZATION AND CONTRACT NUMBER

Pittsburgh Energy Technology Center
00238

PRINCIPAL INVESTIGATORS

B.D. Blaustein
C.J. Drummond
G.E. Johnson

OBJECTIVES

The program objectives are to characterize coal conversion process wastewaters, evaluate the concentrations of effluent contaminants in relation to established standards, and develop and demonstrate the treatment methods capable of meeting such legally established or proposed regulations. It is important that the control technology for treating the highly contaminated wastewaters from coal conversion processes be available when coal conversion processes are commercialized.

APPROACH

Coal liquefaction and other coal conversion wastewaters will be characterized to evaluate contaminant concentrations for various processes. Evaluation and assessment of the treatment of these wastewaters will be conducted using both conventional and advanced wastewater treatment unit operations and processes. The most effective treatment train will be developed, permitting reuse or discharge of these wastewaters.

PROGRESS AND RESULTS

Characterization of coal liquefaction and coal gasification wastewaters was and is being conducted for effluents from various coal conversion processes. Investigations of the treatability of coal conversion wastewaters were made using various biological and physicochemical processes.

These studies involved operation of both individual unit operations and processes and the Pittsburgh Energy Technology Center's integrated wastewater treatment unit, which combines various unit operations and processes into a complete wastewater treatment train.

During fiscal 1979, a series of runs was completed in the continuous complete-mix activated sludge biochemical oxidation reactors. Each run consisted of an acclimation period of approximately 2 weeks and a steady-state period of from 2 to 4 weeks. Wastewaters from the 18 kilogram/hour fluidized bed coal gasification unit and 8 kilogram/hour coal liquefaction support unit were studied. The data generated from these runs were used to complete the development of a kinetic model for the biochemical oxidation of coal gasification wastewaters. A preliminary model was also developed for the biochemical oxidation of coal liquefaction wastewaters. The results of this work are reported in detail in the paper "Biochemical Oxidation of Coal Conversion Wastewaters" presented at the 87th National Meeting of the American Institute of Chemical Engineers, August 1979. Examples of the Michaelis-Menten models developed using biochemical oxygen demand as the substrate are given in Figures 24 and 25.

An assessment of the effectiveness of employing a byproduct from the SYNTHANE coal gasification process to treat liquid wastes from that process has been completed. It was found that the phenolic wastewaters produced in the fluidized-bed coal gasifier could be successfully treated by adsorption with SYNTHANE gasifier chars. Tests indicated that 1 kilogram of char, whose average surface area is 330 square meters/gram, could treat 10 to 15 kilograms of SYNTHANE process wastewater before organic breakthrough occurs. Both equilibrium adsorption isotherms and breakthrough curves were developed, demonstrating the ability of the byproduct char to remove phenolics, total organic carbon, chemical oxygen demand, and color. Phenol removals were greater than 99.9 percent, and chemical oxygen demand and total organic carbon removals were approximately 90 percent using untreated process wastewater. An example of the equilibrium adsorption isotherms developed is given in Figure 26.

Work under contract with the University of Pittsburgh, entitled "Biological Oxidation of Aqueous Thiocyanate Typical of SYNTHANE Gasifier By-Product Water," continued this year. The objective of this project is to develop a kinetic expression and a nitrogen and sulfur material balance for the biological degradation of aqueous thiocyanates. Continuous culture-activated sludge reactors have been operated at various mean-cell-residence times (sludge ages) using thiocyanate as the only source of carbon for the metabolism of the micro-organisms.

PLANS FOR NEXT PERIOD

Efforts will focus on the assessment of environmental controls for coal liquefaction wastewaters. Representative coal liquefaction process wastewaters will be collected from

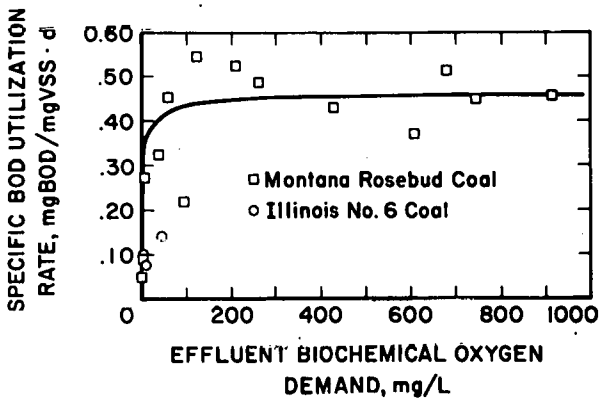


Figure 24. Michaelis-Menten Model for Coal Gasification Process Wastewater

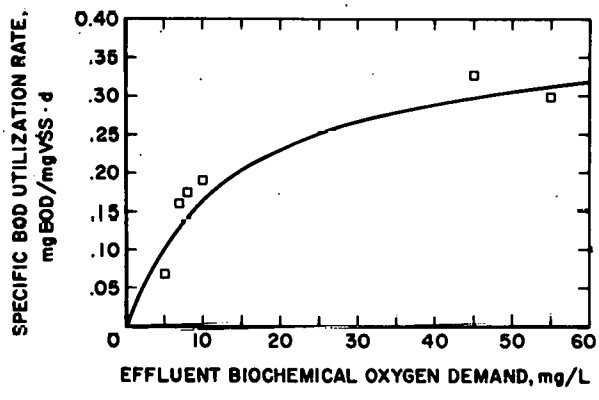


Figure 25. Michaelis-Menten Model for Coal Liquefaction Process Wastewater (Pittsburgh Seam Coal)

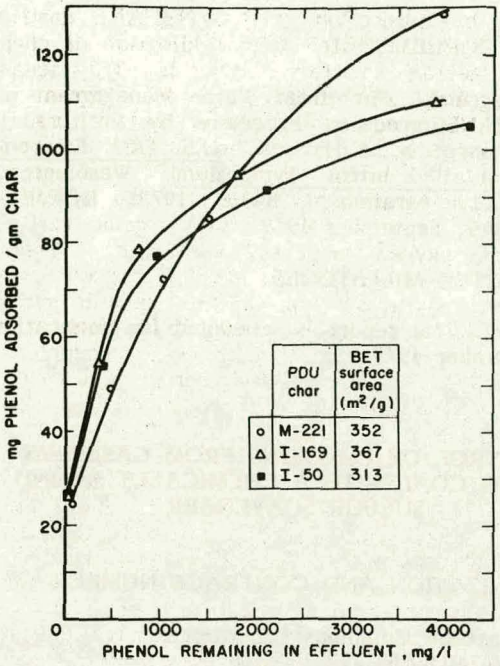


Figure 26. Pure Phenol Adsorption Isotherms for Various Chars

process development units, pilot plants, and demonstration facilities. Bench-scale laboratory evaluations (Figure 27) of the effectiveness of various conventional and advanced environmental control techniques will be conducted. The applicability of these control measures will be demonstrated in the integrated wastewater treatment unit.

REPORTS PUBLISHED

DeGalbo, A.D., et al., "Treatment of Coal Gasification Wastewaters by Adsorption With Gasifier Chars," Proceedings of the National Conference on Energy and the Environment, American Institute of Chemical Engineers, May 1979.

Drummon, C.J., et al., "Biochemical Oxidation of Coal Conversion Wastewaters," 87th National Meeting of the American Institute of Chemical Engineers, Fiche 31, Paper 39b, August 1979.

PROJECTED MILESTONES

June 30, 1980 -- Prepare technical progress report describing the kinetic model

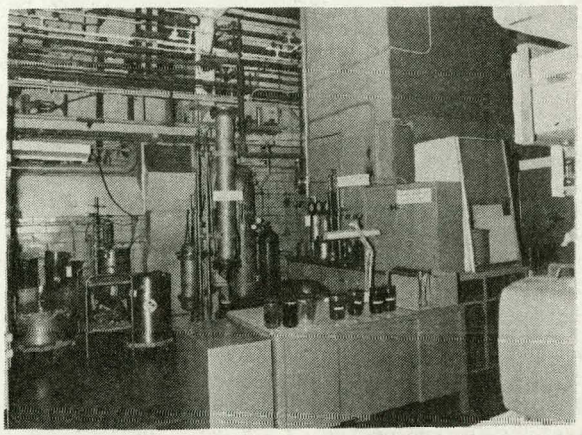


Figure 27. Bench-Scale Char Adsorption Columns

developed for the biochemical oxidation of solvent refined coal wastewater

IMPROVED WATER MANAGEMENT OF COAL CONVERSION PROCESSES

ORGANIZATION AND CONTRACT NUMBER

Davy McKee Corporation
EE-77-C-02-4375

PRINCIPAL INVESTIGATOR

W.A. Parsons

OBJECTIVE

The objective of this study is to evaluate the technical and economic feasibility of controlled two-stage quenching of process gases as a means of enabling improved water management of coal conversion processes. The first-stage quench collects strong electrolytes in a low-volume aqueous purge from the main gas flow. Subsequent gas condensates are amenable to steam stripping of volatile weak electrolytes and bio-oxidation of organic contaminants to yield water suitable for reuse.

APPROACH

The study compares the technical and economic practicality of two-stage quenching

with single-stage quenching for a fixed-bed gasifier plant. The scope of the study includes air-blown and oxygen-blown gasification of a high-halide eastern coal and a low-halide western coal.

A theoretical analysis was made of electrolyte capture as a function of the fraction of gas moisture condensed. Engineering concepts were developed for the treatment, recovery, and disposal of high-electrolyte primary condensates and low-electrolyte secondary condensates. Alternative water management systems were conceptualized to maximize practical recovery of gas condensates and minimize blowdown requirements. An engineering trade-off analysis was performed to provide a comparative technical and economic assessment of single quench and double-quench gas-cleaning systems for the selected situations.

PROGRESS AND RESULTS

The thermodynamic analysis of mass transfer in the gas train indicated that halides and other strong electrolytes would be absorbed to a high degree in a first-stage quench, condensing more than 10 gallons of water per ton of coal. A sound control concept was engineered for the operation of a two-stage quench system.

The secondary condensate was indicated to be amenable to recovery as a low dissolved solids service water after processing by steam stripping and biological treatment. Thiocyanate, when present in the secondary condensate, is expected to produce some residual sulfate in the effluent from biological treatment.

The results indicated that the alternative of preliminary absorption of halides by the application of a two-stage quench system was cost effective to the extent of $0.99/ton for operation of the selected gasifier installation on Illinois No. 6 coal containing 0.25 percent chloride and 0.012 percent fluoride. The conventional single-quench system was cost effective to the extent of $0.95/ton for gasifier operation on Montana Rosebud coal containing 0.03 percent chloride and 0.003 percent fluoride. Coal halide content was indicated as the dominant variable relative to cost effectiveness. The trade-off coal total halide concentrations, expressed as chloride, were 0.15 percent for air-blown operation and 0.16 percent for oxygen-blown operation.

PLANS FOR NEXT PERIOD

The project is scheduled for completion in December 1979.

REPORTS PUBLISHED

Parsons, W.A., "Improved Water Management of Coal Conversion Processes by Preliminary Absorption of Halides," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979 .

PROJECTED MILESTONES

The final report is scheduled for publication in December 1979.

CONTROL OF EMISSIONS FROM GASIFIERS USING COAL WITH A CHEMICALLY BOUND SULFUR SCAVENGER

ORGANIZATION AND CONTRACT NUMBER

Battelle Columbus Laboratories
W-7405-ENG-92

PRINCIPAL INVESTIGATORS

H.F. Feldmann
B.C. Kim

OBJECTIVES

The objectives of this study are to evaluate the environmental and economic advantages of using coal treated by a proprietary process developed by Battelle as an environmentally acceptable feedstock for commercially available gasification systems. The Battelle Process involves chemically incorporating Ca^{++} ions into the coal structure by contacting the coal with a CaO slurry in an autoclave-type reactor at a moderate temperature and pressure. The use of Battelle-treated coal as a gasification feedstock is intended to capture sulfur in the feed coal with the chemically incorporated calcium to produce a low-sulfur fuel gas. In addition, the gasification reactivity of this treated coal is greatly increased, and it is nonagglomerating.

APPROACH

The technical and economic feasibility of using Battelle-treated coal in industrial gasifiers was investigated by conducting laboratory-scale experiments aimed at establishing the treatment conditions required to produce treated coal that would both capture the sulfur from a typical high-sulfur eastern coal and retain the sulfur in a nonleachable form in the ash.

The case of a "typical" industry currently using natural gas was selected as the basis for an economic comparison of the following alternate options:

- Coal-fired boiler with particulate removal and flue gas desulfurization
- Coal gasifier and gas-fired boiler with particulate removal and flue-gas desulfurization
- Coal gasifier with hydrogen sulfide and particulate removal and gas-fired boiler
- Coal gasifier using Battelle treated coal with particulate removal and gas-fired boiler

PROGRESS AND RESULTS

During the course of this program, experiments simulating a conventional moving-bed gasifier into which treated coal was fed demonstrated that

- There was sufficient sulfur retention in the ash to eliminate the need for gas cleaning.
- The gasification reactivity of the treated coal was substantially higher than that of the raw coal.
- The sulfur retained by the ash was stable and would not be leached out.
- Environmental problems associated with water contamination will be reduced (or eliminated) in comparison to conventional gasification systems because the gas can be used hot.
- Agglomeration of the treated coal was not a problem.

The economics of using Battelle-treated coal for industrial steam generation in a commercially available fixed-bed gasifier was estimated to be more attractive than the options mentioned above.

Additional tests demonstrated that the same approach could be used with fluid-bed gasification systems. However, under the uniform reducing conditions that exist in a fluid-bed gasifier, the stable sulfur constituent in the ash is the sulfide, and an additional stage must be provided to oxidize the sulfide to the sulfate. Otherwise, the CaS in the ash would hydrolyze when exposed to the atmosphere and release H_2S.

Bench-scale simulation of both fixed and fluid-bed types of gasification systems revealed some critical insight into factors affecting sulfur capture in gasification and combustion systems. This insight has led to the development of new combustion concepts.

PLANS FOR NEXT PERIOD

The program has been completed, and an American Institute of Chemical Engineers paper is being prepared describing the results of the program.

REPORTS PUBLISHED

Battelle Columbus Laboratories, "Technical and Economic Assessment of Potential Advantages Associated With the Use of Battelle Treated Coal (BTC) in Gasifiers," Contract No. W-7405-ENG-92, July 20, 1979.

Battelle Columbus Laboratories, "Catalyzing Coal for Industrial Gasification," to be presented at American Institute of Chemical Engineers Meeting, June 1980.

PROJECTED MILESTONES

None

FEASIBILITY ANALYSIS OF THE CONCENTRATION OF COAL CONVERSION PROCESS CONDENSATE

ORGANIZATION AND CONTRACT NUMBER

Concentration Specialists, Inc.
EP-78-C-02-4943.A000

PRINCIPAL INVESTIGATOR

W.R. Killilea

OBJECTIVES

The objectives of this study are to establish the technical, economic, and environmental feasibility of applying concentration processes to the reuse/recycle of coal conversion plant wastewaters. Emphasis has been placed on specifying promising process options for (1) ultimate

disposal of the concentrate and (2) acceptability of the associated dilute stream for reuse within the conversion facility. Potential energy and chemical byproducts derived from the processing were also determined.

APPROACH

The approach taken was first to review coal conversion process flowsheets to select candidate aqueous waste streams for study. Wastewaters were then characterized with respect to pollutant concentration. This showed that the process condensate (alternatively referred to as gas liquor, sour water, or foul process water) is the most contaminated stream of high flow. The concentration processes investigated for this stream were reverse osmosis; freezing; and vaporization technologies such as flash distillation, evaporation, and vapor compression. Cost estimates were prepared for the technically feasible options.

PROGRESS AND RESULTS

The concentration processes with their associated pretreatment and concentrate disposal subsystems have been compared economically to the conventionally envisioned process condensate treatment consisting of gravity separation of tars and oils, solvent extraction, steam stripping, biological oxidation, and carbon adsorption. This and the concentration processing trains would be applicable to released water effluent standards that may exist at the time when substantial numbers of synfuel plants are being built. Net treatment costs are presented on the basis of dollars per thousand gallons of influent wastewater processed. Summarizing these cost comparisons and the feasibility analyses of the study allows categorization of the alternatives investigated:

- Conventionally envisioned process condensate treatment: net cost is $36 per 1000 gallons, reflecting minimal byproduct credits for mixed phenolics and ammonia.

- Technically feasible and economically attractive: Freeze concentration (that is, crystallization and removal from a solution of pure solvent -- water) with disposal of the concentrate by gasification to generate synthetic fuel or incineration to generate byproduct steam. The diluted low dissolved solids stream, produced from the melted ice, would be used for the conversion facility's cooling tower makeup water. The projected net cost is $16 to $17 per 1000 gallons.

- Technically feasible but not economically attractive: Reverse osmosis concentrations with concentrate disposal through gasification, incineration, or chemical fixation. The membrane rejection of the predominant phenolic compounds would not be sufficient to avoid the need for further costly treatment of the permeate. The projected net cost is $32 to $40 per 1000 gallons.

- Technically not feasible: Concentration of phenol, the major organic, by means of water vaporization processes such as evaporation, flash distillation, or vapor compression. A phenol-water solution forms an azeotrope (a constant-composition boiling mixture).

The savings attributable to incorporating a freeze concentration system (and ancillary concentrate disposal process) into the treatment of coal conversion process condensate is $20 per 1000 gallons. This potential savings over the "conventional" treatment would result in a final synthetic fuel product cost reduction of $0.15 to $0.16 per million Btu.

PLANS FOR NEXT PERIOD

Freeze concentration incorporating gasification or incineration of residual organic concentrates possesses the greatest economic incentive for process condensate treatment of the options investigated. Freezing is a process that is still under development. Past pilot operations have been in the range of 10,000 to 100,000 gallons per day for sea water desalting applications. Process development work on a bench-scale level is needed for the coal conversion wastewater application. A proposal has been submitted to the Department of Energy.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- January 1980 -- Submit feasibility study final report

EVALUATION OF SOLID WASTE FROM SYNFUELS

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATOR

C.W. Gehrs

OBJECTIVES

The objectives are to identify procedures to attenuate the release of the hazardous components of synfuel solid wastes to surface water or groundwater and to define the environmental chemistry that exerts the strongest influence on the dissolution of toxic materials from synfuel solid wastes and that which controls their mobility through geologic material.

APPROACH

The loss of hazardous components from synfuel solid wastes is being determined using three wastes: a gasifier waste, retorted oil shale, and a liquefaction waste. The quantity and rate of loss from each waste is being compared to losses observed from conventional coal-fired powerplant wastes under similar environmental conditions. These conditions vary from mildly oxidizing conditions typical of many inland shallow streams to highly reducing conditions typical of waterlogged soils and many sanitary landfills. Loss to the aqueous phase will be attenuated by supplementing the waste with various amounts and types of geologic media including limestones, sandstones, and shales, as well as surface and subsurface soils varying in clay content, mineral composition, and pH.

PROGRESS AND RESULTS

To quantify the behavior of the solid waste under conditions of field disposal, the total solid was subjected to distilled water leaching at a variety of Eh (redox potentials) and pH combinations. A matrix was designed to include the pH ranges of 5, 7, and 9 and Eh ranges of 400, 200, and 0. This matrix was chosen to approximate conditions that could exist in both surface and subsurface disposal of the waste.

The influence of both pH and Eh on the 24-hour leachate concentrations of iron, cadmium, nickel, and arsenic was determined for the gasifier waste. The influence of redox potential on element mobility was most apparent at pH 5.0 and was quite predictable (based on known Eh-pH relationships of the elements), given the complexity of the solid waste. Soluble iron exhibited maximum concentrations under the low pH/Eh conditions favoring the persistence of Fe^{++} in solution. The high concentrations of iron under these conditions are believed to result from dissolution of pyrite and/or pyrrhotite (mineral phases known to exist in these solids). Under controlled conditions of elemented pH and Eh, the oxidation of soluble Fe^{++} to the much less soluble ferric form is responsible for the decreased levels of iron in solution. In addition, during time series extractions, as pH was allowed to increase to 9, hydrous iron oxides formed and rapidly precipitated, in many cases removing several other cationic trace elements simultaneously by coprecipitation/adsorption reactions (cadmium, chromium, nickel, manganese, lead), while generally showing little effect on elements forming oxyanions in solution (arsenic, molybdenum, selenium). This behavior of iron may thus be a key factor in the control of leachate concentrations of several elements during initial leaching of the waste.

The organic constituents of the gasified waste were characterized using methylene chloride and aqueous extracts. Total organic content of the waste after gasification was less than 2.5 percent. To date, the extractable organic compounds identified appear to be mainly naphthalene and quinoline derivatives. Considerable quantities of reduced sulfur were detected (1 to 2 percent by weight) and appear to be predominantly in the form of magnetic pyrites (pyrrhotite, $Fe_{1-x}S$).

The gasifier waste was also physically characterized into four fractions: glass-like rods, glass-like shards, aggregates, and fine particles (less than 44 micrometers in diameter), representing approximately 2, 40, 50, and 8 percent by weight, respectively. Concentrations of cadmium, zinc, selenium, and molybdenum in both distilled water and dilute acid (pH 2) extracts increased in the following order: glass shards much less than aggregates and aggregates less than or equal to fine particles. If the gasification process can be controlled or modified to produce primarily the glass shard fraction, element leachability from the gasified waste would be significantly decreased.

PLANS FOR NEXT PERIOD

Work in fiscal 1980 will include physical and chemical characterization of the liquefaction

waste and the retorted oil shale waste. The major emphasis will be on evaluating the Eh-pH conditions that influence the loss rate of toxic metals from these wastes. Studies using various geologic materials to attenuate the movement of toxic metals from waste disposal areas will be initiated in fiscal 1980.

REPORTS PUBLISHED

Gehrs, C.W., et al., "Preliminary Assessment of Three Fossil Energy Related Residues by RCRA Protocols," Oak Ridge National Laboratory, in press.

PROJECTED MILESTONES

- January 15, 1980 -- Continue column experiments
- June 30, 1980 -- Complete controlled environmental extraction on gasified and liquefaction waste
- September 1, 1980 -- Complete initial waste attenuation studies

SLAGGING FIXED-BED GASIFICATION

ORGANIZATION AND CONTRACT NUMBER

Grand Forks Energy Technology Center
FE-7042-GFETC

PRINCIPAL INVESTIGATORS

W.G. Willson
R.S. Majkrzak
L.E. Paulson

OBJECTIVES

The general objectives are to (1) develop data on the slagging fixed-bed gasification of coal, with emphasis on the development of environment-related data and on byproduct and effluent treatment and utilization studies, which will support the commercial and demonstration applications of coal gasification technology; and (2) establish production rates of effluents, fate of trace elements, gas liquor (tar/water) treatment techniques, waste disposal constraints, and occupational health and safety factors.

The immediate objectives are to (1) demonstrate continuous 5-day operating capability on both nonagglomerating low-rank coals and caking bituminous coals in the modified gasification pilot plant; (2) establish process limitations and differences in products and effluents as a function of coal source, type, chemical and physical properties, moisture content, and particle size; (3) improve operability and provide new capabilities on the slagging fixed-bed gasifier through improved hearth design and materials, processing equipment, and control and monitoring systems.

APPROACH

The modified 24-ton/day slagging fixed-bed gasifier, shown schematically in Figure 28, is the only operable unit of its type in the United States. Compared to the commercial dry-ash Lurgi process, the advantages of the slagging process are a twofold to fourfold increase in gas-making capacity for a given gasifier size, a reduction in steam consumption by a factor of five, and a reduction in the rate of production of liquid effluents. The most critical problem with this second generation process is protecting the slag taphole from erosive and corrosive attack while maintaining slag flow. A consortium of U.S. companies has sponsored tests by the British Gas Corporation and Lurgi of a 790-ton-per-day unit at Westfield, Scotland. Successful operation of that unit with caking U.S. coals has been reported; however, most data are proprietary.

PROGRESS AND RESULTS

Modification and relocation of the slagging fixed-bed gasification unit has been delayed; however, installation, with the exception of the precooler and tar/oil/water separator, was about 95 percent complete by the end of 1979.

Preliminary design was completed on a wastewater processing train including (1) sour water stripping, principally for ammonia removal; (2) solvent extraction, for dephenoliation; and (3) cooling tower simulation. Figure 29 is a block diagram of the proposed wastewater treatment train. All units are to be commercial process development units. Equipment was not procured because of a $1.3 million funding cut in the second quarter of fiscal 1979. Design of an improved tar/oil/water separator was completed and the unit delivered, minus the instrumentation. Level control instrumentation was tested and ordered.

Activated carbon treatment of gasifier wastewater was studied. The carbon treatment process followed a pretreatment scheme of

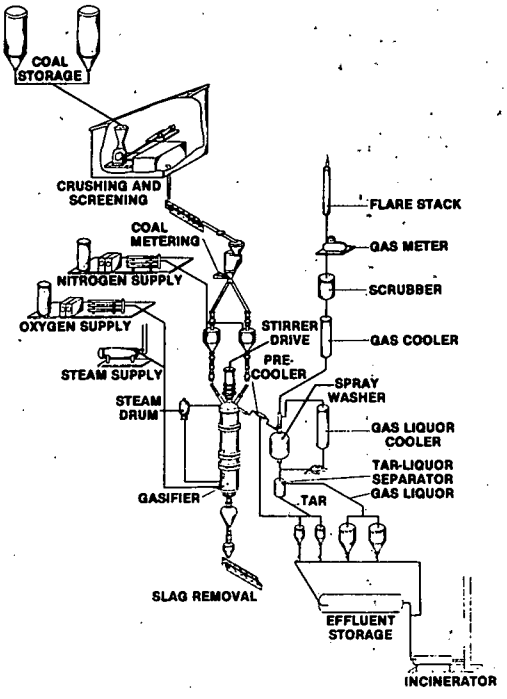


Figure 28. Process Flow Sheet of Modified Gasifier System

lime addition, ammonia stripping, and recarbonation-coagulation. Continuous bench-scale tests reduced the alkalinity, ammonia, and total organic carbon weight percentages by over 98 percent and completely removed concentrations of sulfide, cyanide, phenol, and cresol.

Tar analyses were performed using the Environmental Protection Agency's Level One Environmental Assessment Procedure. Results from tests using Indian Head and Gascoyne lignites and Rosebud subbituminous coal showed that the coal's moisture ash-free composition affects the tar boiling point distribution and the quantities of paraffins, olefins, aromatics, and polar compounds in the tar. Tar analyses were also performed using low-voltage mass spectroscopy. Compound types were identified, and similarities in compounds found in tar from different low-rank coals were observed.

Biological screening and pretreatment studies on slagging fixed-bed gasification wastewater were performed at the University of North Dakota in batch reactors. Treatment by lime precipitation, ammonia stripping, coagulation, and solvent extraction significantly reduced total and volatile suspended solids, thiocyanate, ammonia, sulfate, sulfide, and phosphate from the wastewater.

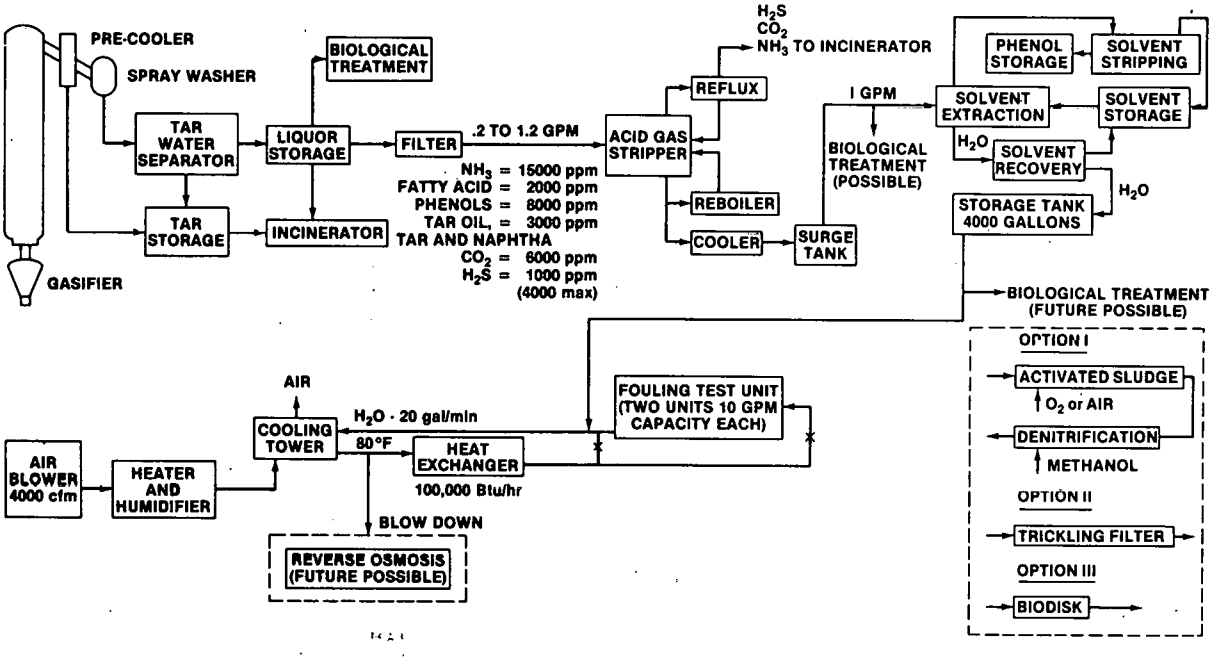


Figure 29. Proposed Wastewater Treatment Facility

Biological treatment studies on slagging fixed-bed gasification wastewater were performed at Carnegie-Mellon University. It was shown that lignite-derived wastewater could be processed at 40-percent strength in continuous stirred tank reactors and that nitrification was feasible with both stripped and unstripped wastewater.

PLANS FOR NEXT PERIOD

Shakedown will be accomplished on a previously tested lignite; progressively longer tests will be performed, culminating in a 5-day operation. Following successful continuous operation on lignite, tests are planned on selected caking coals of increasing caking tendency. Products, byproducts, and effluents will be characterized to support environmental assessment and industrial hygiene studies. Laboratory studies on biological and physical/chemical treatment of gas liquor will be continued. Installation of a pilot processing train for treating gas liquor (including ammonia stripping, phenol extraction, and a simulated cooling tower to be operated on treated liquor) was deferred following a decrease in project funding halfway through the fiscal year. Additional funding for installation and operation of the wastewater processing train, requested for fiscal 1980, has again been deleted from the budget submission. Lack of these funds will again make it necessary to defer most of the wastewater treatment studies.

Operation of the gasifier on caking coal is intended to provide supporting data for the gasification by this process of eastern high-sulfur coals and, specifically, the Continental Oil Company/Department of Energy demonstration plant program, which will demonstrate the technology of the British Gas/Lurgi slagging gasifier in the conversion of a moderately caking U.S. coal.

REPORTS PUBLISHED

Ellman, R.C., et al., "Slagging Fixed-Bed Gasification Project Status at the Grand Forks Energy Technology Center," Tenth Biennial Lignite Symposium, Grand Forks, North Dakota, May 30-31, 1979.

Hajicek and L.E. Paulson, "Development and Operating Characteristics of a Gas Sampling System for the Grand Forks Energy Technology Center's Slagging Fixed-Bed Gasifier," Third Annual Symposium, Instrumentation and Control for Fossil Demonstration Plants, Denver, Colorado, August 20-22, 1979.

Hird, K.B., "A Preliminary Investigation of Physical-Chemical Treatment of Slagging Gasifier Aqueous Effluent," M.S. Thesis, University of North Dakota, August 1979.

Luthy, Sekel, and Tallon, "Biological Treatment of Grand Forks Energy Technology Center Slagging Fixed-Bed Coal Gasification Process Wastewater," FE-2496-42, Eleventh Quarterly Report, March 1979.

Mayer, Hajicek, and Freeman, "Correlating Process Parameters for a Slagging Fixed-Bed Gasifier," Third Annual Symposium, Instrumentation and Control for Fossil Demonstration Plants, Denver, Colorado, August 20-22, 1979.

Miller, D.J., J.K. Olson, and H.H. Schobert, "Mass Spectroscopic Characterization of Tars From the Gasification of Low Rank Coals," presented at American Chemical Society National Meeting, Washington, D.C., September 1979.

Olson, J.K., and H.H. Schobert, "An Overview of Effluents From Some Western Coals," Proceedings North Dakota Academy of Science, Vol. 33, No. 60, presented at North Dakota Academy of Science-South Dakota Academy of Science Joint Meeting, Aberdeen, South Dakota, April 1979.

Olson, J.K., and H.H. Schobert, "Effects of Coal Structure and Processing Conditions and Organic Effluents From Slagging Fixed-Bed Gasification," American Chemical Society, Division of Fuel Chemistry, Preprints, Vol. 24, No. 3, presented at American Chemical Society National Meeting, Washington, D.C., September 1979.

PROJECTED MILESTONES

None

ASSESSMENT OF ENVIRONMENTAL CONTROL TECHNOLOGY FOR SELECTED FIRST-GENERATION COAL GASIFIERS

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATORS

L.K. Mudge
L.J. Sealock

OBJECTIVES

The objectives of the study are to (1) determine whether environmental control technologies in commercial use with Koppers-Totzek and Winkler gasifiers are adequate relative to emission standards, (2) identify areas where improved control technologies are needed, and (3) rank research and development programs in terms of their potential benefits. Efforts for fiscal 1979 were directed toward revision of the draft report to include discussion about the applicability of control technologies to the Texaco and pressurized Koppers-Totzek processes.

APPROACH

Suppliers of Koppers-Totzek and Winkler gasifiers were contacted to obtain mass and energy balances on commercial operations that employ these gasifiers. It was learned that the requested data were not available, and that operating plants in foreign countries were reluctant to cooperate in gathering the data. Information from the literature was therefore used to make the assessment. Uniform standards specific to coal gasification plants have not been established, so standards in related industries, coke manufacture, and petroleum refineries were used in assessing the performance of commercial control technologies.

PROGRESS AND RESULTS

The study was completed in fiscal 1979, and the final report is available.

PLANS FOR NEXT PERIOD

The program was completed in fiscal 1979.

REPORTS PUBLISHED

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

PROJECTED MILESTONES

None

ENVIRONMENTAL ASSESSMENT FOR THE H-COAL PILOT PLANT

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATORS

M.R. Guerin
J.A. Klein

OBJECTIVE

The objective of the H-coal environmental and health program is to provide data and information to support analysis and assessments of coal liquefaction technology. This will permit the Department of Energy and other Federal agencies to make judgments on the potential environmental and health impacts and consequent environmental acceptability of further commercialization of the various liquefaction processes.

APPROACH

This project will assess the environmental and health aspects of the 600-ton-per-day pilot facility being built with funding from the Federal Government and five industrial participants in Catlettsburg, Kentucky. This program is expected to continue for 3 years beginning with the initial startup on coal, expected sometime during spring 1980. State-of-the-art methods will be emphasized in monitoring and testing, and the interests and needs of other Government agencies, such as the Environmental Protection Agency and the National Institute for Occupational Safety and Health, will be integrated into the program.

Program emphasis will be on those aspects of the H-coal process and units that can conceivably be scaled to commercial-sized facilities. Process sampling will be keyed to an examination of products, effluents, and possible occupational exposures and to the information necessary for control technology evaluation. Collection of intermediate process materials is minimized and will be limited to the main process flow due to considerations of cost, difficulties in sample collection, and the lower potential for exposures.

PROGRESS AND RESULTS

Sample port locations have been determined, and a laboratory trailer suitable for providing support to the H-coal environmental and health program has been outfitted. This facility will provide laboratory bench space for any needed onsite analysis equipment as well as disassembly, cleanup, and assembly space for any sampling equipment.

PLANS FOR NEXT PERIOD

An extensive sampling and analysis procedure described in the proposed program plan will be implemented. Some 2000 analyses will be performed on samples acquired. Results of the analysis of these samples, any online monitoring data, and day-to-day operational experience will be used to assess the efficiency of installed environmental control technologies and the need, if any, to improve health and safety controls incorporated into the system to minimize fugitive emissions and other modes of operator exposures.

REPORTS PUBLISHED

Cowser, K.E., ed., "Proposed Environmental and Health Program for H-Coal Pilot Plant," Oak Ridge National Laboratory, May 25, 1979.

PROJECTED MILESTONES

- April 1980 -- Start up H-coal pilot plant on coal
- April 1980 -- Begin full capability for sample acquisition for the Oak Ridge National Laboratory H-coal program.

ENVIRONMENTAL CONTROL TECHNOLOGY SURVEY: U.S. STRIP MINING SITES

ORGANIZATION AND CONTRACT NUMBER

Argonne National Laboratory
W-31-109-ENG-38

PRINCIPAL INVESTIGATORS

J.E. Bogner
D.E. Edgar

OBJECTIVES

The objectives of this study are to (1) assess the effectiveness of the control technologies used in eastern and midwestern surface mines and examine alternatives, (2) assess the Environmental Protection Agency effluent guidelines and Office of Surface Mining regulations for water quality, (3) investigate the distribution and mobility of manganese and other metals in settling-pond sediments at eastern mines with acidic discharges, (4) investigate long-term sediment transport and hydrologic relationships in humid (gulf coast) and arid and semiarid western watersheds where surface coal mining occurs, and (5) recommend future research and development needs and priorities to permit increased coal development in an environmentally acceptable method.

APPROACH

Phase I

Using a narrow definition of control technology (limited to chemical treatment and sediment ponds), effluents at case-study sites will be sampled above and below the treatment facility and as the effluent leaves the site; where possible, background water samples will be collected upstream from the mine site. Temperature, pH, conductivity, and dissolved oxygen content will be measured, and up to 26 chemical parameters determined. In addition, coal, overburden, and treatment sludges will be sampled and analyzed; previously published climatic, hydrologic, and geologic data will also be collected and analyzed. These diverse types of information form a comprehensive data base that will permit assessment of (1) control technology efficiency at the study sites and (2) the Environmental Protection Agency/Office of Surface Mining effluent guidelines for the coal mining industry.

Phase II

Using a broad definition of control technology that includes the application of watershed studies to areas affected by surface coal mining, three study sites will be selected for intensive monitoring of mining-related sediment yield under different climatic regimes. Flow-proportional samples will be collected at appropriate stations in humid, semiarid, and arid study sites. Accessory climatic data will be continuously recorded to permit an assessment of how sediment yield is related to climate and to mining and reclamation practices in the study watersheds.

Phase III

Settling pond sediments at surface coal mines include both transported sediments and precipitates (sludges) from chemical treatment processes. The metals content of these sediments is probably related to water and sediment pH, sediment organic carbon content and clay mineralogy, and metals content of influent water and sediment. Sediment and water (above the sediment/water interface) will be sampled at two or three Eastern U.S. sites characterized by acid influent waters, according to a gridded design. Metals content of sediments will be related to pond (delta) geometry, sediment particle-size distribution, sediment mineralogy and organic matter content, and pond acidity.

PROGRESS AND RESULTS

All sampling, analytical work, and data collection for Phase I has been completed. A computerized data base (System 2000) has been developed to include all the data. Summary reports for the various case-study sites are in progress; organization of the summary volumes assessing the control technologies and the effluent guidelines is being finalized. Preliminary results indicate that for individual sites with acid effluents, simple neutralization facilities dispensing hydrated lime, soda ash, or sodium hydroxide are effective -- if properly maintained -- in producing effluents in compliance with Federal standards for pH and iron. Locally, manganese may be difficult to remove to specified standards. Suspended solids removal and additional oxidation for iron removal are generally accomplished by one or more settling ponds in series following chemical treatment. As a mine operation progresses, treatment facilities and ponds may require relocation. Surface mine operators rarely use large sophisticated (million-gallon-per-day or greater) treatment facilities with thickeners, clarifiers, lime slakers, etc., because surface mine operators must deal with intermittent low flow rates for effluents whose point of discharge changes frequently.

Background bibliographies for Phases II and III are being compiled, and the collected references are being studied. A detailed study plan for Phase III (sediments) is being completed, and preliminary work is underway in examining and choosing suitable study sites.

PLANS FOR NEXT PERIOD

During fiscal 1980, all reports for Phase I work will be completed. Site selection, development of detailed study plans, and sampling and analysis in accordance with those plans will be completed for Phase III (sediments) work. Preliminary contact with representatives of appropriate Government agencies and the coal industry will be made to initiate selection of the three Phase II (watershed studies) sites; in addition, equipment selection and purchase for Phase II work will begin.

REPORTS PUBLISHED

Bogner, J.E., and A.A. Sobek, "Distribution of Selected Transition and Heavy Metals in Clastic Overburden Units of the Appalachian and Interior Coal Basins: Water Quality Implications," Paper given at IX International Congress of Carboniferous Stratigraphy and Geology, June 1979, Urbana, Illinois, Proceedings to be published by American Geological Institute.

Consultant Reports (excluding consultant reports for individual case study sites, 1976-1977):

Barton-Aschman Associates, Inc., in association with ESCOR, Inc., "Surface Mine Discharge Treatment Cost: Southern Appalachian Region," prepared for Energy and Environmental Systems Division, Argonne National Laboratory, 1978.

ESCOR, Inc., "Surface Mine Discharge Treatment Cost: Northern Appalachian Region," prepared for Energy and Environmental Systems Division, Argonne National Laboratory, 1978.

ESCOR, Inc., "Surface Mine Discharge Treatment Cost: Midwestern Region," prepared for Energy and Environmental Systems Division, Argonne National Laboratory, Draft, 1979.

Hayden, R.S., D.O. Johnson, and J.D. Henricks, "Field and Laboratory Procedures for the Determination of Priority Pollutants From Surface Coal Mining and Processing," ANL/EES-TM-21, 1979.

Johnson, D.O., J.E. Bogner, and R.D. Olsen, "Environmental Control Technology: Effluent Survey of U.S. Strip Mining Sites," in Proceedings, Impact of the National Energy Act on Utilities and Industries Due to the Conversion to Coal, December 4-6, 1978, Houston, Texas.

Johnson, D.O., J.E. Bogner, and R.D. Olsen, "Environmental Control Technology Survey of Selected U.S. Strip Mining Sites," U.S.

DOE Environmental Control Symposium, November 28-30, 1978, Washington, D.C., DOE/EV-0046, September 1979.

Papers given at Symposium on Environmental and Mining Research and Demonstration Activities in Southern Appalachia, May 2-3, 1978, University of Tennessee, Knoxville:

Johnson, D.O., "Environmental Control Technology Survey of Selected U.S. Strip Mining Sites."

Leung, S.S., "Water Quality at Three Surface Coal Mines in Eastern Kentucky."

Bogner, J.E., J.P. Schubert, and R.D. Olsen, "Water Quality at a Surface Coal Mine in the Black Warrior Basin, Northern Alabama."

Byerly, D.W., and D.C. Claytor, "The Evaluation of Volumes, Characteristics, and Potential Environmental Impacts of the Mine Wastes and Effluents of Two Coal Strip Mines in the Southern Coalfield of Tennessee."

Papers presented at Annual Meeting, North Central Section, Geological Society of America, May 1979, Duluth, Minnesota:

Doehler, R.W., J.E. Bogner, and A.A. Sobek, "Geochemistry of Neutralization-Treatment Waste Products at Surface Coal Mines."

Henricks, J.D., J. Reiter, and J.E. Bogner, "Flexible Data Management System for Storage and Manipulation of Geochemical and Geological Data."

PROJECTED MILESTONES

- June 1980 -- Complete all Phase I reports
- September 1980 -- Complete site selection and initiation of sampling at humid (gulf coast) site for Phase II (watershed studies)
- September 1980 -- Complete sampling for Phase III (sediments)

TRACE ELEMENT CHARACTERIZATION AND REMOVAL/RECOVERY FROM RAW COAL AND COAL PREPARATION WASTES

ORGANIZATION AND CONTRACT NUMBER

Los Alamos Scientific Laboratory
W-7405-ENG-36

PRINCIPAL INVESTIGATOR

P. Wagner

OBJECTIVES

The objectives of this ongoing research program are to assess the nature and magnitude of the trace elements in the drainage from coal preparation wastes and stored coals, identify the trace elements of greatest environmental concern, and evaluate required pollution control technology for this form of environmental contamination.

APPROACH

This program is divided into several research activities. Initial efforts have included trips to coal preparation plants in the Illinois Basin and in the Appalachian Region to obtain samples of coals and coal wastes. These samples have been subjected to chemical and mineralogical analyses and to studies of weathering and leaching behavior. This research has allowed for formulating the potential for these materials to cause trace element contamination of local groundwater and surface water in the sampled regions and identifying specific trace elements of environmental concern in the coal waste drainages. This information has been used as the basis for the current research in the environmental control technology designed to minimize the water pollution resulting from these refuse-associated drainages.

PROGRESS AND RESULTS

Leaching experiments using coal wastes from three coal preparation plants in the Illinois Basin have revealed that effluents from these wastes contain the trace elements Al, Mn, Fe, Co, Ni, Cu, Zn, As, and Cd in concentrations that exceed the Environmental Protection Agency's recommended minimum acute toxicity effluent values.

The environmental control technology research has taken the form of a concurrent laboratory evaluation for abatement or diminution of the trace element contamination in these drainages. These laboratory investigations have been carried out and the results classified into three environmental control strategies:

- Treatment of the refuse (before disposal) to remove or immobilize mobile trace elements of environmental concern.
- Treatment of the refuse (at the time of disposal) with neutralizing agents, absorbants, or sealants to control the release of undesirable trace elements from the refuse pile.
- Treatment of the contaminated drainage (after disposal) to reduce trace element concentrations to environmentally acceptable levels.

The experimental results indicate that each of these strategies is effective in reducing trace element concentrations in the coal waste drainages to acceptable levels; however, there are appreciable differences in costs, convenience of implementation, permanence, potential Resource Conservation and Recovery Act classification of the wastes, and so on. These aspects have been considered and are included in our reports.

PLANS FOR NEXT PERIOD

The studies on assessment of water contamination by trace elements will be extended to include high- and low-sulfur wastes in the Appalachian Region. The research in environmental control technology continues with the efforts to improve the ease, costs, effectiveness, and permanence of the pollution controls and to evaluate their relative costs.

REPORTS PUBLISHED

Thode, E.F., et al., "Costs of Coal and Electric Power Generation -- The Impact of Environmental Control Technologies for Coal Cleaning Plants," LA-8039-MS.

Wagner, P., et al., "The Assessment of Trace Element Contamination of the Drainages From Coal Cleaning Wastes," Proceedings 72nd National American Institute of Chemical Engineers Meeting, November 1979.

Wagner, P., et al., "Control Technology Strategies for Coal Preparation Waste Drainages," Proceedings Environmental Control Technology Division Wastewater Workshop, June 1979.

Wagner, P., et al., "Environmental Contamination From Trace Elements in Coal Preparation Wastes," Environmental Protection Agency Coal Cleaning Environmental Review, Winter 1979-1980.

Wagner, P., et al., "Environmental Control Strategies for Coal Preparation Waste Disposal," Coal Age Conference and Expo V, October 1979.

Wagner, P., E.M. Wewerka, and J.M. Williams, "Trace Element Assessment in Coal Preparation Waste Drainages," Federation of Analytical Chemistry and Spectroscopy Societies Meeting, November 1978.

Wangen, L.E., et al., "Control Technology for Coal Cleaning Wastes," Workshop on Solid Wastes (ASCE/PRC-EPRI), April 1979.

Wewerka, E.M., et al., "Environmental Control Technology for Contaminated Drainage From Coals and Coal Wastes," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Wewerka, E.M., et al., "Trace Element Characterization of Coal Wastes: 3rd Annual Progress Report," LA-7831-PR.

Wewerka, E.M., M. Gottlieb, and C. Grua, "Environmental Control Technology for Contaminated Coal Refuse Drainage," Proceedings 108th Annual Meeting, American Institute of Mining Engineers, New Orleans, Louisiana, February 1979.

PROJECTED MILESTONES

None

EVALUATION OF THE EFFECT OF COAL CLEANING ON FUGITIVE ELEMENTS

ORGANIZATION AND CONTRACT NUMBER

Bituminous Coal Research, Inc.
EE-77-S-02-4427

PRINCIPAL INVESTIGATORS

C.T. Ford
J.F. Boyer, Jr.

OBJECTIVE

The objective of this project is to assess the effect of controlled cleaning on fugitive elements present in run-of-mine coal. The results of the study will allow conclusions to be drawn concerning the potential for coal cleaning as a strategy for controlling trace elements that otherwise may become an environmental problem during subsequent utilization.

APPROACH

The effect of coal cleaning on fugitive elements is being evaluated by exhaustively studying 20 samples of run-of-mine coal obtained from various geographical locations throughout the United States. All run-of-mine coal samples were subjected to controlled coal cleaning at the Bituminous Coal Research, Inc., laboratory. Each coal was crushed to a 1-1/4-inch top size, sampled, and then screened into 1-1/4 by 1/4-inch, 1/4-inch by 30-mesh, and minus-30-mesh fractions, which are typical of present cleaning plant circuitry. The 1-1/4 by 1/4-inch and the 1/4-inch by 30-mesh fractions were gravity separated at the following gravities: 1.35, 1.55, and 1.80. The minus-30-mesh material was separated into four distinct fractions using a hydraulic classifier.

Samples of eight of the run-of-mine coals were also reduced in size to one lot that is predominantly minus-30-mesh. This lot was screened, using the standard sieve series, down to 270 mesh. The minus-30-mesh lot yielded eight size fractions that were then hydraulically classified to produce, as near as possible, a pure coal fraction, a pure shale fraction, and a pure pyrite fraction.

Each fraction produced by the coal cleaning task was characterized by general chemical and trace element analysis as well as petrographic analysis where appropriate, and the data were evaluated to determine the trace and major element concentrations in the various clean coal and reject fractions. Those elements chosen for study include the trace elements antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, fluorine, lead, manganese, mercury, nickel, selenium, vanadium, and zinc; the major elements silicon, aluminum, iron, calcium, magnesium, titanium, sodium, potassium, and phosphorus; and the more prevalent constituents such as sulfur.

PROGRESS AND RESULTS

All 20 run-of-mine coal samples to be evaluated have been sampled, subjected to laboratory-controlled cleaning, and analyzed. The 20 coals include the Freeport, Illinois No. 6, Rosebud, Beulah-Zap, Hannah No. 60, Adaville, Castle Gate D, Lower Kittanning (2), Pittsburgh (2), Meigs Creek, Pocahontas No. 3, Stockton, Sewell, Mary Lee, Kentucky No. 9, Illinois No. 5, Imboden, and Elkhorn No. 3 seams. Preliminary data evaluations have been completed, and extensive evaluations of the data in view of cleaning and trace element associations are in progress. Thus far, effective removal of many of the constituents of coal that might cause problems with their release to the environment during use has been demonstrated. The cleaning was particularly effective in the removal of arsenic, cadmium, chromium, fluorine, lead, manganese, zinc, silicon, aluminum, iron, calcium, magnesium, titanium, sodium, potassium, and phosphorus.

PLANS FOR NEXT PERIOD

The final report, which will be divided into three sections, is in progress. One section will contain a state-of-the-art review of the effect of coal mining, transportation, preparation, and utilization on fugitive elements. Another section will include a detailed description of analytical methods used in the study as an aid to coal industry and other laboratories. The final section will contain the evaluation of the extensive coal-cleaning data and the trace element associations found during the cleaning.

Through a contract modification, field evaluations have also been initiated to compare the response of trace and major elements to coal cleaning, as actually practiced, to the controlled cleaning procedures used in the laboratory. A proposal to continue these field evaluations as Phase III of this ongoing study was submitted to the Department of Energy in Pittsburgh, Pennsylvania, on July 12, 1979.

REPORTS PUBLISHED

Bituminous Coal Research, Inc., "Analytical Procedures for Trace Elements in Coal," presented to Society of Mining Engineers of American Institute of Mining Engineers Mini-Symposium on Elements in Coal and

Potential Environmental Concerns Arising From These Elements, February 1979.

Bituminous Coal Research, Inc., "Effect of Coal Cleaning on Fugitive Elements: A Progress Report," presented at Environmental Protection Agency Symposium on Coal Cleaning To Achieve Energy and Environmental Goals, September 11, 1978, and U.S. DOE Environmental Control Symposium, November 28-30, 1978.

Bituminous Coal Research, Inc., "Evaluation of the Effects of Coal Cleaning on Fugitive Elements, Phase I," BCR Report L-293, U.S. Department of Energy, August 17, 1978.

PROJECTED MILESTONES

- March 1980 -- Complete final reports including state-of-the-art review, analytical procedures manual, and evaluation of data on cleaning and trace element associations

ENVIRONMENTAL CONTROL IMPLICATIONS OF LIGNITE UTILIZATION

ORGANIZATION AND CONTRACT NUMBER

Texas A&M University
EP-78-S-05-5699

PRINCIPAL INVESTIGATOR

A.R. McFarland

OBJECTIVES

The objectives of this project are to identify existing or anticipated regulatory constraints and to assess air quality and groundwater contamination aspects associated with lignite utilization.

APPROACH

Considerations related to regulation constraints, control technology, and groundwater contamination are to be reviewed through a paperwork study. Air quality aspects are to be investigated by field sampling stack gas particulate matter to determine chemical composition and biological activity.

PROGRESS AND RESULTS

A specialized stack sampler for collecting particles for subsequent chemical and biological assessment has been designed, fabricated, and tested. This device (Figure 30) is basically a centripeter fractionator that separates respirable particulate matter (particles with aerodynamic diameters less than 2.5 micrometers) from the nonrespirable material. Stack gas is drawn into the system through an acceleration jet and directed toward a collection nozzle. Ten percent of the sampled flow rate drives the large particles, with high inertia, into the collection nozzle and subsequently carries them to the large particle collection filter. The remaining air, which is stripped of large particles, is carried to the small particle filter. Thimble filters are used for collection of both fractions. Each flow line is fitted with a metering device, flow controller, and pump.

Laboratory tests of the sampler have been conducted with monodisperse aerosols to characterize the efficiency and wall losses. Efficiency, η, is defined as

$$\eta = \frac{m_l}{m_l + m_s + m_{wl}}$$

Here m_l, m_s, and m_{wl} are the masses of aerosol collected by the large and small particle filters and the mass deposited on the internal sampler walls, respectively. Wall losses, WL, are given by

$$WL = \frac{m_{wl}}{m_l + m_s + m_{wl}}$$

The results (Figure 31) show that the sampler has a cutpoint (aerodynamic particle diameter for which the collection efficiency is 50 percent) of 2.5 micrometers and that the wall losses for particles with sizes near the cutpoint are approximately 5 percent. At 10 micrometers, the losses are increased to 15 percent -- a value that compares very favorably with wall losses of inertial impactor stack samplers wherein losses of 40 to 50 percent are noted for particles of 10 micrometers.

PLANS FOR NEXT PERIOD

Additional field testing of the stack sampling system will be performed. Collection of fly ash samples from an operating system is

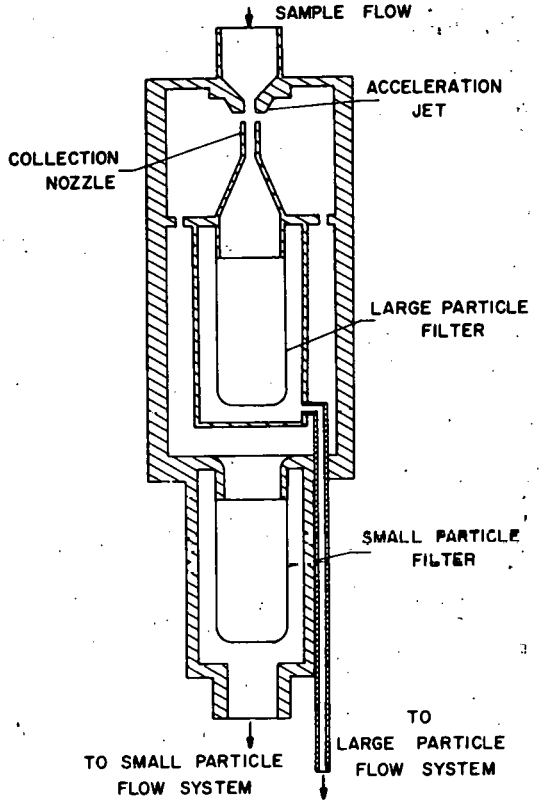


Figure 30. Fractionating Stack Sampler for Collection of Particulate Matter for Chemical and Biological Analyses

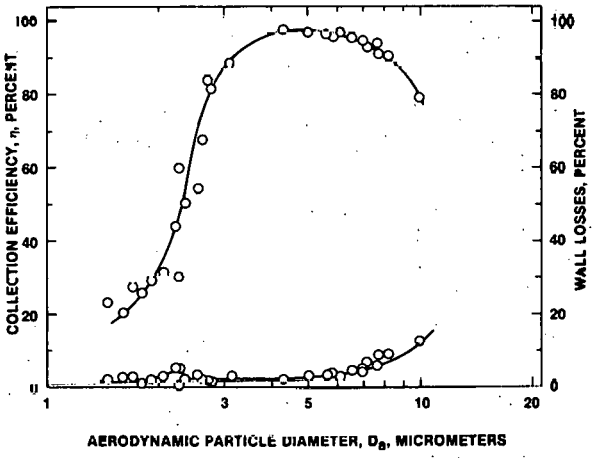


Figure 31. Performance Characteristics of Stack Sampler

still being negotiated. Difficulties have been experienced in gaining access to operating plants; however, it is expected that a clearance can be obtained.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

ENVIRONMENTAL IMPLICATIONS OF ACID MINE DRAINAGE

ORGANIZATION AND CONTRACT NUMBER

West Virginia University
EY-76-5-05-5261

PRINCIPAL INVESTIGATORS

A.W. Pappano
D.L. Gochenour, Jr.

OBJECTIVE

The objective is to develop a measurement of the secondary impacts to be expected from the wide-scale acceptance and use of lime neutralization as an acid mine drainage abatement procedure on the Monongahela River.

APPROACH

The approach is as follows:

1. Establish mathematical models to effectively predict the effluent concentrations from an acid mine drainage lime neutralization plant for cases where the influent data are complete or only partially available.

2. Establish a technique to determine the lime requirements of a neutralization system where influent data are complete or only partially available.

3. Develop a computerized data base for storing and retrieving river flow characteristics, river quality, and waste load characteristics on the river basin.

4. Develop and use a river flow simulation model to examine the effects, including secondary, on river quality of various acid mine drainage abatement scenarios.

A description of the lime neutralization model can be visualized by realizing that typical acid mine drainage is characterized by concentrations of calcium, magnesium, iron, aluminum, manganese, and sodium usually in conjunction with sulfate anions and at a low pH. The basis of the mathematical model is to consider the reactor employed in the neutralization process to be completely mixed and to assume the aqueous reactions to occur very rapidly. In this manner, it is reasonable to assume that all chemical species will attain an equilibrium state; thus, the adoption of the name Ionic Equilibrium Model. In this model, the Davies relationship has been used to compute the coefficient relating the molal concentration of the particular ion with its ionic reactive activity. It is also assumed that the activity coefficients for all single valence ions are equal, the activity coefficients for the nonionized dissolved molecules are unity, and the lime ($CaOH_2$) is added dry to the process.

The data base and simulation model are being programmed in FORTRAN because that language is very common and relatively easy to use. It also ensures that the format of the results are compatible with related work being done by other state and Federal agencies. Because the simulation model is designed to provide dynamic conditions of the river basin, the data base contains (and retrieves for the simulator) such information as river mile identification codes, hydraulic data for the river basin, and waste load data. Information from the data base will be translated and edited before it is entered into the simulator. Results from such treatments can be quickly viewed and evaluated without actually incurring the time and expense of doing the work in the field.

PROGRESS AND RESULTS

Models for predicting effluent hardness levels have been developed and tested for cases where chemical analysis of acid mine drainage are complete or only fragmented. Results indicate that this chemical equilibrium model can be used to reasonably predict the rate of lime usage and effluent hardness levels to be expected in the treatment of a specified acid mine drainage. The model has been set up in subroutine form so that it can be included in the river quality simulation model.

The data base for the Monongahela basin study area has been developed to contain information on (1) the river basin characteristics and (2) waste load and acid mine drainage points on the river. The data base includes all information currently available on the study area. The data base can be accessed to generate average river quality conditions of the basin (as opposed to low-flow conditions). A mass balancing program has also been developed and tested to blend together results from the modeling work, the data base (river quality characteristics), and the treatment alternative for reducing or eliminating the effects of the acid mine drainage problem. Together, this material yields input to the QUAL II simulation program, which predicts water quality as a result of efforts to treat the problem.

To demonstrate application of the model, the worst mine pollution points (within the model) on the three main rivers in the study basin are treated. Effects of the treatment on the river quality are then monitored downstream from the major mine pollution source. Alternatives can be modeled to examine not only the impact of the amount of the treatment but also where (on the river) the treatment is located.

The modeling is also being used to identify where additional data should be obtained on the river(s) to improve upon the reliability of the results generated.

PLANS FOR NEXT PERIOD

The project is basically completed; the final report is being prepared.

REPORTS PUBLISHED

Fang, S.-J., "A Mathematical Model of the Acid Mine Drainage Lime Neutralization Process," MSChE Thesis, West Virginia University, Morgantown, West Virginia, December 1978.

Holland, T., A.W. Pappano, and D.L. Gochenour, Jr., "A QUAL II Simulation Analysis of Treating AMD Problems in the Monongahela River Study Basin," presented (and included in the proceedings) at the 1978 Winter Simulation Conference, Miami Beach, Florida, December 4-6, 1978.

PROJECTED MILESTONES

- May 1980 -- Complete all computer runs
- May 1980 -- Complete final report

ORGANIC COMPOUNDS IN COAL SLURRY WATER

ORGANIZATION AND CONTRACT NUMBER

Lawrence Berkeley Laboratory
W-7405-ENG-48

PRINCIPAL INVESTIGATORS

A.S. Newton
J.P. Fox

OBJECTIVE

The increase in the use of coal, especially western coals which occur far from their ultimate markets, will require a tremendous increase in carrying capacity for coal. Much of this increased carrying capacity will be met by slurry pipelines. At present, there is only one operating coal slurry pipeline in the United States, the Black Mesa pipeline operated by Southern Pacific Pipeline, Inc., from Kayenta, Arizona, to the Mohave generating station at the Colorado River. This pipeline carries some 5 million tons of coal per year. Many more coal slurry pipelines have been planned and, if the projected amount of western coal is to be used, most of these will eventually be constructed.

The purpose of this program is to study the types and amounts of organic contaminants that might be present in the residual coal slurry water after removal of the coal by centrifugation or filtration. In the Black Mesa pipeline system, this problem has not arisen because that system is operated as a closed entity, and all slurry water is used as makeup water in the powerplant or is residual back-filter water, which is evaporated in watertight ponds. No water escapes into the aquatic environment of either the groundwater or surface water system. In general, however, it cannot be assumed that all slurry systems can operate as closed entities. For those that might dump excess slurry water into the aquatic environment, it is important to know the character and amount of what is present in the water to be dumped.

At first glance, it might be assumed that this problem is no different than that incurred by water trickling through a pile of ground coal in a storage area. However, because fair amounts of hydrogen are produced in the process of making the coal slurry in a steel rod mill, the system immediately becomes a reducing system. In the production of hydrogen, the interaction of nascent hydrogen with the coal surface can possibly cause the release of organic compounds from the coal surface. Because of the character of the coal surface, it is expected that some fraction of such molecules will be polynuclear aromatic hydrocarbons, many of which are carcinogens. Phenols represent another compound type that can be formed in coal slurries.

APPROACH

Experiments have been designed to slurry the coal with water in a laboratory-sized rod mill, extract the organics from the water, and characterize and quantitatively determine the concentrations of various organic species in the water.

To check the adsorption of organic compounds by coal, deuterated organic compounds will be added to the water before the preparation of the coal slurry. Other deuterated compounds added to the water after slurry and separation will be used for quantification.

PROGRESS AND RESULTS

This program was funded August 1, 1979, so only a partial year was available for research. A literature survey was made, and some 220 references found and reprints collected. A laboratory rod mill (Figure 32) has been constructed from 8-inch outside diameter pipe, 9 inches long, with 1/2-inch square steel baffles to carry the rods welded lengthwise on the body of the mill. The cap contains a flush valve that can be used to sample the gases produced. The rods are 1-inch diameter cold-rolled steel. The free volume is 5700 milliliters, and 5000 milliliters of slurry can be processed.

Three preliminary studies with Wyodak coal have been made. Before the mill was finished, two studies were performed in glass bottles -- one of which used steel ball bearings as a grinding tool. The third study was in the rod mill.

The centrifuged water was extracted with n-hexane, and the hexane was concentrated to a small volume. Products were studied on the Finnigan Model 4023 gas chromatograph/mass spectrometer/data system.

Compounds boiling in the range of 200° to 400°C (C_{12} to C_{30} hydrocarbon range), which are extractable with hexane, are present in the coal slurry waters at concentrations of less than 1 part per billion. More volatile compounds and

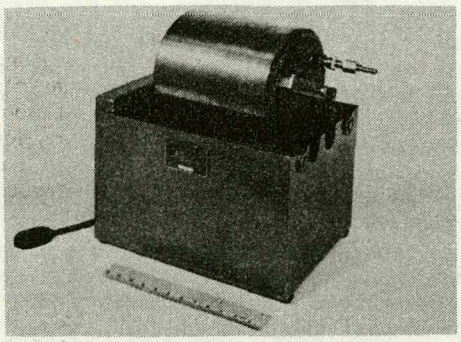


Figure 32. Laboratory Rod Mill and Its Drive for the Preparation of Coal Slurries

more polar compounds would not be found with these extraction methods. The gas was found to be mainly hydrogen mixed with carbon dioxide, nitrogen, and argon. All oxygen from the residual air was reduced to water.

PLANS FOR NEXT PERIOD

Samples of both subbituminous and bituminous coals will be studied at various slurry concentrations of from 5 to 50 percent coal. Gases will be analyzed. Volatile organics will be studied by head space analysis of the centrifuged waters, and phenolics will be isolated by conversion to the methyl ethers and extraction.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

September 1980 -- Publish annual report

ENERGY MATERIAL TRANSPORT SYSTEM CHARACTERISTICS AND POTENTIAL PROBLEMS NOW THROUGH YEAR 2000

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATORS

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

OBJECTIVES

The 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 gaps in the coverage of related programs and recommend action to minimize the potential impact of these problems.

APPROACH

The identification and setting of priorities among potential problem concerns are based on analysis of current system trends, issues, and controversies relating to the transportation of energy materials. Additional information and insight will be gained from contacts with experts in the Government and in the private transportation sector. Priorities will be set by judging a concern's potential severity and immediacy. The product of the severity and immediacy ranking will indicate the relative importance and, hence, the priority of each potential problem.

PROGRESS AND RESULTS

Final task reports containing system characterization and potential problem assessments of petroleum and synfuel transportation were completed and published in fiscal 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 desulfurization 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.

Petroleum Transportation Assessment Task

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 problems and priorities in petroleum transportation were identified. 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 oilspills; (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

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 because 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.

Legal, Regulatory, and Institutional Concerns

Some legal, regulatory, and institutional concerns considered previously in this project have developed new implications, and similar concerns have evolved from recent events. A detailed assessment of eight specific legal and regulatory concerns was 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 to handle emergencies. The report contains 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 material transportation corridors.

Nuclear Materials Transportation Assessment

Spent reactor fuels were the focus of this effort. Improved cask productivity (cask trips per year) 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 can be increased up to 60 percent in some cases if in-plant loading and unloading (turnaround time) is reduced. Significant reductions in turnaround times can be achieved by innovations and modifications in cask design and handling, facility operations, and systems 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

Large increases in the quantities of solid waste produced by coal-fired plants may occur over the next 20 years as a result of a greater dependence on coal-fired powerplants and the increasing use of sludge-producing flue gas desulfurization processes required to meet air pollution standards. The purpose of this study was to determine whether significant long-distance transportation of flue gas desulfurization sludge may be required in the future. It was concluded that utility planning is currently adequate for obtaining disposal sites that meet current regulations and that these sites 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 flue gas desulfurization sludges have been placed in a category called "Special Wastes." It was recommended that the Department of Energy keep this situation under scrutiny 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.

PLANS FOR NEXT PERIOD

The project was completed during fiscal 1979.

REPORTS PUBLISHED

DeSteese, J.G., "Environmental Concerns Influencing the Future Development of Energy Material Transportation Systems -- The Year 2000 Study," PNL-SA-7422, presented at U.S. DOE Environmental Control

Symposium, Washington, D.C., November 28-30, 1978.

DeSteese, J.G., et al., "Energy Material Transport, Now Through Year 2000, System Characteristics and Potential Problems -- Task 3 -- Final Report -- Petroleum Transportation," PNL-2421, Pacific Northwest Laboratory, Richland, Washington, 1979.

Geffen, C.A., "Potential Safety and Environmental Concerns in Petroleum Transportation," PNL-SA-7694, presented at the First International Symposium on Transportation Safety in San Diego, California, July 11-13, 1979.

Schuller, C.R., et al., "Selected Legal and Regulatory Concerns Affecting Domestic Energy Transportation Systems," PNL-2989, Pacific Northwest Laboratory, Richland, Washington, 1979.

Wakamiya, W., et al., "Assessment of Synfuel Transportation to Year 2000," PNL-2768, Pacific Northwest Laboratory, Richland, Washington, 1979.

Winsor, G.H., et al., "Opportunities To Increase the Productivity of Spent Fuel Shipping Casks," PNL-3017, Pacific Northwest Laboratory, Richland, Washington, 1979.

PROJECTED MILESTONES

None

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

PETROLEUM AND GAS

This program is designed to anticipate and alleviate environmental constraints that may hamper the solution of short- and long-term energy supply problems, taking into account economic, environmental, and technological aspects. High-priority activities in fiscal 1979 specifically concerned the safety of liquefied gaseous fuels, the prevention and cleanup of marine oilspills, and the handling of wastewaters stemming from enhanced oil recovery and refining methods.

Liquefied gaseous fuels program activity focuses on developing, in a timely fashion, safety and environmental control information required to ensure that potential hazards associated with this energy technology can be adequately mitigated. The information will be available to industry, regulatory bodies, and the general public for making decisions about these energy potential materials. The fuels of immediate interest are liquefied natural gas, liquefied petroleum gas, and liquid hydrogen. Other energy materials, such as anhydrous liquid ammonia, may receive attention later.

An important milestone in fiscal 1979 was the publication in May 1979 of DOE/EV-0036, "Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report." This document presented the updated Department of Energy plan for the liquefied gaseous fuels safety and environmental control assessment, as well as 22 individual reports detailing progress on the safety and environmental control aspects of handling, storing, transporting, and using liquefied gaseous fuels. This is a major Department of Energy program, conducted by the Environmental Control Technology Division; however, a number of other Federal agencies have related responsibilities and will use the information base developed in this program. These agencies include the Federal Energy Regulatory Commission, Economic Regulatory Administration, U.S. Coast Guard, Office of Pipeline Safety Regulations, U.S. Maritime Administration, Federal Railroad Administration, and National Aeronautics and Space Administration. This cooperative effort also extends to industry, through the Gas Research Institute and the Fertilizer Institute. The specific areas of coordination and cofunding for fiscal 1979 are listed in Table 7.

Under Section 6(b)(3)(Q) of the Federal Non-Nuclear Energy Research and Development

Table 7. Industry and Government Coordination, Funding, and Cofunding of Projects of Mutual Interest, Fiscal 1979

	Department of Energy	National Aeronautics and Space Administration	Gas Research Institute	U.S. Maritime Administration	U.S. Coast Guard	The Fertilizer Institute
Application of a Wind Tunnel to Liquid Natural Gas Vapor Studies	Coord		Fund		Coord	
Liquefied Natural Gas Field Spill Experiments	Cofund		Cofund		Cofund	
Safety Aspects of Gelled Liquefied Natural Gas	Cofund			Cofund		
Research Instrumentation for Detection of Hydrocarbon Vapors	Coord	Fund	Fund		Fund	
Reduction of Liquefied Natual Gas Tanker Fire Hazards	Cofund			Cofund		
Ammonia Spill Hazard Studies	Coord				Fund	Fund

Act of 1974, the Energy Research and Development Administration, and hence the Department of Energy, is authorized and directed to establish program elements and activities ". . . to improve methods for the prevention and cleanup of marine oil spills." As a consequence of this authorization, the Environmental Control Technology Division has supported assessments in areas not already adequately covered by the Environmental Protection Agency, the Coast Guard, or other public and private efforts.

The major initiative of past years, assessing the advantages and disadvantages of using chemical dispersants to respond to a marine oilspill, is drawing to a close; a final report is expected in fiscal 1980. It has been found that dispersants, long prohibited by the Environmental Protection Agency, may be useful and permitted in certain circumstances without prolonged or excessive effect on the ecology. An important initiative in fiscal 1979 was an assessment of burning technique options that can be used to respond to an oilspill. A preliminary report will be available early in fiscal 1980.

The program directed at the petroleum fuel cycle has focused on wastewater treatment options. Specifically, enhanced oil recovery methods may have associated waters contaminated by oil and gas residues. Increased understanding of systems for separating the organic wastes and spent chemicals from the brines and of methods for disposing of the brackish waters is needed in order to realize the full potential of such techniques. In fiscal 1979, additional results were obtained in an assessment of the feasibility of using membrane technology for cleaning produced water/oil emulsions containing a water soluble sulfonate, cosurfactant, and polymer in a synthetic brine. A final report was also issued in fiscal 1979 on a study of the efficacy of using powdered activated carbon as a polishing step for refinery wastewaters initially treated in an activated sludge system.

LIQUEFIED NATURAL GAS SPILL EFFECTS PROGRAM

ORGANIZATION AND CONTRACT NUMBER

Lawrence Livermore Laboratory
W-7405-ENG-48

PRINCIPAL INVESTIGATOR

W.J. Hogan

OBJECTIVES

The objectives of this program are to develop and verify an ensemble of models capable of predicting the phenomena that occur when large amounts of liquefied natural gas are released to the environment. This will require the analysis and collection of sufficient experimental data to establish useful scaling relationships so that large-scale effects can be predicted using data from less than full-scale experiments.

APPROACH

The analytical approach is to evaluate existing models and assemble the best of these into an initial ensemble. Missing pieces will be developed, and all parts will be integrated into a final ensemble. The experimental approach will involve the development of site-selection criteria based on preliminary assessments of the experimental needs. A facility will be designed to accomplish the experimental objectives reliably and safely, and a data collection system will be designed and built. Finally, tests will be conducted and data analyzed for comparison with models.

PROGRESS AND RESULTS

Frenchman Flat at the Nevada Test Site was recommended as the location for scaled experiments larger than 40 cubic meters. The collection of background weather data continued at the potential spill site, and development of model ensembles also continued. Hydrocarbon concentration sensor concepts were compared to the field evaluation of the sensors. A final instrumentation array was designed, and procurement and assembly was begun.

PLANS FOR NEXT PERIOD

Model projections and the assembly and deployment of the instrumentation array for the 40-cubic-meter field tests will be completed. Several dispersion tests involving the release of up to 40 cubic meters of liquefied natural gas will be conducted, and test results will be compared with mathematical models and data derived from wind tunnel tests.

REPORTS PUBLISHED

Department of Energy, Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979:

Bowman, B.R., "Dispersion Model Comparisons," Report B.

Cramer, J.L., and W.J. Hogan, "Evaluation of Sites for LNG Spill Tests," Report M.

Koopman, R.P., et al., "A Review of the 1978 China Lake LNG Dispersion Experiments and Instrumentation," Report K.

Shinn, J.H., "Validity of Desert Site Scale Effects Experiments," Report N.

Stein, W., "The Spreading and Differential Boil-Off for a Spill of LNG on a Water Surface," Report A.

Westbrook, C.K., and L.C. Haselman, "Modeling Detonation and Deflagration Properties of Liquefied Energy Fuels," Report E.

Hogan, W.J., "LLL Participation in LEF Safety Research," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

PROJECTED MILESTONES

- April 1, 1980 -- Initiate 40-cubic-meter liquefied natural gas vapor dispersion test series

DESIGN FOR MEDIUM-SCALE LIQUEFIED GASEOUS FUELS SPILL TESTS

ORGANIZATION AND CONTRACT NUMBER

Holmes & Narver, Inc.
EY-76-C-08-0020

PRINCIPAL INVESTIGATOR

W.H. Jones

OBJECTIVES

The objectives of this study are to (1) evaluate the feasibility of and prepare cost analyses related to the siting of future work associated with the Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program and (2) design a modification to the existing experimental test facility to increase spill capacity to 40 cubic meters.

APPROACH

The contractor is using criteria provided by the Department of Energy and test experience gathered from the U.S. Naval Weapons Center during "small spill test" programs. Commercial equipment exhibiting the latest state-of-the-art will be recommended in the development of facility design, estimated costs, and construction compilation schedules.

PROGRESS AND RESULTS

A design to upgrade the existing 5-cubic-meter experimental test facility to a capacity of 40 cubic meters was completed.

PLANS FOR NEXT PERIOD

None, the project is completed.

REPORTS PUBLISHED

The final design was submitted in February 1979.

PROJECTED MILESTONES

None

INTEGRATED LIQUEFIED NATURAL GAS SAFETY AND CONTROL PROGRAM

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATOR

J.G. DeSteese

OBJECTIVES

The objectives of this program are to (1) conduct research and development in specific areas (principally release prevention and control studies) of the Department of Energy Integrated Liquefied Natural Gas Safety and Control Program and (2) to assist the Environmental Control Technology Division in the planning and technical surveillance of the program.

APPROACH

Research in this program will provide safety and environmental control information and guidance needed by the Department of Energy, industry, regulatory bodies, and the general public for making decisions regarding the handling, transportation, and storage of liquefied natural gas and other liquefied gaseous fuels. Facility and system evaluations will be performed to determine the adequacy of, and possible research and development needs for, release prevention and release control systems for these fuels. Literature surveillance will be maintained to provide quarterly reviews and updated bibliographies, and special studies will assist in implementing and managing the program.

PROGRESS AND RESULTS

System descriptions have been written for a generic liquefied natural gas export terminal, tanker, import terminal, peakshaving plant, and satellite storage facility. For each system, a preliminary hazards analysis was performed to identify important features of the release prevention and release control system and its response to postulated initiating events. Included in the consequences are such aspects as vapor generation control, vapor dispersion control, flame radiation control, and damage control. These initiating events include equipment failures, operator errors, and external events. Areas have been identified that require more detailed study through a failure mode and effect analysis format. Final reports on these tasks are planned for fiscal 1980.

A major effort of this task was to assemble and amalgamate the various reports into the document "Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report," DOE/EV-0036, published in May 1979. The technical literature on liquefied gaseous fuels is continually surveyed and reviewed, and a library of pertinent books, articles, and research reports is maintained. This effort contributed to the annotated bibliographies of safety resarch that appeared in DOE/EV-0036.

PLANS FOR NEXT PERIOD

- The release prevention and release control studies will be completed, and a final report published.

- A document on the status of liquefied gaseous fuels safety research projects sponsored fully or jointly by the Department of Energy will also be prepared.

REPORTS PUBLISHED

Department of Energy, Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979:

Brenchley, D.L., "Ammonia -- Environmental and Safety Concerns," Report V.

DeSteese, J.G., "Annotated Bibliography LNG Safety and Environmental Control Research," Report P.

McNaughton, D.J., and C.M. Berkowitz, "Test Cases for a Phase I Evaluation of LNG Vapor Generation and Dispersion Models," Report C.

Pelto, P.J., E.G. Baker, and E.F. Riedel, "LNG Release Prevention and Control," Report F.

Zaloudek, F.R., et al., "Experimental Strategy Considerations for LNG Field Experimentation," Report O.

McNaughton, D.J., and C.M. Berkowitz, "Overview of U.S. Research Activities in the Dispersion of Dense Gases," Proceedings, Symposium Schwere Gase, Frankfurt, Germany, 1979.

Pelto, P.J., E.G. Baker, and R.J. Hall, "Assessment of LNG Release Prevention and Control," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

PROJECTED MILESTONES

None

SCALE EFFECTS IN LIQUEFIED GASEOUS FUEL HAZARD ANALYSIS AND TESTING

ORGANIZATION AND CONTRACT NUMBER

Massachusetts Institute of Technology
DE-AC02-77EV04204

PRINCIPAL INVESTIGATOR

J.A. Fay

OBJECTIVE

The overall objective of this study is to determine methods for the reliable extrapolation of liquefied gaseous fuels spill phenomena to very large spill volumes and rates, focusing attention on those physical effects that are significant in evaluating field tests or undertaking hazard and risk analyses. A particular characteristic of spills of cryogenic liquefied gases is the formation of a vapor cloud with negative buoyancy. The usefulness and validity of fluid mechanical, thermodynamic, and meteorological models will be assessed with respect to their ability to correlate field data and permit reliable extrapolation to larger scale spills.

APPROACH

A field test, or a typical spill scenario, defines a series of processes (liquefied natural gas spread, boiling, vapor cloud or plume formation and spread, atmospheric mixing, ignition, flame propagation, etc.) that are, to some degree, simultaneous, each of which can be modeled by fluid/thermodynamic models of various levels of complexity. Various models will be exercised to delineate the effect of scale, as measured principally by spill size, in order to understand the relative importance of the various processes and the assumptions used in the models.

PROGRESS AND RESULTS

Earlier efforts focused on fire and radiation hazards from a burning vapor cloud. The emphasis this year was on modeling the gravity spread and dispersion of a negatively buoyant vapor cloud. The model is of intermediate complexity (falling between modified classical models (Fay and Lewis; Germeles and Drake) and a three-dimensional unsteady flow model (SAI SIGMET)), in accordance with the current limited understanding of the basic physical processes involved. The fluid flow equations in the vertical direction have been integrated, and an assumption has been made of entrainment similar to free shear flows. The resulting equations are hyperbolic in nature and require solution by numerical finite difference techniques. Asymptotic solutions have been investigated for the far

field case for several sources, with the following results:

- For quasi one-dimensional steady flow, assuming a strip source normal to a cross wind:
  - A steady flow solution is possible only if the source strength is small compared to wind speed.
  - Contrary to intuition, the vapor speed is always less than the wind speed at great distances downwind.
  - Two solutions exist (subcritical, supercritical), depending on whether the plume speed is less than or more than the local gravity wave speed.
- For quasi one-dimensional unsteady flow (both strip sources and strip puffs):
  - For strong sources, a front moving upwind will form as well as a front moving downwind.
  - A line puff will accelerate to wind speed, even in the absence of entrainment or friction.
  - Asymptotic solutions have been found for line puff drift with respect to the cloud.
- For quasi two-dimensional steady flow, as might be expected, the development of a transverse flow field as a function of distance from the source is closely analagous to the one-dimensional puff.
- For quasi two-dimensional unsteady flow, assuming the cloud would accelerate to wind speed, axisymmetric asymptotic solutions were found for strip sources and line puffs.

The comparison is favorable between results from this model and published data from a more complex model, SIGMET.

PLANS FOR NEXT PERIOD

Further extension to two-dimensional cases and comparison with experimental data is planned.

REPORTS PUBLISHED

Doo, Y-C., "A Two-Dimensional Model of Negatively Buoyant Vapor Cloud Dispersion," M.S. Thesis, Massachusetts Institute of Technology, August 1979.

Fay, J.A., G.J. Desgroseilliers, and D.H. Lewis, Jr., "Radiation From Burning Hydrocarbon Clouds," Report D in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979.

PROJECTED MILESTONES

None

LIQUEFIED GASEOUS FUELS EXPERIMENTAL SPILL TESTS

ORGANIZATION AND CONTRACT NUMBER

U.S. Naval Weapons Center
Interagency Agreement

PRINCIPAL INVESTIGATORS

C.D. Lind
J.C. Whitson

OBJECTIVE

The objective of this program is to provide background analyses and planning assistance and to conduct experimental field tests to determine the hazard extent of vapor clouds, pool fires, and vapor cloud fires resulting from releases of liquefied gaseous fuels on both land and water.

APPROACH

The approach employed uses existing or improved mathematical models as well as wind tunnel predictions to design the experiments (ranging in size from 5 to 40 cubic meters), estimate data needs, and predict experimental results (e.g., extent of vapor cloud travel). Characteristics of flame propagation have been identified to aid in determining whether deflagration or detonation occurs.

PROGRESS AND RESULTS

Two tests on 5-cubic-meter liquefied natural gas were completed. The first were pool fire tests to obtain radiometric measurements to determine whether the flames observed were optically thick. This phase of tests was supported in coordination with the U.S. Coast Guard; results of the test phase will be published as a U.S. Coast Guard report.

The second tests determined downwind vapor dispersion characteristics and evaluated hydrocarbon concentration monitoring instrumentation.

Planning and the final design for modifying the experimental test facility to conduct spills of up to 40 cubic meters has been completed, and fabrication of the upgraded facility was begun.

PLANS FOR NEXT PERIOD

Upgrading of the experimental test facility will be completed. Background analyses and test program planning will be coordinated by wind tunnel tests sponsored by the Gas Research Institute. Liquefied natural gas pool fires and vapor dispersion experiments will be conducted.

REPORTS PUBLISHED

Lind, C.D., and J.C. Whitson, "China Lake Spill Tests," Report L in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979.

PROJECTED MILESTONES

- March 1, 1980 -- Complete modification of experimental test facility and initiate liquefied natural gas pool fire tests
- April 1, 1980 -- Initiate liquefied natural gas vapor dispersion tests
- April 1, 1981 -- Initiate liquefied natural gas vapor cloud fire tests

ATMOSPHERIC METHANE DETECTION

ORGANIZATION AND CONTRACT NUMBER

Massachusetts Institute of Technology,
Department of Mechanical Engineering
EE-77-S-02-4447

PRINCIPAL INVESTIGATOR

C.F. Dewey

OBJECTIVE

The objective of this study is the evaluation and assessment of accurate, reliable, and rapidly responding methods for measuring the concentration of methane in the atmosphere.

APPROACH

Emphasis is placed on instrument concepts suitable to the detection of methane concentrations between 0.1 percent and 100 percent, as would be encountered in hazardous spills of liquefied natural gas or serious ruptures of flammable gas containment vessels.

PROGRESS AND RESULTS

A prototype instrument suitable for use in field tests of liquefied natural gas dispersion has been completed. It uses a helium-neon laser operating at 3.39 μm to produce two beams at slightly different wavelengths. One wavelength is strongly attenuated by methane, whereas the other suffers negligible attenuation and serves as an optical intensity reference. The instrument has an onboard microprocessor and digital tape cassette for local data processing and data storage. The entire unit is battery operated and is turned on by a telemetry signal prior to beginning the field test. Battery operation allows placement of the instrument in the test area without the necessity of power and signal cabling or large-bandwidth telemetry systems for data transfer. The analog/digital converter and digital tape can also record voltages from other satellite instruments.

The measurement concepts developed in this program are also applicable to other gaseous species such as ammonia and liquefied petroleum gas. For example, replacing the helium-neon laser with a multiple-line carbon dioxide laser would produce a system suitable for detecting ammonia.

PLANS FOR NEXT PERIOD

This project was completed in fiscal 1979.

REPORTS PUBLISHED

Dewey, C.F., Jr., et al., "Detection of Atmospheric Methane," Report I in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979.

PROJECTED MILESTONES

None

EVALUATE FEASIBILITY OF METHODS AND SYSTEMS FOR REDUCING LIQUEFIED NATURAL GAS TANKER FIRE HAZARDS

ORGANIZATION AND CONTRACT NUMBER

Arthur D. Little, Inc.
EP-78-C-02-4734

PRINCIPAL INVESTIGATOR

D.S. Allan

OBJECTIVE

The objective of this task is to identify and evaluate new and novel concepts for reducing the hazards presented by liquefied natural gas tanker transits within U.S. navigable waters. It is to consist of a preliminary assessment of the technical and economic feasibility of the concepts that are identified.

APPROACH

Analyses will be performed to establish the feasibility of methods for significantly reducing fire hazards that may be caused by major liquefied natural gas tanker accidents. The fires to be considered are those that could be caused by discharges of large quantities of gas into the water resulting from the breaching of one or more shipborne liquefied natural gas containers or from a major failure in a ship-to-shore transfer line during offloading. Fire hazard reduction methods to be considered include those that may decrease the size of the fire; furnish protection for the ship and crew from the thermal effects of the fire; and provide a means for removing the remaining cargo from a badly damaged, disabled tanker.

PROGRESS AND RESULTS

A draft report containing results of the literature search, evaluation of thermal effects, and methods of disposing of the liquefied natural gas cargo from a disabled tanker was prepared. A preliminary evaluation of the costs associated with suggested modifications is complete, and an evaluation of accident-generated ignition sources was begun.

PLANS FOR NEXT PERIOD

The evaluation of ignition sources will be completed, and the final report will be prepared.

REPORTS PUBLISHED

Allen, D.S., R. Phani Raj, and G. Pollack, "The Feasibility of Methods and Systems for Reducing LNG Tanker Fire Hazards," Report G in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: Status Report, DOE/EV-0036, May 1979.

PROJECTED MILESTONES

- February 1, 1980 -- Prepare final report
- March 1, 1980 -- Complete project

STUDY OF GELLED LIQUEFIED NATURAL GAS

ORGANIZATION AND CONTRACT NUMBER

Aerojet Energy Conversion Company
DE-AC03-78EV02057

PRINCIPAL INVESTIGATOR

M.I. Rudnicki

OBJECTIVE

The objective of this program is to investigate the feasibility of reducing hazards associated with the storage, transportation, handling, and use of liquefied natural gas by gelation. Potential safety advantages of gelled liquefied natural gas will be examined and the practicality of this gelation on an industrial scale will be studied.

APPROACH

The program involves gel characterization, optimization, safety tests, preliminary design of an industrial-scale gelation system, and a preliminary economic assessment of the gelation process. Liquefied natural gas gels of varying gelant concentration using both water and methanol as gelants will be prepared and characterized. Selected gels will be used in safety comparison tests with liquefied natural gas. Based on parameters obtained from these tests, a preliminary design will be made for an industrial-scale gelation system, which will provide a basis for an economic assessment of liquefied natural gas gelation.

PROGRESS AND RESULTS

During the past year, experimental work progressed in measuring shear stress characteristics of gelled liquefied natural gas over a range of shear rates and gelant fractions. Such data are needed to evaluate the hydrodynamic behavior of a gel in a postulated spill analysis. The plastic "yield strength" ranges around 700 dynes/square centimeter (about 0.01 pound-force per square inch). At high shear rates, the gel approaches a Newtonian fluid.

These conclusions have been reached:

- Water is superior to methanol as a gelant (for similar gel structures, less water is required than methanol).
- Gels flow easily through flow coils, exhibiting shear thinning with no evidence of gel structure degradation even after repeated shearing.
- Gel expulsion from tanks was found to be dependent on tank surface area. Gel expulsion efficiency of greater than 90 percent that of neat liquefied natural gas was obtained for a tank with a surface/volume ratio of 8.5.
- Based on unconfined spills of neat liquefied natural gas and gelled liquefied natural gas in approximately 5 gallon quantities on dry earth, gelation decreases the size of maximum spill spread (gel = 7.9 feet; liquefied natural gas = 9.2 feet) and greatly increases the time to complete evaporation (gel = 7.0 minutes; liquefied natural gas = 0.2 minutes).

PLANS FOR NEXT PERIOD

Additional tests will be conducted to compare liquefied natural gas and gelled liquefied natural gas when they are spilled on sand and on water. The leak rate of gelled liquefied natural gas through an orifice and a slit under varying pressure heads will be measured. These tests are intended to provide information needed to assess the impact of some likely scenarios of a leak at a liquefied natural gas facility.

The results of prior work will be presented and discussed in a report to be published in mid-1980. The final report, to include all experimental results, will be published about December 1980.

REPORTS PUBLISHED

Rudnicki, M.I., and E.M. Vander Wall, "Gelled LNG -- A Safety Approach," presented at the 7th International LNG/LPG Conference and Exhibition -- GASTECH 79, Houston, Texas, November 13-16, 1979.

Rudnicki, M.I., and E.M. Vander Wall, "Gelled LNG Increased Safety in Storage, Handling, and Transportation," presented under Topic B, Economic Commission for Europe, Committee on Gas Seminar and Study Tour on LNG Peak Shaving, Washington, D.C., March 5-9, 1979.

Rudnicki, M.I., and E.M. Vander Wall, "Safety Assessment of Gelled LNG," Report H in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979.

PROJECTED MILESTONES

- April 1980 -- Report on liquefied natural gas gel characterization and economic assessment
- December 1980 -- Publish final report

BOILING OF LIQUEFIED PETROLEUM GAS ON WATER

ORGANIZATION AND CONTRACT NUMBER

Massachusetts Institute of Technology,
Department of Chemical Engineering
EE-77-S-02-4548

PRINCIPAL INVESTIGATORS

R.C. Reid
K.A. Smith

OBJECTIVES

The objectives of this task are to (1) measure the rate of boiling (and spreading) of liquefied petroleum gas on water, (2) measure the fractionation that results, and (3) model the process and compare theoretical predictions with experimental results.

APPROACH

Scale spills of liquefied petroleum gas are made in the laboratory in both confined and

unconfined modes, and the rate of vaporization is measured for different types of spills with different initial composition and for different water conditions.

PROGRESS AND RESULTS

Unconfined spill tests of liquefied petroleum gas in water were completed. The boil-off rates were correlated with a theoretical, one-dimensional, moving boundary model.

PLANS FOR NEXT PERIOD

Spills of liquefied petroleum gas on water in an unconfined mode will be conducted, and the rate of boiling and spreading will be measured.

REPORTS PUBLISHED

Reid, R.C., K.A. Smith, and H. Chang, "Simultaneous Boiling and Spreading of Liquefied Petroleum Gas (LPG) on Water," Report S in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979.

PROJECTED MILESTONES

- December 1980 -- Complete project

LIQUEFIED PETROLEUM GAS SAFETY RESEARCH

ORGANIZATION AND CONTRACT NUMBER

Applied Technology Corporation
DE-AC05-78EV06020

PRINCIPAL INVESTIGATOR

J.R. Welker

OBJECTIVE

The objective of this project is to develop information regarding the safety and environmental control of liquefied petroleum gas. The hazards of marine transportation will be analyzed and the effectiveness of liquefied petroleum gas fire-fighting agents will be determined.

APPROACH

Safety analyses of liquefied petroleum gas marine terminals will be conducted. The safety analyses will provide an indication of the likelihood that an accidental release of the gas will occur. It will provide information regarding the likelihood of ignition of the spilled material.

Fire control tests (25 to 1600 square feet) will be conducted. Various agents will be used to control and extinguish the fires, and recommendations regarding the most favorable means will be prepared.

PROGRESS AND RESULTS

A bibliography of liquefied petroleum gas safety information has been prepared. The marine safety analyses and fire control extinguishment tests were begun.

PLANS FOR NEXT PERIOD

The bibliography, the marine safety analyses, and the fire extinguishment and control tests will be completed. Appropriate reports will be prepared and published as time permits.

REPORTS PUBLISHED

Welker, J.R., "LPG Safety Research," Report R in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: Status Report, DOE/EV-0036, May 1979.

Ice, J.N., and N.M. Butcher, "Preliminary Annotated Bibliography of Publications Related to Fire Safety in Marine Transport of Liquefied Petroleum Gas," Report T in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979.

Welker, J.R., et al., "Control and Extinguishment of LPG Fires," Applied Technology Corporation, in press.

PROJECTED MILESTONES

- July 1, 1980 -- Publish report on liquefied petroleum gas marine terminal safety.
- May 1, 1980 -- Publish final report

LIQUEFIED PETROLEUM GAS SAFETY AND ENVIRONMENTAL RESEARCH AND DEVELOPMENT

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATORS

J.G. DeSteese
M.G. Patrick

OBJECTIVE

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. The resulting information will support the Environmental Control Technology Division in developing a research and development program plan for liquefied petroleum gas safety and environmental concerns.

APPROACH

This project is being undertaken in two phases. The first phase is to collect information describing the liquefied petroleum gas industry and the status of current safety and environmental control requirements and practices. The second phase will develop an assessment of safety and environmental control research and development needs based on this information.

PROGRESS AND RESULTS

The Phase 1 study of the industry was completed in fiscal 1979. The efforts of two subcontractors contributed to this study. Battelle Columbus Laboratories supplied system descriptions of liquefied petroleum gas transportation by pipelines, rail, and trucks. In addition, they provided assessments of the research and development state-of-the-art in liquefied petroleum gas vapor generation, dispersion, fires and explosions, and release prevention and control. The Institute of Gas Technology contributed descriptions of production, import/export and peak-shaving plants, together with barge and ship transportation systems. A draft preliminary report was prepared as a compilation of these inputs and results of studies performed at the Pacific Northwest Laboratory.

The perspective gained shows liquefied petroleum gas processing and distribution to be a mature industry using basically sound safety and environmental control technology and practices. Areas of concern that warrant attention in the Department of Energy program are anticipated to be quite specific in terms of the system element to be addressed and the areas of research and development need.

PLANS FOR NEXT PERIOD

A methodology that is responsive to the above perspective wil be used in the assessment phase of this project. The objective of the methodology will be to define safety and environmental research and development work packages that address specific concerns at the system element level. The assessment will be guided by the input of expert opinion and critical reviews during the course of this study.

REPORTS PUBLISHED

"Annotated Bibliography for LNG Safety and Environmental Control Research," Report Q in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979.

PROJECTED MILESTONES

- July 1980 -- Complete the assessment

ASSESSMENT OF ACTIVATED CARBON FOR ENVIRONMENTAL CONTROL OF TRACE ORGANICS IN REFINERY WASTEWATER

ORGANIZATION AND CONTRACT NUMBER

Argonne National Laboratory
W-31-109-ENG-38

PRINCIPAL INVESTIGATORS

W. Harrison
R.D. Flotard

OBJECTIVES

The objectives of this study are to estimate dollar costs and energy impacts for removal of trace organics by (1) granular activated carbon in a continuous flow-through system and (2) powdered activated carbon fed to an activated-sludge system, where either treatment option is in addition to 1983 best-available-treatment-economically-available model requirements.

APPROACH

Attainable trace organic removal levels for any given refinery are based on Argonne National Laboratory data from a Class-B refinery that met model requirements in 1977 for best practicable wastewater control technology currently available. Scaling is done by assuming that the same percent chemical oxygen demand or total organic carbon must be removed as was removed at the Class-B refinery to achieve a similar trace organics removal level. Cost

information developed from industrial wastewater treatment experience with activated carbon systems and design experience from petroleum refinery wastewater treatment plants are used to estimate the costs of adding a granular activated carbon system, including granular-media filtration and carbon regeneration, to the Class-B refinery that was used by Argonne National Laboratory to evaluate the performance of granular activated carbon for removal of trace organic compounds. In addition, the costs of the powdered activated carbon modification of this refinery's activated sludge system are estimated for comparison with the granular activated carbon system costs, using the performance basis mentioned above.

PROGRESS AND RESULTS

The study reached these conclusions:

- Nationwide application of granular activated carbon technology would cost $445 million in capital costs and $127 million for annual operation (1977 dollars)
- Nationwide application of powdered activated carbon technology would cost $172 million in capital costs and $82 million for annual operation (1977 dollars)
- Estimated annual energy impacts are 2.35 million barrels of crude oil (0.044 percent annual throughput) for granular activated carbon and 0.53 million barrels of crude oil (0.0097 percent annual throughput) for powdered activated carbon
- Powdered activated carbon technology should be considered for trace organics control throughout the petroleum refining industry and pilot studies should be done to answer outstanding questions. Powdered activated carbon advantages over granular activated carbon, in addition to more favorable capital, operating, and energy costs, include flexibility in varying carbon type and dose and minimization of the possibility of upset of the activated-sludge process.

PLANS FOR NEXT PERIOD

An assessment of wastewaters derived from refining oil shale crude is underway and is expected to be completed by the third quarter of fiscal 1980.

REPORTS PUBLISHED

Harrison, W., R.D. Flotard, and D. Ford, "Assessment of Activated Carbon for Environmental Control of Trace Organics in Petroleum Refinery Wastewaters," ANL/WR-79-3, Argonne National Laboratory, March 1979.

PROJECTED MILESTONES

- June 1980 -- Publish preliminary assessment of wastewaters from refining oil shale crude

BURNING OF OILSPILLS

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATORS

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

OBJECTIVES

The objectives of the program are to determine the state of knowledge of combustion as a means of mitigating oilspills and ultimately to identify the required program for development of oilspill combustion technology. The generic term "burning" is employed to cover three discrete options for combustion: unrestricted burning, controlled or confined burning, and incineration. Primary emphasis is on the first two options as they apply to use on oil slicks and residual oils in the tanks of standard naval vessels.

APPROACH

The work is being performed through the development of a model of the combustion process as applied to oilspill situations. Input for the modeling is derived from a review of worldwide studies, past spill incidents where combustion was attempted, and related technology.

Initial data collection efforts are focused through dynamic interaction with a generic model identifying the key limiting factors that deter-

mine the feasibility of initiating and sustaining combustion. As the mechanisms relating these factors are elucidated, they are quantified and ultimately built into a mathematical model of the process. The product model will then be employed to evaluate the feasibility of combustion for different sets of spill circumstances as well as the potential for proposed combustion aids.

PROGRESS AND RESULTS

The collection of background material and the development of a preliminary burning model is completed. The final report for this phase is also completed.

PLANS FOR NEXT PERIOD

The plans for next period are to investigate the means to enhance back-radiation of flame heat to promote increased burning of spilled oil and to evaluate categorization of crude oils according to their flammability.

REPORTS PUBLISHED

Thompson, C.H., G.W. Dawson, and J.L. Goodier, "Combustion: An Oil Spill Mitigation Tool," DOE/EV-1830-1, August 1979.

PROJECTED MILESTONES

- November 1980 -- Issue final report

OILSPILL TRAINING SCHOOL

ORGANIZATION AND CONTRACT NUMBER

Corpus Christi State University,
National Spill Control School
EY-76-S-05-4995

PRINCIPAL INVESTIGATORS

R.E. Gilchrist
G.E. Oberholtzer

OBJECTIVE

The objective of this program is to provide a trained manpower base to respond to the needs of the Nation in controlling the problems created by oilspills. To reach this objective, the past year's work has centered on the introduction of an oilspill training school, which will provide instruction and experience to key personnel of companies, organizations, and Government units to effectively and adequately contend with oilspill emergencies.

APPROACH

The program is directed toward oilspill cleanup rather than prevention. However, the subject of prevention will prevail throughout the topical presentations because it is believed that this is the foundation of any spill response program. Personnel from Government and the private sector will be provided with instructional data to effectively and adequately contend with an oilspill.

PROGRESS AND RESULTS

During the past year, using the training aids (both visual and written) and lesson plans developed previously under this contract, the program continued to be evaluated and modified.

PLANS FOR NEXT PERIOD

None, the project is completed.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

ASSESSMENT OF TREATED VERSUS UNTREATED OILSPILLS

ORGANIZATION AND CONTRACT NUMBER

University of Rhode Island
EY-76-5-02-4047

PRINCIPAL INVESTIGATOR

- M.P. Wilson, Jr.

OBJECTIVE

The objective of this study is to determine the practicability and feasibility of treating oilspills with dispersants to mitigate the impact of the spill on the environment.

APPROACH

A holistic approach is used that combines the physical, chemical, microbial, and macro-

fauna response to a spill treated with dispersants and compares this with spills that are left untreated. The program integrates mathematical, laboratory, mesoscale, and in situ experiments and analyses to determine whether the use of dispersants is an effective oilspill response tool.

The program outlined in the original proposal of April 1976 consisted of three phases. Phase I was a feasibility study designed to (1) thoroughly investigate the nature and extent of the problems for assessing the advantages and disadvantages of treated versus untreated oilspills, (2) resolve the critical experimental problem areas anticipated in the mesoscale-type experiments to be conducted in Phase II of the program, and (3) analyze the system concepts for in situ tests to be conducted in Phase III. Phase III was also to include response to spills of opportunity.

PROGRESS AND RESULTS

Phase I and the majority of Phase II are complete. Phase III is in progress and included response to the Department of Energy oil fire/spill at West Hackberry, Louisianna, in September 1978. The results of University of Rhode Island participation in the West Hackberry environmental assessment will be the subject of a separate Department of Energy report.

PLANS FOR NEXT PERIOD

The program will be completed in fiscal 1980, and a final report will be submitted at that time.

REPORTS PUBLISHED

Wilson, M.P., Jr., and J.M. Cece, "Environmental Assessment of Treated Versus Untreated Oil Spills," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

PROJECTED MILESTONES

- February 29, 1980 -- Complete West Hackberry environmental assessment
- April 30, 1980 -- Complete experiments
- September 30, 1980 -- Issue final report

ASSESSMENT OF ENVIRONMENTAL CONTROL ASPECTS OF TREATMENT OF ENHANCED OIL RECOVERY WASTEWATER CLEANUP

ORGANIZATION AND CONTRACT NUMBER

University of Tulsa, Department of Chemical Engineering
EE-77-S-05-5596

PRINCIPAL INVESTIGATOR

R.E. Thompson

OBJECTIVE

The objective of this project is to assess the efficacy and practicability of membrane processes for treatment of wastewaters produced by tertiary oil recovery techniques.

APPROACH

The objective will be met in part by an experimental study to determine the effectiveness of the membrane ultrafiltration process in the concentration and removal of sulfonates and crude oil from wastewaters produced by the micellar flooding technique. By experimentally defining the conditions under which stable and characteristic wastewater samples can be prepared for membrane process evaluation and by developing the effects on filtrate flux of process variables, information will become available that will permit operating and capital costs for full-sized units to be estimated.

PROGRESS AND RESULTS

Experimental data were collected to assess the effectiveness of a tubular cellulose acetate membrane in cleaning simulated micellar-flood wastewaters. The conclusions reached were as follows:

- For synthetic wastewater containing oil/oil-soluble-sulfonate/polymer/brine
  - The permeate was found to consist essentially only of water and alcohol (cosurfactant), with only traces of oil. Essentially all of the oil, sulfonate, and polymer were retained by the membrane.

- Ultrafiltration rates decrease with time, indicating the buildup of a gel layer. The gel layer formation rate is a function of operating pressure, recirculation rate, and feed concentration.

- Emulsions containing oil-soluble sulfonates have significantly higher fluxes (through the membrane) than those containing water-soluble sulfonates. Oil emulsion by itself (no sulfonates) has even lower flux than water sulfonate mixtures.

- Membrane fouling by polymer was eliminated by a suitable cleaning procedure, involving both chemical and mechanical steps.

- For synthetic wastewater containing oil/water-soluble-sulfonate/polymer/brine

  - The permeate was found to contain essentially water and alcohol (cosurfactant), with only traces of oil. Essentially all the oil, surfactant, and polymer were retained by the membrane.

  - Ultimate flux rates were only slightly dependent on feed concentration, although initial fluxes were concentration dependent.

  - Permeate flux was proportional to driving pressure and recirculation rate.

  - Addition of an anionic detergent to the system appears to have had no effect upon ultimate flux; addition of a nonionic detergent lowered the ultimate flux; addition of a cationic detergent raised the ultimate flux significantly, but resulted in a retentate that was a permanent emulsion.

  - A cationic detergent did not clean the membrane effectively, but an anionic detergent did an excellent job.

PLANS FOR NEXT PERIOD

The study will be extended to determine the effect of a polysacchride polymer on both oil-soluble and water-soluble sulfonates.

REPORTS PUBLISHED

Dubey, S.T., "Ultrafiltration of Simulated Micellar Flood Wastewaters," M.S.Ch.E. Thesis, University of Tulsa, Tulsa, Oklahoma, 1979.

Ramakrishnan, B., "Ultrafiltration of Simulated Micellar Flood Wastewater," M.S.Ch.E. Thesis, University of Tulsa, Tulsa, Oklahoma, 1979.

PROJECTED MILESTONES

- September 1980 -- Complete project and issue final report

ASSESSMENT OF ENVIRONMENTAL AND SAFETY CONTROL FOR HYDROGEN

ORGANIZATION AND CONTRACT NUMBER

Los Alamos Scientific Laboratory
W-7405-ENG-36

PRINCIPAL INVESTIGATOR

F.J. Edeskuty

OBJECTIVES

The objectives of this project are to thoroughly define the potential environmental and safety problems associated with large-scale application of hydrogen energy systems and to recommend analytical and experimental solutions.

APPROACH

To achieve the project objectives, the Los Alamos Scientific Laboratory is reviewing existing safety regulations for transportation and use of hydrogen gas and liquid hydrogen. Subjects for study include existing regulations, their applicability to large-scale handling of hydrogen, and areas where further regulations are required. The problem of hydrogen embrittlement is also being reviewed, including a consideration of investigations performed elsewhere.

An assessment of the environmental impact of hydrogen technology has been initiated. Based on these evaluations, on Los Alamos Scientific Laboratory's technical expertise, and on input from consultants, potential problems are

being defined and solutions to these problems will be suggested.

PROGRESS AND RESULTS

Numerous suggestions have been made for the use of hydrogen in energy systems. Because these suggestions imply a concomitant increase in the quantity of hydrogen that must be produced, shipped, stored, and used, the possible safety and environmental impact of these suggestions must be carefully assessed.

This study on safety aspects of hydrogen energy systems has reached these conclusions:

- The problem of hydrogen embrittlement can be solved through further research.
- Existing regulations and standards are adequate to encompass hydrogen development close to present usage levels. Large increases in quantity or degree of public exposure may require reconsideration of existing standards.
- It appears that hydrogen gas can be safely transmitted by pipeline. Whether existing natural gas pipelines can be used safely for hydrogen transmission has not yet been established; however, the addition of hydrogen to natural gas in quantities up to about 10 percent would seem to present no problems.
- Hydrogen is commonly shipped as a cryogenic liquid over long distances in unattended rail tank cars (approximately one per day from Los Angeles to Chicago) or in over-the-road tractor-trailer units. No safety problems have been observed, and this method of shipment could be considerably expanded with existing technology.
- Initial investigation indicates that both the production of the necessary primary energy and its use in the production of hydrogen may be detrimental to the environment; however, the generally positive impact of the end use of hydrogen will to some extent reduce the negative effect of the production process.

Because there are still identified knowledge gaps, areas of additional research are suggested.

PLANS FOR NEXT PERIOD

This assessment has been completed. The final report is expected early in 1980.

REPORTS PUBLISHED

Edeskuty, F.J., "Critical Review and Assessment of Anticipated Problem Areas in Hydrogen Energy Delivery Systems," LA-7405-PR, Los Alamos Scientific Laboratory, August 1978 (November 1, 1976, to September 30, 1977; Initial Report).

Edeskuty, F.J., et al., "Critical Review and Assessment of Environmental and Safety Problems in Hydrogen Energy Systems," LA-7820-PR, Los Alamos Scientific Laboratory, May 1979 (October 1, 1977, to September 30, 1978; Interim Report). Also in U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Edeskugy, F.J., et al., "Hydrogen Safety and Environmental Control Assessment," LA-8225-PR, Los Alamos Scientific Laboratory, February 1980 (October 1, 1978, to September 30, 1979; Final Report).

Edeskuty, F.J., J.R. Bartlit, and R.V. Carlson, "Critical Review and Assessment of Environmental and Safety Problems in Hydrogen Energy System," Report U in Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, DOE/EV-0036, May 1979.

PROJECTED MILESTONES

- May 1980 -- Publish final report

OIL SHALE

Oil shale processing research and development activities for fiscal 1979 were focused on modified in situ retorting technologies. Environmental Engineering Program studies have suggested that retort abandonment and control of pollutant migration is a major concern requiring resolution. Laboratory studies in fiscal 1979 were initiated to determine the severity of the concerns and the control technology options and strategies available for mitigating these impacts. Studies for wastewater control and management with in situ technologies were continued. These studies were directed at determining the technical feasibility and economics of state-of-the-art treatment techniques and the identification of technically feasible options. A laboratory study was initiated to investigate the control technology requirements to mitigate leaching from raw and spent shale materials.

Additional uncertainties being examined include the management of spent shale, land subsidence, and gaseous emissions from retorting operations. Site specificity continued to be emphasized in fiscal 1979 because environmental control needs are intimately related to the nonuniform nature of oil shale deposits and the surrounding environment. Collaborative studies are being promoted with the primary energy developers within the Department of Energy to ensure that site-specific issues can be addressed.

ENVIRONMENTAL CONTROL TECHNOLOGY FOR IN SITU OIL SHALE RETORTS

ORGANIZATION AND CONTRACT NUMBER
Lawrence Berkeley Laboratory
W-7405-ENG-48

PRINCIPAL INVESTIGATORS
J.P. Fox
P. Persoff

OBJECTIVE

Vast resources of oil shale -- more than 600 billion barrels of recoverable syncrude -- exist in the Green River Formation in Colorado, Utah, and Wyoming. The richest of these deposits, scheduled for early development, are located in the Piceance Creek Basin of western Colorado. The rich oil shale layer (the largely impermeable Mahogany Zone) separates layers of fractured leaner shale, which act as confined or unconfined aquifers.

Current industrial plans call for the development of this resource by vertical modified in situ retorting. Figure 33 shows a schematic of the relative positions of the Mahogany Zone, fractured oil shale, artesian aquifers, and vertical modified in situ retorts. Large chambers of underground shale, about 300 to 750 feet high and 200 feet square in cross section, will be formed 1000 to 2000 feet below the surface by mining out 20 to 40 percent of the in-place shale and explosively blasting the balance into the mined-out void. Large vertical pillars, representing nearly 50 percent of the in-place shale, will be left between the retorts to support the overburden. The retort chambers will be pyrolyzed vertically from the top to the bottom by propagating a reaction zone down the packed bed of shale using air and steam. Oil, liquid, and gaseous products will drain to the bottom of the retort and be pumped to the surface for processing. Following processing, the retort is abandoned and large underground chambers of retorted shale are left behind.

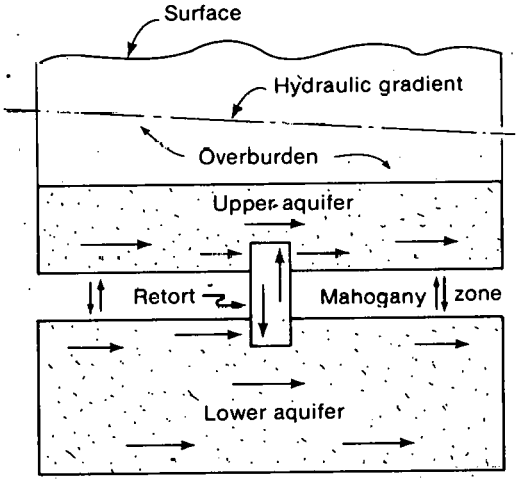


Figure 33. Schematic Showing Location of Vertical Modified In-Situ Retort, Mahogany Zone, and Aquifers in the Piceance Creek Basin, Colorado

This type of oil shale processing may result in a number of environmental impacts, including aquifer disruption, subsidence, and low resource recovery. During processing, the surrounding aquifers are dewatered. On abandonment, groundwater will reinvade the area, leaching retorted shale and transporting leached material into the aquifers where it may be withdrawn in wells or discharged to springs and streams that feed the Colorado River system. Additionally, formerly separated aquifers will now be in communication, allowing waters of different quality to mix. And there is considerable concern that the large overburden and high void fraction (about 40 percent) presently under consideration will result in pillar failure and subsidence over the retorts. Finally, resource recovery in vertical modified in situ retorting is poor because large pillars must be left in place to support the overburden.

The purpose of this program is to identify, develop, and demonstrate control technologies to prevent aquifer disruption and overburden subsidence and to improve resource recovery when vertical modified in situ retorts are used to extract syncrude from oil shale in the Piceance Creek Basin. Some of the options being evaluated include (1) making the retorts impermeable to groundwater flow and strengthening them by forming calcite in the retorts or by filling them with a grout based on retorted shale; (2) modifying the geohydrologic regime to route groundwater flow around rather than through retorts; (3) injecting a slurry of bentonite and/or ion exchange resin into the retorts to remove leachables as they are formed; (4) intentionally leaching the retorts with groundwater that would be recovered, treated, and reused; and (5) modifying the retorting process to minimize leachables in retorted shale. Only the first of these, filling the retort with either a grout or calcite, simultaneously achieves all three goals -- mitigation of groundwater disruption, protection against

subsidence, and the potential for enhanced resource recovery.

APPROACH

This program is being implemented by literature surveys, laboratory studies, and computer modeling. The literature surveys were conducted to fully assess the problem of aquifer disruption and to identify technically and economically viable control technologies to mitigate aquifer disruption and other environmental problems. Based on the results of these surveys, an experimental and analytical program was designed to evaluate each of the candidate control technologies. The purpose of this program is to develop criteria or goals that each control technology must meet to be considered effective and to develop or demonstrate the technology through a series of laboratory experiments.

The criteria for judging acceptability vary with the specific control technology, but in general include the permeability of the retorted area, characteristics of the abandoned retort, long-term stability of the technology, and various water quality criteria. These types of environmental and technological goals are being determined for each control technology by computer modeling and laboratory experiments. Analytical and finite-element rock mechanics calculations are being done to determine the strength and stiffness necessary to prevent subsidence, permit eventual retorting of pillars to improve resource recovery, and withstand hydrostatic and overburden pressures. The resulting strength characteristics will be used to assess subsidence potential and to select a grout that can prevent aquifer disruption, subsidence, and/or allow recovery of the pillars. Permeability reduction in the main retort mass necessary to meet water quality criteria is being determined by hydrologic modeling. The resulting values will be used to judge whether or not the control strategies can provide adequate protection of local groundwaters.

Each control strategy will be developed and evaluated in a series of laboratory and computer modeling studies. A hydraulic grout based on retorted shale will be developed by evaluating spent shales from various surface processes and modifying them to develop or enhance cementitious properties. Admixtures, such as gypsum, and heat treatment will be considered. Candidate grouts and grouted cores will be evaluated by uniaxial and triaxial compression strength tests, permeability measurements, and long-term leaching tests. The penetration of grout through a bed of in situ spent shale will be quantified by pumping candidate grouts into packed columns of retorted shale. Various leaching options, such as recovering and treating the leachate and in-place leachate treatment, will be evaluated in batch and column experiments designed to determine the composition and kinetics of leachate formation, transport, and removal. Treatment processes that might be used to remove organic carbon and salts from the leachates, such as reverse osmosis, ultrafiltration, and carbon adsorption, will be evaluated in treatability studies. Geohydrologic control technologies, such as the use of a grout curtain, will be evaluated using computer modeling techniques.

This experimental program will identify a number of technologies that are technically feasible, and it will develop design parameters sufficient to scale the technology up for field testing. This information will be used in a computer model of the local hydrology and rock mechanics to evaluate the ability of each technology to solve environmental problems. Simultaneously, each technology will be costed. One or more of these technologies will then be selected for more detailed field testing.

PROGRESS AND RESULTS

A literature review and calculations on the water quality effects of leachates from an in situ oil shale industry were completed. This study concluded that a large-scale in situ oil shale industry located in the Piceance Creek Basin of Colorado would result in significant degradation of local surface water and groundwater and that control technology would be required to protect these resources. This work revealed that significant increases in organic carbon, salts, pH, sulfate, phenols, fluoride, and certain other constituents may occur in local waters. These impacts would not be felt until centuries after the termination of retorting due to the slow velocity of groundwater in the area.

A second literature survey to identify potentially viable control technologies to mitigate leaching and other environmental problems and to develop preliminary cost projections was also completed. This study concluded that grouting of abandoned retorts with a grout made from retorted shale will cost about $4 per barrel of oil recovered in situ; intentionally leaching and treating leachate, about $1.20 per barrel; placing a grout curtain around a block of retorts to divert groundwater flow, about $1.50 per barrel; and introducing an adsorbent such as clay into retorts to catch and hold leachables, about $0.50

per barrel. The technical feasibility of all of these technologies remains to be demonstrated. These cost projections are preliminary and were done to identify control technologies worth pursuing. Laboratory investigations were initiated in each of these areas and the following paragraphs discuss the progress that has been made.

Spent Shale Grouts

Experiments were conducted to develop a cementitious material from surface retorted shale. Lurgi spent shale was heated with varying amounts of calcium carbonate at temperatures of from 900°C to 1200°C. X-ray diffraction analysis showed that under these conditions, dicalcium silicate and tricalcium aluminate, active compounds of portland cement, were formed as shown in Figure 34. These experiments have revealed that hydraulic cement

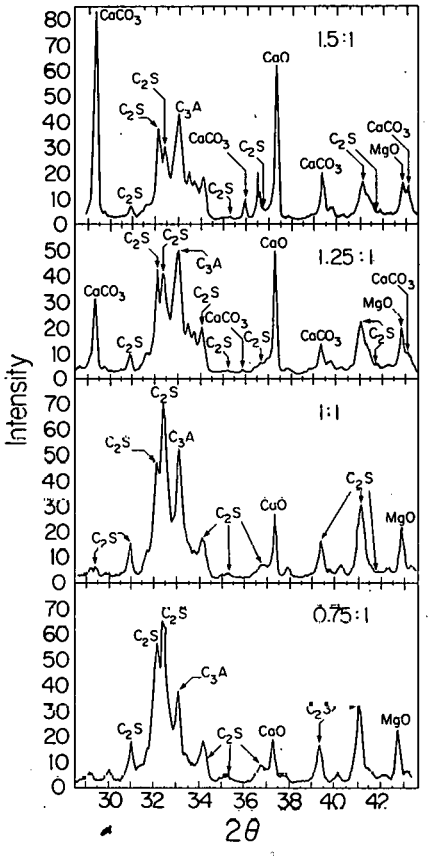


Figure 34. X-ray Diffraction Analysis of Hydraulic Cements Produced by Heating Lurgi Spent Shale With Varying Amounts of Calcium Sulfate for 1 Hour at 1000°C (Calcium sulfate spent shale weight ratios ranged from 0.75:1 to 1.5:1.)

having adequate strength characteristics cannot be produced from as-received Lurgi spent shale due to its low lime-silica ratio. It is possible to make hydraulic cement of adequate quality from this shale by blending equal parts by weight of Lurgi spent shale and calcium carbonate and heat treating the mixture for 1 hour at 1000°C. The resulting cement has a 28-day strength of 3150 psi for a water-cement ratio of 0.52. For comparison, portland cement with this water-cement ratio would test at about 5000 psi.

The distribution of a Lurgi spent shale grout in abandoned retorts are investigated by making viscosity measurements of Lurgi retorted shale slurries and by flowing grouts into packed cylinders of retorted shale. These experiments indicate that a Lurgi spent shale slurry is a non-Newtonian fluid and obeys the Casson model. The yield stress, τ_o, for slurries of Lurgi spent shale and water with water-solids ratios of 1.0, 1.2, 1.5, and 1.8 were 38, 25, 7, and 4 dyne per square centimeter, respectively.

Leaching Strategies

The feasibility of intentionally leaching abandoned in situ retorts and collecting and treating the leachate is being evaluated in a series of column leaching studies and treatability studies. The feasibility of this strategy depends on the number of pore volumes of leachate that must be treated, under field conditions, to reduce leachate concentrations to acceptable levels. A mathematical model of the leaching of salts and organics from in situ spent shale is being developed for this program. Several large-scale column leaching studies using spent shales from Laramie Energy Technology Center's 10-ton retort were leached and analyzed for pH, organic carbon, and electrical conductivity. Mass transfer theory is being used to describe the experimental results so that predictions of field leaching characteristics may be made.

Large batches of leachate were also generated with de-ionized water and with a simulated groundwater for characterization and use in treatability studies. Spent shale from Lawrence Livermore Laboratory's 6-tonne retort was used for these tests. Analysis of the first pore volumes showed that the leachate is saturated in calcium sulfate, which could cause problems if reverse osmosis is used for treatment.

Geohydrologic Strategies

Leaching may be mitigated by surrounding a large block of retorts with a grout curtain or by developing a zone of high permeability around such a block of retorts. These types of strategies

cannot be readily evaluated in laboratory studies, and field experiments would be both very expensive and would yield little useful data. Therefore, work was initiated to develop a groundwater model describing hydrology and chemical transport phenomena in the Piceance Creek Basin. The model that is being used for this purpose, TRUMP, was previously developed by Lawrence Berkeley Laboratory for other applications and is a finite difference model using a mixed explicit-implicit interactive scheme for advancing in the time domain. The model will be used to simulate fluid and heat flow under saturated and unsaturated flow conditions in a fractured aquifer. The model has been set up to simulate flow conditions on lease tract C-a and uses a four aquifer system: alluvial aquifer, upper aquifer, intermediate aquifer, and lower aquifer. It has been evaluated against the Theis equation and is presently being used to investigate the effect of dewatering on local hydrology.

PLANS FOR NEXT PERIOD

Grouting

The production of hydraulic cement from Lurgi and other spent shales will be continued and the effect of various admixtures and retorting conditions on the resulting grouts will be studied. An optimum grout will be selected and a large batch of hydraulic cement made for further testing. Grouted cores will be prepared from this material and simulated in situ spent shale. Permeability, unconfined compressive strength, triaxial compressive strength, and leachability will be measured on these cores.

Rock mechanics calculations will be done to evaluate the strength and stiffness requirements for a grouted in situ retort to minimize subsidence and allow retorting of previously intact pillars. Preliminary calculations will be done using the beam-on-elastic foundation theory, followed by finite element calculations.

Leaching

Additional kinetic data for total organic carbon will be developed from column experiments so that the predictive model of the leaching process of in situ spent shale can be completed.

Geohydrologic Strategies

Development of the groundwater flow model of the Piceance Creek Basin will be completed. This model will be used to determine the environmental impact of each of the control technologies studied, compared them on a uniform basis, and investigate geohydrologic control strategies.

REPORTS PUBLISHED

Fox, J.P., "Water Quality Effects of Leachates From an In Situ Oil Shale Industry," LBL-8997, Lawrence Berkeley Laboratory Report, 1979.

Fox, J.P., et al., "A Strategy for Abandonment of Modified In Situ Oil Shale Retorts," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Fox, J.P., et al., "Control Technology for In Situ Oil Shale Retorts," UCID-8081, Quarterly Progress Report for June 1 to October 31, 1978, Lawrence Berkeley Laboratory, 1978.

Persoff, P., and J.P. Fox, "Control Strategies for Abandoned In Situ Oil Shale Retorts," Proceedings of the Twelfth Oil Shale Symposium, Colorado School of Mines, 1979.

Persoff, P., J.P. Fox, and W.G. Hall, "Control Technology for In Situ Oil Shale Retorts," LBID-003, Quarterly Progress Report for November 1 to December 31, 1978, Lawrence Berkeley Laboratory, 1978.

Persoff, P., J.P. Fox, and W.G. Hall, "Control Technology for In Situ Oil Shale Retorts," LBID-040, Quarterly Progress Report for January 1 to March 31, 1979, Lawrence Berkeley Laboratory, 1979.

Persoff, P., W.G. Hall, and J.P. Fox, "Control Technology for In Situ Oil Shale Retorts," LBID-091, Quarterly Progress Report for April 1 to June 30, 1979, Lawrence Berkeley Laboratory, 1979.

PROJECTED MILESTONES

- Monthly--Issue progress reports
- December 1980--Issue annual progress report
- March 1980--Present paper at the Department of Energy Environmental Control Technology Symposium, Washington, D.C.
- April 1980--Present paper at the 13th Oil Shale Symposium, Golden, Colorado

- August 1980--Present paper at the Department of Energy Environmental Oil Shale Task Force Review, Vail, Colorado

SPENT SHALE AS A CONTROL TECHNOLOGY FOR OIL SHALE RETORT WATER

ORGANIZATION AND CONTRACT NUMBER

Lawrence Berkeley Laboratory
W-7405-ENG-48

PRINICIPAL INVESTIGATOR

J.P. Fox

OBJECTIVE

Production of synthetic crude from oil shale generates from 0.10 to 22 barrels of water and 25 to 100 pounds of solid waste per barrel of oil, depending on the specific process used. The water, referred to as retort water, originates from combustion, mineral dehydration, and groundwater intrusion (in situ processes only). The organic content of retort water may reach 3 percent, although inorganic concentrations of as much as 5 percent are typical. The principal organic constitutents are carboxylic acids and nitrogen-containing organic compounds, and the principal inorganic components are ammonium, sodium, and bicarbonate, with lesser but significant amounts of thiosulfate, chloride, sulfate, and carbonate. The solid waste, referred to as spent shale, is a porous material that contains weight percent concentrations of sodium, calcium, magnesium, iron, potassium, and inorganic carbon. It poses a significant disposal problem for the oil shale industry.

The retort water would be a valuable resource for the arid regions in which oil shale deposits are located if effective and economical treatment methods can be found. However, past attempts to adapt conventional treatment technologies, such as anaerobic fermentation, activated sludge, and carbon adsorption to remove organics and inorganics from retort waters indicate that these methods have serious technical and/or economic limitations. However, an observation made at Lawrence Berkeley Laboratory during the course of other work suggests that spent shale might be used to economically reduce some organic and inorganic components of retort water.

The purpose of this program, which was initiated in June 1978, is to determine whether spent shale can be effectively used in the treatment of in situ retort waters. In situ oil shale processes produce large volumes of water compared to surface processes, and they leave large cavities of spent shale underground. In modified in situ processing, which is currently under development by industry and by the Department of Energy, about 40 percent of the in-place shale is mined and processed in surface retorts. This program is investigating two potential uses of the spent shale for treatment of in situ retort waters. In the first application, the abandoned in situ retort would be directly used in a treatment system. Water generated in one retort would be circulated through an adjacent spent retort to reduce contaminants in the water and to cool the in situ spent retort in preparation for grouting. In the second application, spent shale produced in surface retorts would be used in packed columns similar to powdered activated carbon columns. The exhausted spent shale would be disposed of with other solid wastes in an onsite solid waste disposal facility.

APPROACH

The effect of spent shale treatment on organic carbon, inorganic carbon, electrical conductivity, and pH is being investigated in batch and column studies. The results of these studies will be used to design a complete treatment system that includes spent shale treatment.

Batch studies will be conducted to determine the adsorptive characteristics of various spent shale-retort water combinations from surface and in situ retorts. Equilibrium conditions will be determined for all combinations, and adsorption isotherms will be developed for the most favorable combinations. Continuous-flow column studies will be used to determine optimum operating conditions for favorable spent shale-retort water combinations. When the spent shale columns are optimized, they will be interfaced with a system that includes oil and grease removal, ammonia stripping, and biological treatment.

Batch and continuous flow studies will also be conducted on oil and grease removal, ammonia stripping, and biological treatment. A series of commercially available coagulants that assist in oil and grease removal will be screened, and the promising ones will be jar tested. Air and steam stripping will be investigated in small laboratory-scale units to remove ammonia from the effluent of a spent shale column. Trickling

filters and activated sludge will be studied in batch and continuous flow units for the removal of organics from the effluent of spent shale columns. Kinetic constants will be determined and used to design a pilot-scale system.

PROGRESS AND RESULTS

Equilibrium batch studies of a number of retort water-spent shale combinations have been completed. A gas chromatography fingerprinting technique was developed and applied to determine the organic components removed by the spent shale. Surface areas and chemical compositions have been determined for several spent shales. A number of analytical problems, including those associated with the measurement of total organic carbon and oil and grease in retort water are under investigation. Column studies are in progress to investigate breakthrough characteristics and to obtain design parameters. This work indicates that spent shales are effective in removing color, odor, inorganic carbon, and certain classes of organic compounds and in elevating the pH of retort waters. Spent shale treatment removes the methylene chloride extractable components at pH 2 and 11.

Batch Studies

The effect of spent shale treatment on dissolved organic and inorganic carbon, electrical conductivity, and pH in several retort waters was evaluated in equilibrium batch experiments using 50 grams of shale and 50 milliliters of retort water. The results of these experiments are summarized in Table 8. The specific adsorption ranged from 0.07 to 1.6 milligrams of organic carbon per gram of shale. TOSCO II is the best adsorbent for organic carbon in the retort waters investigated, followed by Paraho spent shale. The remaining four shales, Lurgi,

Table 8. Percent Change in Organic Carbon, Inorganic Carbon, Electric Conductivity, and pH of Retort Water After 120 Hours of Contact With Spent Shale in Batch Experiments

Parameters Measured in Retort Water Experiments	Percent Change[a]					
	Surface Spent Shales			In-Situ Spent Shales		
	Paraho	Lurgi	TOSCO II	L-1	S-14	S-55
Omega-9						
Organic Carbon	-49	NS[b]	---	-18	NS	-12
Inorganic Carbon	-91	-98	-83	-98	-98	-98
Electrical Conductivity	-28	-6	NS	-20	---	-31
pH	+116	+119	NS	+131	---	+136
150-Ton						
Organic Carbon	-24	NS	-48	NS	NS	-7
Inorganic Carbon	-89	-97	-60	-98	-97	-98
Electrical Conductivity	-40	---	NS	-36	---	-54
pH	+111	+110	NS	+116	---	+119
L-2 High Temperature						
Organic Carbon	-51	-17	-66	-13	NS	-18
Inorganic Carbon	-89	-96	-47	-97	-98	-98
Electrical Conductivity	-54	---	---	-60	---	-60
pH	+117	+109	---	+126	---	+123
L-2 Low Temperature						
Organic Carbon	-45	-21	-27	-11	NS	NS
Inorganic Carbon	-91	-93	-65	-97	-99	-97
Electrical Conductivity	-49	---	---	-54	---	-75
pH	+111	+113	---	+121	---	+127

a A negative value indicates that the concentration was reduced by the indicated amount, and a positive value indicates an increase in the retort water.

b No statistically significant change.

L-1, S-14, and S-55, are as much as an order of magnitude poorer in organic adsorptive capacity than the TOSCO II and Paraho samples. The surface area of the various spent shales was measured to determine whether there was any correlation between this parameter and specific adsorption. The surface area measurements, which ranged from 2.1 (L-1) to 10.19 (TOSCO II) square meters per gram indicate that there is a positive correlation between the organic adsorptive capacities and surface area for all shales except Paraho. Paraho spent shale, with a relatively small specific surface area, is one of the best organic adsorbers. This suggests that the chemical nature of the spent shale surfaces may be significantly different.

Spent shale may also remove up to 98 percent of the dissolved inorganic carbon from retort water samples. Spent shales with the highest organic adsorptive capacity appear to be least effective in removing inorganic carbon. Thus, Paraho and TOSCO II spent shales effect the least inorganic carbon reduction and the remaining spent shales, Lurgi, L-1, S-14, and S-55, are the most effective in this respect. The reason for this inverse relationship is unknown, but is probably related to different removal mechanisms. Inorganic carbon may be removed by an ion exchange process, but organic removal may be more dependent on the lipophilic character and organic content of the spent shale.

The reduction in carbonate levels is accompanied by a decrease in electrical conductivity and an elevation in pH. The decrease in conductivity is due to the removal of dissolved inorganic carbon (i.e., CO_3, HCO_3) and possibly ammonia, from the water. Although not measured here, the increase in pH would convert ammonium to ammonia, which could be stripped from the retort water on passage through a column.

Contact of retort water with spent shale elevates the pH from initial levels of 8 to 9 to final values from 10 to 11. The simultaneous decrease in dissolved inorganic carbon and increase in pH is hypothesized to result from chemical reactions between the carbonate species in the retort water and hydroxides formed from the hydration of calcium oxide and other metal oxides present in the spent shale. This type of reaction can be summarized by the following equations:

$$Ca(OH)_2 + HCO_3^- \rightarrow CaCO_3 + H_2O + OH^-$$

$$[Ca_xSi_yO_z] \cdot 2OH^- + HCO_3^- \rightarrow [CA_xSi_yO_z] \cdot CO_3^{=} + H_2O + OH^-$$

Application to Treatment of Retort Waters

These studies indicate that spent shale may be used to reduce the organic and inorganic carbon, electrical conductivity, color, and odor and to elevate the pH of retort waters. These characteristics have important and immediate applications to the treatment of retort water. Conventionally, retort water would be treated using a system similar to that shown in Figure 35. Oil and grease removal would be followed by steam stripping to remove ammonia, biological treatment to reduce soluble organics, and a desalination step to remove dissolved salts. The results of this work suggest that a system similar to that shown in Figure 38 is feasible. A packed bed of spent shale could be placed ahead of the ammonia removal step. The increase in pH achieved in the spent shale column would convert ammonium to ammonia, which could be readily removed from the water by air stripping instead of steam stripping, resulting in a considerable cost savings (air stripping is an order of magnitude cheaper than steam stripping due to reduced energy requirements). The simultaneous reduction of electrical conductivity and dissolved organic and inorganic carbon through the spent shale column would decrease the load of these constituents on subsequent treatment steps, allowing the use of smaller units. (The removal of toxic organic components may improve the operation of the biological treatment system.) These features of using spent shale columns could result in considerable cost savings over conventional treatment systems. Additional work, however, is required to study breakthrough characteristics of spent shale columns and to develop design parameters.

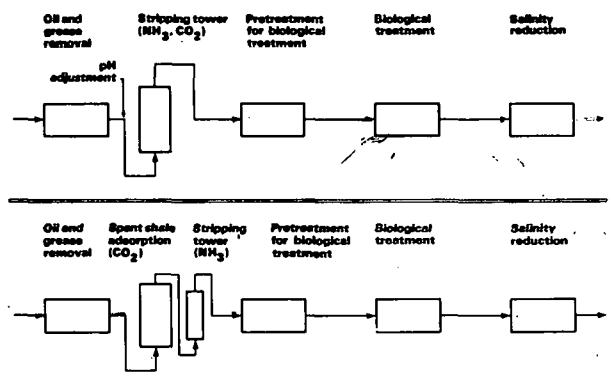


Figure 35. Proposed Treatment System for Upgrading Retort Water Using Conventional Technology (top) and Using Columns of Spent Shale (bottom)

PLANS FOR NEXT PERIOD

Batch studies will be conducted on additional shale-water combinations. Adsorption isotherms and column studies will be conducted using the most promising spent shales. Other unit processes, including oil and grease removal, ammonia stripping, and a biological treatment process will be selected for use with spent shale columns, and batch and continuous flow studies will be conducted on these processes and on a complete treatment system. Work will be continued to develop a rapid and accurate method to measure oil and grease in oil shale retort waters.

REPORTS PUBLISHED

Fox, J.P., and D.L. Jackson, "Potential Uses of Spent Shale in the Treatment of Oil Shale Retort Waters," Proceedings of DOE Wastewater Workshop, Washington, D.C., June 14-15, 1979.

Fox, J.P., et al., "Spent Shale as a Control Technology for Oil Shale Retort Water," Annual Report for October 1, 1978, to September 30, 1979.

Jackson, D.E., and J.P. Fox, "Spent Shale as a Control Technology for Oil Shale Retort Water," UCID-8111, Quarterly Progress Report for October 1, 1978, to December 31, 1978, Lawrence Berkeley Laboratory, 1978.

Jackson, D.E., and J.P. Fox, "Spent Shale as a Control Technology for Oil Shale Retort Water," LBID-070, Quarterly Progress Report for January 1 to March 31, 1979, Lawrence Berkeley Laboratory, 1979.

Sakaji, R.H., et al., "Spent Shale as a Control Technology for Oil Shale Retort Water," LBID-090, Quarterly Progress Report for April 1 to June 30, 1979, Lawrence Berkeley Laboratory, 1979.

PROJECTED MILESTONES

- Monthly -- Issue progress reports
- January 1980 -- Present paper at Department of Energy's 3rd Annual Oil Shale Conversion Symposium
- April 1980 -- Present paper at the 13th Annual Oil Shale Conversion Symposium, Golden, Colorado
- December 1980 -- Issue annual report

ASSESSMENT OF ENVIRONMENTAL CONTROLS FOR MERCURY EMISSIONS DURING OIL SHALE RETORTING

ORGANIZATION AND CONTRACT NUMBER

Lawrence Berkeley Laboratory
W-7405-ENG-48

PRINCIPAL INVESTIGATORS

D.C. Girvin
J.P. Fox

OBJECTIVE

Oil shale offgas is a complex and highly variable corrosive mixture containing significant quantities of entrained oil mist, hydrocarbons, carbon dioxide, carbon monoxide, hydrogen sulfide, and ammonia. Preliminary investigations of simulated in situ oil shale retorts suggest that significant concentrations of mercury may be present in this gas. Calculations indicate that about 160 milligrams of mercury may be emitted to the atmosphere for each barrel of oil produced by in situ methods and that an additional 36 milligrams of mercury may be emitted for each barrel that is combusted.

The purpose of this program is to measure the concentration of mercury in offgases from oil shale processes, identify its chemical form, and assess the ability of existing air pollution control technology to reduce the mercury to acceptable levels. Because major sampling and analytical problems have plagued previous investigators who have attempted to measure mercury in this gas, Zeeman atomic absorption spectroscopy will be developed to continuously analyze mercury in oil shale offgases.

APPROACH

An existing technique, Zeeman atomic absorption spectroscopy, will be refined to measure mercury in oil shale offgases. The resulting instrument will be used at several field sites to make in-place continuous measurements of mercury in the gas stream. In parallel with this measurement activity, published literature and patents will be reviewed to identify techniques suitable for mercury reduction from gas streams containing high levels of organics and carbon dioxide. Suitable technologies will be tested in the laboratory using gases generated by a laboratory-scale retort. The performance of each control technology will be evaluated by measuring mercury in the input and exit gas

using the Zeeman atomic absorption spectrometer developed for field monitoring. The resulting data will be used to recommend suitable control technology to reduce mercury from oil shale off-gases to acceptable levels.

PROGRESS AND RESULTS

A field Zeeman atomic absorption spectrometer capable of continuous online mercury measurements and a gas handling and calibration system was designed, built, and tested during a steam-combustion run of the Lawrence Livermore Laboratory's 6000-kilogram simulated in situ retort. The field Zeeman atomic absorption instrument shown in Figure 36 incorporates some significant advances in state-of-the-art Zeeman atomic absorption spectroscopy and gas monitoring. A new light source, furnace, and gas sampling and calibration system were developed and electronics were redesigned to facilitate parts replacement and to improve stability for long-term field use.

A new, low-pressure mercury gaseous discharge lamp was built and tested that will replace the radio-frequency excited electrodeless discharge lamp previously in use. This new lamp resolves the previous problem of baseline drift with temperature (a serious problem for field use), eliminates radio frequency pickup previously encountered, and the 2357-angstrom line intensity is approximately 50-percent greater than

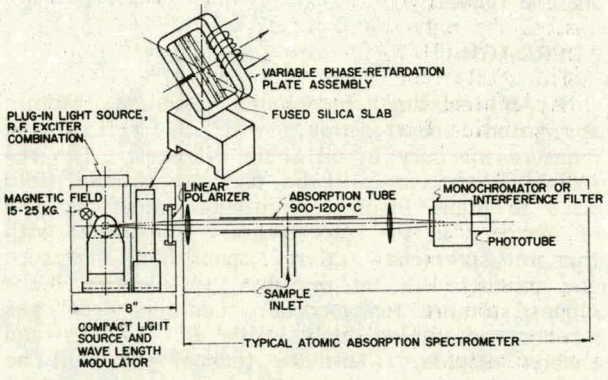


Figure 36. Zeeman Atomic Atomic Absorption Spectrometer

with the electrodeless discharge lamp. This new lamp, shown in Figure 37, consists of a U-shaped quartz tube containing argon and a small quantity of mercury. Minute electrodes are sealed in each end of the tube. The outer diameter of the tube is 7 millimeters. The lamp is surrounded by a soft iron water jacket fitted with a quartz window. The lamp-water jacket assembly fits between the pole tips of the permanent magnet that produces the Zeeman splitting of the resonant lines. The argon plasma and mercury resonance lines are produced by a 700-hertz, high-voltage driver.

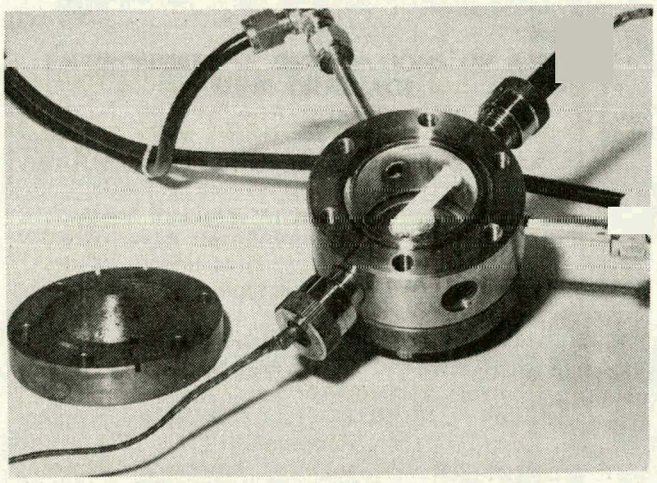


Figure 37. Light-Source Water Jacket Assembly for Zeeman Atomic Absorption Gas Monitor

A new furnace for continuous online analysis of mercury in gas streams was constructed and successfully operated at 900°C for extended periods. The furnace (Figure 38) is constructed of 1.25-centimeter outside diameter, 0.12-centimeter thick wall, 321 stainless steel tubing welded into a tee. The tubing is anodized to lessen corrosion. Incoming gases first pass through the atomization-combustion chamber, which is maintained at 900°C by joule heating. This chamber is filled with ceramic beads to break up the gas flow and increase the thermal contact area. The gases then pass through a small opening into the absorption chamber, which is aligned along the optical path of the spectrometer. Quartz windows at the ends of the absorption chamber pass the 2537-angstrom mercury resonance lines while isolating the hot sample gases from the ambient air. Gases exit the furnace through tubes located near each end of the absorption chamber.

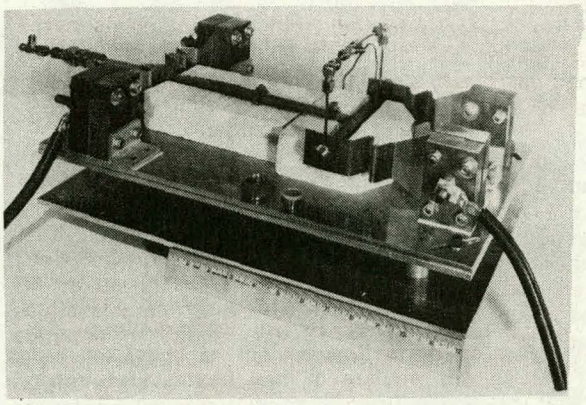


Figure 38. Furnace for Zeeman Atomic Absorption Gas Monitor

The mercury gas monitor was field tested during the Lawrence Livermore Laboratory's 6000-kilogram simulated in situ oil shale retort experiment L-3. The objectives of the field test were to evaluate the new Zeeman atomic absorption spectrometer, test the new gas-handling meter system and the new calibration system, and make long-term mercury measurements at an in situ oil shale retort.

The 4-day test was highly successful and the Zeeman atomic absorption system functioned well. The spectrometer measured mercury concentrations in the offgas as low as 10 parts per billion with up to 85-percent extinction of the analytical line due to broadband ultraviolet absorption (caused by smoke and oil mist).

Mercury was measured upstream and downstream of a condenser system designed to remove oil mist from the gas. Mercury concentrations ranged from less than 5 parts per billion up to 62 parts per billion. Significant reduction in mercury through the condenser train was observed; concentrations of 40 parts per billion ahead of the train were reduced to less than 10 parts per billion after the train. Because the L-3 run was an interrupted experiment in which only a portion of the packed bed of shale was retorted, it was not possible to validate previous work in which a pulse of mercury at the end of the run was observed.

PLANS FOR NEXT PERIOD

The new Zeeman atomic absorption spectrometer will be used during at least one and perhaps several in situ field experiments to make continuous online measurements of mercury. Based on these data, the need for control technology to reduce mercury in oil shale offgases will be assessed.

REPORTS PUBLISHED

Girvin, D.C., T. Hadeishi, and J.P. Fox, "Use of Zeeman Atomic Absorption Spectroscopy for the Measurement of Mercury in Oil Shale Gases," Proceedings of the Environmental Protection Agency Oil Shale Sampling, Analysis and Quality Assurance Symposium, 1979.

Girvin, D.C., and J.P. Fox, "On-line Zeeman Atomic Absorption Spectroscopy for Mercury Analysis in Oil Shale Gases," LBL-9702, Lawrence Berkeley Laboratory, 1979.

PROJECTED MILESTONES

December 1980 -- Issue annual report

ASSESSMENT AND CONTROL OF WATER CONTAMINATION ASSOCIATED WITH SHALE OIL EXTRACTION AND PROCESSING

ORGANIZATION AND CONTRACT NUMBER

Los Alamos Scientific Laboratory
W-7405-ENG-36

PRINCIPAL INVESTIGATOR

P. Wagner

OBJECTIVES

The objectives of this research program are to assess the nature and magnitude of water contamination resulting from the major surface and in situ shale oil extraction methods and to identify control technology suitable for mitigating water pollution from these sources.

APPROACH

There are two basic parts to this research program. A review of existing information is being conducted concerning the types and distribution of the water contaminants produced during recovery and production of shale oil. Potential water pollution problems associated with surface and in situ shale oil recovery techniques are being considered, including production of contaminated water during shale retorting, surface

and groundwater contamination caused by in situ retorts, examination of disposal sites for raw and spent shales, and wastewater production due to onsite upgrading of shale oil. This activity is identifying the water pollution control needs for the various aspects of shale oil recovery and has already revealed some areas where additional environmental research is necessary for support of control technology development. In conjunction with this task, an experimental program is in progress. The main thrusts of this investigation are the acquisition of necessary additional information about the nature and time-dependent behavior of contaminants in various shale-associated leachates and the evaluation of water quality control options available to the oil shale industry. The focus of these studies will be on both chemical and physical methods of prevention or control to reduce the contaminants in retort waters and disposal site effluents to acceptable levels and on measures to prevent groundwater contamination by abandoned in situ retorts.

PROGRESS AND RESULTS

A research plan for this program has been formulated and consists of two tandem tasks. The first task is a literature review and evaluation of existing information pertinent to identifying environmental control needs for contaminated waters produced during or caused by shale oil extraction and upgrading. The document resulting from this review and evaluation is in the final stages of preparation, and its contents have been discussed above.

The second task, which is being performed in conjunction with the first task, is an experimental program to support and define the directions of control technology research. Emphasis is currently being given to the acquisition and analysis of raw shale, spent shale, retort waters, and local surface water and groundwater. Analytical results from this variety of samples is crucial to the definition of the magnitude of potential water contamination. Physical characterization of raw and spent shale samples, including X-ray diffraction, optical microscopy, scanning electron microscopy, and electron microprobe analysis, is being pursued because structural and mineral associations of trace impurities in both the raw and spent shale are vital for mechanistic studies of the release of these trace elements into the environment. Recent investigations in these areas include (1) physical characterization of spent shale and elemental analysis of leachates from samples obtained from a core of Occidental Petroleum Company Retort #3E; (2) analysis of groundwater samples from the vicinity of Occidental Retort #6, Logan Wash area, and upper and lower aquifer water samples from the vicinity of the Rio Blanco Oil Shale Company lease tract C-a; and (3) laboratory-simulated retorting experiments using Rio Blanco shale samples.

From these initial experiments, it has been concluded that leaching behavior and trace element release from spent shales depend on the temperature and atmospheric conditions that existed during the retorting process. In addition, preliminary leaching experiments on the Room 3E abandoned modified in situ retort core samples indicate that the elements aluminum, arsenic, boron, fluorine, and selenium are present in the highest concentrations. Whether or not these elements are environmentally significant will depend upon their time-dependent release and groundwater quality. Investigation of these aspects is in progress.

PLANS FOR NEXT PERIOD

The review document dealing with the assessment of existing information on the types and character of water contamination associated with shale oil recovery and upgrading will be completed and published. Areas where additional environmental assessment is necessary will be addressed. Work on the composition and leachability of raw and spent oil shales will be continued in order to identify control technology needs. Every effort will be expended to ensure a systematic approach to sample acquisition. Analysis of spent shale samples will be best understood if raw shale and groundwater samples from the vicinity of the retort are analyzed concurrently, so that appropriate baseline information is available. Research will begin on the assessment and evaluation of existing technology to control identified water contamination problems. These investigations will indicate the areas of concern, provide evaluation of technical difficulties and economic feasibilities of water quality control options, and elucidate the areas where additional research is warranted.

REPORTS PUBLISHED

Wewerka, E.M., P. Wagner, and P.L. Wanek, "Assessment and Control of Water Contamination Associated With Shale Oil Extraction and Processing Work Plan," LA-7697, March 1979.

PROJECTED MILESTONES

Monthly progress reports and an annual report describing program accomplishments will be written, and formal reviews will be held with the Department of Energy program manager.

ASSESSMENT OF ENVIRONMENTAL CONTROL FOR WASTEWATER IN IN SITU OIL SHALE RETORTING

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATOR

B.W. Mercer

OBJECTIVES

This study is designed to assess the capabilities of current technology for treatment and disposal of shale-oil-related wastewaters to maintain acceptable water quality levels in the receiving waters of the oil shale regions undergoing development. Bench-scale treatability studies are being conducted on actual wastewaters generated by pilot or prototype shale oil extraction facilities to assess the adequacy of state-of-the-art technology to achieve the desired effluent quality. Ultimately, processes and wastes from specific process chains would be categorized with respect to amenability to available treatment technology. The capabilities and limitations of feasible treatment options will be defined for each wastewater, including retort water, mine water, and process water. Effluents discharged from treatment processes will be characterized with respect to conventional effluent quality parameters and with respect to exotic materials that may be of particular concern in the shale oil industry.

APPROACH

Bench-scale treatability studies are being conducted to evaluate current technology for the removal of pollutants from shale oil wastewaters. The wastewater treatment processes selected for evaluation with retort water are essentially patterned after technology used for treating petroleum refinery wastewater. The first steps in a treatment sequence involve the removal of suspended solids and oil by gravity separation or dissolved air flotation. The clarified wastewater is then treated by steam stripping to remove ammonia, which represents a potential byproduct. Ammonia removal is also needed to meet discharge or reuse criteria and to allow effective biological treatment. Biological treatment follows for removal of degradable organic matter. Nonbiodegradable organic matter is then removed by carbon adsorption after chemical coagulation, sedimentation, and filtration to remove suspended matter produced by the biological treatment steps. A demineralization process, such as reverse osmosis, may also be employed to remove excessive dissolved mineral matter. Additional bench-scale studies were undertaken to evaluate evaporation or a treatment process for wastewaters produced in situ. If the results of the bench-scale studies are promising, a pilot-scale evaporation study will be initiated to determine the operating characteristics and costs of retort water evaporation.

PROGRESS AND RESULTS

Biological Treatment

Initial flow-through bench-scale biological treatment experiments were unsuccessful in achieving effective total organic carbon removal by 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 total organic carbon fell off sharply as the concentration of actual retort water exceeded 50 percent. 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 milligrams/liter 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 total organic carbon 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 total organic carbon and chemical oxygen demand was about 45 percent and 65 percent, respectively, without the powdered activated carbon addition to the activated sludge units. Addition of 300 milligrams of powdered activated carbon/liter increased the total organic carbon and chemical oxygen demand removals to about 55 percent and 75 percent, respectively. Removal of thiocyanite (a good indicator of the "health" of the activated sludge) was increased from 67 to 99 percent by the addition of activated carbon. Ammonia levels

increased by about 50 milligrams/liter through the activated sludge process (believed to result from biodegradation of nitrogenous organics and thiocyanate).

Activated Carbon Sorption

Bench-scale studies were conducted with effluents 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-centimeter-diameter by 10-centimeter-high bed of 50 by 120 mesh Filtrasorb® 500 carbon and were operated at a flow rate of 3.9 milligrams/liter/minute. Figures 39 and 40 illustrate total organic carbon and chemical oxygen demand removals, respectively, from both biotreated and untreated steam-stripped retort water with activated carbon. Treatment by activated sludge effectively complements activated 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 chemical oxygen demand 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-centimeter inside diameter glass pipe packed to a depth of

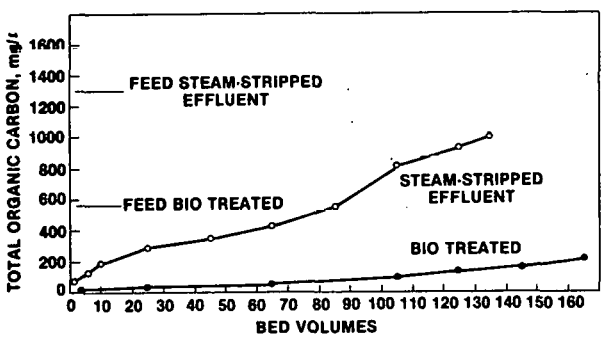


Figure 39. Activated Carbon Treatment for Total Organic Carbon Removal

® Registered trademark of Calgon Corporation, Pittsburgh.

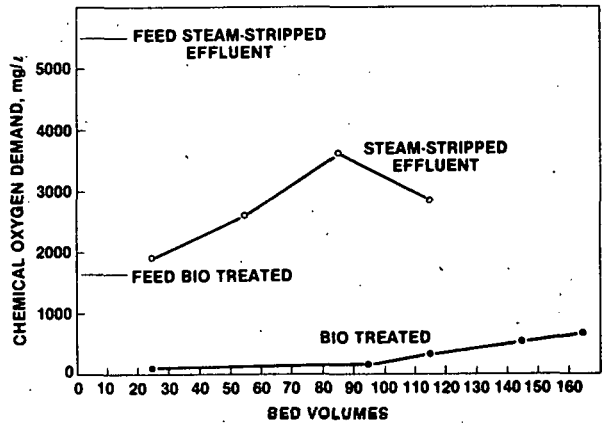


Figure 40. Activated Carbon Treatment for Chemical Oxygen Demand Removal

61 centimeters with either 0.64- or 1.27-centimeter ceramic saddles. Feed to the stripper is introduced at the top of the column of saddles and is countercurrently 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-centimeter diameter stripper with several different process waters are presented in Table 9. 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

Table 9. Steam Stripping Results with 5-Centimeter 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
Aboveground Retort	0.64	27	30	Yes	8.5	6.2	-	38

[a] Intalox saddles.
[b] Percent of feed.

free ammonia (NH_3). Without the alkalinity addition, the performance with recycle and lower boiloff rate would have resulted in ammonia removal levels below 98 percent. With the alkalinity addition, it was possible to achieve 99.95 percent removal. The effect of alkalinity addition on steam stripping of simulated in situ process water is illustrated in Figure 41. Without the addition of caustic soda (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 the ammonia is available as free ammonia above pH 9.5 and can be more effectively removed by stripping.

Steam stripping data in Table 9 for Utah in situ No. 2 show the effect of recycle of the condensate at low boiloff rates. Ammonia removal was only 83 percent with recycle at a boiloff rate of 5 percent. Reducing the packing size for Utah in situ No. 3 appeared instrumental in increasing the ammonia removal. Additional factors that 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 due to the stripping of carbon dioxide from the $NaHCO_3$ present in Utah in situ process water. Ammonia removal for the aboveground retort water was very poor because most of the ammonia was in the fixed form (NH_4^+) without sufficient carbonate alkalinity. The addition of inexpensive alkalinity to this water in the form of lime creates a large amount of calcium carbonate sludge. The sludge formation can be avoided and lime use minimized by removing the free ammonia first in a separate stripper or stripper section (which also removes carbon dioxide), then adding lime to remove the fixed ammonia in another stripper or section of the stripper.

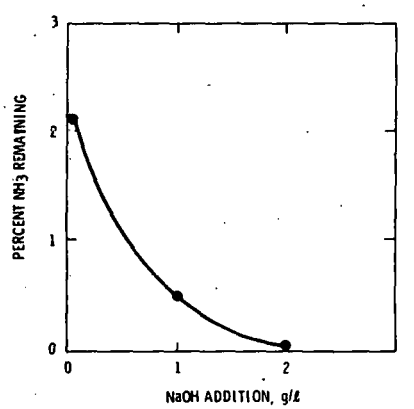


Figure 41. Effect of Alkalinity Addition on Ammonia Removal From Simulated In-Situ Process Water by Stream Stripping

Evaporation of Retort Water

Feasibility tests on the 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.

PLANS FOR NEXT PERIOD

A pilot-scale evaporation study is scheduled following the completion of bench-scale studies to establish the feasibility of this process for treatment of in situ retort water. The quality of the condensate from evaporation of the retort water will be determined and compared with reuse and discharge standards. Additional bench-scale studies will be undertaken to evaluate potential treatment processes to upgrade the quality of the condensate if needed. The impact of shale oil on refinery wastewater treatment will be assessed based on available data on the characteristics of refinery wastewater produced during trial runs.

REPORTS PUBLISHED

"Assessment of Control Technology for Shale Oil Wastewaters," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

"Contribution of Thiosulfate to COD and BOD in Oil Shale Process Wastewater," American Society for Testing Materials Symposium on Analysis of Waters Associated With Alternate Fuel Production, June 1979.

PROJECTED MILESTONES

- February 1980 -- Complete pilot-scale evaporation study on in-situ-produced retort water
- July 1980 -- Complete study on treatment and disposal or reuse of evaporator condensate from treatment of retort water and submit draft report on results
- September 1980 -- Complete study on impact of shale oil on refinery wastewater treatment and submit draft report on results

ANALYSIS OF THE ENVIRONMENTAL CONTROL FOR OIL SHALE AND TAR SAND DEVELOPMENT

ORGANIZATION AND CONTRACT NUMBER

University of Utah
EY-76-S-02-4043 Mod M003

PRINCIPAL INVESTIGATORS

N. de Nevers
B. Glenne
C. Bryner

OBJECTIVE

The objective of the first part of the program (carried out mostly in fiscal 1977) was to analyze the environmental control technology envisaged in the Detailed Development Plans for the three oil shale tracts in the Federal Prototype Leasing Program and all other active oil shale projects. From an integrated analysis of all proposed control technology, it was shown which parts of the environmental plans were based on fact and which were based on extrapolations. The areas where further analysis or laboratory work is needed were determined, and suggestions were made for developing the needed data.

The second part of the program (carried out mostly in fiscal 1978 and completed in fiscal 1979) repeated the same basic process for tar sands. Attention was focused on both the Alberta tar sands, where two large-scale projects are in operation and others have been formally proposed, and on the U.S. deposits (mostly in Utah). An assessment was made of whether the environmental control technology from the Alberta projects can be successfully transferred and applied to the U.S. deposits. Apparently it can be so applied.

APPROACH

By a thorough review and analysis of the available literature, test calculations, and discussions among the principal investigators, an understanding and evaluation of the existing technology was sought to determine the areas of greatest need for additional efforts.

PROGRESS AND RESULTS

The final tar sand report has been approved by the Department of Energy and is in the final printing cycle.

PLANS FOR NEXT PERIOD

The project is completed.

REPORTS PUBLISHED

de Nevers, N., et al., "Analysis of the Environmental Control Technology for Tar Sands Development," COO-4043-2, University of Utah for Oak Ridge National Laboratory, June 1979.

PROJECTED MILESTONES

None

SOLAR, GEOTHERMAL, AND ENERGY CONSERVATION

Environmental control assessment activities for solar energy, geothermal energy, and energy conservation continue to have an important place in the Environmental Engineering Program.

In fiscal 1979, a project to assess environmental problems associated with materials used in solar heating and cooling was continued. The intent is to assist the Department of Energy in evaluating designs submitted for Government support and to assist homeowners in selecting suitable materials for particular applications. Another activity supported is the assessment of environmental controls needed for the "inexhaustible" energy resource of biomass. A survey, identifying control needs for the biomass options, was continued and updated in fiscal 1979. In late fiscal 1979, a study was initiated to identify the environmental control issues and requirements associated with ethanol production from biomass; this study is continuing into fiscal 1980. A preliminary assessment of the sound levels for large wind turbine generators was also initiated in fiscal 1979 and will continue in fiscal 1980.

Geothermal energy, although not uniformly available throughout the United States, can represent a significant energy resource for specific regions. The major objective of the Environmental Engineering Program for geothermal energy continues to be the identification of potential gaps in environmental control capabilities and the fostering of the timely development of control options. Studies were completed on the state-of-the-art liquid waste control systems and gaseous cleanup systems. Noise abatement studies were initiated to assess the noise impact of geothermal energy and to determine the most effective methods for noise reduction. The Environmental Engineering Program also continues to perform independent assessments of environmental controls identified within the Geothermal Loan Guaranty Program to help prevent default because of violations of environmental regulations.

Evaluations of near- to mid-term energy conservation options are continuing. Accomplishments in fiscal 1979 include (1) identification and evaluation of disposal schemes for compressed air energy storage; (2) evaluation of the impact of current industrial pollution control practices in waste treatment technology; (3) review of environmental regulations concerning the effect of overhead electric transmission lines; (4) a study to define the major environmental control techniques associated with energy storage; and (5) an assessment of the need for environmental controls for modified (coal/oil mixture) furnaces.

ANALYSIS OF HAZARDOUS MATERIAL PROPERTIES FOR SOLAR HEATING AND COOLING SYSTEMS

ORGANIZATION AND CONTRACT NUMBER

Sandia Laboratories
AT (29-1)-789

PRINCIPAL INVESTIGATOR

K.R. Darnall

OBJECTIVE

The essence of environmental control for solar heating and cooling technologies is knowledge on the part of the solar designers, engineers, and users of the potentially hazardous properties of the materials used in solar heating and cooling systems. To this end, a handbook of relevant physical, toxicity, and flammability properties of materials used in solar heating and cooling is to be compiled.

APPROACH

The development of the handbook began with a search of solar heating and cooling literature, collection of information from manufacturers of these systems and materials, and a limited laboratory analysis of selected materials to determine their composition. Next, a thorough literature search was made to collect data on the relevant physical, toxicological, and fire properties of the constituents of the solar heating and cooling materials identified. Finally, the handbook itself was developed containing both the information on physical and hazardous properties that had been collected and the explanatory background necessary to understand it and to put it into perspective.

PROGRESS AND RESULTS

An interim version of the handbook was published in December 1978 and announced in a news release and a direct mailing. Approximately 800 requests were received from research organizations including institutes, laboratories, and government agencies (49 percent); manufacturers, suppliers, installers (20 percent); schools and colleges (12 percent); private citizens (6 percent); embassies and other foreign organizations (5 percent); libraries (4 percent); publishers and editors (3 percent); and realtors (1 percent).

A questionnaire was included with each copy to elicit recommendations for improvements in the handbook. Approximately 10 percent of the questionnaires were returned. In response, a revised format of the handbook has been developed to increase its ease of use for both the solar amateur and professional. Also, over 2000 articles, books, newsletters, and other documents have been collected and cataloged to form a solar heating and cooling document library for updating the handbook.

PLANS FOR NEXT PERIOD

A revised edition of the handbook is now being prepared to make it as complete, accurate, useful, and usable as possible.

REPORTS PUBLISHED

Arnold, C., Jr., and R.E. Trujillo, "Composition Stability and Degradation Products of Selected Materials for Solar Heating and Cooling," SAND 78-0681, Sandia Laboratories, March 1979.

Searcy, J.Q., ed., "Hazardous Properties and Environmental Effects of Materials Used in Solar Heating and Cooling (SHAC) Technologies: Interim Handbook," DOE/EV-0028, U.S. Department of Energy, December 1978.

PROJECTED MILESTONES

- June 27, 1980 -- Submit final edition of handbook for DOE review
- August 29, 1980 -- Publish final edition of revised handbook

ASSESSMENT OF ENVIRONMENTAL CONTROLS FOR ENERGY PRODUCTION FACILITIES USING SOLAR-DERIVED FUELS

ORGANIZATION AND CONTRACT NUMBER

Ames Laboratory
W-7405-ENG-82

PRINCIPAL INVESTIGATOR

T.A. Austin

OBJECTIVES

The general objectives of this project are to perform independent assessments of the environmental controls needed for biomass options (bioconversion, bioproduction, and agricultural waste utilization) and to identify and foster development of novel solutions to environmental control problems.

APPROACH

The general approach for this project will be to perform a preliminary assessment of all controls and then to undertake more detailed assessment work that is in concert with and will complement activities sponsored by other environmental groups. This project will be performed in three phases. For Phase 1, an extensive literature review of the state-of-the-art of biomass conversion processes and required controls will be undertaken. For Phase 2, actual data, necessary to evaluate the efficacy and practicability of currently available environmental control techniques, will be collected where justified. For Phase 3, laboratory and field evaluation studies on novel environmental control technologies will be performed.

PROGRESS AND RESULTS

A review of the status of bioconversion processes has shown that anaerobic digestion of animal manures and direct burning of wood, wood byproducts, and crop residues are the most probable immediate applications on a national basis. Laboratory wastewater characterization studies on digested animal manures have been completed, as well as laboratory treatability studies. Experiments to evaluate the quality of leachates from ash disposal sites have been completed.

The wastewater characterization studies included an analysis of the effluent from four anaerobic digesters using beef manure: (1) Iowa State University facility; (2) Ecotope Group digester in a dairy farm near Monroe, Washington; (3) Cornell University digester facility; and (4) Hamilton Standard digester facility located near Bartow, Florida. Digester gas and liquid effluents were sampled. Measure- ments of the latter included biological oxygen demand and chemical oxygen demand to characterize the potential pollutant strength of the effluents, various nitrogen and phosphorous forms to determine any potential limitation on wastewater discharges or land disposal, salinity and heavy metals to assess compatability with plants and soils for land disposal, and Environmental Protection Agency "priority pollutants" to determine concentration.

Further, samples from the Iowa State University facility were treated in a laboratory reactor to determine the effectiveness of aerobic treatment for waste stabilization. Various organic loading rates and solid retention times were used to identify waste treatment. The reactor effluents were also periodically tested for "priority pollutants" concentration to determine whether biological treatment had any effect on these pollutants.

PLANS FOR NEXT PERIOD

The above analysis will be completed and a final report will be published. Future studies will be initiated to evaluate liquid and solid residues from pyrolysis, liquefaction, and gasification. All activities will be coordinated with other parts of the Department of Energy and the Environmental Protection Agency.

REPORTS PUBLISHED

Austin, T.A., "Characterization and Treatment of Anaerobically Digested Cattle Manure," paper to be presented at the U.S. Department of Energy Environmental Control Symposium, March 17-19, 1980.

PUBLISHED MILESTONES

- June 30, 1980 -- Publish final report

PRELIMINARY ASSESSMENT OF THE SOUND OF LARGE WIND TURBINE GENERATORS

ORGANIZATION AND CONTRACT NUMBER

Bolt Beranek and Newman, Inc.
DE-AP01-79 EV 10014

PRINCIPAL INVESTIGATOR

D.N. Keast

OBJECTIVES

Although it is generally assumed that the sound levels from operating wind turbine generators are anticipated to be modest, the purpose of this project is to conduct a preliminary

assessment of the sound levels for these generators and to determine whether these levels are acceptable.

APPROACH

This preliminary assessment used empirical data from operating wind turbine generators (Mod. O) with an analytical model to predict the sound levels for various sized generators. To evaluate the acceptability of the sounds from the generators, three noise limits were selected: the noise regulations of the states of Minnesota and Illinois and the U.S. Environmental Protection Agency guidelines for avoiding noise complaints from the public.

PROGRESS AND RESULTS

The analysis computed the range of acceptable distances for the various generators for the three noise levels as follows;

Generator Design	Range of Distance (feet)
Mod O (Plum Brook, Ohio)	450-1000
Mod OA (200 kW, Clayton, New Mexico)	550-1800
Mod 1 (2 MW, Boone, North Carolina)	1200-6000
Mod 2 (2.5 MW)	1300-4000

Because these predicted levels are severe, it was concluded that confirmatory noise measurements be taken. If the predictions are confirmed, design options that produce lower noise levels should be explored.

PLANS FOR NEXT PERIOD

A final report on the above analysis will be published. Further noise monitoring will be performed on larger wind turbine generators.

REPORTS PUBLISHED

Keast, D.N., and R.C. Potter, "Audible Noise of Constant-Speed, Horizontal-Axis Wind-Turbine Generators: A Preliminary Analysis," Draft, January 1980.

PROJECTED MILESTONES

- June 30, 1980 -- Publish final report

GEOTHERMAL LOAN GUARANTY PROGRAM: ASSESSMENT OF ENVIRONMENTAL CONTROL TECHNOLOGIES

ORGANIZATION AND CONTRACT NUMBER

Lawrence Livermore Laboratory
W-7405-ENG-48

PRINCIPAL INVESTIGATOR

P.L. Phelps, Jr.

OBJECTIVES

The primary objectives of this project are to review Geothermal Loan Guaranty Program environmental analyses, identify environmental control technologies, and independently assess their efficacy and practicability. A secondary objective is to review environmental reports and monitor data on operating control systems to expand knowledge of environmental control technologies.

APPROACH

A Federal Geothermal Loan Guaranty Program was established by Public Law 93-410, the Geothermal Energy Research, Development, and Demonstration Act of 1974. The Environmental Control Technology Division has the responsibility for independently ensuring the adequacy of environmental controls identified as part of Environmental Assessments and Environmental Impact Statements and used by the applicants to help prevent default in the event of noncompliance with environmental regulations. To discharge this responsibility, liaison is maintained with the Loan Guaranty Program Office and the Environmental and Safety Division of the Department of Energy San Francisco Operations Office.

Knowledge of relevant Federal and local laws and regulations and environmental quality standards is developed by site as the need arises. Information relevant to assessing environmental control systems or measures is also drawn from the related project, "Assessments of Environmental Control Technologies for High Priority Geothermal Resource Areas." On-demand reviews and assessments are made as required.

PROGRESS AND RESULTS

Reviews of loan program applications for fiscal 1979 and revisions to applications from prior years have been made. These are summarized in Table 10.

PLANS FOR NEXT PERIOD

This effort will continue during fiscal 1980 as applications are submitted and as approval considerations require.

Table 10. Applications List

Applicant	Approval Goal or Status	Project/Location	Goal (MWe)	Loan Guaranty ($ millions)
	Fiscal 1979			
Northern California Municipal Power Corp. NCPA-2	In review	Powerplant construction	110	40.9 (Bank of Montreal)
	Fiscal 1978			
Republic Geothermal Inc. and MAPCO	Approved	Westmorland Development Project: explore, evaluate and develop field; Westmorland, Imperial Valley, California	55	21.0 (Bank of America)
Honey Lake Hydroponic Farms	To Department of Energy Headquarters, September or October 1980	Honey Lake Farms Project: heat greenhouses and packing sheds, refrigerate produce prior to shipment; Wendell-Amedee KGRA, Susanville, California	(Non-electric)	4.8 (Bank of Montreal)
O'Brien Resources Corp.; Thermal Power Inc.; Amax Exploration, Inc.; and VTN Corp., Inc.	In review	O'Brien Project: verify reservoir and develop field; Roosevelt Hot Springs KGRA, Beaver County, Utah	55	12 (Bank of Montreal)
	Fiscal 1977			
Dry Creek Exploration, Inc. (subsidiary of Geothermal Resources International)	Hold (added preliminary exploratory drilling)	Dry Creek Prospect: explore, evaluate and develop field; Lake County (Geysers, California	165	7.5 (Bank of America)
Republic Geothermal, Inc.	Approved	E. Mesa Development Project: evaluate and develop field; E. Mesa, Imperial Valley, California	48	10.0 (Bank of America)
McCulloch Geothermal Corp.	Approved	CU 1 Venture: explore and evaluate fields; Brawley, California	110	6.3 (Bank of Montreal)
Southern California Public Energy Corp. (City of Burbank)	Hold; no action by applicant for 3 years	Site selection appraisals; Roosevelt Hot Springs, Utah	50 to 200	25.0 (Dean Witter and Co.)
Geothermal Food Processors	Approved	Food Dehydration: rehabilitate existing wells; design and build dehydrator plant; Brady's Hot Springs, Churchill County, Nevada	(Non-electric)	3.5 (Nevada National Bank)
Diablo Exploration, Inc.	Hold; no action by applicant for 3 years	Select site, explore, evaluate, and develop field; Rio Grande Rift Valley, New Mexico	50	21.8 (Kidder, Peabody, Inc.)
Resource Funding Ltd. (Northern California Power Assoc., a consortium of cities)	Construction permit denied	Explore, evaluate, develop field; Cobb Valley, Lake County (Geysers), California	66	14.5

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- October 31, 1980 -- Issue annual report for fiscal 1980

ASSESSMENTS OF ENVIRONMENTAL CONTROL TECHNOLOGIES FOR HIGH-PRIORITY GEOTHERMAL RESOURCE AREAS

ORGANIZATION AND CONTRACT NUMBER

Lawrence Livermore Laboratory
W-7405-ENG-48

PRINCIPAL INVESTIGATOR

P.L. Phelps, Jr.

OBJECTIVES

These assessments are a continuing endeavor to provide the Environmental Control Technology Division with technical and economic information concerning control technologies needed to mitigate environmental impacts resulting from geothermal energy development. The assessments cover technologies required to control airborne emissions such as hydrogen sulfide, liquid and solid wastes, land subsidence, induced seismicity, cooling tower drift, and noise. Immediate objectives include the preparation of a specific report to evaluate the status of hydrogen sulfide control for geothermal energy systems and a comprehensive report to assess diverse environmental control technologies applicable to geothermal development in the Imperial Valley of California. Long-term objectives include provision of technical assistance to the Environmental Control Technology Division in reviewing Environmental Impact Statements and assessing current developments in geothermal environmental control technology.

APPROACH

Information regarding environmental control technology is gathered from first-hand investigations and published reports; private communication, correspondence, and discussions with geothermal systems developers andmanufacturers and users of environmental control technologies; and national and regional regulatory agencies. A multidisciplinary approach has been adopted to evaluate control technologies. Lawrence Livermore Laboratory draws upon disciplines within the laboratory and expertise made available through consulting arrangements.

PROGRESS AND RESULTS

Draft copies of two reports listed below have been prepared. Review comments have been received and are being incorporated. Final reports are being prepared.

- State-of-the-Art Hydrogen Sulfide Control for Geothermal Energy Systems 1979
- A Technology Assessment of Geothermal Development in the Imperial Valley of California. Volume II. Environmental Control Technology

Table 11 is a summary of the assessment of hydrogen sulfide abatement options.

PLANS FOR NEXT PERIOD

The reports cited above will be prepared in final form.

Work will begin on the assessment of control technology required for the abatement of hydrogen sulfide during steam stacking (a procedure wherein steam is vented during geothermal plant shutdowns). An evaluation of current sampling and analysis procedures for determining hydrogen sulfide will also be undertaken to ensure reliable methods for hydrogen sulfide monitoring and for assessing the operational performance of abatement systems.

Studies related to liquid and solid waste disposal will also be initiated in fiscal 1980. An assessment of water treatment technology for removing contaminants such as fluoride from geothermal water will be undertaken. This technology is needed to upgrade the quality of geothermal water after its use in process and space heating systems to permit discharge into surface water or reuse in agricultural irrigation systems. The solid waste study effort will focus on assessing the status of solid waste disposal plans and activities in the Imperial Valley. Adherence of the plans and activities to the guidelines and regulations of the Resource Conservation and Recovery Act of 1976 will constitute an integral part of the study.

REPORTS PUBLISHED

None

Table 11. Evaluation of Hydrogen Sulfide Control Processes for Geothermal Application

Removal Process	Potential Hydrogen Sulfide (Percent)	Status[a]	Ease of Adaptability (+,-)	Cross-Media Impacts	Estimated Reliability	Negative Factors
Upstream						
Steam converters	90+	C[b]	+	None	Excellent	Heat loss
EIC copper sulfate	98 to 99	P	+	Sludge	Excellent	Entrainment?
Deuterium	90	P	+	Unknown	Unknown	Proprietary
Solid sorbents	Unknown	L	-	Unknown	Poor	Costly
Dow oxygenation	90 to 100	L	+	None	Good	Corrosion
UOP catalytic oxidation	Unknown	S	?	Unknown	Unknown	Unknown
SRI electrolytic oxidation	95	L	+	Unknown	Unknown	Unknown
Downstream						
Iron catalyst	80 to 90	U	+	Sludge	Good	Corrosion
Hydrogen peroxide	80 to 90	L	+	Unknown	Unknown	Costly?
Ozone	Unknown	S	?	Unknown	Unknown	Costly
Wackenroder	Unknown	L	?	Unknown	Unknown	Unknown
EIC copper sulfate	98 to 99	S	+	Sludge	Unknown	Unknown
Brine scrubbing	80 to 90	L	+	Unknown	Unknown	Unknown
Off-Gas Stream						
Stretford	99+[c]	U	+	None	Excellent	None
Jefferson Lake	Unknown	L	-	Unknown	Unknown	Complex
Burner-scrubber	50	D	+	Sulfur dioxide	Poor	Many
Ferrox	Unknown	A	?	Sludge	Unknown	Unknown
Caustic soda	Unknown	L	+	Sludge	Unknown	Hazardous
Sodium hypochlorite	Unknown	S	?	Wastewater	Unknown	Hazardous
Potassium permanganate	Unknown	S	?	Sludge	Unknown	Hazardous
EIC copper sulfate	98 to 99	S	+	Sludge	Unknown	Unknown
Benfield	Unknown	S	?	Unknown	Unknown	Produces hydrogen sulfide

a C - Proof-of-concept pilot plant.
P - Pilot-plant scale.
L - Laboratory scale.
U - In current use for geothermal H_2S abatement.
S - Speculative.
A - Abandoned.
D - Discontinued.

b Technology to apply this process to a full-scale unit has been demonstrated by Resources, Conservation Company.

c Stretford unit only; overall abatement efficiency depends on partitioning.

PROJECTED MILESTONES

- May 1, 1980 -- Issue final report, State-of-the-Art Hydrogen Sulfide Control for Geothermal Energy Systems 1979
- June 1, 1980 -- Issue final report, A Technology Assessment of Geothermal Development in the Imperial Valley of California. Volume II. Environmental Control Technology
- September 30, 1980 -- Issue interim report, Hydrogen Sulfide Abatement for Steam Stacking
- September 30, 1980 -- Issue interim report, Treatment and Removal of Fluoride From Geothermal Water
- September 30, 1980 -- Issue status report, Solid Waste Disposal for Geothermal Developments in the Imperial Valley of California

RESEARCH PROGRAM PLAN FOR GEOTHERMAL LIQUID WASTE DISPOSAL

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EV-76-C-06-1830

PRINCIPAL INVESTIGATOR

L.J. Defferding

OBJECTIVES

The objectives of this project are to review the state-of-the-art for disposing of liquid wastes from geothermal (electric and non-electric) installations and identify research needed for developing commercially feasible techniques for waste disposal.

APPROACH

A review team was assembled from within the Pacific Northwest Laboratory. This team reviewed the available literature and evaluated the existing methods for disposing of liquid wastes from geothermal facilities. The techniques were evaluated from legal, technical, environmental, safety, and economic standpoints. During this evaluation, research needs were identified. The results of the evaluation will constitute a state-of-the-art review of disposal methods for geothermal liquid wastes.

PROGRESS AND RESULTS

A draft report on the state-of-the-art review of geothermal liquid waste was issued for comment. Table 12 is a summary of the results of its assessments of the liquid waste disposal options.

PLANS FOR NEXT PERIOD

The project will be completed in fiscal 1979; the final report is being edited for publication.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

EVALUATION OF NOISE ASSOCIATED WITH GEOTHERMAL DEVELOPMENT ACTIVITIES

ORGANIZATION AND CONTRACT NUMBER

Long/Davy/Associates
EP-78-01-6200

PRINCIPAL INVESTIGATOR

M. Long

OBJECTIVE

The objective of this program is to characterize the noise associated with geothermal activities and the methods currently in use for noise abatement. The information obtained will be used to assess the noise impact of geothermal resource development and to determine the most effective methods for noise reduction.

APPROACH

The approach is to survey the available literature in the field, gather data missing from the literature through field measurements, assess the accuracy of the data, and evaluate the state-of-the-art based on these findings.

PROGRESS AND RESULTS

The project has been divided into three tasks. Task 1, Collection of Noise Measurements of Geothermal Activities, includes a review of all available environmental literature on geothermal noise. To date, some 200 documents have been found and reviewed. Of these, approximately 50 contained usable, measured data. These data have been organized into a standard format according to source type. Using this as a base, a detailed measurement plan is being formulated to fill the gaps in the available information.

Task 2, Evaluation of Noise Control Methods, reviews the current state-of-the-art in geothermal noise control. Major manufacturers of noise control products have been contacted for information; a number have responded with product literature and some with measured data. Major geothermal development companies have also been contacted, and several have furnished measured data on noise control devices. These data are being organized and evaluated in a manner similar to that used in Task 1.

Task 3, Determine Compliance with Noise Standards, has been initiated by reviewing noise laws that apply to geothermal development. When the source data have been standardized, compliance will be determined by calculating expected noise levels at given distances for a particular source with and without various types of control devices.

PLANS FOR NEXT PERIOD

Data gathering will continue. Additional detailed measurements will be made to complete the data base. The evaluation of the effective-

Table 12. Evaluation of Geothermal Liquid Waste Disposal Techniques

	Technical Evaluation							Legal (Impact)				Environmental and Safety								
Disposal Methods	Working Experience	Component Availability	Geology & Underground Hydrology	Interaction With Processes	Useful Byproducts	Reliability	Cost	Geothermal Laws	Environmental Laws	Water Rights	Land	Safety	Water Pollution	Air Pollution	Noise Pollution	Toxic Substance Disposal	Solid Waste Disposal	Induced Seismicity	Land Subsidence	Remarks
Direct Release to Surface Waters	In Use (a)	Avail.	Min. geo. hydro. import.	Very low	No	High	Low	Yes	Yes	Yes	Min.	Excel.	Med. potent.	Yes	Yes (5)	No	No	No	Potent.	Low cost with good potent. in low temp. direct heat applications
Treatment & Release To Surface Waters	Min.	Sp. mat.	Min. geo. hydro. import.	Med. (1)	Pos.	Med.	Med.	Yes	Yes	Yes	Min.	Good	Low	Yes	Low	Potent.	Yes	No	Potent.	Cost of treatment must be kept low
Closed Cycle Ponding	In use (b)	Sp. mat. (pond liners)	Min.	Very low	Pos.	High	Low (3)	Yes	Yes	Yes	Yes	Good	Low potent.	Yes	Yes (5)	Potent.	Some	No	Potent.	Reliable liners and low-cost land in arid regions needed
Consumptive Secondary Use	Exper.	Avail.	Min.	Sig. (1)	Yes	High	Low	Yes	Yes	Yes	Yes	Good	No	Low potent.	Low	No	No	No	Potent.	Shows potential for med.- to low-temperature waters
Injection-Producing Horizon	In use (c)	Sp. equip. (pumps)	Large effect	Sig. (1)	Pos.	Med. (2)	Med. (4)	Yes	Yes	No	No	Good	Med. potent.	Low	Low	No	Low	Low, potent.	Low	Very popular but has some potent. problems
Injection-Nonproducing Horizon	Exper.	Sp. equip. (Pumps)	Large effect	Sig. (1)	Pos.	Med.	Med. (4)	Yes	Yes	No	No	Good	Med. potent.	Low	Low	No	Low	Low potent.	Potent.	Used primarily where producing zones are highly fractured.
Treatment & Injection	Exper.	Sp. mat.	Med. effect	Sig. (1)	Pos.	Med. to high	Med.	Yes	Yes	No	No	Good	Low	Yes	Low	Potent.	Yes	Low potent.	Low	Solid disposal may be a big problem

a. Wairakei, New Zealand
Ahuachapan, El Salvador
Iceland
Klamath Falls, Oregon
b. Cerro Prieto, Mexico
c. Ahuachapan, El Salvador
Larderello, Italy

Abbreviations:
Avail. - Available
Excel. - Excellent
Exper. - Experimental state
Geo. hydro. import. - Geological or hydrological importance
Med. - Medium
Min. - Minimal
Pos. - Possible
Potent. - Potential
Sig. - Significant
Sp. equip. - Specialized equipment may be needed
Sp. mat. - Specialized material may be needed

1. Temporary backup systems needed
2. Has shown med. reliability except in lightly permeable zones
3. Depends on liner and land costs
4. Depends on permeability of receiving horizon; lower permeability increases cost.
5. Good designs reduce noise

ness of various control devices and the overall state of compliance will be completed.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- September 30, 1980 -- Issue final report

PREPLANNING OF ENVIRONMENTAL PROJECTS: ASSESSMENT OF ENVIRONMENTAL CONTROL TECHNOLOGIES

ORGANIZATION AND CONTRACT NUMBER

Lawrence Livermore Laboratory
W-7405-ENG-48

PRINCIPAL INVESTIGATOR

P.L. Phelps. Jr.

OBJECTIVE

The objective of this project is to provide up-to-date environmental control technology information for use by the Department of Energy and the geothermal energy development community. Information is gathered regarding technologies intended to protect the air, surface waters and groundwater, ecosystems, geological integrity, and general public health. Emphasis is placed on the following activities:

- Identification of environmental control needs;
- Investigation of current, applicable control technologies and determination of their status and effectiveness;
- Identification of new control technologies being planned or developed;
- Identification of deficiencies in environmental control technologies; and
- Assessment of the adequacy of information pertaining to existing, developing, or planned environmental control technologies.

APPROACH

The project will use the technical workshop approach to accomplishing goals. The workshop is an organized forum in which qualified participants from government, industries, utilities, and the public are brought together to exchange, discuss, evaluate, and disseminate environmental control technological information. A report of proceedings will be published.

The project will be carried out with the assistance of Lawrence Livermore Laboratory personnel whose expertise has been gained from related projects such as Assessments of Environmental Control Technologies for High Priority Geothermal Resource Areas. Other preparations, logistics, and liaison for the workshop are provided by the Geothermal Resources Council, a multidisciplined nonprofit organization for the development of geothermal energy.

PROGRESS AND RESULTS

A workshop on environmental control technology for The Geysers-Calistoga known geothermal resource area was held in Oakland, California, on October 11 and 12, 1978. A report of the proceedings was prepared and published.

PLANS FOR NEXT PERIOD

Lawrence Livermore Laboratory will participate in a management survey course on geothermal environmental problems being organized by the Geothermal Resources Council. The course, entitled "Geothermal Environmental Problems, Control Technology, and Mitigation Measures," is directed toward program managers and administrators. The laboratory will make presentations in the areas of health and safety, water quality, air quality and abatement systems, and subsidence and seismicity.

REPORTS PUBLISHED

"Workshop on Environmental Control Technology for the Geysers-Calistoga KGRA," UCRL-52887, Lawrence Livermore Laboratory, September 1979.

PROJECTED MILESTONES

- September 30, 1980 -- Issue annual report for fiscal 1980

COMPRESSED AIR ENERGY STORAGE: ENVIRONMENTAL CONTROL CONCERNS

ORGANIZATION AND CONTRACT NUMBER
Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATORS
R.A. Craig
G.R. Keizur

OBJECTIVES

The objectives of this program are to identify environmental impacts associated with the construction and operation of compressed air energy storage facilities, describe the nature and magnitude of those impacts, and identify or propose measures required to mitigate potentially adverse impacts.

The Compressed Air Energy Storage Environmental Control Concerns Program funded by the Environmental Control Technology Division is part of the Compressed Air Energy Storage Technology program at Pacific Northwest Laboratories. The technical aspects of developing this technology are supported by the Electrical Energy Systems and Energy Storage Divisions of the Department of Energy.

APPROACH

The approach taken has been to review the literature relating to compressed air energy storage and other technologies sharing similarities, including previous work relating to environmental concerns likely to be associated with compressed air energy storage. Researchers exploring the technical factors associated with compressed air energy storage were also contacted and the information assembled into a program management plan. This plan divides specific environmental concerns into separate research tasks and provides a schedule for their completion.

PROGRESS AND RESULTS

A program management plan outlining specific areas of research, when that research is to be completed, and anticipated required funding levels has been prepared and is in the final stages of revision and review. Also, two tasks performed by subcontractors investigated the environmental concerns associated with disposal of waste generated during compressed air energy storage cavern construction. One study investigated disposal of mined wastes from the caverns constructed in hard rock, and the other studied the disposal of brines generated by solution-mining of caverns in salt beds. Both studies also identified and evaluated alternative disposal schemes.

PLANS FOR NEXT PERIOD

Research efforts in fiscal 1980 will focus on the effects of compressed air energy storage facilities on aquifers and surface waters, including possible contamination of aquifers in which storage facilities are located and possible contamination of surface waters used in a pressure-compensated system. In addition, research into the environmental aspects of these systems will be coordinated and integrated with research into the technical aspects. Other activities will include final revision and review of the program management plan and compilation of the two waste disposal reports into a single document for review and publication.

REPORTS PUBLISHED

"Management Plan: Environmental Concerns in Compressed Air Energy Storage," PNL-2843, Working Paper, Pacific Northwest Laboratory, 1979.

PROJECTED MILESTONES

None

ASSESSMENT OF ENERGY-CONSERVING INDUSTRIAL WASTE TREATMENT TECHNOLOGY

ORGANIZATION AND CONTRACT NUMBER
Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATORS
B.W. Mercer
S.E. Petty

OBJECTIVES

The objectives of this project are to provide an overview of the current industrial pollution control practices, assess Department of Energy activities in this area, assess the impact of recently promulgated Federal pollution control regulations, and prepare a plan on recommended alternative possibilities of energy-conserving industrial waste treatment processes.

APPROACH

A comprehensive literature review will be undertaken to establish an industry priority list, develop industrial process diagrams, determine industrial pollutant discharges, and identify current study areas. Published data and information from industrial trade groups will be used to develop the necessary data base. Possible industrial waste treatment areas, where additional work into energy-conserving processes is needed, will be identified.

PROGRESS AND RESULTS

Prior to fiscal 1979, the objective of the Energy-Conserving Industrial Waste Treatment Technology report was to examine the top 10 industries using significant amounts of energy for pollution control, identify effluents produced by each of these industries, and find the most energy-effective methods available to reduce these effluents. Fiscal 1979 research evaluated the impact upon industry of recent Federal enactments covering discharge of air and water pollutants to the environment. An industrial survey was performed to gain insight into industry's impressions of recent Environmental Protection Agency regulations, ascertain the degree to which industry would comply with these regulations, and locate areas within the industry where research is needed for feasible methods of pollution control.

PLANS FOR NEXT PERIOD

Publish final report

REPORTS PUBLISHED

Ahlstrom, S.B., et al., "Summary of Energy-Conserving Industrial Waste Treatment Technology," Draft, Pacific Northwest Laboratory, August 1979.

PROJECTED MILESTONES

- June 30, 1980 -- Publish final report

ENVIRONMENTAL CONTROL TECHNOLOGY REQUIREMENTS FOR FUTURE ALTERNATING CURRENT, HIGH-VOLTAGE OVERHEAD TRANSMISSION FACILITIES

ORGANIZATION AND CONTRACT NUMBER

SRI International
EV-76-C-03-0115

PRINCIPAL INVESTIGATOR

B.L. Scott-Walton

OBJECTIVE

The objective of this program is to provide the Environmental Control Technology Division with an overview of current understanding about environmental impacts of high-voltage transmission lines by assessing testimony recently submitted for licensing a 765-kilovolt line.

APPROACH

SRI employed a multidisciplinary team to review the 14,000 pages of testimony given before the New York Public Service Commission in two recent cases on the potential environmental effects of 765-kilovolt overhead a.c. transmission lines. The testimony focused on the potential effects of audible noise, biological effects of the electromagnetic fields, electric shocks to people who come in contact with vehicles located under the proposed lines, effects of the electromagnetic fields on electronic cardiac pacemakers, and ozone produced by corona discharge from the lines.

PROGRESS AND RESULTS

The final report was completed in November 1979, and concluded that although the testimony explored the above questions, it did not resolve all of them. The testimony indicates the potential impacts of the audible noise and the electrostatic shocks that people can receive when they touch a large vehicle located under the lines. The testimony also indicates that certain cardiac pacemaker and lead combinations may, under certain circumstances, undergo reversion to a fixed rate of pacing in the presence of the fields under the lines; little risk to cardiac patients results except possibly for those patients for whom competition between the heart's own rate and the pacemaker rate presents a health risk. The testimony fails to demonstrate biological hazards from the field; further research is necessary to better understand the effects of the fields on biological systems. The testimony indicates that ozone produced by the lines will not significantly affect the environment.

PLANS FOR NEXT PERIOD

None

REPORTS PUBLISHED

"Potential Environmental Effects of 765 kV Transmission Lines: Views Before the New York State Public Service Commission, Cases 26529 and 26559, 1976-1978," DOE/EV-0056, November 1979.

PROJECTED MILESTONES

None

ENVIRONMENTAL CONTROL REQUIREMENTS IN SOLID WASTE PROCESSING AND ENERGY RECOVERY FACILITIES: WATER POLLUTION

ORGANIZATION AND CONTRACT NUMBER

Iowa State University
W-7405-ENG-82

PRINCIPAL INVESTIGATOR

J.C. Young

OBJECTIVES

The general objectives of this project are to perform independent assessments of the environmental controls needed for urban waste utilization and to identify and foster development of novel solutions to environmental control problems.

APPROACH

The general approach for this project will be, first, to perform a preliminary assessment of controls needed for air and water pollution and then to undertake more detailed assessment work, which is in concert with and will complement activities sponsored by other environmental groups.

The project consists of three phases. Phase 1 (October 1976 through September 1977) involved surveying existing technology through literature reviews, site visits, and working with design engineering and manufacturing firms. This survey helped to identify points of water use and wastewater production and document available information. In addition, it served as a basis for developing followup procedures for collecting additional data needed to accomplish the objectives of the evaluation program. Phases 2 and 3 (October 1977 and following) will involve detailed followup studies to determine the treatability of wastewaters produced, evaluate the availability and suitability of water pollution control technology to treat these wastewaters, and identify possible ways to reduce water use and wastewater production.

PROGRESS AND RESULTS

Phase 1 (fiscal 1977) has shown that water is used at solid waste processing/energy recovery facilities for scrubbing off-gasses from burning operations, quenching incineration residues, sluicing ash from incinerators and air pollution control devices, cooling, lubricating, fire-fighting, and miscellaneous housekeeping. There has been essentially no documentation of the volume of water used for, or wastewater produced by, these functions. In most cases, no measurements of wastewater quantities have been made and very little data are available on the quality of wastewaters. Wastewater streams are discharged to sanitary sewers without regard to their treatability or impact on municipal treatment systems.

The final report for Phase 1 cataloged known data on water use and wastewater production for the following: (1) mass-burning facilities (Nashville, Tennessee, and Saugus, Massachusetts); (2) mechanical processing for supplemental fuel production (Ames, Iowa; Chicago, Illinois; Milwaukee, Wisconsin; Baltimore County, Maryland; and East Bridgewater, Massachusetts); (3) wet processing (Franklin, Ohio); (4) pyrolysis (Baltimore, Maryland; South Charleston, West Virginia; and El Cajon, California); and (5) bioconversion systems (Pompano Beach, Florida) and landfill gasification.

Phase 2 (fiscal 1978 to 1979) emphasizes (1) treatability of wastewaters from processing/energy conversion facilities by conventional treatment processes and (2) leachate studies related to landfilling or land disposal of liquid and solid residues. The fate of specific organics, especially priority pollutants, is traced through these treatment processes.

Wastewater or solid residue samples have been collected from the following plants:

- Liquid and solid residues from Union Carbide's PUROX pyrolysis process at South Charleston, West Virginia;
- Liquid discharges and solid residues from ash sluicing at the refuse-derived fuel plant in Ames, Iowa;
- Liquid and solids from the anaerobic digestion processes at Franklin, Ohio, and Pompano Beach, Florida, and from

laboratory-scale systems at Iowa State University; and

- Ash and liquids from the mass-burning plant at Nashville, Tennessee.

Phase 3 (fiscal 1979) involves an assessment of the ability of advanced chemical and physical processes to remove the contaminants from wastewaters produced at solid waste processing/energy recovery facilities. Processing plants being considered for assessment include (1) mechanical processing (Ames, Iowa); (2) wet pulping (Franklin, Ohio, or Hempstead, New York); (3) pyrolysis (South Charleston, West Virginia); and (4) bioconversion (Pompano Beach, Florida).

PLANS FOR NEXT PERIOD

Phase 4 (fiscal 1980) involves completion of Phase 2 and 3 test programs and preparation of a project final report with recommendations for design and operating changes and treatment technology needed to minimize water-related environmental impacts of converting urban solid wastes to energy.

REPORTS PUBLISHED

Johnson, L.D., and J.C. Young, "Water Use and Wastewater Production at Solid Waste Processing/Energy Recovery Facilities," Phase I Final Report, September 1978.

Rademaker, A.D., and J.C. Young, "Analysis of Leachates From Solid Residues Produced at Urban Waste-To-Energy Recovery Facilities," Phase II Interim Report, November 1979.

PROJECTED MILESTONES

- May 1980 -- Publish final project report

ENVIRONMENTAL CONTROL ISSUES OF ENERGY STORAGE

ORGANIZATION AND CONTRACT NUMBER

Los Alamos Scientific Laboratory
W-7405-ENG-5

PRINCIPAL INVESTIGATOR

M.C. Krupka

OBJECTIVE

The purpose of this project is to provide an update to a previous study within which environmental control techniques were described and recommendations for needed control technology were made.

APPROACH

This assessment was designed to update the basic information contained in LA-6979-MS, "Environmental Control Technology R&D Requirements for Energy Storage Systems." The specific energy storage technologies under consideration include advanced lead-acid battery, underground hydroelectric pumped, superconducting magnet, compressed air, flywheel, and thermal. In addition, an initial environmental assessment was made concerning fuel cell technology. Strictly speaking, fuel cells per se are not energy storage devices. Further, when coupled to certain recycling units, the total system operates in an energy storage capacity. A brief study was performed related to industrial implementation of energy storage technologies for purposes other than that of centralized electric power generation by utilities. The purpose of the survey was to identify new and significant impacts specifically related to a new application. Wherever possible, an estimate of the additional cost to the energy storage system or to its product, e.g., electricity (kilowatt-hours), due to the implementation of some form of control technology, was made. Finally, a brief analysis was done relative to the possible implications of the Resource Conservation and Recovery Act of 1976 on the disposal of any solid waste materials generated using energy storage technology.

PROGRESS AND RESULTS

An update was published in fiscal 1979. Table 13 is a summary of the findings.

PLANS FOR NEXT PERIOD

None

REPORTS PUBLISHED

Krupka, M.C., et al., "Assessment of Environmental Control Technologies for Energy Storage Systems -- 1979," LA-8308-MS, Los Alamos Scientific Laboratory, April 1980.

PROJECTED MILESTONES

None

Table 13. Environmental Control Issues of Energy Storage: Progress and Results

Storage Technology	Operation	Affected Environment	Impact	Mitigation Control Technology	Mitigation Technology Cost Estimate[a]
Advanced Lead-Acid Battery	Normal	Air, land	Hydrogen, arsine, stibine (plus their oxides)	Catalytic recombination, special scrubbing system including instrumentation	18% plus landfill costs--$7-$9/ton waste (1979$)
	Excursion (fire, acid spill)	Air, land, water	Noxious gases, particulates, acid water	Venting, scrubbing calcium oxide, dilution	
Underground Hydroelectric Pumped	Normal	Land, water, biosystems	Chemical and biological contamination, cyclic stress entrainment	Design and site-selection criteria, fracture detection instrumentation	Not available
	Excursion (structural failure)	Land, water	Leakage, flooding, collapse	Stabilization, diversion, design and site-selection criteria	
Superconducting Magnet	Normal	Land, biosystems	Magnetic field, cyclic stress	Structure reinforcement, distance, shield coil	4.3% of main coil or land $10,000/acre for 10 gauss --$2,000/acre for 0.3 gauss
	Excursion (structural failure, explosion)	Land	Fracture--Wall collapse, emergency shutdown	Stabilization	
Compressed Air	Normal	Air, land, biosystems, Water,	Chemical and biological contamination, wall degradion, subsidence	Cavern design and site-selection criteria development, cyclic stress studies, detection instrumentation	Aquifer - not available Water injection equipment -- $5-50/kW Wells and instrumentation--<5%
	Excursion (structural failure)	Air, land, water	Blowout, cave-in, subsidence, seismicity	Stabilization, sealants, design and site-selection criteria	
Flywheel	Normal	Land	Safety	Design of flywheel and containment system, sensors	5% of installed system-utility and residential Moving base--5-10%
	Excursion (structural failure)	Land	Rotor burst, vacuum bearing failure, secondary particulates	Design	
Thermal	Normal				
Sensible		Air, land, biosystems, water	Leakage	Leakage design, dilution, biodegradation	3%
Sensible-Aquifer		Land, biosystems, water	Chemical and biological contamination subsidence	Site selection, geohydrological studies	Not available
Latent Heat		Air, land, biosystems, water	Leakage	Leakage design, detection instrumentation	8% plus landfill costs--$7-$9/ton waste (1979$)
Reversible Chemical Reaction		Air, land, biosystems, water	Chemical and solution leakage	Leakage design, detection instrumentation	8% plus landfill cost--$7-$9/ton waste (1979$)
	Excursion (major leakage, fire, explosion)	Air, land, water	Chemical and solution leakage	Scrubbing, landfill disposal	
Fuel Cell	Normal	Air, land	Electrolyte disposal, thermal (second generation)	Neutralization, landfill disposal	10% plus landfill costs--$7-$9/ton waste (1979$)
	Excursion (fire, leakage)	Air, land	High-temperature chemical release	Neutralization, landfill dispoal, safety shield (second generation)	

[a] Percentage costs are related to total capital cost of the energy storage system.

ASSESSMENT OF NEED FOR CONTROLS FOR MODIFIED FURNACES

ORGANIZATION AND CONTRACT NUMBER

Ames Laboratory
W-7405-ENG-82

PRINCIPAL INVESTIGATOR

H.R. Shanks

OBJECTIVE

To perform an environmental analysis on the emissions from a slot forge furnace from fuel switching to a coal oil mixture to determine the need for environmental controls as a result of switching to a coal oil mixture from oil.

APPROACH

Answers to the following questions were sought:

1. Stack Emission Standards

   Do emissions comply where regulated standards exist? Are controls needed? What types?

2. Ambient Air Standards

   What is an analytical estimate of ambient degradation from the plant? In what regions can the plants be sighted?

3. State Emission and Air Standards

   Where can these plants be located with respect to state standards?

4. Occupational Safety and Health Administration Standards

   What are the pollutant concentrations (including noise) in the work place? Are they within Administration regulations? Will controls be needed?

5. Strategy for Use of Coal/Slurry Fuel

   Can this fuel be used with or without additional controls? Should this fuel be used routinely or only as "standby" fuel during emergencies?

Stack emission testing was done with standard Environmental Protection Agency sampling methods, and included tests for particulate, sulfur oxide, and nitrogen oxide emissions. Particulate and noise levels in the workplace were determined.

PROGRESS AND RESULTS

All analyses have now been completed. With no particulate control, the furnace emits particulates at too high a level to comply with regulations in 14 states and certain areas of several other states. As tested, the furnace would not comply with State Implementation Plan sulfur oxide regulations in eight states and certain areas in several other states. In most cases, this was because the sulfur level in the fuel did not comply with regulations. Nitrogen oxide emissions were maintained below the Environmental Protection Agency limits for either liquid or solid fossil fuel.

The sound levels experienced near the furnace were very near the Occupational Safety and Health Administration limits for an 8-hour exposure and would exceed proposed National Institute for Occupational Safety and Health noise levels. The ambient (workplace) particulate levels were at or near the Administration's limit. In addition, most of the material was in the respirable fraction.

A simple cyclone type dust collector on the stack will probably be required to reduce particulate emissions to meet requirements in additional areas of the United States. Because a number of states base their sulfur oxide emission controls on the sulfur level in the fuel, a coal with a low sulfur content will have to be used in making the coal-oil mixture. Better exhaust fans and sealing the furnace seams would improve the particulate levels in the workplace.

Although the stack emissions probably would not have any significant effects on the surrounding environment, some controls are still needed as emission levels are sometimes too high in terms of emissions per unit of heat input.

PLANS FOR NEXT PERIOD

Publish final report, "Assessment of Needs for Environmental Controls for Burning Coal-Oil Mixtures in a Slot Forge Furnace," by H.R. Shanks.

REPORTS PUBLISHED

None

PROJECTED MILSTONES

- July 1, 1980 -- Publish final report

NUCLEAR ENERGY

Nuclear energy control technology assessments supported under the Environmental Engineering Program in fiscal 1979 consisted of the following:

- Assessment of the environmental control aspects of alternative nuclear fuel cycles;
- Continuation of the assessment of alternate waste management concepts, including investigation of the environmental and technical feasibility of high-level waste disposal into deep ocean sediments; and
- Development of methods for assessing the adequacy of the environmental protection and public safety afforded by Department of Energy nuclear energy material shipping container systems.

The nuclear fuel cycle activities continue to provide an environmental assessment of the effluent control systems used in the fuel cycle of current and proposed nuclear energy systems. Recommendations were made for development or application to ensure that systems are available to meet present and projected environmental standards and policies.

During fiscal 1979, a major effort was concentrated on identifying effluents and determining environmental control costs and efficiencies (existing and alternate control methods) for light-water reactor fuel cycle facilities, alternate fuel cycles, and thorium and uranium resource recovery. The light-water reactor analysis concentrated on defining the 20 highest ranking radioactive effluents and the 20 highest nonradioactive effluents for the 1977 to 2076 time period. The present and available alternate methods of controlling each release were analyzed, and cost information, as available, was determined. For alternate fuel cycles, the environmental effects of effluents from reprocessing and fabrication of alternate light-water and liquid metal fast breeder reactor fuels are predicted to be at about the same level as those that would result from potential releases from a deep geological repository for storing fuel cycle operations wastes. Fifty-year dose commitments per metric ton of heavy metal resulting from a one-year release of effluents were determined. For thorium and uranium resource recovery, an analysis was completed for thorium that identified major waste effluents from mining, milling, and refining; existing environmental control techniques and costs; and alternative environmental control techniques and costs to meet more stringent control standards. An identification of the major effluents from mining, milling, and refining low-grade uranium was initiated.

Another effort in the nuclear fuel cycle assessment area focused on a study of decommissioning accelerators and fusion devices. An assessment was completed on the decommissioning of four prototype particle accelerators with consideration given to cost, identification of radioactive waste, and radiological health impacts. The major steps associated with decommissioning a commercial fusion Tokamak reactor were also defined. This effort included identifying a commercial fusion reactor facility (based on the present knowledge of fusion plant concepts), developing a preliminary decommissioning plan, and estimating and inventorying the radioactive materials and the prominent decay schemes existing at final shutdown.

The near-term objectives of the ocean bed emplacement studies are (1) to assess the environmental and technical feasibility of providing isolation of high-level radioactive waste beneath the deep ocean floor in a geologically stable and biologically inactive region and (2) to maintain the capability of accessing ocean emplacement programs developed by other countries. During fiscal 1979, detailed assessments of the vertical consistency of the deep ocean sediments were continued by examining sediment core specimens. The initial assessment of the properties barring migration of selected radionuclides through sediment materials was continued for red clay and calcareous sediments, and the characterization of the deep ocean and bottom-dwelling biological communities was continued to determine biological effects and possible biological concentration mechanisms and transport pathways. Also in fiscal 1979, mathematical models were developed to evaluate sediment column response and biological transfer pathways and rates for ion transport.

The assessment of ocean bed emplacement has international implications in terms of the potential for contributing to the solution of the

nuclear waste management problem on a worldwide scale and in terms of the sensitivities and restrictions established by international treaties for any acts that pollute the world oceans. These implications are continually addressed in the assessment program, and information is provided to various joint programs as well as to conferences and discussions of international policies affecting the seas.

During the latter part of fiscal 1979, management responsibility for the ocean bed emplacement program was transferred from the Environmental Control Technology Division to the Office of the Nuclear Waste Management within the Office of the Assistant Secretary for Nuclear Energy. The result is that all of the nuclear waste management analyses have been consolidated into an office whose major concern is the transfer and ultimate storage of all nuclear waste, whether by ocean bed or land emplacement, in an environmentally sound manner.

The Environmental Engineering Program continued analysis and testing in fiscal 1979 designed to assess the adequacy of the environmental controls provided by nuclear fuel and waste shipping container systems used in the fuel cycle. Activities focused on experimental and analytical studies for predicting containment failure under impact accident conditions with the goal of rationally establishing margins of safety and confidence. Experimental and analytical tools as well as needed test data are developed in the program, and the pertinent aspects of commercial transportation systems, within which the nuclear shipments must operate, are also considered. Such data and analysis benefit the safety of all nuclear material shipment systems.

Fiscal 1979 activities include the continuation of the development and efforts to experimentally verify computer codes to predict the impact response of shipping containers, the incorporation of newly developed material behavior descriptions in such codes, and scale model and/or full-scale impact tests of containers. Experimental railcar container system response to impact was compared to computer codes, based on full-scale tests, and was then used to improve the analytical approach.

Efforts were continued to develop and maintain a nuclear transportation accident data bank for use by Government agencies and the public (a continuing program begun in fiscal 1976); collect and publish statistics and data on the Department of Energy's own transportation operations program; and develop films, booklets, and exhibits about the environmental and safety aspects of the transportation of fuels and wastes. This activity incorporates new data, technical information, and visual aid material derived from all related projects to demonstrate the assessment of these environmental control systems.

ANALYSIS OF NUCLEAR FUEL CYCLES

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
DE-AC06-76RLO 1830

PRINCIPAL INVESTIGATORS

M.A. Lewallen
C.H. Bloomster
C.M. Heeb
A.M. Nolan

OBJECTIVE

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 that technologies that control or eliminate the discharge of noxious materials to the environment can be developed and demonstrated in a timely manner.

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.

APPROACH

The approach selected to meet the program objective is to evaluate the light water reactor fuel cycle as a reference point for analyzing alternative fuel cycles and advanced nuclear energy systems and to evaluate specific topics identified as important issues in the environmental control of nuclear fuel cycles. Studies are underway in the areas of fusion, thorium and advanced uranium resource extraction, and alternate fuel cycles.

The technical approach within each program objective is to (1) develop generic descriptions of the fuel cycles and facilities in question, (2) identify potential environmental releases from each facility, (3) assess current capabilities to control environmental releases, and (4) identify areas where environmental control technology should be developed. Cost-effectiveness analysis will be used in areas where there is sufficient information to provide a cost perspective.

PROGRESS AND RESULTS

Alternative Fuel Cycles

The objective of this task was to compare the environmental effects of effluents from the reprocessing and fabrication of alternative light water reactor and liquid metal fast breeder reactor fuels. In addition, this task included a comparison of the environmental hazards of potential releases from a deep geological 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 metric ton of heavy metal resulting from a 1-year release were determined for the total body and four organs. Comparisons of the total body and bone dose commitments for the various fuel types were developed.

The variations in dose commitments for the reprocessing and uranium-233 fuel refabrication plants are a result of the differing quantities of uranium-232 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 refabrication plants can be attributed to the quantity of thorium-233 in each applicable fuel type. The liquid metal fast breeder reactor 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 was estimated for the leaching of repository wastes from a bedded salt site. The concentrations were used to generate a biohazard index for comparing the potential environmental effects of storing fuel cycle waste resulting from the varius fuel types. The waste considered in this task included high-level vitrified wastes and transuranic-waste- contamination hulls and hardware from the fuel reprocessing plant, as well as transuranic wastes from the fuel fabrication and refabrication plants.

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

Light Water Reactor Analysis

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 nuclear fuel cycle was completed. The time period covered was 1977 to 2076. Annual releases from some 250 nonradioactive substances and 175 radioisotopes were computed. Three nuclear generation scenarios were chosen, including 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 20 highest radioactive and 20 highest nonradioactive substances were selected for more detailed analysis. The analysis included a description of the present method of controlling each release and an assessment of available alternative methods in terms of the reduction in the effluents affected by the alternative method and, when cost is available, the cost of implementing the alternative system.

Table 14 lists the 20 highest ranking radioactive effluents for the full recycle scenario; Table 15 shows the 20 highest ranking nonradioactive effluents. The analysis of the control of these effluents is contained in "A Survey of LWR Environmental Control Technology Performance and Cost," PNL-2287, March 1979. In general, the most serious radioactive effluents came from the reactors and reprocessing plants, and the most serious nonradioactive effluents came from the head end of the fuel cycle, i.e., mining, milling, and enrichment.

Thorium and Uranium Resource Recovery

The objectives of this subtask of the nuclear fuel cycle project are to

1. Identify the major waste effluents associated with the mining, milling, and refining of thorium and low-grade uranium.

Table 14. Twenty Highest Dose Nuclides for Full Uranium and Plutonium Recycle

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

[a] FRP - fuel reprocessing plant
BWR - boiling water reactor
PWR - presurized water reactor

2. Identify existing environmental control technologies for these effluents and determine their costs and the current levels of control.

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 results, in terms of costs, are as follows:

Location	Approximate Cost Range Per Pound of Thoria Produced*
Lembi 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**	$0.15 - 1.98

The uranium part of the project is now focused on objective 1. The deposits to be included in the study include

- Chattanooga, Tennessee -- Black shale
- Bokan Mountain, Alaska -- Peralkaline granite
- Thomas Caldera, Utah -- Volcanic and phosphate rock

At this time, no representative site has yet been selected for phosphate rock. This work will be completed during fiscal 1981.

PLANS FOR NEXT PERIOD

Using previous light water reactor environmental control analyses, the sources of production, release pathways, and levels of radioactive effluents from current light water reactors will be obtained. Each of these characteristics will be analyzed as it would be affected by implementing the various light water reactor improvements being proposed. The overall environmental effects will be estimated for these improvements.

Contractors on the liquid metal fast breeder reactor conceptual design study will be contacted, and current and proposed environmental protection system characteristics obtained. These sytems will be evaluated in relationship to current and proposed standards and current liquid metal fast breeder reactor performance.

The advanced uranium mining and milling subtask is a continuation from fiscal 1979. The relationship between cost and level of environmental control will be developed and documented for the advanced uranium sources.

There is currently a renewed interest in gas-cooled reactors for process heat and direct cycle applications. This task will evaluate the specific environmental control implications of each proposed application. To evaluate particular applications, contractors performing design studies will be contacted, and detailed designs obtained.

REPORTS PUBLISHED

Heeb, C.M., et al., "A Survey of LWR Environmental Control Technology Performance and Cost," PNL-2287/UC-11, Pacific Northwest Laboratory, March 1980.

Heeb, C.M., et al., "Enform II: A Calculational System for Light Water Reactor Logistics and Effluent Analysis," PNL-2429/UC-11, Pacific Northwest Laboratory, October 1979.

Nolan, A.M., M.A. Lewallen, and G.W. McNair, "Environmental Control for Fabrication, Reprocessing, and Waste Disposal of Alternative LWR and LMFBR Fuels," PNL-3129/UC-11, Pacific Northwest Laboratory, November 1979.

Schneider, K.J., and T.J. Kabel, "Descriptions of Reference LWR Facilities for Analysis of Nuclear Fuel Cycles," PNL-2286/UC-11, Pacific Northwest Laboratory, September 1979.

Young, J.K., et al., "Economics of Large-Scale Thorium Oxide Production: Assessment of Domestic Resources," PNL-3150/UC-51, Pacific Northwest Laboratory, February 1980.

* Maximum cost is for the more effective, but usually more complex, methods and includes up to 200 percent contingency on estimates. Minimum cost represents 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).

** Does not include mining and milling environmental control costs.

Table 15. Ranking of Dilution Factors for Nonradioactive Airborne Effluent for Full Uranium and Plutonium Recycle

Rank	Dilution Factor (m^3)	Chemical Name	Plant
1	3.268E+15	Ammonia	Uranium fuel fabrication
2	3.266E+15	Sulfur oxides	Enrichment cascade
3	2.533E+15	Nitrogen oxides	Reprocessing
4	1.950E+15	Nitrogen oxides	Enrichment cascade
5	1.609E+15	Uranium	Acid leach mill
6	1.257E+15	Sulfur oxides	Boiling water reactor
7	1.134E+15	Rock dust	Surface mine
8	1.103E+15	Rock dust	Underground mine
9	8.442E+14	Sulfur oxides	Reprocessing
10	6.179E+14	Nitrogen oxides	Aqueous conversion
11	5.029E+14	Nitrogen oxides	Boiling water reactor
12	4.555E+14	Aldehydes	Surface mine
13	3.862E+14	Nitrogen oxides	Acid leach mill
14	3.282E+14	Hexane	Aqueous conversion
15	3.080E+14	Aldehydes	Acid leach mill
16	2.953E+14	Nitric acid	Uranium fuel fabrication
17	2.809E+14	Hydrogen fluoride	Aqueous conversion
18	2.648E+14	Aldehydes	Underground mine
19	2.575E+14	Sulfur oxides	Aqueous conversion
20	2.277E+14	Nitrogen oxides	Surface mine

PROJECTED MILESTONES

- Fourth quarter of fiscal 1980 -- Publish several reports
  - A Survey of Proposed Light Water Reactor Improvements: Environmental Control Implications
  - Liquid Metal Fast Breeder Reactor Environmental Design Overview
  - Assessment of the Environmental Control of Advanced Uranium Recovery
  - Current Status of Gas-Cooled Reactor Technology: Environmental Aspects

STUDY OF DECOMMISSIONING ACCELERATORS AND FUSION DEVICES

ORGANIZATION AND CONTRACT NUMBER

Argonne National Laboratory
W-31-109-ENG-38

PRINCIPAL INVESTIGATOR

J.H. Opelka

OBJECTIVE

All nuclear facilities, including particle accelerators and fusion devices, require appro-

priate radiological safety measures when operation is terminated due to obsolescence or when retirement and decommissioning is undertaken. Several nuclear reactors, including the Atomic Energy Commission Elk River reactor, and several particle accelerators, including the Cosmotron, the Princeton-Penn Accelerator, the Cambridge Electron Accelerator, and the Cornell Electron Synchrotron, have already been decommissioned.

The objective of this study is to prepare a document describing the general technical and environmental effects of the decommissioning of particle accelerators. A second document describing the general technical and environmental effects of decommissioning a fusion device will be prepared.

APPROACH

The following tasks make up the accelerator decommissioning portion of the study.

Task 1

Past decommissioning actions that have occurred in the United States will be reviewed. Technological, environmental, and economic concerns will be emphasized. High-energy accelerators to be studied will include the Princeton-Penn Accelerator at the University of Pennsylvania, the Cambridge Electron Accelerator at Harvard University, and the old Cornell Electron Accelerator at Cornell University. In addition, other smaller accelerators, such as synchrocyclotrons, cyclotrons, betatrons, linear accelerators, and electrostatic accelerators that have been decommissioned will be investigated.

Task 2

A survey will be performed on the existing high- and low-energy particle accelerator facilities (including those at universities). Estimates of future usage and anticipated scheduling of decommissionings will be ascertained, and obvious technical, economic, and environmental implications associated with their future decommissioning will be noted. Emphasized will be the Zero Gradient Synchrotron at Argonne National Laboratory, the Alternating Gradient Synchrotron at Brookhaven National Laboratory, the Betatron at Lawrence Radiation Laboratory, the Stanford Linear Accelerator at Stanford University, the Los Alamos Meson Physics Facility at Los Alamos, the synchrotron at Fermilab, and the new Cornell Electron Synchrotron. Other existing synchrocyclotrons, cyclotrons, betatrons, linear accelerators, and electrostatic accelerators will also be investigated.

Task 3

A plan for decommissioning a particle accelerator will be developed. The economic cost of decommissioning will be assessed. Costs will be determined by activity (such as removing a magnet section) and by period (such as staff salaries). Activity costs will be estimated as fixed cost (for purchase of dismantling equipment) and as unit cost (such as cutting a meter of concrete shielding). The volume, composition, and radiation level of radioactive material that will require disposal at appropriate waste disposal sites will be estimated. Radioactive wastes would be sent to regulated shallow burial grounds. The amount of equipment that can be beneficially used at other facilities will be seriously considered as an alternative to waste disposal. Special emphasis will be placed on the radiation safety aspects of dismantling, transporting, reinstalling, and burial. For the expected decommissioning schedule, the long-term implications for natural resources and society will be determined. Finally, alternatives to dismantling, such as mothballing or entombing, will be investigated. Special attention will be given to the Zero Gradient Synchrotron, which will most likely be the next large accelerator to be decommissioned. The sensitivity of the decommissioning effects to accelerator type and size will be documented. An additional task is to prepare an analysis of fusion device decommissioning.

Task 4

Based on the results of Task 3 and the known similarities of fusion devices and particle accelerators, the technical, environmental, and economic problems associated with decommissioning fusion devices will be assessed. A plan for decommissioning representative fusion demonstration devices will be developed.

PROGRESS AND RESULTS

A generic study was completed to examine the aspects of decommissioning particle-accelerators. There are presently several hundred accelerators in the United States that can produce material containing residual radioactivity. These residuals, after final shutdown, are generally short-lived induced activity and are localized in hot spots around the beam line. This study addressed the decommissioning options, which are mothballing, entombment,

dismantlement with interim storage, and dismantlement with disposal.

The study results indicate that the recycling of components or entire accelerators following dismantlement is a possibility and has been done in the past. Accelerator components can be recycled either immediately at accelerator shutdown or following a period of storage, depending on the nature of induced activation. Considerations of cost, radioactive waste, and radiological health were investigated for four prototype accelerators. Prototypes considered range from small accelerators having minimal amounts of radioactive material to a very large accelerator having massive components containing non-negligible amounts of induced activation. Archival information on past decommissionings was obtained, and recommendations concerning regulations and accelerator design that will aid in the decommissioning of an accelerator were defined.

Additionally, a decommissioning study was completed for commercial fusion reactors. The study, performed at this early stage of fusion technological development, has shown no instrumental problems. All phases of disassembly were reviewed, and the required work, especially those efforts in removal of the reactor, is less difficult than that associated with a fission reactor. This factor stems from the character of the reactor and its built-in and associated maintenance capabilities, which allow for normal removal and replacement of any reactor component or structure, a feature complementary to decommissioning. In addition, the design of the Tokamak systems emphasizes low radioactive inventories and segregation of activated materials, which will reduce the problems of decommissioning.

The commercial fusion reactor study results are presented in Tables 16 and 17 in terms of radioactive materials to be packaged for burial, as well as special or unique buildings and facilities representative of these reactors and other standard type structures. As can be seen by the tabulation, the reactor systems are large as represented by the total mass; however, almost all of the induced radiation is of low specific radioactivity. The materials may be easily handled for storage purposes and are not easily dispersed. One of the most difficult problems identified, for which the plant is initially equipped, is breaking down the massive components to an appropriate size for shipment. Facilities were determined to exist in the plant for disassembling and transporting components to points where dissection may be done with maximum convenience. The results indicate that these commercial facilities can be readily decommissioned using self-contained equipment for disassembly of all radioactive parts and standard techniques for remaining structures. A period of less than 3 years is anticipated with no further development work required. The ongoing design work in fusion reactor development is seriously considering the requirements of decommissioning.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Energy.

REPORTS PUBLISHED

Opelka, J.H., et al., "Decommissioning Study of a Commercial Tokamak Reactor," ANL/FS-93, Draft, Argonne National Laboratory.

Opelka, J.H., et al., "Particle-Accelerator Decommissioning," ANL/ES-82, Argonne National Laboratory, December 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Energy.

ANALYSIS OF THE FUSION FUEL CYCLE

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
DE-AC06-76RLO-1830

PRINCIPAL INVESTIGATORS

W.E. Bickford
L.W. Long
P.J. Mellinger
B.A. Price
V.L. Teofilo
C.E. Willingham
J.K. Young

OBJECTIVE

The goal of this project is to evaluate the environmental effluents released as a consequence of the generation of fusion power. Early investigation of these effluents revealed ways of not

Table 16. Reactor Materials[a] and Disposition Summary

Material	Volume (m^3)	Weight (MT)	Radioactive Waste Classification	Disposition
Vanadium	304	1850[f]	LLW[c]	Disposal
	21	132	---	Reuse
Lithium	740	380	---	Reuse
Graphite	550	1240	LLW	Disposal or reuse
Stainless Steel	27.8	217	HLW[d]	
	1478	11530[e]	LLW	Disposal
	125	975	---	Reuse
Boron Carbide	605	1390	LLW	Reuse
Sodium	500	450	---	Reuse
Tungsten[f]	525	9980	LLW	Disposal or reuse
Niobium Titanium	50	400	LLW	Disposal
Copper[g]	320	2850	LLW	Disposal or reuse

a Includes total material inventory from start of operation.

b Additional bulk shielding around the blanket may permit recycle of coil copper material.

c Will probably be replaced with stainless steel in future designs.

d Although high-level waste is strictly defined in regards to reprocessing spent nuclear fuel from fission reactors, there will be materials which will have very high radiation levels and will require handling and disposal in a manner now contemplated for high-level waste. Those very high specific activity materials are loosely called high-level waste (HLW) in this document.

Table 17. Materials and Disposition Summary for Reactor Support Facilities

Material	Volume (m^3)	Weight (MT)	Radioactive Waste Classification	Disposition
Stainless Steel	280	2200	LLW[a]	Disposal
Reinforced Concrete	300	720	LLW	Disposal
Stainless Steel	140	1100	---	Reuse
Structural Steel	192	1500	---	Reuse
Reinforced Concrete	52,000	135,200	---	Landfill
Equipment	---	3000	---	Reuse

a Low-level waste.

only controlling but also reducing the consequences of such effluent releases. This project will identify the environmental control requirements associated with all aspects of the fusion materials and resource cycle (fusion fuel cycle) of Tokamak magnetic fusion powerplants using deuterium and tritium fuel.

APPROACH

The technical approach selected to meet the project objectives is to first develop generic descriptions of the deuterium-tritium-lithium fusion fuel cycle and its support facilities. Potential environmental releases from these facilities will be identified, and the current control measures to limit these releases will then be assessed to determine their effectiveness. Lastly, areas where environmental control technology should be developed will be identified.

Several alternative fusion material cycles will be analyzed, all based on the production of electricity using the deuterium-tritium-lithium fuel cycle. Lithium forms considered will be liquid natural lithium and isotopically enriched solid lithium compounds.

Fusion reactor design envelopes will be specified and will serve as a basis for determining material requirements. Materials flow to and from a fusion powerplant will be characterized. The entire materials cycle will be analyzed from resource extraction to ultimate disposal for all materials, resulting in a potential major impact on the fusion fuel cycle.

The source of each significant material required for fusion will be identified, and processes and facilities required to prepare the material for use in a powerplant will be investigated. A mass balance will be developed,and significant effluents, identified. Estimated release rates will be compared to existing standards and regulations, which are expected to be modified. Where standards do not exist, the toxicity of the materials will be evaluated. Materials to be addressed will definitely include deuterium, tritium, helium, lithium, beryllium, and niobium; other materials may be included when the reactor design envelope has been specified.

PROGRESS AND RESULTS

Fusion powerplant materials requirements were determined for two Tokamak magnetic fusion reactor designs: Option 1 incorporates a liquid lithium-cooled blanket with no neutron multiplier; Option 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 were determined for the principal fusion reactor materials: niobium, lithium, beryllium, deuterium, and tritium.

The deuterium requirements are met by heavy water extraction and electrolytic decomposition. Canadian heavy water production, in excess of 3000 metric tons per year, is expected to supplement U.S. production at Savannah River, Georgia, which is 165 metric tons per year. The environmental effluent of greatest concern associated with the production of heavy water is hydrogen sulfide released to water. During normal operation, electrolysis will not release any harmful pollutants to either air or water.

The initial tritium inventory for fusion powerplants will be obtained from tritium production facilities dedicated principally for strategic materials. The periodic replacement requirements will be obtained from the blanket breeding in lithium and associated tritium extraction systems of the fusion powerplant. The only important effluent associated with tritium production is tritium itself, ^{3}H, a beta-emitting radioactive isotope of hydrogen with a half-life of 12.3 years. An unknown but probably small fraction of normal released tritium would be attributed to the increment introduced to meet initial fusion powerplant inventories. The Savannah River tritium production plant normally releases about 10^{5} curies per year to the atmosphere and also 10^{4} curies per year to water. There are no standards limiting the amount of tritium discharged from facilities; rather, the standards apply to the allowable dose to individuals, from which maximum allowable concentrations in the environment are determined.

The control of tritium effluents from a fusion powerplant will require a multiple-barrier containment system to prevent the release of tritium gas or tritiated water. The overall goal is to reduce the tritium loss to the environment to less than 10 curies per day. The final tritium barrier is a containment structure shell enclosing the entire reactor hall. Along with an emergency tritium containment system and a tritium effluent removal system, this barrier should be adequate to prevent the escape of any abnormal tritium releases within the reactor building to the environment.

Helium production from natural gas or helium releases from the fusion powerplant do not emit any significant or harmful materials to

the atmosphere or water table. Abnormal operating conditions also will not result in harmful pollutant releases to the biota.

The proven U.S. lithium reserve and recoverable resources are approximately 3×10^6 metric tons, which should be more than adequate to supply the initial inventory and replacement requirements for fusion powerplants. The major effluents from lithium mining and metal production are airborne particulates of lithium compounds or gaseous effluents; of the gaseous effluents, only hydrogen sulfide and sulfur dioxide are of environmental significance. The releases are well within the present Environmental Protection Agency standards and the limits of current environmental control technology.

Reserves of beryllium are somewhat uncertain. Although there are several known deposits of beryllium crystals or pegmatitic ores, recovery is not economically attractive with current technology. In the mining and fabrication of beryllium, the only effluent release is beryllium dust. However, since beryllium is toxic, potential release of this material is carefully controlled to within Environmental Protection Agency standards by current environmental control technology.

At present, there is no domestic production of niobium, and the United States has no deposits of niobium that can be classified as reserves. According to the most recent data published by the Bureau of Mines, world proven reserves are 10^7 metric tons of contained niobium. Of this amount, Brazil has 77 percent; the African countries, 10 percent; and Canada, 6 percent. The remaining 7 percent is in Eastern Europe and the Soviet Union.

In the milling and fabrication of niobium, the airborne effluent is primarily niobium dust from thermite reactors. Additional effluents of hydrogen fluoride vapor and ammonia gases accompany the niobium-tantalum process for producing niobium metal. These effluents are readily controlled by current environmental control technology.

The effect of supplying the above materials to the fusion fuel cycle and the adequacy of the present or planned environmental control technology for reducing the associated effluents is being assessed. The resource production facilities considered operate under existing standards for liquid, solid, and airborne effluent releases. Only airborne effluents are significant.

The anticipated effluent concentrations of the fusion fuel cycle compared to the maximum levels allowed under current regulations are listed in Table 18. When compared to the current maximum ambient air concentration levels allowed, present or planned environmental control technology appears to be adequate.

PLANS FOR NEXT PERIOD

In fiscal 1980, an independent review and analysis of current fusion facilities that presently generate or will generate radioactive wastes or effluents to the environment will be performed. Those fusion facilities in operation or under construction will be considered including the magnetic fusion facilities -- Tokamak Fusion Test Reactor, Tritium Systems Test Assembly, and Fusion Materials Irradiation Test Facility. The analysis will be extended to the magnetic fusion Engineering Test Facility, which is presently in the preconceptual stages of design. In addition, activation products and tritium inventories will be analyzed, and the toxicities of significant radioactive nuclides, evaluated. The results of the analysis will indicate the environmental impact of the accumulated activated wastes and possible effluents from operations through disposal. Based on these analyses, the experimental data needed to support the environmental control technology of fusion facilities will be evaluated. Recommendations as to possible experiments to support these needs will be made, and appropriate experiments will be designed and performed.

REPORTS PUBLISHED

Teofilo, V.L., et al., "The Fusion Fuel Cycle: Material Requirements and Potential Effluents," PNL-3182, Pacific Northwest Laboratory, June 1980.

PROJECTED MILESTONES

- Fiscal 1981
  - Complete fusion facility analysis
    - -- Tritium analysis
    - -- Radioactive material inventory
    - -- Assessment of inertial confinement fusion facilities
  - Evaluate and control radioactive material inventories at the Engineering Test Facility
  - Design environmental control technology experiment

Table 18. Anticipated Effluents of Fusion Fuel Cycle Compared to Present Standards

Annual Effluents Anticipated From Fusion Fuel Cycle		Present Environmental Standards, Annual Average	
Effluent	Air Concentration (g/m^3)	Effluent	Air Concentration
$LiALSi_2O_6$ (dust)	$2x10^{-5}$	Li(LiH)	25 $\mu g/m^3$[a]
Li_2CO_3 (dust)	$2x10^{-5}$		
Li_2NaPO_4 (dust)	$3x10^{-6}$		
Nb (dust)	$6.3x10^{-6}$	Nb	0.05 mg/m^3
Be ore (dust)	$4.1x10^{-6}$	Be	0.01 $\mu g/m^3$
$Be(OH)_2$ (dust)	$5.6x10^{-4}$		
D	$3.0x10^{-6}$	D	No standard
Particulates	0.18	Particulates	75 $\mu g/m^3$[b]
SO_2	$1x10^{-5}$[c]	SO_2	80 $\mu g/m^3$
	$1.3x10^{-2}$[b]		
CO_2	0.13	CO_2	$9x10^3$ mg/m^3
NO_x	$4.4x10^{-3}$	NO_x	$1x10^2$ $\mu g/m^3$
HF	$1.2x10^{-3}$	HF	3 ppm
NH_3	$2.6x10^{-2}$	NH_3	18 mg/m^3
H_2S	10^{-5}	H_2S	15 mg/m^3
T gaseous	10^{-10} Ci/cm^3	T	$4x10^{-5}$ Ci/ml
liquid	10^{-5} Ci/cm^3		

[a] Eight-hour time-weighted average; occupational number only.
[b] Standards for particulates, sulfur oxides, and nitrogen oxides vary according to state or region.
[c] From lithium production.
[d] From heavy water production.

- Fiscal 1982

  - Initiate environmental control technology experiments

SUB-SEABED DISPOSAL PROGRAM

ORGANIZATION AND CONTRACT NUMBER

Sandia Laboratories
AT(29-1)-789

PRINCIPAL INVESTIGATORS

D.R. Anderson
D.M. Talbert

OBJECTIVES

The objectives of the program are to determine the environmental and technical feasibility of disposing of high-level radioactive wastes into the deep ocean floor in geologically stable and biologically inactive sediments and to develop and maintain a capability of assessing the ocean

radioactive waste disposal programs of other nations.

APPROACH

The approach is first to assess and define an entire disposal system and to determine the feasibility of sub-seabed disposal from firm scientific and technical information. The safety and environmental effects of such a system are then to be determined, and the requirements to carry out sub-seabed disposal, defined, based on the findings of the first program and subject to considerations of both feasibility and safety of the system. The final step is to prove system capability with a combination of tests and demonstrations.

An integral part of the seabed disposal program is the Seabed Working Group of the Nuclear Energy Agency Radioactive Waste Management Committee, with representatives from the United Kingdom, France, Japan, Canada, the Netherlands, and the United States. The objectives of this group, which meets annually, are to provide a forum for discussion of technical progress, plan future experiments, coordinate joint cruises and experiments, share facilities and unique test equipment, exchange technical information, and maintain cognizance of international policy issues relating to seabed disposal.

PROGRESS AND RESULTS

The following activities were accomplished:

- Mathematical models were developed to evaluate sediment column response to emplacement and heat burden and to evaluate the sediment column response to quasi-static emplacement.
- Development was begun on a biological transfer model to address pathways and rates of ion transport.
- An initial barrier assessment of bulk calcareous sediments was completed for selected ions.
- The assessment of retention factors of the red clay sediment column was continued for ions of the reference waste, using both laboratory columns and mathematical models.
- The natural pore water movement was quantified by chemical and thermal means.
- The effects of temperature were determined on the permeabilities measured in the laboratory.
- The detailed assessment of the vertical consistency of the sediment column in MPG-1 was continued.
- The initial screening of canister materials using electrochemical methods was completed.
- Techniques were developed for culturing, handling, storing, and analyzing hypobaric micro-organisms.
- The analysis of deep-sea near-bottom plankton samples was continued.
- A multiple open-closing net system and an animal trap respirometer for free vehicle use were developed.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Energy, Division of Waste Isolation, and incorporated into the National Waste Terminal Storage Program.

REPORTS PUBLISHED

Anderson, D.R., "Nuclear Waste Disposal in Subseabed Geologic Formations: The Seabed Disposal Program," SAND78-2211, Sandia Laboratories, May 1979.

Anderson, D.R., "Proceedings of the Fourth Annual Seabed Working Group Meeting," Albuquerque, New Mexico, March 5-7, 1979, August 1979.

Anderson, R.N., M.A. Hobard, and M.G. Langseth, "Geothermal Convection Through Oceanic Crust and Sediments in the Indian Ocean," Science, (submitted).

Corliss, B.H., et al., "A Paleoenvironmental Model for Cenozole Sedimentation in the Central North Pacific," The Heezen Memorial Volume, John Wiley & Sons, 1979.

Dawson, P., "Emplacement and Sedimentary Response," 19th Annual American Society of Mechanical Engineers Symposium, Geological Disposal of Nuclear Waste, March 15-16, 1979.

Heath, G.R., et al., "Geochemical and Sedimentological Assessment of Deep-Sea Sediments," Progress Report for Period January 1, 1978, to December 31, 1978, February 1979.

Heath, G.R., "Ion Transport in Deep-Sea Sediments," 19th Annual American Society of Mechanical Engineers Symposium, Geological Disposal of Nuclear Waste, March 15-16, 1979.

Hollister, C.D., "Geologic Siting Considerations for the Disposal of Radioactive Waste Into Submarine Geologic Formations," 19th Annual American Society of Mechanical Engineers Symposium, Geological Disposal of Nuclear Waste, March 15-16, 1979.

Hollister, C.D., W.P. Bishop, D.D. Deese, "Siting Considerations and Political Implications for the Disposal of High Level Nuclear Wastes Beneath the Deep Sea Floor," Marine Sciences and Ocean Policy Symposium: A Definition of the Issues and a Search for a Consensus on Multiple Uses, University of California, Santa Barbara, June 17-20, 1979.

Hollister, C.D., B.H. Corliss, and D.R. Anderson, "Submarine Geologic Disposal of Nuclear Waste," International Symposium on the Underground Disposal of Radioactive Wastes, IAEA-SM-243/99, July 1979.

Krumhansl, J.L., and G.R. Hadley, "Thermal and Chemical Properties of Saturated Marine Clays in a Near Field Environment," presented at Seabed Working Group of the Nuclear Energy Agency Radioactive Waste Management Committee, Paris, France, September 1979.

Krumhansl, J.L., and D.F. McVey, "Near-Field Interactions," 19th Annual American Society of Mechanical Engineers Symposium, Geological Disposal of Nuclear Waste, March 15-16, 1979.

McVey, D.F., D.K. Gartling, and A.J. Russo, "Thermal/Fluid Modeling of the Response of Saturated Marine Red Clays to Emplacement of Nuclear Waste," presented at Seabed Working Group of the Nuclear Energy Agency Radioactive Waste Management Committee, Paris, France, September 1979.

Seabed Programs Division, "Subseabed Disposal Program Plan," SAND79-1157, Sandia Laboratories, Draft, September 1979.

Smith, K.L., Jr., G.A. White, and M.B. Laver, "Oxygen Uptake and Nutrient Exchange of Sediments Measured In-Situ Using a Free Vehicle Grab Respirometer," Deep Sea Research, Vol. 26A, pp. 337 to 346, Pergamon Press Ltd., 1979.

Talbert, D.M., "Seabed Disposal Program Annual Report, January to December 1977," Vol. I, SAND78-1359, Sandia Laboratories, January 1979.

Talbert, D.M., "Seabed Disposal Program Annual Report, January to December 1977," Vol. II -- Appendices, SAND78-1359, Sandia Laboratories, January 1979.

Talbert, D.M., "Subseabed Disposal Program Annual Report, January to December 1978," Vol. I and II, SAND79-1618, Sandia Laboratories, October 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Energy.

TRANSPORTATION SAFETY STUDIES

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATORS

R.E. Rhoads
A.L. Franklin

OBJECTIVE

To ensure adequate protection of man and the environment when transporting energy material, it is necessary to understand the safety risks and potential environmental effects involved in shipping such material, both in normal transport and under accident conditions. The objective of the transporation safety studies project is to assess these potential effects in terms of risk. Initially, the scope involved the development and use of a model to assess the risk associated with the shipment of radioactive material. The program has since been expanded to include nonnuclear energy-related materials. Risk is defined as the probability that an undesirable event will occur, multiplied by the type and degree of consequences.

APPROACH

The analysis method developed in this program can be used to systematically evaluate the risks involved in shipping various energy materials and can also be used to

- Provide information to assist in determining the acceptability or unacceptability of the risk;
- Identify the principal factors controlling the risk, to provide a basis for selecting corrective or preventive action should the risk be judged unacceptable;
- Permit comparison of overall transportation risks between different energy systems; and
- Permit comparison of the risk in energy material transport with that of other commonly shipped hazardous materials (e.g., chlorine, pesticides).

Risk assessments are performed by comprehensive investigation of all the relevant system parameters (packaging or container characteristics, transportation accident characteristics, shipment activity, etc.), using a consistent methodology. An added advantage of such an approach is that it inherently identifies areas where sufficient data are not available to fully understand the safety of the system, thus providing for additional studies within or outside the Environmental Control Technology Division.

PROGRESS AND RESULTS

During the past year, a number of energy material transportation risk assessments have been carried out. Final reports were published 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. Additional studies were undertaken to assess the risk of shipping Department of Energy transuranic wastes and low-level reactor wastes, and to characterize the transportation requirements for the nuclear fuel cycle.

The assessment of the risk of transporting gasoline by truck predicted about 28 fatalities per year from 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-free analysis methodology employed in previous studies in this project. The results were in agreement with available historical data. The peer review of the draft report was completed, necessary revisions were made, and the final report was published.

The risk to the public in the mid-1980s from spent fuel shipments by truck was found to be much lower than the risk from many other man-caused or natural events. The analysis of the risk from train shipments of spent fuel in the mid-1980s showed the risks from train shipments of spent fuel to be comparable to the risks from truck shipments. Greater consequences are possible with train casks because of the larger spent fuel inventories. Peer review of the draft assessment of the risk of shipping spent fuel by truck was completed, and the final report was published.

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.

The analysis of the risk of shipping chlorine by train was also completed. The analysis predicted that about 11 fatalities per year would occur from chlorine rail shipments in the mid-1980s.

Reviews of the draft report on the conceptual design of a shipping container for transporting solidified high-level waste by rail were completed. The final report was published in December as PNL-2244 (Peterson and Rhoads, 1978).

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 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. The analysis of the risk of transporting low-level reactor wastes was also completed using the revised methodology.

The analysis of the risk of transporting contract-handled Department of Energy transuranic wastes was completed. The analysis was based on transportation, using existing shipping systems.

Nuclear fuel cycle transportation systems were characterized to develop the basic system description information needed to perform risk assessments.

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, which will complete research in this project.

REPORTS PUBLISHED

Andrews, W.B., et al., "An Assessment of the Risk of Transporting Liquid Chlorine by Rail," Draft, September 1979.

Andrews, W.B., et al., "Pacific Northwest Laboratory (PNL) Spent Fuel Transportation and Handling Facility Models," PNL-3105, Pacific Northwest Laboratory, Richland, Washington, 1979.

Geffen, C.A., et al., "An Assessment of the Risk of Transporting Propane by Truck and Train," Draft, September 1979.

Geffen, C.A., "Potential Safety and Environmental Concerns in Petroleum Transportation," PNL-SA-7676A, presented at the First International Symposium on Transportation Safety in San Diego, California, July 11-13, 1979.

Greenborg, J., et al., "Application of ALARA Principles to Shipment of Spent Nuclear Fuel," PNL-SA-7902A, Abstract for submittal to American Nuclear Society Meeting in San Francisco, November 1979.

PROJECTED MILESTONES

None

DEVELOPMENT OF MATERIAL CONSTITUTIVE DESCRIPTIONS FOR ENVIRONMENTAL AND SAFETY CONTROL ASSESSMENTS OF ENERGY MATERIAL SHIPPING CONTAINER SYSTEMS

ORGANIZATION AND CONTRACT NUMBER

Argonne National Laboratory
W-31-109-ENG-38

PRINCIPAL INVESTIGATORS

R.A. Valentin
H.C. Lin

OBJECTIVE

The overall objective of this project is the development of constitutive descriptions for the materials used in shipping container systems, with particular emphasis on the modeling of rapid transient loading. These descriptions and the related containment failure analyses and experiments will provide the basis for developing a rational margin of confidence in such container systems.

APPROACH

To achieve this overall objective, the scope of effort has been divided as follows:

- Assessment and application of endochronic plasticity theory for the dynamic analysis of energy material shipping containers,
- Failure analysis of energy material shipping containers and analytic representation of dynamic failure modes and effects,
- Constitutive representation of thermal/structual interactions,
- Development of analytical methods for estimating and bounding structural damage to energy material shipping containers,
- Development of analysis support experiments, and

- Design optimization of energy material shipping containers subjected to extreme loading conditions.

PROGRESS AND RESULTS

This activity was initiated during the last quarter of fiscal 1977, with primary emphasis on assessing the endochronic theory of plasticity and its potential for aiding in the dynamic analysis of energy material shipping containers. Essentially the entire effort during fiscal 1978 was devoted to this assessment.

During fiscal 1979, work was centered on completing a user-oriented finite element code that would allow comparison between endochronic plasticity and conventional treatments for a variety of impact conditions. This code was restricted to axisymmetric problems and to shell structures. Additional work was initiated on large strain formulations that allow the calculation of penetration dynamics resulting from impact against small diameter rigid structures, e.g., those used in drop tests for puncture of shipping containers.

Alternate formulations of endochronic plasticity that allow unloading in a manner closer to pure elastic unloading were developed during this period. The objective of this work was to remove certain objections to the endochronic formulation that cause a creeplike behavior during the time when force is applied to a structure.

To provide a method for global estimations of structural damage, work was initiated on a distributed damage formulation. The objective is to assign to a given shipping cask, subjected to known loads, a damage index analogous to the lifetime calculations used in fatigue analysis that would indicate nearness to failure -- with failure being defined as crack initiation. Work during fiscal 1979 concentrated on developing the initial formalism and demonstrating its use in certain simple applications.

Due to the projected termination of this activity at the end of fiscal 1979, a considerable effort during the latter part of the fiscal year was devoted to preparing draft material for eventual publication to provide proper documentation of the completed work. All new work on the program was thus stopped, and existing work in progress was placed in a form that would allow eventual publication (after any editing resulting from reviews of the draft reports).

PLANS FOR NEXT PERIOD

None. Work was terminated at the end of fiscal 1979.

REPORTS PUBLISHED

"Applications of Endochronic Plasticity in the Dynamic Finite Element Analysis of Structures," Proceedings, 5th International Conference on Structural Mechanics in Reactor Technology, Paper L9/3, Berlin, West Germany, August 13-17, 1979.

"The Applications of Endochronic Plasticity Theory in Modeling the Dynamic Inelastic Response of Structural Systems," J. Applied Mechanics (submitted).

"Continuous Damage Theory of Structures and Its Application to Impact Loading of Shipping Containers," Technical Memorandum ANL-CT-80-17, ANL Components Technology Division.

"The Use of Endochronic Plasticity for Multi-Dimensional Small and Large Strain Problems," Technical Memorandum ANL-CT-79-19, ANL Components Technology Division.

PROJECTED MILESTONES

None

DEVELOPMENT OF STRUCTURAL AND THERMAL ANALYSIS METHODS FOR ENVIRONMENTAL AND SAFETY CONTROL ASSESSMENTS OF ENERGY MATERIAL SHIPPING CONTAINER SYSTEMS

ORGANIZATION AND CONTRACT NUMBER

Los Alamos Scientific Laboratory
W-7405-ENG-36

PRINCIPAL INVESTIGATOR

T.A. Butler

OBJECTIVE

The objective of this program is to develop experimentally substantiated analytical techniques for assessing the environmental protection and

public safety provided by Department of Energy shipping container systems. The techniques developed will predict the occurrence and degree of containment failure in severe accident conditions.

APPROACH

Theoretically exact solution techniques for container accident response problems do not exist, primarily because of the difficulties in mathematically modeling the geometric configurations and the nonlinear behavior of container system deformations under accident conditions. The Los Alamos Scientific Laboratory approach is to approximate container response with analytical methods using nonlinear computer codes. The codes employ both the finite element method and lumped-mass techniques. A key part of the development work is experimental substantiation of the computer codes with test data obtained at the Los Alamos Scientific Laboratory and at other Department of Energy contractor laboratories.

PROGRESS AND RESULTS

A series of drop tests was performed with Battelle Columbus Laboratory at Los Alamos Scientific Laboratory's K-Site drop tower to determine the margins to failure for scale models of representative containers. The secondary test objectives were to study scaling laws and to provide data for verifying analytical techniques. In addition to working with Battelle Columbus Laboratory in planning and performing the tests, Los Alamos performed an extensive post-test investigation of three models that were shielded with depleted uranium.

The two-dimensional computer code CRASHC, developed during fiscal 1977, was improved and used to simulate the end-on drop tests from the test series described above. In particular, the 70-foot drop test of a 1/4-scale container shielded with lead was studied extensively. Results of this study and other work with CRASHC were summarized in a topical report.

The lumped mass computer code SIC, which predicts the tip velocity of a container at secondary impact (slap-down), was used to predict the worst-case primary impact angles for the model tests. Data from the tests were then used to determine the accuracy of the predictions. Data from a drop test of the Knapp Mills container at the Oak Ridge National Laboratory were also used to verify SIC calculations.

Railcar container system response to impact was studied extensively using the Los Alamos computer code RICTL. Data from a series of full-scale tests performed at the Savannah River Plant during fiscal 1978 were reduced and then used for verifying and improving the analytical approach.

PLANS FOR NEXT PERIOD

None

REPORTS PUBLISHED

Bartholomew, R.J., and T.A. Butler, "Analysis of Railcar-Shipping Container System Response to Impact Conditions," LA-8122-MS, Los Alamos Scientific Laboratory, January 1980.

Butler, T.A., "The Effects of Drop Testing on Scale Model Shipping Containers Shielded With Depleted Uranium," LA-8120-MS, Los Alamos Scientific Laboratory, February 1980.

Butler, T.A., "A Program to Develop Analytical Tools for Environmental and Safety Assessment of Nuclear Material Shipping Container Systems," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Butler, T.A., E.G. Endebrock, and J.B. Payne, "CRASHC--A Two-Dimensional Code to Compute the Response of Axisymmetric Shipping Containers to End-On Impacts," LA-8121-MS, Los Alamos Scientific Laboratory, January 1980.

Cook, W.A., "Endochronic Viscoplasticity Model," LA-8097-MS, Los Alamos Scientific Laboratory, October 1979.

Cook, W.A., "Finite Element Linear Models for Symmetrically Loaded Shells of Revolution," Proceedings of 5th International Seminar On Computational Aspects of Finite Element Methods, August 20-21, 1979, Berlin, West Germany.

Cook, W.A., "A Finite Element Model for Nonlinear Shells of Revolution," Proceedings of 5th International Conference On Structural Mechanics in Reactor Technology," August 13-17, 1979, Berlin, West Germany.

Cook, W.A., "A Finite Element Model for Nonlinear Shells of Revolution,"

LA-8138-MS, Los Alamos Scientific Laboratory, November 1979.

Straight, J.W., "Nuclear Shipping Container Secondary Impact Analysis," LA-8081-MS, Los Alamos Scientific Laboratory, October 1979.

PROJECTED MILESTONES

None

DEPARTMENT OF ENERGY TRANSPORTATION STATISTICS DATA BANK

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATORS

P.J. Mason
R.A. Tannert

OBJECTIVE

The objective of this program is to develop and implement a central data base information facility concerning every movement of material to and from every Department of Energy contractor site in the United States, whether the material is moved by commercial, government, or public carrier. The data bank will provide management with the capability to evaluate how well the Department manages its transportation costs, more coherent data in administrative and legislative proceedings, and improved liaison with carrier management.

APPROACH

A system was developed through the extensive use of traffic management workshops. Other data bank systems were reviewed to prevent duplicate collection of data, and computer programs were developed that would automatically interface with systems such as the Nuclear Materials Management Safeguards and Security. Guidance was received from the Department of Energy concerning its information needs, and all data elements to be collected for each shipment were analyzed.

All contractor site participants collect and submit data to the data bank. Special management exception reports can be prepared and issued as deemed appropriate. The programming staff produces the desired reports in 1 to 5 days.

PROGRESS AND RESULTS

Ten additional contractor facilities were implemented in the data base. At the end of fiscal 1979, transportation data for 18 Department of Energy contractor sites were being collected and reported. Participating contractors included all Idaho, Nevada, Oak Ridge, Washington, and Chicago Operations Offices.

Approximately 7000 nonnuclear and 1500 nuclear transactions were processed per month. Nonnuclear data are accepted from contractor sites via punched cards, magnetic tape, computer link, or form UCN-12622. Transactions on nuclear material are automatically captured by interface software with the Nuclear Materials Management and Safeguards System.

Monthly reports were produced for traffic management at each facility, and the quarterly Transportation Activity Report was produced for each Operations Office. Approximately 15 data retrieval requests were processed against the data bank. Retrievals were primarily for hazardous or nuclear material, and the average response time was 2 days.

PLANS FOR NEXT PERIOD

The implementation plan for fiscal 1980 will include the installation of Albuquerque Operations Office contractors. Data collection, analysis, and retrieval is projected to be greater than 90-percent complete for the movement of material to and from every Department of Energy contractor site in the United States. A prototype online retrieval system is scheduled to be developed for Oak Ridge Operations.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

STUDY OF PHYSICAL PARAMETERS OF TRANSPORTATION ACCIDENTS

ORGANIZATION AND CONTRACT NUMBER

Sandia Laboratories
DE-AC04-76DP000789

PRINCIPAL INVESTIGATORS

J.D. McClure
A.W. Dennis

OBJECTIVE

The objective of this task is to describe the transportation accident environment to which radioactive material packages may be exposed. These basic environmental descriptions are required to determine the risk of shipping radioactive material and to prepare environmental impact statements.

APPROACH

The basic approach used in this type of study has been to search historical records for the details of air, highway, railroad, and marine transport accidents. From this data base, a description or profile of the various accident types can be formed, and the probability of occurrence of selected environmental parameters can then be determined.

PROGRESS AND RESULTS

The basic studies in this series, as they were originally conceived, have been completed or are nearing completion. The reports for these events are given below. A draft report on the severity of marine transport accidents will be published in October 1979.

PLANS FOR NEXT PERIOD

The transportation accident environment severity studies are generic documents in the sense that they have been used as input for various risk analyses and as source documents on the profile of transportation accidents in general. An additional use of these studies is for input to the revision of U.S. and international regulations. The revision of International Atomic Energy Agency Safety Series No. 6, Regulation for the Safe Transport of Radioactive Materials (1973 ed), is tentatively scheduled to be completed in 1983. The studies mentioned above and other regulatory assessments will be used to support the regulatory revision process.

The Transportation Technology Center at Sandia Laboratories was established in October 1978. Studies related to the transportation of radioactive materials were previously funded through the Environmental Control Technology Division and are now being funded through the Office of Nuclear Energy.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- Fiscal 1980 -- Additional Study, Marine Transport Accident Environment

ATOMS ON THE MOVE EXHIBIT

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge Associated Universities
AT(40-1)-GEN-33

PRINCIPAL INVESTIGATOR

R. Content

OBJECTIVE

The objective of this project is to prepare an exhibit primarily designed for conferences, meetings, and other appropriate locations. It illustrates that nuclear materials are not moved until they are safely packaged.

APPROACH

At exhibit showings, a teacher/demonstrator will describe and show the various methods of handling, containing, and shielding radioactive materials.

PROGRESS AND RESULTS

During fiscal 1979, this exhibit was displayed at seven different conferences and meetings (Table 19) and was seen by almost 10,000 people, including Federal Government staff, chemists, engineers, and industrial safety personnel.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of the Assistant to the Secretary for Public Affairs.

Table 19. Fiscal 1979 Summary of "Atoms on the Move" Exhibit Showings

Place Shown	Date	Attendance
National Defense Transportation Association Expo Washington, D.C.	October 1-4, 1978	400
National Science Teachers Association Atlanta, Georgia	March 23-26, 1979	2000
Association County Commissioners of Georgia Atlanta, Georgia	April 8-10, 1979	700
International Trucking Show Atlanta, Georgia	May 16-18, 1979	3000
Safety Expo '79 New York, New York	June 26-28, 1979	1200
National Association of Counties Kansas City, Missouri	July 15-18, 1979	1400
International Association of Fire Chiefs Kansas City, Missouri	September 16-20, 1979	1078
		9778

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

FULL-SCALE IMPACT TESTING FOR ENVIRONMENTAL AND SAFETY CONTROL ASSESSMENTS OF ENERGY MATERIAL SHIPPING CONTAINER SYSTEMS

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATORS

R.D. Seagren
W.D. Box
R.C. Muller

OBJECTIVES

Current Federal regulations require the Department of Energy's large radioactive materials shipping containers (casks) to survive a 30-foot (9-meter) drop onto an essentially unyielding surface in the orientation for which the most damage is expected. The objectives of this overview and assessment task are to (1) experimentally determine whether casks can satisfy these regulations without sustaining damage that would release radioactivity to the environment and (2) demonstrate that scale-model tests and analytical techniques developed by other Environmental Control Technology Division overview and assessment contractors can be confidently used in place of expensive full-scale drop tests.

APPROACH

Retired casks that are reasonably similar in materials and construction to modern shipping containers are available at modest cost. Drop tests of instrumented casks provide records of strain history and experimental information on

damage to seal and closure designs as well as an indication of the type (e.g., gas, liquid) and amounts of activity that might be released if loss of containment should occur.

The tests provide engineering data on the behavior of these casks under severe conditions and consequently provide information necessary to substantiate mathematical models for predicting cask damage and, more importantly, potential survivability. The release of radioactive materials to the environment that might occur in an extremely severe accident is most likely through the seal area of the cask.

PROGRESS AND RESULTS

Two 1/2-scale models of a Battelle Columbus Laboratories prototype spent-fuel cask were subjected to 9-meter drop tests at the Oak Ridge National Laboratory Tower Shielding Facility. One model contained lead shielding, and the other was shielded with a uranium-molybdenum alloy. Each of the models weighed approximately 2 metric tons.

These tests were part of a cooperative effort among Battelle Columbus Laboratories, Los Alamos Scientific Laboratories, and the Oak Ridge National Laboratory to demonstrate the predictability of scaling. The opposite ends from the closures of both models were impacted at an angle of 30 degrees from the horizontal, thus subjecting the closure ends to the severe stresses encountered during the secondary impacts. Both models developed small leaks in the closures.

Damage to the models was as predicted from the results of 1/8- and 1/4-scale model tests previously performed by Los Alamos Scientific Laboratories, thus enhancing the viability of model testing.

PLANS FOR NEXT PERIOD

None

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

TRANSPORTATION SYSTEM SAFETY EVALUATION

ORGANIZATION AND CONTRACT NUMBER

Sandia Laboratories
DE-AC04-76DP000789

PRINCIPAL INVESTIGATORS

R.E. Luna
R.T. Reese
R.P. Sandoval

OBJECTIVES

This program provides a comprehensive safety evaluation of the shipping systems used for nuclear materials. The program includes an experimental assessment of the response of the containers themselves, the contents, and the containers and contents. The environments considered in the experimental evaluations include extreme trauma and simulated intentional acts. The information needed is whether a fission product source term could exist in these environments and, if one does, to measure the quantities describing it. With measured source term data or data indicating a lack of a source term, objective safety analyses can be performed in terms of possible radiological consequences and associated risk analyses.

APPROACH

With the formation of the Transportation Technology Center, additional funding became available and the direction of the program changed. The initial direction was to determine the response of the packages to extreme trauma and intentional acts only. The portion of the funding for this program from the Environmental Control Technology Division was focused on continuing the determination and evaluation of package response.

The new approach is to determine the range of possible adversary actions that would complete the work in this area. Generic and plate models representing current and anticipated package designs will then be subjected to simulated intentional acts and various extreme conditions. From these tests on packages containing surrogate

and irradiated waste (spent fuel initially), the fission product source term will be determined. Radiological consequence and risk analyses will be performed using these data to determine the level of protection offered the public.

PROGRESS AND RESULTS

Generic model and plate representations of current and anticipated containers have been designed and fabricated. Initial tests have been performed on plate models exposed to full-scale intentional acts. From this and previous work, it has been shown possible to breach a container with devices that focus energy. To date, no effective mitigation devices have been formed other than the very effective designs of containers themselves. An adversary would require skill, training, opportunity, and access to possible devices or explosives.

In terms of extreme trauma conditions, work was completed on defining the anticipated environments for normal transport. The concern is to determine the response of the package contents (with initial emphasis on spent light water reactor fuel) for various transport environments. Because a significant body of work has been performed on simulated reactor accidents and reprocessing of spent fuel, this work was reviewed in terms of what additional testing would be required to determine cask and contents response with the normal transport conditions outlined.

PLANS FOR NEXT PERIOD

The emphasis in this next year will be on experimentally determining the existence of and parameters for possible fission product source terms for intentional acts and extreme thermal environments. In addition, a concerted effort will be made to establish correlation among the responses of various surrogate and irradiated fuels for various environments.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

FULL-SCALE VEHICLE TESTING PROGRAM/ TRANSPORTATION SYSTEMS TEST SUPPORT

ORGANIZATION AND CONTRACT NUMBER

Sandia Laboratories
University of Texas
DE-AC04-76DP000789

PRINCIPAL INVESTIGATORS

H R. Yoshimura
J.E. Hamann
M. Huerta
D. Klein
W.B. Leisher
R.A. May
H.J. Rack
L.E. Romesberg

OBJECTIVES

The project objectives are to provide technical support to the Transportation Technology Center and to complete any remaining tasks on the spent fuel cask test program.

APPROACH

The approach taken to meet these objectives is to respond to the Transportation Technology Center and provide technical support as needed.

PROGRESS AND RESULTS

The University of Texas was contracted to provide multidimensional thermal modeling of the 74-ton spent fuel cask/railcar, which was subjected to a fully engulfing fossil-fuel pool fire test in January 1978. This task supplements the pre-test thermal analysis work performed in support of the fire test. The thermal modeling performed by the University of Texas should account for the effects of fire nonuniformity; interaction of the fire, car, and cask; lead melt; coolant vaporization; and variable cask absorptance.

A metallurgical examination was conducted to determine the failure mechanisms involved in the cracking of the outer stainless steel shell of the 74-ton rail cask during the pool fire test. The final report, which describes the results of the metallurgical investigation, is in draft form.

One-eighth and one-quarter scale models of a generic overpack low-level waste transport container were fabricated under this activity. Documentary coverage was provided in support of the low-level waste package model test program.

At the request of Bundesanstalt fuer Materialpruefung, a high-speed impact test (129 meters per second onto an unyielding surface) was conducted by Sandia on an 18-B plutonium nitrate shipping container modified by the Federal Republic of Germany. The test provided the impact environment specified in NUREG-0360, "Qualification Criteria to Certify a Package for Air Transport of Plutonium." Similar containers have been subjected by the German organization to extended fire, dynamic crush, and low-altitude helicopter drops onto semi-hard

targets. A comparison of the results indicated that the package damage produced by the high-speed impact test conducted by Sandia was significantly greater than that produced by the dynamic crush or helicopter drop tests conducted by the Germans.

PLANS FOR NEXT PERIOD

This activity terminates in fiscal 1979. Uncompleted tasks will be transferred to programs in the Transportation Technology Center.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

SCALE MODEL IMPACT TESTING FOR ENVIRONMENTAL AND SAFETY CONTROL ASSESSMENTS OF ENERGY MATERIALS SHIPPING CONTAINER SYSTEMS

ORGANIZATION AND CONTRACT NUMBER

Battelle Columbus Laboratories
W-7405-ENG-92

PRINCIPAL INVESTIGATOR

R.J. Burian

OBJECTIVE

The objective of this experimental scale model program is the collection of data on the structural response of spent fuel and high-level waste energy material shipping container systems to assess the effects of impact accident environments on safety and the potential environmental consequences. The immediate purpose is to provide information for computer code correlation for codes being developed by other Department of Energy contractors to analyze shipping container accident conditions.

APPROACH

For many years, nuclear energy material has been shipped in carefully engineered casks or shipping containers. As the size, heat rating, and complexity of these systems have increased, so have the demands on engineering design and analysis. Broadly speaking, the technical areas that must be evaluated for safety are criticality, shielding, thermal, and structural. The criticality, shielding, and thermal assessments are relatively well etablished in terms of approaches to analysis, and computer codes have been experimentally substantiated.

This is not yet the case for structural analysis, particularly in the area of dynamic loading. Although many data are available and some simplified computer codes may be used to approximate certain types of hypothetical impact accidents, there are no generally acceptable techniques for analyzing dynamic loading.

The approach used in this program is to conduct a few carefully selected experiments for specified container accident conditions and simulated environments. The containers used in the present experiments are replica-scale models of typical spent fuel and high-level waste shipping casks. These experiments are being closely coordinated with other Department of Energy contractors to provide baseline data for correlation of the computer codes being developed.

The tasks planned in this program to accomplish the overall objective of assessing safety and environmental issues are as follows:

- Engineering and analysis to determine relevant parameters, proper scaling criteria, and scale model design.
- Experimentation with scale models to assess dynamic accident response modes of containment shells, shielding, and radioactive contents -- the models will simulate SS/Pb, SS/U, impact limiter systems, and spent fuel elements. The experiments will include the effects of geometry, temperature, impact direction, thermal stresses, and containment seals. Material property tests will be performed on conventional testing machines for some of the selected model materials, where such information is unavailable.
- Liaison with related Government programs to use Battelle Memorial Institute experimental data to corroborate computer code development, refine risk assessment, aid in interpreting full-scale retired cask experiments, and provide documentary film production.

PROGRESS AND RESULTS

Eighteen models were tested in this series, including 1/8-, 1/4-, and 1/2-linearly scaled models representative of a truck-type shipping cask. Fourteen of the models used lead shielding and four used depleted uranium-2 weight percent molybdenum alloy shielding. The tests were

intentionally designed to produce severe damage, including, if possible, cracking of the structural components, leakage of the seals, and high deformation of the container in general. The tests included drops from 15 to 140 feet onto a steel target which, for practical purposes, is considered essentially unyielding. Three basic orientations were considered (on the basis of preliminary analytical evaluation) to be most likely to produce the greatest damage to the containers: axial (end on), corner center of gravity, and 30° off-angle (slap-down). In 15 of the tests, the models impacted initially on the botton end; in the remaining 3, the models impacted initially on the top end.

On the basis of qualitative examinations of both lead and depleted uranium-shielded models, "scaling relations" appear to be valid for large deformations in the three sizes of models examined. Responses of different size models during the impact event are similar as observed from high-speed motion picture film. Behavior such as localized deformation and overall bowing, as well as the incidence of seal leakage, was similar among the three scale sizes of models. In depleted uranium-shielded models, the bowing produced similar types of separation between adjacent depleted uranium segments. On the basis of comparison of only two models, the size of the separation did not appear to follow scaling relationships. However, scaling validity was indicated for both lead- and depleted uranium-shielded models in the energy absorbed during the initial impact and, for the models tested in the slap-down orientation, in the angular velocity of the model after initial impact. Although qualitatively the bowing of the models tested in the slap-down orientation appears similar, quantitatively the amount of bow showed agreement with scaling predictions in only a few cases. The lack of complete agreement is attributed to large tolerances in the measurements. The slump of the lead for axial drops from up to 140 feet was found to agree with commonly accepted methods for predicting this occurrence in lead-shielded casks.

In addition to the scaling validity assessment, several other phenomena were observed. It was noted that for lead-shielded models dropped bottom-end down from 70 feet and 140 feet in the axial orientation, the lead can pull the cavity shell with it as it slumps. This can result in deformation and weld cracking in the cover recess of the cask. In addition, for these orientations and drop heights, the outer shell welds at the vulnerable bottom end corner undergo extreme stresses, and welds can crack if complete weld penetration was not attained. Another phenomena observed was that the depleted uranium, normally considered a brittle material at the test temperatures, exhibited good ductility. Strains estimated to be in excess of 15 percent at high strain rates were experienced without evidence of crack formation or the extension of cracks present before the tests.

PLANS FOR NEXT PERIOD

The program was terminated.

REPORTS PUBLISHED

Battelle Columbus Laboratories, "Validity of Scale Modeling as a Tool for Environmental Assessment," Documentary Film Produced by the Center for Improved Education, December 1979.

Burian, R.J., et al., "The Validity of Scale Modeling for Large Deformations in Shipping Containers," Battelle Columbus Laboratories, October 19, 1979.

Deel, O.L., and R.J. Burian, "The Mechanical Properties of Depleted Uranium-2 With Molybdenum Alloy," Battelle Columbus Laboratories, July 16, 1979.

Hadden, J.A., and R.J. Burian, "Scale Model Drop Tests to Evaluate Impact Response of Lead and Uranium Shielded Radioactive Material Shipping Containers," Battelle Columbus Laboratories, September 30, 1979.

PROJECTED MILESTONES

None

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

DECONTAMINATION AND DECOMMISSIONING

The continuing overall objective of the Decontamination and Decommissioning Program is to reduce to acceptable levels any potential health and environmental impacts associated with sites and facilities no longer required or used in the Nation's nuclear programs. Decontamination and decommissioning activities in fiscal 1979 within the Environmental Control Technology Division were organized into four major program areas:

- Decontamination of surplus radioactively contaminated Department of Energy facilities,
- Remedial action for inactive uranium mill tailings sites,
- Grand Junction offsite remedial action program, and
- Remedial action at formerly utilized Manhattan Engineer District and Atomic Energy Commission contractor sites.

The following are important fiscal 1979 accomplishments in the Decontamination and Decommissioning Program areas:

- Over 100 former Manhattan Engineer District and Atomic Energy Commission sites have been identified and are being evaluated to determine the extent of the need for remedial action.
- Twenty-five inactive uranium mill tailings sites have been designated as candidates for remedial action under the provisions of Public Law 95-604, "The Uranium Mill Tailings Radiation Control Act of 1978."
- The Offsite Remedial Action Program for Grand Junction, Colorado, was approximately 60-percent completed.

In late fiscal 1979, the Department of Energy consolidated the conduct of all nuclear waste management programs in the Office of the Assistant Secretary for Nuclear Energy, which is now responsible for the seabed disposal program and the actual performance of surveillance, decontamination, decommissioning, and remedial actions. The Office of the Assistant Secretary for Environment is responsible for independently providing and documenting assurance for the Department that potential health hazards at facilities used directly or indirectly by the Government in past nuclear operations have been identified, controlled, or eliminated by remedial action projects. Only the fiscal 1979 progress and results of the projects transferred to the Office of Nuclear Energy are described here; planned activities are not addressed.

DECONTAMINATION AND DECOMMISSIONING ASSISTANCE

ORGANIZATION AND CONTRACT NUMBER

The Aerospace Corporation
DE-AM03-76SF01101

PRINCIPAL INVESTIGATORS

W.B. McNulty
E. Vierzba
A. Wallo III
C.D. Young

OBJECTIVE

The objective of this project is to provide technical assistance to the Environmental Control Technology Division in the identification/verification, radiological characterization, and certification of remedial actions for sites and facilities contaminated by past nuclear operations. This includes (1) inactive uranium mill tailings sites under the provisions of Public Law 95-604, "The Uranium Mill Tailings Radiation Control Act of 1978"; (2) privately owned contaminated facilities that were utilized for the Manhattan Engineer District/Atomic Energy Commission nuclear operations; and (3) surplus radioactively contaminated facilities owned by the Department of Energy.

APPROACH

The approach is to conduct a focused data acquisition and evaluation program to establish a sound understanding of the efficacy and practicability (e.g., control efficiency, cost, operability) of mitigating measures required for existing site/facility conditions. The radiological characterization program has been accomplished by review and evaluation of radiological surveys and monitoring conducted for the Division by the Department's laboratories.

PROGRESS AND RESULTS

Aerospace assisted in the development and maintenance of surveillance systems to monitor the activities and status of the decontamination and decommissioning remedial action programs. These systems cover the Formerly Utilized Sites Remedial Action Program, Surplus Sites Program, Inactive Uranium Mill Tailings Sites Program, and Grand Junction Offsite Program. In addition, planning assistance was provided, and background and technical documents were prepared or reviewed.

Under the provisions of Public Law 95-604, enacted on November 8, 1978, 25 inactive uranium mill tailings sites have been identified (Figure 42) and evaluated for inclusion in the Department of Energy's remedial action program. The surveillance system data provided by

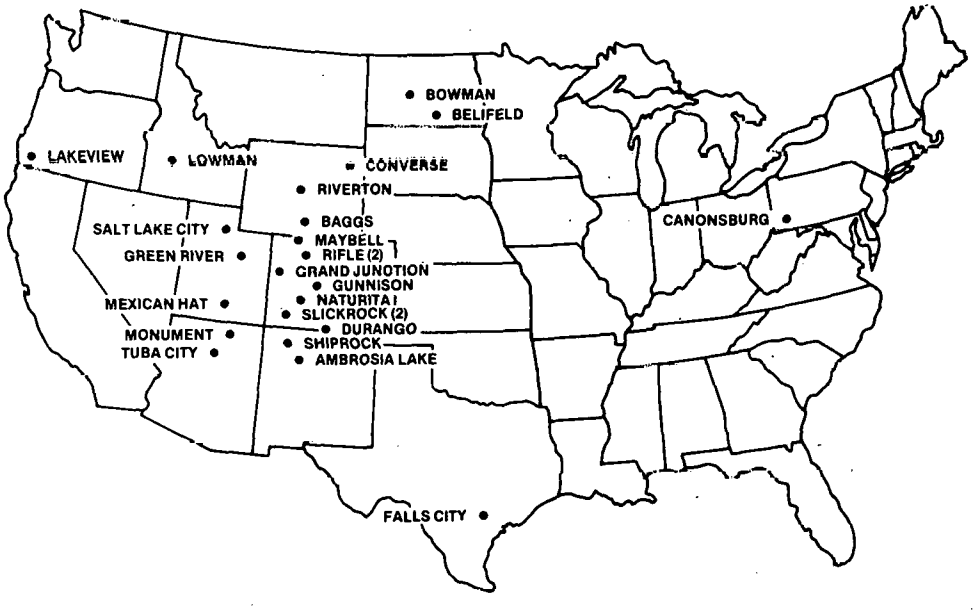


Figure 42. Identified and Verified Inactive Uranium Mill Tailings Sites

Aerospace has included past and present site operational functions, physical characteristics of these sites, property owner histories, radiological characterization at each site, and environmental impact assessments.

Aerospace assisted the Environmental Control Technology Division in the preparation of a July 1, 1979, report to Congress on sites within the United States on Government or acquired lands containing residual radioactive materials and other radioactive wastes. The report, which was mandated by Public Law 95-604, specified the Federal agency jurisdiction over the sites, and, where appropriate data were available, provided a description of the radiological status for each of the reported sites.

Over 100 former Manhattan Engineer District/Atomic Energy Commission sites have been identified and are being evaluated under the Formerly Utilized Sites Remedial Action Program. The information collected and presented in the background report for the program is being compiled by Aerospace and includes the past and present site functions, physical characteristics, locations, owner history, and radiological status.

PLANS FOR NEXT PERIOD

Aerospace technical assistance activities will provide technical support in the designation of inactive uranium mill tailings sites as candidates for remedial action; assisting in the identification and verification of facilities formerly utilized for nuclear operations and properties in the vicinity of designated inactive uranium mill tailings sites containing residual radioactive materials from such sites; providing technical assistance in developing the Department's First Annual Status Report to Congress on the Inactive Uranium Mill Tailings Sites Remedial Action Program; and preparing two departmental initial draft background reports on the Formerly Utilized Sites and Inactive Uranium Mill Tailings Sites Remedial Action Programs.

REPORTS PUBLISHED

Environmental Control Technology Division, "Report on Remedial Radioactive Materials on Public or Acquired Lands of the United States," DOE/EV-0037, July 1, 1979.

PROJECTED MILESTONES

- November 8, 1979 -- Designate inactive uranium mill tailings sites as candidates for remedial action
- January 1, 1980 -- Complete draft of the Department's First Annual Status Report to Congress on the Inactive Uranium Mill Tailings Sites Remedial Action Program
- September 1980 -- Complete site identification and verification, document the results, and prepare background reports on the Formerly Utilized Sites and Inactive Uranium Mill Tailings Sites Remedial Action Programs

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

MANAGEMENT OF SURPLUS RADIOACTIVELY CONTAMINATED DEPARTMENT OF ENERGY FACILITIES

At the beginning of fiscal 1979, the Environmental Control Technology Division was responsible for planning, budgeting, and implementing the program for the safe management and disposition of the Department of Energy facilities that are radioactively contaminated and have been declared surplus to programmatic needs. There are currently more than 460 of these facilities, including cribs, ponds, trenches, buildings, and reactors, more than 80 percent of which are located at Hanford, Washington. During the latter part of fiscal 1979, these functions were transferred to the Office of the Assistant Secretary for Nuclear Energy.

The overall plan for the management of surplus contaminated facilities owned by the Department continues to be based on the long-term objective of eliminating potential hazards and reducing the need for perpetual surveillance and maintenance. Where practicable, however, the goal is to release property for alternative productive use without restrictions. Activities within the program include (1) providing surveillance and maintenance to ensure that surplus facilities remain in an environmentally safe condition; (2) developing improved techniques for the safe and economic decontamination and disposition of radioactive facilities, equipment, materials, and land; (3) developing plans, priorities, costs, and schedules for disposition projects; and (4) implementing projects leading to improved safety, elimination of the expense of continuing surveillance and maintenance, and restoration of needed facilities or land areas without radiological restriction.

A part of the strategy of this program is the development of a method for establishing the relative priority for projects within the inventory and for selecting the optimum decommissioning approach from the options (e.g., salvage for other use, continued surveillance and maintenance, entombment, or dismantling). Complementing this approach will be the effort to develop and document decontamination technology as more structures are decommissioned. This will not only be of value to those responsible for the future disposition of surplus Department of Energy facilities, but it will also provide technology for this aspect of the commercial nuclear fuel cycle. Such new and improved technology for the disposition of surplus nuclear facilities was developed in fiscal 1979, for example, the decontamination of concrete, the volume reduction of process equipment, and the decontamination of metals through smelting.

The planned activity includes developing a system for identifying projects and assigning priorities from among the more than 460 surplus facilities currently listed in a comprehensive inventory. The priorities established will provide a rational basis for future planning and budgeting activities. The planning system will provide a basis for developing future annual budgets, 5-year planning projections, and long-term budget requirements for the disposition of surplus facilities.

IDAHO NATIONAL LABORATORY SHUTDOWN REACTORS SURVEILLANCE

ORGANIZATION AND CONTRACT NUMBER

EG&G Idaho, Inc.
DE-AC07-76ID01570

PRINCIPAL INVESTIGATORS

R.H. Meservey
J.A. Chapin

OBJECTIVE

The objective of this project is to provide minimum surveillance and security for Idaho National Engineering Laboratory surplus radioactively contaminated facilities to keep them in a safe condition.

APPROACH

The surveillance and security of the Idaho National Engineering Laboratory contaminated facilities will be accomplished by existing staffs of security, fire protection, radiation protection, and property management organizations to provide surveillance and maintenance for laboratory shutdown facilities, including Test Area North Radioactive Waste Evaporation System, Hallam Reactor Components stored at Test Area North, Organic Moderated Reactor Experiment, Initial Engine Test Facility, Materials Test Reactor, Army Reentry Vehicle Facility Site, Auxiliary Reactor Area-IV, BORAX-V Facility, and many other minor surplus contaminated facilities.

PROGRESS AND RESULTS

Surveillance has been maintained with no adverse incidents. In addition, some decontamination and cleanup work was performed where needed to control the spread of contamination.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

GNOME SITE SURVEILLANCE

ORGANIZATION AND CONTRACT NUMBER

Reynolds Electrical & Engineering Company, Inc.
DE-AC08-76NV00410

Environmental Protection Agency
DE-AE08-76D800539

PRINCIPAL INVESTIGATOR

J.B. Cotter

OBJECTIVE

The objective is to provide inspection services to the Gnome Site in Carlsbad, New Mexico, and provide a long-term hydrologic monitoring program.

APPROACH

Department of Energy personnel visit the Gnome site on a periodic basis to reconfirm the public safety and environmental conditions existing on or near the site. Biweekly patrols of the site are made by a locally hired caretaker. These patrols will end following final decommissioning activities in September 1979.

Additionally, the Environmental Protection Agency performs a long-term hydrologic monitoring program on an annual basis. This includes the sampling of both surface and well water sources on and near the Gnome site. All samples are analyzed for selected radionuclides. Based on the results of these analyses, suspect samples are analyzed for appropriate naturally occurring and manmade isotopes. Splits of each sample are retained as long as a need exists for this purpose. If a meaningful increase in radionuclide concentration occurs, the Office of Safety and Health and the Radiological Branch, Nevada Operations Office, are notified immediately.

PROGRESS AND RESULTS

The analyses from the hydrologic monitoring program have shown that all wells, with the exception of two wells in which tracer isotopes were injected, are at background levels.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

BOILING NUCLEAR SUPERHEATER POWER STATION SURVEILLANCE

ORGANIZATION AND CONTRACT NUMBER

University of Puerto Rico, Center for Energy and Environment Research
EY-76-C-05-1833

PRINCIPAL INVESTIGATOR

N. Irizarry

OBJECTIVE

The objective of this program is to perform surveillance of a partially decontaminated and entombed boiling water superheat reactor originally operated by the Puerto Rico Water Resources Authority.

APPROACH

An annual detailed radiological survey and site inspection will be performed and a report issued.

PROGRESS AND RESULTS

The annual radiological survey was performed in May 1979, and a report submitted to the Environmental Control Technology Division. No radiation dose levels above established limits were detected. Also, an annual site inspection by Oak Ridge Operations Health Physics staff was conducted in June 1979. No problems were noted.

PLANS FOR NEXT PERIOD

The annual radiological survey and site inspection will be performed. Additional surveys, as may be requested by the Puerto Rico Electric Authority, will be conducted.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- May 1980 -- Perform annual radiation survey and submit report
- June 1980 -- Perform annual site inspection

SURVEILLANCE OF HANFORD 200 AREA SURPLUS FACILITIES

ORGANIZATION AND CONTRACT NUMBER

Rockwell Hanford Operations
DE-AC06-77RL01030

PRINCIPAL INVESTIGATORS

A.N. Gallegos
A.W. Graves

OBJECTIVE

The objective is to provide surveillance and maintenance of contaminated facilities and correct problems that may affect the environment. Surface stabilization of the outdoor radiation areas is required to control the transport of radionuclides to the environment pending development of the final disposal methods for soils and sediments.

APPROACH

Periodic surveillance of the retired structural facilities is required to determine whether there has been destruction by natural causes, deterioration, or tampering by personnel. Facilities where services are still provided, such as ventilation, heating, or where building repairs are required, must be maintained and repairs made as deemed necessary. Outdoor radiation areas included are cribs, ponds, trenches, burial grounds, and identified unplanned release sites.

Surface stabilization of retired contaminated burial grounds, cribs, and other outdoor radiation areas will include the removal of contaminated vegetation and the top surface of contaminated soil if required, installation of biobarriers as

necessary, re-coverage with clean soil, and revegetation of the surface with native grasses.

All retired sites will be posted with appropriate signs to include the radiological status.

PROGRESS AND RESULTS

- The fire access road from the B-C cribs to the army loop road was graded and ballasted.
- An unplanned release site, UN-216-W-5, was decontaminated, stabilized, covered with gravel cover to prevent contamination spread, and released from surface contamination control requirements.
- Approximately 22,000 square feet of the 202-S (Redox Building) roof have been repaired to correct leaks into the contaminated canyon areas of the building.
- Concrete marker posts were placed at crib areas 216-B-43 through 216-B-50.
- Aerial photographs were taken, radiological characterization was performed, and stabilization procedures were prepared for the retired burial grounds in the 200 East Area: 218-E-2, 218-E-2A, 218-E-4, 218-E-5, 218-E-5A, 218-E-9, and 218-E-12A.
- Decontamination, vegetation removal, and load testing of 218-E-2, 218-E-5, 218-E-5A, 218-E-9, and 218-E-12A burial ground trenches and access roads were completed.
- A cave-in at the 218-E-12A burial ground was repaired (Figures 43 and 44).
- Approximately 30 percent of the trenches in the 218-E-12A burial ground had biobarriers placed (Figure 45) and were seeded with native grasses.
- An area adjacent to the 218-E-12A burial ground was released from radiation area status (120 by 1000 feet).
- All retired contaminated facilities and outdoor sites were posted to comply with new radiological posting criteria.
- Work was initiated to remove surface contamination and stabilize the BC crib area trenches.
- Structural facility surveillance and maintenance was performed on the 202-S complex (Redox), 271-C (Hot Semiworks), 200-N buildings and all outdoor retired contaminated structural facilities.

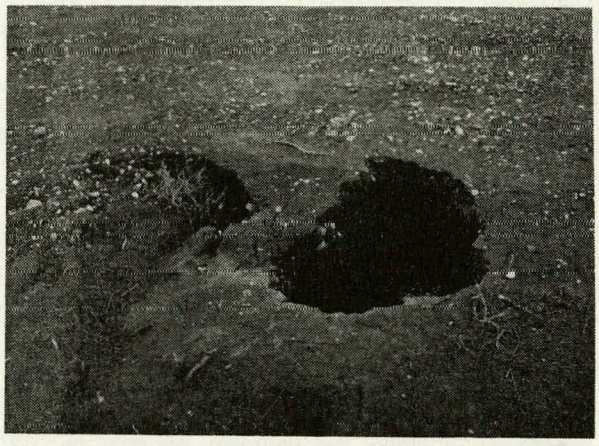


Figure 43. Burial Ground 218-E-12A Cave-in

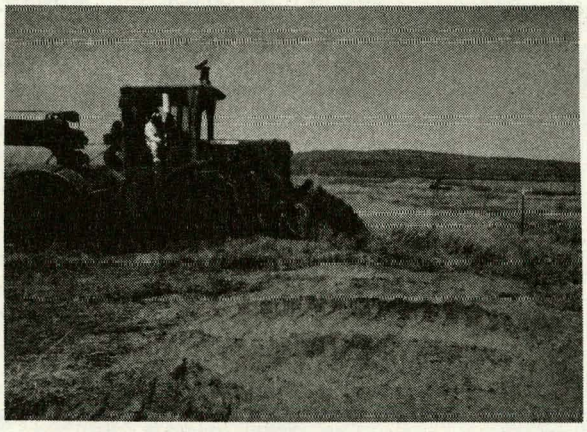


Figure 44. Filling Cave-in in Burial Ground 218-E-12A

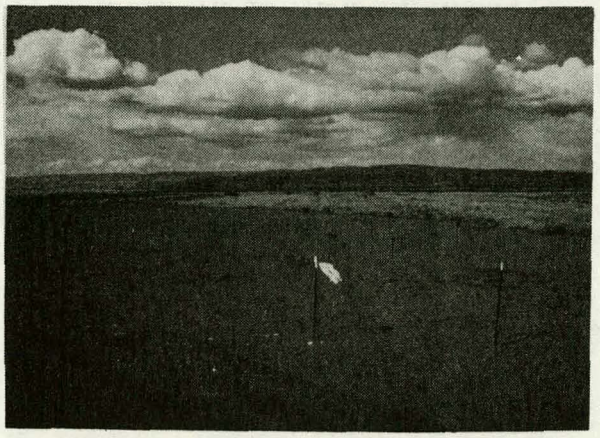


Figure 45. Staking Access Roads and Trenches in Burial Ground 218-E12A Prior to Installing Biobarriers

- Structural facility surveillance and maintenance was performed on the 202-S complex (Redox), 271-C (Hot Semiworks), 200-N buildings and all outdoor retired contaminated structural facilities.
- A straw mulcher was received to aid in the revegetation and surface stabilization effort on retired outdoor sites.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

Graves, A.W., R.D. Prosser, and J.H. Roecker, "Reduction of Radiation Area Project Plant," RHO-CD-648, Rev. 1, Rockwell Hanford Operations, August 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

SURVEILLANCE OF HANFORD 100 AREA SURPLUS FACILITIES

ORGANIZATION AND CONTRACT NUMBER

United Nuclear Industries, Inc.
DE-AC06-76RL01857

PRINCIPAL INVESTIGATOR

R.K. Wahlen

OBJECTIVE

There are currently four production reactor facilities at Hanford in a surplus status. A surplus facilities surveillance program has been established to ensure that potential radiological and industrial hazards are promptly corrected and to maintain an effective property control system.

APPROACH

The surplus facility surveillance program is implemented by a system of procedures that identify periodic industrial, radiological, and environmental surveillance requirements. In addition, procedures are included for the maintenance, inspection, and testing of emergency alarm and fire protection systems. The frequency of the inspections is based on several factors:

- Facility status (e.g., occupied, partially occupied, unoccupied)
- Condition of the buildings
- Fire potential
- Potential safety and environmental hazards

Records are maintained of all inspections, showing current facility condition, actions required, and actions taken to correct potentially hazardous conditions.

PROGRESS AND RESULTS

All required inspections have been completed on schedule. Potentially hazardous conditions identified during these inspections have been corrected. The facility surveillance program was revised and updated to ensure its adequacy.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferrred to the Office of Nuclear Waste Management.

HEAVY WATER COMPONENTS TEST REACTOR SURVEILLANCE

ORGANIZATION AND CONTRACT NUMBER

E.I. duPont de Nemours & Company, Inc.
DE-AC09-76SR00001

PRINCIPAL INVESTIGATOR

E.L. Albenesius

OBJECTIVE

The objective is to maintain the Heavy Water Components Test Reactor in sufficiently good physical condition to ensure its continued safety, so that it can eventually be decommissioned with a minimum expenditure of time and money.

APPROACH

Area patrols and inspections are provided to ensure that the facility is protected. It is also necessary to provide minimum ventilation and lighting of the reactor's containment building control house and administration building.

PROGRESS AND RESULTS

The reactor was maintained in a controlled and safe manner.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECOMMISSIONING OF HANFORD FACILITIES: TECHNOLOGY

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATOR

R.R. King

OBJECTIVES

The objectives of this project are to conceive, develop, and test advanced technology applicable to the Hanford decommissioning effort.

APPROACH

The project is divided into several tasks that encompass the extremely diverse technology applicable to the Hanford decommissioning effort.

PROGRESS AND RESULTS

Technology Assessment

The objectives of this task are to assess the present state of decontamination technology, identify critical technology development needs, and maintain a strong interface with other Hanford contractors engaged in decommissioning activities. These task activities have assisted in the interchange of decommissioning technology information among Hanford contractors and have identified the need for improved contamination stabilizing coatings (fixatives) for use in decommissioning operations.

Concrete Decontamination

The objective of this task is the development of equipment for the removal of contaminated concrete surfaces. The equipment and techniques currently under investigation are a rock splitter, a water cannon, and the use of a very high-pressure water jet. Tests have demonstrated the ability of each method to remove the surface of typical Hanford concrete. However, further development is required to simplify operations, increase surface removal rates, and prevent contamination of the cleaned areas.

Dry Ice Blasting

The objective of this task is to evaluate the potential application of dry ice blasting to decommissioning activities. Work with equipment developed by Pacific Northwest Laboratory has been discontinued because the capacity of the equipment appears limited. Contact is continuing with commercial equipment suppliers to stay abreast of developments in high-pressure equipment. Concrete samples have been provided to seven manufacturers for equipment performance tests.

Arc Saw Evaluation

The objective of this task is to evaluate and demonstrate the application of the arc saw to decommissioning activities. Several longitudinal cuts on both stainless steel and carbon steel pipe, ranging up to 8 inches in diameter with 1/2-inch walls, were performed on the arc saw to demonstrate feasibility. Data were taken on arc parameters, blade wear, feed rates, and characterization of detritus. In summary, the work supported the capability of the arc saw and indicates that work in this area should continue in order to optimize the application.

Burial Ground Stabilization

The objective of this task is to evaluate the ability of a cobble barrier to prevent penetration of contaminated burial grounds by plants and animals. Extensive field tests and greenhouse experiments have been conducted using lithium chloride mixed with soil to simulate radioactive wastes. The results show that cobble is an effective barrier for burrowing animals and insects. The addition of asphalt emulsion, root toxin, and small stones between topsoil and cobble is 100-percent effective in preventing root penetration.

Instrumentation Development

The objective of this task is to develop sensitive instrumentation for detection of low-level transuranic contamination on surfaces. A series of experiments was completed that evaluated the applicability of a Phoswich detector for in situ field analysis of both transuranic and beta-gamma fission products. Final comparisons of the transuranic element sensitivities and detection limits to those obtained earlier with a germanium diode spectrometer are not totally completed; however, preliminary indications are that the germanium system is more versatile and sensitive. The sensitivity and detection limits of the Phoswich system for mixtures of strontium-90, cesium-13, and ruthenium-106 were determined as a function of thickness for various overburdens (sand, wood, etc.). An open literature publication describing these results and the utility of a portable Phoswich system for surveying beta-gamma-contaminated surfaces has been prepared.

Concrete Properties

The objective of this task is to evaluate the degradation of Hanford concrete and to identify damage mechanisms. A microstructural analysis of existing Hanford concrete has been performed and compared with the results for test specimens kept in a simulated Hanford environment.

Electropolishing/Vibratory Finishing Applications

The objective of this task is to demonstrate the applicability of the highly successful electropolishing and vibratory finishing process to decommissioning applications. All major metallic and nonmetallic components of a plutonium glove box (metal structure, Plexiglas panels, gaskets, and gloves) have been successfully decontaminated to below the 10-nanocurie/gram transuranic waste limit using vibratory finishing techniques. The ability to decontaminate the internal surfaces of an operating plutonium glove box to below transuranic waste limits using in situ electropolishing techniques was also demonstrated.

Fixatives

The objective of this task is to identify, develop, and demonstrate improved coatings to stabilize contamination for use in decommissioning operations. Two promising fixatives have been identified and tested as part of glove box refurbishing and building decontamination operations. Both compounds fixed essentially all the loose plutonium contamination and substantially minimized contamination exposure to operating personnel.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

Cline, J.F., "Bio-Barriers Used in Shallow Burial Ground Stabilization," PNL-2918, Pacific Northwest Laboratory, July 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

RECYCLE OF CONTAMINATED SCRAP METALS

ORGANIZATION AND CONTRACT NUMBER

National Lead Company of Ohio
DE-AC05-760R01156

PRINCIPAL INVESTIGATOR

J.H. Cavendish

OBJECTIVES

There are two tasks involving the recycle of contaminated scrap metals. The objective for Task A is to have current Federal regulations amended to permit unlicensed possession, sale, and use of metal contaminated with special nuclear materials below a specified concentration. For Task B, the objective is to provide a means for decontaminating the scrap metal so that it meets the proposed concentrations.

APPROACH

Concerning Task A, present Federal regulations (10 CFR 70) prohibit the possession, use, or sale of any quantity of special nuclear materials except by holders of a specific license. Because this is not practical for the sale of metal scrap homogeneously contaminated with small quantities of special nuclear materials, an amendment to 10 CFR 70 establishing a concentration for enriched uranium and technetium-99, which would allow unrestricted sale of the metal scrap, is being pursued. For Task B, the primary decontamination method being pursued to achieve these concentrations is that of smelting.

PROGRESS AND RESULTS

For Task A, an Environmental Impact Assessment covering the proposed amendments was completed in August 1976. This assessment was reviewed by the Nuclear Regulatory Commission, and Battelle Pacific Northwest Laboratories was contracted to prepare an Environmental Impact Statement. The first draft of this statement was completed and reviewed by the Nuclear Regulatory Commission in December 1978. Minor revisions were required and were completed. The Nuclear Regulatory Commission review is proceeding.

On Task B, a comprehensive review of the smelting of contaminated steel scrap was completed in January 1978. This included an economic evaluation of portable versus fixed-site smelter options. Results indicated smelting of the steel scrap would be economically attractive, providing the product could be sold without restriction. The portable smelter option appeared most attractive. Following this review, Oak Ridge Operations Office made a decision to suspend further work on steel scrap smelting pending resolution of the regulatory changes described under Task A.

Work has continued on the development of decontamination processes for copper and aluminum scrap generated in the Cascade Improvement/Uprating Program. Development of a copper smelting process utilizing existing furnaces at the Feed Materials Production Center has been completed. Authorization for installing necessary additional equipment was granted by the Oak Ridge Operations Office; scrap precleaning equipment tests have indicated a promising shredder-granulating unit for this work.

The Pacific Northwest Laboratory was given a contract to evaluate the feasibility of decontaminating aluminum scrap generated in the Cascade Improvement/Uprating Program, by electropolishing. This has proven successful for surface-contaminated scrap, and an attempt is being made to develop techniques for separating surface and homogeneously contaminated scrap. Review of this work and future application is under study.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

Cavendish, J.H., "Treatment of Metallic Wastes by Smelting," National Lead Company of Ohio, presented at the International Symposium on the Decommissioning of Nuclear Facilities, November 13-17, 1978.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

CONTAMINATED EQUIPMENT VOLUME REDUCTION

ORGANIZATION AND CONTRACT NUMBER

Rockwell Hanford Operations
DE-AC06-77RL01030

PRINCIPAL INVESTIGATORS

G.A. Beitel
A.W. Graves

OBJECTIVE

The objective of this program is to design, develop, and demonstrate process equipment that will reduce the volume of contaminated equipment to a size and form suitable for disposal.

APPROACH

Studies during the past 4 years have concluded that meltdown is the optimum final step in preparing metallic waste for disposal if fume control and remote operation can be achieved. Control of fumes associated with the melting process dictates the use of a closed furnace. A vacuum furnace has been chosen as the ideal containment system.

A vacuum furnace capable of melting up to 400 kilograms of steel scrap per batch has been designed. Melting is to be accomplished by direct arc heating in a water-cooled copper crucible. Mechanical pumps will provide the requisite vacuum. The furnace was designed to maximize cleanliness and minimize complexity. Following successful operation of the vacuum furnace with uncontaminated scrap, the system may be redesigned and modified to accept radioactive scrap. Simultaneously, laboratory- scale (up to 4 kilogram) tests will be conducted with contaminated materials to investigate the redistribution of radionuclides and to determine the feasibility of slag separation of radionuclides during meltdown.

Meltdown in a reasonably sized vacuum furnace requires that the initial contaminated equipment first be size-reduced, i.e., cut into small pieces (less than 20 inches long and less than 100 pounds). A high-speed, remotely operated size reduction system based on the arc saw concept had been proposed.

PROGRESS AND RESULTS

A contract was placed for the fabrication of an operable vacuum furnace system, including the electrode. Fabrication of the electrode was begun, and the vendor has placed orders for most of the major components and materials for the furnace system.

Standard components for the vacuum furnace system were received separately from the fabrication contract. Building 277-W was identified as the location for the vacuum furnace and the large arc saw. Installation engineering for utilities and floor space modifications was begun. The vacuum pumps and pumping system were ordered and are scheduled for delivery by September 30, 1979.

The size reduction development effort consists of testing a small arc saw (parametric development tests) and a large arc saw (full-scale size reduction demonstrations).

The small arc saw installation was completed (Figure 46), and checkout was performed and witnessed by Rockwell Hanford Operations and the component vendors. One engineer and one technician were qualified for arc saw cutting. Over 200 separate cuts (Figure 47) were made to develop optimum cutting parameters for stainless steel. Preliminary vibration measurements were made to characterize the normal saw vibrational modes.

At the time the small arc saw was designed and built, a large saw head was also fabricated, the control system had provisions incorporated to control the large saw in two dimensions, and a hydraulic power unit of sufficient capacity was purchased. The power supply purchased for the furnace will drive either arc saw. A carriage with five degrees of freedom is required to move the saw.

Safety reviews were held on the laboratory-scale contaminated metal melting testing, and the noncontaminated metal testing was initiated.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

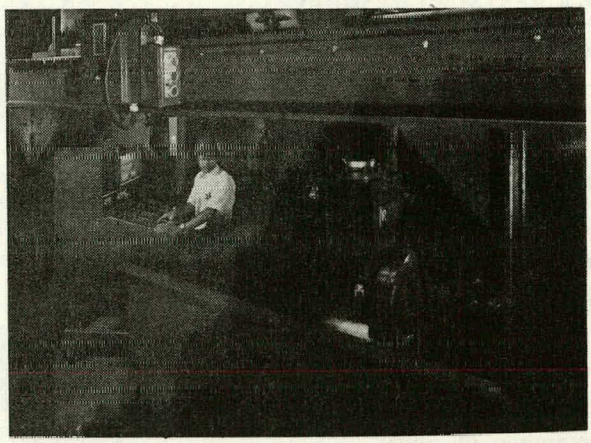


Figure 46. Small Arc Saw Installation in Building 277-W

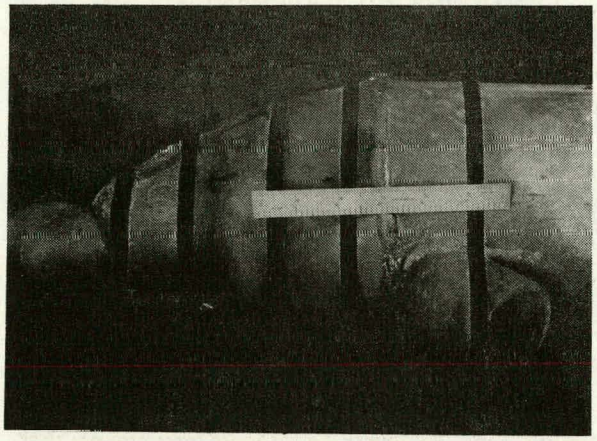


Figure 47. Demonstration of Arc Saw Cutting Irregularly Shaped Pieces

REPORTS PUBLISHED

"Volume Reduction of Metallic Waste by Vacuum Meltdown," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

REMOVAL OF ACTINIDES FROM CONTAMINATED SOIL

ORGANIZATION AND CONTRACT NUMBER

Rockwell International, Energy Systems Group, Rocky Flats Plant
AL-03-533

PRINCIPAL INVESTIGATORS

J.A. Hayden
R.L. Olsen
W.E. Sperry
G.H. Thompson

OBJECTIVES

The objectives are to develop and demonstrate soil decontamination processes for removal or concentration of actinides in contaminated soils from Department of Energy facilities.

APPROACH

Work on this project was initiated in June 1978. Procedures were established to collect, analyze, and ship actinide-contaminated soils from other Department of Energy sites to Rocky Flats for soils decontamination studies. Five Department of Energy sites were selected to participate in this program by collecting and analyzing soils to be considered for testing at the Rocky Flats Plant. The results of these offsite soil analyses were evaluated and four Department of Energy sites were authorized to collect and ship samples of their actinide-contaminated soils to the Rocky Flats Plant for soil decontamination studies. These offsite soil analyses were verified by the Rocky Flats analytical laboratory before starting the decontamination studies. These analyses identified the radionuclide content, chemical composition and physical characteristics of the soil, and physical form of the alpha-emitting nuclide. Soil decontamination tests were conducted based on the evaluation of analytical results.

PROGRESS AND RESULTS

Samples of actinide-contaminated soils from Hanford, Idaho National Engineering Laboratory, Los Alamos Scientific Laboratory, and Mound Laboratory have been received at Rocky Flats for testing. The Rocky Flats analytical laboratory has completed analyses on Hanford and Idaho Laboratory soil samples and Health, Safety, and Environment has approved procedures for decontamination tests of these soils. The results of analyses of the Los Alamos and Mound soils are being evaluated by Health, Safety, and Environment prior to approving procedures for decontamination testing.

Petrographic analysis of the Hanford soil identifies the predominant minerals to be quartz (40 percent) and plagioclase (20 percent). The remainder is composed of K-spar, chert, volcanic rock fragments, and a mixture of other minerals. The textural class of the soil is sand loam-loamy sand. The particle size is in the sand and silt range with only about 6 percent falling into the clay size range. The actinides are present in a dispersed form (as opposed to discrete particles). Discrete particles with a plutonium oxide equivalent size greater than 0.1 micron were not detected in the soils examined. The activity is mostly on the outer surface of the soil grains although basaltic rock fragments were found that contained activity below the surface. The latter fragments are more difficult to decontaminate than the bulk of the soil. Attrition scrubbing with the low pH solution removed 93 percent of the contamination from approximately 60 percent of the soil. At higher acid concentrations (two-normal solution of hydrochloric acid), 99.6 percent of the activity was removed from 97 percent of the soil. The indication is that leaching is the mechanism of removal and that most of the activity readily dissolves. The exception is the larger basaltic fragments that have activity below the surface of the rock. This activity leaches more slowly. The cold product usually contains activity in excess of the Environmental Protection Agency guide (30 disintegrations/minute/gram). Reductions from 10^5 disintegrations/minute/gram to 10^2 disintegrations/minute/gram were achieved in bench-scale tests.

Petrographic analysis of the Idaho Laboratory soil shows the predominant minerals to be quartz (23 percent), chert (18 percent), plagioclase (12 percent), and volcanic rock fragments (14 percent). The remainder is composed of mixtures and traces of other minerals. The textural class of the soil is loam-clay loamed. The particle size distribution reveals 9 percent gravel, 36 percent sand, 30 percent silt, and 25 percent clay. The actinides are present in dispersed, concentrated, and particulate form. Autoradiographs indicate that the concentrated form is predominant. This form yields concentrated spots of tracks rather than stars, and it is indicative of actinide association with other components in the soil. Discrete particles (yielding star track patterns) were observed. The equivalent size, calculated as pure plutonium oxide, ranged from 0.09 to 1.2 microns. About 20 to 25 percent of the actinide is in the form of discrete particles.

Decontamination (attrition scrub) tests on the Idaho Laboratory soil show 93 percent of the activity removed from 34 percent of the soil using a low-pH scrubbing solution, and 98.7 percent of the contamination removed from 43 percent of the soil when the acid concentration is increased to a two-normal solution of hydrochloric acid. The amount of activity remaining in the "cold" fraction is well above the Environmental Protection Agency guide.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

Hayden, J.A., et al., "Soil Decontamination at Rocky Flats," Proceedings of Conference on Decommissioning of Nuclear Facilities, Sun Valley, Idaho, September 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECOMMISSIONING HANDBOOK

ORGANIZATION AND CONTRACT NUMBER

Nuclear Energy Services, Inc.
EP-78-C-02-4775

PRINCIPAL INVESTIGATORS

W.J. Manion
T.S. LaGuardia

OBJECTIVE

The objective of this project is to develop a handbook for use in planning the decommissioning of facilities used in nuclear power research, generation, or production by the Department of Energy. The detailed guidance provided in the handbook to accomplish the various techniques used in decommissioning will improved the efficiency and consistency of future decommissioning programs.

APPROACH

The decommissioning handbook will be developed in three phases.

Phase I -- Identification of Factors

The factors of primary concern in the decommissioning of each category of facility will be elicited. Typical facility characteristics and pertinent parameters such as operating history, materials of construction, and plant arrangement will be defined.

Phase II -- Development of Technical Information

Each of the following topics will be investigated, evaluated, and presented in the handbook:

- Description of decommissioning options
- Selection of decommissioning options
- Estimation of radioactive inventory and occupational exposures
- Decontamination methods
- Disposition of radioactive and nonradioactive waste
- Removal of radioactive metals
- Removal of radioactive concrete
- Removal of contaminated systems
- Transportation of radioactive materials
- Environmental impact assessments
- Estimation of cost

The sources of information on these topics will be technical papers published on related subjects; vendor contact to investigate relevant processes and equipment; site visits to obtain first-hand information on typical facility layouts; and Nuclear Energy Services, Inc., decommissioning experience during the decommissioning of the Elk River and BONUS reactors.

Phase III -- Compilation of the Decommissioning Handbook

The analytical and instructional information generated in Phase II will be integrated into a handbook format. Introductory and summary information will be prepared, and the compiled document will be delivered to the Department of Energy.

PROGRESS AND RESULTS

Phases I and II, dealing with the identification of facility characteristics and plant arrangements and with the development of technical information, have been completed. Phase III is 90 percent complete.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

LaGuardia, T.S., "Decommissioning Methods and Equipment," presented at the American Nuclear Society Conference on Decontamination and Decommissioning of Nuclear Facilities, Sun Valley, Idaho, September 16-19, 1979.

LaGuardia, T.S., and W.J. Manion, "Reactor Decommissioning Information Pertinent to Planning," presented at the American Nuclear Society Winter Meeting, Washington, D.C., November 12-16, 1978.

Manion, W.J., "Summary of a Decommissioning Handbook for Nuclear Facilities," presented to the International Symposium on the Decommissioning of Nuclear Facilities, Vienna, Austria, November 13-17, 1978, published as International Atomic Energy Agency Document, IAEA-SM-234/44.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

RESEARCH AND DEVELOPMENT IN SUPPORT OF IDAHO NATIONAL ENGINEERING LABORATORY DECOMMISSIONING PROJECTS

ORGANIZATION AND CONTRACT NUMBER

EG&G Idaho, Inc.
DE-AC07-76ID01570

PRINCIPAL INVESTIGATORS

R.H. Meservey
J.A. Chapin
R.E. Hine
D.L. Smith

OBJECTIVE

The objective of this project is to perform the necessary research and development to support current and future Idaho National Engineering Laboratory decommissioning projects. Areas covered by this work include characterization of contaminated facilities so that decommissioning plans can be written, soil decontamination techniques, liquid metal processing, and solid waste volume reduction.

APPROACH

The approach is to develop a plan for each research and development task and then to perform the work necessary to execute those plans. Final reports will be published for all tasks.

PROGRESS AND RESULTS

Characterization of the MTR-605 Process Water Building, TAN-TSF Outside Areas, ARA-III, Organic Moderated Reactor Experiment Leach Pond, Heat Transfer Reactor Test Assemblies, TAN Liquid Waste Evaporation System (PM-2A), SPERT-IV, and BORAX-V Facilities was completed. Decommissioning plans were then written for the Heat Transfer Reactor Test Assemblies, PM-2A, SPERT-IV, and BORAX-V projects.

A liquid metal storage area, Army Reentry Vehicle Facility Site, was inspected and a preconceptual design completed for a system to process the stored liquid metal (NaK). Several soil decontamination techniques were investigated, including the use of plants, mechanical separation, and chemical processes. Mechanical compaction and electric smelting were investigated and compared to current techniques for handling and reducing the volume of solid waste generated by decommissioning programs.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

"Characterization of MTR-605 Process Water Building," PR-W-79-015, June 1979.

"Characterization of the TAN-TSF Outside Areas," PR-W-79-031, September 1979.

"OMRE Leach Pond Characterization," PR-W-79-029, September 1979.

"Decontamination and Decommissioning (D&D) Plan for the Heat Transfer Reactor Test Assemblies HTRE-2 and HTRE-3," PR-W-79-001, January 1979.

"BORAX-V Decontamination and Decommissioning Plan," PR-W-79-017, September 1979.

"Feasibility of Using Plant to Decontaminate Radioactive Soils," TREE-1366, July 1979.

"Decontamination of Soil Utilizing Water Hyacinth," PR-W-79-026, September 1979.

"Preliminary Assessment for Decontamination of INEL Radioactive Soils Using Chemical Extraction Process," RE-M-79-012, September 1979.

"Soil Decontamination Final Report," PR-W-79-027, September 1979.

"Preconceptual Studies for Processing of the EBR-I Mark II Contaminated NaK," RE-D-79-221, September 1979.

"D&D Waste Volume Reduction Study," PR-W-79-032, September 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

PIPELINE DECOMMISSIONING DEMONSTRATION

ORGANIZATION AND CONTRACT NUMBER

Los Alamos Scientific Laboratory
W-7405-ENG-36

PRINCIPAL INVESTIGATORS

D.C. Nelson
J.L. West

OBJECTIVE

The objective of this program is to field-test various media, such as foam, asphalt, and grout, to determine which is most effective for controlling internal contamination during the removal of buried pipelines previously used to transfer radioactive liquid wastes.

APPROACH

Clay tile pipelines of 300-foot lengths will be assembled aboveground. These pipelines will be coated on the inside with an ultraviolet powder to simulate radioactive contamination. The pipe will be severed in several sections in a similar manner to that used in an actual pipeline removal operation. These breaks will be examined under a black light and photographed to establish a reference case. The remaining pipe sections will be filled with the various media to be tested, after which the pipe will be broken and disturbed. These breaks will also be examined and photographed under a black light for comparison with the reference case to determine the effectiveness of each medium.

PROGRESS AND RESULTS

All material and equipment have been delivered, and field tests are ready to begin.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

PLANNING FOR DECOMMISSIONING OF RETIRED HANFORD FACILITIES

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EV-76-C-06-1830

PRINCIPAL INVESTIGATOR

J.C. King

OBJECTIVES

Several hundred radioactively contaminated facilities at Hanford have been removed from active service and must eventually be decommissioned. These facilities include production and test reactors, fuel fabrication facilities, fuel separation plants, laboratories, and solid and liquid waste disposal and storage sites. A comprehensive, long-range plan for decommissioning of surplus Hanford facilities is needed because of the range of available decommissioning alternatives; the large number, diversity, and varied condition of these facilities; and the variety of potential uses for the Hanford site. It is the primary objective of this project to provide such a plan. A supporting objective is to provide facility and site data bases and other supporting studies required for the development and revision of the long-range decommissioning plans and individual facility decommissioning plans.

APPROACH

Two work items were addressed in fiscal 1979: updating the Hanford decommissioning Resource Book (BNWL-MA-88) and maintaining and updating the Hanford Decommissioning Information System.

PROGRESS AND RESULTS

Five Resource Book update packages were identified with the objectives of issuing missing sections of the Resource Book and of incorporating newly available information into existing sections. The five update packages included the laboratories descriptive section (Section D.6) and associated data sheets (Appendix VI); waste management descriptive section (Section D.11) and associated data sheets (Appendix XI); uranium facilities descriptive section (Section D.10) and associated data sheets (Appendix X); revised data sheets showing estimated decommissioning costs; and revised data sheets incorporating characterization information published in UNI-946, Radiological Characterization of the 100 Areas. The technical approach to developing and issuing each package was similar, consisting of identifying the Hanford facilities to be encompassed by each revision package, compiling pertinent information into the general descriptive section and associated data sheets of each revision package, transmitting the draft general descriptive sections and associated data sheets to cognizant Hanford

operating contractors for review, and issuing the completed revision package.

The laboratories package was issued in final form in April 1979, and the uranium facilities package was available in final draft in September. The UNI-946 data revision package and waste management facilities were in draft form in September. It was decided that incorporation of cost estimates in the Resource Book would not be appropriate. Two update cycles were completed during the year, including addition of data on Hanford laboratory facilities and on Hanford uranium facilities.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

Resource Book -- Disposition of Retired Contaminated Facilities at Hanford, BNWL-MA-88, Pacific Northwest Laboratory, Richland, Washington, 1979 (Revisions.)

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

CHARACTERIZATION OF HANFORD 300 AREA BURIAL GROUNDS

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATOR

S.J. Phillips

OBJECTIVES

Substantial quantities of high-level, transuranic, and other nuclear materials have been placed in solid waste burial facilities at Hanford, Washington. The location, composition, physiochemical status, and migration of these waste materials and isotopes are not accurately known. The project's primary objective is to develop the technologies required to conduct comprehensive geologic, geophysical, biologic, and computer model analysis of specific sites. The secondary objective is to integrate the results obtained through technology development into the development of decommissioning alternatives. These studies will provide analyses of the risks associated with the alternatives of designating sites either for permanent storage or for removal of wastes and contaminated sediments.

APPROACH

Development of technologies capable of characterizing buried waste materials has required initiation of specific task activities, including collecting plants and animals from specific burial sites and radiologically analyzing them, drilling for collecting contaminated sediments, determining the radionuclide/sediment geochemical interactions, monitoring micrometeorological and sediment water parameters and computer modeling water transport in sediments, and performing geophysical surveys to locate buried wastes and to define the physical composition of waste forms.

In addition to research performed to develop specific technologies, an evaluation of regulatory issues pertinent to decommissioning was prepared.

PROGRESS AND RESULTS

Several radioactive waste burial sites were drilled and core samples taken for radiological analysis. Results of radiochemical analysis showed no migration of contaminants from their original burial structures. Core sediment samples were analyzed by germanium-lithium, sodium-iodide, liquid scintillation, and alpha spectrometry methods.

Contaminated sediment cores were taken from within a liquid radioactive waste disposal crib. Standard geochemical techniques and projects were developed, and techniques and methodologies were applied to analysis of these sediments. Analyses included neutron-enhanced autoradiography; ultra thin section petrographic microscopy; X-ray fluorenscence, X-ray diffraction, and electron microprobe. Uranium was found to preferentially sorb onto minerals or compounds containing phosphorus, thereby retarding the migration of uranium from migrating within the groundwater system.

Radioactive waste burial sites were monitored using belowground-surface soil monitoring systems and micrometeorological monitoring transducers. Data from these sytems were used as input to computer models. Computer models were developed to determine the potential for groundwater to carry radioactive materials to the

biosphere. Model results indicated that the predominant factor potentially controlling groundwater movement within the partially saturated groundwater system of the Hanford site was frequently precipitation. Using pest meteorological records and monitoring data, it has been shown that in a few instances, water drained into the saturated groundwater system; thus, when precipitation is above normal in consecutive years, water may carry radionuclides through burial structures into the saturated groundwater system. However, with present data, no evidence of radionuclide transport has been found.

Methods have been developed to characterize and quantify radionuclide uptake and exposure to plants and animals inhabiting burial sites. The results of characterization studies have shown that animals burrowing into burial structures exhume contaminated waste materials and that these animals are exposed to significant amounts of radiation. Plants also exhume buried waste materials through their root systems. Hazard to radiation workers and to the population is negligible, however, because radionuclides from the animals and plants do not enter into the food chain for humans.

Surveys of the ground surface of burial grounds were conducted to determine potential gamma exposure. At the time of the surveys, no surface exposure in excess of background was found. However, in the past, exposure has been noted, caused by differential settlement of burial trenches and possibly erosion. Remedial activities have been completed to reduce exposure to background.

A geophysical survey system was developed and used to locate and map buried waste. The system consists of metal detectors, magnetometers and ground-penetrating radar. This system was used to demonstrate belowground-surface mapping of burial structures and to generally define the composition of materials within these structures.

Regulatory issues that may influence decommissioning alternatives selected for the Hanford 300 Area Burial Grounds were reviewed. The results of this activity suggested that perpetual care may be the most advantageous alternative.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

Ames, L.L., and S.J. Phillips, "Characterization of the Hanford 300 Area Burial Grounds --Decontamination and Decommissioning Regulatory Issues, Task II -- Geological Analysis," PNL-2658, Pacific Northwest Laboratory, Richland, Washington, 1979.

Gee, G.W., and C.J. Simmons, "Characterization of the Hanford 300 Area Burial Grounds -- Decontamination and Decommissioning Regulatory Issues, Task III -- Fluid Transport and Modeling," PNL-2921, Pacific Northwest Laboratory, Richland, Washington, 1979.

Morris, F.A., R.F. Smith, and S.J. Phillips, "Characterization of the Hanford 300 Area Burial Grounds," PNL-2875, Pacific Northwest Laboratory, Richland, Washington, 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

NATIONAL DEPARTMENT OF ENERGY DECOMMISSIONING PLANNING SYSTEM

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATOR

J.C. King

OBJECTIVES

The principal objective of this project is to maintain the National Decommissioning Information System, a computer-based information system carrying administrative, physical, radiological, and decommissioning information on contaminated Department of Energy facilities nationwide. A second objective of this project is to provide decommissioning related information in response to incidental requests, both offsite and onsite.

APPROACH

The National Decommissioning Information System is currently maintained on a UNIVAC

host computer using the SYSTEM 2000 (S2K) data base management system. Reporting and updating is accomplished using S2K Immediate Access and Report Writer features. Complex programs requiring system data may be established using the S2K Procedural Language Interface feature. The system may be remotely accessed using dial-up terminals.

PROGRESS AND RESULTS

The system was maintained in an online condition throughout the year using the S2K data management system on the UNIVAC host machine. Decommissioning-related information was provided during the year in response to inquiries from persons and organizations both onsite and offsite.

Funds from this project, together with funds from the Hanford Decommissioning Planning Project, were applied to the conversion of a model for estimating decommissioning costs for liquid and solid waste disposal sites to operate on S2K data bases. This model, PDCST, originally developed for the Hanford decommissioning planning effort, has subsequently proved to be useful in developing "first cut" cost estimates for decommissioning liquid and solid waste disposal and storage facilities. Estimates may be made for both safe storage and dismantlement modes, and unit costs for specific waste items may be readily updated.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

SUPERVISION AND DECONTAMINATION OF NIAGARA FALLS SITE

ORGANIZATION AND CONTRACT NUMBER

National Lead Company of Ohio
DE-AC05-760R01156

PRINCIPAL INVESTIGATOR

J.H. Cavendish

OBJECTIVE

The objective of this project is the decommissioning of the 191-acre Department of Energy Niagara Falls Site and its return to unrestricted use.

APPROACH

This site is used as a radioactive waste storage area. No radioactive wastes were or are generated on the site. The wastes were shipped there from several production locations between 1944 and 1953. National Lead Company of Ohio currently provides supervision and caretaking activities on the site.

The residuals not owned by the Department of Energy are expected to be removed by a private contractor prior to fiscal 1983. After this is completed, the residues owned by the Department of Energy will be removed, buildings demolished, and the site decommissioned.

PROGRESS AND RESULTS

The study of methods for reduction of radon exhalation from wastes was continued, and asphaltic emulsion coating of some residues was completed. A detailed radiological survey of the site was subcontracted to Battelle-Columbus, and the majority of the field work was completed.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

"Informational Report on the U.S. Department of Energy, Niagara Falls Site," NLCO-003EV, Draft for approvals, July 1979.

"Spoil Pile Radiological Survey, DOE-Niagara Falls Site, Lewiston, New York," NLCO-001EV, May 17, 1979.

"Spoil Pile Radon Reduction Alternatives, DOE-Niagara Falls Site, Lewiston, New York," NLCO-002EV, June 19, 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

NATIONAL DEPARTMENT OF ENERGY DECOMMISSIONING PLANNING SYSTEM

ORGANIZATION AND CONTRACT NUMBER

Atomics International Division, Energy Systems Group
DE-AI-03-76SR75008

PRINCIPAL INVESTIGATOR

A.M. Stelle

OBJECTIVE

The objective is to develop and implement a system to generate priorities and a long-range plan for the Department of Energy's decommissioning program. The system output will be a 20-year plan, which identifies projects, priorities, alternate decommissioning strategies, schedules, costs, work force requirements, and waste quantities. The plan will assist the Department in preparing annual budget requests.

APPROACH

The plan and supporting information for the decommissioning of surplus radioactively contaminated facilities will be collected. All information on the condition and characteristics of the facilities will be kept on a retrievable archive. The information will be processed to develop a priority preference and estimated cost for the proposed decommissioning. The indicated activities will be scheduled so as to be within the Department of Energy budget forecast for the year. The results, along with the data and assumptions used to develop the plan, will be published.

PROGRESS AND RESULTS

The updated preliminary plan for decommissioning of the Department of Energy radioactively contaminated surplus facilities was issued twice in draft form. The first draft was reviewed, and comments received were incorporated into the second draft. The second draft was prepared in final format and submitted to the Department of Energy for final approval. Publication of the report will occur during fiscal 1980.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

NATIONAL DEPARTMENT OF ENERGY DECOMMISSIONING PLANNING SYSTEM

ORGANIZATION AND CONTRACT NUMBER

United Nuclear Industries, Inc.
AC06-76RL01357

PRINCIPAL INVESTIGATOR

J.W. Jones

OBJECTIVES

A draft plan has been prepared in response to the need for a coordinated long-term decommissioning program. Its objectives are to

- Develop a centralized approach to estimating the cost, planning, and schedule requirements of decommissioning projects;
- Define the total decommissioning effort;
- Enable the Department of Energy to apply resources in a disciplined manner to minimize potential hazards and to maximize the speed and efficiency of the decommissioning program; and
- Present a system of planning that can be expanded to include facilities yet to be declared surplus and subsequently to be decommissioned.

The plan was prepared by Atomics International with assistance from UNC Nuclear Industries.

APPROACH

The approach is to

- Assist Atomics International in collecting data, validating additions to the Surplus Facilities List, and grouping facilities into decommissioning projects;
- Provide descriptions and disposition information on approximately 50 projects; and
- Provide revised information on approximately 70 projects to reflect comments from the Department of Energy.

PROGRESS AND RESULTS

A final draft of the subject plan was completed on September 21, 1979.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

BUILDING 350 GLOVEBOX DISPOSAL

ORGANIZATION AND CONTRACT NUMBER

Argonne National Laboratory
W-31-109-ENG-38

PRINCIPAL INVESTIGATORS

W.H. Kline
P.E. Neal

OBJECTIVES

The objectives are to decommission the Argonne National Laboratory Surplus Plutonium Fabrication Facility and make the area available for further nuclear work by New Brunswick Laboratory. The project includes dismantling gloveboxes; ventilation ductwork; utility systems and associated internal and external equipment, including necessary size reduction to fit acceptable packaging for the Department of Energy transuranic waste retrievable storage site; and decontamination of the facility to acceptable levels.

APPROACH

Prior to size reduction, equipment will be disassembled and bagged out and attempts will be made to decontaminate glovebox interiors to less than retrievable transuranic waste levels using simple cleaning techniques followed by the coating of all inside surfaces with latex paint. Size reduction will be accomplished by disassembly and mechanical cutting in a specially constructed plastic enclosure. The enclosure is maintained at a negative pressure relative to the general work area, and the workers wear protective clothing, with air supplied by respirators (Figure 48). Complete dismantlement and decontamination of the remaining systems and structures will be performed.

PROGRESS AND RESULTS

- A temporary contamination control enclosure, including an exhaust ventilation system, was constructed and tested, and after a safety review, it was placed in operation for size reduction operations.
- A protective clothing system, including a breathing air supply and a National Institute for Occupational Safety and Health approved respirator for use by those personnel who perform size reduction operations inside a contamination control enclosure, was developed.
- Additional dismantling techniques were developed, and procedures were prepared and subjected to safety reviews.
- A direct reading survey instrument that distinguishes from nontransuranic waste was field tested and put into use.
- Two sections and four complete gloveboxes, including all internal equipment, were successively decontaminated, dismantled, size reduced, packaged, and shipped offsite. Two of these boxes had been part of those in controlled storage.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

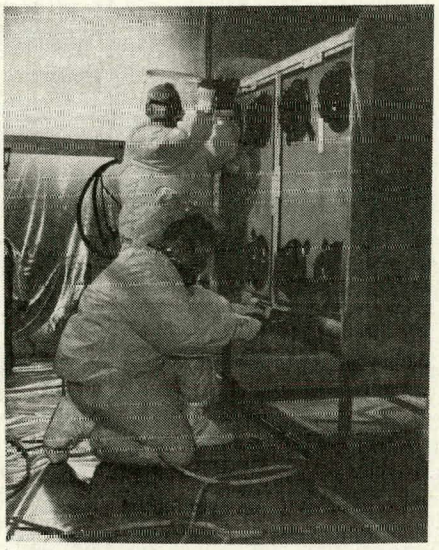


Figure 48. Workers Wearing Protective Clothing and Air-Supplied Respirators Begin Disassembly of a Plutonium Glovebox Section Inside a Contamination Control Enclosure

REPORTS PUBLISHED

Roche, C.T., et al., "A Nondestructive Assay System for Use in Decommissioning of Plutonium-Handling Facility," ANL-79-60, Argonne National Laboratory, July 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECOMMISSIONING OF SURPLUS CONTAMINATED LOS ALAMOS SCIENTIFIC LABORATORY FACILITIES

ORGANIZATION AND CONTRACT NUMBER

Los Alamos Scientific Laboratory
W-7405-ENG-36

PRINCIPAL INVESTIGATORS

A. Valentine
R. Garde
J. Harper

OBJECTIVE

The primary objective of this project is to decommission excess Los Alamos Scientific Laboratory facilities that are contaminated with radioactive materials.

APPROACH

Excess facilities have been identified and ranked for priority of disposition. As funding becomes available, the following actions are taken to accomplish disposition:

- A historical records search is made to establish a data base of construction drawings and contamination levels.
- Preliminary radiation surveys are performed to identify and characterize the existing contamination levels within the remaining facility, equipment, and the surrounding land area.
- Procedures and techniques are developed for the project. Conventional demolition methods are used to remove the remaining building structures after the contaminated equipment items and building materials are removed and disposed of onsite.
- Contaminated debris and soil is transported to an onsite radioactive waste burial site.
- Final monitoring results and release of the area or facility are documented.

PROGRESS AND RESULTS

Decommissioning of an actinide-contaminated exhaust air filter building (TA-21-153) was completed (Figure 49). This project began in fiscal 1978. Remaining contamination levels were measured and determined to meet the as-low-as-practicable criteria.

Decontamination of a tritium facility was the major project during fiscal 1979. This facility (TA-35-TSL-2A-12) included tritium-contaminated glovebox lines, hoods, and effluent treatment equipment items. Removal and onsite disposal of these items was accomplished by using techniques to fix and contain the tritium contamination in the equipment items. Several of these techniques are described.

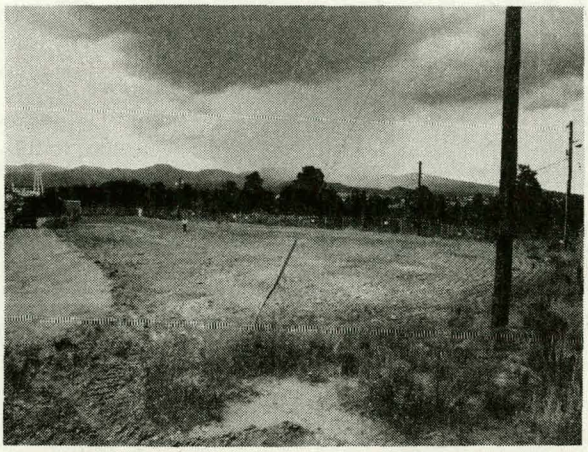


Figure 49. Final TA-21-153 Site Condition

Contaminated copper pipe lines were cut into sections, which were sealed with metal caps containing silastic. The exterior of the seal joint was coated with flashlite (cold roofing tar) cement. These seals prevented the escape of tritium during packaging, transport, and burial. The copper pipes and other highly contaminated items such as electrodryers (Figure 50), a gas blower, a recombiner, and heat exchangers were packaged in large fiberglass plywood boxes for transport and burial onsite.

The glovebox interiors were coated with an asphalt undercoating to fix loose particulate materials. Gloveboxes were separated, and the ends were sealed by inserting putty tape between the open glovebox end and a metal plate. The external surfaces were then coated with flashlite cement.

The primary methods used to preclude exposures were the use of polyvinyl chloride, two-piece supplied air suits, ventilation, supplied air respirator packs, plastic shoulder-length gloves, asphalt undercoating, flashlite cement, and silastic. Expanding foam (polyurethane foam #302) was introduced into some of the copper lines prior to cutting them. The foam displaced tritium-contaminated air and particulates, thereby allowing pipes to be cut with minimal airborne control problems.

Over a period of 125 workdays, 158 cubic meters of solid waste, containing an estimated 6000 curies of tritium, was disposed of.

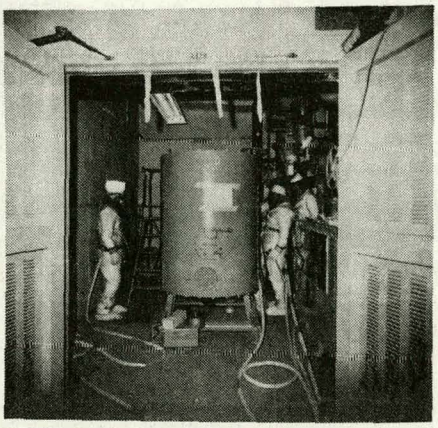


Figure 50. Tritium-Contaminated Electrodryer Removal Operation

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECOMMISSIONING OF THE NEW BRUNSWICK LABORATORY

ORGANIZATION AND CONTRACT NUMBER

Chicago Operations and Regional Office

PRINCIPAL INVESTIGATORS

T. Balamut
J. Condoles

OBJECTIVE

The objective of the project is to return to unrestricted use the site of the old New Brunswick Laboratory facilities in New Jersey.

The laboratory consists of several building complexes on a 1.4-acre site.

APPROACH

Radioactive contamination in the buildings will be reduced to acceptable levels by removal of equipment, materials, and portions of the structure as necessary. The underground piping system and a stockpile of pitchblende-contaminated soil buried on the site will be removed. Following decontamination, all remaining structures will be demolished, and the site will be released for unrestricted use.

PROGRESS AND RESULTS

Initial decontamination was accomplished by a commercial firm under contract to the Department of Energy during fiscal 1978. This work involved removal of all contaminated furniture, equipment, ventilation and filter systems, and the entire aboveground piping systems.

An architect-engineer firm is presently under contract to prepare a Phase II design package for further decontamination work at the site. This will consist of procedures for removal of the remainder of building contamination, including the underground sewer system and demolition of all structures.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECOMMISSIONING OF THE ORGANIC MODERATED REACTOR EXPERIMENT

ORGANIZATION AND CONTRACT NUMBER

EG&G Idaho, Inc.
DE-AC07-76ID01570

PRINCIPAL INVESTIGATORS

R.H. Meservey
R.E. Hine

OBJECTIVE

The objective of this decommissioning project is to dismantle and remove the Organic Moderated Reactor Experiment facility (Figure 51) in its entirety. The reactor, all associated systems, buildings, roadways, parking lot, power poles, and contaminated soil will be removed. The area will be restored to its natural state by grading and seeding with a native grass.

APPROACH

The approach was to completely dismantle and dispose of the entire facility. Contaminated items and materials were placed in plywood boxes and transferred to the Radioactive Waste Management Complex. Noncontaminated items were placed on surplus materials lists if they had salvage value, or transported to a sanitary landfill if they had no salvage value.

PROGRESS AND RESULTS

A decommissioning plan and safety evaluation were written in preparation for starting the dismantling work. All contaminated and noncontaminated reactor support systems and components were removed. All underground tanks and structures were excavated and properly disposed of. The electrical and instrumentation systems were removed and the reactor control room dismantled.

The main reactor building and other smaller support structures were dismantled and removed from the site. Following removal of the buildings, all concrete pads and structures were demolished. The noncontaminated concrete was used as fill material for some of the larger excavations on the site.

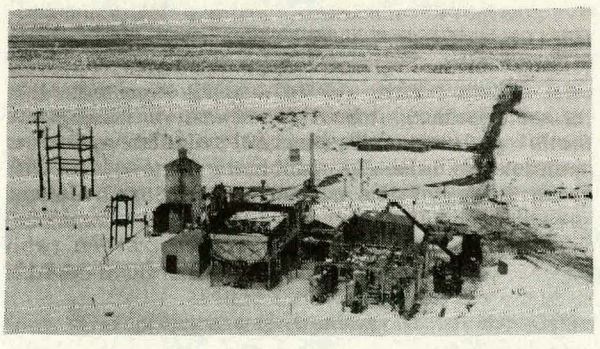


Figure 51. Organic Moderated Reactor Experiment Facility Before Decommissioning

Noncontaminated material was assessed for its salvage value. Noncontaminated material having no salvage value was hauled to a sanitary landfill at the Idaho National Engineering Laboratory.

Contaminated material was cut into pieces small enough to be placed in plywood boxes 128 cubic feet in volume and taken to the Radioactive Waste Management Complex for disposal. About 250 boxes were filled during the Organic Moderate Reactor Experiment dismantling operation.

Disassembly of reactor piping systems required nonflame (mechanical) cutting techniques because they still contained the flammable organic coolant. The piping was also insulated with asbestos, and thus, all disassembly and handling required safety precautions.

Following removal of all hardware, systems, and buildings, the contaminated soil was removed. After establishing radiation surveys of the remaining areas, the excavations were filled, and final grading and seeding were accomplished (Figure 52). A final project report was published.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

"Decontamination and Decommissioning (D&D) Plan for the Organic Moderated Reactor Experiment (OMRE)," WMP-77-17, Revision 1, December 1977.

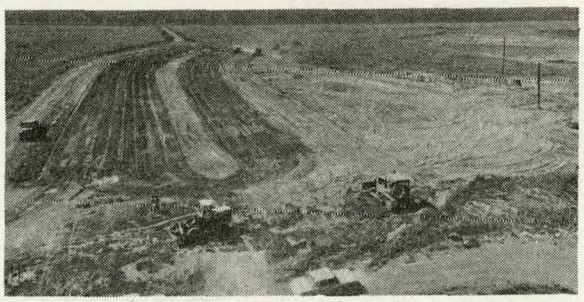


Figure 52. Organic Moderated Reactor Experiment Site During Final Grading and Seeding Operation

"Final Report -- Decontamination and Decommissioning of the Organic Moderated Reactor Experiment (OMRE) Facility," PR-W-79-037, September 1979.

"Safety Evaluation for Decontamination and Decommissioning of the Organic Moderated Reactor Experiment," PR-W-79-010, April 1978.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

GNOME SITE DECOMMISSIONING

ORGANIZATION AND CONTRACT NUMBER

Fenix & Scisson
DE-AC08-76NV00038

Reynolds Electrical & Engineering Company
DE-AC08-26NV00410

EG&G Idaho, Inc.
DE-AM08-76NV01183

PRINCIPAL INVESTIGATOR

R.D. Clarke

OBJECTIVE

The objective of this project is to clean the Gnome site (Figure 53) in accordance with the proposed criteria and return the land to the Bureau of Land Management, with no restriction on surface use by the general public.

APPROACH

During Phase I, aerial and ground radiological surveys were conducted; approval of radiological cleanup criteria was obtained; and an operational plan for decommissioning activities, based on survey results, was developed. During Phase II, two existing wells (one from the Coach drift and one in the Gnome cavity) are to be cleaned out, USGS-1 will be rehabilitated as a water supply well with pump and piping installed, and other preparations will be made to inject the muck pile into the Gnome cavity. During Phase III, the muck pile will be crushed, slurried, and pumped into the Gnome cavity, and

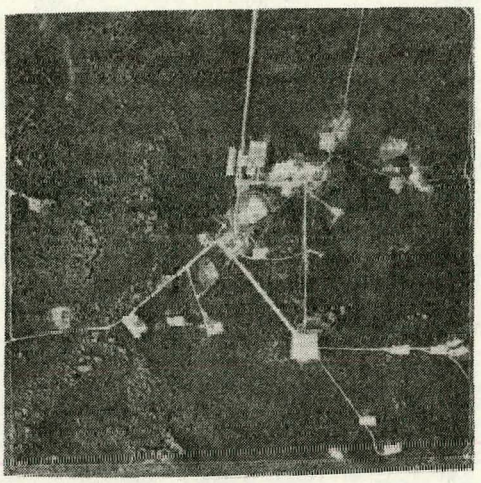


Figure 53. Aerial Photograph of Gnome Site

other site restoration will be performed as required. The land will be returned to the custody of the Bureau of Land Management.

PROGRESS AND RESULTS

Phase I has been completed, and the Phase I radiological report has been received. It was concluded by pathway analysis that the exposure to the public would be negligible.

Phase II and III were planned around the quantative information derived from Phase I. They were conducted as a single operation beginning in April 1979 and terminating in September 1979. Phase II consisted of the cleanout and opening of the Gnome reentry holesSR-2A and LRL-7. Phase III consisted of a downhole slurrying operation. A mobile plant was erected consisting of a series of three crusher units and seven conveyer belts for transport of materials to a hopper where they were mixed with water for maximum dissolution and transport through a pipeline into tubing running downhole into the Gnome cavity. SR-2A was selected as the first reentry hole, and a new cavity reentry hole, designated DD-1, was drilled later to enter the highest point of the cavity.

To conserve cavity space for solids, the operation was later changed by recycling the fluid from the cavity and tunnel complex back to the surface through a piping system and then directly to the wellhead of the new reentry well for direct discharge into the hopper and immediately downhole. The recycled fluid was returned to the surface by a pump run in Hole LRL-7 and discharged into a storage tank at the LRL-7 location. The water was carried to hole DD-1 by gravity flow.

The downhole slurrying operation was terminated when the cavity fillup reached the surface measured depth of 1115 feet, leaving approximately 10 feet of freeboard to the cavity roof. The approximate 6000 cubic yards of uncontaminated salt remaining were buried in a deep trench excavated in the area just north and adjacent to the former salt muck pile locations. LRL-8 and SR-2A were plugged with cement from the lowest practical depth back to the surface. LRL-7 and DD-1 were completed and will be used as long-term monitoring holes to check the possible fluctuation of the cavity fluid level and observe the "leach zone" immediately above the salt formation.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

"Safety Analysis Report for Tory II-C Fuel Recovery," NVO-164, December 1975.

"Gnome Site Decontamination and Decommissioning -- Phase I Radiological Survey and Operations Report -- Carlsbad, New Mexico," NVO/0410-48, December 1978.

"Project Gnome Decontamination and Decommissioning Plan," NVO-202, April 1979; Addendum A, July 1979; Addendum B, September 1979; and Errata, September 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

NUCLEAR ROCKET DEVELOPMENT STATION SURVEY AND CLEANUP

ORGANIZATION AND CONTRACT NUMBER

Reynolds Electrical & Engineering Company
DE-AL08-76N00410

PRINCIPAL INVESTIGATOR

P.K. Fitzsimmons

OBJECTIVE

This project was begun in fiscal 1978 by conducting a comprehensive survey of Area 25 to complete the delineation of radioactivity on and in equipment, facilities, and land areas. The scope of this project was made with the assumption that Area 25 would remain under Department of Energy control, that E-MAD and ETL facilities were currently in use and not considered as part of the project, and that systems and very large fixtures to which access can be limited to negate any health hazard would be isolated and remain in place. The goal is to make Area 25 as radiologically clean as feasible.

APPROACH

This project is being accomplished in conjunction with support to the weapons program. The management controls are line supervision and technical support within the Environmental Sciences Department of the Reynolds Electric & Engineering Company. Services are required from other departments within the company.

PROGRESS AND RESULTS

During fiscal 1978, a comprehensive survey of facilities was conducted. In addition, the contaminated material and equipment in the R-MAD CWD and RMSF buildings were relocated to the U3ax radioactive waste management site.

Most of the fiscal 1979 effort was expended in decontaminating the R-MAD building, which will be completed by September 20, 1979. Late in the year, the two exhaust ducts from ETS-1 were transported to the U3ax Radioactive Waste Mangement site. Two trailers are currently being moved from the R-MAD compound to the U3ax Radioactive Waste Management site.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECONTAMINATION OF THE CENTER FOR ENERGY AND ENVIRONMENT RESEARCH MAYAGUEZ FACILITIES

ORGANIZATION AND CONTRACT NUMBER

University of Puerto Rico, Center for Energy and Environment Research
EY-76-C-05-1833

PRINCIPAL INVESTIGATOR

H. Barcelo

OBJECTIVE

Except for the facilities being retained by the University under Nuclear Regulatory Commission licenses (Natural Uranium Graphite Moderated Subcritical Pile and GO-CO Gamma Source), the Center for Energy and Environmental Research Mayaguez facilities are to be decontaminated to unrestricted use levels.

APPROACH

Based on a comprehensive radiological survey and an approved decontamination plan, an engineering assessment will be made of the decontamination requirements for the Center's training research and isotope production reactor and its L-77 training reactor, and other research and support facilities at the Mayaguez site. The engineering assessment will define the current radiological status of the facilities, provide a logical cost-effective sequence of work tasks with full application of the as-low-as-reasonably-achievable principle, and provide an engineering cost estimate for the decontamination work.

Using the engineering assessment and the decontamination plan as a guide, a subcontractor will initiate decontamination of the Mayaguez facilities, which will require significant demolition work. The Center will undertake limited decontamination work, which will not involve structural integrity of the facilities or associated radiological control systems. Included in this effort will be shipment of currently accumulated radioactive wastes and debris to thecontinental United States for commercial disposal, plus shipment of L-77 fuel and excess neutron sources to a site designated for storage by the Department of Energy.

The center will also perform radiological surveys to ensure that decontamination criteria are met during remedial action efforts and to certify the site for unrestricted use or to recommend additional remedial actions if it is still contaminated. Finally, the center will have a subcontractor perform final decontamination work to release the site for unrestricted use.

PROGRESS AND RESULTS

The decommissioning plan for the L-77 reactor was completed. Engineering assessments, including supplemental radiological survey data, were completed by the selected subcontractor and a draft report was submitted in August 1979. Oak Ridge Operations Office and Center for Energy and Environmental Research comments were provided to the subcontractor in September 1979.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

WELDON SPRING SITE SUPERVISION AND DECOMMISSIONING

ORGANIZATION AND CONTRACT NUMBER

National Lead Company of Ohio
DE-AC05-760R01156

PRINCIPAL INVESTIGATOR

J.H. Cavendish

OBJECTIVE

The objective of this project is to decommission the Department of Energy-Weldon Spring site and return it to unrestricted use.

APPROACH

The site consists of four pits that contain the radioactive wastes generated from the production of uranium metal at the Weldon Spring Production Center from 1957 to 1966. The Department of Energy also has possession of a quarry located 4 miles from the Weldon Spring Plant, which was used for the disposal of contaminated rubble and thorium residues. The residues contained in the four pits are to be removed by private contractor. The National Lead Company of Ohio will monitor the removal of the sludges and pump any surface runoff as necessary back into the pits. After the sludges have been removed, the supernatant liquors will be treated and discharged to the Missouri River and the site will be graded to an essentially natural contour. Pending geological and risk assessments, there may be an attempt made to seal a portion of the floor of the quarry with grouting. If this proves successful, the quarry area will be filled, graded, and seeded.

PROGRESS AND RESULTS

Substantial agreement has been reached with a private contractor on the terms of a contract that calls for removal of the wastes from the four pits over a period of 2 years. The Department of Energy has solicited a nonrevokable permit from the Department of the Army, which would give the contractor the use of the Army's railspur and land at Weldon Spring. Biodenitrification studies of pit water have been initiated at the Oak Ridge National Laboratory. Background information on the quarry has been summarized, and geological and risk assessments have been initiated through the Oak Ridge National Laboratory toward isolation of the quarry from the environment.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECOMMISSIONING OF HANFORD 200 AREA SURPLUS FACILITIES

ORGANIZATION AND CONTRACT NUMBER

Rockwell Hanford Operations
DE-AC06-77RL01030

PRINCIPAL INVESTIGATORS

A.W. Graves
J.H. Hummer
J.E. Toomey

OBJECTIVES

The objectives of this program are to develop planning, equipment and process technology, and field operational procedures necessary for the ultimate disposition of surplus contaminated Hanford facilities under Rockwell Hanford Operations' control and to demonstrate these developments in a plutonium-contaminated process building.

APPROACH

Scheduling of surplus facilities for decommissioning is established by a priority system that considers the relative significance of a set of mutually independent variables: potential offsite radiological hazards, onsite environmental and personnel radiological and industrial safety hazards, cost of continued surveillance and maintenance, and compatability of the facility with other projected future uses of the site. Decommissioning operations are executed in an identified long-range schedule.

Within this program, the composite efforts are separated into five major categories to assist in overall program and project planning and assignment of functional responsibilities. The specific categories used are program management and control, engineering and planning, tooling and equipment development, decommissioning operations, and radioactive waste handling; all the efforts involved in the program fall into one of these categories.

Specific project planning and operations are implemented through a series of supporting documents. For each facility selected for decommissioning, a facility decommissioning plan defining the scope and requirements of the decommissioning effort is prepared. Activity requirements documents are written for each major task to define, in detail, the scope and requirements applicable to completing the task. Subordinate to activity requirements, an engineering activity plan is generated to identify the necessary engineering efforts and schedule all subtasks through final physical completion of the activity. All field operations are conducted according to work procedures with provisions for documenting pertinent data. All work is documented in engineering reports summarizing the work conducted for each activity.

PROGRESS AND RESULTS

A long-range schedule was formulated giving a priority sequence for decommissioning of the surplus facilities under Rockwell's control in support of the Department of Energy's National Disposition Planning Program. A Rockwell long-range decommissioning plan was prepared to establish a specific sequence for decommissioning the 322 retired contaminated facilities under Rockwell's control: buildings, stacks, other structures, and approximately 3000 acres of outdoor waste management sites such as ponds, ditches, trenches, cribs, and burial grounds. Nine engineering reports presenting physical and radiological characterization data for various projects and a description of the scope of effort needed to decommission the facilities were also prepared.

Decommissioning operations were initiated in the 233-S building (Figure 54), an alpha contamination process facility. The following activities were executed:

- Reactivation, repair, and installation of the utilities and safety systems to support personnel occupancy in the 233-S building;
- Readiness reviews using the Management Oversight and Risk Tree techniques for two activities: decommissioning of a combined two-room area and dismantling of a plutonium-product loadout hood;
- Preparation and issue of a safety assessment document for decommissioning operations;
- Dismantling, decontamination, and release (undetectable surface contamination remaining) of the two-room area;
- Partial dismantling and decontamination of a third room;
- Decontamination and contamination fixing in the loadout hood and partial dismantlement; and

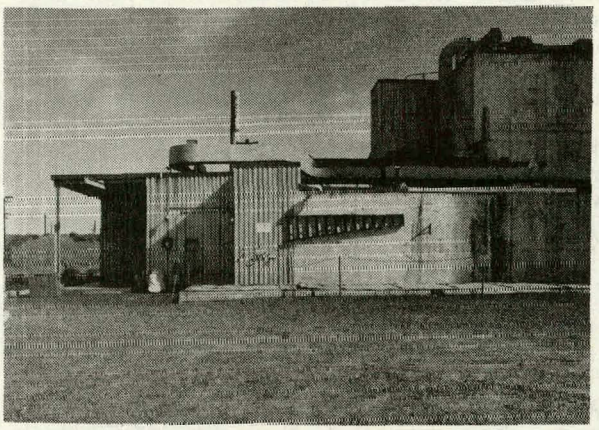


Figure 54. 233-S Building Exterior

- Interface with the Pacific Northwest Laboratory and Hanford Engineering Development Laboratory for processing and analyzing alternative methods of (1) treating transuranic solid waste materials generated from decommissioning operations; (2) vibratory finishing and electrochemical polishing; and (3) Radioactive Acid Digestion Test Unit combustible waste disposal.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

Graves, A.W., "Decontamination and Decommissioning Program Plan," RHO-CD-421, March 1979.

Nunn, S.E., and D.C. Shoemaker, "233-S Building Decontamination and Decommissioning Safety Assessment Document," RHO-CD-658, March 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECOMMISSIONING OF SODIUM REACTOR EXPERIMENT FACILITIES

ORGANIZATION AND CONTRACT NUMBER

Atomics International Division, Energy Systems Group
DE-AI-03-76SF75008

PRINCIPAL INVESTIGATORS

B.F. Ureda
J.W. Carroll

OBJECTIVE

The objective of the task is to dismantle the Sodium Reactor Experiment facility and to remove all significant reactor-originated radioactivity from the site, thus releasing the facility from all requirements for radiological control, licensing, or monitoring, and make the site available for other uses.

APPROACH

The approach is the complete dismantling and disposal by land burial of all activated structures or components, dismantling or decontamination of all contaminated structures or components, and disposal by land burial of all radioactive waste generated as part of the dismantling activity.

PROGRESS AND RESULTS

The upper 5 feet of the concrete monolith in which the fuel storage cells were encased were removed, and all of the fuel storage cells were removed and shipped for burial.

Installation of the shoring piles was completed so that excavation of the interior of the building could proceed. The concrete biological shield, which surrounded the reactor, was exposed to a depth of 15 feet and was broken into rubble and removed. The entire vertical wall of the biological shield steel liner was segmented, removed (Figure 55), and shipped to burial. The interior of the remaining part of the biological shield, which was activated to a depth of approximately 15 inches, was 90 percent removed.

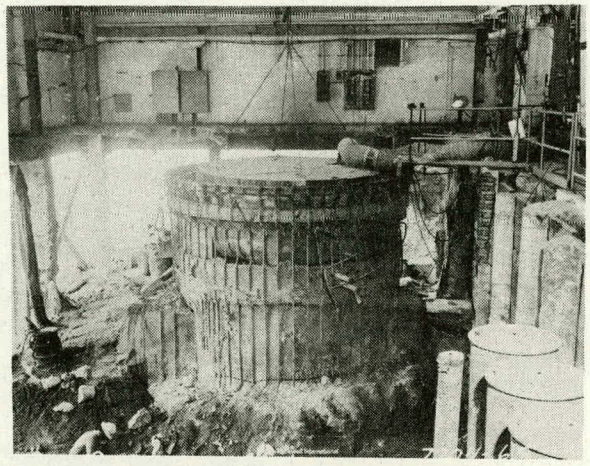


Figure 55. Excavation Around Reactor Core Cavity Liner

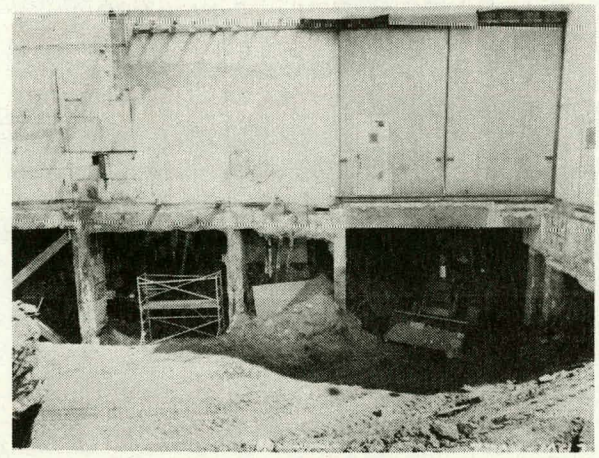


Figure 56. Excavation Beneath Sodium Reactor Experiment Facility

Excavation of the exterior contaminated soil at the northeast corner of the building was completed (Figure 56). Seismic and wind bracing was installed to protect the building during the prolonged excavation period. Temporary supports for two building columns were installed to allow removal of contaminated portions of columns and footings and rebuilding of the columns. The primary pipe gallery vaults, walls, and floors were removed and the kerosene trenches were decontaminated. A total of 43,000 cubic feet of activated or contaminated soil and rubble was shipped for burial during the fiscal year.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

Brengle, R.G., "Decontamination of Concrete," presented at the American Nuclear Society Decommissioning Seminar, September 16-20, 1979.

Brengle, R.G., and E.L. Babcock, "Equipment for Remote Dismantling," presented at the American Nuclear Society Decommissioning Seminar, September 16-20, 1979.

Kittinger, W.D., and G.W. Meyers, "Decommissioning the Sodium Reactor Experiment, A Status Report," presented at the American Nuclear Society Decommissioning Seminar, September 16-20, 1979.

Kittinger, W.D., B.F. Ureda, and J.W. Carroll, "Experience and Techniques in AI's Recent Decommissioning Program," presented at the Health Physics Society Annual Meeting, July 8-13, 1979.

Meyers, G.W., and W.D. Kittinger, "Progress Report on Dismantling of the Sodium Reactor Experiment," presented at the International Symposium on the Decommissioning of Nuclear Facilities, November 13-17, 1978, and at the American Nuclear Society Winter Meeting, November 16, 1978.

Ureda, B.F., and J.W. Carroll, "Environmental Protection Experience in Atomics International's Recent Decommissioning Programs," presented at the DOE Environmental Control Symposium, November 28-30, 1979.

Ureda, B.F., and J.W. Carroll, "Environmental Protection Experience in Atomics International's Recent Decommissioning Programs," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECOMMISSIONING OF HANFORD 100 AREA RETIRED PRODUCTION REACTORS

ORGANIZATION AND CONTRACT NUMBER

United Nuclear Industries, Inc.
AC06-76RL01857

PRINCIPAL INVESTIGATOR

A. Russell

OBJECTIVES

The objectives of this project are to establish engineering, planning, tool/process development, and field operation for decommissioning the contaminated portion of the retired plutonium production reactors at Hanford.

APPROACH

A project planning approach will be applied to the decommissioning of the 100-F production reactor and similar development efforts will be made for other 100-F site facilities, commensurate with the problems expected to be encountered during their disposition. The project will be conducted in phases:

- Prepare radiological and physical descriptions of the site and facilities;
- Develop a dismantling plan identifying and defining the major tasks, identifying proposed techniques, developing detailed procedures, and identifying tooling or process development requirements; and
- Decontaminate and remove facilities, install biological shields over ground disposal areas, and document end product.

PROGRESS AND RESULTS

The following plans have been developed for decommissioning work:

- Prepared and issued planning documentation,
- Initiated development contract for preparation of special metal cutting tooling,
- Restored service to some necessary reactor building facilities,
- Removed instrumentation from 100-F, reactor control room,
- Removed portions of contaminated biological research facilities, and
- Developed preliminary cost and manpower requirements.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

DECOMMISSIONING OF THE SPECIAL POWER EXCURSION REACTOR TEST-IV FACILITY

ORGANIZATION AND CONTRACT NUMBER

EG&G Idaho, Inc.
DE-AC07-76ID01570

PRINCIPAL INVESTIGATORS

R.H. Meservey
D.L. Smith

OBJECTIVE

The objective of this project is to remove all remaining contaminated equipment from the Special Power Excursion Reactor Test-IV Facility. The facility would then be released for further use.

APPROACH

The approach is to dismantle and remove all contaminated piping, pumps, and valves remaining in the facility. The reactor tanks (pool type reactor) will then be sectioned, using plasma torches. After disassembly and sectioning, all contaminated materials will be placed in boxes and taken to the Radioactive Waste Management Complex for disposal.

PROGRESS AND RESULTS

A decommissioning plan was written and followed during the operation of this project. All contaminated components were disassembled or sectioned and removed. A total of about 70 cubic meters of solid radioactive waste was generated as a result of this decommissioning project. The project was completed and the building restored to use by the EG&G Idaho, Inc., Materials Science Laboratory.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

"Decontamination and Decommissioning Plan for the SPERT-IV Reactor Building," PR-W-79-002, February 1979.

"Final Report -- SPERT-IV Decontamination and Decommissioning," TREE-1373, August 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

HALLAM COMPONENT SODIUM REMOVAL

ORGANIZATION AND CONTRACT NUMBER

EG&G Idaho, Inc.
DE-AC07-76ID01570

PRINCIPAL INVESTIGATORS

R.H. Meservey
L.K. Huntsman

OBJECTIVES

The Hallman Nuclear Power Facility at Hallam, Nebraska, was dismantled between 1964 and 1968. At that time, several major components (heat exchangers, primary pumps, evaporators, air eliminators, and superheaters) were shipped to the Idaho National Engineering Laboratory for storage. Until October 1977, the components were maintained under a nitrogen purge to protect and stabilize the contaminated sodium they contained.

The objectives of the Hallam Component Sodium Removal Project are to design and build a system to react the sodium in the components and then to remove the resulting caustic solution from them. The caustic solution is to be neutralized and disposed of, and if possible, the components are to be decontaminated and added to the surplus materials list.

APPROACH

The sodium processing system was designed to use the wet nitrogen process. That is, the components were purged with gaseous nitrogen to eliminate any oxygen in the system. Steam was then introduced into the nitrogen purge, thus permitting the sodium-water reaction to take place. Pressures, temperatures, and hydrogen and oxygen contents in the exhaust gas stream were monitored throughout the processing operation. The reaction rate was controlled by controlling the steam flow rate.

PROGRESS AND RESULTS

All of the Hallam components were processed during fiscal 1979. Individual components were processed with nitrogen and steam until the hydrogen concentration in the exhaust stream had decreased to a value of less than 4 percent. At that time, the nitrogen/steam flow was stopped, and the component was filled with water. The water filling operation was approached cautiously with only small amounts (approximately 10 gallons) added at a time during the initial steps. Hydrogen content, pressure, and temperature data dictated the rate at which increments of water were added to the vessel. If after several incremental additions of water no further evidence of a sodium-water reaction could be detected, the component was slowly filled with water. As a general rule, the components were allowed to stand full of water for several days before an attempt was made to neutralize and drain the caustic solution. Following the water filling operation, the caustic solution was neutralized, drained, and disposed of at a disposal area.

After the processing operation was completed, all components were opened for inspection. This involved extensive cutting of the large components to several inner surfaces. With the exception of some special bellows assemblies in the superheaters and steam generators, all surfaces were clean and free of sodium. These special assemblies did not allow steam or water penetration and thus still contained small amounts of unreacted sodium.

Components that contained neither sodium nor radioactive contamination were disposed of as surplus material. Contaminated components were taken to the Radioactive Waste Management Complex for disposal, and those still containing these small amounts of sodium were taken to the Idaho National Engineering Laboratory sanitary landfill for storage.

The processing operation was very successful and was completed in a safe and efficient manner. However, it did demonstrate the need for a complete inspection following processing to determine whether complete and total sodium removal was accomplished.

Disposal of the Hallam components was completed in fiscal 1979.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

"Decontamination and Decommissioning (D&D) Plan for the Hallam Project," WMP-77-18, Revision 1, December 1979.

"Safety Evaluation Report for the Decontamination and Decommissioning of the Hallam Reactor Components," PR-W-79-013, May 1978.

"Sodium Removal From Hallam Reactor Components," TREE-1368, August 1979.

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

SPECIAL METALLURGICAL BUILDING ROOF REPAIR

ORGANIZATION AND CONTRACT NUMBER

Mound Facility
DE-AC-4-76-DP00053

PRINCIPAL INVESTIGATORS

D.L. Balsmeyer
E.L. Murphy
L.E. Fye

OBJECTIVES

The objectives of this project are to remove portions of the radioactively contaminated roof in the special metallurgical building roof, repair and reseal the roof, and repair building air conditioning equipment.

APPROACH

Four roof areas, totaling approximately 300 square feet and known to be contaminated with quantities of plutonium-238, were covered with a temporary environmental enclosure, and all roof materials were removed to the metal decking. The work areas and workers were protected and monitored for contamination.

Roof repairs consisted of replacing areas with a new built-up roof and then sealing the entire roof with a 40-mil urenthane membrane, thereby eliminating water leakage into the unoccupied contaminated area and occupied uncontaminated office, laboratory, and building service areas.

Air conditioning repairs included replacing piping from the cooling water pumps to the cooling tower and repairing the cooling tower. This equipment services the air handling unit in operation to service the building.

PROGRESS AND RESULTS

All work was completed during fiscal 1979. The roof was repaired and resealed without environmental or personnel radiation exposures exceeding health limits. Selected areas were removed from the roof, thereby reducing the radiation release potential from the roof. Water leakage into the building was eliminated, minimizing contaminated water generation. The urethane membrane also provides additional contamination containment on the roof.

The air conditioning equipment was repaired, thereby ensuring air conditioning within the uncontaminated occupied areas of the building.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

The project was transferred to the Office of Nuclear Waste Management.

REMEDIAL ACTIONS AT INACTIVE URANIUM MILL TAILINGS SITES

The continuing objective of this program is to eliminate or control radiological health impacts to the public from accumulations of uranium mill tailings that resulted from the milling of uranium to supply the needs of Government programs. Proposed legislation for remedial actions at inactive mill tailings sites was introduced in fiscal 1978. On November 8, 1978, legislative authority to implement a remedial action program was provided by the Congress in Public Law 95-604, "The Uranium Mill Tailings Radiation Control Act of 1978." Title I of the Act authorizes the Department of Energy, in cooperation with the affected States and Indian Nations, to provide a program of assessment and remedial action at such sites, to stabilize and control these tailings in a safe and environmentally sound manner and to minimize or eliminate the radiation health hazards to the public.

Radiological assessments of inactive uranium mill tailings sites in the United States led to the identification of 25 processing sites as candidates for remedial action. Under the provisions of the Act, the Department of Energy is assessing the potential health effects to the public from the residual radioactive materials on or near the 25 sites; with the advice of the Environmental Protection Agency, the Department is to establish priorities for performing remedial action not later than November 8, 1979.

The Act required the Department of Energy to provide, no later than July 1, 1979, a report summarizing the results of a study undertaken by the Department to identify all sites on public or acquired lands of the United States containing residual radioactive materials and other radioactive wastes that had not been previously reported to the Congress. The report was provided and indicated that 48 new sites had been identified by the 18 Federal agencies that participated in the study. The Environmental Control Technology Division supported implementation of the Act by conducting aerial and ground radiological surveys and radon monitoring projects to identify properties where residual material derived from the processing sites is present. The data will be used in the process of designating the properties as candidates for remedial action.

RADIOLOGICAL SURVEY OF INACTIVE URANIUM MILL TAILINGS SITES

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATOR

F.F. Haywood

OBJECTIVES

The objectives of this program are to determine the current radiological status of inactive uranium mills, provide analytical support for engineering and environmental contractors performing studies at these sites, and develop information that will serve as a basis for an assessment of the radiological impact of tailings piles at these mills. A specific objective is to characterize the spread of contamination at each site through studies of airborne, terrestrial, and

aquatic pathways, and to document the findings in technical reports.

APPROACH

Radiological studies at inactive uranium mills include the measurement of gamma-ray exposure rates at 1 meter above the ground on tailings in the former mill areas, in an area surrounding the site, and in background areas uninfluenced by the presence of tailings. Measurements of radon-daughter concentrations will be made in existing mill structures and in structures that have been built over tailings or where tailings have been used as backfill around the structure. Measurements of radionuclide concentrations will be made in groundwater and surface waters, stream sediments, tailings, soil from beneath tailings piles, soil in surface drainage paths, soil from areas surrounding the mill sites, and in background surface soil samples collected in areas where there is only a remote chance that the samples would be influenced by tailings. Calculations of the distribution of radon as a function of compass direction and distance from the center of the tailings piles will be included. Once remedial action has been completed, a final survey will be conducted to provide information to the Office of the Assistant Secretary for Environment for an independent determination by that office, of the suitability of the site for future uses.

PROGRESS AND RESULTS

All initial survey activities and sample analyses have been completed. All survey reports have been prepared in draft form; of these, one has been published. The remaining reports will be published in early fiscal 1980. Technical support was provided to an engineering firm working under contract to prepare engineering assessments of the inactive uranium mill tailings sites. It was found that some radioactivity has been displaced from the tailings piles due to wind and water erosion. Except in rare cases, it does not appear that radioactivity has been transported away from the tailings piles by groundwater. An analysis of radiological data reveals that the inhalation of radon daughters constitutes the principal exposure pathway to humans.

PLANS FOR NEXT PERIOD

Funding for Oak Ridge National Laboratory will provide support for a modest staff level through fiscal 1980. The principal anticipated activities include technical assistance in characterizing the radiological status of sites that are candidates for receiving tailings that may be moved from their present location. In addition, technical assistance will be provided to subcontractor firms in the preparation of engineering and environmental assessments where followup radiological measurements are required to further define boundaries of contamination.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

Activities of this project are dependent on progress made by other agencies involved in remedial action at inactive uranium mills. Priorities will be established as soon as scheduling of activities is possible.

ENVIRONMENTAL ASSESSMENTS OF INACTIVE URANIUM MILL TAILINGS SITES

ORGANIZATION AND CONTRACT NUMBER

Ford, Bacon & Davis Utah Inc.
EW-76-C-13-1658

PRINCIPAL INVESTIGATORS

V.C. Rogers
R. Overmyer
K. Nielson
B. Sermon
J. Keithley

OBJECTIVE

The objective is to perform an assessment of the impacts resulting from the presence of inactive uranium mill tailings piles and implementation of remedial action options at the sites as identified in this program in fiscal 1978. The information developed will provide a basis for decisionmaking for appropriate remedial actions for each of the sites.

APPROACH

In assessing the impacts of the current radiological conditions and potential remedial action alternatives at each mill tailings site, evaluations of the following factors were included:

- Exhalation of radon gas from the tailings,

- Onsite and offsite direct radiation,
- Land contamination from windblown tailings,
- Hydrology and contamination by water pathways, and
- Potential health impacts.

Based on previous work in fiscal 1978, the remedial action alternatives may be placed within three main categories:

- Minimum remedial action, which amounts to remedial action on offsite areas;
- Stabilization designed for long-term storage of tailings in their current location; or
- Removal of tailings to alternative sites suitable for long-term storage and stabilization.

Tailings were carried away from some of the sites and used at nearby residences and businesses. Remedial actions were also considered for these associated locations, except at Grand Junction, Colorado, where a remedial action program is already underway.

The general scope of the Title I assessment included the following:

- Preparation of an environmental assessment report for each site based on impacts expected from implementing reasonable remedial action alternatives and their estimated costs as determined in this program in fiscal 1978;
- Evaluation of radiation exposures of individuals and nearby populations resulting from the inactive uranium millsite, with specific attention to gamma radiation, radon, radon-daughter concentrations, and radium and other naturally occurring radioisotopes in the tailings;
- Investigation of site hydrology and meteorology;
- Performance of demographic and land use studies;
- Investigation of community and area planning and industrial and growth projections; and
- Evaluation of the environmental impacts of implementing the various alternative remedial actions for each site to arrive at health effects, estimated costs, and socioeconomic impact based on population and land use projections and expected radiological conditions

PROGRESS AND RESULTS

Draft environmental assessment reports were published on sites in fiscal 1979. These sites are indicated in the publication titles listed below.

PLANS FOR NEXT PERIOD

Environmental Assessments will be completed for most of the 22 sites.

REPORTS PUBLISHED

Ford, Bacon & Davis Utah Inc., "Environmental Assessment of the Grand Junction Site and Associated Properties, Grand Junction, Colorado," FBDU 251-303, Draft Report, August 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Assessment of the Mexican Hat Site and Associated Properties, Mexican Hat, Utah," FBDU 251-302, Draft Report, August 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Assessment of the Slick Rock Site and Associated Properties, Slick Rock, Colorado," FBDU 251-304, Draft Report, September 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Assessment of the Vitro Site and Associated Properties, Salt Lake City, Utah," FBDU 251-301, Draft Report, June 1979.

PROJECTED MILESTONES

- December 31, 1979 -- Complete Environmental Assessments for 11 additional sites (program started in July 1978)

ASPHALT EMULSION SEALING OF URANIUM MILL TAILINGS

ORGANIZATION AND CONTRACT NUMBER

Pacific Northwest Laboratory
EY-76-C-06-1830

PRINCIPAL INVESTIGATORS

J.N. Hartley
P.L. Koehmstedt

OBJECTIVE

The basic objective of this project is to investigate the use of asphalt emulsion sealants to contain radon and radium in uranium tailings, including development of engineering criteria for sealing inactive uranium mill tailings.

APPROACH

The approach taken in this project is to carry out both laboratory and field studies on the use of asphalt emulsion as a long-term sealant for radon and radium in uranium mill tailings. Laboratory studies include (1) uranium tailings characterization, (2) asphalt emulsion-tailings seal formulation, (3) radon and radium diffusion and permeation measurements, (4) asphalt emulsion-tailings seal stability tests, and (5) bio-barrier development. Field studies include (1) application equipment review and testing, (2) radon measurement system development, and (3) conducting field tests at selected tailings sites. The most promising stabilization/sealing procedures will be tested. The stability of the tailings asphalt emulsion seal will be studied, including effects of weathering, mechanical abuse, overburden requirements, root penetration, etc. The effectiveness of this method in radiation containment will then be established and monitored with time. The criteria needed for carrying out a full-scale sealing demonstration at a selected tailings pile will be established.

PROGRESS AND RESULTS

Results of laboratory tests indicated a radon flux reduction of greater than 99 percent using either a poured on seal (1/8 to 3/8 inch thick) or an admix seal (approximately 3 inches thick containing 18 percent by weight asphalt) using Armak Redicote E-65 cationic asphalt emulsion. Tailings from several sites were tested. To simulate the field sealing procedure in the laboratory, the asphalt emulsion was mixed with tailings in a heavy duty mixer and then compacted. The 3-inch admix seals were then tested in the radon pressure test apparatus for radon diffusion measurement (Figure 57).

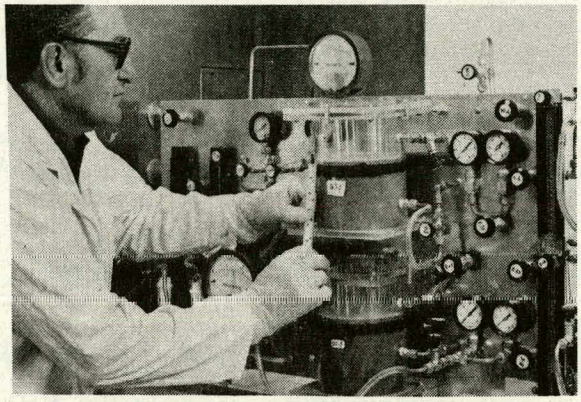


Figure 57. Asphalt Emulsion - Tailings Seal Reduces Radon Flux by 99.9 Percent in Radon Pressure-Test Apparatus

The results of the field test at the Grand Junction tailings pile show a reduction in radon flux ranging from 4.5 percent to greater than 99.9 percent with an average flux reduction of 75.5 percent using a 5-inch admix seal with a sprayed on top coat. At least 10 inches of overburden is necessary to prevent breaching of the seal by the equipment moving over the seal. The stabilization/sealing procedure used for this field test consisted of (1) site preparation (contouring, watering, etc.); (2) asphalt emulsion application using a hydrostatic stabilizer (Figure 58) followed by vibratory compaction to form the radon seal; and (3) overburden installation including herbicide application over a selected area to prevent root penetration.

PLANS FOR NEXT PERIOD

The criteria for the admix seal for the field test will be established in the laboratory. This will include asphalt emulsion type, the required percent weight of emulsion for seal formulation, and tailings characteristics. Also included will be the physical-chemical, mixing, compaction, and stability requirements. Radon diffusion measurements will be made on all the various seals. The effects of seal formulation on radon emanation will be determined. The stability of the admix seals, either tailings-asphalt emulsion or overburden asphalt emulsion, will be evaluated. In addition, bio-barriers will be

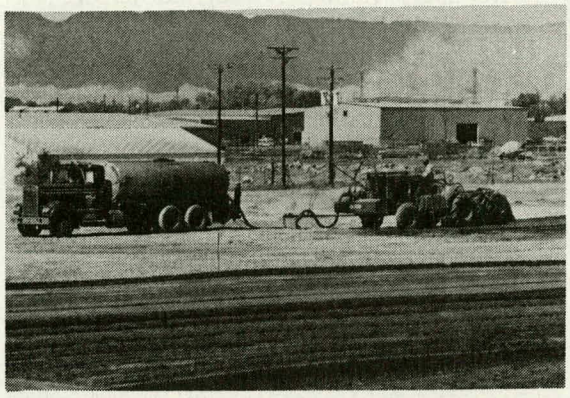


Figure 58. Hydrostatic Stabilizer Mixes Asphalt Emulsion With Tailings

investigated, including the barrier formed by adding herbicides directly to the emulsion. A sealing procedure will be developed in conjunction with the application equipment testing.

The most promising application equipment will be tested and selected for the field test, and an improved radon measuring system will be fabricated and tested. A tailings site for the field test will be selected based on Department of Energy priorities. A field test will be carried out at a selected tailings site to evaluate the technical and economic feasibility of the sealing procedure. A minimum of 2 acres will be sealed using at least two different sealing techniques. Monitoring of this field test will be initiated, and monitoring of the Grand Junction will be continued to evaluate effects of overburden, herbicide, weathering, etc. Requirements for maintaining seal integrity will be identified. Preliminary engineering criteria for carrying out a full-scale sealing demonstration will be established. Additional research and development requirements will be established.

REPORTS PUBLISHED

Hartley, J.N., et al., "Asphalt Emulsion Sealing of Uranium Mill Tailings Laboratory and Field Studies Annual Report," November 1979, in progress.

PROJECTED MILESTONES

- March 1980 -- Establish seal criteria for field test
- May 1980 -- Select application equipment
- August 1980 -- Completed field test at selected tailings site using improved application procedures
- September 1980 -- Establish preliminary engineering criteria for sealing procedure
- June 1981 -- Conduct engineering-scale field demonstration at selected site
- September 1981 -- Establish final engineering criteria for sealing procedure

EXTRACTION OF POTENTIALLY HAZARDOUS RADIONUCLIDES FROM URANIUM ORES/TAILINGS

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATOR

A.D. Ryon

OBJECTIVE

The objective of this project is to explore the technical feasibility of removing uranium decay chain long-lived nuclides through an experimental investigation of processing and recovery methods.

APPROACH

The investigation will include two principal studies: (1) the use of alternative chemical reagents for increasing the leaching efficiencies of uranium and its long-lived daughters from the ore beyond that achieved by present-day methods and (2) the development of chemical methods (solvent extraction, precipitation, or ion exchange) for removing uranium and its daughters from leach liquors to result in separate product streams of uranium and daughters. Because of the very low levels of radioactivity associated with the residues from leaching and with the waste liquors from separation processes, it is expected that a significant effort will be expended to develop satisfactory analytical methods.

PROGRESS AND RESULTS

Studies were made emphasizing the leaching of uranium ore and mill tailings to remove

radium. A few scouting tests were performed to obtain data on the recovery of radium, thorium, and uranium from leach liquors and on the recycle of leaching agents. Nitric acid, hydrochloric acid, ethylenediaminetetraacetic acid, and diethylenetriaminepentaacetic acid were evaluated as leachants using one sample of a western U.S. ore and two samples of tailings obtained from different uranium mills that employ the sulfuric acid leach process.

Leached solids with radium contents approaching 10 picocuries/gram (98-percent radium removal) were obtained after six stages of batch, crosscurrent leaching with 3 moles of nitric acid at 33-percent concentration of solids and a temperature of 60°C. Hydrochloric, ethylenediaminetetraacetic, and diethylenetriaminepentaacetic acids have not yet been tested through six stages of crosscurrent leaching. However, on the basis of two-stage tests on mill tailings, 0.5 mole ethylenediaminetetraacetic acid solutions at pH values of 8.2 to 11.6 were found to be more effective, and hydrochloric acid in two- or three-stage tests was less effective than nitric acid. Solutions of 0.3 mole ethylenediaminetetraacetic acid (pH, 4.0) and 0.05 mole diethylenetriaminepentaacetic acid (pH, 4 to 10) were ineffective.

Essentially no important differences were observed in the leaching behavior of ore and of mill tailings derived from the same ore. The residue remaining after six stages of nitric acid leaching was relatively intractable to radium leaching with water or additional nitric acid leaching. Initial tests indicated that the recycle of nitric acid is chemically feasible by evaporating the leach liquors to recover unused acid and then thermally decomposing the metal salts to recover consumed acid. Radium recoveries of 99+ percent by carrying on barium sulfate were shown to be chemically feasible in a series of experiments with leach liquors, but processing applications would probably require methods for barium recycle and barium-radium separation. Recovery of thorium-230 and uranium from nitrate leach liquors by tri-n-butyl phosphate extraction appears promising in initial tests.

PLANS FOR NEXT PERIOD

None, the project terminated in fiscal 1979.

REPORTS PUBLISHED

Scheitlin, F.M., and W.D. Bond, "Removal of Hazardous Radionuclides From Uranium Ore and/or Mill Tailings: Progress Report for the Period October 1, 1978, to September 30, 1979," Draft, 1979.

PROJECT MILESTONES

None

ASSESSMENT OF GROUNDWATER CONTAMINATION FROM INACTIVE URANIUM MILL TAILINGS SITES

ORGANIZATION AND CONTRACT NUMBER

University of Colorado
EY-76-S-02-4017

PRINCIPAL INVESTIGATORS

W.R. Chappell
F. Heuze
G. Markos
R. Meglen
C. Zaidins

OBJECTIVES

The objectives are to (1) establish the presence of groundwater, if any, at all inactive uranium mill tailings piles originally studied by Ford, Bacon & Davis Utah Inc.; (2) establish the likelihood of groundwater contamination by seepage; (3) predict the quantity of contaminated fluids and the concentration of contaminants that could emanate from the piles; and (4) measure contaminant concentrations in the ground surrounding the piles and make comparisons to the predictions.

APPROACH

This work will be performed at selected sites that present the highest potential for contamination. In addition, two or three target sites will be selected for full study. A detailed plan of action for the next phase (12 to 18 months) will be proposed.

The following tasks will be performed:

- Field inspections of the tailings;
- Literature surveys;
- Selection of sites for geochemical and hydraulic investigations;

- Permeability tests;
- Sampling (water and solids) for chemical studies;
- Leaching experiments/analysis for elements likely to be of environmental concern;
- Chemical analysis of leachates and water samples for uranium, molybdenum, arsenic, selenium, vanadium, chromium, lead, phosphate, chloride, carbonate, sulfate, and major elements (sodium, potassium, calcium, magnesium), plus pH and Eh;
- Initiation of data storage and retrieval system; and
- Evaluation of the data and compiling a report on the results.

PROGRESS AND RESULTS

The results of geochemical studies have shown high concentrations of water-soluble salts; extreme variations in geochemical parameters that control mobility (pH, Eh, ionic strength, and activity of components); and variations in conditions of available water. Deliquescent and hygroscopic behavior of salts (water is obtained from atmospheric moisture and shallow groundwater table) result in a self-dissolution process and migration from moist to dry areas by surface tension of water film and fluctuating vapor pressure. Asmotic pressure and capillary tension also contribute to salt migration.

Rock mechanic studies included the following: (1) an initial survey of 18 sites for soil mechanics and hydrologic purposes; (2) preliminary sampling of most piles and detailed sampling of three; (3) preliminary testing of soil samples to outline the general mechanical and hydraulic properties of tailings materials; (4) detailed testing of the Grand Junction pile; and (5) determination of groundwater conditions at several piles from direct probing and from resistivity surveys. Direct soil and water testing was successful; the use of resistivity traverses gave mixed results.

The results from analytical chemistry were as follows: (1) an automated system for performing trace chemical analyses was developed to meet the needs of the project investigators; (2) a computerized system of data storage and retrieval, analytical computations, and statistical analyses was implemented; (3) a comprehensive quality assurance program was designed and implemented for monitoring analytical performance; and (4) through December 1979, 8875 chemical analyses were performed, and accuracy estimation by several techniques was ±10 percent.

Radionuclide measurements determined the counting efficiency of a hyperpure germanium detector, initiated a counting chamber design, and established an optimum sample design.

The status and planned dates of work units completion are delineated in Table 20.

PLANS FOR THE NEXT PERIOD

The next phase of the work will consist of studies to identify the extent of water pollution occurring from existing sites, an evaluation of the hydrology of alternate sites, and an evaluation of the hydrology of sites being considered as final repositories for tailings piles.

This phase of the work will consist of efforts directed toward improving the state-of-the-art of tailings stabilization from the viewpoint of prevention of water pollution. It will also cover site-specific evaluations and recommendations concerning the long-term stabilization plans.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

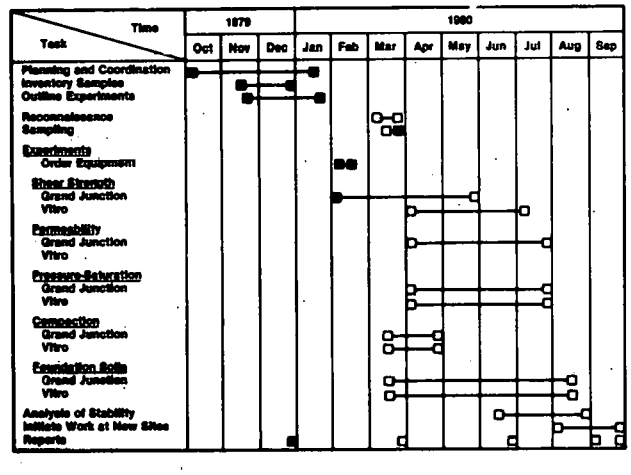


Table 20. Status of Site Investigations

Location	Recon.	Field Work Site	Field Work Background	Sample Preparation	Chemical and Radiochemical Analysis	Data Analysis	Data Interpretation	Report
Salt Lake City, Utah	compl.	compl.	compl.	compl.	3/31	4/30	5/10	5/15
Grand Junction, Colorado	compl.	compl.	compl.	compl.	3/31	4/30	5/10	5/15
Canonsburg, Pennsylvania	compl.	compl.	compl.	3/31	9/30	10/30	11/15	11/30
Riverton, Wyoming	compl.	compl.	4/30	5/31	9/30	10/30	11/30	12/15
Shiprock, New Mexico	compl.	compl.	5/31	5/31	9/30	10/30	11/30	12/31
Durango, Colorado	compl.	compl.	7/31	5/31	(9/30/80)			
Gunnison, Colorado	compl.	7/31	7/31	10/31	(3/31/81)	These efforts are scheduled for completion during fiscal 1981.		
Rifle New, Colorado	compl.	7/31	7/31	10/31	(3/31/81)			
Rifle Old, Colorado[9]	compl.	7/31	7/31	10/31	(3/31/81)			
Mexican Hat, Utah[9]	compl.	7/31	7/31	10/31	(3/31/81)			

[a] The Rifle Old tailings have been added in this status chart, with regard to the original proposal, but it seems there will be no problem in completing the field and sample preparation work in fiscal 1980.

Chemical and radiochemical analyses of samples are done at the University of Colorado and its chemical laboratory. The completion dates of the work on tailings sites is contingent on the supply of analytical data from the university's chemical laboratory. The dates given here under Chemical and Radiochemical Analysis are those obtained from the university's chemical laboratory.

ENGINEERING FEASIBILITY OF URANIUM MILL TAILINGS STABILIZATION METHODS

ORGANIZATION AND CONTRACT NUMBER

Ford, Bacon & Davis Utah Inc.
EW-76-C-13-1658

PRINCIPAL INVESTIGATORS

V.C. Rogers
R. Overmyer
K. Nielson
B. Sermon
J. Keithley

OBJECTIVE

The objective is to determine the effectiveness and suitability of various cover materials for stabilizing uranium mill tailings. Experiments are to be performed to determine the behavior of radon gas and its exhalation from tailings and cover materials under environmental conditions.

APPROACH

Based on work performed in fiscal 1978, certain materials were selected for further testing of their effectiveness and suitability in reducing radon fluxes from tailings. Small-scale field tests of Calcilox in 8-foot diameter test chambers were conducted. The Calcilox was prepared and applied by Dravo. Other materials including sand, charcoal, coal, and oil were tested in the laboratory for effectiveness in attenuating radon exhalation. Gaseous diffusion of radon was also investigated using standard "time-of-flight" gaseous diffusion techniques adapted to radiation detection instruments.

The general scope of this research and development activity included evaluation of various methods, techniques, and materials for stabilizing uranium mill tailings to prevent wind and water erosion, to inhibit or eliminate radon exhalation, and to minimize maintenance and control costs.

PROGRESS AND RESULTS

The small-scale field tests were prepared after characterization of the tailings in the test chambers. The Calcilox was applied using tailings in mixing the cover as well as using clean sand for application over the test surfaces. Soil and sand covers were also applied as controls. Moisture probes were provided to monitor moisture conditions in test chambers. The first application of the stabilizer Calcilox resulted in excessive drying, cracking, and improper curing. After monitoring the results of the initial application, the Calcilox covers were removed and the tests repeated. Final measurements and results will be reported in early fiscal 1980.

The effectiveness of charcoal, coal, and oil was determined by placing the material in cover over tailings and by mixing with surface layers of tailings in laboratory tests. The attenuation

of radon exhalation as compared to fluxes from control samples was measured. The results of these measurements will also be included in the report to be published in early fiscal 1980.

Diffusion of radon gas through air was measured under various conditions to allow determination of adequate diffusion coefficients. The results of these measurements will be reported in early fiscal 1980.

PLANS FOR NEXT PERIOD

The results of tests of chemical and physical stabilization materials are being finalized in the small-scale field tests to determine performance of the stabilizers under varying climatic conditions and will be reported.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- October 31, 1979 -- Complete and report the present program of testing stabilizing materials

MINERAL AND CONTAMINATION SURVEY OF THE MONTICELLO, UTAH, MILLSITE AND TAILINGS PILES

ORGANIZATION AND CONTRACT NUMBER

Bendix Field Engineering Corporation
DE-AC13-76GJ01664

PRINCIPAL INVESTIGATOR

C.L. Bruner

OBJECTIVE

The objective is to provide sufficient information for development of a decontamination and decommissioning plan for the Monticello mill tailings site owned by the Department of Energy.

APPROACH

The four mill tailings piles and adjacent land will be drilled and sampled to determine (1) the residual uranium trioxide and vanadium oxide mineral values, (2) the extent of radioactive contamination beneath the tailings piles, and (3) the extent of radioactive contamination of adjacent property. Based on this information, a decontamination and decommissioning plan will be developed for the site. Current plans anticipate the sale and removal of the tailings for reprocessing, decontamination of the land beneath and adjacent to the tailings piles, and excessing of the decontaminated mill tailings area.

PROGRESS AND RESULTS

In August 1979, the Bendix Field Engineering Corporation awarded a subcontract for drilling and sampling the tailings piles. A sample preparation facility was established at the site and drilling commenced in early September 1979. Drilling and sampling are expected to be complete by the end of September.

PLANS FOR NEXT PERIOD

The project was transferred to the Office of Nuclear Waste Management.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

MILL TAILINGS SITE DESCRIPTIONS

ORGANIZATION AND CONTRACT NUMBER

Ford, Bacon & Davis Utah Inc.
EW-76-C-13-1658

PRINCIPAL INVESTIGATORS

V.C. Rogers
R. Overmyer
K. Nielson
B. Sermon
J. Keithley

OBJECTIVE

The objective is to identify and prepare written descriptions of mill tailings sites as well as obtain ownership information for these sites and adjacent properties.

APPROACH

Sites will be identified. Site descriptions and ownership information will then be developed

from county records, company records, other public agency records, and surveys.

PROGRESS AND RESULTS

Site maps, with written descriptions, were prepared for publication in the Federal Register by the Department of Energy. Ownership information was obtained for both onsite and offsite properties.

PLANS FOR NEXT PERIOD

Additional information will be obtained as required for planning implementation of the Title II remedial action work.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

GRAND JUNCTION REMEDIAL ACTION PROGRAM

The Grand Junction Remedial Action Program implements the legislative authority provided by the Congress in Title II of P.L. 92-314 amended by P.L. 95-236. The objective of the program is to remedy conditions of potentially excessive radiation exposure to people as a result of the use of uranium mill tailings in the construction of structures at Grand Junction, Colorado. The law specifies that the Federal Government shall provide 75 percent of the cost of a State-operated remedial program.

Remedial action for approximately 44 percent of 800 structures estimated to be eligible under the program has been completed. It is estimated that the program can be completed by fiscal 1985 at an accelerated rate of about 100 structures per year.

GRAND JUNCTION REMEDIAL ACTION PROGRAM

ORGANIZATION AND CONTRACT NUMBER

State of Colorado
DE-AC13-76GJ01621

PRINCIPAL INVESTIGATOR

A.J. Hazle

OBJECTIVE

The objective of this program is to reduce the radiation exposure to the public resulting from the use of tailings from the former uranium ore processing mill in Grand Junction, Colorado, as a construction material.

APPROACH

The remedial action program was authorized by Congress in 1972 under Title II of Public Law 92-314. The U.S. Surgeon General established remedial action guidelines at the request of the Colorado Department of Health. Radiation measurements are first made to determine whether structures for which owners have made application for remedial action qualify under the guidelines. The state is responsible for conducting the remedial work, most of which is carried out by an architect-engineer contractor. The state draws up remedial action plans and submits them to the Department of Energy for approval. Under the law, the Department of Energy has the final responsibility for selection of the appropriate remedial action for each structure. In most instances, the remedial action method used is to remove the floor slab, excavate the tailings, replace them with clean fill, and pour a new concrete floor. In some cases, an epoxy sealant is used on the inside of concrete surfaces to prevent radon gas, generated by the radium in the tailings, from diffusing into the living space.

A priority system was established under which houses and schools were given priority over industrial buildings. Priority was also given to the structures with the highest radiation levels.

PROGRESS AND RESULTS

Through fiscal 1979, remedial action has been carried out on a total of 351 structures, including 301 residences, 15 schools, and 35 commercial buildings. Under the provisions of Public Law 92-314, the Federal Government pays 75 percent of the remedial program cost and the State of Colorado pays the remainder. About 26 structures were completed in fiscal 1979.

PLANS FOR NEXT PERIOD

Plans will be made to accelerate the program during fiscal 1980 in order to complete

work on eligible structures by 1985. It is estimated that a total of about 800 structures will qualify for remedial action.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

- June 1980 -- Application deadline
- June 1981 -- Complete radiological assessments
- September 1981 -- Complete engineering assessments
- October 1984 -- Complete remedial action
- October 1985 -- Complete effectiveness evaluation

REMEDIAL ACTIONS AT FORMERLY UTILIZED MANHATTAN ENGINEER DISTRICT/ATOMIC ENERGY COMMISSION SITES

The objective of this program is to identify and characterize the condition of sites formerly used by the Manhattan Engineer District and the Atomic Energy Commission and, where appropriate, implement remedial action programs at sites found to have residual radioactive contamination above levels currently acceptable for unrestricted use. The program includes a review of the retired files of the programs operated by the Manhattan Engineer District and the Atomic Energy Commission to identify all facilities used for nuclear activities and to determine the status of radiological conditions at the completion of remedial actions. As a result of record searches, conversations with current and previous owners, and, in some cases, site visits and radiological surveys, the Department of Energy was able to verify that conditions at a number of sites indicated a need for further evaluations. Full radiological surveys were performed or scheduled to be performed on 39 of those sites. Based on preliminary results, the Department of Energy currently estimates that some form of remedial action may be required for about 33 of the sites. The remedial actions that may be required range from control of a property through restricted use or decontamination of small areas, to major efforts involving the removal of contaminated soil and either decontamination or demolition of entire structures. Engineering evaluations were completed for three of these sites and were initiated at three other sites to identify options for remedial action, their estimated costs, and potential environmental impacts.

OAK RIDGE NATIONAL LABORATORY RADIOLOGICAL SURVEY OF FORMERLY UTILIZED MANHATTAN ENGINEER DISTRICT/ATOMIC ENERGY COMMISSION SITES

ORGANIZATION AND CONTRACT NUMBER

Oak Ridge National Laboratory
W-7405-ENG-26

PRINCIPAL INVESTIGATOR

F.F. Haywood

OBJECTIVE

The objective of this project is to determine and document the current radiological status of numerous industrial sites formerly utilized under contract to the U.S. Government. The levels of residual radioactivity are compared with current Federal and/or state radiation control guidelines so that the need for remedial action can be ascertained. In addition, technical support is provided to engineering and environmental contractors in the preparation of engineering assessments and pertinent documents related to the National Environmental Policy Act.

APPROACH

To complete the objectives of this project, the following tasks will be carried out: (1) review existing records and verify that the site qualifies as a formerly utilized site, (2) visit each site to make exploratory measurements and to participate with the Department of Energy in determining the need for a formal site survey, (3) prepare radiological survey plans, (4) conduct a series of measurements and collect environmental samples in accordance with the survey plans to characterize the current radiological condition of each site, (5) document survey findings and provide an evaluation of potential personnel radiation exposure under present and possible future occupancy and use

conditions, and (6) provide technical backup to engineering and environmental contractors to conduct followup measurements and perform calculations as needed for the preparation of documents required by the National Environmental Policy Act. Once remedial action has been completed, a final survey is conducted to provide information to the Assistant Secretary for Environment upon which an independent assessment can be made of the suitability of the site for unrestricted use.

PROGRESS AND RESULTS

Visits and exploratory surveys have been conducted at all but one assigned site (former Superior Steel Company site in Carnegie, Pennsylvania). Some followup radiation survey work was done at several sites to provide technical assistance to engineering firms working under subcontract to provide engineering assessment documents for the former Middlesex Sampling Plant and the Municipal Landfill sites in Middlesex, New Jersey; the former Vitro Rare Metals Plant in Canonsburg, Pennsylvania; and the former Kellex Laboratory in Jersey City, New Jersey. Extensive radon and radon-daughter measurements were made at the former Vitro Plant to initiate a study of the total radon source term in two buildings on that site. The objective of this study is to develop a methodology for the control of radon exposures in buildings constructed on soil contaminated with radium-226. Radon surveys were conducted in outdoor areas at the time of an aerial radiological survey of the Lake Ontario Ordnance Works, Lewiston, New York, and as a followup to the aerial measurements, ground-level radiation measurements were made to assess the status of radioactivity found in areas surrounding the site.

Due to current development of the former Kellex Laboratory site in Jersey City, New Jersey, the Department of Energy initiated remedial action to remove soil contaminated with radium-226, thorium-232, and natural uranium. An environmental evaluation of the proposed cleanup action and a detailed engineering plan for the cleanup was prepared under subcontract by the Envirosphere Company. Three contaminated areas on the portion of the site being developed as a shopping center were decontaminated in August 1979. A final survey was conducted by Oak Ridge National Laboratory personnel to certify that residual radiation levels were less than the maximum guideline values given in decontamination criteria.

PLANS FOR NEXT PERIOD

Funding for Oak Ridge National Laboratory will provide support at the current staff level through fiscal 1980. It is anticipated that remedial action at the former Kellex site will be completed in early fiscal 1980 and that some remedial action will be carried out in Middlesex, New Jersey. Overview surveys during remedial action will be conducted, and final surveys will be conducted at completion of remedial actions. Results will be used to document past decontamination conditions at these sites. In addition, it is likely that some overview and certification surveys will be conducted at the Department of Energy surplus facilities where decontamination and decommissioning operations have been completed. Some additional surveys will be required at sites identified in late fiscal 1979.

REPORTS PUBLISHED

Berven, B.A., et al., "Results of Ground Level Radiation Measurements in Support of the 1978 Aerial Survey of the Lake Ontario Ordnance Works, Lewiston, New York," ORNL/TM-7004, Oak Ridge National Laboratory, September 1979.

Haywood, F.F., et al., "Radon and Radon Daughter Measurements at and Near the Former Middlesex Sampling Plant, Middlesex, New Jersey," ORNL/TM-5489, Oak Ridge National Laboratory, to be published.

Haywood, F.F., et al., "Radon and Radon Daughter Measurements at and Near the Vitro Rare Metals Plant, Canonsburg, Pennsylvania," ORNL/TM-5533, Oak Ridge National Laboratory, to be published.

"Radiological Survey of the E.I. du pont de Nemours and Company, Deepwater, New Jersey," Final Report, DOE/EV-0005/8, December 1978.

"Radiological Survey of the Former Horizons, Inc., Metal Handling Facility, Cleveland, Ohio," Final Report, DOE/EV-0005/10, February 1979.

"Radiological Survey of the Pennsylvania Railroad Landfill Site, Burrell Township, Pennsylvania," Final Report, DOE/EV-0005/12, February 1979.

"Radiological Survey of the Seneca Army Depot, Romulus, New York," Final Report, DOE/EV-0005/11, February 1979.

Roy F. Weston, Inc., "Environmental Impact Assessment for Proposed Action at the Former AEC St. Louis Airport Storage Site, St. Louis, Missouri," prepared for Oak Ridge National Laboratory under subcontract No. S-7402, July 1979.

PROJECTED MILESTONES

It is expected that all final radiological survey documents for the formal surveys conducted prior to September 30, 1979, will be completed by January 1, 1980. Reports for followup radiological surveys, surveys in support of aerial measurements, and additional formal surveys will be submitted in draft form approximately 90 days after the completion of field work. Reports of final surveys after completion of decontamination and decommissioning operations will receive top priority and will be submitted as soon as analytical results become available.

RADIOLOGICAL ASSESSMENT OF CONTAMINATION AT FORMERLY UTILIZED MANHATTAN ENGINEER DISTRICT/ATOMIC ENERGY COMMISSION SITES

ORGANIZATION AND NUMBER

Los Alamos Scientific Laboratory
W-7405-ENG-36

PRINCIPAL INVESTIGATORS

W.R. Hansen
A.K. Stoker

OBJECTIVE

The objective of this program is to develop current documentation and new information as necessary to determine the adequacy of decontamination of sites formerly utilized or affected by Manhattan Engineer District/Atomic Energy Commission operations.

APPROACH

Old records were searched, related environmental measurements were compiled, new environmental measurements were made, and the results were interpreted in terms of radiological effects under conditions of present and projected future land uses.

PROGRESS AND RESULTS

The documentation for the removal of portions of a contaminated wasteline in the Los Alamos Townsite was completed and the final report published (DOE/EV-0005/14). Pipe, manhold structures, and contaminated soil were removed from about 400 meters of trench. No significant contamination remained.

The radiological survey and evaluation of Bayo Canyon (Los Alamos, New Mexico) was completed and the final report published (DOE/EV-0005/15). Minor amounts of strontium-90 and natural or depleted uranium remain from decontamination in 1963. No measurable doses are being received now by residents of Los Alamos or occasional recreational users of the area. Hypothetical evaluations of possible land uses including development as a residential area showed that some incremental doses above background could be received. The maximum cases were residents who might consume a large proportion of home garden produce (50-year dose commitment of about 45.6 millirem to the bone, which is about 25 percent of the annual background dose in the area) and construction workers who might be involved in excavation work (50-year dose commitment of 23 millirem to the bone, which is about 13 percent of the annual background dose in the area).

Field work is completed and reports are in preparation for the Acid-Pueblo Canyon and Chupadera Mesa (Trinity Site) radiological surveys.

Some preliminary evaluation and planning have been accomplished for the requested follow-on reports regarding potential management options for the Bayo Canyon and Chupadera Mesa areas. Basic options identified for evaluation of engineering feasibility, cost, reduction of contaminant levels and dose potential, and environmental consequences are administrative controls, stabilization, and several levels of further decontamination.

PLANS FOR NEXT PERIOD

Plans include completing radiological survey reports and planning management option studies.

REPORTS PUBLISHED

U.S. Department of Energy, "Radiological Survey of the Bayo Canyon, Los Alamos, New Mexico," Final Report, DOE/EV-0005/15, June 1979.

U.S. Department of Energy, "Removal of a Contaminated Industrial Waste Line, Los Alamos, New Mexico," Final Report, DOE/EV-0005/14, April 1979.

PROJECTED MILESTONES

- First Quarter Fiscal 1980 (December) -- Submit draft of report "Radiological Survey of Liquid Waste Treatment Plant Site (TA-45) and Acid-Pueblo Canyon, Los Alamos, New Mexico," to the Department of Energy, Albuquerque Operations Office.
- First Quarter Fiscal 1980 (December) -- Submit proposed Work Elements Plan for requested Management Options Studies of Bayo Canyon, Acid-Pueblo Canyon, and Chupadera Mesa (Trinity) areas to the Department of Energy, Headquarters.
- Second Quarter Fiscal 1980 (February) -- Submit draft of report "Radiological Survey of the Trinity Event Fallout Path, South-Central New Mexico," to the Department of Energy, Albuquerque Operations Office.

RADON EVALUATION AT FORMER MANHATTAN ENGINEER DISTRICT/ATOMIC ENERGY COMMISSION SITES

ORGANIZATION AND CONTRACT NUMBER

Mound Facility
AG-70-04/P79-03-229 and
DE-AC04-76-DP00053

PRINCIPAL INVESTIGATORS

W.G. Yates
G.R. Hagee
P.H. Jenkins

OBJECTIVES

The objectives of this program are to (1) organize, develop, and implement radon monitoring survey networks for radioactively contaminated sites that are designated by the Environmental Control Technology Division; and (2) implement a monitoring network plan for radon and decay products at the Vitro Rare Metals processing plant, Canonsburg, Pennsylvania, by November 3, 1979.

APPROACH

The radon and decay products monitoring effort is a coordinated effort of several Department of Energy national laboratories and subcontractors. Mound Facility's task will be to provide

- Long-term radon and decay products monitoring for each designated site;
- Quarterly reports for each designated site;
- Monitoring during remedial action and ultimate certification for restricted or unrestricted use of the site; and
- Recommendations, based on an evaluation of the monitoring results, for remedial action and ultimate certification.

Mound's initial efforts were to obtain and assimilate all pertinent information and factual data of previous work performed by these agencies for the designated sites. The Canonsburg, Pennsylvania, site was designated as Mound Facility's first task to implement a radon monitoring network plan.

Three key elements were used to develop the radon and decay products monitoring plan for Canonsburg: topographical considerations, meteorological data, and statistical analysis of existing data.

PROGRESS AND RESULTS

The radon and decay products monitoring network plan for the Canonsburg site was presented July 31, 1979, to the Environmental Control Technology Division and was approved for implementation. The plan will be implemented November 4, 1979.

The radon laboratory needed to support the program is currently under construction with completion targeted for October 15, 1979. The laboratory will also be used to evaluate existing and new instrumentation and techniques.

All instrumentation necessary for the monitoring plan for the Canonsburg site and lab based support equipment has been purchased and is operational.

PLANS FOR NEXT PERIOD

In addition to the Canonsburg, Pennsylvania, effort, similar programs will be

initiated at Lake Ontario Ordnance Works, Lewiston, New York; Middlesex Sampling Plant, Middlesex, New Jersey; and associated areas. It is further expected that a similar program will be initiated for mill tailing sites, such as Salt Lake Vitro Site, Salt Lake City, Utah.

A radon calibration chamber will be constructed in fiscal 1980 to support designated and future sites that will be monitored by the Mound Facility.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

RADON MONITORING OF FORMERLY UTILIZED MANHATTAN ENGINEER DISTRICT/ATOMIC ENERGY COMMISSION SITES

ORGANIZATION AND CONTRACT NUMBER

Environmental Measurements Laboratory

PRINCIPAL INVESTIGATORS

A.J. Breslin
A.C. George

OBJECTIVE

The Environmental Measurements Laboratory is monitoring radon at Middlesex, New Jersey; Canonsburg, Pennsylvania; and Lewiston, New York, to determine average air concentrations that people are exposed to onsite and offsite, as appropriate. Brief surveys and experiments are performed to identify sources of radon and to develop effective means of control.

APPROACH

For all three sites, the Environmental Measurements Laboratory has provided instrumentation and monitoring plan for implementation by local personnel. Instruments are rotated among a monitoring locations at each site on a weekly schedule to obtain broad coverage; detectors removed from the instruments after exposure are mailed to the laboratory for analysis. By means of this arrangement, approximately 115 locations are being monitored with the equivalent of 1.5 man years per year.

PROGRESS AND RESULTS

Monitoring Status

At Middlesex, the initial focus was on concentrations of radon and radon daughters in buildings onsite. U.S. Marine Corps personnel, who occupied the facility, provided the necessary local support. Later, offsite radon monitoring was initiated with the support of the New Jersey Bureau of Radiation Protection to establish values of background concentration for the Middlesex area. Monitoring onsite was discontinued early in 1979 when the Marine detachment moved to other quarters. Currently, 20 offsite locations are being monitored for radon.

At Canonsburg, initial emphasis was also on indoor exposures onsite. When additional instruments became available, monitoring was extended to offsite locations, both to determine background concentrations and to detect the spread of radon from the site to adjoining neighborhoods. The Pennsylvania Department of Environmental Resources provided the local support for all monitoring activities until February 1979, when arrangements were made with the University of Pittsburgh to take over the onsite work. At present, 63 locations are being monitored.

Radon monitoring was undertaken in Lewiston to supplement measurements already being obtained by National Lead Company of Ohio at the fence around the Niagara Falls site. The Environmental Measurements Laboratory established a program encompassing 2 locations within the fence and 24 offsite locations. This number was later increased to 32, the current degree of effort (excluding the 8 fence-line locations administered by the National Lead Company of Ohio). The instruments are also serviced by their resident personnel.

The laboratory has been assisting them in determining the locations and strengths of radon sources. This project consists mainly of measuring radon flux from the spoil pile and its surroundings and from wastes stored inside buildings. The laboratory has been providing charcoal canisters and has been analyzing canisters after exposure.

Measurement Results

Prior to the departure of the Marine Corps detachment from Middlesex, radon was monitored for 12 months in the Administration Building; for 9 months in the Reserve Building, Boiler House, and Garage; and for 9 months outdoors onsite. During those periods, average concentrations

among rooms were from 1.6 to 13 pCi/liter in the Administration Building and from 10 to 40 pCi/liter in the Reserve Building. Average concentrations were 2.2 pCi/liter in the Boiler House and 2.3 pCi/liter in the Garage. The average concentration outdoors was 0.46 pCi/liter. In the Administration Building, all concentrations were reduced to less than 1 pCi/liter after the utility chase was provided with exhaust ventilation at the end of December 1978. These results further verified the results of a brief experiment conducted by the Environmental Measurements Laboratory in May 1978, which consisted of connecting a small industrial exhaust fan to an aperture in the utility chase for a 2-week period. Radon measurements were begun in December 1978, in buildings adjoining the site and at more remote locations. With the exception of the Rectory at Our Lady of Mount Virgin, known to have radium wastes in the surrounding soil, concentrations in these buildings average from 0.21 to 0.96 pCi/liter. The average concentration in the rectory is 2.9 pCi/liter. The average concentration in outdoor air at the Middlesex landfill is 0.2 pCi/liter.

During the year, the cellar of the Reefer house was surveyed for contamination at the request of the Environmental Control Technology Division; no evidence of contamination was found. Also, at their request, radon flux was measured in the cellar of the Rectory. Results indicating areas of high radon emanation were transmitted to the Oak Ridge National Laboratory.

Average radon concentrations within buildings on the Canonsburg site are in a range from 6 to 66 pCi/liter. The highest concentrations occur in buildings #3 (up to 53 pCi/liter, 0.32 working level), #10 (up to 66 pCi/liter, 0.47 working level), and #16 (up to 50 pCi/liter, 0.34 working level). The highest concentrations in all three of these buildings are in enclosed office spaces, which should be amenable to the method of control suggested in a status report submitted on November 30, 1978.

The air concentrations at individual monitoring locations do not display consistent temporal variations, but overall average concentrations follow a pronounced yearly cycle with the minimum occurring in the summer months and the maximum occurring in late fall and early winter. It should be anticipated that concentrations will be increasing again in the next few months throughout the complex, including the office areas in buildings 3, 10, and 16.

Outdoor radon concentrations on the site are from 0.7 to 2.4 pCi/liter, the latter occuring along the fence on the east side. Outdoor radon concentrations at distances of a few hundred feet outside the fence in the southerly, westerly, and northerly directions are about 0.4 pCi/liter. At 1000 feet downwind in the easterly direction, the concentration is 0.8 pCi/liter; at about twice that distance to the east, the concentration is 0.4 pCi/liter. The average outdoor background concentration in the general area is 0.3 pCi/liter.

Average radon concentrations in offsite buildings are from 0.5 to 0.9 pCi/liter, except the Slovenia Savings and Loan Building where the concentration is 1.9 pCi/liter and the old Strabane Municipal Building where the concentration is 4.8 pCi/liter. Radon in the latter two buildings appears to be natural in origin.

At the Niagara Falls site, outdoor radon concentrations vary from background (approximately 0.25 pCi/liter) to 7.1 pCi/liter along the site's western boundary. The monitoring data show a clear picture of radon distribution with maximal concentrations occurring in the southwest corner of the site and concentrations above background extending short distances beyond the fence in all directions. The highest concentration that is being detected offsite (0.8 pCi/liter) is at the "radar station," a few hundred feet south of the southern boundary. Concentrations along public roads around the site are within the range of background with the possible exception of the J&T Junkyard on Belmer Road, northwest of the site. However, measurements have not been obtained there for a full year. Average radon concentrations in buildings offsite are from 0.4 to 0.8 pCi/liter, within the normal range.

PLANS FOR NEXT PERIOD

Plans are to continue radon monitoring at the three sites.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

FORMERLY UTILIZED MANHATTAN ENGINEER DISTRICT/ATOMIC ENERGY COMMISSION SITES REMEDIAL ACTION PROGRAM

ORGANIZATION AND CONTRACT NUMBER

Ford, Bacon & Davis Utah Inc.
EW-76-C-13-1658

PRINCIPAL INVESTIGATORS

V.C. Rogers
R. Overmyer
J.J. Keithley

OBJECTIVES

The objectives of this project are to prepare Title I engineering evaluations and environmental analyses of possible remedial actions at four sites where radioactive contamination has been found and to prepare Title II engineering plans and specifications for remedial action work.

The engineering evaluation reports include a physical description of the sites; radiological guidelines used as a basis to determine the need for remedial actions; comparison of present radiological conditions at the site to present guidelines, indicating where remedial action is advised; and several alternative remedial actions with attendant cost estimates.

The environmental analysis reports include information regarding the existing environment, an analysis of potential environmental impacts pertaining to the present radiological conditions, and impacts resulting during and after implementation of remedial action alternatives.

APPROACH

Radiological data taken by Oak Ridge National Laboratory at four sites in Middlesex, New Jersey; Canonsburg, Pennsylvania; and Burrell Township, Pennsylvania, are the basis for the formulation of remedial action alternatives. These alternatives include no action, minimal action (access restriction), stabilization of contamination at the present site, partial decontamination, or decontamination and restoration. In the past, contaminated materials were carried away from some of the sites and used around offsite structures. Remedial actions were also considered at these locations.

The general scope of the Title I engineering evaluations include preparing an engineering evaluation report for each site with remedial action alternatives and their estimated costs; determining property ownership; preparing topographic maps of the sites; and performing engineering evaluations of structures where contaminated material was located, to identify the remedial action alternatives and estimated costs. Evaluations are made of the availability of suitable fill and stabilizing cover materials. Site meteorology and hydrology are investigated from available information. Residual values of uranium recovered from the contaminated materials and residues at the sites are estimated; however, this information is not included in the final report.

The environmental analysis reports for each site consider the impacts of the remedial action alternatives formulated in the engineering evaluation reports. The environmental analysis efforts include demographic and land use studies, investigation of community and area planning, and industrial and population growth projections. They provide a description of the physical environment of the site and evaluate the radiation exposures to individuals and nearby populations with specific attention to gamma radiation, radon, radon-daughter concentrations, and radium and other radioisotopes in the contaminated materials and residues. Analysis of the impacts associated with the performance of the remedial actions and after the remedial actions is also completed.

The Title II activity includes preparing plans showing the location and extent of contaminated material to be removed from each property; preparing plans for an interim storage facility, if required; preparing specifications for removal and transport of contaminated materials; preparing plans and specifications for the restoration of the involved properties; preparing "owner packages" explaining remedial action work to be performed at each offsite location where contaminated material has been found; preparing a two-volume briefing package consisting of a compilation of the "owner packages" and a second volume consisting of a program overview, technical specification, and drawings; and providing assistance in preparing bid packages to contractors for performance of the remedial action work.

PROGRESS AND RESULTS

Preliminary draft and final reports of engineering evaluations and environmental analyses were completed for four sites. Proposed plans and specifications for remedial actions for the associated properties at the Middlesex, New Jersey, Sampling Plant were completed, and

individual "owner packages" were developed for each property. A compilation of remedial action descriptions was developed as a part of the briefing package.

PLANS FOR NEXT PERIOD

None

REPORTS PUBLISHED

Ford, Bacon & Davis Utah Inc., "Engineering Evaluation of the Former Middlesex Sampling Plant and Associated Properties, Middlesex, New Jersey," FBDU-230-001, July 1979.

Ford, Bacon & Davis Utah Inc., "Engineering Evaluation of the Vitro Rare Metals Plant, Canonsburg, Pennsylvania," FBDU-230-002, July 1979.

Ford, Bacon & Davis Utah Inc., "Engineering Evaluation of the Pennsylvania Railroad Landfill Site, Burrell Township, Pennsylvania," FBDU-230-003, July 1979.

Ford, Bacon & Davis Utah Inc., "Engineering Evaluation of the Middlesex Municipal Landfill Site, Middlesex, New Jersey," FBDU-230-004, July 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Analysis of the Former Middlesex Sampling Plant and Associated Properties, Middlesex, New Jersey," FBDU-230-005, July 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Analysis of the Vitro Rare Metals Plant, Canonsburg, Pennsylvania," FBDU-230-006, July 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Analysis of the Pennsylvania Railroad Landfill Site, Burrell Township, Pennsylvania," FBDU-230-007, July 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Analysis of the Middlesex Municipal Landfill Site, Middlesex, New Jersey," FBDU-230-008, July 1979.

PROJECTED MILESTONES

None

RADIOLOGICAL SURVEY OF FORMERLY UTILIZED MANHATTAN ENGINEER DISTRICT/ATOMIC ENERGY COMMISSION SITES

ORGANIZATION AND CONTRACT NUMBER

Argonne National Laboratory
W-31-109-ENG-38

PRINCIPAL INVESTIGATORS

R.A Wynveen
W.H. Smith

OBJECTIVE

The objective is to conduct comprehensive surveys, designed to characterize the radiological environment in and around sites and facilities previously owned, leased, or utilized by the Manhattan Engineer District/Atomic Energy Commission and descendent organizations, and surplus radioactivity contaminated facilities owned by the Department of Energy. This includes sites scheduled for decontamination and decommissioning. These sites and facilities may have been contaminated with radioactive materials during the time of their operations. The surveys provide data indicating surface contamination levels, ambient radiation exposure levels, soil and air contamination levels, and nuclide identification as necessary. An analysis of the survey results provides the basis for determining the need for remedial action and enables evaluation of the efficiency and effectiveness of any remedial action and decontamination or decommissioning efforts. The nature of the surveys ranges from exploratory surveys designed to determine whether an extensive, detailed survey is necessary, to confirmatory surveys designed to confirm the results of previous surveys of others, to extensive detailed surveys designed to delineate areas of contamination that may require further action. Survey results will be documented.

APPROACH

Residual contamination on exposed surfaces is initially monitored by means of gas-flow proportional floor monitors and hand-held survey instruments, operated in the alpha and beta-

sensitive mode. This is followed by surveys using gamma detection instruments, including micro-R meters, FIDLERs, end window C-M detectors, and other specialized instrumentation as necessary. Smear surveys for "removable" contamination are conducted as deemed necessary from an on-the-spot judgment. Sufficient air samples are taken to document radon concentrations as well as long-lived radioactive airborne contaminants, if any. Spectrum analyses are conducted where such analyses are judged necessary to evaluate the radiological nature of the site in question. Soil corings are completed, and a profile analysis is conducted of the coring after the proper radiochemical or gamma spectral analysis has been performed on each segment of the core. Well (bore hole) logging is also conducted, where applicable.

PROGRESS AND RESULTS

- A detailed radiological assessment of the entire Harshaw Chemical Company facilities, Cleveland, Ohio, was initiated during this period. This assessment was prompted by the results of the earlier (May 1976) radiation survey performed by Argonne National Laboratory on Plant C in the Harshaw Complex. Some 25 buildings and approximately 24 acres of open areas on the complex were surveyed. A radiological subsurface investigation of the Cuyahoga River bottom will be performed upon receipt of the necessary equipment and development of the extraction methodology.

- A radiological assessment was conducted of Building 1 at 9200 Latty Avenue, Hazelwood, Missouri, during this period at the request of the Nuclear Regulatory Commission and with the concurrence of the Department of Energy. A report was prepared and submitted to the Environmental Impact Studies Division, Argonne National Laboratory, for evaluation and followup.

- A detailed radiological assessment of the U.S. Bureau of Mines site, Albany, Oregon, was continued. This included initiation of a radiological assessment for the sewer line servicing the U.S. Bureau of Mines, the city of Albany waste treatment plant, and a farm used as a disposal site for the treated sludge. A radiological assessment effort is continuing on this site.

- Soil samples from the West Jefferson Facility (Battelle Memorial Institute, Columbus, Ohio) were processed and submitted for radiochemical analyses. This is a part of an ongoing radiological assessment (third party) of the West Jefferson Plutonium Facility decontamination and decommissioning effort. Continuing effort will be supplied throughout the decontamination and decommissioning process.

- A detailed procedure of subsurface investigation was initiated at the New Brunswick Laboratory, New Brunswick, New Jersey for delineating the contents of previously buried pitchblende. Several cursory surveys were also made during this period. Compilation of results are continuing.

PLANS FOR NEXT PERIOD

Four person-years of effort are to be devoted during fiscal 1980 to the ongoing surveys and assessments of the radiological conditions of the several sites. Exploratory trips to additional sites, as they become identified, will be made to accomplish the necessary preplanning of the scope and details of any survey operations to follow. This will include possible mill tailing sites.

REPORTS PUBLISHED

Argonne National Laboratory, "Radiological Survey of the Former GSA 39th Street Warehouse, 1716 West Pershing Road, Chicago, Illinois," DOE/EV-0005/9, January 1979.

Argonne National Laboratory, "Radiological Survey of the Museum of Science and Industry, 57th Street and Lake Shore Drive, Chicago, Illinois," DOE/EV-0005/13, February 1979.

PROJECTED MILESTONES

None

AERIAL MEASUREMENT RADIOLOGICAL SURVEYS

ORGANIZATION AND CONTRACT NUMBER

EG&G Idaho, Inc.
DE-AC08-76NV001183

PRINCIPAL INVESTIGATORS

H.A. Lamonds
J.F. Doyle

OBJECTIVE

The objective is to radiologically survey selected formerly utilized Manhattan Engineer District/Atomic Energy Commission sites to evaluate existing site operations, ensure effective management and control of effluents, and compare the sites with existing and proposed standards.

APPROACH

Radiological survey information using aerial measurements will be gathered and analyzed with in-house computers.

PROGRESS AND RESULTS

The radiological survey data (Table 21) was gathered using arrays of sodium iodide detectors flown, in fixed-wing aircraft or helicopters, depending on altitude, speed, and payload requirements of a given mission. Photographic data was obtained using large format aerial cameras. The data gathered, to date, has been put into computers for analysis. Letter reports of the surveys were forwarded to the Environmental Control Technology Division.

PLANS FOR NEXT PERIOD

Plans are to publish final status reports of the surveys and conduct aerial surveys of additional sites as shown in Table 21.

REPORTS PUBLISHED

None

PROJECTED MILESTONES

None

Table 21. Status of Aerial Surveys

Site	Date Flown	Letter Report Submitted	Estimated 45 Day Report	Estimated Final Report
Attleboro (Shpack Dump Site)	08-79	10-02-79	10-20-79	08-80
Blairsville (Industrial Site)	04-78	11-22-78	N/A	04-80
Canonsburg (Industrial Site)	04-78	06-28-78	N/A	08-80 (combined)
Canonsburg (Industrial Site	07/08-79	09-11-79	11-05-79	
Cleveland (Harshaw Chemical)	09-79	10-02-79	11-26-79	09-80
Cleveland (Horizons-Clecon)	09-79	10-05-79	11-28-79	09-80
Curtis Bay (W.R. Grace Co.)	07-79	07-31-79	10-15-79	08-80
Lake Ontario Ordnance Works	10-78	02-16-79	N/A	10-80
Middlesex (Industrial Site)	05-78	10-28-78	N/A	05-80
Niagara Falls (Industrial Site)	11-78	03-12-79	N/A	09-80 (combined)
Niagara Falls (INdustrial Site)	09-79	10-01-79	11-27-79	
NFS West Valley (for NRC)	09-79	10-01-79	11-27-79	09-80
Tonawanda (Industrial Site)	09-79	10-01-79	11-28-79	09-80
Albany (U.S. Bureau of Mines)	To be performed in fiscal year 1980			
Falls City (Conoco/Susquehanna)				
Gunnison (Gunnison Mining Co.)				
Rifle (Union Carbide)				
St. Louis (Mallinckrodt Chem/Airport)				
Salt Lake City (Vitro)				
Shiprock (Foote Mineral Co.)				

BIBLIOGRAPHY

BIBLIOGRAPHY

The publications listed in this bibliography were developed with either total or partial Environmental Control Technology Division funding.

CONTENTS

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

COAL

Adams, E.E., and D.R.F. Harleman, "Summary Report of Waste Heat Management in the Electric Power Industry: Issues of Energy Conservation and Station Operation Under Environmental Constraints," MIT Energy Laboratory Report No. MIT-EL 79-040, 1979.

Adams, E.E., et al., "Hydrothermal Performance of Shallow Cooling Ponds," Massachusetts Institute of Technology Energy Laboratory, to be published; and presented at the 2nd conference on Waste Heat Management and Utilization, Miami Beach, December 1978. (Also published as R.M. Parsons Laboratory Report.)

Adams, E.E., et al., "Mathematical Models for Cooling Lake Design, Part B: Users Manual for MITEMP, Part C: Development of Quasi-Steady Models," MIT Energy Laboratory Report No. MIT-EL 79-039, 1979.

Albanese, A.S., and M. Steinberg, "Environmental Control Technology for Atmospheric Carbon Dioxide," Final Report, BNL 51116, Brookhaven National Laboratory, September 1979.

Albanese, A.S., and M. Steinberg, "Environmental Control Technology for the Flash Hydropyrolysis of Coal," Progress Report No. 3, BNL 50983, Brookhaven National Laboratory, February 1979.

Allemann, R.T., "Incentives for Use of Dry Cooling in Support of Advanced Energy Generating Systems," Battelle, Pacific Northwest Laboratory, 1979, to be published.

Argonne National Laboratory published the following reports under the title "Environmental Control Implications of Generating Electric Power from Coal":

Argonne National Laboratory, "Technology Status Report," ANL/ECT-1, Vol. I-condensation, Vol.II-detailed information, December 1976.

Bechtel Corporation, "Coal Preparation and Cleaning Assessment Study," ANL/ECT-3, Appendix A, Part 1, December 1977.

Argonne National Laboratory and Bechtel Corporation, "Coal Preparation and Cleaning Assessment Study Appendix," ANL/ECT-3, Appendix A, Part 2, December 1977.

Air Products and Chemicals, Inc., "Assessment of Status of Technology for Solvent Refining of Coal," ANL/ECT-3, Appendix B, December 1977.

KVB, Inc., "Assessment of NO_x Control Technology for Coal Fired Utility Boilers," ANL/ECT-3, Appendix D, December 1977.

Southern Research Institute, "A Review of Technology for Control of Fly Ash Emissions From Coal in Electric Power Generation," ANL/ECT-3, Appendix E, December 1977.

Tennessee Valley Authority, "Flue Gas Desulfurization in the United States-1977," ANL/ECT-3, Appendix F, December 1977.

Tennessee Valley Authority, "State-of-the-Art Review of Simultaneous Removal of Nitrogen Oxides and Sulfur Oxides From Flue Gas," ANL/ECT-3, Appendix G, December 1977.

Argonne National Laboratory, "Comparative Assessments Methodology," ANL/ECT-2, in press.

Argonne National Laboratory, abstracts published for papers given at Symposium on Environment and Mining Research and Demonstration Activities in Southern Appalachia, University of Tennessee, Knoxville, May 2-3, 1978:

Johnson, D.O., "Environmental Control Technology of Selected U.S. Strip Mining Sites."

Leung, S.S., "Water Quality at Three Surface Coal Mines in Eastern Kentucky."

Bogner, J.E., J.P. Schubert, and R.D. Olsen, "Water Quality at a Surface Coal Mine in the Black Warrior Basin, Northern Alabama."

Byerly, D.W., and D.C. Claytor, "The Evaluation of Volumes, Characteristics, and Potential Environmental Impacts of the Mine Wastes and Effluents of Two Coal Strip Mines in the Southern Coalfield of Tennessee."

Arthur G. McKee & Co., "Improved Water Management of Coal Conversion Processes by Preliminary Absorption of Halides," draft, January 1979.

Baes, C.F., Jr., et al., "Options for the Collection and Disposal of Carbon Dioxide," Final Report, in preparation.

Baes, C.F., Jr., S.E. Beall, and G. Marland, "Options for Collection and Disposal of Carbon Dioxide From Concentrated Sources," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Bartke, T.C., et al., "Status of Fourth Underground Coal Gasification Experiment at Hanna, Wyoming," SPE 7510, Society of Petroleum Engineers of AIME, 1978.

Bartke, T.C., et al., "Status Report on the Hanna III and Hanna IV Underground Coal Gasification Experiments," Proceedings of the Fourth Underground Coal Conversion Symposium, SAND-78-0941, July 17-20, 1978, June 1978.

Barton-Aschman Associates, Inc., in association with ESCOR, Inc., "Surface Mine Discharge Treatment Cost: Southern Appalachian Region," prepared for Energy and Environmental Systems Division, Argonne National Laboratory, 1978.

Battelle Columbus Laboratories, "Catalyzing Coal for Industrial Gasification," to be presented at American Institute of Chemical Engineers Meeting, June 1980.

Battelle Columbus Laboratories, "Technical and Economic Assessment of Potential Advantages Associated With the Use of Battelle Treated Coal (BTC) in Gasifiers," Contract No. W-7405-ENG-92, July 20, 1979.

Battelle Columbus Laboratories, "Energy and Economic Impacts of Flue Gas Desulfurization Systems," draft.

Battelle, Pacific Northwest Laboratory, "Dry/Wet Cooling Towers - Assessment of Environmental Factors Arising From Large-Scale Use of Dry/Wet Cooling of Power Plants," B.M. Johnson, Project Manager.

Bently, J., et al., "An Experimental and Analytical Study of a Unique Wet/Dry Surface for Cooling Towers," Trans. AMSE, J. of Heat Transfer, Vol. 100, No. 3, pp. 520-526, August 1978.

Bituminous Coal Research, Inc., "Analytical Procedures for Trace Elements in Coal," presented to Society of Mining Engineers of American Institute of Mining Engineers Mini-Symposium on Elements in Coal and Potential Environmental Concerns Arising From These Elements, February 1979.

Bituminous Coal Research, Inc., "Effect of Coal Cleaning on Fugitive Elements: A Progress Report," presented at Environmental Protection Agency Symposium on Coal Cleaning To Achieve Energy and Environmental Goals, September 11, 1978, and U.S. DOE Environmental Control Symposium, November 28-30, 1978.

Bituminous Coal Research, Inc., "Evaluation of the Effects of Coal Cleaning on Fugitive Elements, Phase I," BCR Report L-293, U.S. Department of Energy, August 17, 1978.

Bogner, J.E., and A.A. Sobek, "Distribution of Selected Transition and Heavy Metals in Clastic Overburden Units of the Appalachian and Interior Coal Basins: Water Quality Implications," at IX International Congress of Carboniferous Stratigraphy and Geology, June 1979, Urbana, Illinois, Proceedings to be published by American Geological Institute.

Bogner, J.E., and D.O. Johnson, "Environmental Control Technology Program Studies at Argonne National Laboratory: Surface Mine Effluents," Proceedings of Fifth National Conference on Energy and the Environment, Cincinnati, Ohio, November 1-3, 1977.

Bogner, J.E., et al., "Water Quality Impacts and Overburden Geochemistry of Ohio Study Site," Environmental Control Technology Survey of U.S. Strip Mining Sites, Vol. 2a, draft, Argonne National Laboratory, 1978.

Bogner, J.E., J.P. Schubert, and R.D. Olsen, "Water Quality at a Surface Coal Mine in the Black Warrior Basin, Northern Alabama," presented at Symposium on Environmental and Mining Research and Demonstration Activities in Southern Appalachia, University of Tennessee, Knoxville, May 2-3, 1978.

Bosshart, R.E., and L.D. Howe, "Determination of Arsenic, Selenium, and Antimony in Coal and Coal Ash Reference Standards After Ignition With Eschka's Mixture by Hydride Generation-Atomic Absorption," Analytical Chemistry, to be published, August 1979.

Bosshart, R.E., et al., "Analytical Procedures Used at BCR for the Determination of Trace Elements in Coal," Bituminous Coal Resarch, Inc., to be published, November 1979.

Boyer, J.F., and C.T. Ford, "Effect of Cleaning Ten Coals on Trace and Major Effluents," Bituminous Coal Research, Inc., to be published, May 1979.

Branstetter, B., and J.P. Fox," Trace Element Analysis on the Naval Oil Shale Reserve No. 1," Quarterly Report, July 1 - September 30, Lawrence Berkeley Laboratory, 1978.

Branstetter, B., J.P. Fox, and S. Lubic, "Trace Element Analysis of the Naval Oil Shale Reserve No. 1," Quarterly Report, October 1 - December 31, Lawrence Berkeley Laboratory, 1978.

Buder, M.K., et al., "A Study of Coal Preparation and Cleaning - Summary and Results," Proceedings of the Fifth National Conference on Energy and the Environment, Cincinnati, Ohio, October 31 to November 3, 1977, pp. 264-272.

Byerly, D.W., and D.C. Claytor, "The Evaluation of Volumes, Characteristics, and Potential Environmental Impacts of the Mine Wastes and Effluents of Two Coal Strip Mines in the Southern Coalfield of Tennessee," presented at Symposium on Environmental and Mining Research and Demonstration Activities in Southern Appalachia, University of Tennessee, Knoxville, May 2-3, 1978.

Campbell, J.H., E.D. Pellizzari, and S.D. Santor, "Results of a Ground-Water Quality Study Near an Underground Coal Gasification Experiment (Hoe Creek I)," UCRL-52405, Lawrence Livermore Laboratory, 1978.

Campbell, J.H., et al., "Groundwater Quality Near an Underground Coal Gasification Experiment," Journal of Hydrology, Vol. 44, No. 241, 1979.

Carnegie-Mellon University, "Modeling of Environmental Control Systems for Coal-Based Power Generation," Draft.

Carter, R.P., et al., "Special Committee To Study Health and Environmental Effects of Increased Coal Production," Chapter 9 - Reclamation, Argonne National Laboratory, 1977.

Choi, M., and L. Glicksman, "The Effects of Different Methods of Replacing Lost Capacity on the Economic Optimization of Dry Cooling Tower Systems," presented at Electric Power Research Institute Workshop on Power System Economics, October 1978.

Choi, M.K.-W., and L.R. Glicksman, "Computer Optimization of Dry and Wet/Dry Cooling Tower Systems for Large Fossil and Nuclear Plants," Massachusetts Institute of Technology, Energy Laboratory Report No. MIT-EL 79-034, 1979.

Choi, M.K.-W., and L.R. Glicksman, "Computer Optimization of the MIT Advanced Wet/Dry Cooling Tower Concept for Power Plants," Massachusetts Institute of Technology, Energy Laboratory Report No. MIT-EL 79-035, 1979.

Cowser, K.E., ed., "Proposed Environmental and Health Program for H-Coal Liquefaction Facility," Oak Ridge National Laboratory, draft in preparation.

Cowser, K.E., ed., "Proposed Environmental and Health Program for Pike County Coal Gasification Facility," draft, Oak Ridge National Laboratory, December 18, 1978.

Cowser, K.E., ed., "Proposed Environmental and Health Program for University of Minnesota Gasification Facility," Oak Ridge National Laboratory, January 23, 1978.

Cowser, K.E., ed., "Environmental and Health Program for Pike County Coal Gasification Facility," Oak Ridge National Laboratory, August 1979.

Cowser, K.E., ed., "Proposed Environmental and Health Program for H-Coal Pilot Plant," Oak Ridge National Laboratory, May 25, 1979.

Cowser, K.E., G.V. McGurl, and R.W. Wood, "Environmental and Health Study of a Low-Btu Gasifier," Proceedings of the Tenth Synthetic Pipeline Gas Symposium, Des Plaines, Illinois, October 1978.

Cowser, K.E., G.V. McGurl, and R.W. Wood, "Monitoring and Testing Program of Low-Btu Gasifiers," Symposium Proceedings: Environmental Aspects of Fuel Conversion Technology, IV, Hollywood, Florida, April 1979.

Dalton, V.A., and J.H. Campbell, "Laboratory Measurements of Ground-Water Leaching and Transport of Pollutants Produced During Underground Coal Gasification," UCRL-80834, Lawrence Livermore Laboratory, 1978.

Daniels, T., et al., "Bibliography of the Effects of Selected Coal Mine Pollutants on Aquatic Systems," Environmental Control Technology Survey of U.S. Strip Mining Sites, draft, Argonne National Laboratory, 1979.

DeGalbo, A.D., et al., "Treatment of Coal Gasification Wastewaters by Adsorption With Gasifier Chars," Proceedings of the National Conference On Energy and the Environment, American Institue of Chemical Engineers, May 1979.

DeSteese, J.G., "Environmental Concerns Influencing the Future Development of Energy Material Transportation Systems -- The Year 2000 Study," PNL-SA-7422, Pacific Northwest Laboratory, presented at U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

DeSteese, J.G., and A.L. Franklin, "Identification and Prioritization of Concerns in Coal Transportation Now Through 2000," PNL-SA-6967, Symposium on Critical Issues in Coal Transportation, National Research Council, Commission on Sociotechnical Systems, Washington, D.C., June 14-15, 1978.

DeSteese, J.G., and R.E. Rhoads, "Identification and Prioritization of Potential Problems in Nuclear Material Transportation Now Through 2000," PNL-SA-6527, Proceedings 5th International Symposium on the Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

DeSteese, J.G., et al., "Energy Material Transport, Now Through Year 2000, System Characteristics and Potential Problems - Task 1 - Progress Report - Nuclear Material Transportation," BNWL-2248, draft, Battelle, Pacific Northwest Laboratory, April 1977.

DeSteese, J.G., et al., "Energy Material Transport, Now Through Year 2000, System Characteristics and Potential Problems - Task 2 - Final Report - Coal Transportation," PNL-2420, Battelle, Pacific Northwest Laboratory, June 1978.

DeSteese, J.G., et al., "Energy Material Transport, Now Through Year 2000, System Characteristics and Potential Problems -- Task 3 -- Final Report --Petroleum Transportation," PNL-2421, Pacific Northwest Laboratory, Richland, Washington, 1979.

DeSteese, J.G., et al., "Energy Material Transport, Now Through Year 2000, System Characteristics and Potential Problems - Task 4 - Final Report - Natural Gas Transportation," PNL-2422, Battelle, Pacific Northwest Laboratory, July 1978.

Doehler, R.W., J.E. Bogner, and A.A. Sobek, "Geochemistry of Neutralization-Treatment Waste Products at Surface Coal Mines," presented at Annual Meeting, North Central Section, Geological Society of America, Duluth, Minnesota, May 1979.

Drummon, C.J., et al., "Biochemical Oxidation of Coal Conversion Wastewaters," presented at 87th National Meeting of the American Institute of Chemical Engineers, Boston, Massachusetts, Fiche 31, Paper 39b, August 19-22, 1979.

Ellman, R.C., and B.C. Johnson, "Slagging Fixed-Bed Gasification at the Grand Forks Energy Research Center," Eighth Synthetic Pipeline Gas Symposium, Chicago, Illinois, 1976.

Ellman, R.C., and E.A. Sondreal, "Environmental Control Activities on Slagging Fixed-Bed Gasification at the Grand Forks Energy Technology Center," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Ellman, R.C., and H.H. Schobert, "Pilot Plant Operation of a Fixed-Bed Slagging Gasifier," 173rd National American Chemical Society Meeting, New Orleans, Louisiana, 1977.

Ellman, R.C., B.C. Johnson, and M.M. Fegley, "Studies in Slagging Fixed-Bed Gasification at the Grand Forks Energy Technology Center," Tenth Synthetic Pipeline Gas Symposium, Chicago, Illinois, October 1978.

Ellman, R.C., et al., "Current Status of Studies in Slagging Fixed-Bed Gasification at the Grand Forks Energy Research Center," Ninth Biennial Lignite Symposium, Grand Forks, North Dakota, 1977.

Ellman, R.C., et al., "Slagging Fixed-Bed Gasification Project Status at the Grand Forks Energy Technology Center," Tenth Biennial Lignite Symposium, Grand Forks, North Dakota, May 30-31, 1979.

Ellman, R.C., et al., "Slagging Fixed-Bed Gasification," Fourth International Conference on Coal Gasification, Liquefaction, and Conversion, Pittsburgh, Pennsylvania, 1977.

ESCOR, Inc., "Surface Mine Discharge Treatment Cost: Midwestern Region," prepared for Energy and Environmental Systems Division, Argonne National Laboratory, Draft, 1979.

ESCOR, Inc., "Surface Mine Discharge Treatment Cost: Northern Appalachian Region," prepared for Energy and Environmental Systems Division, Argonne National Laboratory, 1978.

Fang, S.-J., "A Mathematical Model of the Acid Mine Drainage Lime Neutralization Process," MSChE Thesis, West Virginia University, Morgantown, West Virginia, December 1978.

Farber, P.S., "Capital and Operating Costs of Particulate Control Equipment for Coal-Fired Power Plants," Proceedings of the Fifth National Conference on Energy and the Environment, Cincinnati, Ohio, October 31 to November 3, 1977, pp. 434-440.

Farber, P.S., and C.D. Livengood, "Effects of the Proposed New Source Performance Standards: A Comparative Assessment of the Energy and Economic Impact," Proceedings of the 71st Annual Meeting of the Air Pollution Control Association, Houston, Texas, June 1978.

Farber, P.S., et al., "Status of Development, Energy, and Economic Aspects of Alternative Technologies," Proceedings of the EPA Symposium on Flue Gas Desulfurization, Las Vegas, Nevada, March 1979.

Farrier, D.S., et al., "Environmental Research for In Situ Oil Shale Processing," Eleventh Oil Shale Symposium Proceedings, April 12-14, 1978, Colorado School of Mines Press, Golden, Colorado, November 1978.

Farrier, D.S., L.W. Harrington, and R.E. Poulson, "Integrated Compliance and Control Technology Research Activities for In Situ Fossil Fuel Processing Experiments," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Fisher, J.F., and G.R. Peterson, "Control of Hydrocarbon and Carbon Monoxide Emissions in the Tail Gases From Coal Gasification Facilities," ORNL/TM-6229, Oak Ridge National Laboratory, August 1978.

Ford, C.T., "Analytical Procedures for Trace Elements in Coal," presented at the AIME Annual Meeting, New Orleans, Louisiana, February 19-22, 1979.

Ford, C.T., "Coal Cleaning to Remove Trace Elements Prior to Utilization," Fourth Symposium on Coal Utilization, Louisville, Kentucky, October 18-20, 1977.

Ford, C.T., and J.F. Boyer, "Effect of Coal Cleaning on Fugitive Elements: A Progress Report," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Ford, C.T., and J.F. Boyer, "Effects of Coal Cleaning on Elemental Distributions," EPA Symposium on Coal Cleaning To Achieve Energy and Environmental Goals, Hollywood, Florida, September 9-11, 1978.

Foster Wheeler Energy Corp., "Assessment of Low-Btu Gas Combined Cycle Power Generation, ANL/ECT-3, Appendix C of Technology Status Report, Argonne National Laboratory, in press.

Ganow, H.C., "In Situ Coal Gasification at the Hoe Creek, Wyoming, Field Site -- An Overview," UCRL-82987, Lawrence Livermore Laboratory, 1979.

Ganow, H.C., and D.W. Carpenter, "Post-Burn Drilling Results From Hoe Creek Experiment II," submitted for presentation to the Fifth Underground Coal Conversion Symposium, Alexandria, Virginia, July 18-21, 1979.

Ganow, H.C., D.W. Carpenter, and S.W. Mead, "In Situ Coal Gasification Induced Subsidence - The Hoe Creek II Case History," submitted for presentation to the 54th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers of AIME, Las Vegas, Nevada, September 23-26, 1979.

Ganow, H.C., R.C. Greenlaw, and R.T. Langland, "Geothermal Instrumentation Applied to In Situ Coal Gasification Induced Subsidence," Proceedings of the Fourth Annual Underground Coal Conversion Symposium, July 17-20, 1978. Also published as UCRL-81267, Lawrence Livermore Laboratory, 1978.

Geffen, C.A., "Potential Safety and Environmental Concerns in Petroleum Transportation," PNL-SA-7694, Pacific Northwest Laboratory, presented at the First International Symposium on Transportation Safety in San Diego, California, July 11-13, 1979.

Gehrs, C.W., et al., "Preliminary Assessment of Three Fossil Energy Related Residues by RCRA Protocols," Oak Ridge National Laboratory, in press.

Gerstle, J., R. Barbera, and D. Marks, "A Water Rights Transfer Model With Considerations of Hydrologic and Institutional Factors," presented at ASCE Water Systems Specialty Conference, Houston, Texas, March 1979. (A revised edition will be submitted to ASCE for journal publication.)

Gottlieb, M., C.D. Livengood, and K.E. Wilzbach, "Environmental Control Implications of Increased Coal Utilization Under the National Energy Plan," Proceedings of the 71st Annual Meeting of the Air Pollution Control Association, Houston, Texas, June 1978.

Greenlaw, R.C., H.C. Ganow, and R.L. Langland, "Subsidence and Stability Studies for Underground Coal Gasification," UCID-17674, Lawrence Livermore Laboratory, 1977.

Greenlaw, R.C., H.C. Ganow, and R.T. Langland, "Non-Linear Subsidence Modeling at Hoe Creek," Proceedings of the Fourth Annual Underground Coal Conversion Symposium, July 17-20, 1978.

Hajicek and L.E. Paulson, "Development and Operating Characteristics of a Gas Sampling System for the Grand Forks Energy Technology Center's Slagging Fixed-Bed Gasifier," Third Annual Symposium, Instrumentation and Control for Fossil Demonstration Plants, Denver, Colorado, August 20-22, 1979.

Hakkila, E.A., et al., "A Preliminary Electron Microprobe Study of Green River and Devonian Oil Shales," Analytical Chemistry of Liquid Fuel Sources, Chapter 13, P.C. Uden, S. Siggia, and H.B. Jensen, eds., Advances in Chemistry Series 170, American Chemical Society, Washington, D.C., 1978.

Hakkila, E.A., et al., "Electron Microprobe Studies of Mahogany Zone and Devonian Shale," (NTIS) LA-6414-MS, Los Alamos Scientific Laboratory, July 1976. Also in Proceedings of the Symposium on Analytical Chemistry of Tar Sands and Oil Shales, (NTIS) LA-UR-76-2279, American Chemical Society, New Orleans, Louisiana, March 1977.

Hansen, L.D., et al., "Analytical Study of the Effluents From a High Temperature Entrained Flow Gasifier," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978. Also presented at the 3rd Rocky Mountaln Fuel Symposium, Albuquerque, New Mexico, February 10-11, 1978, and at the Symposium on Characterization of Coal Combustion Products at the Meeting of the Electrochemical Society, Boston, Massachusetts, May 6-11, 1979.

Harleman, D., et al., "Waste Heat Management in the Electric Power Industry: Issues of Energy Conservation and Station Operation Under Environmental Constraints," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Hayden, R.S., D.O. Johnson, and J.D. Henricks, "Field and Laboratory Procedures for the Determination of Priority Pollutants From Surface Coal Mining and Processing," Environmental Control Technology Survey of U.S. Strip Mining Sites, ANL/EES-TM-21, Argonne National Laboratory, 1979.

Hendrickson, P.L., "An Overview of Issues Affecting the Demand for Dry and Wet/Dry Cooling for Thermal Power Plants," BNWL-2268-Rev. 1, Battelle, Pacific Northwest Laboratory, 1978.

Henning, R.J., et al., "Water Quality Impacts and Overburden Chemistry of Pennsylvania Study Sites," Environmental Control Technology Survey of U.S. Strip Mining Sites, Vol. 2e, draft, Argonne National Laboratory, 1979.

Henning, R.J., et al., "Water Quality Impacts and Overburden Geochemistry of Tennessee Study Sites," Environmental Control Technology Survey of U.S. Strip Mining Sites, Vol. 2d, draft, Argonne National Laboratory, 1979.

Henricks, J.D., et al., "Water Quality Impacts and Overburden Geochemistry of Alabama Study Site," Environmental Control Technology Survey of U.S. Strip Mining Sites, Vol. 2b, draft, Argonne National Laboratory, 1979.

Henricks, J.D., J. Reiter, and J.E. Bogner, "Flexible Data Management System for Storage and Manipulation of Geochemical and Geological Data," presented at Annual Meeting, North Central Section, Geological Society of America, Duluth, Minnesota, May 1979.

Hird, K.B., "A Preliminary Investigation of Physical-Chemical Treatment of Slagging Gasifier Aqueous Effluent," M.S. Thesis, University of North Dakota, August 1979.

Holland, T., A.W. Pappano, and D.L. Gochenour, Jr., "A QUAL II Simulation Analysis of Treating AMD Problems in the Monongahela River Study Basin," presented (and included in the proceedings) at the 1978 Winter Simulation Conference, Miami Beach, Florida, December 4-6, 1978.

Homsy, R.V., "Two-Dimensional Transient Dispersion and Adsorption in Pourous Media," in Proceeedings of the Fifth Underground Coal Conversion Symposium, Alexandria, Virginia, June 18-21, 1979, pp. 295-303. Also published as Lawrence Livermore Laboratory Report UCRL-81970, Rev. 1, 1979.

Huettenhain, H., J. Yu, and S. Wong, "A Technical and Economic Overview of Coal Cleaning," Proceedings of the 71st Annual Meeting of the Air Pollution Control Association, Houston, Texas, June 1978.

Johnson, B.C., H.H. Schobert, and M.M. Fegley, "The Grand Forks Slagging Gasifier: Gas-Solid Reactions in the Real World," AIChE Symposium, Theory and Practice of Gas-Solids Contactors in Fossil Fuel Processing, New York, 1977.

Johnson, D.O., J.E. Bogner, and R.D. Olsen, "Environmental Control Technology Survey of Selected U.S. Strip Mining Sites," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978. Also presented at Symposium on Environmental and Mining Research and Demonstration Activities in Southern Appalachia, University of Tennessee, Knoxville, May 2-3, 1978.

Johnson, D.O., J.E. Bogner, and R.D. Olsen, "Environmental Control Technology: Effluent Survey of U.S. Strip Mining Sites," Proceedings, Impact of the National Energy Act on Utilities and Industries Due to the Conversion to Coal, Houston, Texas, December 4-6, 1978.

Johnson, D.O., L. Lewis, and M.L. Wilkey, "Future Coal Production and Selection of Case Study Sites," Environmental Control Technology Survey of U.S. Strip Mining Sites, Vol. 1, draft, Argonne National Laboratory, 1977.

Keast, D.N., "Noise Control Needs in the Developing Energy Technologies," DOE Report COO-4889-1, Bolt Beranek and Newman Inc., March 1978.

Ketschke, B.A., and M.R. Anderson, "Use of a Porous Dike To Reduce Entrainment and Entrapment in Power Plant Cooling Water Intake Systems," Northeast Fish and Wildlife Conference, Providence, Rhode Island, April 1979.

Killilea, W.R., "Feasibility Analysis of Chemical Recovery From Coal Conversion Plant Waste Streams by Advanced Concentration Processes," draft final report, Concentration Specialists, Inc., Andover, Massachusetts, March 1979.

Klein, J.A., "National Progress in Control of Wastewater From Coal Conversion Processes," Symposium Proceedings: Potential Health and Environmental Effects of Synthetic Fossil Fuel Technologies, Gatlinburg, Tennessee, September 1978.

Klein, J.A., and D.D. Lee, "Biological Treatment of Aqueous Wastes From Coal Conversion Processes," Symposium Proceedings: Biotechnology in Energy Production and Conservation, Gatlinburg, Tennessee, May 1978.

Klein, J.A., and R.E. Barker, "Assessment of Environmental Control Technology for Hydrocarbonization," Symposium Proceedings: The Second Pacific Chemical Engineering Congress (Pachec 1977), Denver, Colorado, August 29-31, 1977.

Klein, J.A., and R.E. Barker, "Assessment of Environmental Control Technology for Coal Conversion Aqueous Wastes," ORNL/TM-6263, Oak Ridge National Laboratory, July 1978.

Klein, J.A., C.H. Brown, and D.D. Lee, "Wastewater Treatment Technology for Coal Conversion Plants," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Kromrey, R.V., et al., "Development of Coatings for Protection of Coal During Transport and Storage," COO-4632-2, Atlantic Research Corporation, Alexandria, Virginia, November 1978. Also in U.S. DOE Environmental Control Symposium, DOE/EV-0046, September 1979.

Kromrey, R.V., et al., "Development of Coatings To Reduce Fugitive Emissions From Coal Stockpiles," presented at the EPA Third Symposium on Fugitive Emissions, San Francisco, California, October 23, 1978.

KVB, Inc., "Current and Advanced NO_x-Control Technology for Coal-Fired Industrial Boilers," ANL/ECT-4, Argonne National Laboratory, 1978.

KVB, Inc., "NO_x Control for Coal-Fired Utility Boilers and Applications Viewpoint," presented at Second EPRI NO_x Control Technology Seminar, Denver, Colorado, November 1978.

KVB, Inc., "Relationship of Particulate Characteristics to Coal and Combustion Conditions," draft.

KVB, Inc., "Status of Combustion Modification Programs," draft.

Lee, M.L., et al., "Analytical Study of the Effluents From a High Temperature Entrained Flow Gasifier," American Chemical Society Division of Fuel Chemistry, Preprints, Vol. 23, 119, 1978; also presented at the 175th National Meeting of the American Chemical Society, Anaheim, California, March 12-17, 1978.

Lee, M.L., et al., "Effects of Operating Conditions on Effluents From a High Temperature Entrained Flow Coal Gasifier," in preparation.

Lee, M.L., et al., "Study of By-Products and Potential Pollutants From High Temperature Entrained Flow Gasifiers," Final Report, U.S. DOE Contract No. EE-77-S-02-4377.

Leung, S.S., "Water Quality of Three Surface Coal Mines in Eastern Kentucky," presented at Symposium on Environmental and Mining Research and Demonstration Activities in Southern Appalachia, University of Tennessee, Knoxville, May 2-3, 1978.

Lindberg, S.E., "The Need for Mass-Balance Studies in Coal Conversion Waste Research," Oak Ridge National Laboratory, In preparation.

Lippek, H.E., "Selected Regulatory Issues Affecting Coal Transportation Requirements," Symposium on Critical Issues in Coal Transportation, National Research Council, Commission on Sociotechnical Systems, Washington, D.C., June 14-15, 1978.

Lippek, H.E., G.B. Walters, and T.P. Hunter, "Selected Legal and Regulatory Concerns Affecting Domestic Energy Transportation Systems," draft, Battelle, Pacific Northwest Laboratory.

Livengood, C.D., P.S. Farber, and S.H. Wong, "Environmental Control Strategies for Coal-Fired Power Plants: A Comparative Evaluation," Proceedings of the Fifth National Conference on Energy and the Environment, Cincinnati, Ohio, October 31 to November 3, 1977, pp. 230-236.

Luthy, Sekel, and Tallon, "Biological Treatment of Grand Forks Energy Technology Center Slagging Fixed-Bed Coal Gasification Process Wastewater," FE-2496-42, Eleventh Quarterly Report, March 1979.

Manhattan College, "Control Technology for Fine-Particulate Emissions," ANL/ECT-5, Argonne National Laboratory, 1978.

Margler, L.W., and M.B. Rogozen, "Effects of Coal Slurry on Sewage Bacteria and Bacteriophage," submitted to the Water Pollution Control Federation Journal, February 7, 1979.

May, R.P., et al., "Deposition and Corrosion Phenomena on Aluminum Surfaces Under Deluged Dry Cooling Tower Conditions," PNL-2752, Battelle, Pacific Northwest Laboratory, 1978, to be published.

Mayer, D.W., and E.M. Arnold, "Potential Use of Dry Cooling in Support of Advanced Energy Generation Systems," PNL-3149, Pacific Northwest Laboratory, Richland, Washington, 1979.

Mayer, G.G., J.K. Olson, and H.H. Schobert, "Standard Methods for the Analysis of Coal Gasification Effluents-Caveat Emptor," National CIC Meeting, Winnipeg, 1978.

Mayer, Hajicek, and Freeman, "Correlating Process Parameters for a Slagging Fixed-Bed Gasifier," Third Annual Symposium, Instrumentation and Control for Fossil Demonstration Plants, Denver, Colorado, August 20-22, 1979.

Mead, S.W., et al., "Environmental Studies of LLL's Hoe Creek II Underground Coal Gasification Experiment," UCRL-82409, Lawrence Livermore Laboratory, 1979. Also presented at the Fifth Annual Underground Coal Conversion Symposium, Alexandria, Virginia, June 18-21, 1979.

Mead, S.W., et al., "Ground-Water Effects of Underground Coal Gasification Experiments in Northeastern Wyoming," presented at the 54th Annual Fall Technical Conference and Exhibition of the Society of Petroleum Engineers of AIME, Las Vegas, Nevada, September 23-026, 1979.

Mead, S.W., et al., "LLL Environmental Studies of In Situ Coal Gasification," UCRL-50032-78, Annual Report Fiscal Year 1977, Lawrence Livermore Laboratory, 1978.

Mead, S.W., F.T. Wang, and H.C. Ganow, "Control Aspects of Underground Coal Gasification: LLL Investigations of Ground-Water and Subsidence Effects, UCRL-81887, Lawrence Livermore Laboratory, 1978. Also presented at U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Mead, S.W., F.T. Wang, and H.C. Ganow, "Environmental Investigations of In Situ Coal Gasification Experiments," Proceedings of Environmental Aspects of Non-Conventional Energy Resources-II, September 26-29, 1978. Also published as UCRL-81395, Lawrence Livermore Laboratory, 1978.

Mead, S.W., H.C. Ganow, and F.T. Wang, "Ground-Water and Subsidence Investigations of the LLL In Situ Coal Gasification Experiments," Proceedings of the Fourth Annual Underground Coal Conversion Symposium, July 17-20, 1978. Also published as UCRL-81271, Lawrence Livermore Laboratory, 1978.

Mead, S.W., J.H. Campbell, and D.R. Stephens, "Ground-Water Quality Effects of an Underground Coal Gasification Experiment," UCRL-79867, Lawrence Livermore Laboratory, 1977. Also published in Proceedings of the Third Annual Underground Coal Conversion Symposium, Conf. 770652, 1977.

Midwest Research Institute, "Energy and Economic Impacts of Particulate Control," draft.

Miller, D.J., J.K. Olson, and H.H. Schobert, "Mass Spectroscopic Characterization of Tars From the Gasification of Low Rank Coals," presented at American Chemical Society National Meeting, Washington, D.C., September 1979.

Mitre/Metrek, "An Assessment of Fluidized-Bed Combustion," draft.

Mittelhauser Corp., "Environmental Control for Industrial Coal Use," draft.

Monsanto Research Corporation, Mound Facility, "An Assessment of Natural Radionuclides in the Coal Fuel Cycle," The Natural Radiation Environment III, University of Texas, School of Public Health, April 23-28, 1978, in press.

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

Murphy, B.D., et al., "The Effects of a District Heating System on Annual Urban Sulfur Dioxide Emissions," in District Heating/Cogeneration Symposium, April 2-3, 1979, Proceedings, CONF-790401, Oak Ridge National Laboratory, October 1979.

Najjar, K.F., J.J. Shaw, and E.E. Adams, "An Environmental and Economic Comparison of Cooling System Designs for Steam-Electric Power Plants," Massachusetts Institute of Technology, Energy Laboratory Report No. MIT-EL 79-037, 1979. Also published as R.M. Parsons Laboratory Report.

Neufeld, R.D., C.J. Drummond, and G.E. Johnson, "Biokinetics of Activated Sludge Treatment of Synthane Fluidized-Bed Gasification Wastewaters," Proceedings of the 175th National ACS Meeting, Anaheim, California, Vol. 23, No. 2, March 12-17, 1978.

Oak Ridge National Laboratory, "Evaluation of Solid Wastes From Coal Conversion Processes Using the Resource Conservation and Recovery Act (RCRA) Testing Protocols," C.W. Gehrs, ed. Leaching: D.K. Brown and H.W. Wilson. Chemistry: W.H. Griest et al. Environmental testing: D.S. Shriner et al. Biological testing: J.L. Epler et al. To be published as ORNL-TM.

Oak Ridge National Laboratory, Section 10, "Fossil Energy Quarterly Progress Report for the Period Ending June 30, 1977," ORNL-5327, L.E. McNeese, Program Director.

Oak Ridge National Laboratory, Section 10, "Fossil Energy Quarterly Progress Report for the Period Ending September 30, 1977," ORNL-5357, L.E. McNeese, Program Director.

Oak Ridge National Laboratory, Section 10, "Fossil Energy Quarterly Progress Report for the Period Ending December 31, 1977," ORNL-5387, L.E. McNeese, Program Director.

Oak Ridge National Laboratory, Section 10, "Fossil Energy Quarterly Progress Report for the Period Ending March 21, 1978," ORNL-5421, L.E. McNeese, Program Director.

Oak Ridge National Laboratory, Section 10, "Fossil Energy Quarterly Progress Report for the Period Ending June 30, 1978," ORNL-5444, L.E. McNeese, Program Director.

Oak Ridge National Laboratory, Section 10, "Fossil Energy Quarterly Progress Report for the Period Ending September 30, 1978," ORNL-5487, L.E. McNeese, Program Director.

Olson, J.K., and H.H. Schobert, "An Overview of Effluents From Some Western Coals," Proceedings North Dakota Academy of Science, Vol. 33, No. 60, presented at North Dakota Academy of Science-South Dakota Academy of Science Joint Meeting, Aberdeen, South Dakota, April 1979.

Olson, J.K., and H.H. Schobert, "Effects of Coal Structure and Processing Conditions and Organic Effluents From Slagging Fixed-Bed Gasification," American Chemical Society, Division of Fuel Chemistry, Preprints, Vol. 24, No. 3, presented at American Chemical Society National Meeting, Washington, D.C., September 1979.

Olson, J.K., and H.H. Schobert, "Evaluation of Methods for Determination of Sulfide in Coal Gasification Wastewater," 176th National ACS Meeting, Miami, Florida, 1978.

Olson, J.K., and H.H. Schobert, "Production of C_1-C_4 Hydrocarbons in the Gasification of Some North Dakota Lignites," North Dakota Academy of Science Meeting, Grand Forks, North Dakota, 1978.

Paddock, R.A., and J.D. Ditmars, "An Assessment of the Once-Through Cooling Alternative for Central Steam-Electric Generation Station," ANL/WR-78-6, Argonne National Laboratory.

Paddock, R.A., and J.D. Ditmars, "Assessment of Once-Through Cooling Water Control Technology," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Parry, H.L., et al., "Augmented Dry Cooling Surface Test Program: Analysis and Experimental Results," PNL-2746, Pacific Northwest Laboratory, Richland, Washington, 1979.

Parsons, W.A., "Improved Water Management of Coal Conversion Processes by Preliminary Absorption of Halides," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Paulson, L.E., H.H. Schobert, and R.C. Ellman, "Sampling, Analysis, and Characterization of Effluents From the Grand Forks Energy Research Center Slagging Fixed-Bed Gasifier," 175th NationalACS Meeting, Anaheim, California, 1978.

Phillips, L.R., "Analytical Study of the Product and Effluent Streams From a High Temperature and Pressure Entrained Gasifier," Master's Thesis, Brigham Young University, Provo, Utah, 1979.

Rajendran, N., et al., "Acoustic Precipitation of Aerosol Under Standing Wave Condition," Journal of Aerosol Science, Vol. 10, No. 329, 1979.

Ramanathan, V., S. Reigel, and P. Gorman, "Assessment of Energy and Economic Impacts of Particulate Control Technology in Coal-Fired Power Plants," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Raymond, R., Jr., et al., "Electron Microanalyses of Coal," AAPG-SEPM Annual Meeting, Washington, D.C., June 15, 1977.

Reddy, G.N., "Advanced Processes for Generation of Electric Power: Solvent Refining of Coal and Combined Cycle Plants," Proceedings of the Fifth National Conference on Energy and the Environment, Cincinnati, Ohio, October 31 to November 3, 1977, pp. 161-166.

Reddy, G.N., "Burning of SRC: A Viable Means of Compliance," presented at 1978 Industrial Fuel Conference, Purdue University, October 1978.

Reddy, G.N., "Commercialization Potential, Energy Conversion Efficiency, Environmental Impact and Economics of SRC and Combined Cycle Plants," Proceedings of the 70th Annual AIChE Meeting, New York, N.Y., November 1977.

Reddy, G.N., "Dynamic Simulation of Coal-Based Combined Cycle Plants for Development of Process Control Guidelines," Proceedings of the 1978 Symposium on Instrumentation and Control, Newport Beach, California, June 1978.

Reddy, G.N., and G.C. Krohm, "Modifications and Costs of Converting to Low Sulfur Western Coals," Proceedings of the NCA/BCR Coal Utilization Symposium, Louisville, Kentucky, October 1977.

Research-Cottrell, Inc., "Removal of NO_x and SO_2 From Flue Gases Using Electron Beam Irradiation," report to the U.S. Department of Energy in compliance with contract EP-78-C-02-4902.

Rhoads, R.E., An Overview of Transportation in the Nuclear Fuel Cycle, BNWL-2066, Battelle, Pacific Northwest Laboratory, Richland, Washington, May 1977.

Rogozen, M.B., "Coal Slurry Pipelines: The Water Issues," D. Env. thesis, Environmental Science and Engineering Program, University of California at Los Angeles, June 1978.

Rogozen, M.B., et al., "Water Pollution Control for Coal Slurry Pipelines," University of California at Los Angeles, Institute of Geophysics and Science Applications, Inc., for U.S. Department of Energy, June 30, 1978.

Schobert, H.H., "Petrochemistry of Coal Ash Slags. 2. Correlation of Viscosity With Composition and Petrographic Class," Joint CIC-ACS Conference, Montreal, 1977.

Schobert, H.H., B.C. Johnson, and M.M. Fegley, "Carbonization Reactions in the Grand Forks Slagging Gasifier," 176th National ACS Meeting, Miami, Florida, 1978.

Schobert, H.H., et al., "Petrochemistry of Coal Ash Slags. 1. Formation of Melilite and a High-Temperature Glass From a Calcium-Rich, Silica-Deficient Slag," Joint CIC-ACS Conference, Montreal, Canada, 1977.

Schubert, J.P., et al., "Water Quality Impacts and Overburden Geochemistry of Eastern Kentucky Study Site," Environmental Control Technology Survey of U.S. Strip Mining Sites, Vol. 2c, draft, Argonne National Laboratory, 1979.

Schuller, C.R., et al., "Selected Legal and Regulatory Concerns Affecting Domestic Energy Transportation Systems," PNL-2989, Pacific Northwest Laboratory, Richland, Washington, 1979.

Sealock, L.J., Jr., and L.K. Mudge, "Environmental Control Assessment of Entrained Flow Gasifiers - Commercial Control Systems," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Shaw, D.T., and K.Tu, "Acoustic Particle Agglomeration Due to Hydrodynamic Interaction Between Monodisperse Aerosols," Journal of Aerosol Science, Vol. 10, No. 317, 1979.

Shaw, D.T., and N. Rajendran, "Application of Acoustic Agglomerators for Emergency Use in LMFBR Plants," Nuclear Science and Engineering, Vol. 70, No. 127, 1979.

Shaw, J.J., et al., "Economic Implications of Open Versus Closed Cycle Cooling for New Steam-Electric Power Plants: A National and Regional Survey," Massachusetts Institute of Technology, Energy Laboratory Report No. MIT-EL 79-038, 1979. Also published as RM. Parsons Laboratory Report.

Sonnichsen, T.W., R.E. Thompson, and H. Huang, "Assessment of Current and Advanced NO_x Control Technology for Coal-Fired Industrial Boilers," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Steinberg, M., A.S. Albanese, and V.D. Dang, "Environmental Control Technology for Atmospheric Carbon Dioxide," BNL 50794, Progress Report No. 1, June 20, 1977, to September 30, 1977, Brookhaven National Laboratory, January 1978.

Steinberg, M., A.S. Albanese, and V.D. Dang, "Environmental Control Technology for Carbon Dioxide," BNL 24999, Brookhaven National Laboratory, presented at 71st Annual Meeting of American Institute of Chemical Engineers, Miami, Florida, November 12-16, 1978. Also presented at U.S. DOE Environmental Control Symposium, "Energy and Environmental Goals: Compatibility Through Environmental Controls," Washington, D.C., November 28-30, 1978.

Steinberg, M., and A.S. Albanese, "Environmental Control Technology for Atmospheric Carbon Dioxide," BNL 50877, Progress Report No. 2, October 1 to March 31, 1978, Brookhaven National Laboratory, July 1978.

Steinberg, M., and A.S. Albanese, "Environmental Control Technology for the Flash Hydropyrolysis of Coal," BNL 50793, Quarterly Progress Report No. 1, June 20, 1977, to September 30, 1977, Brookhaven National Laboratory, January 1978.

Steinberg, M., and A.S. Albanese, "Environmental Control Technology for the Flash Hydropyrolysis of Coal," Progress Report No. 3, April 1, 1978, to December 31, 1978, Brookhaven National Laboratory.

Steinberg, M., and A.S. Albanese, "Environmental Control Technology for the Flash Hydropyrolysis of Coal," BNL 50906, Progress Report No. 2, October 1, 1977, to March 31, 1978, Brookhaven National Laboratory, September 1978.

Stolzenbach, K.D., et al., "Operational Issues Involving Use of Supplementary Cooling Towers To Meet Stream Temperature Standards With Application to the Browns Ferry Nuclear Plant," Massachusetts Institue of Technology, Energy Laboratory Report No. MIT-EL 79-036, 1979. Also published as R.M. Parsons Laboratory Report.

Strand, R.H., "Environmental Data: Management and Analysis Considerations," Proceedings of the Fourth Annual SAS User's Group Conference, Clearwater Beach, Florida, January 28-31, 1979.

Strand, R.H., et al., "The Preparation and Publication of a Toxic Effects Document Using SAS and Com.," Proceedings of the Fourth Annual SAS User's Group Conference, Clearwater Beach, Florida, January 28-31, 1979.

Stuermer, D.H., et al., "Chemical Analyses of Ground-Water Samples Obtained Near an In Situ Coal Gasification Experiment," to be presented at the Meeting of the American Chemical Society, Honolulu, Hawaii, April 1-6, 1979.

Styron, C.E., "A Radiological Impact Assessment of a Power Plant Utilizing Western Coal," MLM-2512(OP) Natural Radiation Environment III Symposium, Houston, Texas, April 23-28, 1978.

Styron, C.E., "Preliminary Assessment of the Radiological Impact of Radionuclides in Western Coal on Health and Environment, 1978," Proceedings of the Second National Conference and Exhibition on Technology for Energy Conservation, Albuquerque, New Mexico, Information Transfer, Inc., January 23-27, 1978.

Styron, C.E., and B. Robinson, "Preliminary Assessment of the Radiological Impact of Western Coal Utilization, 1977," Proceedings of the Third International Conference on Environmental Problems of the Extractive Industries, The Wright Company, Dayton, Ohio, November 29-30 and December 1, 1977, and Proceedings of the Fourth Joint Conference on Sensing of Environmental Pollutants, New Orleans, Louisiana, American Chemical Society, November 6-11, 1977. Also presented at the 35th Annual Meeting of the East Central Section, Air Pollution Control Association, Akron, Ohio, September 21-23, 1977.

Styron, C.E., et al., "Assessment of the Radiological Impact of Coal Utilization. I. Preliminary Studies on Western Coal," MLM-2514, Mound Facility, Miamisburg, Ohio, February 12, 1979.

Thode, E.F., et al., "Costs of Coal and Electric Power Generation -- The Impact of Environmental Control Technologies for Coal Cleaning Plants," LA-8039-MS, Los Alamos Scientific Laboratory.

Thompson, R.E., and H. Huang, "Assessment of Current and Advanced NO_x Control Technology for Coal-Fired Utility Boilers," presented at 175th National Meeting, American Chemical Society, Anaheim, California, March 15, 1978.

Turner, R.R., J.R. Lund, and S.E. Lindberg, "Leachability of Arsenic From Coal Ash and Its Oxidation State in Leachate," Oak Ridge National Laboratory, in preparation.

United Technologies Research Center, "Low Btu Gasification/Combined-Cycle Power Generation," draft.

Virgona, J.E., et al., "Preliminary Environmental Results of the LETC Hanna III Underground Coal Gasification Experiment," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Wagner, P., E.M. Wewerka, and J.M. Williams, "Trace Element Assessment in Coal Preparation Waste Drainages," Federation of Analytical Chemistry and Spectroscopy Societies Meeting, Boston, Massachusetts, October 30 to November 2, 1978.

Wagner, P., et al., "Control Technology Strategies for Coal Preparation Waste Drainages," Proceedings Environmental Control Technology Division Wastewater Workshop, June 1979.

Wagner, P., et al., "Environmental Contamination From Trace Elements in Coal Preparation Wastes," Environmental Protection Agency Coal Cleaning Environmental Review, Winter 1979-1980, Los Alamos Scientific Laboratory.

Wagner, P., et al., "Environmental Control Strategies for Coal Preparation Waste Disposal," Coal Age Conference and Expo V, October 1979.

Wagner, P., et al., "The Assessment of Trace Element Contamination of the Drainages From Coal Cleaning Wastes," Proceedings 72nd National American Institute of Chemical Engineers Meeting, November 1979.

Wakamiya, W., et al., "Assessment of Synfuel Transportation to Year 2000," PNL-2768, Pacific Northwest Laboratory, Richland, Washington, 1979.

Wakamiya, W., K.B. Sebelien, M.A. Parkhurst, Assessment of Synfuel Transportation to Year 2000, draft, Battelle, Pacific Northwest Laboratory, January 1979.

Wang, F.T., "A Comparison of Analytical Methods for Phenols, Cyanide and Sulfate as Applied to Ground-Water Samples From Underground Coal Gasification Sites," UCRL-82702, Lawrence Livermore Laboratory, 1979. To be published in the ASTM Symposium volume on Analysis of Waters Associated With Alternate Fuel Production.

Wang, F.T., "A Laboratory Study of the Adsorption of Organic and Inorganic Compounds by Coal," to be presented at the Meeting of the American Chemical Society, Honolulu, Hawaii, April 1-6, 1979.

Wang, F.T., "The Sorptive Property of Coal," in Proceedings of the Fifth Underground Coal Conversion Symposium, Alexandria, Virginia, June 18-21, 1979. Also published as Lawrence Livermore Laboratory Report UCRL-82703, 1979.

Wang, F.T., and H. Wasserman, "Transport of Metal Ions Through Coal," presented at the 1978 Fall Meeting of the American Geophysical Union.

Wangen, L.E., et al., "Control Technology for Coal Cleaning Wastes," Workshop on Solid Wastes (ASCE/PRC-EPRI), April 1979.

Wewerka, E.M., "Assessment and Control of Trace Element Contamination From Coal Preparation Wastes," HRL Seminar, Los Alamos Scientific Laboratory, February 28, 1978.

Wewerka, E.M., "Environmental Contamination From Coal Cleaning Wastes," H-9 Seminar, Los Alamos Scientific Laboratory, January 23, 1976.

Wewerka, E.M., "The Production of Petroleum From Western Oil Shales," Southwest Meeting of the AAAS, Albuquerque, New Mexico, April 27, 1978.

Wewerka, E.M., and J.M. Williams, "Aqueous Drainage From Coal Preparation Wastes and Coal Storage Piles," Environmental Control Aspects of Increased Coal Utilization, Chapter 6, Department of Energy, November 1977.

Wewerka, E.M., and J.M. Williams, "Review of Progress in LASL Program on Environmental Contamination From Trace Elements in Coal Preparation Wastes," ERDA-ECT, Washington, D.C., May 20, 1976.

Wewerka, E.M., and J.M. Williams, "The LASL Program on the Chemistry of Trace Elements in Coal Cleaning Wastes, presented at seminar given at U.S. Geological Survey, Reston, Virginia, October 8, 1975.

Wewerka, E.M., and J.M. Williams, "Trace Element Characterization of Coal Wastes, First Annual Report," Interagency Energy-Environment R&D Program, EPA-600/7-78-028, (NTIS) LA-6835-PR, Los Alamos Scientific Laboratory, March 1978.

Wewerka, E.M., and J.M. Williams, "Trace Elements Contamination in Coals and Coal Wastes," Annual Program Review, Washington, D.C., October 5, 1977.

Wewerka, E.M., and J.M. Williams, "Trace Elements in Coals and Coal Wastes," Los Alamos Scientific Laboratory, Midyear Program Review, Washington, D.C., April 27-28, 1977.

Wewerka, E.M., and N.E. Vanderborgh, "Fossil Fuel Research," presented to DPR, Molecular Sciences Branch, visitors, October 21, 1975.

Wewerka, E.M., and P. Wagner, "Trace Elements Contamination in Coal and Coal Wastes," Midyear Program Review, EPA, Research Triangle Park, North Carolina, June 28, 1978.

Wewerka, E.M., et al., "Accessory Elements in Coal Preparation Wastes: Environmental Considerations," Workshop on Accessory Elements in Coals, Nuclear Regulatory Commission, Washington, D.C., March 1, 1977.

Wewerka, E.M., et al., "Characterization and Environmental Behavior of Trace Elements in Coals and Coal Wastes," Confab 1977, Saratoga, Wyoming, July 28, 1977.

Wewerka, E.M., et al., "Control of Trace Element Leaching From Coal Preparation Wastes," Proceedings of the U.S. EPA Symposium on Coal Cleaning, LA-UR-78-2507, Hollywood, Florida, September 11-15, 1978, in press.

Wewerka, E.M., et al., "Environmental Contamination From Trace Elements in Coal Preparation Wastes: A Review and Assessment of the Literature," DOE/EPA Interagency Report, EPA-600/7-76-007, (TIC) LA-6600-MS, Los Alamos Scientific Laboratory, August 1976.

Wewerka, E.M., et al., "Environmental Control Technology for Contaminated Drainage From Coals and Coal Wastes," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Wewerka, E.M., et al., "Trace Element Characterization of Coal Wastes - Second Annual Report," DOE/EPA Interagency Report, EPA-600/7-78-028a, (NTIS) LA-7360 PR, Los Alamos Scientific Laboratory, July 1978.

Wewerka, E.M., et al., "Trace Element Characterization of Coal Wastes: Third Annual Progress Report," LA-7831-PR, Los Alamos Scientific Laboratory.

Wewerka, E.M., J.M. Williams, and N.E. Vanderborgh, "Contaminants in Coals and Coal Residues," Proceedings of the Fourth National Conference on Energy and the Environment, (NTIS) LA-UR-76-2197, October 5-7, 1976.

Wewerka, E.M., J.M. Williams, and N.E. Vanderborgh, "Disposal of Coal Preparation Wastes: Environmental Considerations," Proceedings of the Fourth National Conference on Energy and the Environment, (NTIS) LA-UR-76-2198, October 5-7, 1976.

Wewerka, E.M., J.M. Williams, and N.E. Vanderborgh, "Environmental Problems Associated With Coal Preparation Wastes," Department of Chemistry, University of Maryland, October 17, 1976.

Wewerka, E.M., J.M. Williams, and P. Wagner, "The Use of Multimedia Environmental Goals to Evaluate Potentially Hazardous Trace Elements in the Drainage From High Sulfur Coal Preparation Wastes," Los Alamos Scientific Laboratory, in preparation.

Wewerka, E.M., J.M. Williams, and P.L. Wanek, "Assessment and Control of Environmental Contamination From Trace Elements in Coal Preparation Wastes," Proceedings of the Symposium on Health/Environmental Effects and Control Technology Aspects of Energy Research and Development, EPA-600/7-76-002, (NTIS) PB-256 (Entire Proceedings Only), February 9-11, 1976.

Wewerka, E.M., M. Gottlieb, and C. Grua, "Environmental Control Technology for Contaminated Coal Refuse Drainage," Proceedings 108th Annual Meeting, American Institute of Mining Engineers, LA-UR-78-3232, New Orleans, Louisiana, February 1979.

Wewerka, E.M., P. Wagner, and P.L. Wanek, "Assessment and Control of Water Contamination Associated With Shale Oil Extraction and Processing," Work Plan, LA-7697, Los Alamos Scientific Laboratory, in press.

Wewerka, E.M., published under title "Trace Element Characterization and Removal/Recovery From Coal and Coal Wastes," Los Alamos Scientific Laboratory:

Work Plan for the Period July 1, 1975, to June 31, 1976, (NTIS) LA-6496-PR, September 1976.

Work Plan for the Period October 1, 1976, to September 30, 1977, (NTIS) LA-6822-PR, June 1977, with J.M. Williams and N.E. Vanderborgh.

Work Plan for the Period October 1, 1977, to September 30, 1978, (NTIS) LA-7048-PR, December 1977, with J.M. Williams.

Work Plan for the Period October 1, 1978, to September 30, 1979, et al.

Quarterly Report No. 1, (NTIS) LA-6497-PR, September 1976.

Quarterly Report No. 2, (NTIS) LA-6498-PR, September 1976.

Quarterly Report No. 4, (NTIS) LA-7117-PR, February 1978, et al.

Quarterly Report No. 5, (NTIS) LA-6933-PR, October 1977, et al.

Quarterly Report No. 6, (NTIS) LA-7104-PR, February 1978, et al.

Quarterly Report No. 9, DOE Progress Report, in press, et al.

Quarterly Report No. 10, DOE Progress Report, in press, et al.

Third Annual Progress Report, in preparation.

Wheeler, K.J., A.B. Johnson, Jr., and R.P. May, "Aluminum Alloy Performance Under Dry Cooling Conditions," PNL-2292-Rev. 1, Battelle, Pacific Northwest Laboratory, 1978, to be published.

Wheeler, K.J., and A.B. Johnson, Jr., "Deposition Studies of Deluged Surfaces Under Wet/Dry Tower Operating Conditions," Battelle, Pacific Northwest Laboratory, 1979, to be published.

Wheeler, K.J., and A.B. Johnson, Jr., "Surface Treatment of Aluminum Alloys for Corrosion Resistance Under Wet/Dry Cooling Tower Conditions," Battelle, Pacific Northwest Laboratory, 1979, to be published.

Wiley Interscience, "Acoustic Agglomeration of Aerosols," in Recent Developments in Aerosol Science," Chapter 13, New York, 1978.

Williams, J.M., and E.M. Wewerka, "Distribution and Associations of Trace Elements in Coal Preparation Wastes," Coal Minerals Workshop, Urbana, Illinois, March 23, 1978.

Williams, J.M., and E.M. Wewerka, "Trace Elements and Leaching From Coal Feed Preparation Wastes," Gordon Research Conference on Fuels Science, Plymouth, New Hampshire, July 7, 1977.

Williams, J.M., et al., "Environmental Pollution by Trace Elements in Coal Preparation Wastes," Proceedings of the Sixth Symposium on Mine Drainage Control, (NTIS) LA-UR-77-1850, Louisville, Kentucky, October 1977.

Williams, J.M., et al., "Environmental Pollution by Trace Elements in Coals and Coal Wastes," Los Alamos Scientific Laboratory, Analytical Colloquium, November 30, 1977.

Williams, J.M., et al., "Trace Element Distributions in Several Coal Conversion Processes," (NTIS) LA-7100-MS, Los Alamos Scientific Laboratory, February 1978.

Wilzbach, K.E., C.D. Livengood, and P.S. Farber, "Environmental Control-Coal Utilization Program," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Winsor, G.H., et al., "Opportunities To Increase the Productivity of Spent Fuel Shipping Casks," PNL-3017, Pacific Northwest Laboratory, Richland, Washington, 1979.

Winsor, G.H., Potential Problems and Opportunities for Improvement in the Handling of Spent Nuclear Fuel, draft, Battelle, Pacific Northwest Laboratory, September 1978.

PETROLEUM AND GAS

Ahmadjian, J., and P.F. Lynch, "Chemical Analysis of Dispersed Oil in the Water Column," Proceedings of the ASTM Symposium on Chemical Dispersants for the Control of Oil Spills, October 1977.

Anderson, P.J., and E.J. Daniels, "LNG Industry: Past, Present, and Future," Appendix B of DOE/EV-0002, February 1978.

Brown, C.W., "Where the Argo Merchant Oil Didn't Go," Proceedings of "In the Wake of the Argo Merchant," COMS Conference, University of Rhode Island, January 1978.

Brown, C.W., and P.F. Lynch, "Tanker Tragedies: Identifying the Source and Determining the Fate of Petroleum in the Marine Environment," Proceedings of the 10th Rochester Conference on Environmental Toxicity, May 1977.

Brown, C.W., P.J. Lynch, and M. Ahmadjian, "Computerized Dispersive Infrared Spectroscopy," Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, March 1978.

Carmer, J.L., and W.J. Hogan, "Evaluation of Sites for LNG Spill Tests," UCRL-52520, Lawrence Livermore Laboratory, September 15, 1978.

Carpenter, et al., "Liquefied Natural Gas Wind Tunnel Simulation and Instrumentation Assessments," NTIS SAN/W-1364-01, R&D Associates, April 1978.

Cornillion, P., "Oil Droplet Measurements Made in the Wake of the Argo Merchant," Proceedings of "In the Wake of the Argo Merchant," COMS Conference, University of Rhode Island, January 1978.

Creighton, J.R., and C.M. Lund, "Modeling Study of Flame Structure in Low Pressure Laminar Premixed Methane Flames," UCRL-80832, August 1978. NBS Meeting - 10th Materials Research Symposium, September 1978 - proceedings.

Department of Energy, Liquefied Gaseous Fuels Safety and Environmental Control Assessment Progam: A Status Report, DOE/EV-0036, May 1979:

Report A, "The Spreading and Differential Boil-Off for a Spill of LNG on a Water Surface," W. Stein, Lawrence Livermore Laboratory.

Report B, "Dispersion Model Comparisons," B.R. Bowman, Lawrence Livermore Laboratory.

Report C, "Test Cases for a Phase I Evaluation of LNG Vapor Generation and Dispersion Models," D.J. McNaughton and C.M. Berkowitz, Pacific Northwest Laboratory.

Report D, "Radiation From Burning Hydrocarbon Clouds," J.A. Fay, G.J. Desgroseilliers, and D.H. Lewis, Jr., Massachusetts Institute of Technology.

Report E, "Modeling Detonation and Deflagration Properties of Liquefied Energy Fuels," C.K. Westbrook and L.C. Haselman, Lawrence Livermore Laboratory.

Report F, "LNG Release Prevention and Control," P.J. Pelto, E.G. Baker, and E.F. Riedel, Pacific Northwest Laboratory.

Report G, "The Feasibility of Methods and Systems for Reducing LNG Tanker Fire Hazards," D.S. Allen, R. Phani Raj, and G. Pollack, Arthur D. Little, Inc.

Report H, "Safety Assessment of Gelled LNG," M.I. Rudnicki and E.M. Vander Wall, Aerojet Energy Conversion Company.

Report I, "Detection of Atmospheric Methane," C.F. Dewey, Jr. et al., Massachusetts Institute of Technology.

Report K, "A Review of the 1978 China Lake LNG Dispersion Experiments and Instrumentation," R.P. Koopman et al., Lawrence Livermore Laboratory.

Report L, "China Lake Spill Tests," C.D. Lind and J.C. Whitson, U.S. Naval Weapons Center.

Report M, "Evaluation of Sites for LNG Spill Tests," J.L. Cramer and W.J. Hogan, Lawrence Livermore Laboratory.

Report N, "Validity of Desert Site Scale Effects Experiments," J.H. Shinn, Lawrence Livermore Laboratory.

Report O, "Experimental Strategy Considerations for LNG Field Experimentation," F.R. Zaloudek et al., Pacific Northwest Laboratory.

Reports P and Q, "Annotated Bibliography LNG Safety and Environmental Control Research," J.G. DeSteese, Pacific Northwest Laboratory.

Report R, "LPG Safety Research," J.R. Welker, Applied Technology Corporation.

Report S, "Simultaneous Boiling and Spreading of Liquefied Petroleum Gas (LPG) on Water," R.C. Reid, K.A. Smith, and H. Chang, Massachusetts Institute of Technology.

Report T, "Preliminary Annotated Bibliography of Publications Related to Fire Safety in Marine Transport of Liquefied Petroleum Gas," J.N. Ice and N.M. Butcher, Applied Technology Corporation.

Report U, "Critical Review and Assessment of Environmental and Safety Problems in Hydrogen Energy System," F.J. Edeskuty, J.R. Bartlit, and R.V. Carlson, Los Alamos Scientific Laboratory.

Report V, "Ammonia -- Environmental and Safety Concerns," D.L. Brenchley et al., Pacific Northwest Laboratory.

Desgroseilliers, G.J., "Radiation From Burning Hydrocarbon Clouds," M.S. Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1978.

Dewey, C.F., Jr., "Field Measurements of Atmospheric Methane With a Two-Wavelength Laser System," presented at the 1978 Conference on Analytical Chemistry and Applied Spectroscopy, Cleveland, Ohio, March 3, 1978.

Doo, Y-C., "A Two-Dimensional Model of Negatively Buoyant Vapor Cloud Dispersion," M.S. Thesis, Massachusetts Institute of Technology, August 1979.

Dubey, S.T., "Ultrafiltration of Simulated Micellar Flood Wastewaters," M.S.Ch.E. Thesis, University of Tulsa, Tulsa, Oklahoma, 1979.

Edeskuty, F.J., "Critical Review and Assessment of Anticipated Problem Areas in Hydrogen Energy Delivery Systems," LA-7405-PR, Los Alamos Scientific Laboratory, August 1978 (November 1, 1976, to September 30, 1977; Initial Report).

Edeskuty, F.J., "Hydrogen Safety," in Transmission and Storage of Hydrogen, Its Technology and Implications, Vol. II, Cox and Williamson, ed.

Edeskuty, F.J., et al., "Hydrogen Safety and Environmental Control Assessment," LA-8225-PR, Los Alamos Scientific Laboratory, February 1980 (October 1, 1978, to September 30, 1979; Final Report).

Edeskuty, F.J., et al., "Critical Review and Assessment of Environmental and Safety Problems in Hydrogen Energy Systems," LA-7820-PR, Los Alamos Scientific Laboratory, May 1979 (October 1, 1977, to September 30, 1978; Interim Report). Also in U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Edeskuty, F.J., J.R. Bartlit, and R.V. Carlson, "Assessment of Environmental and Safety Problems in Hydrogen Energy Systems," 15th International Congress of Refrigeration, Venice, Italy, September 23-29, 1979, to be published in proceedings. Also in International Journal of Refrigeration, Vol. 2, No. 6, pp. 239-243, November 1969.

Eiber, R.J., et al., "State-of-the-Art -- LNG Safety and Control R&D," Appendix D in DOE/EV-0002, February 1978.

Fay, J.A., "A Preliminary Analysis of the Effect of Spill Size on the Level of Hazard From LNG Spills on Land and Water," Appendix F in DOE/EV-0002, February 1978.

Flotard, R.D., D.L. Ford, and W. Harrison, "Use of Granular Activated Carbon to Remove Trace Organics From the Effluent of a Class-B Refinery, A Case Study," Proceedings of the Seventh Annual Industrial Pollution Conference, WWEMA, Philadelphia, Pennsylvania, 1979.

Goldfarb, D., "Collection and Analysis of Treated and Untreated Oil Spill Vapors," M.S. Thesis, Department of Chemistry, University of Rhode Island, 1978.

Harrison, W., R.D. Flotard, and D.L. Ford, "Assessment of Activated Carbon for Environmental Control of Trace Organics in Petroleum Refinery Wastewater," ANL/WR-79-3, Argonne National Laboratory, March 1979.

Hogan, W.J., "LLL Participation in LEF Safety Research," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Jasper, W., "Drop Size Distribution of Oil Dispersed in Sea Water," M.S. Thesis, Department of Mechanical Engineering and Applied Mechanics, University of Rhode Island, 1977.

Jasper, W., T.J. Kim, and M.P. Wilson, Jr., "Drop Size Distributions in a Treated Oil-Water System," Proceedings of the ASTM Symposium on Chemical Dispersants for the Control of Oil Spills, October 1977.

Lewis, D.H., Jr., "The Combustion of Unconfined Vapor Clouds Burning in a Fireball Configuration," Ph.D. Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, September 1977.

Lichte, H.W., and M.K. Breslin, "Performance Testing of Three Offshore Skimming Devices," (NTIS) HCP/P3241-01, April 1978.

Lind, C.D., and J.C. Whitson, "China Lake Spill Tests," U.S. Naval Weapons Center progress report for U.S. Department of Energy, Environmental Control Technology Division, in press.

Lind, C.D., and J.C. Whitson, "Explosion Hazards Associated With Spills of Large Quantities of Hazardous Materials, Phase II," NTIS AD A047585, U.S. Naval Weapons Center for U.S. Coast Guard Office of Research and Development, November 1977.

Lind, C.D., and J.C. Whitson, "Explosion Hazards Associated With Spills of Large Quantities of Hazardous Materials, Phase I," NTIS AD A001242, U.S. Naval Weapons Center for U.S. Coast Guard Office of Research and Development, October 1974.

Lynch, P.F., and M.M. Brady, "Computerized Infrared Spectroscopy as a Separation Technique - Analysis of Complex Organic Mixtures Extracted From Water," Analytical Chemistry, submitted for publication.

Massachusetts Institute of Technology, Department of Chemical Engineering, "Confined Boiling Rates of Liquefied Petroleum Gas on Water," NSF/DOE Report HCP/P4548-01, May 1978.

McNaughton, D.J., and C.M. Berkowitz, "Overview of U.S. Research Activities in the Dispersion of Dense Gases," Proceedings, Symposium Schwere Gase, Frankfurt, Germany, 1979.

McNaughton, D.J., and C.M. Berkowitz, "Test Cases for a Phase I Evaluation of LNG Vapor Generation and Dispersion Models," Report H, Liquefied Gaseous Fuels Safety and Environmental Control Assesment Program: A Status Report, Section III, Battelle, Pacific Northwest Laboratory for Department of Energy, to be published.

Noll, C., and M. Spaulding, "Application of an Oil Spill Computer Model to Narragansett Bay and Rhode Island Sound," IOPPE Conference in Hamburg, Germany, September 1978.

Patrick, M.G., et al., "Liquefied Petroleum Gas Safety and Environmental Control Assessment," Report Q, Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, Section III, Battelle, Pacific Northwest Laboratory for Department of Energy, to be published.

Pelto, P.J., E.G. Baker, and E.F. Riedel, "LNG Release Prevention and Control," Report F, Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, Section III, Battelle, Pacific Northwest Laboratory for Department of Energy, to be published.

Pelto, P.J., E.G. Baker, and R.J. Hall, "Assessment of LNG Release Prevention and Control," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Pfeffer, F., W. Harrison, and L. Raphaelian, "Organics Reduction Through Add-On Activated Carbon at Pilot Scale," Proceedings Second Open Forum on Management of Petroleum Refinery Wastewaters, 1977.

Raj, P.K., "A Criterion for Classifying Accidental Liquid Spills Into Instantaneous and Continuous Types," Combustion Science and Technology.

Ramakrishnan, B., "Ultrafiltration of Simulated Micellar Flood Wastewater," M.S.Ch.E. Thesis, University of Tulsa, Tulsa, Oklahoma, 1979.

Raphaelian, L., and W. Harrison, "Trace Organics Variation Across the Wastewater Treatment System of a Class-B Refinery and Estimate of Removal of Refractory Organics by Add-On Mixed-Media Filtration and Granular Activated Carbon at Pilot Scale," EPA-600/7-78-125, Argonne National Laboratory, 1978.

Raphaelian, L.A., "Measurement of Trace Organics Variation Across a Wastewater Treatment System of an Oil Refinery by Capillary Column GC/MS," presented at Chicago Chromatography Discussion Group, Symposium on Recent Advances in Chromatography, AMOCO Research Center, Naperville, Illinois, March 13, 1979.

Reid, R.C., "Confined Boiling Rates of Liquefied Petroleum Gas on Water," National Science Foundation/ Department of Energy Report, HCP/P4548-01, May 1978.

Reid, R.C., and K.A. Smith, "Behavior of LPG on Water," Hydro. Proc., Vol. 57, No. 4, p. 117, 1978.

Rudnicki, M.I., and E.M. Vander Wall, "Gelled LNG -- A Safety Approach," presented at the 7th International LNG/LPG Conference and Exhibition -- GASTECH 79, Houston, Texas, November 13-16, 1979.

Rudnicki, M.I., and E.M. Vander Wall, "Gelled LNG Increased Safety in Storage, Handling, and Transportation," presented under Topic B, Economic Commission for Europe, Committee on Gas Seminars and Study Tour on LNG Peak Shaving, Washington, D.C., March 5-9, 1979.

Russ, R.M., Jr., "Detection of Atmospheric Methane Using a Two-Wave Length HeNe Laser System," M.S. Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, June 1978.

Spaulding M., "Surface and Subsurface Oil Spill Trajectory Forecasting," Proceedings of "In the Wake of the Argo Merchant," COMS Conference, University of Rhode Island, January 1978.

Stein, M.I., "The Design of a Device to Measure Methane Concentration," B.S. Thesis, Massachusetts Institute of Technology, June 1978.

Thompson, C.H., G.W. Dawson, and J.L. Goodier, "Combustion: An Oil Spill Mitigation Tool," DOE/EV-1830-1, August 1979.

Traxler, R.W., and L.S. Bhattacharya, "Effect of a chemical Dispersant on Microbial Utilization of Petroleum," Proceedings of the ASTM Symposium on Chemical Dispersants for the Control of Oil Spills, October 1977.

University of Rhode Island, "Assessment of Treated Versus Untreated Oil Spills (Interim Report)," NTIS HCP/W4047-02, June 1978.

University of Rhode Island, "The Argo Merchant Oil Spill - A Preliminary Scientific Report," Special Report, National Oceanographic and Atmospheric Administration, March 1977.

University of Rhode Island, "The Spreading, Retention and Cleanup of Oil Spills," NTIS HCP/P2756-01, May 1978.

Urban, R.W., D.J. Graham, and S.H. Schwartz, "Performance Tests of Four Selected Oil Spill Skimmers," (NTIS) EPA-600/2-78-204, September 1978.

Walter, C.E., "Assessment of LNG Spill Effects Program Plan," UCID-17627, October 1977.

Walter, C.E., et al., "Preliminary Site Criteria for Large Scale LNG Spill Experiments," UCID 17628 and Appendix G of DOE/EV-0002, Lawrence Livermore Laboratory, October 1977 and February 1978.

Welker, J.R., et al., "Control and Extinguishment of LPG Fires," Applied Technology Corporation, in press.

Westbrook, C.K., "An Analytical Study of the Shock Tube Ignition of Mixtures of Methane and Ethane," UCRL-81507, Journal of Combustion Science and Technology, July 1978.

Wilson, M.P., Jr., "Summary of Physical Studies," Proceedings of "In the Wake of the Argo Merchant," COMS Conference, University of Rhode Island, January 1978.

Wilson, M.P., Jr., "The Assessment Problems of Whether or Not To Treat Oil Spills," Proceedings of the ASTM Symposium on Chemical Dispersants for the Control of Oil Spills, October 1977.

Wilson, M.P., Jr., "What Are We Doing About Oil Spills?", Maritimes, August 1976.

Wilson, M.P., Jr., and J.M. Cece, "Environmental Assessment of Treated Versus Untreated Oil Spills," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Zaloudek, F.R., et al., "Experimental Strategy Considerations for LNG Field Exerpimentation," Report G, Liquefied Gaseous Fuels Safety and Environmental Control Assessment Program: A Status Report, Section III, Battelle, Pacific Northwest Laboratory for Department of Energy, to be published.

OIL SHALE

De Nevers, N., B. Glenne, and C. Bryner, "Analysis of the Environmental Control Technology for Tar Sand Development," probable DOE Report No. is COO/4043-2, University of Utah, College of Engineering, December 1978.

De Nevers, N., et al., "Analysis of the Environmental Control Technology for Oil Shale Development," DOE Report No. COO/4043-1, University of Utah, College of Engineering, February 1978.

De Nevers, N., et al., "Analysis of the Environmental Control Technology for Tar Sands Development," COO-4043-2, University of Utah for Oak Ridge National Laboratory, June 1979.

Fox, J.P., "Formation and Composition of Leachates From an In Situ Oil Shale Industry," Task Report to DOE, LBL-6300, Lawrence Berkeley Laboratory, 1979.

Fox, J.P., "Water Quality Effects of Leachates From an In Situ Oil Shale Industry," LBL-8997, Lawrence Berkeley Laboratory Report, 1979.

Fox, J.P., and D.L.Jackson, "Potential Uses of Spent Shale in the Treatment of Oil Shale Retort Waters," Proceedings of DOE Wastewater Workshop, Washington, D.C., June 14-15, 1979.

Fox, J.P., et al., "A Strategy for Abandonment of Modified In Situ Oil Shale Retorts," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979. Also published as LBL-8426, Lawrence Berkeley Laboratory.

Fox, J.P., et al., "Control Technology for In Situ Oil Shale Retorts," UCID-8081, Quarterly Progress Report for June 1 to October 31, 1978, Lawrence Berkeley Laboratory, 1978.

Fox, J.P., et al., "Spent Shale as a Control Technology for Oil Shale Retort Water," Annual Report for October 1, 1978, to September 30, 1979.

Girvin, D.C., and J.P. Fox, "On-line Zeeman Atomic Absorption Spectroscopy for Mercury Analysis in Oil Shale Gases," LBL-9702, Lawrence Berkeley Laboratory, 1979.

Girvin, D.C., T. Hadeishi, and J.P. Fox, "Use of Zeeman Atomic Absorption Spectroscopy for the Measurement of Mercury in Oil Shale Gases," Proceedings of the Environmental Protection Agency Oil Shale Sampling, Analysis and Quality Assurance Symposium, Denver, Colorado, LBL-8888, 1979.

Hakkila, E.A., et al., "A Preliminary Electron Microprobe Study of Green River and Devonian Oil Shales," Advances in Chemistry, in press.

Jackson, D.E., and J.P. Fox, "Spent Shale as a Control Technology for Oil Shale Retort Water," UCID-8111, Quarterly Progress Report for October 1, 1978, to December 31, 1978, Lawrence Berkeley Laboratory, 1978.

Jackson, D.E., and J.P. Fox, "Spent Shale as a Control Technology for Oil Shale Retort Water," LBID-070, Quarterly Progress Report for January 1 to March 31, 1979, Lawrence Berkeley Laboratory, 1979.

Mead, S.E., D.D. Farrier, and J.P. Fox, "The State-of-the-Art for Controlling the Wastewater Produced During the Production of Shale Oil," Proceedings of the 12th Oil Shale Symposium, Colorado School of Mines, 1979.

Mercer, B.W., "Disposal of Shale Oil Processing Wastes," Proceedings of the Industrial Waste Management Conference, Pacific Northwest Pollution Control Association, Portland, Oregon, October 18-20, 1977.

Mercer, B.W., A.C. Campbell, and W. Wakamiya, "Evaluation of Land Disposal and Underground Injection of Shale Oil Wastewaters," PNL-2596, Battelle, Pacific Northwest Laboratory, March 1979.

Mercer, B.W., A.C. Campbell, and W. Wakamiya, "Land Disposal and Underground Injection of Shale Oil Wastewaters," presented at the National ACS Meeting, Anaheim, California, March 1978.

Mercer, B.W., and G.W. Dawson, "Low Cost Wastewater Treatment Options for Oil Shale Development," presented at Confab 77 Meeting held by the Laramie Energy Research Center at Saratoga Hot Springs, Saratoga, Wyoming, July 26, 1977.

Mercer, B.W., and W. Wakamiya, "Oil Shale Minewater Treatment Alternatives," Contractor Report, Battelle, Pacific Northwest Laboratory, planned publication date August 1979.

Mercer, B.W., et al., "Analysis, Screening, and Evaluation of Control Technology for Shale Oil Wastewater," Contractor Report, Battelle, Pacific Northwest Laboratory, planned publication date September 1979.

Mercer, B.W., et al., "Assessment of Control Technology for Oil Shale Development," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Pacific Northwest Laboratory, "Assessment of Control Technology for Shale Oil Wastewaters," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Pacific Northwest Laboratory, "Contribution of Thiosulfate to COD and BOD in Oil Shale Process Wastewater," American Society for Testing Materials Symposium on Analysis of Waters Associated With Alternate Fuel Production, June 1979.

Persoff, P., "Control Technologies for In Situ Oil Shale Retorts - Literature Survey," LBL-8780, Lawrence Berkeley Laboratory, 1979.

Persoff, P., and J.P. Fox, "Control Strategies for Abandoned In Situ Oil Shale Retorts," Proceedings of the Twelfth Oil Shale Symposium, Colorado School of Mines, 1979.

Persoff, P., J.P. Fox, and W.G. Hall, "Control Technology for In Situ Oil Shale Retorts," LBID-003, Quarterly Progress Report for November 1 to December 31, 1978, Lawrence Berkeley Laboratory, 1979.

Persoff, P., J.P. Fox, and W.G. Hall, "Control Technology for In Situ Oil Shale Retorts," LBID-040, Quarterly Progress Report for January 1 to March 31, 1979, Lawrence Berkeley Laboratory, 1979.

Persoff, P., W.G. Hall, and J.P. Fox, "Control Technology for In Situ Oil Shale Retorts," LBID-091, Quarterly Progress Report for April 1 to June 30, 1979, Lawrence Berkeley Laboratory, 1979.

Sakaji, R.H., et al., "Spent Shale as a Control Technology for Oil Shale Retort Water," LBID-090, Quarterly Progress Report for April 1 to June 30, 1979, Lawrence Berkeley Laboratory, 1979.

Wewerka, E.M., P. Wagner, and P.L. Wanek, "Assessment and Control of Water Contamination Associated With Shale Oil Extraction and Processing Work Plan," LA-7697, March 1979.

Wong, A.L., and B.W. Mercer, "Contribution of Thiosulfate to COD and BOD in Oil Shale Process Wastewater," Paper to be presented at the Symposium on Analysis of Waters Associated with Alternate Fuel Production, sponsored by the American Society for Testing Materials, to be held at Pittsburgh, Pennsylvania, June 4-8, 1979.

SOLAR, GEOTHERMAL, AND ENERGY CONSERVATION

Ahlstrom, S.B., et al., "Summary of Energy-Conserving Industrial Waste Treatment Technology," Draft, Pacific Northwest Laboratory, August 1979.

Ananth, K.P., "Overview of H_2S Control Technology for Geothermal Energy Sources," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Arnold, C., Jr., and R.E. Trujillo, "Composition Stability and Degradation Products of Selected Materials for Solar Heating and Cooling," SAND 78-0681, Sandia Laboratories, March 1979.

Austin, T.A., "Characterization and Treatment of Anaerobically Digested Cattle Manure," paper to be presented at the U.S. Department of Energy Environmental Control Symposium, March 17-19, 1980.

Beck, C.A., et al., "Compressed Air Energy Storage (CAES) Environmental Control Concerns," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Beck, C.A., et al., "Compressed Air Energy Storage (CAES); Environmental Control Concerns and a Management Program Plan," in draft (PNL-2843), Battelle, Pacific Northwest Laboratory, to be published.

Davidson, A.R., "Active Reduction of Low Frequency Sound From Large Vibrating Surfaces," Doctoral Dissertation, School of Engineering and Applied Sciences, George Washington University, August 1975.

Defferding, L.J., "Geothermal Liquid Waste Disposal - State-of-the-Art Review," draft, BNWL 2404, Battelle, Pacific Northwest Laboratory, September 1978.

Defferding, L.J., and R. Walter, "Disposal of Liquid Effluents From Geothermal Installations," Battelle, Pacific Northwest Laboratory, July 1978.

Hassenzahl, W., M.W. Mahaffy, and W. Weihofen, "Evaluation of Environmental Control Technologies for Magnetic Field," DOE Report, NTIS No. DOE/EV-0029, Dist. Category UC-11, Los Alamos Scientific Laboratory, August 1978.

Johnson, L.D., and J.C. Young, "Water Use and Wastewater Production at Solid Waste Processing/Energy Recovery Facilities," Phase I Final Report, September 1978.

Keast, D.N., and R.C. Potter, "Audible Noise of Constant-Speed, Horizontal-Axis Wind-Turbine Generators; A Preliminary Analysis," Draft, January 1980.

Kebely, V., E. Fullenwider, and J.C. Tomlinson, "Environmental Control Technology for Mobile Diesel Engines," The Aerospace Corporation, November 1978.

Kebely, V., et al., "Review of the Research Status on Diesel Exhaust Emissions, Their Health Effects, and Emission Control Technologies," ATR-78(7716)-3, Reissue A, The Aerospace Corporation, July 1978.

Keller, W.E., "Evaluation of Environmental Control Technologies for Magnetic Fields," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Krupka, M.C., et al., "Assessment of Environmental Control Technologies for Energy Storage Systems -- 1979," LA-8308-MS, Los Alamos Scientific Laboratory, April 1980.

Lawrence Livermore Laboratory, "A Preliminary Assessment of Environmental Control Technologies for Geothermal Applications at Selected Sites in The Geysers, New Mexico, and Hawaii," to be published.

Lawrence Livermore Laboratory, "Assessment of Environmental Control Technologies for Geothermal Applications in the Imperial Valley of California," to be published.

Lawrence Livermore Laboratory, "Proceedings of the Workshop on Environmental Control Technology for The Geysers - Calistoga KGRA," to be published.

Lawrence Livermore Laboratory, "Workshop on Environmental Control Technology for The Geysers - Calistoga KGRA," UCRL-52887, Lawrence Livermore Laboratory, September 1979.

Los Alamos Scientific Laboratory, "Evaluation of Environmental Control Technologies for Magnetic Fields," Project Report for the Division of Environmental Control Technology, U.S. Department of Energy.

Pacific Northwest Labortory, "Management Plan: Environmental Concerns in Compressed Air Energy Storage," PNL-2843, Working Paper, 1979.

Rademaker, A.D., and J.C. Young, "Analysis of Leachates From Solid Residues Produced at Urban Waste-To-Energy Recovery Facilities," Phase II Interim Report, November 1979.

Scott-Walton, B.L., "Environmental Effects of Overhead High-Voltage Transmission Lines," published in the proceedings of the 18th Annual Hanford Life Sciences Symposium, Biological Effects of Extremely Low-Frequence Electromagnetic Fields, Richland, Washington, October 16-18, 1978. Also Final Report, SRI Project No. 6339, CRESS Report No. 57, SRI International, June 1978.

Searcy, J.Q., "Environmental and Safety Aspects of Materials Used in Solar Heating and Cooling (SHAC) Technologies," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Searcy, J.Q., ed., "Hazardous Properties and Environmental Effects of Materials Used in Solar Heating and Cooling (SHAC) Technologies: Interim Handbook," DOE/EV-0028, U.S. Department of Energy, December 1978.

Searcy, J.W., et al., "A Survey of Potential Environmental Effects and Regulations Related to the Disposal of Solar Heating and Cooling (SHAC) Heat Transfer Liquids," SAND 78-1782, Sandia Laboratories, November 1978.

Shah and Associates Inc., "Review of State/Federal Environmental Regulations Pertaining to the Electrical Effect of Overhead Transmission Lines 1978," HCP/EV-1802.

Snoeberger, D.F., and J.H. Hill, "Identification of Environmental Control Technologies for Geothermal Development in the Imperial Valley of California," UCRL-52548, Lawrence Livermore Laboratory, October 5, 1978.

SRI International, "Potential Environmental Effects of 765 kV Transmission Lines: Views Before the New York State Public Service Commission, Cases 26529 and 26559, 1976-1978," DOE/EV-0056, November 1979.

Stottlemyre, J.A., and W.V. Loscutoff, "Environmental Concerns for Compressed Air Energy Storage in Porous Media Systems," 1978 Compressed Air Energy Storage Symposium Proceedings, sponsored by U.S. Department of Energy and Electric Power Research Institute, NTIS CONF-780599, May 1978.

Stottlemyre, J.A., et al., "Environmental Concerns Related to Compressed Air Energy Storage," Proceedings of the American Nuclear Society: Conference on Environmental Aspects of Nonconventional Energy Resource - II, September 1978.

Young, J.C., and L.D. Johnson, "Water Use and Wastewater Production of Solid Waste Processing/Energy Recovery Facilities," Ames Laboratory, Iowa State University, to be published.

NUCLEAR ENERGY

Anderson, D.R. (ed.), "The Third International Seabed High-Level Waste Disposal Assessment Workshop, Albuquerque, New Mexico, February 6-7, 1978; A Report to the NEA Radioactive Waste Management Committee," SAND78-0869, Sandia Laboratories, October 1978.

Anderson, D.R., "Nuclear Waste Disposal in Subseabed Geologic Formations: The Seabed Disposal Program," SAND78-2211, Sandia Laboratories, May 1979.

Anderson, D.R., "Proceedings of the Fourth Annual Seabed Working Group Meeting," Albuquerque, New Mexico, March 5-7, 1979, August 1979.

Anderson, R.N., M.A. Hobard, and M.G. Langseth, "Geothermal Convection Through Oceanic Crust and Sediments in the Indian Ocean," Science, (submitted).

Andrews, W.B., et al., "An Assessment of the Risk of Transporting Liquid Chlorine by Rail," Draft, September 1979.

Andrews, W.B., et al., "Pacific Northwest Laboratory (PNL) Spent Fuel Transportation and Handling Facility Models," PNL-3105, Pacific Northwest Laboratory, Richland, Washington, 1979.

"Applications of Endochronic Plasticity in the Dynamic Finite Element Analysis of Structures," Proceedings, 5th International Conference on Structural Mechanics in Reactor Technology, Paper L9/3, Berlin, West Germany, August 13-17, 1979.

Argonne National Laboratory, "Applications of Endochronic Plasticity Theory in Modeling the Dynamic Inelastic Response of Structural Systems," draft.

Argonne National Laboratory, "Continuous Damage Theory of Structures and Its Application to Impact Loading of Shipping Containers," Technical Memorandum ANL-CT-80-17, ANL Components Technology Division.

Argonne National Laboratory, "The Applications of Endochronic Plasticity Theory in Modeling the Dynamic Inelastic Response of Structural Systems," J. Applied Mechanics (submitted).

Argonne National Laboratory, "The Use of Endochronic Plasticity for Multi-Dimensional Small and Large Strain Problems," Technical Memorandum ANL-CT-79-19, ANL Components Technology Division.

Balmert, M.E., and J. Groom, "Correlation of Experimental Shipping Cask Model Structural Behavior by Computer Analysis," Proceedings of the 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Bartholomew, R.J., "Cargo Response to Railcar Impact and Tiedown Load Analysis," LA-7469-MS, Los Alamos Scientific Laboratory, LA-7469-MS, September 1978. Also presented at Fifth International Symposium on Packaging and Transportation of Radioactive Materials, May 1978.

Bartholomew, R.J., and T.A. Butler, "Analysis of Railcar-Shipping Container System Response to Impact Conditions," LA-8122-MS, Los Alamos Scientific Laboratory, January 1980.

Battelle Columbus Laboratories, "Validity of Scale Modeling as a Tool for Environmental Assessment," Documentary Film Produced by the Center for Improved Education, December 1979.

Brenchley, D.L., et al., "Environmental Assessment Methodologies for Nuclear Fuel Cycles," BNWL-2219, Battelle, Pacific Northwest Laboratory, July 1977.

Brown, C.L. and S.W. Heaberlin, "Importance of Quality Control in Plutonium Packaging Loading," Proceedings 4th International Symposium on Packaging and Transportation of Radioactive Materials, Miami, Florida, September 22-27, 1974; CONF-740901, Battelle, Pacific Northwest Laboratory.

Burian, R.J. "Scale Model Experiments of Energy Material Shipping Containers," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Burian, R.J., et al., "The Validity of Scale Modeling for Large Deformations in Shipping Containers," Battelle Columbus Laboratories, October 19, 1979.

Butler, T.A., "A Program to Develop Analytical Tools for Environmental and Safety Assessment of Nuclear Material Shipping Container Systems," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Butler, T.A., "The Effects of Drop Testing on Scale Model Shipping Containers Shielded With Depleted Uranium," LA-8120-MS, Los Alamos Scientific Laboratory, February 1980.

Butler, T.A., E.G. Endebrock, and J.B. Payne, "CRASHC--A Two-Dimensional Code to Compute the Response of Axisymmetric Shipping Containers to End-On Impacts," LA-8121-MS, Los Alamos Scientific Laboratory, January 1980.

Butler, T.A., J.B. Payne, and E.G. Endebrock, "CRASHC-A Two-Dimensional Code to Compute the Response to Axisymmetric Containers to End-on Impacts," Los Alamos Scientific Laboratory Report, to be published.

Chavez, P.F. and P.R. Dawson, "COUPLEFLO - A Computer Code for Coupled Creeping Viscous Flow and Conductive-Convective Heat Transfer, Part II, User's Manual," SAND-78-1407, Sandia Laboratories, November 1978.

Clarke, R.K., et al., "Severities of Transportation Accidents," SAND74-0001, Sandia Laboratories, July 1976.

Clarke, R.K., et al., "Summary: Severity of Transportation Accidents--Small Packages," Proceedings of Fourth International Symposium on Packaging and Transportation of Radioactive Materials, September 1974.

Cook, W.A., "A Finite Element Model for Nonlinear Shells of Revolution," LA-8138-MS, Los Alamos Scientific Laboratory, November 1979. Also in Proceedings of the Fifth International Conference on: Structural Mechanics in Reactor Technology, Berlin, West Germany, August 13-17, 1979.

Cook, W.A., "Endochronic Viscoplasticity Model," LA-8097-MS, Los Alamos Scientific Laboratory, October 1979.

Cook, W.A., "Finite Element Linear Models for Symmetrically Loaded Shells of Revolution," Proceedings of 5th International Seminar On Computational Aspects of Finite Element Methods, August 20-21, 1979, Berlin, West Germany.

Cook, W.A., "Linear and Nonlinear Symmetrically Loaded Shells of Revolution Approximated With the Finite Element Method," LA-7538-MS, Los Alamos Scientific Laboratory, October 1978.

Corliss, B.H., et al., "A Paleoenvironmental Model for Cenozole Sedimentation in the Central North Pacific," The Heezen Memorial Volume, John Wiley & Sons, 1979.

Counts, J., and J.B. Payne, "Comparison of Predicted and Measured Drop Test Responses of Type B Shipping Containers," LA-6642-MS, Los Alamos Scientific Laboratory LA-6642-MS, January 1977.

Counts, J., and J.B. Payne, "Evaluation of Analysis Methods for Type B Shipping Container Impact Problems," LA-6640-MS, Los Alamos Scientific Laboratory, January 1977.

Counts, J., and J.B. Payne, "IMPAC2--A Lumped-Mass Nonlinear Spring Computer Program to Analyze Type B Shipping Container Impact Problems," LA-6643-MS, Los Alamos Scientific Laboratory, January 1977.

Davidson, C.A., "Data Management--Part I," 48th DOD Shock and Vibration Bulletin, September 1978.

Davidson, C.A., and J.T. Foley, "Transportation Technical Environmental Data Center Index," SAND75-0248D, Sandia Laboratories, 1979.

Dawson, P., "Emplacement and Sedimentary Response," 19th Annual American Society of Mechanical Engineers Symposium, Geological Disposal of Nuclear Waste, March 15-16, 1979.

Dawson, P.R. and P.F. Chavez, "COUPLEFLO - A Computer Code for Coupled Creeping Viscous Flow and Conductive-Convective Heat Transfer, Part I, Theoretical Background," SAND78-1406, Sandia Laboratories, November 1978.

Dawson, P.R., "Buoyant Movement of Nuclear Waste Canisters in Marine Sediment," SAND78-0841, Sandia Laboratories, July 1978.

Dawson, P.R., and P.F. Chavez, "Seabed Waste Disposal Program One-Dimensional Hole Closure Simulations, SAND78-1275, Sandia Laboratories, July 1978.

Deel, O.L., and R.J. Burian, "The Mechanical Properties of Depleted Uranium-2 w/o Molybdenum Alloy," Battelle, Columbus Laboratories, in draft.

Deel, O.L., and R.J. Burian, "The Mechanical Properties of Depleted Uranium-2 With Molybdenum Alloy," Battelle Columbus Laboratories, July 16, 1979.

Dennis, A.W., "Predicted Occurrence Rate of Severe Transportation Accidents Involving Large Casks," Proceedings of 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Dennis, A.W., et al., "Severities of Transportation Accidents Involving Large Packages," SAND77-0001, Sandia Laboratories, May 1978.

Dennis, A.W., et al., "Summary: Severities of Transportation Accidents--Large Packages," Proceedings of Fourth International Symposium on Packaging and Transportation of Radioactive Materials, September 1974.

Elder, H.K., et al., "An Assessment of the Risk of Transporting Spent Nuclear Fuel by Truck," PNL-2588, Battelle, Pacific Northwest Laboratory, November 1978.

Elder, H.K., W.B. Andrews, and R.E. Rhoads, "Risk of Transporting Spent Nuclear Fuel by Truck," Proceedings 5th International Symposium on the Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978; PNL-SA-6520, Battelle, Pacific Northeast Laboratory.

Foley, J.T., and C.A. Davidson, "Transportation Environment Data Bank Index," SAND75-0248, A, B, C, Sandia Laboratories, publication dates: A, 1976; B, 1977; C, 1979.

Foley, J.T., C.A. Davidson, and J.D. McClure, "The Sandia Transportation Technical Environment Information Center and its Application to Transportation Risk Analysis," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978; SAND-78-1953C, Sandia Laboratories.

Foley, J.T., et al., "Technical Information Center for Transportation Analyses," Proceedings of 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Geffen, C.A., "Potential Safety and Environmental Concerns in Petroleum Transportation," PNL-SA-7676A, presented at the First International Symposium on Transportation Safety in San Diego, California, July 11-13, 1979.

Geffen, C.A., and J.F. Johnson, "An Assessment of the Risk of Transporting Uranium Hexafluoride by Truck and Train," PNL-2211, Battelle, Pacific Northwest Laboratory, August 1978.

Geffen, C.A., et al., "An Assessment of the Risk of Transporting Propane by Truck and Train," Draft, September 1979.

Geffen, C.A., R.E. Rhoads, and J.F. Johnson, "Risks of Shipping Uranium Hexafluoride by Truck and Train," PNL-SA-7034 S, presented at the American Nuclear Society 1978 Winter Meeting, Washington, D.C., November 12-17, 1978.

Greenborg, J., et al., "Application of ALARA Principles to Shipment of Spent Nuclear Fuel," PNL-SA-7902A, Abstract for submittal to American Nuclear Society Meeting in San Francisco, November 1979.

Hadden, J.A., and R.J. Burian, "Scale Model Drop Tests to Evaluate Impact Response of Lead and Uranium Shielded Radioactive Material Shipping Containers," Battelle Columbus Laboratories, September 30, 1979.

Hall, R.J., "An Assessment of the Risk of Transporting Plutonium Dioxide and Liquid Plutonium Nitrate by Train," BNWL-1996, Battelle, Pacific Northwest Laboratory, February 1977.

Hall, R.J., and L.D. Williams, "Techniques for Evaluating Risks From the Transport of Radioactive Materials," presented at the ANS Topical Meeting, Toronto, Canada, June 1976.

Heaberlin, S.W., "Plutonium Transport Package Closure Survey," PNL-2288, Battelle Pacific Northwest Laboratory, Richland, Washington, April 1978.

Heaberlin, S.W., et al., "Consequences of Postulated Losses of LWR Spent Fuel and Plutonium Shipping Packages at Sea," PNL-2093, Battelle, Pacific Northwest Laboratory, October 1977.

Heaberlin, S.W., et al., "Evaluation of the Consequences of LW Spent Fuel and Plutonium Shipping Package Loss at Sea," BNWL-SA-5744, IAEA International Seminar, IAEA-SR-10/14, Vienna, Austria, August 23-27, 1976.

Health, G.R., and E.P. Laine, "Cruise Report, R/V Endeavor Cruise EN-024, Seabed Disposal Program North Atlantic Study Area MPG-III, 35°30'N, 61°00'W, June 30-July 11, 1978," Oregon State University, Corvallis, Oregon, 1978.

Heath, G.R., "Ion Transport in Deep-Sea Sediments," 19th Annual American Society of Mechanical Engineers Symposium, Geological Disposal of Nuclear Waste, March 15-16, 1979.

Heath, G.R., et al., "Geochemical and Sedimentological Assessment of Deep-Sea Sediments," Progress Report for Period January 1, 1978, to December 31, 1978, February 1979.

Heeb, C.M., et al., "A Survey of LWR Environmental Control Technology Performance and Cost," PNL-2287/UC-11, Pacific Northwest Laboratory, March 1980.

Heeb, C.M., et al., "Enform II: A Calculational System for Light Water Reactor Logistics and Effluent Analysis," PNL-2429/UC-11, Pacific Northwest Laboratory, October 1979.

Heeb, C.M., et al., "ENFORM: An ENergy INFORMation System," BNWL-2195, Battelle, Pacific Northwest Laboratory, March 1977.

Hessler, R.R., C.L. Ingram, A.A. Yayanos, and B.R. Burnett, "Scavenging Amphipods From the Floor of the Philippine Trench," Deep-Sea Research, Vol. 25, pp. 1029-1047, 1978.

Hollister, C.D., "Geologic Siting Considerations for the Disposal of Radioactive Waste Into Submarine Geologic Formations," 19th Annual American Society of Mechanical Engineers Symposium, Geological Disposal of Nuclear Waste, March 15-16, 1979.

Hollister, C.D., B.H. Corliss, and D.R. Anderson, "Submarine Geologic Disposal of Nuclear Waste," International Symposium on the Underground Disposal of Radioactive Wastes, IAEA-SM-243/99, July 1979.

Hollister, C.D., M.F. Glenn, and P.F. Lonsdale, "Morphology of Seamounts in the Western Pacific and Philippine Basin from Multibeam Sonar Data," Earth and Planetary Science Letters, Vol. 41, pp. 405-418, 1978.

Hollister, C.D., W.P. Bishop, D.D. Deese, "Siting Considerations and Political Implications for the Disposal of High Level Nuclear Wastes Beneath the Deep Sea Floor," Marine Sciences and Ocean Policy Symposium: A Definition of the Issues and a Search for a Consensus of Multiple Uses, University of California, Santa Barbara, June 17-20, 1979.

Hsieh, B.J., "On the Uniqueness and Stability of Endochronic Plasticity Theory," ANL-CT-78-51, Argonne National Laboratory.

Huerta, M., "Analysis, Scale Modeling, and Full-Scale Test of a Railcar and Spent-Nuclear-Fuel Shipping Cask in a High Velocity Impact Against a Rigid Barrier," SAND78-0458, Sandia Laboratories, to be published.

Huerta, M., "Analysis, Scale Modeling, and Full-Scale Tests of a Truck Spent-Nuclear-Fuel Shipping System in Impacts Against a Rigid Barrier," SAND77-0270, Sandia Laboratories, February 1978.

Huerta, M., "Analytical and Scale Modeling Techniques for Predicting the Response and Spent-Nuclear-Fuel Shipping Systems Involved in Severe Transportation Accidents," Proceedings of the 5th International Symposium on Transportation and Packaging of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Huerta, M., and H.R. Yoshimura, "A Crash Test of a Nuclear Spent Fuel Cask and Truck Transport System," SAND77-0419, Sandia Laboratories, January 1978.

Huerta, M., H.R., Yoshimura, and A.W. Dennis, "Impact Analysis of Nuclear Spent Fuel Casks," presented at CUBE Symposium, Sandia Laboratories, Albuquerque, New Mexico, August 1976.

Jefferson, R.M., and H.R. Yoshimura, "Crash Testing of Spent Nuclear Fuel Shipping Containers," SAND77-1462, Sandia Laboratories, February 1978.

Johnson, J.F., and R.J. Hall, "The Usefulness of the Risk Assessment Technique in Solving Transportation Problems," Proceedings of 56th Annual Meeting of the Transportation Research Board, National Academy of Sciences, Washington, D.C., January 24, 1977; BNWL-SA-5947, Battelle, Pacific Northwest Laboratory.

Johnson, J.F., and W.B. Andrews, "Risk of Shipping Uranium Hexafluoride by Truck and Train," Proceedings 5th International Symposium on the Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978; PNL-SA-6528, Battelle, Pacific Northwest Laboratory.

Johnson, J.F., and W.B. Andrews, "Risks of Shipping Plutonium by Truck, Train and Cargo Aircraft," Proceedings 5th International Symposium on the Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978; PNL-SA-6530, Battelle, Pacific Northwest Laboratory.

Kabele, T.J., et al., "Data Book on Effluents in LWR Fuel Cycles," BNWL-2287, Battelle, Pacific Northwest Laboratory, to be published.

Kelly, W.S., et al., Results of Structural Analysis of Plutonium Packaging," Proceedings 4th International Symposium on Packaging and Transportation of Radioactive Material, Miami, Florida, September 22-27, 1974; CONF-740901, BNWL-SA-5089, Battelle, Pacific Northwest Laboratory.

Krumhansl, J.L., and D.R. McVey, "Near-Field Interactions," 19th Annual American Society of Mechanical Engineers Symposium, Geological Disposal of Nuclear Waste, March 15-16, 1979.

Krumhansl, J.L., and G.R. Hadley, "Thermal and Chemical Properties of Saturated Marine Clays in a Near Field Environment," presented at Seabed Working Group of the Nuclear Energy Agency Radioactive Waste Management Committee, Paris, France, September 1979.

Lin, H.C., B.J. Hsieh, and R.A. Valentin, "The Use of Endochronic Plasticity Theory in Modeling the Dynamic Inelastic Response of Shipping Containers: A Preliminary Assessment," Proceedings Fifth International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, pp. 384-390, May 1978.

Lin, H.C., R.A. Valentin, and B.J. Hsieh, "The Application of Endochronic Plasticity in Structural Dynamics," abstract submitted for presentation at ANS meeting, Atlanta, Georgia, June 1979.

Los Alamos Scientific Laboratory, report on a computer code for predicting railcar-container dynamics during impact, to be published.

Los Alamos Scientific Laboratory, report on an evaluation of the endochronic material model for predicting plastic deformation of metals, to be published.

Los Alamos Scientific Laboratory, report on dynamics of nuclear material shipping containers after initial impact, to be published.

Loscutoff, W.V., and R.J. Hall, "A Safety and Economic Study of Special Trains," BNWL-SA-5770, Conference on Transportation of Radioactive Materials (Atomic Industrial Forum), Minneapolis, Minnesota, May 25-28, 1976.

Loscutoff, W.V., et al., "A Safety and Economic Study of Special Trains for Shipment of Spent Fuel," BNWL-2263, Battelle, Pacific Northwest Laboratory, December 1977.

McClure, J.D., "An Analysis of the Qualification Criteria for Small Radioactive Material Shipping Packages," Review Draft, SAND76-0708, Sandia Laboratories, October 1977. Also presented at the IAEA Advisory Group on Transport Package Test Standards, Vienna, Austria, December 1977; and in the Proceedings, 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

McClure, J.D., "Severities of Marine Transportation Accident" Sandia Laboratories, to be published.

McClure, J.D., and W.A. Von Riesemann, "An Analysis of the Engine Fragment Threat and the Crush Environment for Small Packages Carried on U.S. Commercial Jet Aircraft," Proceedings of Fifth International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

McClure, J.D., and W.A. Von Riesemann, "The Crush Environment for Small Containers Carried by U.S. Commercial Jet Aircraft," SAND76-0533, Sandia Laboratories, August 1977.

McSweeney, T.I., "A Risk Assessment Model for Radioactive Material Shipments," Proceedings 4th International Symposium on Packaging and Transportation of Radioactive Materials, Miami, Florida, September 22-27, 1974; CONF-740901, BNWL-SA-5088, Battelle, Pacific Northwest Laboratory.

McSweeney, T.I., and J.F. Johnson, "An Assessment of the Risk of Transporting Plutonium Dioxide by Cargo Aircraft," BNWL-2030, Battelle, Pacific Northwest Laboratory, June 1977.

McSweeney, T.I., and R.J. Hall, "An Assessment of the Risk of Transporting Plutonium Oxide and Liquid Plutonium Nitrate by Truck," BNWL-1846, Battelle, Pacific Northwest Laboratory, August 1975.

McSweeney, T.I., C.L. Brown, W.S. Kelly, S.N. Liu, J. Mishima, E.C. Watson, and S.W. Heaberlin, "Risk Analysis of Shipping Plutonium Oxide and Plutonium Nitrate," Proceedings 4th Internationl Symposium On Packaging and Transportation of Radioactive Materials, Miami, Florida, September 22-27, 1974; CONF-740901, Battelle, Pacific Northwest Laboratory.

McVey, D.F., D.K. Gartling, and A.J. Russo, "Thermal/Fluid Modeling of the Response of Saturated Marine Red Clays to Emplacement of Nuclear Waste," presented at Seabed Working Group of the Nuclear Energy Agency Radioactive Waste Management Committee, Paris, France, September 1979.

Mishima, J., "Fractional Airborne Release of Plutonium Under Shipping Accident Conditions," Proceedings 4th International Symposium on Packaging and Transportation of Radioactive Materials, Miami, Florida, September 22-27, 1974; CONF-740901, Battelle, Pacific Northwest Laboratory.

Mishima, J., "Potential Aerosol Generation Mechanisms From Damaged Shipping Packages," BNWL-SA-5742, IAEA International Seminar, IAEA-SR-10/15, Vienna, Austria, August 23-27, 1976.

Mundis, R., et al., "Health Physics Concerns at Accelerator Decommissioning and Disposal," Proceedings of Low Level Radioactive Waste Management Symposium, Health Physics Society, February 12-15, 1979, to be published.

Murphy, E.S., "Analysis of Freight Train Accident Statistics for 1972-74," Proceedings 5th International Symposium on the Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978; PNL-SA-6521, Battelle, Pacific Northwest Laboratory.

Nolan, A.M., M.A. Lewallen, and G.W. McNair, "Environmental Control for Fabrication, Reprocessing, and Water Disposal of Alternative LWR and LMFBR Fuels," PNL-3129/UC-11, Pacific Northwest Laboratory, November 1979.

Opelka, J.H., et al., "Decommissioning Study of a Commercial Tokamak Reactor," ANL/ES-93, draft, Argonne National Laboratory.

Opelka, J.H., et al., "Particle-Accelerator Decommissioning," ANL/ES-82, Argonne National Laboratory, December 1979.

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

Platt, A.M., et al., "United States Experience in the Transportation of Radioactive Materials," BNWL-SA-6077, IAEA Conference on Nuclear Power and Its Fuel Cycle, IAEA-CN-36/563, Salzburg, Austria, May 2-13, 1977.

Pope, R.B., et al., "Environmental Effects of Transporting Radioactive Materials in Nuclear Waste Management Systems," SAND78-1211C, Sandia Laboratories, November 1978.

Rhoads, R.E., and C.A. Geffen, "Risk Assessment of Energy Material Transportation Systems," PNL-SA-7230, U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Rhoads, R.E., and J.F. Johnson, "Risks in Transporting Materials for Various Energy Industries," Nuclear Safety Journal, PNL-SA-6547, Vol. 19, No. 2, Battelle, Pacific Northwest Laboratory, March-April 1978.

Rhoads, R.E., and P.L. Peterson, "Conceptual Design of a Shipping Cask for Rail Transport of Solidified High-Level Waste," PNL-SA-6526, Proceedings 5th International Symposium on the Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Rhoads, R.E., et al., "An Assessment of the Risk of Transporting Gasoline by Truck," PNL-2133, Battelle, Pacific Northwest Laboratory, November 1978.

Rhoads, R.E., et al., "Placing the Special Trains Issue in Perspective," Proceedings 5th International Symposium on the Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978; PNL-SA-6519, Battelle, Pacific Northwest Laboratory.

Rhoads, R.E., W.A. Brobst, and S.W. Heaberlin, "Considerations in the Transportation of Spent Fuel and Other Radioactive Material by Sea," Proceedings 5th International Symposium on the Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978; PNL-SA-6523, Battelle, Pacific Northwest Laboratory.

Robinson, R.A., "Strain Rate Effects for Some Common Structural Materials Used in Radioactive Packaging and Transportation Systems," IAEA-SR-10/8, IAEA International Seminar on Design, Construction, and Testing of Packaging for the Safe Transport of Radioactive Materials, Vienna, Austria, August 1976.

Robinson, R.A., "Use of Scale Models to Assess Structural Response of Nuclear Shipping Containers Under Accident Conditions," IAEA-SR-10/9, IAEA International Seminar on Design, Construction, and Testing of Packaging for the Safe Transport of Radioactive Materials, Vienna, Austria, August 1976.

Robinson, R.A., and J.A. Hadden, "Experimental Studies With Lead-Shielded Scale Model Shipping Containers," Proceedings of the 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Robinson, R.A., and S.J. Basham, "Dynamic Modeling of Lead Slump in Shipping Cask Design," TANSAO, Vol. 21, presented at 1975 ANS Annual Meeting, June 1975.

Robinson, R.A., J.A. Hadden, and S.J. Basham, "Experimental Studies of Dynamic Impact Response With Scale Models of Lead Shielded Radioactive Material Shipping Containers," BMI-2001, Battelle, Columbus Laboratories, September 1978.

Robinson, R.A., W.J. Zielenbach, and A.A. Lawrence, "A Survey of Strain-Rate Effects for Some Common Structural Materials Used in Radioactive Material Packaging and Transportation Systems," BMI-1954, Battelle, Columbus Laboratories, August 1976.

Sandia Laboratories, "Accident Safe?", Sound Film (14-1/2 minutes), March 1978.

Sandia Laboratories, "Five Full-Scale Cask Tests," Sound Film (3 minutes), February 1978.

Sandia Laboratories, "Indispensable Element," Sound Film (27 minutes), November 1976.

Sandia Laboratories, "On the Move," Sound Film (28 minutes), April 1974.

Sandia Laboratories, "Safety in Salt," Sound Film (26 minutes), March 1971.

Sandia Laboratories, "Ship With Care," Sound Film (4 minutes), January 1977.

Sandia Laboratories, "Technical Information for Transportation Analysis," Sound Film, April 1978.

Schimmel, W.P., and C.E. Hickox, "Application of Thermal Conduction Models to Deepsea Disposal of Radioactive Wastes," SAND77-0752, Sandia Laboratories, March 1978.

Schneider, K.J., and T.J. Kabel, "Descriptions of Reference LWR Facilities for Analysis of Nuclear Fuel Cycles, PNL-2286/UC-11, Pacific Northwest Laboratory, September 1979.

Schneider, K.J., et al., "Analysis of LWR Fuel Cycle Facilities," BNWL-2286, Battelle, Pacific Northwest Laboratory, to be published.

Seabed Programs Division, "Subseabed Disposal Program Plan," SAND79-1157, Sandia Laboratories, Draft, September 1979.

Seagren, R.D., "Full Scale Impact Testing for Environmental and Safety Control of Energy Material Shipping Container Systems," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Seagren, R.D., et al., "Testing of the Knapp Mills Cask," Oak Ridge National Laboratory, to be published.

Seagren, R.D., et al., "The ORNL Radioactive Carrier Drop Test Facility: The Design, Construction, and Operating Capability," Proceedings of the 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Shappert, L.B., et al., "The Obsolete Cask Program: Drop Tests of the HWCTR Cask," Proceedings of the 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Shappert, L.B., et al., "The Obsolete Cask Program: Initial Test," ORNL-TM-1312, Vol. 14, Oak Ridge National Laboratory, November 1974.

Shappert, L.B., et al., "The Obsolete Cask Program: Oblique and Center of Gravity Drop Tests," ORNL-TM-1312, Vol. 17, Oak Ridge National Laboratory, in press.

Shappert, L.B., et al., "The Obsolete Cask Test Program, HWCTR Cask Drop Tests on Closure With and Without an Impact Limiter and Puncture Test at TSF," ORNL-TM-1312, Vol. 19, Oak Ridge National Laboratory, March 1977.

Shappert, L.B., et al., "The Obsolete Cask Test Program, Test Number 2," ORNL-TM-1312, Vol. 16, Oak Ridge National Laboratory, April 1975.

Smith, D.R., and J.T. Thomas, "Review of Bases for Regulations Governing the Transport of Fissile and Other Radioactive Material," Proceedings of 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Smith, K.L., "Benthic Community Respiration in the N.W. Atlantic Ocean: In Situ Measurements From 40 to 5200 m," Marine Biology, Vol. 47, pp. 337-347, 1978.

Smith, K.L., Jr., G.A. White, and M.B. Laver, "Oxygen Uptake and Nutrient Exchange of Sediments Measured In-Situ Using a Free Vehicle Grab Respirometer," Deep Sea Research, Vol. 26A, pp. 337-346, Pergamon Press Ltd., 1979.

Soldat, J.K., "Methodology for Calculation of Radioactive Doses in the Environs From Nuclear Fuel Cycle Facilities," BNWL-2075, Battelle, Pacific Northwest Labortory, August 1976.

Straight, T.W., "Nuclear Shipping Container Secondary Impact Analysis," LA-8081-MS, Los Alamos Scientific Laboratory, October 1979.

Suber, L.A., Jr., "Package Failure From Malevolent Attack: Summary Report Through December 1976," SAND77-0810, Report Classified NCSI, Sandia Laboratories, to be published.

Talbert, D.M., "Seabed Disposal Program Annual Report, January to December 1977," Vol. I, SAND78-1359, Sandia Laboratories, January 1979.

Talbert, D.M., "Seabed Disposal Program Annual Report, January to December 1977," Vol. II - Appendices, SAND78-1359, Sandia Laboratories, January 1979.

Talbert, D.M., "Subseabed Disposal Program Annual Report, January to December 1978," Vol. I and II, SAND79-1618, Sandia Laboratories, October 1979.

Teofilo, V.L., et al., "The Fusion Fuel Cycle: Material Requirements and Potential Effluents," PNL-3182, Pacific Northwest Laboratory, June 1980.

Thomas, J.T. and D.R. Smith, "Review of Criteria for Nuclear Criticality Safety Control in Transportation," Proceedings of 5th International Symposium on Packaging and Transportation of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Valentin, R.A., B.J. Hsieh, and H.C. Lin, "Applications of Endochronic Plasticity in the Dynamic Finite Element Analysis of Structures," Paper L9/3, 5th International Conference on Structural Mechanics in Rector Technology (SMiRT-5), Berlin, Germany, August 1979, to be presented pending approval by DOE/ECT.

Valentin, R.A., H.C. Lin, and B.J. Hsieh, "An Assessment of Endochronic Plasticity Theory and Its Potential Applications in Modeling the Dynamic Inelastic Response of Energy Materials Shipping Containers," ANL-CT-79-2, Argonne National Laboratory.

Watson, E.C., "Potential Environmental Consequences of Postulated Transportation Accidents Involving Plutonium Shipments," Proceedings 4th International Symposium on Packaging and Transportation of Radioactive Materials, Miami, Florida, September 22-27, 1974; CONF-740901, Battelle, Pacific Northwest Laboratory.

Williams, L.D., and R.J. Hall, "Risk of Transporting Plutonium Dioxide and Liquid Plutonium Nitrate by Truck and Rail," BNWL-SA-5743, IAEA International Seminar, IAEA-SR-10/13, Vienna, Austria, August 23-27, 1976.

Williams, L.D., and R.J. Hall, "Transportation Safety Studies," BNWL-SA-5670, Proceedings of 55th Annual Meeting of the Transportation Research Board, National Academy of Sciences, Washington, D.C., January 19-23, 1976.

Yarrington, P., "A Comparison of Calculations With High Velocity Soil Penetration Data," SAND78-0311, Sandia Laboratories, June 1978.

Yayanos, A.A., "Recovery and Maintenance of Live Amphipods at a Pressure of 580 Bars From an Ocean Depth of 5700 Meters," Science, Vol. 200, pp. 1056-1059, 1978.

Yayanos, A.A., and J.C. Nevenzel, "Rising-Particle Hypothesis: Rapid Ascent of Matter From the Deep Ocean," Naturwissenchaften, Vol. 65, S.255, 1978.

Yoshimura, H.R., "Crash Testing of Spent-Nuclear Fuel Shipping Systems," presented at Waste Management/78 Symposium, Tucson, Arizona, March 1978.

Yoshimura, H.R., "Full Scale Simulations of Accidents on Spent-Nuclear-Fuel Shipping Systems," presented at 5th International Symposium on Transportation and Packaging of Radioactive Materials, Las Vegas, Nevada, May 7-12, 1978.

Yoshimura, H.R., "Full Scale Vehicle Testing Program," presented at Transportation Research Board 55th Annual Meeting, Washington, D.C.; SAND76-5039, Sandia Laboratories.

Yoshimura, H.R., "Full-Scale Tests of Spent Fuel Shipping Systems," ANS Transactions, Vol. 27, 1977.

Yoshimura, H.R., and M. Huerta, "Full Scale Tests of Spent-Nuclear-Fuel Shipping Systems," presented at Conference on Transport Packaging for Radioactive Materials, IAEA-SR-10/17, Vienna, Austria, August 1976.

Yoshimura, H.R., R.B. Pope, M. Huerta, and R.H. Nilson, "Environmental Impact of Accidents Involving Radioactive Materials Shipping Systems," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Young, J.K., et al., "Economics of Large-Scale Thorium Oxide Production: Assessment of Domestic Resources," PNL-3150/UC-51, Pacific Northwest Laboratory, February 1980.

Young, J.R., "Procedures for Estimating Nuclear Fuel Cycle Costs," BNWL-2210, Battelle, Pacific Northwest Laboratory, March 1977.

MANAGEMENT OF SURPLUS RADIOACTIVELY CONTAMINATED DEPARTMENT OF ENERGY FACILITIES

Ames, L.L., and S.J. Phillips, "Characterization of the Hanford 300 Area Burial Grounds -- Decontamination and Decommissioning Regulatory Issues, Task II -- Geological Analysis," PNL-2658, Pacific Northwest Laboratory, Richland, Washington, 1979.

Atomics International, "Building 143 Detailed Working Procedure for Excavation of the SRE to Remove Below-Grade Contaminated and Activated Material and Structures," N704DWP990065.

Atomics International, "Deactivation of Building 143 Retention Pond and Sanitary Sewer System," N704DWP990060.

Atomics International, "Decontamination and Dismantling of the Hot Cell Facilities at SRE," N704DWP90062.

Atomics International, "Detailed Work Procedure for the Removal of the SRE Core Tank Bottom," N704DWP990048.

Atomics International, "Detailed Working Procedure for Outer Tank Removal," N704DWP990049.

Atomics International, "Detailed Working Procedure for Scoring the Core Cavity Liner," N704DWP990053.

Atomics International, "Detailed Working Procedure for Super-X Insulation Removal," N704DWP990051.

Atomics International, "Final Report -- SRE Fuel Decladding," N704FDR990004.

Atomics International, "Radiological Survey Results -- Release to Unrestricted Use, SRE Region II (Building 163, Box Shop)," N704TI990028.

Atomics International, "Radiological Survey Results -- Release to Unrestricted Use, SRE Region I," N704TI990027.

Atomics International, "Radiological Survey Results -- Release to Unrestricted Use, SRE Region IV (West Parking Lot)," N704TI990030.

Atomics International, "Report on Passivation of the SRE Reactor Vessel and Associated Components," N704TR990007.

Atomics International, "SRE Activity Requirement No. 29, Final Closeout of the SRE Facility," N704ACR990027.

Atomics International, "SRE Site Survey Plan for Release to Unrestricted Use," N704DWP990063.

Ausmus, B.S., and F.A. O'Hara, "Overview Assessment Report of the Information Conference on the DOE Western New York Nuclear Service Center Study," presented December 16, 1978.

Ausmus, B.S., et al., "Preliminary Environmental Implications of Alternatives for Decommissioning and Future Use of the Western New York Nuclear Services Center," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Barker, L.V., "Quality Assurance Program Plan - 100-F Disposition," UNI 1006, United Nuclear Industries, September 12, 1978.

Battelle, Pacific Northwest Laboratory, "Alternatives for Managing Wastes From Reactors and Post-Fission Operations in the LWR Fuel Cycle," Vol. 2, Section 15: Retired Facilities (Decontamination and Decommissioning), May 1976.

Beitel, G.A., "Remote Disassembly of Radioactively Contaminated Vessels by Means of an Arc Saw," ARH-SA-289, Rockwell Hanford Operations, June 1977.

Beitel, G.A., and P.G. Ortiz, "Volume Reduction of Metallic Waste," RHO-SA-91, Rockwell Hanford Operations, October 24, 1978.

Boback, M.M., K.N. Ross, and D.A. Fuchs, "FMPC Environmental Monitoring Annual Report for 1977," NLCO 1151, National Lead Company of Ohio, April 1, 1978.

Bond, A., "Safety Analysis Report for TORY-II-C Fuel Recovery," NVO-164, Energy Research and Development Administration, Nevada Operations Office, September 1975.

Brengle, R.G., "Decontamination of Concrete," presented at the American Nuclear Society Decommissioning Seminar, September 16-20, 1979.

Brengle, R.G., and E.L. Babcock, "Equipment for Remote Dismantling," presented at the American Nuclear Society Decommissioning Seminar, September 16-20, 1979.

Bromley, C.P., "Nuclear Fuel Recovery Operations at the Nuclear Rocket Development Station," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Cavendish, J.H., "Feasibility Study of a Portable Smelter for Scrap Metals," NLCO-1132, Special, National Lead Company of Ohio, June 1976.

Cavendish, J.H., "Treatment of Metallic Wastes by Smelting," NLCO-1157, September 25, 1978. Also presented at the International Symposium on the Decommissioning of Nuclear Facilities, Vienna, Austria, November 17, 1978.

Chapin, J.A., "1979 Revision of the INEL Decontamination and Decommissioning Long Range Plan," Department of Energy, Idaho Operations Office, to be published April 1979.

Chapin, J.A., and R.E. Hine, "Decontamination and Decommissioning Long Range Plan - Idaho National Engineering Laboratory," TREE-1250, Volumes I and II, Department of Energy, Idaho Operations Office, June 1978.

Chapin, J.H., "Characterization and Decommissioning for the Organic Moderated Reactor Experiment Leaching Pond," PR-W-79-003, Department of Energy, Idaho Operations Office, January 1979.

Cline, J.F., "Bio-Barriers Used in Shallow Burial Ground Stabilizaton," PNL-2918, Pacific Northwest Laboratories, July 1979.

Cline, J.F., "Experimental Design for Demonstration of Bio-Barriers Placed in a Simulated Burial Trench," BNWL-2035, Battelle, Pacific Northwest Laboratory, May 1976.

Dorian, J.J., "Environmental Assessment of 100-F Decontamination and Decommissioning Program," UNI 802 Rev. 1, United Nuclear Industries, May 12, 1978.

Dorian, J.J., and V.R. Richards, "Radiological Characterization of the Retired 100 Areas," UNI 946, United Nuclear Industries, May 12, 1978.

EG&G Idaho, Inc., "BORAX-V Decontamination and Decommissioning Plan," PR-W-79-017, September 1979.

EG&G Idaho, Inc., "Characterization of MTR-605 Process Water Building," PR-W-79-015, June 1979.

EG&G Idaho, Inc., "Characterization of the TAN-TSF Outside Areas," PR-W-79-031, September 1979.

EG&G Idaho, Inc., "D&D Waste Volume Reduction Study," PR-W-79-032, September 1979.

EG&G Idaho, Inc., "Decontamination and Decommissioning (D&D) Plan for the Hallam Project," WMP-77-18, Revision 1, December 1979.

EG&G Idaho, Inc., "Decontamination and Decommissioning (D&D) Plan for the Heat Transfer Reactor Test Assemblies HTRE-2 and HTRE-3," PR-W-79-001, January 1979.

EG&G Idaho, Inc., "Decontamination and Decommissioning (D&D) Plan for the Organic Moderated Reactor Experiment (OMRE)," WMP-77-17, Revision 1, December 1977.

EG&G Idaho, Inc., "Decontamination and Decommissioning Plan for the SPERT-IV Reactor Building," PR-W-79-002, February 1979.

EG&G Idaho, Inc., "Decontamination of Soil Utilizing Water Hyacinth," PR-W-79-026, September 1979.

EG&G Idaho, Inc., "Feasibility of Using Plant to Decontaminate Radioactive Soils," TREE-1366, July 1979.

EG&G Idaho, Inc., "Final Report -- Decontamination and Decommissioning of the Organic Moderated Reactor Experiment (OMRE) Facility," PR-W-79-037, September 1979.

EG&G Idaho, Inc., "Final Report -- SPERT-IV Decontamination and Decommissioning," TREE-1373, August 1979.

EG&G Idaho, Inc., "OMRE Leach Pond Characterization," PR-W-79-029, September 1979.

EG&G Idaho, Inc., "Preconceptual Studies for Processing of the EBR-I Mark II Contaminated NaK," RE-D-79-221, September 1979.

EG&G Idaho, Inc., "Preliminary Assessment for Decontamination of INEL Radioactive Soils Using Chemical Extraction Process," RE-M-79-012, September 1979.

EG&G Idaho, Inc., "Safety Evaluation Report for the Decontamination and Decommissioning of the Hallam Reactor Components," PR-W-79-013, May 1978.

EG&G Idaho, Inc., "Safety Evaluation for Decontamination and Decommissioning of the Organic Moderated Reactor Experiment," PR-W-79-010, April 1978.

EG&G Idaho, Inc., "Sodium Removal From Hallam Reactor Components," TREE-1368, August 1979.

EG&G Idaho, Inc., "Soil Decontamination Final Report," PR-W-79-027, September 1979.

Environmental Control Technology Division, "Report on Remedial Radioactive Materials on Public or Acquired Lands of the United States," DOE/EV-0037, July 1, 1979.

Gee, G.W., and C.J. Simmons, "Characterization of the Hanford 300 Area Burial Grounds -- Decontamination and Decommissioning Regulatory Issues, Task III -- Fluid Transport and Modeling," PNL-2921, Pacific Nothwest Labortory, Richland, Washington, 1979.

Graves, A.W., "Decontamination and Decommissioning of Plutonium-Contaminated Facilities at the Hanford Site," RHO-SA-68, Rockwell Hanford Operations, October 24, 1978.

Graves, A.W., "Decontamination and Decommissioning Program Plan," RHO-CD-421, March 1979.

Graves, A.W., and D.A. Phillips, "Plasma Arc Cutting of Reactor Vessels," ANS Winter Meeting, San Francisco, California, November 27 through December 2, 1977.

Graves, A.W., and G.P. Streechon, "Explosive Cutting of Reactor Components," ANS Winter Meting, San Francisco, California, November 27 through December 2, 1977.

Graves, A.W., R.D. Prosser, and J.H. Roecker, "Reduction of Radiation Area Project Plant," RHO-CD-648, Rev. 1, Rockwell Hanford Operations, August 1979.

Halter, J.M., and R.G. Sullivan, "Techniques for Removing Contaminated Concrete Surfaces," Proceedings of the Fourth International Symposium on Contamination Control, Washington, D.C., September 11-13, 1978.

Harper, J., and R. Garde, "Decommissioning of a ^{239}Pu Contaminated Incinerator Facility," presented at IAEA Symposium on the Decommissioning of Nuclear Facilities, Vienna, Austria, November 1978.

Harper, J., and R. Garde, "Decommissioning of TA-21-153; An Actinide Contaminated Filter Building," draft, Los Alamos Scientific Laboratory, 1979.

Harper, J., and R. Garde, "Decommissioning of TA-42; A Plutonium Contaminated Incineration Facility," draft, Los Alamos Scientific Laboratory, 1979.

Hayden, J.A., and W.L. Polzer, "Physical Characterization of Actinides in a Liquid Waste/Soil Medium Using Nuclear Tract Methods," RFP-2858, Rockwell International, in press.

Hayden, J.A., et al., "Soil Decontamination at Rocky Flats," Proceedings of Conference on Decommissioning of Nuclear Facilities, Sun Valley, Idaho, September 1979.

Heinz, W.F., and A.W. Graves, "Preparation for Decontamination and Disposition of the Sodium Reactor Experiment (SRE) and Other ERDA Facilities at AI," presented at First Conference on Decontamination and Decommissioning of ERDA Facilities, Idaho Falls, Idaho, August 1975.

Heinz, W.F., and B.F. Ureda, "Decontamination and Disposition of Hallam and Fluid Reactors," presented at First Conference on Decontamination and Decommissioning of ERDA Facilities, Idaho Falls, Idaho, August 1975.

Hine, R.E., "Decontamination and Decommissioning (D&D) Plan for TAN Radioactive Liquid Waste Evaporation System (PM-2A)," PR-W-78-022, Department of Energy, Idaho Operations Office, December 1978.

Hine, R.E., "OMRE D&D Project at the Idaho National Engineering Laboratory," presented at the U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978.

Huey, E.A., "Report on Preliminary Geological, Hydrological, and Radiological Survey at Weldon Spring Quarry During FY 1976 and FY 1977," National Lead Company of Ohio, December 14, 1978.

Huntsman, L.K., "Decontamination and Decommissioning (D&D) Plan for the Hallam Project," WMP-77-18, Department of Energy, Idaho Operations Office, December 1977.

Huntsman, L.K., "Hallam Project Processing Operations," PR-W-78-018, Department of Energy, Idaho Operations Office, September 1978.

Jones, J.W., "Production Reactor Decommissioning Study - The Planning Phase," United Nuclear Industries, November 1978.

Jones, J.W., "Program Plan - Production Reactor Decontamination Study," UNI 888, United Nuclear Industries, December 1, 1977.

King, J.C., and J.W. Litchfield, "Application of a Computerized Planning System to Plan for Decommissioning of Retired Hanford Facilities," PNL-SA-6931, Battelle, Pacific Northwest Laboratory, 1978.

Kispert, R.C., "Recovery of Uranium From Pit Sludges and Coal Metal Oxide," NLCO-1149, National Lead Company of Ohio, January 1978.

Kittinger, W.D., "Decontamination and Dismantling of the Sodium Reactor Experiment," presented at Annual Joint Meeting of Rocky Mountain Section American Industrial Hygiene Association and Rio Grande Chapter Health Physics Society, October 27 and 28, 1977.

Kittinger, W.D., and G.W. Meyers, "Decommissioning the Sodium Reactor Experiment, A Status Report," presented at the American Nuclear Society Decommissioning Seminar, September 16-20, 1979.

Kittinger, W.D., B.F. Ureda, and J.W. Carroll, "Experience and Techniques in AI's Recent Decommissioning Program," presented at the Health Physics Society Annual Meeting, July 8-13, 1979.

Kochen, R.L., and J.D. Navratil, "Development of Actinide Decontamination Processes for Rocky Flats Soil: I. Laboratory-Scale Process Development," CRD-78-0, Rockwell International, August 2, 1978.

Kusler, L.E., "Survey of Decontamination and Decommissioning Techniques," ARH-CD-948, Rockwell Hanford Opertions, May 25, 1977.

LaGuardia, T.S., "Decommissioning Methods and Equipment," presented at the American Nuclear Society Conference on Decontamination and Decommissioning of Nuclear Facilities, Sun Valley, Idaho, September 16-19, 1979.

LaGuardia, T.S., and W.J. Manion, "Reactor Decommissioning Information Pertinent to Planning," presented at the American Nuclear Society Winter Meeting, Washington, D.C., November 12-16, 1978.

Lawrence, A.A., "Description and Status of the Facilities, Nuclear Fuel Services, Inc., West Valley, New York," Section 2, draft report, Battelle, Columbus Laboratories, July 1978.

Litchfield, J.W., "Interactive Planning System for Developing Decommissioning and Decontamination Plans at Hanford," BNWL-SA-6539. Also presented at Association for ERDA Systems, Operations and Programming (AFSOP), Boston, Massachusetts, September 13-14, 1977.

Litchfield, J.W., and J.C. King, "Decommissioning and Decontamination Planning for Hanford Nuclear Facilities Using Multiattributed Decision Analysis," BNWL-SA-6007, Battelle, Pacific Northwest Laboratories, May 1977.

Litchfield, J.W., and J.C. King, "Planning for Decommissioning and Decontamination of Hanford Nuclear Facilities," BNWL-SA-6450, Battelle, Pacific Northwest Labortory, August 1977.

Manion, W.J., "Summary of a Decommissioning Handbook for Nuclear Facilities," presented to the International Symposium on the Decommissioning of Nuclear Facilities, Vienna, Austria, November 13-17, 1978, published as International Atomic Energy Agency Document, IAEA-SM-234/44.

Markus, J., "Feasibility Study for Portable Smelter for NLO," JN 1548-765, February 1976.

Marsh, D.A., "Surveillance and Maintenance of Retired Surplus Facilities Project Plan," DO101pp0001, Rockwell Hanford Operations Report, May 9, 1978.

Mautz, E.W., "Ferrous and Non-Ferrous Metals Industries and Associated Scrap Metals - A Review," NLCO-1128, National Lead Company of Ohio, November 1975.

Mautz, E.W., "Literature Survey - Portable Equipment and Scrap Metal Industry," NLCO-125, National Lead Company of Ohio, August 1975.

Meservey, R.H., "Decontamination and Decommissioning Projects at the Idaho National Engineering Labortory," presented at the International Symposium on the Decommissioning of Nuclear Facilities, sponsored by the International Atomic Energy Agency, Vienna, Austria, November 13-17, 1978.

Meyers, G.W., and W.D. Kittinger, "Progress Report on Dismantling of the Sodium Reactor Experiment," presented at the International Symposium on the Decommissioning of Nuclear Facilities, November 13-17, 1978, and at the American Nuclear Society Winter Meeting, November 16, 1978.

Morris, F.A., R.F. Smith, and S.J. Phillips, "Characterization of the Hanford 300 Area Burial Grounds," PNL-2875, Pacific Northest Laboratory, Richland, Washington, 1979.

National Lead Company of Ohio, "Environmental Impact Assessment Concerning Proposed Rulemaking Exemption From Licensing Requirements for the Sale and Use of Metal Scrap Homogeneously Contaminated With Enriched Uranium and Technetium-99 Below a Specified Concentration," U.S. Energy Research and Development Administration, July 1976.

National Lead Company of Ohio, "Informational Report on the U.S. Department of Energy, Niagara Falls Site," NLCO-003EV, Draft for approvals, July 1979.

National Lead Company of Ohio, "Spoil Pile Radiological Survey, DOE-Niagara Falls Site, Lewiston, New York," NLCO-001EV, May 17, 1979.

National Lead Company of Ohio, "Spoil Pile Radon Reduction Alternatives, DOE-Niagara Falls Site, Lewiston, New York," NLCO-002EV, June 19, 1979.

Neblett, F.W., "Economic Projections for the Decontamination of Steel Scrap by Smelting," NationalLead Company of Ohio, December 29, 1977.

Nemec, J.F., "An Engineered Approach to Decommissioning," United Nuclear Industries, November 1978.

Nielson, K.K., R.L. Brodzinski, and N.A. Wogman, "In Situ Transuranium Element Measurement Technique for Wastes Associated With Power Reactor Fuels," Proceedings of the American Nuclear Society Topical Meeting on Analytical Methods for Safeguard and Accountability Measurement of Special Nuclear Material, Williamsburg, Virginia, May 15-17, 1978.

Nunn, S.E., and D.C. Shoemaker, "233-S Building Decontamination and Decommissioning Safety Assessment Document," RHO-CD-658, March 1979.

O'Hara, F.A., et al., "Preliminary Environmental Implictions of Alternatives for Decommissioning and Future Use of the Western New York Nuclear Fuel Services Center," BMI-X698, Battelle, Columbus Laboratories, December 1978, revised February 1979.

Olsen, R.L., "Soil Characterization Procedures," CRD-78-096, Rockwell International, August 31, 1978.

Pacific Northwest Laboratory, Resource Book -- Disposition of Retired Contaminated Facilities at Hanford, BNWL-MA-88, Richland, Washington, 1979 (Revisions).

Phillips, S.J., et al., "Initial Site Characterization and Evaluation of Radionuclide Contaminated Solid Waste Burial Grounds," BNWL-2184, Battelle, Pacific Northwest Laboratory, 1977.

Powers, E.W., and E.A. Wegerner, "Hanford Production Reactor Decommissioning Study - 100-F Site Disposition Plan and Activities Definition," UNI 1002, United Nuclear Industries, April 28, 1978.

Punnet, M., "Design and Material Study for Portable Smelter Air Structure," Birdair 7737-1, December 1977.

Randolph, M.L., A.P. Watson, and F.R. O'Donnell, "Generic Assessment of Radiation Exposures to Workers in a Portable Smelter and to the Surrounding Population," ORNL-TM-6442, Oak Ridge National Labortory, October 1978.

Rasmussen, T.L., "Decontamination and Decommissioning (D&D) Plan for the Organic Moderated Reactor Experiment (OMRE)," WMP-77-17, Department of Energy, Idaho Operations Office, December 1977.

Reynolds Electrical & Engineering Company, "Project Gnome Decontamination and Decommissioning Plan," NVO-202, April 1979; Addendum A, July 1979; Addendum B, September 1979; and Errata, September 1979.

Reynolds Electrical & Engineering Company, "Safety Analysis Report for Tory II-C Fuel Recovery," NVO-164, December 1975.

Reynolds Electrical & Engineering Company, Inc., "Gnome Site Decontamination and Decommissioning - Phase 1, Radiological Survey and Operations Report, Carlsbad, New Mexico," NVO/0410-48, December 1978.

Rickard, W.H., and E.L. Klepper, "Ecological Aspects of Decommissioning and Decontamination of Facilities on the Hanford Reservation," BNWL-2033, Battelle, Pacific Northwest Laboratory, June 1976.

Roche, C.T., et al., "A Nondestructive Assay System for Use in Decommissioning of Plutonium-Handling Facility," ANL-79-60, Argonne National Laboratory, July 1979.

Rockwell Hanford Operations, "Environmental Assessment, Decommissioning and Decontamination Activity, Hanford Building Disposal Demonstration Project, Redox Plutonium Concentration (233-S) Building," DOE/EA-0021, March 1978.

Rockwell Hanford Operations, "Volume Reduction of Metallic Waste by Vacuum Meltdown," U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1978, DOE/EV-0046, September 1979.

Sande, W.E., et al., "Decontamination and Decommissioning of Nuclear Facilities - A Literature Search," BNWL-1917, Battelle, Pacific Nothwest Labortory, May 1975.

Smith, D.L., "Decommissioning Plan for the BORAX-V Reactor Facility," Department of Energy, Idaho Operations Office, to be published June 1979.

Smith, D.L., "Decontamination and Decommissioning (D&D) Plan or the Heat Transfer Reactor Test Assemblies, HTRE-2 and HTRE-3," PR-W-79-001, Department of Energy, Idaho Operations Office, January 1979.

Stelle, A.M., "SBER Facility Decommissioning Final Report," ESG-DOE-13237, Rockwell International, February 25, 1976.

Tuttle, R.J., "Radiation Protection in Decommissioning the Sodium Reactor Experiment," ANS Winter Meeting, Washington, D.C., November 1978.

United Nuclear Industries, "Hanford Production Reactor Decommissioning Study - 100-F Site Disposition Plan - Activities Description," UNI 1003:

Koochi, A.K., "Activity Description No. I - Site Preparation," in draft.

Koochi, A.K., "Activity Description No. II - 100-F Building Decontamination and Decommissioning," December 15, 1978.

Powers, E.W., "Activity Description No. III - 100-F Reactor Block Dismantling," September 15, 1978.

Koochi, A.K., "Activity Description No. IV - Reactor Support and Biological Facilities Decontamination and Decommissioning," in draft.

Ureda, B.F., and G.W. Meyers, "Design Considerations for Facility Decommissioning," presented at the American Nuclear Society Decommissioning Seminar, September 16-20, 1979.

Ureda, B.F., and J.W. Carroll, "Environmental Protection Experience in Atomics International's Recent Decommissioning Programs," presented at the U.S. DOE Environmental Control Symposium, Washington, D.C., November 28-30, 1979, DOE/EV-0046, September 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Assessment of the Grand Junction Site and Associated Properties, Grand Junction, Colorado," FBDU 251-303, Draft Report, August 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Assessment of the Mexican Hat Site and Associated Properties, Mexican Hat, Utah," FBDU 251-302, Draft Report, August 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Assessment of the Slick Rock Site and Associated Properties, Slick Rock, Colorado," FBDU 251-304, Draft Report, September 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Assessment of the Vitro Site and Associated Properties, Salt Lake City, Utah," FBDU 251-301, Draft Report, June 1979.

Ford, Bacon & Davis Utah Inc., "Laboratory Research on Tailings Stabilization Methods and Their Effectiveness in Radiation Containment," GJT-21, April 1978.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Vitro Site," GJT-1 and 1S, April 30, 1976.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Converse County Site," GJT-15 and 15S, December 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Ambrosia Lake Site," GJT-13 and 13S, December 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Falls City Site," GJT-16 and 16S, December 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Durango Site," GJT-6 and 6S, November 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Green River Site," GJT-14 and 14S, December 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Grand Junction Site," GJT-9 and 9S, October 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Lakeview Site, GJT-18 and 18S, December 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Gunnison Site," GJT-12 and 12S, November 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Maybell Site," GJT-11 and 11S, October 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Lowman Site," GJT-17 and 17S, December 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Monument Valley Site," GJT-4 and 4S, March 31, 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Mexican Hat Site," GJT-3 and 3S, March 31, 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Ray Point," GJT-20, December 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Naturita Site," GJT-8 and 8S, November 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Riverton Site," GJT-19 and 19S, December 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Rifle Sites," GJT-10 and 10S, October 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Slick Rock Sites," GJT-7 and 7S, October 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Shiprock Site," GJT-2 and 2S, March 31, 1977.

Ford, Bacon & Davis Utah Inc., "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Tuba City Site," GHT-5 and 5S, March 31, 1977.

Ford, Bacon & Davis Utah Inc., "Radiation Pathway and Potential Health Impacts From Inactive Uranium Mill Tailings," GJT-22, July 1978.

Goldsmith, W.A., and F.F. Haywood, "Radon Lung Dosimetry: Exposure Condition - A Survey of the Literature," ORNL/TM 5286, Draft, Oak Ridge National Laboratory.

Goldsmith, W.A., F.F. Haywood, and D.J. Crawford, "Atmospheric Dispersion of Radon From Uranium-Mill Tailings," presented at Nuclear Regulatory Commission Workshop on Modeling Radon Releases From Uranium Mines and Mills, Bethesda, Maryland, November 8-9, 1978.

Goldsmith, W.A., F.F. Haywood, and R.W. Leggett, "Transport of Radon Which Diffuses From Uranium-Mill Tailings," presented at Natural Radiation Environment III Symposium, Houston, Texas, April 23-28, 1978.

Hartley, J.N., "Use of Asphalt Emulsion Sealants for Stabilizing Uranium Mill Tailings," BNWL-SA702, Battellem Pacific Northwest Laboratory, presented at the EPRI Fuel Cycle Risk Assessment Workshop, February 9-10, 1977.

Hartley, J.N., and P.L. Koehmstedt, "Asphalt Emulsion Sealing of Uranium Tailings," in Pacific Northwest Laboratory Annual Report for 1978 to the DOE Assistant Secretary for Environment, Part 5, PNL-2850, Battelle, Pacific Northwest Laboratory, February 1979.

Hartley, J.N., et al., "Asphalt Emulsion Sealing of Uranium Mill Tailings Laboratory and Field Studies Annual Report," November 1979, in progress.

Haywood, F.F., et al., "Assessment of the Radiological Impact of the Inactive Uranium-Mill Tailings at Mexican Hat, Utah," ORNL-5448, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Assessment of the Radiological Impact of the Inactive Uranium-Mill Tailings Pile at Salt Lake City, Utah," ORNL/TM-5251, Oak Ridge National Laboratory, November 1977.

Haywood, F.F., et al., "Assessment of the Radiological Impact of the Inactive Uranium-Mill Tailings at Monument Valley, Arizona," ORNL-5449, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Assessment of the Radiological Impact of the Inactive Uranium-Mill Tailings at Naturita, Colorado," ORNL-5454, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Assessment of the Radiological Impact of the Inactive Uranium-Mill Tailings at Shiprock, New Mexico," ORNL-5447, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Assessment of the Radiological Impact of the Inactive Uranium-Mill Tailings at Grand Junction, Colorado," ORNL-5467, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Tailings at Gunnison, Colorado," ORNL-5453, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Ambrosia Lake, New Mexico," ORNL-5458, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Durango, Colorado," ORNL-5451, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Green River, Utah," ORNL-5459, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Rifle, Colorado," ORNL-5455, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings (Spook Mill), Converse County, Wyoming," ORNL-5460, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Slick Rock, Colorado," ORNL-5452, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Tuba City, Arizona," ORNL-5450, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Falls City, Texas," ORNL-5462, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Riverton, Wyoming," ORNL-5461, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Lakeview, Oregon," ORNL-5464, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Inactive Uranium-Mill Tailings at Ray Point, Texas," ORNL-5463, Draft, Oak Ridge National Laboratory.

Haywood, F.F., et al., "Radiological Survey of the Radioactive Sands and Residues at Lowman, Idaho," ORNL-5465, Draft, Oak Ridge National Laboratory.

Haywood, F.F., P.T. Perdue, and B.S. Ellis, "Radiological Survey of the Inactive Uranium-Mill Tailings at Maybell, Colorado," ORNL-5456, Draft, Oak Ridge National Laboratory.

Jensen, C.M., et al., "Emanating Power and Diffusion of Radon Through Uranium Mill Tailings," Ford, Bacon & Davis Utah Inc., Proceedings of the Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings, OECD Nuclear Agency, Albuquerque, Nex Mexico, July 1978.

Koehmstedt, P., J. Hartley, and D. Davis, "Engineering Evaluation of the Former Middlesex Sampling Plant and Associated Properties, Middlesex, New Jersey," Brookhaven National Laboratory, in progress.

Koehmstedt, P., J. Hartley, and D. Davis, "Engineering Evaluation of the Former Vitro Rare Metals Plant, Canonsburg, Pennsylvania," Brookhaven National Laboratory, in progress.

Koehmstedt, P., J. Hartley, and D. Davis, "Engineering Evaluation of the Middlesex Municipal Landfill Site, Middlesex, New Jesey," Brookhaven National Laboratory, in progress.

Koehmstedt, P., J. Hartley, and D. Davis, "Engineering Evaluation of the Pennsylvania Railroad Landfill Site, Burrell Township, Pennsylvania," Brookhaven National Laboratory, in progress.

Koehmstedt, P., J. Hartley, and D. Davis, "Environmental Analysis of the Former Vitro Rare Metals Plant, Canonsburg, New Jersey," Brookhaven National Laboratory, in progress.

Koehmstedt, P., J. Hartley, and D. Davis, "Environmental Analysis of the Former Middlesex Sampling Plant and Associated Properties, Middlesex, New Jersey," Brookhaven National Laboratory, in progress.

Koehmstedt, P., J. Hartley, and D. Davis, "Environmental Analysis of the Middlesex Municipal Landfill, Middlesex, New Jersey," Brookhaven National Laboratory, in progress.

Koehmstedt, P., J. Hartley, and D. Davis, "Environmental Assessment of the Vitro Site and Associated Properties, Salt Lake City, Utah," Draft, Brookhaven National Laboratory, October 1978.

Koehmstedt, P., J. Hartley, and D. Davis, "Use of Asphalt Emulsion Sealants To Contain Radon and Radium in Uranium Tailings," BNWL-2190, Battelle, Pacific Northwest Laboratory, January 1977.

Macbeth, P.J., et al., "Measurement of the Surface Radon Flux From Uranium Mill Tailings," Ford, Bacon & Davis Utah Inc., presented at ANS Conference, New York City, June 1977.

Overmyer, R.F., and V.C. Rogers, "Reduction of Radon Flux From Uranium Tailings," Ford, Bacon & Davis Utah Inc., presented at American Mining Congress, Las Vegas, Nevada, October 1978.

Perdue, P.T., R.W. Leggett, and F.F. Haywood, "A Technique for Evaluating Airborne Concentrations of Daughters of Radon Isotopes," presented at Natural Radiation Environment III Symposium, Houston, Texas, April 23-28, 1978.

Rogers, V.C., "Engineering Assessment of Inactive Vitro Uranium Mill Tailings at Salt Lake City, Utah," Ford, Bacon & Davis Utah Inc., presented at ANS 1976 International Conference, Washington, D.C., 1976.

Rogers, V.C., "Health Effects Estimations of the Inactive Vitro Uranium Mill Tailings," Ford, Bacon & Davis Utah Inc., presented at ANS 1976 International Conference, Washington, D.C., 1976.

Rogers, V.C., "Radiological Criteria for the Phase II Inactive Mill Tailings Program," Ford, Bacon & Davis Utah Inc., presented at ANS Conference, San Francisco, California, November 1977.

Rogers, V.C., and R. Baird, "Radiation Pathways and Potential Health Impacts From Inactive Uranium Mill Tailings," American Nuclear Society Transactions, Ford, Bacon & Davis Utah Inc., November 1978.

Rogers, V.C., R.F. Overmyer, and R.C. Varley, "Engineering Evaluation of the Decommissioning of Former Uranium Ore Processing Facilities," Ford, Bacon & Davis Utah Inc., presented at International Symposium on the Decommissioning of Nuclear Facilities, Vienna, Austria, November 1978.

Scheitlin, F.M., and W.D. Bond, "Removal of Hazardous Radionuclides From Uranium Ore and/or Mill Tailings: Progress Report for the Period October 1, 1978, to September 30, 1979," Draft, 1979.

GRAND JUNCTION REMEDIAL ACTION PROGRAM

State of Colorado, "Progress Report on the Grand Junction Uranium Mill Tailings, Remedial Action Program," Report to Congress, February 1979.

REMEDIAL ACTIONS AT FORMERLY UTILIZED MANHATTAN ENGINEER DISTRICT/ATOMIC ENERGY COMMISSION SITES

Argonne National Laboratory, "Radiological Survey of Site A, Palos Park Forest Preserve, Chicago, Illinois," DOE/EV-0005/7, April 1978.

Argonne National Laboratory, "Radiological Survey of the Former GSA 39th Street Warehouse, 1716 West Pershing Road, Chicago, Illinois," DOE/EV-0005/9, January 1979.

Argonne National Laboratory, "Radiological Survey of the Museum of Science and Industry, 57th Street and Lake Shore Drive, Chicago, Illinois," DOE/EV-0005/13, February 1979.

Berven, B.A., et al., "Results of Ground Level Radiation Measurements in Support of the 1978 Aerial Survey of the Lake Ontario Ordnance Works, Lewiston, New York," ORNL/TM-7004, Oak Ridge National Laboratory, September 1979.

Cagle, C.D., and L.P. Pugh, "Decommissioning Study for the Homogeneous Reactor Experiment No. 2 (HRE-2)," ORNL/CF-76/66, Oak Ridge National Laboratory, February 19, 1976.

Cagle, C.D., and L.P. Pugh, "Decommissioning Study for the Low-Intensity Testing Reactor," ORNL/CF-75-6-67, Oak Ridge National Laboratory, June 25, 1975.

Cagle, C.D., and L.P. Pugh, "Decommissioning Study for the ORNL Graphite Reactor (OGR)," ORNL/CF-76/196, Oak Ridge National Laboratory, July 8, 1976.

Cagle, C.D., and L.P. Pugh, "Decommissioning Study for the ORNL Molten-Salt Reactor Experiment (MSRE)," ORNL/CF-77/391, Oak Ridge National Laboratory, Aguust 25, 1977.

Ford, Bacon & Davis Utah Inc., "Engineering Evaluation of the Former Middlesex Sampling Plant and Associated Properties, Middlesex, New Jersey," FBDU-230-001, July 1979.

Ford, Bacon & Davis Utah Inc., "Engineering Evaluation of the Middlesex Municipal Landfill Site, Middlesex, New Jersey," FBDU-230-004, July 1979.

Ford, Bacon & Davis Utah Inc., "Engineering Evaluation of the Pennsylvania Railroad Landfill Site, Burrell Township, Pennsylvania," FBDU-230-003, July 1979.

Ford, Bacon & Davis Utah Inc., "Engineering Evaluation of the Vitro Rare Metals Plant, Canonsburg, Pennsylvania," FBDU-230-002, July 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Analysis of the Former Middlesex Sampling Plant and Associated Properties, Middlesex, New Jersey," FBDU-230-005, July 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Analysis of the Middlesex Municipal Landfill Site, Middlesex, New Jersey," FBDU-230-008, July 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Analysis of the Pennsylvania Railroad Landfill Site, Burrell Township, Pennsylvania," FBDU-230-007, July 1979.

Ford, Bacon & Davis Utah Inc., "Environmental Analysis of the Vitro Rare Metals Plant, Canonsburg, Pennsylvania," FBDU-230-006, July 1979.

Goldsmith, W.A., F.F. Haywood, and D.J. Crawford, "Atmospheric Dispersion of Radon From Uranium-Mill Tailings," presented at Nuclear Regulatory Commission Workshop on Modeling Radon Releases From Uranium Mines and Mills, Bethesda, Maryland, November 8-9, 1978.

Goldsmith, W.A., F.F. Haywood, and R.W. Leggett, "Transport of Radon Which Diffuses From Uranium Mill Tailings," presented at Natural Radiation Environment III Symposium, Houston, Texas, April 23-28, 1978.

Haywood, F.F., "In Search of Yesteryear," presented at the 23rd Annual Meeting of the Health Physics Society, Minneapolis, Minnesota, June 18-23, 1978.

Haywood, F.F., et al., "Radon and Radon Daughter Measurements at and Near the Former Middlesex Sampling Plant, Middlesex, New Jersey," ORNL/TM-5489, Oak Ridge National Laboratory, to be published.

Haywood, F.F., et al., "Radon and Radon Daughter Measurements at and Near the Former Middlesex Sampling Plant, Middlesex, New Jersey," ORNL-5489, Oak Ridge National Laboratory, to be published in FY 1979.

Haywood, F.F., et al., "Radon and Radon Daughter Measurements at and Near the Vitro Rare Metals Plant, Canonsburg, Pennsylvania," ORNL/TM-5533, Oak Ridge National Laboratory, to be published.

Haywood, F.F., et al., "Radon and Radon Daughter Measurements at and Near the Vitro Rare Metals Plant, Canonsburg, Pennsylvania," ORNL-5533, Oak Ridge National Laboratory, to be published in FY 1979.

Leggett, R.W., H.W. Dickson, and F.F. Haywood, "A Statistical Methodology for Radiological Surveying," to be published in proceedings of IAEA International Symposium on Advances in Radiation Protection Monitoring, Stockholm, Sweden, June 26-30, 1978.

Los Alamos Scientific Laboratory, "Radiological Survey and Decontamination of the Former Main Technical Area (TA-1) at Los Alamos, New Mexico," LA-6887, December 1977.

Oak Ridge National Laboratory, "Radiological Survey of the E.I. du Pont de Nemours and Company, Deepwater, New Jersey," Final Report, DOE/EV-0005/8, December 1978.

Oak Ridge National Laboratory, "Radiological Survey of the Former Horizons, Inc., Metal Handling Facility, Cleveland, Ohio," Final Report, DOE/EV-0005/10, February 1979.

Oak Ridge National Laboratory, "Radiological Survey of the Pennsylvania Railroad Landfill Site, Burrell Township, Pennsylvania," Final Report, DOE/EV-0005/12, February 1979.

Oak Ridge National Laboratory, "Radiological Survey of the Seneca Army Depot, Romulus, New York," Final Report, DOE/EV-0005/11, February 1979.

Perdue, P.T., R.W. Leggett, and F.F. Haywood, "A Technique for Evaluating Airborne Concentrations of Daughters of Radon Isotopes," presented at Natural Radiation Environment III Symposium, Houston, Texas, April 23-28, 1978.

Roy F. Weston, Inc., "Environmental Impact Assessment for Proposed Action at the Former AEC St. Louis Airport Storage Site, St. Louis, Missouri," prepared for Oak Ridge National Laboratory under subcontract No. S-7402, July 1979.

U.S. Department of Energy, "Radiological Survey of the Ashland Oil Company (Former Haist Property), Tonawanda, New York," Final Report, DOE/EV-0005/4, May 1978.

U.S. Department of Energy, "Radiological Survey of the Bayo Canyon, Los Alamos, New Mexico," Final Report, DOE/EV-0005/15, June 1979.

U.S. Department of Energy, "Radiological Survey of the E.I. du Pont de Nemours and Company, Deepwater, New Jersey," Final Report, DOE/EV-0005/8, December 1978.

U.S. Department of Energy, "Radiological Survey of the Former Linde Uranium Refinery, Tonawanda, New York," Final Report, DOE/EV-0005/5, May 1978.

U.S. Department of Energy, "Radiological Survey of the Former Vitro Rare Metals Plant, Canonsburg, Pennsylvania," Interim Report, DOE/EV-0005/3, April 1978.

U.S. Department of Energy, "Radiological Survey of the Middlesex Sampling Plant, Middlesex, New Jersey," Final Report, DOE/EV-0005/1, November 1977.

U.S. Department of Energy, "Radiological Survey of the Seaway Industrial Park, Tonawanda, New York," Final Report, DOE/EV-0005/6, May 1978.

U.S. Department of Energy, "Removal of a Contaminated Industrial Waste Line, Los Alamos, New Mexico," Final Report, DOE/EV-0005/14, April 1979.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

CONTRACTOR INDEX

CONTRACTOR INDEX