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SAND77-0034

Unlimited Release

Sandia Laboratories Energy Programs

Prepared by Sandia Laboratories, Albuquerque, New Mexico 87115
and Livermore, California 94550 for the United States Energy Research
and Development Administration under Contract AT(29-1) 789

Printed March 1977

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Sandia Laboratories

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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

Price: Printed Copy \$4.50 ; Microfiche \$3.00

SAND77-0034

Printed March 1977

SANDIA LABORATORIES ENERGY PROGRAMS

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ABSTRACT

Projects in the major fields of energy research and development are summarized. An overview is provided of Sandia's role as a multiprogram laboratory of the Energy Research and Development Administration.

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SANDIA LABORATORIES ENERGY PROGRAMS

INTRODUCTION

As one of the multiprogram laboratories of the Energy Research and Development Administration, Sandia Laboratories applies its resources to a number of nationally important programs. About 75 percent of these resources are applied to research and development for national security programs having to do primarily with nuclear weapons—the principal responsibility of the Laboratories. The remaining 25 percent are applied to energy programs and energy-related activities, particularly those requiring resources that are also used in nuclear weapon and other national security programs. Examples of such energy programs and activities are research into nuclear fusion, protection of nuclear materials from theft or diversion, and the disposal of radioactive waste. A number of technologies and disciplines developed for the weapon program are immediately applicable for the development of various energy sources. Instruments developed to detect, measure, and record the detonation of nuclear devices underground, now being used to support the development of in-situ processing of coal and oil shale, are examples. The purpose of this report is to provide an overview of these and other energy programs being conducted by these laboratories in the development of economical and environmentally acceptable alternative energy sources.

RESOURCES AND RESPONSIBILITIES

Sandia Laboratories, with facilities in Albuquerque, New Mexico, Livermore, California, and Tonopah, Nevada, is operated by the Bell System for the Energy Research and Development Administration under a no-fee, no-profit contract with the Western Electric Company. The federal government owns all facilities and supplies all funds for Sandia operations.

The Laboratories originated during World War II as part of the Manhattan Engineer District for development of the atomic bomb. The predominant responsibility of the Laboratories, while considerably enlarged since those beginnings, is fundamentally the same now as it was then: to develop and maintain the scientific and engineering expertise which will assure that our nation's nuclear weapon technology is second to none; to conduct research to generate new weapon concepts; to design and develop nuclear ordnance in conjunction with other national laboratories; to verify that the weapon stockpile remains a credible deterrent through continual assessment of safety and reliability; to modify weapons as necessary to meet new requirements, and to develop and apply advanced technologies for the protection of nuclear materials from theft.

Energy programs are undertaken when they require capabilities used at the Laboratories for the weapon program, and when they have no adverse effect upon that primary mission. The parallel operation of weapon and energy activities allows optimum use of facilities and other resources.

The average number of employees in fiscal year 1976 was 6700; this number is expected to increase to about 7200 in fiscal year 1977. Of the 6700 employees, 1800 were technical staff members with degrees about equally divided among PhD's, Masters, and Bachelors. About 70 percent of the technical staff members held degrees in engineering, 15 percent in physics, 6 percent in mathematics, 5 percent in chemistry, and the remaining 4 percent in various other technical fields. The technical staff was supported by 1900 technicians and craftsmen.

Some of the Sandia Laboratories research, engineering, and administrative buildings in Albuquerque, New Mexico, above; and Sandia Laboratories, Livermore, California, below.

Technical programs are directed by system engineering staffs. These staffs and Sandia management coordinate programs with ERDA through its Headquarters divisions and its Albuquerque Operations Office. These offices formulate major program direction and guidance, and establish priorities, levels of effort, and budgets. Once a program is established, the system engineering staff is responsible for providing technical direction as well as programmatic and fiscal control.

The system engineering staff is supported by scientists and engineers in all pertinent technical fields. These specialists are assigned to organizations dedicated to specific disciplines and technologies. Each of these organizations applies its resources to programs requiring its particular expertise, and also conduct research to advance its field. This arrangement provides capabilities in a wide range of disciplines that are available for a variety of programs. The regular application of acquired knowledge and skills to a spectrum of weapon and energy programs assures challenges to scientific and technical personnel and contributes to organization continuity and employee stability.

Technical capabilities are identified on the following page, with areas of specialty listed for each capability, and the operating budgets for fiscal years 1976 and 1977 are summarized.

A test and evaluation installation is located 8 kilometres south of the Albuquerque laboratory. Responses of systems and components to severe environments are determined here.

MANAGERIAL CAPABILITIES

SYSTEM ENGINEERING AND MANAGEMENT

Technical Management
Fiscal Controls
Program Direction

COMPONENT DEVELOPMENT

Electronic
Electrochemical
Explosives
Electromechanical
Mechanical

QUALITY ASSURANCE

Technical Management
Analysis
Testing
Evaluation

TECHNICAL CAPABILITIES

SCIENCE AND ENGINEERING

PHYSICAL SCIENCES SAND74-0074*

Physics of Surfaces and Near-Surface Layers
Physics of Solids
Solid Dynamics and Shock Wave Phenomena
Interaction of Radiation with Matter
Laser Physics
Relativistic Electron Beam Research
Research Reactors

APPLIED MATHEMATICS SAND74-0079

Development of Computer Codes
Discrete Mathematics
Mathematical Physics
Theoretical Mathematics
Statistical Analysis

EXPLOSIVES AND PYROTECHNICS

Detonation Physics SAND74-0081
Chemistry of Explosives
Chemistry of Pyrotechnics

ELECTROCHEMISTRY SAND74-0081

Electrochemical Power Sources
Physical Chemistry
Thermal Analysis

EARTH SCIENCES SAND74-0085

Numerical Methods
Terradynamics
Underground Physics
Drilling, Magma, and
Diagnostic Technologies
Rock Mechanics

ELECTROMECHANISMS SAND74-0081

Environmental Sensing
Guidance and Control
Switching Technology
Timing Technology
Analysis

MATERIALS AND PROCESSES SAND77-0002

Metallurgy
Composites
Surface Characterization and Film Deposition
Polymers
Ceramics
High-Temperature Characterization of Materials
Chemical and Laboratory Analysis

BIOSCIENCES

Environmental Biology
Applied Biology
Analytical Biology

ELECTRONICS SAND74-0086

Active Semiconductors
Hybrid Microcircuits
Vacuum Tubes
Pulsed High Energy Technology

AEROSCIENCES SAND74-0075

Aeroballistics
Aerodynamics
Atomic and Fluid Physics
Aerothermodynamics
Aerophysics
Atmospheric Environments
Fluid Dynamics
Aeromechanical Design

SAFETY ASSURANCE SAND74-0090

Safety Assessment
Safety Assurance
System Safety

RELIABILITY ASSURANCE SAND74-0080

Reliability Assessment
Statistical Design and Analysis
Human Factors
Quality Control

ANALYSIS AND TESTING

SYSTEMS ANALYSIS SAND74-0089

Problem Definition and Assessment
Concept Formulation
System Evaluation
Concept Optimization

ENGINEERING ANALYSIS SAND74-0087

Structural Mechanics
Stress Wave Analysis
Explosive Technology
Heat Transfer
Aerospace Engineering
Mechanism Analysis
Environment Analysis
Controls Engineering
Electrical Engineering
Nuclear Engineering
Reactor Safety Analysis

TESTING SAND74-0088

Environmental Simulation
Mechanical Loading
Radiation Loading
Development and Evaluation
Aerosciences
Material Response
Nondestructive Testing
Solar Systems
Field Testing
Tonopah Test Range
Nevada Test Site
Kauai Test Facility
Mobile Facilities
Remote Ranges

INSTRUMENTATION SAND74-0083

Data Acquisition
Transducers
Communications
Optical Recording
Mobile and Transportable Instrumentation
Special Instrumentation
Meteorological
Photometric
Quality Assurance
Radiation Analysis
In Situ Measurements and Control

DATA REDUCTION SYSTEMS SAND74-0083

Magnetic
Optical

SUPPORT FUNCTIONS

FABRICATION SAND76-0413

Metals
Glasses and Ceramics
Composites and Plastics
Electrical Components
Heat Treating and Finishing

INFORMATION SCIENCE SAND74-0082

Information Management
Information Dissemination
Reference and Translation

COMPUTATION SYSTEMS SAND74-0080

System Planning, Development, and Support
Central Computing
Remote Computing
Interactive Graphics
Computer-Based Special-Purpose Systems

DESIGN DEFINITION SAND76-0413

Design Drawings and Specifications
Computer-Aided Design
Information Control Systems

MEASUREMENT STANDARDS SAND74-0077

ERDA Standardization Program Management
Direct-Current Electrical Quantities
Microwave Quantities
Radiation
Mechanical
Environmental

ENVIRONMENTAL HEALTH SAND74-0082

Hazard Control
Radiation Dosimetry
Radiation Counting
Effluent Documentation

Feb. 1977

* Each of these technical capabilities is described in detail in separate reports, which are identified by number beside the titles. The reports are summarized in SAND74-0091 and are compiled in their entirety in SAND74-0092.

OPERATING BUDGET

Actual Cost for FY 76 and Estimated Cost for FY 77*
(\$ in Millions)

Activity	FY 76 (Excluding 1976T)	FY 77
For ERDA		
Weapons	\$196.3	\$227.3
Nuclear Material Security	4.6	13.1
Electron Beam and Laser Fusion	8.5	9.8
Fossil Energy	3.9	6.4
Solar, Geothermal, and Advanced Energy Systems	8.7	22.9
Conservation	1.0	2.4
Nuclear Energy	5.4	8.7
Environment and Safety	2.1	3.7
Total ERDA	\$230.5	\$294.3
For Other Federal Agencies		
Department of Defense	\$ 47.5	\$ 42.8
Nuclear Regulatory Commission	5.3	17.8
Other	3.8	6.5
Total Other Federal Agencies	\$ 56.6	\$ 67.1
Miscellaneous	\$.1	\$.2
TOTAL	\$287.2	\$361.6

*Compiled February 1977

ENERGY PROGRAMS AT SANDIA LABORATORIES*

*These energy programs are described in a report titled "Sandia Laboratories Energy Programs" and is identified by SAND77-0034.

SOLAR ENERGY

It is postulated in ERDA's national plan for developing alternate sources of power that solar energy will contribute to the nation's energy supply in two phases. In the midterm (1985-2000), it is projected that solar energy will be used in significant quantities to heat and cool entire business and residential communities. In the long term (post-2000), it is expected that solar electric energy may have wider application and could be produced by a variety of methods such as thermal, photovoltaic, and wind power.

Solar energy R&D at Sandia is concentrated in several aspects of the thermal and photovoltaic options. Numerous technical problems facing researchers in these areas must be solved before the various options can become economically competitive in the next 30 to 50 years.

If ERDA's goals are to be achieved, low-cost, reliable components with long operational lives must be developed. Materials for these components must be fabricated and engineered. Thermodynamic cycles compatible with temperatures and conditions associated with solar energy systems must be selected for efficient energy conversion. Performance standards and test procedures must be established for evaluating and improving energy conversion systems.

Sandia's system engineering organizations, supported by specialized technical organizations, provide capabilities for solving these problems. The capabilities range from conducting advanced system analyses, through providing detailed engineering design and operation of one-of-a-kind test facilities, to managing large experimental demonstration systems.

* * * * MAJOR PROJECTS * * * *

Central Receiver Solar Thermal Power System

A "central receiver" concept being developed by Sandia consists of a field of individually guided mirrors (heliostats) that redirect the sun's energy to a receiver mounted on top of a tower. In the receiver, radiant solar energy is absorbed in a circulating fluid and then is either used directly to power a conventional steam turbine generator or is transferred to a storage system for later use.

Although no technological breakthroughs are required for the central receiver concept, the program demands considerable new technology. Research and development initially is being concentrated on developing low-cost components and integrating these into efficient systems. The three major subsystems that require development are the receiver and collector, and thermal storage. The cost of the mirror field, for example, represents about a third to a half of the total cost for the plant.

Sandia's major responsibility in the solar thermal electric area is technical project management for a 10-megawatt (electric) Solar Central Receiver Pilot Plant, which is scheduled to be completed by 1980. To assist in resolving some of the technical problems that will be encountered in the design and construction of the plant, a 5-megawatt (thermal) Solar Thermal Test Facility is being constructed, with completion scheduled for December 1977. The facility will be used to evaluate heliostat mirror arrays, solar receiver boilers, and other critical components. It is expected that this facility will become an internationally used research and development tool, and will serve for many decades as a center for evaluating advanced solar hardware.

Mirror arrays, receivers, systems, and components will be tested and evaluated at this 5-megawatt installation which, when completed in late 1977, will be the largest such facility in the world. It will provide a center where scientists and engineers from the U.S. and other countries can test and evaluate solar designs.

Solar Total Energy

The purpose of the Solar Total Energy concept is to make it possible to provide most of the electrical, heating, air conditioning, and hot water needs of a small community by solar power. This concept, first proposed at Sandia in 1972, has now progressed to the point where a Solar Total Energy Test Facility is being constructed. Objectives of the facility are to:

- Establish concept feasibility by constructing a demonstration system that will supply the energy needs of an office building.
- Provide a versatile evaluation center for further development of subsystems and components.
- Determine areas of research and development that will best advance knowledge necessary for the Solar Total Energy project.
- Develop and validate a system-analysis computer program capable of evaluating possible total energy system configurations.
- Encourage private industry and business to participate in development of components which will eventually be placed on the market as commercial ventures.

The facility will have four different types of collector fields. The designs, being prepared by contractors, will be installed during 1977-78. Solar power will first be supplied to the office building in 1978. The system will be completed in 1979 and most of the building's power needs will be supplied by the sun in that year.

Sandia has been named Technical Project Manager for the National Solar Total Energy Program, with the responsibility of assuring that technical goals and schedules are realistic and that technical efforts associated with the program are making proper progress. Both in-house and contractor technical activities will be monitored.

The in-house effort is to develop and maintain technical expertise in tasks for which capability does not exist in the industrial sector, as well as to supplement and evaluate the results of contracted work.

Future project plans include maintaining a technology development program, managed by ERDA and performed by private industry, to assure that a choice of proven components and sub-systems is available for future solar total-energy systems. Also planned are two large-scale experiments with systems in the 200-500 kilowatt (electric) range, and construction of at least six demonstration plants, each with approximately a 2-megawatt (electric) output. These plants will be commercially operated.

The Solar Total Energy Test Facility, to be completed and operating by 1978, will be a versatile test bed for evaluation of materials, components, and systems needed for a practical solar energy center. As ERDA's Technical Project Manager for the National Solar Total Energy program, Sandia will aid in and monitor experiments conducted at the center by industrial contractors and others.

Photovoltaics

Photovoltaics is the direct conversion of solar energy into electricity through the use of solid-state devices. The central objectives of the national photovoltaic program are to develop low-cost systems and to stimulate industrial and commercial interest in producing and distributing them. To accomplish these objectives it is necessary to identify the most efficient and cost-effective systems, and to demonstrate the concept in residential, commercial, and industrial applications.

Of three project managers chosen by ERDA for the national program, Sandia was given responsibility for system definition. With this responsibility, Sandia is concerned with developing conceptual designs to the point where a preferred system can be identified, and with determining the technologies required to attain desired subsystem performance. Designs and specifications are provided for a wide range of photovoltaic applications potentially significant to the national program. Current activity is directed toward developing low-cost components in order to make the system price-competitive as soon as possible. This effort involves system studies, practical application of techniques, examination of power processing and control, storage and concentration, and test and demonstration of pilot facilities. Information gained will be widely disseminated to others involved in the program.

Specific projects being pursued are:

- Determining performance of photovoltaic systems in direct sunlight;
- Investigating single-crystal solar cells for use at illumination levels of 50 to 100 suns;
- Simulating performance of photovoltaic energy systems by computer.

This array of photovoltaic devices is part of an experiment to develop low-cost methods of converting solar energy directly into electricity. If these or similar devices are proven successful, they would allow the bypassing of conventional intermediate conversion steps such as the heating of water.

Other Solar Energy Activities

Sandia seeks economical vertical-axis wind turbine systems that can produce electrical power in sufficient quantity for utility grids. Two intermediate objectives have been set:

To construct a demonstration test device (55-ft turbine diameter) which will allow early investigation of a complete system;

To establish a scale-up design comparable to the ERDA 100 kilowatt (electric) horizontal-axis system. This will allow comparative performance and cost judgments to be made.

The ultimate goal of the program is to design and install a megawatt-range system.

The Darrieus vertical-axis wind turbine, with 15-foot blades, has been in operation at Sandia since 1974. The turbine extracts about 35% of the energy from passing winds, compared to 38 to 40 percent for horizontal propeller designs. However, it is simpler in construction and lighter in weight than conventional "windmills." This design produces 1 kw of electricity in a 15-mph wind. A 55-foot system is being installed to produce 60 kw; this model will be followed in 1978 by a 100-foot system that will generate 100 kw. Such designs could ultimately provide up to 10 percent of the nation's electricity.

Other solar energy activities include the design, construction, and initial operation of a solar-powered irrigation pump. This project is being performed in cooperation with New Mexico State University. Sandia is also assisting the ERDA Solar Heating and Cooling Technology Branch by applying system analysis techniques to help identify the most promising Research and Development avenues in solar-powered heating and cooling. Related to solar-energy activities are studies and laboratory experiments being conducted on advanced methods of energy storage such as compressed gas and flywheels.

This conceptual drawing illustrates an experiment in which solar energy will be used to furnish power to an irrigation system. The experiment is being conducted jointly by Sandia and New Mexico State University.

FOSSIL ENERGY

For the near term, part of the national energy plan is directed at expanding major domestic energy systems: locating new sources for coal, gas, and oil, and developing improved extraction techniques for known sources. For the mid-term and beyond, the plan calls for accelerated development of new processes for extracting oil from shale and for producing synthetic fuels from coal.

Sandia has ongoing projects in drilling, offshore technology, enhanced gas extraction, in-situ coal gasification, in-situ oil-shale retorting, coal liquification, coal combustion, and magnetohydrodynamics. All of these projects need instrumentation for process evaluation and control. Data thus obtained, coupled with system analyses and the use of process models, provide information needed for advanced development studies.

Various elements of the nuclear weapon program have immediate application in fossil-energy research and development projects. These include:

- Use of advanced instrumentation and diagnostic techniques.

- Availability of mobile data-acquisition facilities.

- Determination of material properties.

- Development of materials capable of withstanding adverse environments.

- Advanced modeling and diagnostic techniques used in studying fluid flow.

In one project, instrumentation and diagnostic methods are being developed to assist in evaluation of enhanced gas-extraction techniques. Massive hydraulic fracturization is receiving the greatest attention for this application. Fractures are produced in a low-permeability reservoir by pumping fluid and sand into wells under high pressure. The fractures are kept open by the sand, so that larger volumes of gas can flow into the production well.

Projects dealing with massive hydraulic fracturing are being pursued in cooperation with commercial gas and oil companies. One project is the development of instrumentation techniques that can help characterize the orientation and dimensions of fractures. In another project at the Nevada Test Site, parametric studies of fracturing processes are underway. In this case, direct physical observation of the fracturing process is made possible by mining into the fractured zone.

Successful development of offshore oil and gas reserves is dependent upon improvements in drilling technologies. Drilling materials and fluids required to perform in these harsher environments are under evaluation and development. A more critical problem is the need to measure the severe engineering environmental forces that will be encountered in new offshore regions. Sandia's earth-penetrating weapon system is being modified for use in evaluating seabed characteristics, the objective being a vehicle/instrument system that can be emplaced in an ocean or arctic environment to measure engineering properties remotely, transmitting the data to distant receiver stations.

The use of coal to generate electricity or for other commercial activities is limited by environmental considerations. Efforts to remove sulfur and nitrogen effluents from coal to make it more acceptable include the use of advanced diagnostic tools for studies of combustion processes, development of alloys able to withstand the severe corrosion that results from coal desulfurization, and the modeling of gas flows in magnetohydrodynamic processes.

Mid-term energy projects include investigation of the causes of catalyst deactivation in desulfurization processes during coal liquefaction, the role of mineral matter in the liquefaction process, and the kinetics of coal liquefaction and hydrodesulfurization.

Instrumentation and analytical support are being provided for the study of in-situ processing of coal and oil shale. Instrumentation is used to determine the size and extent of fractures produced in fossil beds when explosives are detonated in drill holes. Additional instrumentation determines the rate and location of underground coal combustion, and these data are used in controlling the process. Analytical tools provide information needed for controlling the fracturization of fossil beds by modeling the physical characteristics of the underlying earth.

* * * * * MAJOR PROJECTS * * * * *

Enhanced Gas Extraction

In 1973, the Federal Power Commission estimated that there are 600 trillion cubic feet of natural gas in three basins in the western U.S. The purpose of the enhanced gas extraction program is to study ways of economically obtaining this resource from the tight sandstone reservoirs in which it is contained. Limited efforts have been devoted to developing a massive hydraulic fracturing technology which gives indications of becoming a commercially viable way of putting this gas to use. However, the mixed results obtained from facturing experiments emphasize the need for developing a greater understanding of the technology and for devising improved diagnostic techniques for the process.

Sandia's responsibilities in the enhanced gas extraction program are twofold:

To develop diagnostic techniques by which hydraulically created fractures can be characterized as an aid to the evaluation of field experiments;

To conduct simultaneous experiments in which hydraulic fracturing parameters are studied directly, leading to improved techniques.

In the first of these areas, Sandia is developing seismic and electrical potential geophysical diagnostic techniques to be used in mapping fracture systems. Field experiments have been conducted in collaboration with the El Paso Natural Gas Company, the Amoco Production Company, and the Columbia Gas Company. The azimuthal orientation and some asymmetries of fracture patterns have been determined to date.

In the second area, simulation tests are being conducted at the Nevada Test Site. This site contains a sizable complex of tunnels which are being used to investigate fracturing fluids, proppants (material used to sustain crack openings -- generally sand), injection conditions, and the effects of geological formations on fracturing processes. Created fracture systems are exposed by mining, allowing direct observation and measurement.

An advisory panel from private industry provides guidance in designing fracturing experiments.

Offshore Technology

Production of crude oil and natural gas from domestic sources has been declining since 1972. If this trend is to be halted, new sources must be located. The U.S. Geological Survey estimates that the largest remaining undiscovered sources are probably in the Gulf of Alaska and other arctic regions, and off the Atlantic seaboard. Exploration and development of new fields in these areas undoubtedly will present a spectrum of problems such as seismic activity, massive ice movements, and violent storms of the kind currently being encountered in the North Sea. Before such new petroleum provinces can be developed, it is necessary to monitor and measure these environmental forces as well as to obtain geophysical data on ocean-bottom sediments.

The ERDA Division of Oil, Gas, and Shale Technology has funded Sandia to apply its earth-penetrating weapon and instrumentation technologies to the development of an instrumentation system that will be easy to emplace and can measure a number of parameters that will aid in defining these hostile environments. The effort has been designated the Marine Sediment Penetrometer project.

Instrumentation packages capable of being dropped from aircraft or ships penetrate the soil or sediments. Description of the physical properties of the soil or sediments is then transmitted to the surface. These penetrometers are being developed to measure and monitor environmental forces related to geophysical exploration in ocean-bottom sediments.

The penetrometer is an aero- and hydrodynamically shaped projectile that can be deployed from ships. After falling free through the water, the penetrometer enters the seabed sediments, coming to rest between 20 and 100 feet below the ocean floor. Measurements of the projectile's deceleration as it passes through the muds will give a qualitative estimate of sediment strength and stratification. Sensors, mounted in the penetrometer, are capable of measuring a variety of parameters while the projectile is embedded in the ocean bottom. Initial emphasis will be directed at

measuring strong sediment motions caused by seismic activity. The data will be stored in an on-board solid-state memory and transmitted on command over an acoustic data link to a shipboard receiving station, or through a sonobuoy relay to an overflying aircraft. An existing model of the penetrometer uses a hardwire connected to a recorder on a surface vessel for transmitting deceleration data during sediment penetration. A proposed model will have an expanded sensing capability and will eliminate the hardwire, providing a truly remote long-life sensing station.

Coal Gasification

The in-situ or underground burning of coal in order to extract its usable gases is a way of obtaining energy from coal deposits without mining. Such an approach would make resource utilization more efficient and make it possible to extract resources impractical or impossible to obtain through mining. Some aspects of the process are environmentally attractive since most of the potentially polluting ash and sulfur contaminants remain underground. There is concern that groundwater may become polluted by process residues, and studies of underground liquid transfer mechanisms are underway to address this concern.

The process involves gaining access to the coal by drilling wells, establishing the permeability of coal seams between wells, igniting the seams, sustaining gasification by injecting air or oxygen, and withdrawing the product gas (chiefly hydrogen, carbon monoxide, carbon dioxide, and methane) from neighboring wells. The product gas can be burned on-site to generate electricity, or used as a chemical feedstock, or possibly upgraded to synthetic natural gas.

Development of gasification technology requires both a thorough understanding and control of the process; lack of this knowledge has prevented the use of in-situ coal gasification despite worldwide interest for over 100 years. The Sandia program, funded by the ERDA Division of Oil, Gas, and Shale Technology, addresses these unknowns by modifying instrumentation techniques developed in the nuclear weapon underground testing program. Such techniques are required because the coal combustion process, hundreds of feet underground, can be made to proceed more efficiently if factors affecting combustion can be detected and adjusted.

Sandia's program has been conducted in association with the Laramie Energy Research Center's in-situ coal gasification program and its field experiments being held near Hanna, Wyoming. Both in-situ diagnostic and remote sensing techniques have been fielded, using a combination of instrumentation wells and near-surface instrumentation arrays. Numerous thermocouple sensors provide temperature information as well as a space-time description of the process. Sampling canisters are used to obtain gas samples for analysis and for the measurement of local pressures. Results provide an overall picture of the continuously changing gasification process and will form the basis for a process-control system.

Synthetic Fuels

Chemical Studies of the Synthoil Process

Large quantities of natural gas and crude oil are burned in generating electricity. These two rapidly diminishing fossil fuels could be used for other purposes if coal, an abundant resource, could be burned in an environmentally acceptable manner for electricity generation. One approach, being pursued by the Pittsburgh Energy Research Center and sponsored by ERDA's Division of Coal Conversion and Utilization, is to convert coal into a clean-burning liquid fuel for use by utility companies. The fuel is called Synthoil.

To make Synthoil, coal, in a recycled oil slurry, is converted into a liquid by heat and pressure in the presence of a catalyst. Contaminant sulfur is combined with hydrogen and removed from the coal, leaving Synthoil a comparatively clean-burning fuel. The process still has unresolved problems. Sandia is working with Pittsburgh Energy Research Center in three major areas:

Investigation of the causes of catalyst deactivation and techniques to improve catalyst lifetime;

Examination of the role of naturally occurring minerals in liquefaction; and

Measurement of the kinetics of coal liquefaction and the hydrodesulfurization process under Synthoil-stimulated conditions.

In the first task a wide variety of surface- and bulk-sensitive analytical instruments are used to determine the state of new, used, and regenerated catalysts. These analyses indicate physical and chemical changes that occur during processing, and offer insight into deactivation and reactivation mechanisms. Although catalysts are not consumed in the chemical reactions they initiate, secondary chemical activity during the process does attack the catalyst, ultimately limiting its effectiveness; the catalyst may become coated, preventing necessary contact with the reacting materials.

In the second task, studies are performed to assess the contribution minerals make in coal liquefaction. Some naturally occurring minerals are catalytic and aid the liquefaction process, suggesting the possibility of using them instead of commercial catalysts. The study involves establishing correlations among mineral content, extent of liquefaction, and product quality.

The third task involves the design, construction, and operation of a bench-scale Synthoil reactor system. The test reactor, which will create pressures up to 5000 pounds/in² and temperatures up to 500 degrees C, will permit detailed experimentation with process control and operation, with the objective of aiding in the optimization of the Synthoil process.

Oil Shale

Efforts to extract oil from the nation's vast oil-shale reserves have primarily consisted of conventional mining of the shale and crushing it to a size suitable for surface retorts, where heat is used to transform the solid hydrocarbon kerogen into liquid oil.

This proven technology, if applied on a scale sufficient to ease the country's oil shortage, might create significant environmental problems. The process consumes large quantities of water, leaves immense amounts of spent shale, and requires large-scale mining operations. For economic reasons, surface processing is limited to higher-grade shales (those containing 30 gallons or more of oil per ton of rock); some 67 percent of the nation's estimated 2-billion-gallon resource might never be used by this method. In-situ processing may overcome some of these disadvantages.

A modified in-situ processing technology involves driving tunnels into shale, removing about 20 percent of the shale to create porosity, fracturing the remainder with explosives, and generating heat via combustion for the conversion process. This method, which is in a preliminary state of development, extracts oil, but requires the removal of large amounts of shale from below ground.

During true in-situ retorting, the shale is completely processed in place. Access is gained to the shale by boreholes, porosity is created by mechanical or explosive means, the shale is fractured, and oil is produced by combustion or by injection of hot fluids. A successful in-situ technology could have

economical and environmental advantages and at the same time should increase the amount of oil shale which could be exploited. The process, however, is still in the experimental stage, and a number of complex problems remain to be solved.

The oil-shale program at Sandia, funded by the ERDA Division of Oil, Gas, and Shale Technology, consists of three parts:

- Assessing experimental techniques for the best way of reducing oil-shale beds to rubble (rubbleizing) and of retorting the beds;

- Developing advanced instrumentation techniques with which to monitor, evaluate, and control in-situ fracturing and retorting processes; and

- Studying rock mechanics to determine mechanical properties and to develop numerical modeling techniques for describing the static and dynamic responses of oil shale.

The field program is a series of experiments conducted with the Laramie Energy Research Center in the Green River oil-shale formation near Rock Springs, Wyoming. Two methods of emplacing explosives are being tested for their ability to reduce shale to rubble. One method is detonation of explosives in boreholes drilled into the shale. The other is detonation of a liquid explosive injected into horizontal hydraulic fractures in the shale. The first test of each method is being made without subsequent retorting. Instead, the fractured region is "frozen" by squeeze grouting, followed by extensive coring to assess the extent and degree of fracturing. The second experiment will include both rubbleization and retorting.

Another part of the oil-shale program is the development of numerous instrumentation techniques that will allow assessment of shale rubbleization. An array of stress gages placed in the shale around the explosive charges will monitor spatial and temporal distribution of stress waves. A comparison of resulting data with fracture-strength data will make it possible to estimate the extent of fracturing. Simulation calculations, based on site-specific properties and correlated with stress-gage results, will improve understanding of shale fracturing. Standard wellbore logging techniques are also used to assess fracturing in the immediate vicinity of wellbores and out through the fracture region.

Techniques being developed for fracture assessment include air/tracer flow methods, an acoustic holography method, and formation resistivity tests. Data collected during tests using these techniques will be correlated with core and wellbore logs and stress-gage data to assess the advantages of each technique.

FUSION ENERGY

Thermonuclear fusion is a potential long-range technological solution to the nation's energy problem, mainly because of its essentially inexhaustible fuel supply (deuterium from sea water) and its apparent environmental compatibility. To date, however, the only successful energy production by thermonuclear fusion has been in nuclear weapons. It is therefore understandable that Sandia, with its background in weapon work, is involved in fusion energy experimentation, conforming to ERDA's intention to develop a fusion power reactor by the early 21st century.

Two mechanisms for accomplishing controlled thermonuclear fusion are magnetic confinement and inertial confinement. While Sandia supports both approaches through its studies in radiation damage and reactor material development, the main thrust is toward the inertial confinement principles first derived from weapon physics concepts. This goal is being pursued with lasers and particle beams (electron and ion) as power sources. The first is the more advanced one of the three, but the latter two are attractive alternatives.

* * * * MAJOR PROJECTS * * * *

Particle-Beam Fusion

Sandia's particle-beam fusion program was begun in 1965 with the objective of determining the feasibility of using pulsed power technology to produce focused particle beams for inertial-confinement fusion. This approach has the potential for providing a simple and relatively inexpensive ignition source for reactor applications.

Two of the most critical near-term goals are to demonstrate that relativistic electrons can deposit their energy efficiently in low-mass targets, and that ignition can be caused in targets using the highest possible beam voltages that will not cause dielectric breakdown at the vacuum/insulator interface. We are approaching these goals from two directions: by increasing the current delivered on target and by reducing current requirements through target design and deposition enhancement.

The technological basis of particle-beam fusion is being advanced with development of Proto I, a particle accelerator built in 1975 expressly for fusion studies, and Proto II, a water-insulated accelerator that will begin operation early in 1977, and which delivers power a factor of four higher than Proto I. The ultimate value of these tools will be demonstrated in EBFA, a 40-terawatt electron-beam fusion accelerator scheduled for completion in 1979.

The Proto II Particle-beam accelerator is designed to transmit 8 terawatts of peak power in a pulse lasting 24 nanoseconds. The accelerator will be in operation in early 1977.

Laser Fusion

Substantial advances in high-power laser technology are required to meet mid-term goals. Sandia's laser project is aimed at developing the necessary technology on a time scale consistent with the overall laser fusion program plan. Emphasis is on development of general laser technology and on systems that require advances in the state of the art. Technology developed in this program will be incorporated into new laser systems as promising high-power laser media become available. Prototype laser systems now being studied are also possible candidates for ERDA's first experimental power reactor.

Most of Sandia's program is directed toward development of three prototypical laser systems: iodine, oxygen, and hydrogen fluoride.

Although the iodine laser is the most highly developed, the oxygen laser offers promise. To obtain a complete physical and optical characterization of these important systems, we are studying excited-state production efficiencies, e-beam device development, and low-pressure gain phenomena. Through these studies, technology applicable to low-gain e-beam-excited high-power lasers will be developed.

In the Hydrogen Fluoride project we are developing technology applicable to high-power, high-energy-gain laser systems. Many high-gain lasers offer high efficiency, but their use requires mode control (control of the resonance of the laser beam within the cavity) and excitation with high-power sources. E-beam excitation of high-gain laser media offers the possibility of laser outputs of several hundreds of terawatts, but mode control must be proven. The Hydrogen Fluoride laser has been selected as a prototypical high-gain medium because it offers high efficiencies both electrically (in excess of 100%) and chemically (over 10%).

High-power lasers are being developed to meet midstream goals of the energy plan. The physical and optical characteristics of lasers are being determined for application in the fusion energy program.

By careful selection of prototypes, we believe we have maximized contributions to the rapid development of laser systems to meet mid-term and long-term goals of the laser fusion program. Our specific development programs are supplemented by a broad-base laser technology investigation, including studies in advanced excitation-source development, nonlinear optics, advanced oscillators, gas kinetics, electric discharge phenomena, classical and semiclassical optics, and laser fusion plasma phenomena.

FISSION ENERGY

According to the national energy plan, a major consideration in whether the country will be able to meet its energy needs through this century will be the continued development and commercialization of safe and reliable nuclear power. Light-water reactors now produce about 9 percent of the nation's electrical energy. Plants now planned or under construction may increase this capacity by three or four times in the next decade. If breeder reactor experimentation results in the construction of commercial breeder reactors in the late 1980's, further electrical generating capacity will be added, and more important, the quantity of available fissionable material will be greatly increased. There is also the possibility that plutonium may be recycled, which would further extend uranium fuel supplies.

The continued contribution of fission energy toward meeting the nation's present and potential needs for electricity depends upon adequate assurance in several areas:

That nuclear power generation continues to be safe, and will be considered environmentally acceptable.

That safe and environmentally acceptable waste treatment, storage, and disposal processes will have been established.

That strategic materials will be adequately safeguarded against theft and diversion.

Sandia is contributing to fission-energy pursuits by analyzing the safety of reactors and the fuel cycle, as well as by studying waste management and safeguards. Experience in system engineering and management, gained through weapon program responsibilities, weapon safety analysis techniques, and resources for design analysis, testing, and applied sciences, are readily applicable to the evaluation of various aspects of the nuclear fuel cycle. Pulsed test reactors developed for simulating weapon effects are suitable for studying the safety of fast breeder reactors.

Reactor and fuel-cycle safety research and analytical studies are being conducted for the Nuclear Regulatory Commission; waste management programs are carried out for ERDA; and programs on safeguards are being conducted for both ERDA and NRC.

* * * * MAJOR PROJECTS * * *

Light-Water Reactor Safety Research

This program is a technological effort to evaluate the safety of commercial light-water reactors (LWRs). Broadly based studies are in progress to develop methods for assessing public risk associated with operation of nuclear power reactors and other facilities that are integral with the fuel cycle. The studies examine possible causes of accidents, physical phenomena that cause releases of radioactive materials, and the consequences to the public of such releases.

Accident causes being studied include equipment failure, human operating error, sabotage, and events outside the plant such as tornados or wartime attack. Event and fault tree analyses and other reliability methods are used to determine the possibility of reactor plant accidents being initiated by failure of engineered safety features.

Combined theoretical and experimental studies are conducted to investigate phenomena occurring during a hypothetical core meltdown that would be expected to have a major influence on the quantity of radioactive materials released. These studies focus on accident phenomenology and modeling, the effectiveness of reactor safety systems, and the containment of radioactivity. Current emphasis is on the interaction of molten core materials with concrete and other structural materials, and on vapor explosions resulting from contact of molten materials with water. A probabilistic computer model is being developed to help quantify the consequences of radioactive release on man and the environment. Inputs from many diverse fields are being employed to supply knowledge in areas such as medical effects of radioactivity exposure.

To assist those concerned with LWR licensing, technical support is being provided to the Nuclear Regulatory Commission. Analyses are being performed of the operation of proposed emergency core cooling systems and of reactor vessel support loads resulting from reactor depressurization. Research is underway to evaluate methods of obtaining more realistic estimates of the effectiveness of emergency core cooling.

One possible result of a hypothetical accident of a reactor would be the formation of high-temperature molten fissile fuel. Of concern is the breaching of the steel and concrete containment vessel caused by the molten fuel melting a hole in the structure. Large-scale experiments designed to determine the interaction of molten metals with structural materials are underway.

Fast Reactor and Fuel Cycle Safety

Research is directed toward assessment of the safe operation of fast breeder reactors. The program is focused upon research needed in the study of key safety issues of concern to NRC as the Liquid Metal Fast Breeder Reactor is developed and commercialized through the 1980's. The Clinch River (Tennessee) Breeder Reactor, the first demonstration power reactor in the U.S., is receiving current emphasis. The program includes analytic and experimental studies of hypothetical accident scenarios and the development of instrumentation and test facilities to be used in the studies. Major objectives are to develop physical models to describe potential accidents, and to conduct experiments to validate these models.

Studies of the possible response of the fissile fuel of a liquid metal fast breeder reactor to hypothetical accidents is part of the reactor safety program. A pulsed reactor specially designed to produce intense pulses of radioactivity is used to simulate transient accident conditions in test fuels. To maintain the fuels at desired test temperatures, a molten helium cooling loop has been designed.

The program uses facilities such as the Sandia test reactors and large melt facilities which were developed for weapon programs but are especially suitable for fast reactor safety studies. The program includes:

- Studies to determine the potential energy release of and containment requirements for hypothetical core-disruptive accidents.

- Experimental investigation of post-accident behavior, coolability, and containment of core debris.

- Experimental investigation of the ability of the plant to contain large sodium spills.

Studies directed at the quantification of elevated-temperature failure modes of materials used in Liquid Metal Fast Breeder Reactor primary and secondary coolant loop components.

Development of diagnostic techniques to observe the motion of molten fuel during a simulated accident, and the effect of fuel movement on accident severity.

Development of a coded aperture imaging system for the Annular Core Pulsed Reactor to provide the capability for obtaining three-dimensional pseudoholographic images of Liquid Metal Fast Breeder Reactor fuel pins in simulated accident tests.

Development of the capability to conduct large-scale field tests to simulate hypothetical Liquid Metal Fast Breeder Reactor core-disruptive accidents.

Design and development of laboratory test reactor facilities to improve the U.S. capability to simulate prototypical accident conditions; including, at present, a major upgrade to Sandia's Annular Core Pulsed Reactor to provide a factor of two and one-half increase in pulsed power.

Data accumulated and models developed in the investigations are used in analyzing and predicting event sequences associated with hypothetical abnormal behavior of power reactor systems and in estimating risks to the public. The analysis forms the base for licensing decisions by the Nuclear Regulatory Commission, and is part of their confirmatory research effort.

Waste Management

Waste Isolation Pilot Plant

Sandia is responsible for the conceptual design and technical direction of a radioactive waste isolation plant that will demonstrate the feasibility of permanent waste disposal in deep underground salt beds in Southeast New Mexico. The facility will be used to isolate transuranic and intermediate-level wastes generated by the U.S. defense program, and to perform and evaluate high-level waste experiments.

Initial steps in the program include site characterization and evaluation, analyses of safety aspects of the facility, and the preparation of an Environmental Impact Statement. Supporting technical studies are being made of the effects of radiation on salt and on waste canisters in contact with salt, isotope transport through salt, brine migration, and thermal and structural properties of salt formations.

Throughout development and operation of the pilot plant, Sandia will provide technical direction to the architect-engineer and the operating contractor. Results from plant operations and from in-situ experiments will be studied to determine whether it is feasible for the pilot plant to be converted to a permanent operational facility.

Geologic Disposal Studies

A general evaluation of geologic disposal is underway. Among areas of study are the suitability of geologic media and formations other than bedded salt for radioactive waste isolation; physical and chemical effects on natural formations of heat radiation and waste emplacement processes, and the ability of formations thus altered to isolate radioactive waste.

The first geologic medium other than salt to be investigated is shale, to be followed by limestone, granitic rock, and basalt. Stable formations 1000 to 5000 feet below the surface, in remote locations, will be identified. Tests in which the medium is heated electrically will produce data on rock stresses, fluid flow, and gas generation. Core samples will be analyzed to determine thermal and chemical degradation. If results of near-surface tests are favorable, they will be followed by deep-vault and/or drill-hole tests. Limited quantities of radioactive materials will be used in final tests.

Preliminary geological studies are underway in the salt beds of southeastern New Mexico for the construction of this pilot waste disposal plant. Sandia will provide technical direction throughout development and operation of the plant, which will be used to isolate transuranic and intermediate-level wastes generated by the U.S. defense program, and to perform and evaluate high-level radioactive waste experiments. Results from plant operations and experiments will be studied to determine the feasibility of converting the pilot plant to a permanent operational facility.

Seabed Disposal Program

Sandia is responsible for a feasibility assessment program for the disposal of high-level radioactive waste in geologic formations beneath the sea floor. The aim is to look carefully at the oceans and the geologic formations beneath them, and to assess the possibility of using some portion of that 72 percent of the earth's surface for geologic disposal. While it is too early for the assessment to be conclusive, two oceanic regimes — the mid-plate/mid-gyre regions and the flanks of the mid-ocean ridges — have been identified as offering possibilities for waste disposal. Studies conducted to date are directed specifically at describing the environments in those regions, how they might interact with an emplaced waste canister, or how radioactive material might be transported in these environments to areas where they could present a danger to mankind. The goal is to measure the rates of such processes for comparison to the decay rates of dangerous isotopes requiring disposal.

Initial steps include analyses of existing oceanographic data with respect to submarine geologic formations, mineral sources, biology, and physical and chemical properties of the sediments and the water column. Supporting investigations are underway to supplement existing data and to address questions newly generated when high-level radioactive waste disposal is considered: interactions between the water, biology, and sediments with the waste and its new set of radiation, chemical, and thermal conditions.

Sandia provides program management and technical direction for scientific investigations and analyses being conducted both at Sandia and at oceanographic institutions and universities. The ultimate objective of the program is to determine the technical and economic feasibility of providing terminal storage for high-level radioactive waste beneath the deep ocean floor in a geologically stable and relatively biologically inactive region. An additional objective is to develop and maintain a capability for assessing any ocean disposal program developed by another country. Broad tasks of both objectives involve oceanographic investigations, effects investigations, environment impact assessment, system development and engineering, and ultimately, site selection and survey.

Other Fission Energy Activities

Technologies necessary to assure economic and beneficial uses of radioactive materials are being developed, as are processes for isolating and encapsulating isotopes.

Using cesium-137, a nuclear power plant by-product, sewage sludge is being sterilized for safe application as a fertilizer and as an animal feed supplement. Major effort is directed toward establishing thermoradiation and radiation treatment levels required to eliminate pathogenic organisms in sludge. Three groups of pathogenic microorganisms are being studied: viruses, bacteria, and parasites.

Treated sludge (anaerobically digested and undigested) is being studied by New Mexico State University as a ruminant animal feed and fertilizer. The sludge is used in greenhouse plants for the fertilizer study and will be added later to field crops.

The demonstrated applicability of the Sandia waste solidification process to the recovery of cesium from high-level liquid waste is being explored to improve their availability. Successful application of this process demands reasonably efficient recovery of cesium without substantial increases in the waste volume to be disposed of, and with sufficient separation from transuranic elements to preclude significant neutron production.

Future work will emphasize the development of recovery processes for isotopes other than cesium, and of fabrication methods for ceramic cesium sources.

Economic and beneficial uses of nuclear waste are being explored. Experiments are underway to determine whether cesium-137, in combination with heat, can sterilize sewage sludge to the point where it can be safely used as a fertilizer or an animal feed supplement.

NUCLEAR MATERIAL SECURITY

Development and commercialization of nuclear power requires that nuclear facilities be protected against sabotage that may result in harm to the public. Special nuclear materials that might be used to make a nuclear explosive or to poison the environment also must be protected against theft or diversion; this is of special concern in view of the possibility that plutonium may be recycled in the light-water reactor fuel cycle. The same protection would need to be extended to the liquid-metal fast breeder reactor fuel cycle, which will depend upon a plutonium economy, and to the high-temperature gas reactor fuel cycle, which is based upon highly enriched uranium. The worldwide increase in terrorist activities has emphasized the need for physical protection of all nuclear material and facilities.

Sandia has long been involved with the physical protection of nuclear weapon systems in transit or storage. Knowledge gained in these areas is now being extended to the physical protection of nuclear facilities in all phases of power reactor fuel cycles.

Physical protection of fuel cycle facilities requires development and demonstration of protection systems consisting of components such as perimeter and interior alarms, secure portals, fixed and remotely activated barriers, secure transportation systems, and reliable communications. Simulation of adversary actions, both analytical and physical, is used extensively as a way of testing and evaluating protection equipment and integrated safeguard systems. Results suggest directions for future development and improved cost effectiveness.

Analytical methods being developed for the Nuclear Regulatory Commission will be used in evaluating the effectiveness of protection systems in meeting performance regulations. These methods are used by the Nuclear Regulatory Commission to evaluate proposed physical protection plans. The same techniques are given to licensees to assist them in designing and establishing physical protection systems. The methodology will be used to evaluate protection techniques for materials both in transit and at fixed facilities.

* * * * * MAJOR PROJECTS * * * * *

Physical Protection of Nuclear Facilities

The objective is to define, develop, evaluate, and demonstrate advanced systems for safeguarding nuclear materials at representative government and industrial facilities. An integrated system to protect against theft, loss, and sabotage is structured around three elements: detection and assessment, delay, and response. These integrated safeguard systems must be effective against threats ranging from forcible attack by well-organized terrorist groups to internal diversion by stealth or collusion.

The program uses analytical, developmental, test, evaluation, and demonstration techniques in four major categories.

System Assessment

Activities include threat analysis, effectiveness and design evaluation, and facility assessment. Threat analysis will provide a data base and an understanding of the attributes of potential adversaries as well as a range of credible threat levels. Computer models to assist in design evaluation and facility assessments are being used to evaluate conceptual and current safeguard system designs, and will be available to assess safeguard systems submitted by licensees.

Computer models are used to evaluate the relative cost and effectiveness of safeguard system options for representative nuclear facilities over a range of threats to provide a basis for final design decisions.

Equipment Evaluation, Application, and Development

Evaluation of the performance, reliability, and vulnerability of currently available physical protection equipment is in progress, with initial emphasis on perimeter and interior intrusion detectors and entry control devices. Physical protection equipment is developed in situations where equipment is not available or where significant improvements are required. This activity covers intrusion detectors, entry control systems for personnel and material, item protection equipment, information protection system elements, barriers, guard equipment, special nuclear material use-denial technology, and transportation.

Various types of physical protection equipment are being developed and evaluated for use in safeguards system to control personnel and material at nuclear facilities.

System Development and Operational Test and Evaluation

Balanced protection subsystems and systems in operational environments are tested and evaluated to verify compatibility with the operating force and physical environments. Initial activity is planned at two facilities: The Sandia Research Reactor Safeguards Demonstration Project, encompassing a complete balanced protection system including exterior and interior intrusion detection and assessment subsystems, improved barriers, an entry control subsystem for both personnel and contraband material, and improved guard equipment and communications to insure prompt, adequate response; and the Hanford Plutonium Storage Facility Project that involves integrated item protection for plutonium metal and oxide. The system provides closed-loop control as well as real-time accountability for individual packages of plutonium metal/oxide. Access to the vault and movements of plutonium are monitored by sensors, and information is transmitted over data links to control centers. Deviations from authorized procedures prompt a response by the guard force.

Fuel Cycles

Design efforts are underway to define integrated safeguard systems for demonstration with light-water reactor fuel-cycle facilities (nitrate-to-oxide conversion, mixed-oxide fuel fabrication, plutonium storage, and liquid waste solidification). Similar activity is being initiated for liquid metal fast breeder reactor facilities (the fuel fabrication facility and the breeder reactor).

The integrated safeguard system concept for fuel cycle facilities comprises three elements. The Personnel Control element prevents unauthorized admittance to the facility, excludes all but essential personnel from sensitive areas in the plant, and permits entry and exit of authorized personnel and materials through designated portals. The Item Operation Control element provides central closed-loop physical control of all activity involving special nuclear materials outside the process line. This is accomplished by specifically outlining and authorizing each activity in advance and by monitoring the activity while it proceeds. If a discrepancy is detected, the operation is inhibited or terminated. The Material Measurements and Accounting element is being developed by Los Alamos Scientific Laboratory. The three elements operate in a coordinated and interactive manner with the plant operation control system.

Protection of Nuclear Material in Transit

The primary objective is to develop and validate methods for assessing the effectiveness of transportation safeguards. Studies of the safe transportation of nuclear materials includes terminals, in-transit transfers, and storage, as well as actual movement. The purpose is to devise a system that will best protect the material against theft and sabotage, whether by force, stealth, or deceit, that might result in release of radioactive material. All practical combinations of adversary characteristics, resources, actions, and modes of action are taken into account. Protection offered by the system against threats will be evaluated. Alternative transportation systems, with associated strategies and required defensive actions, will be examined. Exemplary transportation systems are defined and alternative ways of testing and validating methodologies will be investigated.

Initially this program will focus on the transportation of material during plutonium recycling for light-water reactors. A secondary interest is the transportation of highly enriched uranium and uranium-233. Protection of high-level wastes and by-products from each fuel cycle will be considered in the future.

Safeguards

Current safeguard studies deal with the protection of light-water reactors against acts of sabotage that could endanger the public by causing the release of radioactivity. The studies have resulted in identification of major plant vulnerabilities and recommendations for design, administrative control, and emergency response measures to reduce the possibility of successful sabotage. System concepts have been developed for implementation of recommended measures. Workshops are held to allow electric utility companies, nuclear power plant architectural engineering firms, and nuclear system vendors to review study results, evaluate the practicability of recommendations, suggest alternate solutions, and propose areas for additional research. Ways to integrate safeguard requirements into the reactor licensing process are being examined. Similar studies on other fuel-cycle facilities (advanced as well as light-water reactor cycles) are in planning stages.

ENERGY CONSERVATION

Ninety-five percent of all energy demands in the U.S. are met by the burning of fossil fuels, and through the end of the century, combustion will continue to be the major method of energy generation. Because of this, storage and conversion technologies are being studied with a view toward improving their efficiency without sacrificing environmental quality.

For over a decade Sandia has been developing and using advanced laser optical diagnostics, numerical fluid mechanics modeling, and chemical materials research. In the course of this work, which is carried on as part of the national security program, these capabilities have been identified as applicable to combustion research related to the national energy program. More recently it has been recognized that they can equally well be applied to the analysis of chemical-reaction energy storage and transport.

Sandia's combustion program is designed to increase knowledge of processes that govern the efficiency and emission characteristics of all combustion devices. Techniques are being developed for measuring and predicting temporal and spatial details of temperature, pressure, species concentration, and turbulence. Laser-based diagnostics are providing combustion researchers their first opportunity to obtain space- and time-resolved measurements of combustion details inside flames, engines, and other sealed-system combustors.

The program is being implemented to develop energy storage and transport concepts based on reversible chemical reactions. Catalytic and laser-induced reactions are initially being emphasized. Sandia will provide both program management and in-house technology development for the program.

A variable-displacement engine that was invented, analyzed, designed, and built at Sandia is being tested on a dynamometer for fuel economy and emissions. Data show substantial improvements in fuel economy over existing engine performance.

* * * * MAJOR PROJECTS * * * *

Combustion Research

Advanced laser-based diagnostic methods are being developed to obtain technical information on combustion processes needed for development of more efficient, less polluting devices such as engines, boilers, and furnaces. These methods are providing the first opportunity for obtaining space- and time-resolved measurements of combustion process details inside flames, engines, and other combustors. This information will allow prediction of temporal and spatial details of temperature, pressure, species concentration, and turbulence levels.

These diagnostic tools are currently focused on combustion processes in spark-ignition engines, including homogeneous-charge, direct-injected stratified-charge, and dual-chamber stratified-charge configurations. Sandia is the technical coordinator for ERDA of a joint ERDA-university-industry research program on direct-injected stratified-charge engines. The program involves participation and technical exchange for ERDA by Sandia, Lawrence Livermore Laboratory, and Los Alamos Scientific Laboratory; for the universities by Princeton, and for industry by the General Motors Research

Laboratories. Technical issues being addressed at Sandia include experimental and theoretical descriptions of pre-ignition fluid motion, fuel/air distributions, and post-ignition flame propagation.

In association with these duties, Sandia is involved in two activities of an international character. The first is a cooperative effort with Volkswagenwerk, and the second is acting as the ERDA representative to the International Energy Agency in the area of combustion research.

A stratified-charge combustion facility has been lent to Sandia by Volkswagen for application of advanced diagnostic methods to the study of fundamental combustion processes. Features of the device include a poppet valve for intake charge, gasoline fuel injector, multiple geometry options, pressure output, and sophisticated timing electronics.

Energy Storage

National energy resources will be more efficiently used when better ways of storing energy are found. Such methods will help make autos and power-generating plants more effective and will speed the economical use of wind, solar, and other alternative energy sources.

Several energy storage projects are underway. These include assisting ERDA in planning and implementing a program to develop energy storage and transport concepts based upon reversible chemical reactions. Such a concept offers numerous advantages over sensible and latent heat storage: increased energy densities, ambient storage, transportability, and long-term capabilities. Since the technology required to apply and implement chemical reactions is largely undeveloped, one cannot yet assess the practicality of chemical storage concepts.

This program consists of in-house projects and subcontracted efforts, with participation by various members of industry and universities. Specific projects being pursued include:

- Development of a sulfuric acid dilution scheme for heating and cooling buildings;
- Investigation of chemical heat pumps based on coupled dissociation/association reactions;
- Use of the decomposition of ammoniated halide salts and various salt hydrates;
- Economic feasibility of the $\text{CH}_4/\text{H}_2\text{O}$ reformation/methanation cycle in heat-pipe applications;
- Economic feasibility of baseload solar thermoelectric power plants using extended chemical energy storage;
- Material compatibility studies with sulfur-oxygen based chemical systems.

In another energy storage project, the use of the flywheel is under investigation. Flywheels store energy kinetically in a disk rotating at very high speeds. Preliminary estimates indicate that supplementary flywheel energy could approximately double gas mileage in conventional automobile engines used on city streets.

The energy storage capacity of a flywheel is governed by its mass, diameter, shape, and speed of rotation. The limiting factor in energy storage is the strength of the flywheel material. Flywheels wound from high-strength, filament-reinforced composites, making use of technology developed for missile nose cones, are being investigated.

The most advanced wheels constructed to date have been made of Kevlar fiber, an organic material. Wheels up to 16 inches in diameter have been made and are being tested at high rotational speeds. A wheel 20 inches in diameter, 2 inches thick, weighing about 25 pounds and rotating at 40,000 rpm, would store about 40 watt-hours of energy per pound of flywheel material. This is three to four times the energy storage capacity of a lead-acid battery of similar weight. The maximum storage capacity of this material appears to be 50 to 70 watt-hours per pound, which is four or five times that of steel. It is believed that wheel systems occupying the same amount of space as a spare tire can eventually be incorporated into vehicles.

Variable-Displacement Spark-Ignition Engine

A variable-displacement, spark-ignition research engine has been designed and built and has been under intensive testing for the past year. This design reduces partial-load fuel consumption by reducing throttling and friction losses. Power is controlled by changing the piston stroke rather than by throttling, except at idle and very low power levels. A novel linkage arrangement allows for continuous changes in stroke length and thus in engine displacement, which in the prototype varies from 43 to 190 cubic inches.

More than a year of dynamometer testing has been accomplished to date, mostly in the range of loads and speeds encountered in typical driving situations, and has yielded extensive data on power, fuel consumption, and emissions. The thrust of testing so far has been to measure fuel economy without controlling emissions. The tests demonstrate that a substantial fuel saving can be achieved by using the variable-displacement concept.

Computer simulations based on laboratory test results project urban driving fuel economy of the variable-displacement engine to be about 30 percent better than that of 1976 production engines in 3500-pound cars.

Prototype Pouliot variable-displacement engine mounted for dynamometer testing (above) and cross-sectional view (below) showing the offset crankshaft, threaded stroke-control adjustment rod, and three connecting rods. Power is controlled by changing the piston stroke rather than by throttling, except at idle or very low power levels. Displacement can be varied in this prototype from 43 to 190 cubic inches, depending upon power demand. The design has been under intensive testing for over a year. Computer simulations based on test results indicate that urban driving economy would be about 30% better than 1976 production engines in 3500-pound automobiles.

GEOTHERMAL ENERGY

In the recognition that geothermal energy may ease the nation's energy predicament, at least on a regional basis, ERDA sponsors experimental drilling and logging activities at Sandia.

Geothermal drilling differs from conventional drilling in many ways, making conventional technology inapplicable. Deeper wells, higher temperatures, higher formation pressures, and corrosive gases, all encountered in geothermal drilling require improved materials, fluids, and techniques for economical drilling. Higher temperatures and extremely hard igneous rocks make favorable drilling rates hard to achieve. These rates must be improved. There is also a critical need for being able to measure formation parameters at the extreme depths and temperatures found in geothermal wells.

Sandia is responding to these needs by developing three new kinds of drill bits, any of which if successful should improve both penetration rates and downhole drill life. In cooperation with a commercial firm, Sandia is applying high-temperature components to improved logging tools. The technological feasibility of extracting energy direction from deeply buried circulating magma sources is being investigated

* * * * MAJOR PROJECTS * * * *

Drilling Technology

As gas and oil wells that are shallow and more easily found become depleted, drilling companies in trying to develop deeper wells are encountering more severe environmental problems. Higher temperatures and pressures, and corrosive gases found at depth require improved materials, fluids, and techniques if adequate drilling rates and reliability are to be achieved. Sandia's responsibilities are to study new oil-drilling technologies and to transfer the results to private industry.

Several studies are being conducted. A high-temperature materials project is focused on the use of materials developed originally for nuclear weapons, as well as on quality-control techniques and testing procedures. The objective is to improve overall drilling performance. Specific material problems encountered by the drilling industry are being analyzed.

Drilling fluid (mud), which is circulated in the wellbore and whose performance critically influences drilling operations is being investigated. Conventional fluids degrade substantially at conditions encountered in deep wells. Research is underway to develop fluids with higher temperature capabilities. In a related effort it was found that available fieldtest equipment does not adequately characterize fluids at the high temperatures and pressures encountered at the bottom of a hole, a condition which leads to economic losses and safety problems. In collaboration with private industry, improved test equipment is being developed for field applications.

If oil and gas are to be obtained from new sources, drilling operations must be extended to substantially greater depths. This will involve increases in drilling time, expense, and engineering problems caused by higher temperatures and pressures, and harsher environments.

Three new drill bits are being designed to speed the cutting of drill holes by increasing both penetration rates and downhole bit life: the spark drill, the terra drill, and the chain bit.

The spark drill, conceived by Russian technologists, may have the greatest potential for improving drilling performance. However, its operation is complex, and development problems are formidable. A downhole electrical pulse generator creates high-voltage sparks between electrode gaps on the bottom surface of the bit. The spark creates a high-pressure shock wave in the drilling fluid (mud) used in the drill hole. This wave, which alone can break rock, is followed by cavitation. It is believed that jetting associated with the process increases rock breakage.

Low-energy laboratory models of the spark drill have been developed. For spark energies of 100 to 200 joules, equivalent to 1-½ to 3 horsepower, shock pressures of 2000 to 10000 times atmospheric pressure have been measured. Drilling rates as high as 30 feet per hour have been achieved in test materials. At the design objective of 150 horsepower, the bit may drill at rates of more than 100 feet an hour and have a life of 100 hours.

The terra drill fires projectiles between the spacings of a standard tri-cone roller bit to fracture rock ahead of the bit. This concept is based on the principle that highly fractured rock can be drilled more rapidly than unfractured, homogeneous rock. Tests in limestone indicate that the terra drill can double the penetration rate achieved by a conventional tri-cone roller bit. Development efforts are now focused on selecting the best projectile materials and the best design for the firing magazine.

The chain bit is being developed primarily for slim-hole (4-3/4 to 1 inch diameter) exploratory drilling applications. The chain bit has a diamond-studded cutting surface on the face of a continuous chain that circulates between two sprockets, one on the bottom of the bit and the other several feet distant at the top of the bit. The hole is cut by the portion of the chain that is wrapped around the bottom sprocket. When this approximately 6-inch cutting portion becomes dull, another segment is cycled into place without removing the bit from the hole. This design currently has sufficient links for 13 complete cutting-surface changes. On the assumption that each surface has one-third the life of a conventional diamond bit, it is calculated that the new system could result in a four to five-fold improvement in bit life.

Continuous chain bit, designed primarily for exploratory drilling, has a diamond-studded cutting surface on the face of a continuous chain allowing down-hole replacement of the cutting portion of the drill.

Logging

Logging tools lack the high-temperature capabilities (200-500°C) needed for use in geothermal well drilling, severely limiting borehole measurements and analyses. In collaboration with Gearhart-Owens, Inc., Sandia will be applying high-temperature components (275°C) to logging tools. This logging capability, as well as log interpretation techniques, will be made available to the geothermal energy program.

Magma Energy Research Project

Geothermal energy resources exist in a variety of forms: dry steam, hot water, geopressurized water, hot/dry rock, thermal gradients in the earth's crust, and magma. The objective of the Magma Energy Research Project is to investigate the technological feasibility of extracting energy directly from deeply buried circulating magma sources. The project embodies the concept of a fully closed heat-exchange system inserted directly into a magma source to allow heat energy to be brought to the surface with minimal environmental impact. Since this heat can be converted to a usable form, such as electricity, by reasonably conventional techniques located on the surface, our project concentrates on underground technology: source location and definition, source tapping, magma characterization and materials compatibility, and energy-extraction studies.

Little is known about the precise location and physical configuration of magma sources. Extant knowledge is based almost entirely on evidence gleaned from areas near active volcanoes and eroded structure of ancient volcanoes. Although many methods have been developed for remote subsurface sensing of geologic structures for a variety of purposes, until very recently none has been used to detect and locate molten magma sources. With the cooperation of the U.S. Geological Survey Hawaii Volcano Observatory, experiments have been initiated to evaluate the effectiveness of subsurface sensing techniques over a known molten-rock body, the Kilauea Iki Lava Lake in Hawaii.

A molten lava/single tube boiler experiment confirmed heat-extraction calculations and provided other data required for evaluating the feasibility of energy extraction from magmas. It was shown that corrosion of the steel heat exchanger is not a problem, even though the temperature of the molten lava is higher than that of the heat exchanger. A solidified lava crust formed next to the heat exchanger as predicted. High-quality steam (>90 percent) was produced, and measured heat-extraction rates were between 180 and 310 kW/m².

ENVIRONMENT AND SAFETY

As discussed in ERDA's National Energy Plan, an energy future which results in inexpensive goods and services, but neglects the cost of damage to man and the environment, would be unacceptable. Adverse impacts of technology can never be totally eliminated, and, at a given level of energy production, the direct cost of supplying energy to the consumer increases as requirements for associated processes such as land reclamation, waste disposal, and air and water pollution control are increased. The challenge of today's technologists is to create a future in which the total cost of energy, represented by the sum of direct costs to the consumer plus indirect social and environmental costs, is acceptable, and to provide the data base required to properly guide the tradeoff between direct and indirect costs. This task imposes an urgent responsibility to improve our knowledge of the societal and environmental implications of available and emerging energy alternatives so that these may be properly integrated into the ERDA decision making process.

Environment and Safety activities at Sandia encompass a broad range of nuclear, fossil, fuel, solar, and geothermal energy issues, as well as general problems of measuring atmospheric pollution. Programs discussed in the context of specific energy developments and addressed elsewhere in this report are not discussed further here. Four program areas are highlighted in this section: activities of our new Office of Environmental Policy Analysis which provides broad guidance to ERDA in selected problem areas; analysis of transportation safety of nuclear materials; theoretical and experimental investigations of atmospheric pollution; and combustion research. Many of our activities evolved from previous experience in weapon research and development programs. For example, experimental and analytical evaluations of the consequences of hypothetical accidents involving shipments of nuclear materials have utilized facilities and computational techniques developed for studies of hypothetical nuclear weapon accidents. Similarly, expertise in atmospheric studies, as typified by the Da Vinci Program described below, resulted from extensive experience in the atmospheric-testing readiness program.

* * * * MAJOR PROJECTS * * * *

Office of Environmental Policy Analysis

The Office of Environmental Policy Analysis at Sandia Laboratories is part of an ERDA program being developed for the purpose of identifying and analyzing critical environmental issues that could affect energy policy decisions and goals. Currently there are three facets of this program: regional surveillance, review and evaluation activities, and immediate response activities.

Regional surveillance involves the development and maintenance of local, state, and regional contacts to maintain an awareness of developments, policies, laws, and regulations that relate to energy development and environmental concerns. The intent of this activity is to provide ERDA with timely information on regional concerns by providing a visible vehicle for their expression.

Review and evaluation activities are undertaken in an effort to identify and scope critical environmental policy issues. Potential issues arise from other laboratory programs, regional surveillance, and ERDA headquarters. Issues that are potentially critical are further analyzed to determine their degree of importance, possible approaches to their resolution, ERDA programs that may be involved, objectives and goals to be met in resolving the issues, and cost-effectiveness of alternative approaches.

Immediate response activities are intended to be less detailed than review and evaluation efforts, requiring less in-depth knowledge, but are expected to provide a vehicle for similar laboratory and regional response to problems of immediate concern as they are identified by ERDA headquarters.

The program is operated with the collaboration and participation of numerous persons, organizations and institutions in the Rocky Mountain, Southwest, and Gulf Coast regions.

Transportation

Energy systems consist of a number of interrelated elements. In fossil energy, for example, there is mining, refining or processing, power production, and a power distribution system. Components of the nuclear industry are much the same, with the addition of fuel fabrication and waste disposal functions. However, an important component of such energy systems is often left out of account: transportation. Without a way to transport the fuels, materials, wastes, and recovery products of these power systems, there could be no fuel cycle of any consequence.

Sandia is addressing problems inherent in the transportation of energy-related materials. To some degree, these programs are based on data collected over the past 10 years concerning the environments in which hazardous or valuable materials have been shipped. This data bank, available to the public, contains information on both normal and abnormal transport conditions. Even this data bank is incomplete, however, because statistical experience is concentrated in relatively minor and therefore less severe accidents. In an attempt to supply the lacking information, a number of companion programs are being pursued, including evaluation of environments surrounding the shipment of massive cargos, the consequences of extra severe accidents, and the adequacy of shipping casks in resisting malevolent attack.

The three primary accident scenarios involved in full-scale testing are the collision of a spent-fuel shipping cask, mounted on a tractor-trailer, into a solid concrete barrier at 60 mph; the collision of a railroad locomotive with a trailer bearing a spent-fuel shipping cask, and the collision of a 150-ton spent-fuel cask with a concrete barrier at about 70 mph. Analytical and scale model studies which have preceded these tests are used to predict the outcome of full-scale events.

Complementary to these tests is a series involving attempts to breach spent-fuel casks with explosive devices.

On the bases of background data and experience from these programs, a spent-fuel shipping system for the liquid metal fast breeder reactor is being developed.

Some work is directed toward supporting the review of applications from industry for licensing of spent-fuel casks. In addition, a package is being developed for the air transport of plutonium. The container, now undergoing final testing, will contain about 5 pounds of plutonium dioxide powder, will weigh about 400 pounds, and will be capable of surviving a series of assaults equivalent to the maximum credible environments of impact, crush, puncture, fire, and immersion.

Sandia, with other laboratories, is promoting the establishment of a coherent transportation program within ERDA to address problems surrounding the interstate movement of energy-related materials.

Atmospheric Pollution

Many cities experience air-pollution episodes mainly when they are downwind of other far-distant cities. On the other hand, high pollutant concentrations frequently occur in rural areas far removed from any pollutant source. Both observations reflect the importance of the long-distance effects of air pollution.

To devise an effective strategy for controlling such long-distance effects, it is necessary to understand how pollutants are transported through the atmosphere, how they change chemically and physically as they are transported, and how they are removed by natural processes. It is the goal of Project Da Vinci to help provide that information. The objective is to elucidate the "life cycle" of several classes of pollutants deriving from energy-related and urban sources.

An instrumented balloon is launched near the pollutant source to be investigated, and is carried by the wind along with the polluted air. It marks the trajectory of the air and makes continuous measurements of pollutant behavior as time elapses. Auxiliary instrumented aircraft map the spread of pollutants in the vicinity of the balloon, and ground-based mobile units determine how pollutant concentrations change at ground level. Altogether, the history of the volume of polluted air is recorded in as much detail as possible. Such experiments extend over the life of the pollutants — at least a few days.

To date, three Da Vinci experiments have been conducted. The first established the feasibility of the technique. The following two, during the summer of 1976, were manned flights that tracked the St. Louis mixed urban/industrial plume for 24 hours and several hundred kilometers. The on-board scientist operated instrumentation for over a dozen participating laboratories and universities. The data are still being analyzed, but new information has already been obtained on the long-distance behavior of ozone and sulfur compounds.

This experience with the technique has demonstrated its capability to provide the kind of information on long-distance effects needed by regulatory agencies. It has also pointed up the necessity for modifying the experiments to gain greater flexibility and cost effectiveness. This will be done in future experiments by making use of automated, unmanned balloon measurement platforms which take advantage of state of the art computer technology.

BASIC ENERGY SCIENCES

The long-term effectiveness of the energy program will gain immensely if new knowledge can be obtained which makes possible new solutions for some of the problems involved. For this reason, ERDA is sponsoring programs in certain scientific fields. A program to which Sandia is contributing significantly is called Basic Energy Sciences. Fundamental studies, particularly in materials and diagnostic instrumentation, that have advanced the weapon program find a direct relation to a number of problems in the energy program.

* * * * MAJOR PROJECTS * * * *

Material Sciences

Gases in Metals

This program encompasses both experimental and theoretical aspects of the interactions of gases (particularly hydrogen and helium) with solids. The transport properties of these two gases in solids, and the role they play in influencing material behavior, are important because of both technological relevance and fundamental scientific value. The basic objective is to increase our fundamental understanding of the behavior of helium and hydrogen in metals and the influence of these gases on the mechanical properties of metals.

Magnified view of reactor wall degradation

A portion of this program is a study of diffusion, trapping, and clustering of helium in metals and alloys. The gas is introduced nonenergetically into a lattice by tritium decay and the effects of helium introduced in this way on mechanical properties are measured. Specifically, the approach is to determine helium release behavior during annealing from ~100 K to ~1200 K using an in-situ chamber: initial tritium loading, aging to desired ^3He levels, and release measurements are performed without moving the sample. Information on the relationship of energies of binding to specific defects is obtained from these annealing studies and is correlated with data on gas release from ion-implanted samples. Theoretical calculations of the activation energy for He migration, and energies of binding of He to simple defects, will be made on the same materials.

Defects and Impurities in Ion-Implanted Insulators and Semiconductors

Applications for insulating and semiconducting materials in new and proposed energy production or conversion technologies require materials whose performance exceeds present-day capabilities. In these applications, the near-surface region of the materials often plays a dominant role in determining overall properties. The behavior of this near-surface region can be modified by microscopic or macroscopic structural defects, either ambient, or created by bombardment with ions, neutrons, electrons, or photons. A fundamental understanding of these defects in near-surface regions is therefore necessary for the characterization and improvement of material performance.

The present program is an effort to characterize lattice defects by means of techniques such as frequency-dependent cathodoluminescence, in-situ measurements of the lateral stress induced by volume changes in radiation-damaged near-surface layers, and measurement of the optical properties and thermoluminescence of defects. A cantilever beam technique, depth-resolved and frequency-dependent cathodoluminescence, and thermoluminescence are all essentially new methods introduced in this program for investigating defects produced by ion implantation. Results from these techniques, combined with a knowledge of the partitioning of the energy of the ion-implanted beam into atomic collision and ionization processes, should provide a significant increase in fundamental understanding of defects in these materials.

Surface Physics Research

A survey of the unsolved problems in energy-related basic research and technology reveals that many of them are related to the physics and chemistry of solid surfaces. The principal object of research in this area is to obtain a fundamental understanding of the nature of a surface and its effect on the interaction of the solid with various environments. The economic importance of catalysis, for example, to the petroleum and chemical industries is enormous in spite of the fact that a fundamental understanding of the nature of the catalytic surface and its interaction with atomic and molecular species is not yet available.

A major reason for this lack is our current inability to determine the physical and chemical properties of these species when they are on the surface.

In the present work, two studies are conducted which involve new techniques with the promise of contributing valuable information about the way in which molecules and surfaces interact. The first study involves an application of the Sandia-developed Imaging Field Desorption Mass Spectrometric technique to the problem of imaging molecules during their interaction with solid surfaces. The second involves the application of several electron spectroscopic techniques to a series of molecular species and molecular surface combinations which cause the local atomic environment and surface interaction strength to vary in a systematic way. In conjunction with advanced data reduction techniques and theoretical characterization, this work will produce a data base of absolute standards by which arbitrary spectral line shapes can be compared to determine the spectrum of surface species involved.

Combustion Research

Because of the present heavy dependence upon fossil fuels in the United States, combustion research has the potential for making major contributions to our energy future by allowing development of more efficient, less polluting systems. In the past, such research has been hindered by lack of adequate diagnostic techniques. In their absence, it has not been possible to develop and verify accurate models for combustion processes in real engines. Such models would be of great assistance in fixing the design and operating parameters which would optimize engine efficiency and minimize pollutant generation. Now, new diagnostic techniques, using lasers, promise to remedy the situation. The laser techniques offer excellent sensitivity, as well as good temporal and spatial resolution; most important, unlike probe methods used in the past, they do not disturb the combustion process itself.

The application of sophisticated laser technology to combustion research grew out of the laser capability which had been developed for other programs — applied research in aerodynamics and controlled fusion, as well as basic research in atomic and molecular physics.

Sandia Laboratories has proposed a National Combustion Research Center at Livermore to fully exploit new diagnostic and computational techniques. This Center will devote approximately one-third of its activity to understanding the fundamental processes that take place in all practical combustion systems. An additional one-half of the Center's activities will be concerned with the application of basic research results to practical combustion systems, with initial focus on automotive combustion. The remaining one-sixth of the Center's effort will deal with development and updating of diagnostic tools.