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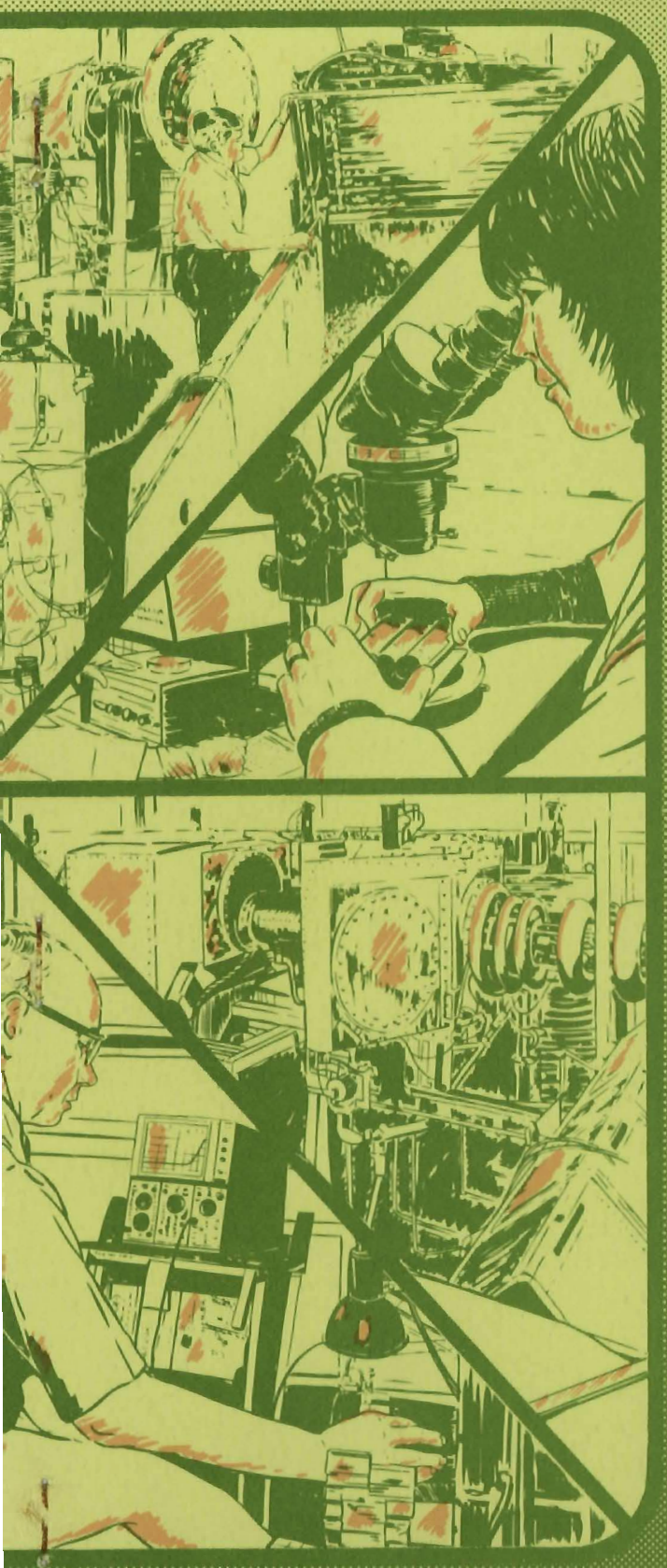

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LONG-RANGE PROGRAM PLAN 1977–1983

for OAK RIDGE NATIONAL LABORATORY

March 1977

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830
operated by
Union Carbide Corporation
for the
Energy Research and Development Administration

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LONG-RANGE PROGRAM PLAN 1977–1983 for OAK RIDGE NATIONAL LABORATORY

Senior Planning Group
H. Postma
F. L. Culler
C. R. Richmond
M. W. Rosenthal
D. B. Trauger
A. Zucker

Planning Group Staff
J. B. McGrory
C. C. Burwell
D. J. Crouse
J. E. Jones Jr.
R. S. Livingston
J. Poston

Managing Editor
J. S. Nunley

Graphic Design
A. D. Richardson

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Foreword

This is the third Long-Range Program Plan for the Oak Ridge National Laboratory in a series of formalized planning efforts. These Plans were developed during a crucial period that has seen immense change and transition in agencies and an increased public awareness of energy and related environmental problems.

Through these three years, ORNL's planning has been an internal exercise characterized mainly by formal planning efforts involving top management of the Laboratory, by recognition and documentation of the chief areas of emphasis for the Laboratory, and by a promulgation of those intentions to the staff for the guidance and development of their detailed planning and budgeting. For internal purposes, the planning process has also been important because it exposed our shortcomings, provided us an objective framework in which issues have been resolved, and tied together in a coordinated way the diverse interests that exist in any large organization. It has focused our attention on the goals, objectives, and directions toward which the institution can now direct its scarce and precious resources.

Just as we have been evolving an effective planning mechanism internal to the Laboratory, ERDA has also been giving significant attention to national energy research and development (R&D) planning. From its inception, ERDA has wisely committed much effort to overall mission planning and has counted heavily upon that to guide the thinking of the agency, the Congress, and the Office of Management and Budget (OMB) about the research and development necessary to implement a national energy policy. The series of resulting documents are entitled *A National Plan for Energy Research, Development, and Demonstration* (ERDA-76), Volumes 1 and 2.

In addition, ERDA has extended its planning efforts from this broad national level to specific long-range planning for individual programs that will help meet the national goals defined. The results of this process are program planning. The strategies and goals defined through program planning are then used in conjunction with the actual resources made available through the near-term budgeting process to determine the commitments that each ERDA program will fulfill through the next fiscal year. These are contained in documents called Program Approval Documents (PADs). The spring planning projection process and the two-year budget formulation process (in which the Laboratory now participates through the annual "189" cycle) are two other activities in ERDA's planning system that help form the link between the long-range planning activities and the actual near-term budgeting process.

In this planning network, ERDA is now attempting to form a link between program planning and the accomplishment of its objectives, with due consideration of the national resources available. The national laboratories are among the prime participants in this process. ERDA is requesting that 17 of its major laboratories, as well as laboratories of other agencies significantly involved in ERDA programs, write long-range "Institutional Plans." The objective of this planning is to integrate the various long-term responsibilities that have been assigned to an individual institution and the resources needed to carry out these responsibilities. Guidelines for the planning process and the content of the planning document will be provided by ERDA. Therefore, it is believed that this present Plan will be the last of the ORNL Long-Range Program Plans to retain this particular format and that ORNL's internal long-range planning activities will now be more closely and formally coordinated with ERDA's planning system. It is hoped that the end product, combining the best experience of both organizations in planning, will be a more realistic Plan that will more effectively serve both the Laboratory and ERDA.

Indeed, each year as we proceeded in our internal planning activities we learned more about how to plan creatively. Each year we have identified deficiencies in our planning process and have attempted to correct each deficiency over which the Laboratory had internal control. The principal deficiency of the past, however, has clearly been the inadequacy of feedback from the ERDA program divisions on the Laboratory's planning decisions, including agreement on the basic programmatic directions, the basic technical goals for the Laboratory, and a recognition of the needed resource requirements such as manpower, facilities, and equipment. It is hoped that the newly requested Institutional Plans and the interactive process between ERDA Headquarters and the laboratory through which they will be developed will finally correct this deficiency for future ORNL plans. At the same time, I must express personal appreciation for the substantive feedback that has been forthcoming from the ERDA Oak Ridge Operations Office during the past three planning cycles and hope that this interaction will be continued and strengthened in the new ERDA process.

Finally, as we form this transition between an internal ORNL and an integrated ERDA planning system, it should be emphasized that any planning effort must be dynamic. Our present Plan could not fully anticipate the changes that have occurred in the recent past as well as those now anticipated in the new administration of the country, that is, shifting congressional relationships and committees, reorganizations and consolidations of agencies, and the appearance of new people, new ideas, and new programs within ERDA. Indeed, if this Plan were fulfilled in the next five years as presently constituted, it would mean that there would be no external circumstances or new ideas that would influence our activities. Because the basic aim of the Laboratory is the creation of new ideas and options, we expect our achievements to differ substantially from this Plan at the end of the five-year period. Oak Ridge National Laboratory looks forward with optimism and anticipation that the solution of the many major problems in energy and environment now facing the country will be properly addressed through research, development, and demonstration and that the Laboratory will continue to play an important role in creating those solutions. We look forward to increased interactions with ERDA through the planning contacts in the expectation that they will lead to the best utilization of the Laboratory in finding research and development solutions to the many problems facing ERDA.

Herman Postma

Herman Postma, Director
Oak Ridge National Laboratory

EXECUTIVE SUMMARY

Oak Ridge National Laboratory (ORNL) is a *national energy laboratory* concerned with the development and efficient use of environmentally acceptable supplies of energy from various sources. ORNL is a federal government facility controlled by the Energy Research and Development Administration (ERDA), and most of the work carried out at the Laboratory is sponsored by ERDA. The details of the entire program are presented in the main body of this Plan and are highlighted here.

PROGRAM HIGHLIGHTS

The present ORNL program is dominated by four general areas of research and development. These programs, ordered according to the size of their FY 1976 ERDA budgets, are:

- Nuclear Energy Development—fuel cycle [primarily for liquid metal fast breeder reactor (LMFBR) and gas-cooled reactors], high-temperature materials, reactor physics, and reactor safety
- Basic Energy Sciences—properties of materials at high temperatures, radiation damage, heavy-ion physics, neutronics, catalysis, high-temperature chemistry, actinide chemistry
- Magnetic Fusion Energy—physics of toroidally confined plasmas, plasma heating by neutral-beam injection, large superconducting magnet development, fusion reactor technology
- Biomedical and Environmental Sciences—environmental impact of energy effluents, somatic and genetic effects of energy effluents, environmental policy analysis, detection of environmentally associated health effects

This plan projects program budgets through FY 1983. Between FY 1977 and FY 1983, the plan projects particularly significant growth in the magnetic fusion and fossil energy programs. Thus, by FY 1983, the ordered list would become:

- Nuclear Energy Development
- Magnetic Fusion Energy
- Fossil Energy—high-efficiency alkali-metal steam systems, fluidized-bed combustion, components testing, basic research in coal chemistry, and properties of materials at high temperatures
- Basic Energy Sciences
- Biomedical and Environmental Sciences

Each of these dominant research areas encompasses a large number of diverse research and development programs. There are one or more programs in each research area which will play especially important roles at ORNL over the next several years. They are important because of the primary position they play in ERDA's program to meet the nation's energy needs and, in most cases, because of the impact they have on total Laboratory resources, by virtue of their size.

Most of these dominant programs integrate a broad range of disciplinary activities. The range of these important programs is described here.

LMFBR Fuel Cycle—ORNL has been assigned the lead role in developing the fuel reprocessing technology of the LMFBR cycle. The central element in this program is the Integrated Prototype Equipment Test Facility, which will be designed and assembled by FY 1981. This facility will provide for testing of the components of an LMFBR fuel reprocessing plant and developing efficient remote maintenance procedures. It is conceived as the precursor to a pilot reprocessing plant, the Hot Pilot Plant, to be built by 1986 to 1988. Basic research in the areas of actinide chemistry and fission-product separation science supports the fuel cycle work. In biomedical and environmental science, the route of radioactive wastes through the ecosystem and the biological effects of radioactive effluents on animals are major areas of investigation in support of the total fuel cycle program. Finally, ORNL will help prepare guidelines for permissible releases of radioactive materials and develop adequate safeguards for the storage of special nuclear materials.

Fusion Power Development—ORNL is a major center of research and development for fusion energy technology. The program concentrates on theoretical and experimental studies of toroidal confinement fusion devices and, in particular, on the use of neutral-beam injection for plasma heating. In fusion reactor technology, ORNL has a leading role in the design and development of large superconducting magnets. Fundamental physical research in support of reactor technology is in the area of properties of materials at high temperatures, neutron cross sections relevant to fusion technology, neutron-induced radiation damage, heavy ion simulation

of neutron radiation damage, and basic chemical and engineering studies relevant to tritium handling. These studies will utilize several of the accelerators and reactors available at the Laboratory. The fate of fusion technology effluents in the ecosystem and the biological effects of these effluents will be studied with increasing intensity in the biomedical and environmental research programs.

Heavy-Ion Science—The Holifield Heavy Ion Research Facility (HHIRF), when completed in FY 1979, will be the center of ERDA's heavy-ion science program. The energetic heavy-ion beams produced in this facility will be used in basic nuclear physics, in chemistry studies of reactions between complex nuclear systems, and in studies of new isotopes far from stability. The beams will be used in applied research on materials radiation damage and actinide chemistry.

Nuclear Reactor Technology—ORNL has an important role in ERDA's reactor technology programs, mainly in support of LMFBR and gas-cooled reactors. Principal components of the program include development and evaluation of structural alloys and fuels and development of high-temperature structural design methods and joining technology. These are complemented by basic research on alloy properties. Neutronics analyses, cross-section measurements, and shielding studies provide an important technology input for reactor design and safety. The program also includes heat transfer and fluid flow studies and development of advanced instrumentation and control methods for reactor systems.

These programs, which are large programs in terms of budget and personnel, are continuations of established programs. ORNL has started a program in coal conversion and is probing for an appropriate role in the other major technologies, conservation and solar and geothermal energies. These efforts are smaller in terms of money and personnel, but they are in areas of high potential impact; we hope they will play a more significant role in our total effort in the next few years.

Coal Technology Program—The coal technology program includes basic research and engineering. Four major engineering components of the coal technology program are (1) a hydrocarbonization development program, (2) a major coal conversion component test facility, (3) a potassium vapor topping cycle facility, and (4) a fluidized-bed boiler for industrial application or for application in Modular Integrated Utility Systems (MIUS). Increasing basic research in coal chemistry and materials should provide a basis for major improvements in advanced coal conversion processes. The environmental and biological impact of coal technology is a growing area of research in the biomedical and environmental sciences.

Conservation—The most immediate means of achieving some of our national energy goals is through energy conservation. Our conservation activities include development of the Annual Cycle Energy System (ACES), evaluation of end-use conservation in household appliances, analysis of insulation materials for industrial energy conservation, and development of low-temperature thermal storage systems.

Solar and Geothermal Energy—The programmatic involvements of the Laboratory in solar energy are in the areas of development of high-efficiency low-cost heat exchangers for ocean thermal conversion, assessment of appropriate goals for solar energy development, and agricultural applications of solar energy. In physical research, methods of nuclear doping and ion implantation will be used to develop high-efficiency photovoltaic cells which use polycrystalline silicon material, as well as other materials. The geothermal program is primarily in the area of chemical and materials basic research, including brine-induced corrosion and the mechanics of scale formation, power cycle development, and analysis of environmental impacts.

RESOURCES NEEDED

The estimated operating costs needed to meet our goals are summarized in Figure 1 for the major program areas. The estimated size of the full-time regular staff is shown in Figure 2. The information in Figures 1 and 2 is discussed in some detail in Chap. VI. The budget reaches $280 million in FY 1983, but this figure should not be correlated directly with personnel growth. A considerable fraction of this money (about $75 million) will be put out on subcontracts to private industry or used for construction of research facilities, as we take on more and more program-management tasks. Beyond this, the budgets presented in the body of this plan represent the input of individual staff research groups. The sum of these individual budgets is about $400 million. The $280 million total Laboratory budget shown in Figure 1 is based on two considerations:

1. The best thinking of the senior Laboratory management as to the expected directions of major programs at ORNL in the coming years.
2. The fact that, in past years, the final approved Laboratory budget has been about 77% of the initial budget request submitted two years prior to final authorization.

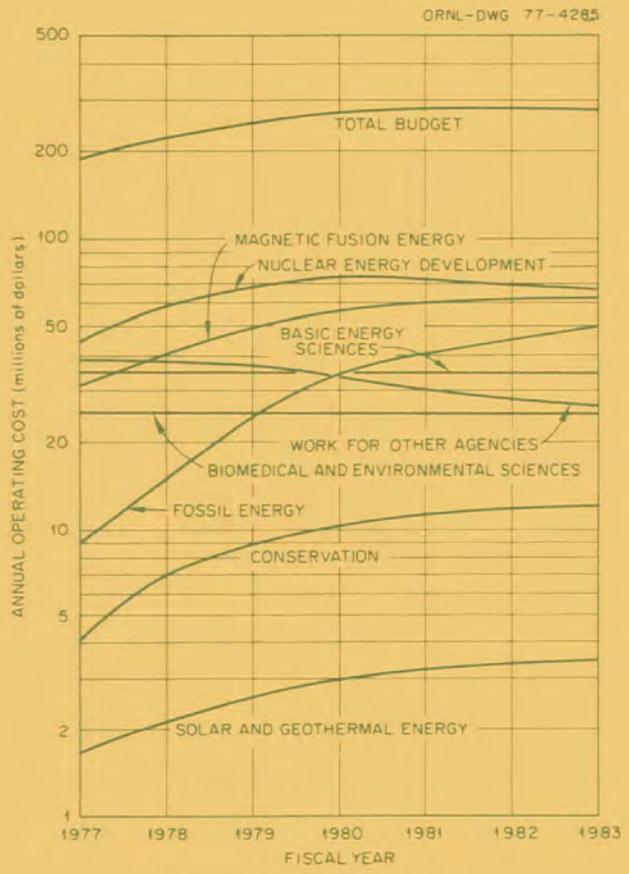


Figure 1. Operating Cost.

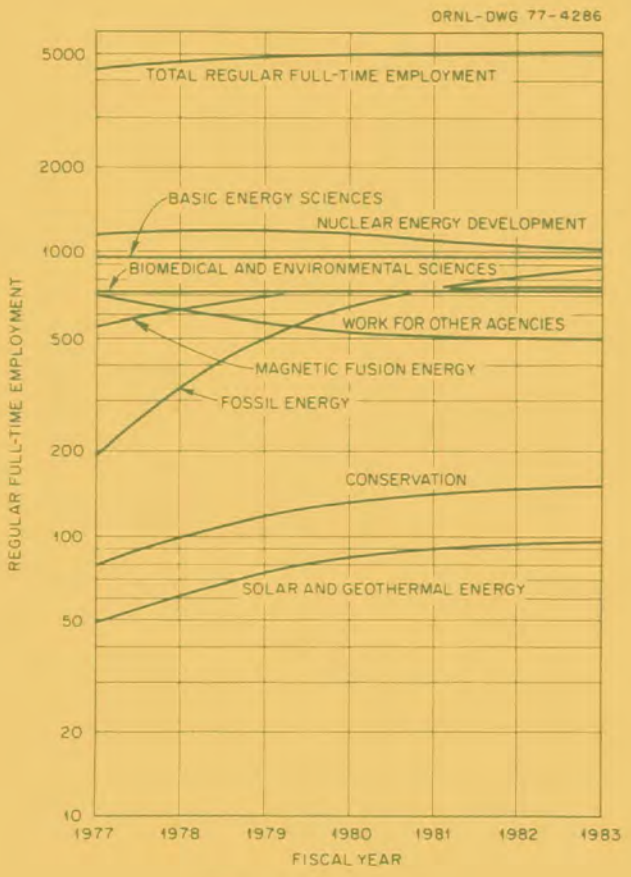


Figure 2. Employment.

KEY ISSUES

A number of problems need to be resolved if our research is to proceed effectively. The issues are stated more fully in Chap. IV of this plan, but brief descriptors for these key issues are listed here:

Programmatic Issues

- Support of long-range basic research by technology programs
- Long-term national strategy for gas-cooled reactors
- Future role of NRC work at ERDA facilities

Facilities and Research Equipment

- Long-term continuing support of special facilities, reactors, separators
- Adequate computer capacity
- Laboratory and office space for relieving present overcrowded conditions and inadequate buildings
- Funding for general plant projects (GPP) and general-purpose equipment (GPE)
- Adequate review of placement of major new facilities

Administrative Issues

- Transfer of technologies to industry
- Interactive planning between laboratories and headquarters
- Increased program flexibility and breadth
- Creation of "lead laboratories"
- Funding of foreign travel

I. INTRODUCTION

This document is the Oak Ridge National Laboratory Long-Range Program Plan for the fiscal years 1977 through 1983 and is the third Plan in a series. It describes what we expect to accomplish during this period, how these accomplishments will be attained, and what resources will be required.

Objectives

The major objectives of the Oak Ridge National Laboratory (ORNL) are:

- To develop new and environmentally acceptable energy technologies that will offer the nation safe options for energy supply and efficient systems for energy use.
- To generate, analyze, and systematize new scientific knowledge.
- To perform research and development in support of other national needs where the Laboratory's experience or abilities permit us to make important contributions.

The Laboratory is owned by the federal government, controlled by the Energy Research and Development Administration (ERDA), and supported almost completely by government funds. Thus, it has the responsibility to devote its activities to the major national problems that fall within the areas of concern of the Laboratory's sponsoring agencies. Primary support (80%) is provided by ERDA; about 10% of the work is supported by the Nuclear Regulatory Commission (NRC) and about 10% by other agencies (National Institutes of Health, National Science Foundation, etc.). In addition to conducting research, the Laboratory is a national and regional resource in the education and training of technical personnel and provides some of the best opportunities for professional employment in the Southeast.

Staff and Facilities

ORNL is one of the largest scientific and technological multiprogram laboratories in the world. One of ORNL's strengths is the diversity of the technical staff. Forty percent of the personnel are college graduates, including more than 700 with the Ph.D. degree. There are 700 engineers, primarily chemical, electrical, and mechanical engineers, about 100 mathematicians, 350 chemists, 330 physicists, and more than 300 biomedical and environmental scientists. Finally, there is a growing staff of social scientists, now numbering more than 30. The activities of the Laboratory cover a broad span of related functions: basic research, pilot plant operation, large-scale high-technology development. The ORNL program is dominated by four general program areas that are roughly equal in size, namely, fission energy development, biomedical and environmental research, basic energy sciences, and magnetic fusion energy. In addition, there are rapidly growing programs in fossil energy and conservation.

In support of this program, there exist a variety of special facilities and extensive laboratory and office space. There are a number of unique facilities at ORNL. Included in these facilities are two high-flux reactors now devoted to isotope production, materials irradiation studies, and neutron scattering [High-Flux Isotope Reactor (HFIR) and Oak Ridge Research Reactor (ORR)], and several smaller reactors devoted to shielding and radiation effects studies. There are six charged-particle accelerators engaged in nuclear and atomic physics research, and an electron linear accelerator which is designed to produce neutrons for neutron cross-section measurements. Several laboratories are specifically designed for handling transuranium and other radioactive elements involved in the fission reactor fuel cycle. The world's largest electromagnetic stable isotope separator is at ORNL. In the area of life sciences, there is a 30,000-acre ERDA-owned tract of land ideal for ecological and aquatic studies, and there are extensive animal facilities.

ORNL and two other major ERDA facilities in the Oak Ridge area, the Oak Ridge Gaseous Diffusion Plant (ORGDP) and the Y-12 Plant, are managed under a contract with ERDA by the Union Carbide Corporation Nuclear Division (UCCND). There exists an engineering-support program of 1300 employees plus subcontracted architect-engineers for all three facilities with capabilities far beyond those which would be required for ORNL itself. Also in the Oak Ridge area are the University of Tennessee-ERDA Comparative Animal Research Laboratory (CARL), which has extensive whole-body animal irradiation facilities, and the Oak Ridge Associated Universities (ORAU). ORAU administers a number of cooperative programs with universities through which faculty members and students participate in Laboratory programs for varying periods of time. Finally, ERDA's Oak Ridge Operations Office (ORO) is located in Oak Ridge. ORO will play a particularly important role in the management of technology programs in the future.

Recent Changes in Priorities

The Long-Range Plan must be revised periodically because circumstances change both inside and outside the Laboratory. Since the 1976–1982 Plan was published, a new report *A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices for the Future, 1976* (ERDA-76), has been published, and the appropriation bill for the FY 1977 ERDA budget has been approved by Congress. We summarize briefly the key changes and trends which are suggested in these documents and which have an impact on the Laboratory's plans.

The ERDA-76 Plan gives an increased priority to the technologies that can make a contribution in the near term (by 1985). In particular, conservation has become the highest priority technology. In addition, ERDA-76 again stresses the importance of the transfer of technology from the laboratories to the stage of commercialization by private industry.

The FY 1977 ERDA budget gives the largest percentage increases (about 100%) to conservation, solar energy research, and research and development related to the nuclear fuel cycle. Other near-term technology programs (fossil fuels, geothermal energy, and solar space heating and cooling) are given about 33% increases. One of the smallest increases (8%) is in the area of supporting basic research.

The FY 1977 budget points to several changes or trends specifically at ORNL. The budget includes no funding for the molten salt reactor project. A decision has been made to place control for the rapidly expanding geologic radioactive waste isolation program in a new Office of Waste Isolation (OWI), which reports directly to the president of UCCND. The budget also indicates that ORNL will have major responsibility for the high-temperature gas-cooled reactor (HTGR) fuel recycle and LMFBR fuel reprocessing programs and will experience a significant expansion in the fusion program. There continues to be a trend at ORNL toward nonnuclear programs in the physical and life sciences, toward environmental sciences as opposed to biological and health sciences, toward large hardware development as opposed to staff expansion, and toward some management responsibility for ERDA programs, accompanied by a decline in work for the NRC and other non-ERDA organizations.

Development of This New Plan

The development of this Long-Range Plan began with a review of the 1976–1982 Long-Range Program Plan by the technical management of the Laboratory. New program element goal statements and cost estimates were prepared by the staff. The individual program elements were reviewed by the Laboratory Director and Associate Directors, and the sum of these elements was reviewed as a total Laboratory program. Several constraints were put on the total program. We expect the Laboratory to be asked by ERDA to assume responsibility for managing certain programs that will be carried out partly by subcontractors. This is equivalent to saying that the Laboratory will not experience personnel growth proportional to budget growth. We assumed a limit to the growth of the Laboratory staff at an average rate of 2% between 1978 and 1983. A second constraint was imposed by making a deliberate choice of the profile of the Laboratory program we would like to see in the last year considered in this Plan, 1983. We would like to have the percentages of our operating funds shown below under FY 1983 (exclusive of money spent outside ORNL) expended in the indicated areas. For comparison, we show a similar breakdown for FY 1977.

	FY 1977(%)	FY 1983(%)
Basic Energy Sciences	22	19
Biomedical and Environmental Sciences	17	14
Conservation	1	3
Nuclear Energy Development	26	20
Fossil Energy	4	17
Magnetic Fusion Energy	13	15
Solar and Geothermal Energy	1	2
Work for Other Agencies	16	10

This implies relatively strong growth in fossil energy, somewhat less growth in conservation, and some relative reduction in our work for other agencies and in nuclear energy development. The apparent relative decreases in the Basic Energy Sciences and Biomedical and Environmental Sciences results from our assumption that these programs remain at fixed dollar levels in this Plan (see discussion in Chap. VI). One of the most significant changes in this Plan as a result of these considerations is a large increase in the amount of money that will be spent outside the Laboratory by subcontracting and construction.

II. LABORATORY POLICIES

The following policy statements are arranged to deal successively with the questions of who our sponsors will be, what type of work we will undertake, and how we will assure that high-quality work is produced. The Laboratory will:

- Be responsive to the full range of ERDA programs.
- Perform NRC work that utilizes unique local competence and/or augments other existing programs, provides information on which policies and regulations can be based, and avoids conflicts of interest.
- Perform work for other federal agencies and for institutions [such as Electric Power Research Institute (EPRI)] that complements ERDA programs and uses unique Laboratory facilities or skills.
- Seek problems in technology development that are important with respect to national energy needs, use the Laboratory's multidisciplinary capabilities, and have too high a risk for private industry.
- Seek to become a "lead laboratory" in important areas of technology development.
- Continue strong basic research programs in the physical and life sciences that are related to energy problems or use unique Laboratory facilities.
- Cooperate with industry and work for rapid transfer of new technologies to industry.
- Use "seed money" funds to encourage the development of innovative programs.
- Cooperate with other ERDA contractors and with universities and local government units, particularly in studies of a regional nature that involve technological questions having political and sociological components.
- Develop joint programs with the Energy Research Centers so that the Laboratory and research centers can make maximum use of each other's expertise.
- Balance Laboratory activities with an appropriate mixture of near-, middle-, and long-term programs.
- Regularly evaluate programs to assure that they contribute to the attainment of Laboratory goals and to establish a basis for decisions when it becomes necessary to redirect program efforts.
- Use assessments and evaluations to guide and support the experimental and developmental programs and to provide information from such studies to policy makers.
- Use social scientists to provide guidance in their areas of competence to the technology development programs.
- Encourage the formation of outside groups to use unique Laboratory facilities.
- Maintain high-quality support organizations and facilities in engineering, computer science, instruments and controls, analytical chemistry, fabrication, maintenance, and health physics.
- Encourage information activities that have a close association with our research and development programs.
- Encourage responsible efforts by the staff to inform the public concerning energy programs.
- Maintain a staff of exceptional quality through highly selective recruiting and careful development.

Of all these policies, the one most important to the success of the Laboratory is the last one. In order better to meet the aim of this policy, the *Long-Range Plan for Human Resources 1976-1981* was developed and published in 1975. The Plan is a statement of Laboratory policy with respect to human resources and a commitment to actions which implement those policies. These commitments are designed to assure the proper availability, optimum utilization, and continuing welfare of a strong and viable staff able to contribute to the achievement of the Laboratory objectives. More than 125 programs are described in the Plan; they deal with staffing, staff development, and the conserving of staff. The staffing programs deal with recruitment, placement, internal mobility, and termination or retirement. The staff development program deals with training and education programs which contribute to employee professional and/or organizational growth. The conserving programs deal broadly with programs that protect and motivate the employees. The *Long-Range Plan for Human Resources* will be periodically reviewed and revised to reflect changing circumstances.

III. LABORATORY PROGRAM SUMMARY

In this section, we present short reviews of the Laboratory programs in the following order:

- Basic Energy Sciences
- Biomedical and Environmental Sciences
- Conservation
- Nuclear Energy Development
- Nuclear Regulatory Commission Programs
- Fossil Energy
- Magnetic Fusion Energy
- Solar and Geothermal Energy
- Information, University Relations, and Commercialization

The programs are organized in much the same way that the programs are organized in *A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices for the Future, 1976, Vol. 1, The Plan,* ERDA-76. Thus, we first present the broad supporting basic research programs in the physical and life sciences. Then, we discuss the specific technology programs in order of near-, middle-, and long-term technologies. We have combined all our nuclear reactor programs, including breeder reactor efforts, into one section. We discuss work for the NRC separately. Finally, we discuss less-technical support programs.

BASIC ENERGY SCIENCES

To develop new knowledge relevant to the nation's energy goals, an accompanying program of long-range fundamental research must be implemented. Only by gaining new insights can major improvements be made in existing technologies and entirely new concepts developed. A national program of basic energy science must include two types of research. One type looks for new phenomena and/or new fundamental laws and principles. The technological impact of such research is highly uncertain and perhaps remote in time, but it is potentially great and has proved to be the long-range basis for really profound advances in technology in the past. The second type of research is designed to exploit the nearly complete technologies where the basic science is well in hand except in a few critical areas, or where the environmental or health aspects alone preclude widespread utilization. This type of physical research is characterized by its specificity, urgency, and close ties to the national Research, Development, and Demonstration (RD&D) programs. In either case, if optimum application of research results is to occur, there must be a conscious effort to transfer this knowledge to those responsible for development and demonstration. Below, we describe the general areas of research in the physical sciences and highlight the parts of the basic energy sciences program that offer direct support to ERDA's technology programs.

Materials Research

The materials research program is a broad-based program directed at solving materials problems encountered in advanced energy conversion systems. The traditional emphasis in materials science has been on materials for fission reactors. We expect increasing emphasis in the coming years on materials for emerging technologies such as fusion and coal conversion. The mechanical, physical, and optical properties of solids, as well as the characteristics of their surfaces, will be investigated. In the next few years, particular emphasis will be given to physical and mechanical properties of materials at high temperatures in corrosive environments. Materials needed for direct solar energy conversion will be investigated, along with those related to energy transport (e.g., superconductors) and storage. Problems relevant to fusion reactor development, such as atom-surface interactions and diffusion of hydrogen through solids, will be studied. A better understanding of the factors that contribute to the properties of advanced alloys will also be an objective. Basic understanding of the magnetic, electronic, and lattice dynamic properties of solids will be pursued by theoreticians and experimentalists working in close collaboration. Neutron scattering will continue to be a valuable tool in these basic studies. The High-Flux Isotope Reactor (HFIR) will continue to supply neutron beams of unsurpassed intensity for scattering experiments.

Chemical Research

The chemical research program will emphasize the study of catalysis because of the fundamental role it will play in the development of coal conversion, shale utilization, and other chemical energy sources. Thermodynamic and kinetic data relative to conversion processes will be determined, and the analytical chemistry and separation techniques

needed for adequate identification and safe handling of noxious by-products will be developed. Thermochemical, photochemical, and biochemical processes for the production of synthetic fuels (such as hydrogen) and electrochemical properties of fused salts needed for the development of high-temperature fuel cells and batteries will be investigated. Hydrates and fused salts for potential use in thermal energy storage systems will also be studied. The corrosive effects and high-temperature chemistry of geothermal solutions will be investigated, as well as the properties and reactions of fusion reactor blanket materials. The electrochemistry underlying stress corrosion will be investigated.

The HFIR will supply important transplutonium elements for research in the United States and foreign countries on the disposal of waste actinides in reactors and the chemical properties of the actinide elements pertinent to prediction of their behavior in the environment.

Nuclear and Atomic Physics and Chemistry

The nuclear and atomic physics and chemistry research program will provide nuclear data, particularly on neutron cross sections, for support of fusion reactor development, for recycling of actinide wastes from fission reactors, for new materials of potential interest for fission reactors, and for materials selected as standards upon which other measurements are based. Nuclear techniques will be applied to the material sciences, and the properties of charged ions in ion-atom and ion-solid interactions will be investigated. Particle-surface interactions and hot-atom chemistry relevant to fusion reactor first-wall problems will be investigated. The microscopic properties of materials to be used in energy conversion devices will be characterized through the determination of the electronic distributions in the materials of interest. In nuclear science, the Laboratory will be a leader in heavy-ion research, a field that is judged to be of increasing interest and importance in nuclear, as well as atomic, physics; results of this research should yield new theoretical insights, as well as new experimental discoveries. The first phase of the new Holifield Heavy Ion Research Facility (HHIRF) will be completed by FY 1979. This laboratory will provide the nation with a source of precise beams of a large variety of heavy ions useful to nuclear physics for nuclides over the entire periodic table and to atomic physics over the full range of elements. In FY 1979, we will request the authorization of phase II of the HHIRF, the addition of a powerful second-stage accelerator to extend the capabilities of the facility and make it the most versatile and most powerful heavy-ion laboratory in the world. Heavy ions allow us to produce neutron-like damage in materials at much faster rates than any neutron source now known; this is of great significance to radiation-damage studies. The new laboratory will also enable researchers to push the limits of known nuclides further into the "sea" of instability and into the region of the superheavy elements, if these prove stable for even very short periods. This facility will be available equally to users from ORNL, universities, and other laboratories.

Engineering Sciences

The engineering sciences research program will provide fundamental chemical and physical information for advanced energy systems and will study the basic engineering aspects of conversion systems such as transport processes, turbulent flow phenomena, and separations processes. New concepts, such as bioreactors and large-scale reversible chemical sorption systems for storage and recovery of energy, will be investigated.

BASIC ENERGY SCIENCE SUPPORT OF TECHNOLOGY PROGRAMS

An appreciable fraction of the effort of the basic energy sciences program is oriented toward direct support of ERDA technologies. In FY 1977, for example, approximately 10% of the basic energy sciences budget will support research directly applicable to the fusion reactor technology program. This research includes (1) studies of methods for the separation and containment of tritium; (2) studies of the effects of radiation on materials relevant to magnetic fusion devices; (3) studies of plasma-surface interactions, including the effects of impurity ions; and (4) the evaluation of neutron cross sections at energies and with materials characteristic of the fusion reactor concept. Another 10% of the basic energy sciences budget supports research bearing directly on problems of fission reactor technology. This research covers neutron cross-section measurement and evaluation, materials studies, separations studies for waste stream processing, and the production, separation, and study of the actinides.

Basic studies pertinent to the fossil energy programs will continue to receive increasing attention. Research into the structure of coal will develop

information at the molecular level to assist in the development of economic coal conversion processes. The coal combustion and pyrolysis processes will be studied, along with the structure and properties of both homogeneous and heterogeneous conversion catalysts. The corrosion of structural materials by the harsh environments generated in conversion processes is being investigated.

In solar energy conversion, materials and process problems relevant to solar energy conversion are under study. One program will give special attention to techniques for the preparation of single-crystal and polycrystalline semiconducting materials for improved efficiencies of photovoltaic conversion. A study of the physical properties of selective absorber coatings is planned in the near future. Other areas of investigation include the energy transfer process in photosynthesis and photophysical processes. We hope to initiate a study into solar energy conversion by photosensitive reversible equilibria in the near future.

Basic research relevant to geothermal energy conversion at ORNL is currently directed toward determining the thermodynamic and physical-chemical parameters of geochemical and geophysical processes. We propose to investigate the thermochemical behavior of magmas and the interaction of aqueous media with constituents of natural formations.

In conservation, we now have basic physical research programs in hydrogen production and energy storage, and we hope to begin a program looking at the low-temperature alternating-current transport properties of metals. In energy storage, the possible role of superionic conductors as solid electrolytes in advanced battery systems is being investigated, along with the physical chemistry of high-temperature fuel-cell electrolytes such as molten carbonates.

BIOMEDICAL AND ENVIRONMENTAL SCIENCES

Environmental Research

A unique contribution of ORNL in environmental research derives from its capabilities to attack problems with an integrated ecosystems approach. We have developed a comprehensive program of investigation of basic ecosystem processes and assessment of the impact of effluents from specific energy technologies on the environment. The activities encompass both the coal and nuclear fuel cycles, including low-level waste management. Future research will deal with the transport and behavior of effluents from geothermal energy and nuclear fusion as these technologies are developed. The program will involve a broad range of studies from experimental work on poorly understood ecosystem models to field studies of actual impact. Thus, this effort represents a significant test of our present ecosystem insights and our ability to assess environmental impacts.

Carcinogenesis and Mutagenesis Testing

In the search for new energy sources, some previously unknown biological hazards are likely to surface. These hazards must be identified rapidly so that corrective action can be taken before exposure of the general population occurs. Major research programs are involved with the development of genetic and somatic testing systems designed to screen large human populations for a variety of potentially hazardous substances. Development of the testing systems is supported by research efforts in carcinogenesis and mutagenesis required for the validation and improvement of the tests.

Toxicologic Effects Research

Toxic effects will be the first detrimental health effect that will be detected in humans from occupational or environmental exposures to energy sources and their by-products. Many of the techniques that were developed during the past 30 years to study the risks to human well-being from exposure to radiation are also applicable to estimating the risk to humans from chemicals. However, there are some special problems, such as identifying the chemicals and mixtures of chemicals of interest, determining the methods of exposure to them, and determining the dose received. These problems will require development of new procedures and new general knowledge on which to base these procedures. The aim of the research is to predict the hazards to humans from exposure to energy by-products through comparative toxicity studies in experimental animals. Thus, a rational basis for limiting exposures can be provided, and, moreover, the results should assist in the selection of safe technologic processes.

Early Detection of Environmentally Associated Health Effects

The objectives of the early detection program are to provide the maximum possible contribution to national health goals and serve the needs of the biomedical community through various approaches,

including the development of innovative radionuclide systems. These objectives will be attained by integration of the Laboratory's capabilities in the areas of (1) research and development of radionuclides, (2) synthesis of radiopharmaceuticals, (3) elucidation of biological mechanisms of pharmacology and distribution in the body, (4) immunology, (5) measurement of radiation dose to body organs from radiopharmaceuticals, (6) development of instrumentation specific for nuclear medicine applications, and (7) development of computing technology for biomedical application. Early detection of possible adverse human health effects associated with fuel cycles for various energy-producing technologies is important because early detection increases the probability of modifying or repairing the effect.

Biotechnology

New initiatives are being taken in interdisciplinary programs in biotechnology and bioengineering. The development of bioprocesses useful in the areas of energy production, resource recovery, conservation, and pollution abatement will become increasingly important. Investigations will include activated sludge reactors for process waste treatment and bioconversion to fuels, abatement of pollution due to the organic contaminants in the effluents of coal conversion processes by bioreactors utilizing immobilized enzymes or microorganisms, coal beneficiation and resource recovery by slurry reactors using microorganisms, and removal and concentration of dangerous heavy-metal pollutants or resource materials from dilute aqueous streams using bioreactors.

Coal Conversion Technology—Health and Environmental Effects

The coal conversion study will provide the information necessary to ensure that coal conversion will be an acceptable technology when implemented on a large scale. To attain this goal, potentially hazardous constituents in effluent and product streams will have to be identified and characterized, methods of monitoring must be developed. Information on the carcinogenic, mutagenic, teratogenic, and toxic properties of these constituents, as well as on their potential impact on the environment, are needed. Physical and biological information related to environmental transport is also necessary before an assessment of the potential hazards can be made.

Environmental Policy Analysis

ERDA has the responsibility for creating energy choices for the future that are economically sound, socially acceptable, and in accord with health, safety, and continued acceptable environmental quality. Nuclear energy is receiving considerable attention relative to its safety and deleterious effects on health and environmental quality. Environmental policy issues concerning the nuclear fuel cycle and, in particular, nuclear waste isolation are being directed to ERDA for analysis, evaluation, and judgment. The Office of Environmental Policy Analysis has been established recently by ERDA to deal with current and future policies relating to the development and utilization of energy and to provide inputs for decision making by ERDA management and higher councils of government. Each multipurpose ERDA laboratory has established an Office of Environmental Policy Analysis. In this program, ORNL has been assigned responsibility for performing critical issue analyses of the nuclear fuel cycle (particularly the management of radioactive wastes), coal conversion technology, and possibly the general area of toxic substances.

CONSERVATION

Energy conservation is a high-priority program in the overall set of federal energy activities. The program is in recognition of the need for careful custodianship of diminishing U.S. resources of oil and gas, the environmental benefits of reducing energy demand through improving the efficiency of energy use, and the high cost of importing oil and gas, extracting new indigenous oil and gas resources, or converting coal to these fuel forms. The federal conservation program deals with energy policy formulation and technology development at the point of energy end use. This program is divided into six major categories: industry, buildings, transportation, electrical systems, storage, and modeling of energy use. Programs within each category are designed to improve the efficiency of energy end use, to use or recycle waste energy and materials, and to substitute end-use technologies based on plentiful U.S. fuel resources for those dependent on fuels in short supply.

The major continuing conservation activity at the Laboratory focuses on consumptive end uses in buildings. It includes analyses of heating and cooling systems, energy loss through the walls of structures, the efficiency of various appliances, and lighting. Air-conditioning systems, heat pumps, and compressor designs are being studied. A major new activity will be in energy storage, where the Laboratory has been assigned the responsibility for developing the low-temperature element of thermal

energy storage by sensible heating and phase-change modes for a wide range of heating and cooling applications. This involves storage applications at temperatures up to about 250° C.

Other activities include studies on insulation materials, particularly high-temperature insulation for industrial process applications and gaseous and liquid insulators for high-voltage electrical transmission. The Laboratory is involved in the development and use of computer models and data bases to assist in evaluating energy conservation policies, technologies, and strategies. In addition, conservation-related activities at the Laboratory include the development of coal-fired Modular Integrated Utility Systems (MIUS) and an alkali metal vapor topping cycle for power plants.

NUCLEAR ENERGY DEVELOPMENT

In the fission energy area, the Laboratory concentrates strongly on the nuclear fuel cycle in its entirety, on special aspects of reactor technology, and on nuclear safety.

Nuclear Fuel Cycle

All facets of the nuclear fuel cycle must be well established technologically and economically if nuclear power is to be acceptable and safe. The Laboratory will be increasingly involved in developments bearing on fuel fabrication, fuel reprocessing and refabrication, and waste management. The Laboratory is concerned with fuel cycle developments for the LMFBR and the HTGR and is participating (with the Savannah River Laboratory) in the new ERDA effort to establish a viable light-water reactor (LWR) fuel reprocessing industry.

The LMFBR fuel reprocessing program focuses on development of processes and equipment for the steps where this technology departs from present reprocessing methods. This includes development of methods for retention of krypton, tritium, and carbon-14 and much more efficient methods for retention of iodine in the processing plant. Particular attention is also being given to development of equipment and techniques for remote operation and maintenance. Much of the new technology is potentially applicable to LWR fuel reprocessing. The effort in this program is being rapidly expanded; the objective is to achieve operation of a hot reprocessing pilot plant for LMFBR fuel by 1986 to 1988. A second major element in the LMFBR fuel cycle is the development of high-performance fuel elements with both advanced fuel and cladding materials capable of attaining high burnup, which is essential for short doubling time.

The Laboratory has been delegated overall management responsibility for the HTGR fuel recycle program, including conceptual design of an HTGR fuel recycle demonstration facility (HRDF). Under this program, the Laboratory is responsible for fuel refabrication development, for hot-cell testing of key processes and equipment for both fuel reprocessing and refabrication, and for coordinating activities in this area with the General Atomic Company, Allied Chemical Corporation, and others.

High-Level Wastes

The final step in the fuel cycle, the management of the high-level wastes, is a major public issue and potential obstacle to nuclear power development. New approaches to waste management, including partitioning of the long-lived actinides from the shorter-lived fission products, are being evaluated for potential inclusion in the overall waste management system.

Reactor Technology

The ORNL reactor technology efforts are concentrated in areas where ORNL has unique capabilities, particularly in reactor physics and materials studies. The principal emphasis is in support of the LMFBR, but important support is given to gas-cooled reactor programs, and the benefits from these programs cross several reactor systems. With respect to LMFBR support, the Laboratory has an important relationship with the Clinch River Breeder Reactor Plant (CRBRP) project; our research results will be applied to the design, operating philosophy, and licensing considerations for the CRBRP.

Oak Ridge National Laboratory has the only reactor in the United States, the Tower Shielding Facility (TSF), that is designed for shielding studies. Computer codes are developed for reactor shielding design calculations and are verified through experiments at the TSF. Related radiation transport methods are developed for calculations of the cores of LMFBRs and gas-cooled fast reactors (GCFRs). A program of neutron cross-section measurements is carried out at the Oak Ridge Electron Linear Accelerator (ORELA), the most advanced facility of its type.

The materials program is mainly directed toward development of a verified high-temperature structural design and materials technology applicable to reactor vessels, components, and core structures. The materials development work aims at understanding materials behavior in regions of

temperature and stress beyond the elastic limits and eventually will result in new materials and engineering standards for LMFBR and other high-temperature systems. There is a growing program on development of advanced alloys and fuels for use in LMFBR cores. Materials efforts in support of gas-cooled reactors include fuels and materials development, fission product behavior and coolant chemistry studies, and behavior of prestressed concrete reactor vessels.

The Laboratory has important involvement in development of reactor surveillance and diagnostics measurement methods and instrumentation.

In the blowdown heat transfer (BDHT) program, heat transfer data are being obtained in an electrically heated simulated core under LWR core conditions that would exist immediately following accidental blowdown and during activation of the emergency core cooling system (ECCS). This information is needed to confirm adequacy of the present ECCS. Important materials studies are also being made to determine the amount of swelling and oxidation of Zircaloy fuel rods that would result from the temperature-pressure transient during and after blowdown.

The LMFBR safety program centers on determining the thermal-hydraulic behavior of LMFBR fuel assemblies under normal and accident conditions (flow loss, coolant channel blockages, etc.) and on investigating the release of radionuclides from fuel under a range of accident conditions. There is a rapidly growing program on LMFBR safety analysis.

NUCLEAR REGULATORY COMMISSION PROGRAMS

The legislative act creating the Nuclear Regulatory Commission (NRC) specifies that, where possible, ERDA shall make its facilities available to NRC. Approximately 10% of the total Laboratory budget comes from NRC. The Laboratory conducts programs for NRC in both nuclear safety research and nuclear regulation.

Reactor Safety Research

All the LWR safety studies at ORNL and important parts of the LMFBR and HTGR safety studies are funded by the NRC. The NRC safety programs are discussed in the previous section on reactor safety.

Nuclear Regulation

The Laboratory is involved in the regulatory program in several important areas, including preparation of environmental statements for nuclear and related systems, assistance in safety reviews for the licensing of fuel reprocessing plants, the preparation of "as low as reasonably achievable" (ALARA) guides and assessment methodologies for the release of radioactive materials, and safeguards development. For the first of these activities— preparation of environmental statements—we are concentrating on areas where our interdisciplinary capabilities can be brought to bear on nonroutine assessments, including the development of unified transport modeling techniques and the social aspects of plant siting. Efforts in the safeguarding area concentrate on materials handling during the nuclear fuel cycle. This includes development of computer-based theft detection systems. Pilot plants developed for these systems will serve as safeguards models for commercial nuclear power plants.

Other Research

Several research programs are being carried out for NRC in areas other than reactor safety. These programs are intended to enhance the NRC's ability to perform the assessments and reviews that are a necessary part of the licensing process. These programs include research in social impacts, environmental effects, waste management, and computer modeling and forecasting.

FOSSIL ENERGY

The United States currently imports about one-half of its oil requirements. Future demand for oil and gas will continue to outstrip the domestic supply to an increasing degree. The major goals of federal activities in fossil energy are to (1) augment domestic supplies of oil and gas through enhanced recovery of conventional resources and through development of a process technology to allow use of oil shale resources and (2) increase reliance on the plentiful supplies of coal through development of technology to allow direct combustion in an environmentally acceptable fashion and through development of process technology to convert coal into liquid and gaseous fuels.

The major effort of the ORNL fossil energy program is on coal utilization, both by direct combustion and by conversion. A small program of supporting research contributes to enhanced oil recovery.

The Laboratory's program on direct combustion is oriented toward development of fluidized-bed coal combustion systems. A companion program is the development of an alkali metal vapor cycle for converting high-temperature energy to electricity with an overall thermal efficiency approaching 50%.

Coal-fired fluidized-bed systems utilizing a small closed-cycle turbine obtaining energy from the fluidized bed are being developed. The systems are potentially applicable to MIUSs serving residential and commercial customers, or they can be scaled up to industrial size. These systems will generate electricity, and process or space heat will be recovered from the exhaust gas.

The Laboratory's program on coal conversion includes a laboratory development program on catalysts, solid-liquid separation, coal analysis, and chemical structure of coal. This effort is substantially enhanced by fundamental work in the Laboratory's basic energy sciences program. Engineering development work on coal conversion is directed toward both process and component development (particularly for liquefaction).

Supporting both the direct combustion and coal conversion activities are expanding programs in engineering studies and evaluations and in materials engineering. The Laboratory's studies and evaluations programs will be used to evaluate alternatives, identify R&D requirements, and contribute to the planning process for fossil energy development. The Laboratory will have a lead role in environmental assessments and information dissemination involving coal conversion and utilization.

Finally, a major new activity in components testing is being proposed at the Laboratory. The initial element of this program would be a valve test module and would be the first unit of a Critical Components Test Facility for valves, pumps, compressors, turbines, coal preparation equipment and feed systems, pressure vessels, and gas cleanup equipment.

MAGNETIC FUSION ENERGY

Two basic approaches to controlling the nuclear fusion process are being pursued in the federal RD&D program: (1) magnetic fusion—magnetic confinement of atomic ion plasmas to simultaneously attain the required plasma densities, temperatures, and confinement time; and (2) laser fusion—inertial confinement systems based on use of high-power laser and electron beams to initiate the burning of small packets of thermonuclear fuels solidified through the use of cryogenic temperatures.

The federal program in support of magnetic fusion is organized into four subprograms: confinement systems (conduct of major experiments), development and technology (engineering support for experiments and reactor design), applied plasma physics (theoretical and computational activities), and reactor projects (construction of large projects). The Laboratory has key roles in all these magnetic fusion subprograms.

Oak Ridge National Laboratory's effort on plasma physics and confinement systems is aimed at making significant contributions to the U.S. and international undertaking to bring toroidal systems to the point that they can be used for practical power plants. Our present activities center around the operation of ORMAK and the Elmo Bumpy Torus (EBT). During the immediate future, we expect to construct two toroidal magnetic confinement devices. The first, a relatively inexpensive tokamak device about the size of ORMAK but with greater experimental capability, will be built in cooperation with the General Atomic Company and will be used to investigate impurity effects and to develop diagnostic capability. The second, also a tokamak, will replace the present ORMAK device with a slightly larger, high-field device that will explore the limits of neutral injection heating and plasma pressure.

Operation of the EBT will continue for several years; a decision about whether or how to further exploit the bumpy-torus concept will be made in the near future.

The general goal of the fusion reactor technology and development programs is to provide the components and systems that will be required for producing stable thermonuclear plasmas and for extracting power in practical, economic systems. Our major responsibilities are the development of the large superconducting magnets that will be needed for tokamak power reactors and the development of the high-power, high-energy neutral-beam injectors that are needed for the experimental toroidal devices now being built and for future power-producing systems. Investigation of the behavior of materials represents a smaller activity at present but will expand into a larger program aimed at identifying or developing materials usable under reactor conditions. Our present small investigation of tritium behavior is expected to grow into a program to develop the systems needed for the handling and containment of tritium in power reactors. A program in fusion reactor fueling technology has been initiated and is expected to grow substantially in the next few years.

Finally, we are performing the conceptual design of The Next Step (TNS), the first experiment in the U.S. program that would be capable of igniting a deuterium-tritium plasma. Plasma system design and timing will depend on what is learned in the magnetic fusion effort during the next several years, but we propose that ORNL be given an early assignment of responsibility for construction and operation of TNS so that an orderly design and development program can begin soon.

TNS will have a superconducting magnet system and will be as large as or larger than the deuterium-tritium burner with conventional copper coils now being built at Princeton. It will provide a testing system for demonstration of superconducting coils and large neutral-beam injectors. It will also contribute to the understanding and resolution of important physics questions having to do with the control of large plasma currents, large heating power inputs, and the physics of fusion-like plasmas.

SOLAR AND GEOTHERMAL ENERGY

Solar energy and geothermal energy are large energy sources that are essentially unused for energy production today because of technical and/or economic considerations. The collection, transformation, and use of solar and geothermal energy are different from traditional approaches to conversion of stored fuel such as coal or oil for energy production.

Solar

The federal RD&D program for solar energy is divided into activities leading to near-term use of solar energy for heating and cooling buildings and activities leading to long-term development of the solar-electric technologies: solar thermal, ocean thermal, photovoltaic, wind, and biomass.

The Laboratory's present small effort in solar energy is directed toward the long-term technologies, including thermal conversion, photovoltaic conversion, and assessment of economic and environmental impacts.

In thermal conversion, the major effort is in developing high-performance–low-cost heat transfer technology applicable to ocean thermal energy conversion. Another program incorporates studies of the application of the Laboratory's considerable expertise in high-temperature molten salt technology to the solar "power tower" concept. Finally, the Laboratory is providing technical support to ERDA through studies and evaluations of solar electric applications and alternatives.

Photovoltaic conversion devices are currently not economically feasible except for special applications. The Laboratory's materials research capabilities will be applied to preparing high-purity polycrystalline silicon material, rendering the material into sheets of solar-cell quality, and controlling properties through nuclear doping, ion implantation, and other techniques in an effort to improve efficiency and reduce cost of solar cells.

A key element in many applications of solar energy is storage. The Laboratory plans to participate in the study and evaluation of solar energy in agricultural, industrial, and biophysical applications where production and use of various forms of biomass provide inherent solar energy storage.

Geothermal

The federal RD&D program in geothermal energy conversion incorporates all major sources of geothermal energy: vapor-dominated hydrothermal, liquid-dominated hydrothermal, and hot dry rock. The Laboratory's efforts are concentrated on (1) low-temperature power systems, (2) scale formation, (3) corrosion, and (4) environmental assessments. Low-temperature power systems activities include development and testing of improved heat transfer technology, better methods of collecting heat, and conversion to useful work in Rankine-type engines. Studies and field tests will be performed in control of corrosion and scale formation. In the area of environmental assessment, the Laboratory will take a lead role in analysis of ERDA geothermal programs.

INFORMATION, UNIVERSITY RELATIONS, AND COMMERCIALIZATION

Information

The explosion of technical information has created a need for information centers featuring computer processing, storage, and rapid retrieval of selected bibliographic information. All scientific information, including computer technology and compilations of numeric data, requires technical evaluation and repackaging into more useful exchangeable forms. A large number of specialized information centers have grown at the Laboratory in response to programmatic needs. The centers in the

biomedical and environmental fields have been organized into a single complex, which we expect to grow rapidly during this planning period. The established information analysis centers, embedded in the programmatic divisions, can expect a steady increase in usage during the period.

University Relations

Because of ERDA's interest in personnel development, we will continue and expand our cooperative programs with universities. New emphasis will be given to involving social science students and faculty in our programs and to increasing the opportunities for minority students in the engineering disciplines. The University of Tennessee Oak Ridge Graduate School of Biomedical Science will continue to be an important center for graduate education in the biomedical sciences and will add programs in environmental sciences. The first E. P. Wigner postdoctoral appointments were made in 1976. The number of appointments will be increased from five to ten in 1977.

Commercialization and Technology Transfer

ERDA has as a high-priority objective the rapid transfer of energy technology from the laboratory to private industry for commercial development. The technology utilization program, which includes the publication of the Industrial Cooperation Bulletin, will continue to bring research spin-off ideas to the attention of private industry. Many large high-technology capital-intensive energy development programs will be carried forward in collaboration with private industry. A pilot program for the development of an energy extension service will be started in cooperation with the University of Tennessee. It will aim to transfer conservation and solar "small" technology to private citizens and to small business and industry.

SOCIAL SCIENCES

The role of the social sciences in the national energy technology development program is expected to grow at an increasing rate in the next few years. We briefly discuss the Laboratory's overall social sciences program here. Specific activities are described in the technological program elements discussed below.

The involvement of the Laboratory in the development of information related to the social issues of energy production and use continues to grow. In April 1976, the Laboratory employed 32 social scientists. Nineteen of these were full-time employees, of whom 13 held Ph.D. degrees. Half the social scientists were economists. Other disciplines represented included sociology, political science, and geography. The social science programs are integrated closely with the technology research programs, primarily with the activities of the Energy Division. Social science research in regional analysis focuses on four areas: (1) the prediction of economic activity and the associated supply and demand of various energy sources for a given geographical region, (2) development of computer-assisted methodology to assist in site selection for various energy facilities, (3) analysis of socioeconomic effects, and (4) collection, organization, computerization, and analysis of tabular geographical data.

In addition, social scientists are (or will be) involved in the development and application of engineering-economic models of residential, commercial, and industrial energy use and are participating in the preparation of environmental statements.

As was mentioned in the program element on university relations, the Laboratory is seeking to increase the involvement of undergraduate students in the social sciences in various training programs.

IV. KEY ISSUES

The Laboratory faces some difficult technical problems in helping to accomplish national goals. Given adequate funding and sufficient time, most of these problems can be overcome. However, certain issues related to ERDA policies and concepts concerning resource allocations will have a strong influence on the Laboratory's success in solving these problems. Some of these are listed below.

PROGRAM ISSUES

Programmatic Support of Basic Research

The ultimate success of technology development programs, particularly for the middle- and long-term technologies, will require the development of a broad base of fundamental knowledge achieved through a strong basic research program in the physical and life sciences. In FY 1977, approximately $11.0 million of Division of Physical Research (DPR) funds will be spent on basic research directly supporting various energy technologies. This support will double for FY 1978 (see discussion in "Basic Energy Science Program Goals"). The basic research needs must be recognized within the various technology programs, and an increased share of programmatic funds should be directed to the support of basic research.

Funding of Gas-Cooled Reactor Projects

In the past year, private industry has acted to reduce its involvement in the HTGR development program. There is now great uncertainty as to the future of this program, a large component of which is at ORNL. If the HTGR program were terminated, many of the people could be absorbed in some of the fuel cycle programs. Thus the uncertainty in the HTGR program introduces an uncertainty into the remainder of the reactor program. The HTGR development is important as a precursor to the GCFR, the most promising alternative to the LMFBR. The present low funding of the GCFR is inconsistent with the commitment to develop a breeder reactor as part of the long-range solution to the energy problem.

Nuclear Regulatory Commission (NRC) Work at ORNL

At present, NRC work comprises 10% of the ORNL research effort. In the next few years, we expect ERDA support at ORNL will increase at a faster rate than will space and/or staff. In the projections shown in this Plan, the total Work for Others (WFO) program decreases by 30% between FY 1977 and FY 1983. This will mean that the Laboratory will be unable to accept some requests from the NRC. On the other hand, NRC requests of national laboratories could decline as a result of efforts to divorce nuclear regulatory activities from nuclear energy development activities. ERDA and NRC should reach agreement on the involvement of ERDA laboratories in NRC work and the level of NRC work at national laboratories.

FACILITIES ISSUES

Support of Special Facilities

Several of the large facilities at the Laboratory (e.g., reactors, accelerators, isotope separators and processing plants, animal facilities) are service facilities for the nation. In large part, they are funded by service fees. When the users are few and in diverse programs, a decision at a low level of management to cut back on the use of the facility results in higher prices to other users. An obvious chain of events can lead to shutdown and the loss of a valuable facility because of a few decisions made at a relatively low administrative level. The Oak Ridge Research Reactor (ORR) is a specific case in point. Uncertainties in the use of the facility by the HTGR project for fuel element studies or by the Magnetic Fusion Energy (MFE) program for radiation damage studies and the possibility that NRC will put some of its work overseas all threaten the continued operation of this valuable research tool. A similar situation is developing with respect to the High Flux Isotope Reactor (HFIR). ERDA should give its full support and assistance to the continued operation of these valuable national assets.

Computer Needs

A report, *Computing Facilities Long-Range Plans—Oak Ridge National Laboratory 1976-1982,* was issued in March 1976. This report indicates that in order to meet the demands for batch processing of computer input at ORNL in 1977 and 1978, a computer in the class of the IBM 370/195 must be acquired in FY 1977 and a next-generation interactive computer must be added in FY 1979. The request for the first computer has already been deferred until FY 1979. If prompt action is not taken by ERDA to authorize these computers, ORNL will face a serious computer saturation problem in early FY 1978.

Laboratory and Office Space

ORNL is thirty-five years old. Many of the original buildings, still in use, are deteriorating. In the past few years, the Laboratory staff has grown and new programs have started. These new programs create unique requirements which are not met by our present buildings. A proposal has been made for an Energy Systems Research Laboratory (ESRL) to meet some of these needs in the new nonnuclear energy technology programs. The fusion program has undergone a large expansion; there is a need to restructure the present facilities at Y-12 for the fusion program to provide adequate space for this expansion. Prompt action on these proposals is needed to ensure that space limitations will not impede the progress of these programs.

Funding for General Plant Projects and General-Purpose Equipment

Our General Plant Projects (GPP) and General-Purpose Equipment (GPE) budgets have been inadequate for several years. Antiquated facilities must be replaced, and existing research and service facilities must be modernized. Some of these modifications are required to meet fire codes. GPP funding is needed to purchase modular office units to help solve our space problem. The inadequate funding for GPE has not allowed ORNL to comply with equipment replacement criteria established by ERDA. Designated GPP and GPE funds should be provided to realize significant energy savings in our plant operation through the installation of a centralized computerized energy control system. GPP funding in past years has been between $2 and $3 million per year. We estimate that ORNL could meet these needs if this level were increased to $5 million per year. Similarly, GPE funding in recent years has been about $1.5 million. This level should be doubled and then allowed to grow with the size of our operating budget.

Placement of Major Facilities

ERDA's present procedures for selecting sites for new major facilities implicitly require many installations to prepare and submit proposals for many different facilities, as illustrated by the long list of proposed construction items in Table VI.3 of this Plan. The preparation of these proposals is expensive and consumes much of the time of outstanding people. The procedures should be modified so as to reduce these inefficiencies.

ADMINISTRATIVE ISSUES

Transfer of Technologies to Industry

ERDA has wisely placed a high priority on the rapid transfer of new technologies to industry. Development programs and administrative policies should be structured to encourage active cooperation between the national laboratories and industry. We hope that the implementation of patent policy under ERDA will not inhibit this cooperation. Internally, we need to develop more effective policies to encourage cooperative projects with industry, including temporary transfer of personnel. Planning for technology transfer activities should begin early in the stages of RD&D activities that lend themselves to eventual transfer, and mechanisms to ensure the accuracy and soundness of such planning should be set up.

Planning

Development of ERDA plans in research and development should be an interactive process between ERDA program managers and the managers at ERDA laboratories. We urge that procedures be adopted to encourage input from the laboratories at an early stage in the planning process and to allow timely review by the laboratories of plans nearing completion. Laboratory long-range plans such as this one will reach their ultimate usefulness only when they are closely reviewed by the ERDA managers and when there is substantive feedback on the plans from ERDA to the laboratories.

Need for Increased Program Flexibility and Breadth

At a time when many new ideas are being explored and rapid progress is desired, more flexibility and freedom of action should be given to the Laboratory. We favor a program that allows the Laboratory to shift funds, within reasonable bounds, between specific research and development targets within a broad program area. This flexibility could be used to encourage innovative ideas and to assure rapid growth in program areas where technological breakthroughs arise. A complementary step would be to encourage the submission and approval of form 189s that are fewer in number and broader in scope and that have an inherent flexibility of 5%.

Lead Laboratory

ERDA should establish "lead laboratories," especially in the new energy technology areas where rapid expansion of program is needed. In the lead laboratory role, ORNL would assume major management responsibility for a progam. It would subcontract substantial work to private industry and carry on a limited supporting research and development program within the Laboratory.

Foreign Travel

In many areas, foreign technology is more advanced than U.S. technology. Solutions to important elements of the energy problem will require open cooperation between the technological communities in many nations. In order to keep abreast of foreign development and to establish working arrangements for international cooperation, foreign travel by technical staff members is a vital necessity. In recent years, the trend has been to make it more difficult to get approval for foreign travel. This trend should be reversed.

V. PROGRAM GOALS

In this chapter, we present a comprehensive summary of the goals of the various Laboratory programs. For planning purposes, the total program has been broken into units called program elements, which may be either discipline-oriented or project-oriented. A single program element may receive funding from several sources and may involve several Laboratory divisions.

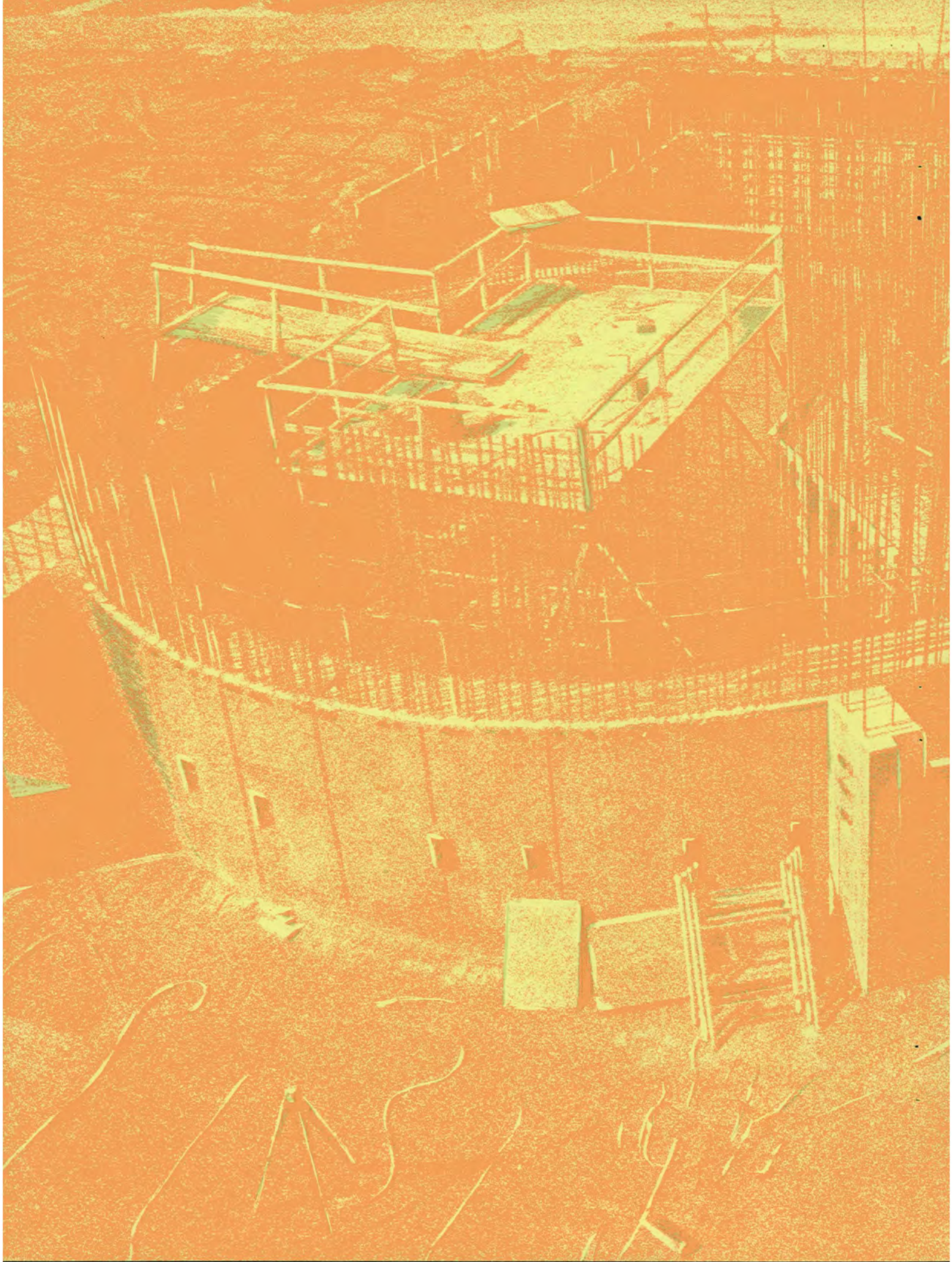
For this report, we have grouped the program elements into the following sections:

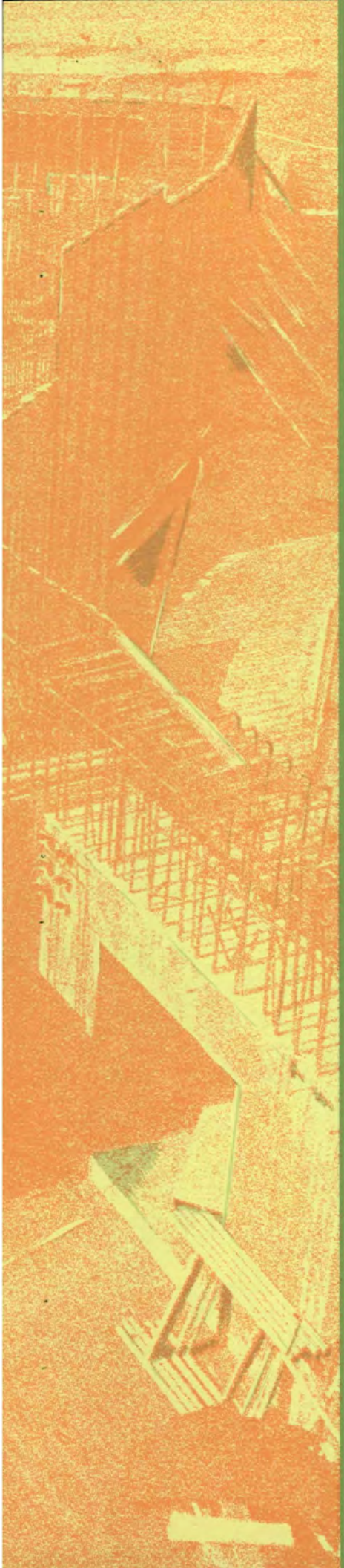
A. BASIC ENERGY SCIENCES
B. BIOMEDICAL AND ENVIRONMENTAL SCIENCES
C. CONSERVATION
D. NUCLEAR ENERGY DEVELOPMENT
E. NUCLEAR REGULATORY COMMISSION PROGRAMS
F. FOSSIL ENERGY
G. MAGNETIC FUSION ENERGY
H. SOLAR AND GEOTHERMAL ENERGY
I. INFORMATION, UNIVERSITY RELATIONS, AND COMMERCIALIZATION

Sections A and B deal with broad-based supporting basic research programs. Sections C through H deal successively with specific energy technologies for near-, middle-, and long-term utilization; Section I deals with broad supporting programs, which are mostly nontechnical.

We have attempted to define each program element by means of a goal statement and have estimated the operating costs needed to achieve these goals. The costs from FY 1978 to FY 1983 are based on dollars of constant value. For each program element, we show the funding sources by ERDA budget and reporting numbers and/or all other agency support from the program [Work for Others (WFO)]. The transition quarter costs are not shown but are approximately 27% of the FY 1976 costs. Capital equipment needs and major construction plans are summarized in Chap. VI.

The budgets shown in this section represent the thinking of individual research groups at ORNL. The growth rate for any given program could be easily absorbed. However, when the budgets are added together, the implied growth for the entire Laboratory is larger than can be expected realistically. Our previous experience has been that we receive about 77% of the budget levels requested. In order to develop the more realistic total resource requirements for ORNL, which are shown in Chap. VI, we use a correction factor of this size, as well as some other judgments by the Laboratory management.





A. Basic Energy Sciences

The Holifield Heavy Ion Research Facility currently under construction at ORNL will be the center of ERDA's heavy-ion science program. The new laboratory will feature a 25-MV tandem electrostatic accelerator which, when completed in FY 1979, will dominate the ORNL skyline.

A. BASIC ENERGY SCIENCES

The proposed research program in basic energy sciences involves broad areas of physics, chemistry, and metallurgy. The nuclear physics program is planned in anticipation of the completion of the first phase of the Holifield Heavy Ion Research Facility (HHIRF) and assumes the use of ORELA to measure neutron cross sections of the actinide elements. In chemistry, metallurgy, and solid-state physics, the plan calls for expanding efforts in catalysis, basic thermodynamics, corrosion and erosion, and properties of materials at high temperatures. In this section, we discuss the entire basic energy sciences program in some detail. Over the last several years, the budgets for these programs have been held relatively constant. The budgets shown here are projected to increase rather significantly in the next several years to meet new needs of the rapidly expanding technology programs.

Much of the basic energy science research discussed in this section (about 30%) can be identified directly with one or more of the emerging energy technologies. In part AA of this section, we summarize this research for each of the energy technologies and we indicate the level of support for this research. Somewhat more detailed descriptions of this research are given at the ends of the sections on the energy technologies. Long-range basic research is of critical necessity to energy technology development, and the type of research described here and funded by the Division of Physical Research should be funded directly by the energy technology programs (see "Key Issues," above).

Finally, in part AAA we present brief descriptions of proposed new programs or facilities we would like to see established at ORNL.

A.1 Materials Research

A.1.1 Radiation Effects in Metals and Alloys

Continued emphasis in the near term will be placed on developing an understanding of methods for simulating neutron damage in fission and fusion reactors. Primary attention will be directed toward obtaining a quantitative relationship between heavy-ion and neutron irradiations. In FY 1977, equipment will be constructed to simulate fusion reactor irradiations by bombarding materials with heavy ions while simultaneously implanting them with helium atoms. A facility for simulating irradiation creep using light-ion bombardment will be completed in FY 1977 and then used to study mechanisms of deformation during irradiation. Phase relationships and impurity segregation during irradiation will be studied in multicomponent systems using Auger and advanced analytical microscopy techniques. X-ray and neutron small-angle and x-ray diffuse scattering techniques will be developed as quantitative tools for describing defect concentrations and structures. Details of the evolution of the defect structures will be studied by irradiations in the high-voltage electron microscope. Theoretical calculations on damage production, annealing kinetics, and defect interactions will be made for the support and guidance of the experimental programs. X-ray and electron scattering theory applied to defects in solids will be developed in support of the x-ray and electron microscope programs.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	2.1	2.3	2.6	2.7	2.7	2.8	2.8	2.8

A.1.2 Neutron Scattering

The neutron scattering program will continue to utilize the high-intensity neutron beams at the HFIR and the specialized apparatus at the ORR to obtain fundamental information about condensed matter. Studies requiring high energy transfers will be carried out at ORELA. Small-angle scattering investigations will be performed to study fluxoid pinning and motion in type II superconductors and to study precipitation hardening in alloys. Investigation of defects introduced into metals by slow-neutron irradiation will be carried out through inelastic neutron scattering measurements of perturbations of the phonon spectra of the host metals. The program of research on the correlation between the transition temperatures and phonon anomalies in superconductors with high transition temperatures will be continued. Magnetic exchange, magnetic anisotropy, and spin density in rare earth metals, alloys, and compounds and in *d* transition metals will continue to be studied. Neutron scattering studies of hydrogen binding and hydrogen diffusion in metal hydrides will be carried out, and a program of preparation and characterization of

hydrides by high-resolution neutron diffractometry will be initiated. A users group will be fully functional in FY 1977. The funding increase shown here does not imply significant program growth. Between FY 1977 and FY 1983, HFIR charges for this work will increase by about $0.4 million. Finally, we have made the optimistic assumptions that ORR will continue to operate full time and that the ORELA modifications will proceed on schedule.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	1.4	1.7	2.0	2.0	2.1	2.1	2.2	2.2

A.1.3 Surface Physics, Insulators, and Ceramics

In surface science, our immediate goals include (1) examination of clean and adsorbate-covered surfaces by investigations of the angular dependence of Auger and photoelectron emission in order to establish lattice site locations and the nature of adsorbate-substrate bonding, (2) development of combined ion backscattering and low-energy electron diffraction techniques as a method for surface studies, (3) investigations of the reactive scattering of molecular beams, and (4) studies of the reactivity of nonmetallic substrates with low-energy ion beams.

In the middle term, we expect to (1) establish the nature of bonding and the role of surface geometry and electron density of states in chemisorption processes and the effects of redox reactions in adsorption-desorption phenomena, (2) identify molecular step processes in reactive molecular-beam scattering, (3) measure Raman scattering from small molecules (typically derived from coal conversion processes) chemisorbed on surfaces, and (4) investigate structures in which the atomic arrangement of the surface differs from that of the underlying bulk.

In the long term, this should lead to (1) new models and theories; (2) better knowledge of the effects of impurities on adsorption, reaction, electron emission, and scattering processes; (3) investigation of complex adsorbed species by infrared, Auger, and photoelectron spectroscopy; (4) characterization of surface properties of ion-implanted solar conversion and superconducting materials; and (5) studies of the surface electronic structure of amorphous material.

Studies of ceramics and insulators will be conducted to determine relationships between microscopic imperfections and macroscopic properties. In support of the nuclear options, fundamental studies will focus on oxides, nitrides, and carbides as advanced fuels and absorbers. Thermodynamic and mass transport studies will be performed to evaluate compositional and structural stability in strong radiation fields (FY 1977 through 1981). Investigations of radiation damage behavior on appropriate ceramic single crystals will be initiated to develop high-integrity insulators for magnetic fusion energy (MFE) applications (FY 1977 through 1983). In support of nonnuclear energy systems, studies on the transition-metal carbides and nitrides, superionic conductivity, mechanical properties, and high-temperature physical properties of ceramics (such as MgO, Al_2O_3, and Y_2O_3) will be pursued (FY 1977 through 1983). A study of the properties of ceramic liners for use in coal conversion systems will be continued (FY 1977 through 1983). High-temperature optical techniques will be developed to investigate defects and their relationship to electrical, magnetic, and thermal properties (FY 1980 through 1983).

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	1.3	1.5	2.0	2.1	2.3	2.3	2.5	2.5
EE 04	0.2	0.3	0.4	0.5	0.6	0.6	0.6	0.6
Total	1.5	1.8	2.4	2.6	2.9	2.9	3.1	3.1

A.1.4 Superconductivity and Research Materials

The research effort in superconductivity is directed toward a better understanding of fluxoid behavior in type II superconductors and of recently developed superconducting materials for improved performance in applications requiring high current densities, such as power transmission, MFE plasma containment, and radio-frequency (RF) cavities. Investigations of the influence of mechanical stresses on superconducting behavior are also being emphasized because such effects can impose serious limitations on materials for high-field generation.

Initial and middle-term goals include (1) studies of fluxoid structures, fluxoid motion, and fluxoid-defect interactions in type II

superconductors by small-angle neutron scattering and various electromagnetic techniques; (2) characterization of the important superconducting parameters (transition temperature, critical current density, and critical fields) of potentially useful materials as they are affected by controlled modification of metallurgical variables; (3) investigation of the effects of mechanical stress on the properties of superconducting materials; and (4) investigations of materials prepared by conventional and novel techniques, including vapor deposition, ion implantation, and eutectic solidification.

Over the long term, it is expected that the research will lead to (1) advances or extensions in the present theories of fluxoid dynamics and fluxoid-defect interactions in superconductors and (2) development of optimized new materials suited for specific requirements (e.g., high-field generation under large mechanical stress and in radiation environments).

The research materials program will continue to develop techniques that may be required for the initial purification, crystal growth, and characterization of research-quality specimens. Special emphasis will be placed on (1) supplying high-purity refractory metal and metal-alloy specimens (such as Fe-Cr-Ni, Ni-Al, Ni-Ti, Ni-V, and Ni-Mo) in rod, sheet, and foil form for an investigation of the effects of neutron irradiation and ion bombardment on the properties of structural materials proposed for the CTR and LMFBR programs (FY 1977 through 1983); (2) high-melting-point refractory metal eutectic compounds for magnetohydrodynamics (MHD) and turbine blade applications (FY 1977 through 1981); and (3) materials associated with other energy system technologies. The latter will involve special high-temperature metals (FY 1977 through 1980), A15-type intermetallic superconducting compounds (FY 1977 through 1981), ceramic oxides and spinels (FY 1977 through 1982), type II superconducting compounds such as Nb-Ta, Nb-Mo, and Nb-Ti alloys (FY 1977 through 1983), and samples for an investigation of hydrogen and deuterium transport and retention in oxides, solid electrolytes, and superionic conductors (FY 1977 through 1983). Special attention will also be given to techniques of purification and preparation of single and polycrystalline semiconducting materials and compounds (such as Si and GaAs) that can be used in the development of efficient and economic methods for the collection and conversion of solar energy (FY 1977 through 1983).

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	1.6	1.7	2.0	2.0	2.3	2.4	2.5	2.7

A.1.5 Mechanical Properties of Solids

The ultimate success of most of the emerging technologies will depend critically on the availability of new structural materials, metals, alloys, ceramics, and composites. In particular, components in many advanced storage systems must operate at extremely high temperatures in aggressive environments and under complex stresses. The ultimate aim of this program is to develop sufficient fundamental understanding of the response of structural materials to extreme conditions to allow the prediction of the behavior of a given material in some ill-defined environment and to form a base for developing materials with desirable properties. One component of the present program deals with deformation characteristics of metal-oxide composites and with surface deformation processes in metals and ceramics, which are important to erosion and wear phenomena. A major expansion of effort is planned over the next three years in the area of fracture. In the near term, the macroscopic variables that characterize the state of a material will be studied as a function of temperature and deformation history. In the middle term, the macroscopic studies will concentrate on time-dependent behavior (creep), and experimental investigations of the microstructure of creep and fracture will be initiated. These studies will use the environmental cell and deformation stage of the 1-MeV electron microscope. Dislocation models will be used to relate cracks typical of various deformation modes, defect configurations, and crack growth. The long-term objective of this expanding effort in fracture will be to develop a model for the general treatment of inelastic behavior. This program will begin to model crack nucleation and will attempt to make solid-state theoretical calculations of surface energy in the presence of a stress field. The microstructural studies will focus on the ductile-to-brittle transition and the transition from transgranular to intergranular fracture. The area of fundamental research on fracture has been neglected, and a large effort will be needed to make significant progress. This is reflected in the rapidly increasing budget in this area during the planning period covered here.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	0.4	0.4	0.8	1.0	1.2	1.4	1.7	2.0

A.1.6 Structure, Physical and Transport Properties, Corrosion, and Electrochemistry

These studies determine the crystal structure and microstructure experimentally for comparison with solid-state theory and to relate chemical, mechanical, or physical properties to the structure. Small-angle x-ray scattering (using a new 10-m small-angle x-ray scattering facility) and diffuse x-ray scattering provide information on phase transformations and anharmonic and anisotropic thermal motion of atoms. Studies using the Stanford synchrotron as an x-ray source were initiated in FY 1976 and will be expanded. Studies on the physical structure of coal will be expanded.

Physical properties research will emphasize precise measurements for determining transport mechanisms in metals, alloys, and ceramics. Interaction of acoustic and optic phonon modes in insulators will be clarified by FY 1978. By 1980, measurement techniques will be extended to 2500° C. Mass transport studies in metals and ceramics will explore the interaction between diffusing species and point-defect configurations. Transport properties in selective absorbing films suitable for solar collections will be incorporated into the program.

We anticipate that several corrosion problems will be recognized as new coal conversion systems reach the pilot-plant stage; therefore our studies of gaseous corrosion will emphasize the complex reactions occurring on alloys in high-temperature mixed-gas environments. Reactions are characterized in terms of the nature and concentration of defects and of diffusion processes in oxide and sulfide scales on Fe-Cr alloys. Mechanisms of stress generation and relaxation during oxidation and sulfidation are considered important. Similar studies on ceramic-metal composites are also being carried out. The materials to be investigated during the next several years will have either direct or potential application in coal conversion plants or as very-high-temperature turbine blades. The long-term goal of the research is to develop a sufficiently detailed analysis of alloy oxidation mechanisms that the influences of alloying additions can be fully understood and the use of substitute materials facilitated. In the area of aqueous corrosion, stress-corrosion cracking is regarded as a major problem in the nuclear power industry and in many other technologies.

Electrochemical studies on corrosion mechanisms will be redirected to emphasize localized corrosion and stress-corrosion cracking phenomena related to energy technologies. The ultimate objective of these studies is to increase our understanding of the mechanism of cracking in selected alloy-electrolyte systems by investigating the environmental reactions that result in crack initiation and propagation and by investigating the role of lattice structures and stresses in contributing to these reactions. The emphasis of the research will be on factors affecting repassivation kinetics, the role of sulfide precipitates, and the influence of modifications in environmental conditions, such as use of pH and redox buffers.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	1.2	1.5	2.0	2.3	2.3	2.6	2.6	2.9

A.1.7 Theoretical Solid-State Physics

Theoretical research at ORNL in the field of solid-state physics and materials science covers a broad range of problems related to the experimental programs both within the Laboratory and at other research institutions. Strong theoretical programs exist in the areas of (1) radiation-induced defect production, (2) ion channeling and ion scattering, (3) computer simulation of radiation damage cascades, (4) electronic energy band calculations for metals and alloys, (5) electronic and vibrational properties of insulating crystals containing point defects and the relationship of these to the optical properties of such crystals (including absorption, luminescence, infrared, and Raman spectra), (6) magnetic properties of transition and rare earth metals and compounds, (7) lattice dynamics of both normal and superconducting materials from first principles, as well as from phenomenological models, and (8) advanced alloy theory. More recently, increased emphasis has been placed on areas having direct relevance to the development of advanced energy systems. This new work has included the development and use of theoretical techniques for analyzing data from angular-dependent low-energy electron diffraction (LEED), Auger, and photoemission experiments; fundamental studies of the properties of adsorbates on surfaces and the relationship of these properties to catalysis and corrosion; the development of

computer programs to treat clusters of atoms (rather than the entire crystal) for studies of electronic and vibrational properties of surfaces, impurities in solids, and alloys; and application of previously developed programs to studies of first-wall damage in CTR devices.

Near- and middle-term goals of the theoretical research are the further development of existing theoretical models and associated computer programs for use in interpreting experimental results in the areas of ion-solid interactions, surface physics, lattice dynamics and electron-phonon coupling in superconductors having high transition temperatures, electronic and vibrational properties of alloys, radiation damage, optical properties of defects in insulators, and magnetism. Middle- and long-term goals of the research include the development of new theoretical models and computer programs for further research in these areas and for research in other areas such as superionic conductivity, high-temperature properties of materials, catalysis, phase transformations, hydrogen storage in metals, hydrogen embrittlement, photothermal and photovoltaic converison, and fracture.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	0.9	1.2	1.5	1.6	1.7	1.7	1.9	1.9

A.2 Chemical Properties and Reactions

A.2.1 Aqueous Chemistry, Fused Salts, and Organic Chemistry

A major part of the basic research needed in support of emerging technologies in fossil and geothermal energy is chemical in nature. Much of the chemistry research program at ORNL is in the areas of aqueous chemistry, fused-salts chemistry, and organic chemistry, all of which bear directly on these technologies.

The aqueous chemistry program will study thermodynamic and kinetic properties of aqueous systems, particularly at elevated temperatures, in order to advance the knowledge of the equilibrium and transport behavior of components under conditions encountered in energy-related technological and natural processes. Measurements will be made on hydrolysis of metal ions, association of metal chlorides, ionization of natural and practical buffers, and phase equilibria of oxides, sulfates, carbonates, and silicates, as well as transport and thermodynamic properties of electrolyte solutions. New experimental techniques and simplified mathematical models for representations and predictions will be developed in the programs. Between now and 1980, increasing emphasis will be placed on geochemical systems, and the research will include studies on the interaction of waters with magmas at very high temperatures.

The fused-salts program involves the measurement and interpretation of transport and thermodynamic properties in selected fused-salt systems. In addition, basic chemical information is provided on fused-salt systems that are possible homogeneous catalysts for coal conversion or electrolytes for high-temperature fuel cells. Beginning in about FY 1978, an expansion of fused-salt research is expected to occur in areas related to high-temperature batteries, partitioning of actinides and lanthanides from wastes from the nuclear fuel cycle, and systems of thermal energy storage.

Research in organic chemistry will be concerned with determining which chemical bonds are changed during the coal liquefaction process as vitrinite is converted to preasphaltenes, asphaltenes, and oils. Techniques to be employed on the original vitrinite, as well as upon the three fractions, will include the use of carbon-14-labeled organic reagents as well as carbon-13 and proton NMR spectroscopy. Once the bonds that are broken or altered during liquefaction processes have been identified, it should be possible to devise more economical methods for carrying out the processes. Studies of changes that take place in the composition of the liquefied products during aging will also be undertaken.

At the present time, an intensive investigation of the fates of several kinds of linkages found in coal under liquefaction conditions is under way. The use of vitrinite itself as a hydrogen donor during these processes is being studied. Within the next few years, a sufficient number of sensitive bonds should have been identified to permit investigations into methods for cleaving or otherwise altering these bonds in novel and (it is hoped) economical ways. Intermediate results will point the way to necessary studies in the future, but it is expected that the successful methods will be perfected, expanded, and applied to new conversion processes that have been developed in the interim.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
EE 04	0.8	1.0	1.4	1.8	2.2	2.4	2.5	2.7
Total	1.1	1.3	1.8	2.2	2.6	2.8	2.9	3.1

A.2.2 Physical and Inorganic Chemistry and Tritium Behavior

The physical and inorganic chemistry program will increase its research in support of fossil energy and LMFBR fuel cycle technology by both expansion and redirection. For instance, the surface physics program will shift its interest from fission-related thorium and uranium compounds to fossil-related molybdenum compounds. The filtration program will be redirected from waste treatment and environmental questions to research in support of enhanced oil recovery. In these and other cases, similar research techniques will be used on different compounds.

The fundamental research areas of interest in physical and inorganic chemistry are spectroscopy, photochemistry, atomic and molecular beams, electron spin resonance, structural chemistry, and theoretical chemistry. In the expanding area of fossil-energy-related research, we will study the chemistry of free radicals produced pyrolytically to understand the initial reactions occurring during the pyrolysis of coal. The elementary reactions of combustion will be studied using crossed atomic and molecular beams and photochemical techniques. The structure of molecular constituents of coal and catalysts will be determined by x-ray and neutron diffraction. Surface reactions on catalysts will be studied in a carefully controlled situation with atomic and molecular beams. Hydrogen production by means of thermal reaction cycles and bio-photolysis will be explored. The energy transfer process in photosynthesis will be investigated to find ways toward photochemical solar energy conversion. For energy storage, we plan to study the structure, nucleation, crystallization, and properties of hydrates. ORNL has a lead role in the ERDA LMFBR fuel cycle program. As part of this program, the Laboratory will expand work on the properties of actinide carbides, nitrides, and oxides; the chemistry involved in trapping fission products from off-gas streams; and uranium isotope separation. Other topics will include first-wall problems in fusion reactors and the photochemistry of actinide elements.

The tritium program will be an area of particular growth during the next three years. It will provide fundamental chemical and engineering information needed to predict and control tritium behavior in fusion and fission reactor systems. The low tritium pressures and concentrations that must be maintained in fusion systems present particularly difficult process and handling requirements. The Laboratory will develop (1) information needed to evaluate and develop processes for recovering tritium from fusion reactor blankets; (2) techniques for removing tritium from fusion reactor plasmas, purifying the fuel, and recycling fuel to the plasma; and (3) data on methods for containing tritium to prevent release to the environment (or to the reactor steam system). Items 2 and 3 will receive the major attention until 1980 because the information will be important to fusion projects designed during the next few years. Item 1 will attract increasing interest well into the 1980s; fusion reactor experiments with breeding blankets are likely to be designed during the mid-1980s. Development of blanket recovery processes will require fundamental physical and chemical data on distribution of tritium between liquid lithium and potential sorbent or extraction media and fundamental engineering data on the mass transfer steps involved in these processes. A better understanding of the sorption processes that appear to be most promising for fusion reactor vacuum pumps will be developed. These are low-temperature processes for which little quantitative mass transfer information is available. Studies of tritium containment will investigate permeation and oxidation-sorption processes. Permeation processes through metals with oxide or impurities on their surfaces are particularly important, and a better understanding of these processes under realistic conditions is greatly needed.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	1.3	1.3	1.5	1.9	2.0	2.2	2.3	2.3
EE 04	1.1	1.2	1.5	1.6	1.7	1.7	1.7	1.7
Total	2.4	2.5	3.0	3.5	3.7	3.9	4.0	4.0

A.3 Analytical Chemistry Methodology

Fundamental research in methodology for chemical analysis underlies virtually all of our analytical chemistry activities, many of which are cited elsewhere as inherent parts of the plans for specific programs. Emphasis in this research is determined by anticipated programmatic directions (e.g., organic vs inorganic materials), by improved technology (e.g., microelectronics), and by new concepts (e.g., array detectors for multispectral analysis). Currently, we are emphasizing (1) spectroscopic research, both optical and electron; (2) the use of microelectronics in novel analytical instrumentation; (3) mass spectrometry for both inorganic and organic analysis; and (4) the use of computers in analytical chemistry. Work in these four areas will increase in the next five years.

In spectroscopic research, the Laboratory plans to study optoacoustic techniques, the use of lasers in analytical spectroscopy, new excitation sources, and multispectral detection methods. Current research and experience with the use of microelectronics in analytical instrumentation will expedite the study and development of in-line and on-line analysis hardware for both nuclear and fossil energy technologies. In mass spectrometry, we plan to capitalize on our current research into the multielement isotope dilution technique by exploring the measurement of fission product nuclides in waste isolation matrices and by developing techniques for handling the variety of sample materials encountered in diverse energy technologies. Mass spectroscopic research is also planned into methodology for the determination of the age, origin, and composition of geological formations. Organic mass spectrometry is paramount among structural identification techniques, and ORNL plans to significantly expand research in this area. The development of ion sources and ion production techniques and means for exact mass measurement will be studied extensively. Techniques for multicomponent analysis by mass spectrometry will also be investigated. Emphasis in our computer utilization work will be placed on data acquisition and management and on the utilization of pattern recognition techniques in chemistry.

The above plans indicate the future directions of ongoing work. We anticipate increased interest in (1) trace contaminants, including inorganic, organic, and metallo-organic substances; (2) surface analysis techniques; and (3) the measurement of chemical species as opposed to elemental composition. Therefore, new and/or expanded efforts are planned in instrumental neutron activation analysis, automated x-ray fluorescence analysis, electron spectrometry with in-situ sample handling, and chromatographic and electrochemical techniques that respond to species.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 04	0.8	0.8	1.1	1.2	1.4	1.4	1.4	1.4

A.4 Catalysis

Research on catalysis is aimed at a mechanistic understanding of chemical reactions whose rates are altered by means of a catalyst. The chemical reactions of interest involve the use or production of hydrogen or the use of compounds such as water to supply hydrogen in fuel processing. The reaction of carbonaceous materials in molten salts, the use of enzymes as catalysts in the production of hydrogen, the use of catalysts in removing heteroatoms from coal, and the application of both solid-state physics and chemical methods in characterizing solid catalysts are all under study. Near-term goals include a study of complexes in molten salt catalysts, the development of methods to characterize hydrodesulfurization catalysts, measurement of the kinetics of an enzyme-catalyzed hydrogen-producing reaction, and the determination of the surface electronic density of states of known catalytic materials. Middle-term goals involve measurement of the interaction between model compounds and a broadened range of molten salts, the initial modeling of reaction processes for coal hydrodesulfurization, studies of the rates of selected chemical reactions related to enzyme catalysis, the study of interaction of gaseous species on well-defined faces of single crystals for obtaining catalytic decomposition of water, studies of reaction luminescence and photocatalysis, and the development of new solid materials whose properties are such that catalytic activity is anticipated. Long-term goals are a clarified view of the role of complex ions in molten salt catalysis, the establishment of the behavior of oxygen and nitrogen during coal hydrogenolysis, kinetic studies on enzymes for fuel gas production, and a better understanding of bonding processes and reaction mechanisms at solid surfaces, including the determination and understanding of differences between the surface and bulk electronic density of states.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
EE 04	0.4	0.6	0.8	1.0	1.0	1.0	1.0	1.0
Total	0.7	0.9	1.1	1.3	1.3	1.3	1.3	1.3

A.5 Heavy-Ion Science

A.5.1 Heavy-Ion Accelerators

The primary goal in heavy-ion science is to establish the Holifield Heavy Ion Research Facility (HHIRF) as an operational national center for heavy-ion science by FY 1980. The steps toward this goal include the completion and operation during FY 1979 of the 25-MV tandem electrostatic accelerator and of the modifications to the Oak Ridge Isochronous Cyclotron (ORIC) to serve as an

energy booster. Necessary development of operating procedures and training of operating personnel will be accomplished. Liaison with an active national users organization will be continued at a high level to develop and prepare specific experimental apparatus for research programs in nuclear physics, nuclear chemistry, atomic physics, solid-state physics, health physics, and materials research.

ORNL will maintain a support and development program for the existing cyclotron facility and the HHIRF. The program will include improvements to the cyclotron control system and the negative-ion source and the development of a data acquisition system for the HHIRF.

The projected large increase in funding for this program reflects a large increase in funds for operating the HHIRF when it becomes operational in FY 1979.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 01	1.9	2.4	3.1	3.5	3.8	3.8	3.9	4.0

A.5.2 Heavy-Ion Nuclear Research—Experiment and Theory

Heavy-ion nuclear research is a basic research program devoted to studying the properties of nuclear matter under conditions of high excitation, high rotation, and extreme distortion.

One effort in this program explores the bulk properties of nuclear matter as revealed by the remnants of a "head-on" heavy-ion collision, including such processes as complete fusion, deep inelastic scattering, and multiple particle and x-ray emission. An emphasis on light heavy-ion beams (atomic masses greater than or equal to 6) is evident in this work because of the capability of the ORIC for high-intensity and high-energy beams in this mass region. An understanding of these phenomena in terms of hydrodynamical models can lead to information on the viscosity, surface tension, and compressibility of the nuclear fluid. Another effort is concerned with the nuclear surface and the nuclear properties that can be explored by surface interactions. Excitation of rotational and vibrational modes of the nuclear surface by heavy-ion inelastic scattering or by transfer reactions is particularly useful in obtaining detailed information on charge distributions, moments of inertia, triaxiality, and other collective properties of nuclei. A third effort in this program is devoted to the properties of nuclear matter far from the region of stable isotopes. An on-line isotope separator (UNISOR), a fast tape transport system, and a helium-jet transport system will be used to carry short-lived species to the detection equipment. Ion source development should allow the UNISOR program to extend its studies from the mercury, thallium, lead, and bismuth isotopes to other regions of the periodic table. Chemical and physical properties of elements above element 102 are under study. Commissioning of the HHIRF during this period will enable these studies to be extended toward the "superheavy" or "island of stability" region, which is thought to be centered near element 116.

The nuclear theory program will continue to move into areas that will be relevant to the experimental program in the HHIRF, primarily aspects of nuclear structure and reactions pertinent to heavy-ion physics. Most of the theoretical projects will make extensive use of the large computers available at ORNL. Investigations of the gross properties of reactions following the collision of two heavy ions will be made with both microscopic and macroscopic models. The microscopic models include a three-dimensional time-dependent Hartree-Fock model and a classical relativistic model of two systems of discrete particles interacting through schematic two-body forces. The macroscopic model is a classical three-dimensional hydrodynamic model in which nuclei consist of viscous compressible fluids that obey the Navier-Stokes equations.

Studies of direct reactions will focus on the microscopic origins of phenomenological heavy-ion interaction potentials, mostly in terms of folding models. Some effort will continue in the area of nuclear shell-model spectroscopy. In the long term, part of the theoretical nuclear physics effort will be shifted into atomic physics to meet some of the needs of the magnetic fusion program.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 01	2.3	2.6	3.0	3.2	3.3	3.5	3.5	3.5

A.5.3 Atomic and Molecular Physics

The Laboratory's goal is to build a strong basic research program in atomic and molecular physics. The program will take advantage of the available unique facilities, such as our various accelerators, the ion-source test stand, and the positive and negative heavy-ion sources. However, we will not be confined to the use of accelerators, because this would impose an unnatural limitation on the broad areas of atomic and molecular physics research that

are expected to be strongly coupled to energy technology. We will continue a broad effort in the following programs: charge-changing cross sections, stopping powers of particles in matter, electron spectroscopy, infrared spectroscopy, beam-foil spectroscopy, inner-shell excitation and ionization, crystal channeling, surface reflection of charged particles, ion-induced x-ray and soft-x-ray spectroscopy, radiative electron capture and bremsstrahlung, and fundamental tests of quantum electrodynamics. A growing component of this program will have as a long-range goal a fundamental understanding of energy losses in fusion plasmas due to ion impurities. At present, the focus is on the interaction of highly stripped ions with atomic hydrogen. Starting in FY 1977, merged-beam techniques will be used to study ion-electron interactions. Cross sections for such energy-absorbing processes as ionization, charge exchange, and radiative scattering will be measured. The program will later be extended to include proton-ion interactions.

Much of this work is done on the tandem Van de Graaff accelerator. Support of this facility by Nuclear Science Research will be dropped when the heavy-ion facility is operational. The aggressive growth in the EE 04 budget reflects ORNL's assumption that this support will be provided by Molecular Sciences.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 01	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0
EE 02	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5
EE 04	0.8	1.0	1.3	1.7	1.8	1.9	2.1	2.5
Total	1.3	1.6	1.9	2.2	2.2	2.3	2.5	3.0

A.6 Actinide Science

A.6.1 Nuclear and Chemical Properties of the Actinides

In the nuclear area, we have begun to (1) measure and evaluate an initial data base of neutron fission and capture cross-section information that is most urgently required for analysis of long-term production and burnup or disposal of highly radioactive transuranium wastes from fission reactor fuel reprocessing, (2) develop and apply analytical tools to define the sensitivity of important waste-management parameters to uncertainties in nuclear decay-scheme and cross-section information, and (3) work toward an understanding of the nuclear level structure, decay characteristics, and fission behavior of the actinides. The program, expected to grow in the next few years, is closely associated with the program elements discussed in Section A.8 on "Neutron Reaction Studies for Fusion and Fission Technology."

In this connection, in accord with ERDA's decision to stress actinide chemistry, ORNL expects to begin expanding the program substantially in FY 1978 to study such phenomena as the behavior of actinides in solution in the presence of various complexing ligands. Complexation constants and reaction kinetics will be studied, with the intent of supporting and complementing applied work being done in the areas of environmental science and fuel recycling and purification.

In other basic chemical areas, ORNL is constructing equipment that will allow preparation of milligram quantities of the actinide metals for measurements of heats of solution and heats of sublimation and as starting materials for preparation of compounds. These pure metals and compounds will also be used in photoelectron spectroscopy studies of electronic levels and x rays and in determinations of magnetic susceptibilities. Changes in crystal structure and chemical bonding that are induced by high pressures (up to 100 kilobars) will be determined by x-ray diffraction techniques beginning in FY 1977. Electrical resistivity changes under such high pressures (including possible inducement of superconductivity) will begin in FY 1978. Spectroscopy of actinide compounds in solution, in the solid state, and in nonaqueous media will continue to be pursued.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 01	0.6	1.0	1.2	1.5	1.6	1.6	1.6	1.6

A.6.2 Production and Separation of Actinide Elements

The complex consisting of the HFIR and the Transuranium Processing Plant (TRU) has been established for the purpose of supplying transplutonium elements for research programs throughout the United States. As the production, storage, and distribution center for the ERDA heavy-element research program, this complex functions integrally with the researchers, not merely as a supplier. HFIR has been operating at full capacity and will continue to do so to provide high-flux neutron irradiation facilities for the production of heavy elements and for other purposes. A portion of the total cost of

HFIR operations ($1.7 to $2.4 million per year) is not shown below but is distributed in other sections of the plan. The projected significant increase in funding between FY 1977 and FY 1978 reflects the impact of the new utility charging system at ORNL and the need to replenish the reactor fuel under the inventory accounting system.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 01	5.6	5.5	6.6	7.0	7.2	7.4	7.6	7.7

A.7 Experimental Nuclear Science

Experimental nuclear science is a basic research program using a variety of light projectiles (neutrons, protons, deuterons, alpha particles, pions, kaons, antiprotons) and a variety of accelerators [ORELA, ORIC, EN Tandem, Indiana University Cyclotron Facility (IUCF), Los Alamos Meson Production Facility (LAMPF), and Fermi National Accelerator Laboratory (FNAL)] to investigate nuclear structure and nuclear reaction mechanisms on a very broad front. Total, (n,γ), (n,p), and (n,α) cross-section measurements continue to provide spectroscopic information bearing on nuclear structure and stellar evolution. This period will be the beginning of a program to obtain systematic optical-model parameters for elastic scattering of low-energy pions made possible by the increased beam intensity at LAMPF. A bulk property of nuclear matter under continuing study is the high-energy (more than 10 MeV) excitation of nuclear matter that goes by the name of giant resonance excitation. Dipole and quadrupole giant resonances are well established, and higher-multipole modes of excitation are eagerly sought after. Most of the studies of giant resonances will be conducted at the IUCF, to take advantage of the much higher energy projectiles available there. The structures of the elementary particles themselves are being studied with the highest energy accelerators available. Analysis of the design of high-energy experiments will continue; the long-range goal is focused on definitive transport calculation for high-energy particles. A synergistic stimulation exists between this program and program A.5.2, "Heavy-Ion Nuclear Research—Experiment and Theory."

As part of the machine operation and support program for low-energy nuclear sciences, the ORELA will be modified to allow klystron bunching in order to improve time resolution.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 01	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5
EC 01	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5
Total	1.8	1.8	1.9	2.0	2.0	2.0	2.0	2.0

A.8 Neutron Reaction Studies for Fusion and Fission Technology

This program is designed to provide measurement, analysis, and evaluation of neutron cross sections and related quantities. The work will be motivated primarily by needs of the developing technologies for fusion and fission power generation. Projects will be chosen according to the results of sensitivity and other analyses to pinpoint expected cross-section requirements. Results having sufficient precision must be available if expensive development programs or important assessments of alternatives are not to be delayed or impaired by inadequacies in the evaluated data base. At present, many scattering and reaction data for important nuclides have not been measured at all, and some of the frequently measured quantities (such as the average number of neutrons emitted per fission by californium-252) still have unacceptably large uncertainties. Results will be made readily available for practical use and, whenever possible, will be analyzed for information on nuclear structure and/or reaction mechanisms that could have indirect applicability. Included is development of measurement standards against which direct cross-section measurements can be performed, but excluded are studies of such immediate concern to particular reactor projects that development funding can be obtained. In order to meet ERDA's MFE program goals, a number of relevant cross sections will be needed by FY 1981. The budget expansion projected for FY 1978 through FY 1980 is needed to meet this deadline (see related work under elements A.6.1 and C.1.3.1).

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 01	0.5	0.6	0.9	1.1	1.2	1.2	1.2	1.2

A.9 Electromagnetic Separation of Isotopes

The objective of this program is to provide the research materials collection with enriched isotopes

of the stable and actinide elements for which the electromagnetic separation facility is uniquely applicable. The isotopes to be emphasized are those required in programmatic research and development activities. In order to satisfy the increasing demands from environmental and neutronic measurement activities, special attention will be required in the separation of heavy elements. The primary research and development activities will be in the areas of ion source technology, beam transmission, and ion collection efficiency applicable to maximizing isotopic purity and separator efficiency in the production of stable isotopes used as precursors in the nuclear medical field.

The program will also continue to provide the anticipated worldwide requirements for highly enriched electromagnetically separated isotopes. The major production efforts in this area will be directed toward maintaining a viable inventory of the 25 high-market-demand isotopes. At the minimum, 24 separators are needed to maintain the stable isotope inventory against current demands. Current operation, however, utilizes only 16 of the 30 available tanks. A corollary goal of the program will be to extend and encourage the use of separated products and to improve their distribution and marketing to provide additional revenue. In FY 1978, the program is expected to shift to a funded inventory accounting system. A consequence of this will be some reduction in direct ERDA funding, but there is no indication yet how large this reduction will be.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 01	1.3	1.2	1.3	1.3	1.2	1.2	1.2	1.2
RT 01	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2
WFO								
ZA 01	1.2	1.1	1.2	1.3	1.3	1.4	1.5	1.5
Total	2.5	2.4	2.6	2.7	2.7	2.8	2.9	2.9

A.10 Separations Science

Separations are central to basic and applied chemistry—in analysis, in producing and processing materials and fuels, and in control of resulting pollutants. The goal of the separations science program is to develop new and improved methods for (1) chemical separations needed in processes such as the recovery of values from ores, especially from ores that are now refractory or submarginal (uranium from shales, rare metals from coal residues) and chemical separations needed in the isolation and purification of special isotopic materials; (2) chemical and physical separations in the upgrading and conversion of nonnuclear fuels, such as removing ash and catalysts from viscous coal liquids and fractionating coal-hydrogenation products (low level in FY 1976 and 1977 to increase in FY 1978); (3) waste processing, fission product separation, and control of long-lived nuclides, including investigation of redox kinetics, hydrolysis and adsorption equilibria, and factors interfering with extractions; (4) removal of pollutants from aqueous streams by solvent extraction, adsorption, and membrane filtration; miniplant demonstration of removal from plating-industry effluents (supported in FY 1976 by NSF/RANN) to be extended in FY 1978 to other industrial and metallurgical aqueous streams. Basic principles and mechanisms underlying separations processes, such as thermodynamic properties, transport phenomena across interfaces and through membranes, hydodynamic effects, and reaction kinetics, are studied. New contractor concepts that may be important in large-scale applications of separation processes will be pursued.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 02	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
EE 04	1.1	1.2	1.7	2.0	2.1	2.3	2.3	2.4
Total	1.4	1.5	2.0	2.3	2.4	2.6	2.6	2.8

A.11 Mathematics and Statistics Research

The mathematics and statistics research program will feature research on the following problems or topics: methods (including the finite-element method) of solving moving-boundary problems such as arise in the fusion and materials science programs; methods (including pattern recognition) of handling the multivariate, multipopulation classification problem that occurs in the search for fuel and in biomedical and environmental research; experimental design; applied operator theory and its applications to physics and materials science; fundamental mathematics problems in the analysis of fault trees, which are of importance to the safety of electric generating plants; methods of assessing the risks of competing lethal and nonlethal diseases; and development of a technology to handle very large sparse matrices and to obtain solutions to the more inclusive generalized-eigenvalue problem which arises in atomic physics and materials research.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 04	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.6
RT 01	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Total	0.6	0.6	0.8	0.8	0.9	0.9	0.9	0.9

A.12 Engineering Science Research

Most of the Laboratory's engineering research and development efforts are directed toward well-defined process goals. As an adjunct to these efforts, ORNL is now developing a program in which pertinent engineering concepts can be investigated in a more fundamental mode. Although these fundamental studies will be supportive of our applied programs in a general sense, the results of each research effort should have general utility to the engineering sciences as a whole.

The first research area to be investigated will be heterogeneous interaction in solid-fluid systems. In the initial phase, the effects of heat and mass transfer, coupled with chemical kinetics, will be investigated for appropriate solid-fluid systems, including interacting systems useful in coal conversion processes. Later, the phenomena associated with movement of one or more fluid phases relative to porous or dispersed solids will be studied.

Other areas of interest in the engineering sciences include basic investigations of heat transfer, fluid dynamics, membrane phenomena, and particle nucleation. Heat transfer studies will include an investigation of the role of surfaces in boiling, condensing, and single-fluid-phase transfer. A basic understanding of turbulent flow, including a more definitive mathematical interpretation, is of interest, and a further study of the dynamics of membrane separation processes will be considered. Also, a study of nucleation and growth of solids from solution will have utility in a number of areas.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 04	0	0.1	0.2	0.3	0.5	0.7	0.8	0.8

A.13 Reactor Operations

The future operation of the reactors at ORNL is highly uncertain because of funding difficulties (see "Key Issues"). These difficulties include rising costs, stable or declining budgets, lack of a commitment by ERDA to fund these reactors directly, restrictions on the non-ERDA work that can be sought, and the placing at European reactors of some NRC irradiations that could be done in the United States. As a result of these vagaries, the ORR facility has been shut down most of the time since August 1, 1976, and may operate only about one-fourth of the time in FY 1977. The Tower Shielding Reactor (TSR) will be down most or all of FY 1977, and HFIR will also operate on a reduced schedule. If the MFE program utilizes the ORR as expected in FY 1978, it will be in full operation that year. Full support for the TSR is also anticipated in FY 1978. In the operating cost projections shown below, normal operation is assumed for the ORR, Bulk Shielding Reactor (BSR), and TSR. If shutting down the ORR is necessary, $0.3 million will be needed to shut it down and maintain it for future restart, and the operating costs for the BSR would increase to $0.7 million.

There are five research and test reactors at ORNL. The ORR, ERDA's only high-flux general-purpose testing reactor, has application to reactor development and the MFE program, besides being a neutron source for scattering experiments. HFIR is used for production (radioactive actinide isotopes), is one of the world's most intense neutron sources for scattering experiments, is used by the fission reactor and thermonuclear programs for materials damage studies, and produces medical isotopes. The BSR is used for liquid-helium-temperature irradiations and for various reactor pressure-vessel radiation damage studies. The TSR is used for radiation shielding studies. The Health Physics Research Reactor (HPRR) is used for studies of biological effects of radiation, especially those due to fast neutrons.

Operating cost (millions of dollars)[a]

Reactor	'76	'77	'78	'79	'80	'81	'82	'83
HFIR	3.5	4.3	5.0	5.1	5.2	5.3	5.4	5.5
ORR	1.0	0.3[b]	1.5	1.6	1.7	1.7	1.7	1.7
BSR	0.2	0.7[c]	0.3	0.3	0.3	0.3	0.3	0.3
HPRR	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TSR	0.2	0.1[d]	0.2	0.2	0.2	0.2	0.2	0.2
Total	5.0	5.5	7.1	7.3	7.5	7.6	7.7	7.8

[a] The costs are distributed among the reactor users and are included in other sections of the Plan. No inflation is considered after '78. Cost increases are due to fuel inventory system.

[b] ORR will operate one-fourth time in '77; full operation is assumed thereafter.

[c] BSR costs increase in '77 because most of the cost formerly shared with ORR must be borne; 75% operation is assumed in '77 and '78, half time thereafter.

[d] TSR will operate only about one-third time in '77; full-time operation is assumed thereafter.

Support of ORNL Reactors by ERDA Programs

	FY 1977		FY 1978	
	Program	Support (%)	Program	Support (%)
HFIR	EE	82	EE	83
	ED	4	ED	3
	RT	5	RT	5
	KJ	9	KJ	9
ORR	WFO	54	EE	16
	NURE	24	ED	53
			KJ	22
	Production	22	WFO	9
BSR	EE	81	EE	70
	WFO	19	WFO	30
HPRR	RT	100	RT	100
TSR	KJ	100	KJ	100

AA. BASIC ENERGY SCIENCE SUPPORT OF TECHNOLOGY PROGRAMS

More than one-third of the Basic Energy Sciences program is directly concerned with the pressing national energy goals entrusted to ERDA. Two kinds of research are discernible: one is problem solving for nearly complete technologies, typified by much of the fossil energy program; the other is long-range exploratory research, typified by the solar energy program. In all cases, it is evident that two characteristics of national laboratories are essential for the success of the endeavor. One is the ability to attack a problem in a multidisciplinary way, and the second is the existence of large and often unique tools for research.

In this section, we very briefly describe the research supported at ORNL by ERDA's Division of Physical Research (DPR) that directly supports the various energy technologies. We indicate the level of DPR support for these programs. This research and the funds cut across all the program elements discussed previously, so no new money is discussed here. Also, no money from previous program elements is included more than once in this brief section. Finally, this programmatic support is discussed in more detail at the end of each of the energy technology program summaries in Sections C through H.

Magnetic Fusion Energy

Radiation Damage and Materials Research—Neutron-induced radiation damage to materials that might be used in MFE reactors is now being studied. Simulation of this damage by alpha particles and heavy ions will be investigated. Radiation-induced creep and properties of MFE technology materials at high temperatures will be studied. Basic research in superconductivity will complement the large superconducting magnet project of MFE.

Atomic and Surface Physics—Basic research in atom-surface and plasma interactions will support MFE impurities studies. Energy loss from ion-plasma interactions will be investigated, and critical charge-exchange cross sections will be measured.

Nuclear Cross Sections—To meet ERDA's MFE program goals, a number of neutron cross sections involving MFE materials will be needed by 1981. The direction of the neutron cross-section measurement program will be influenced by these needs.

Tritium Behavior and Containment—Basic chemical and engineering research will deal with recovery of tritium from fusion-reactor blankets, removal of tritium from plasmas, and tritium containment.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
2.2	2.7	3.7	4.0	4.3	4.5	4.6	4.6

Solar Energy

Basic physical research in support of solar energy technology will be directed toward the development of materials with increased efficiencies for the conversion of solar energy by photovoltaic, photothermal, and photochemical processes. Methods of neutron doping will be refined, and searches for photovoltaic materials other than silicon will be carried out. Materials research will focus on improved means for crystal production. A program to study properties of selected absorber coatings will be developed.

Funding (millions of dollars)

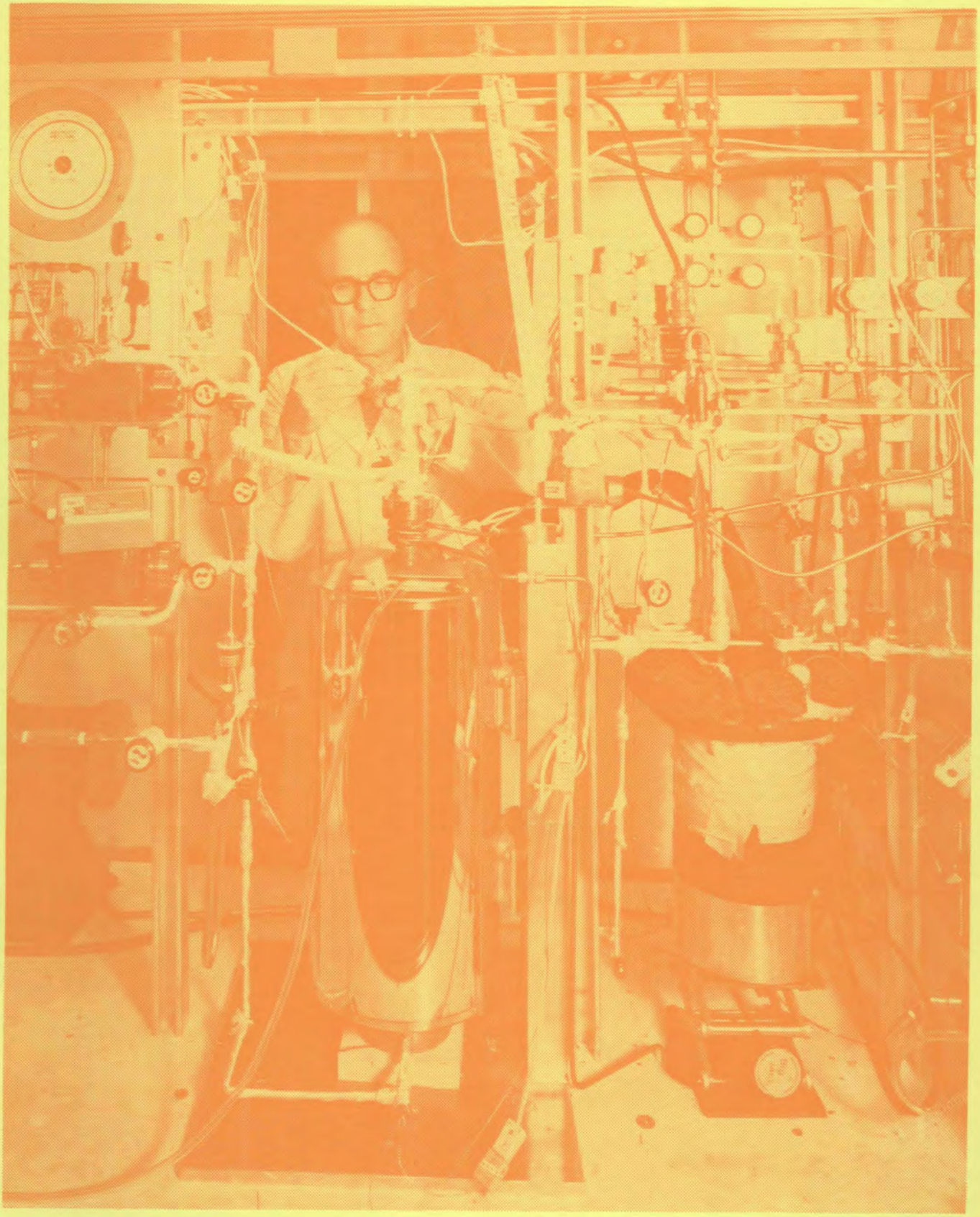
'76	'77	'78	'79	'80	'81	'82	'83
0.4	1.0	1.6	1.9	2.0	2.1	2.2	2.3

Geothermal Energy

Physical research in support of geothermal energy will focus on potentiometric, isopiestic, conductance, and calorimetric properties of brines. We will initiate a program to investigate thermochemical properties of magmas. The Laboratory will also develop a project to supply information needed to describe the transport of elements through natural formations.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
0.1	0.5	0.6	0.6	0.7	0.7	0.7	0.7



This apparatus is used to measure the tritium permeability of very clean metals and alloys that are candidates for use in high-temperature high-pressure steam generating equipment.

Fossil Energy

One of the important areas of growth in our basic research support of energy technologies is fossil energy. The program can be divided into three areas.

1. *Structure and Reactions of Coal and Its Derivatives*—This includes studies of the molecular structure of coal, elementary combustion reactions, and free radicals formed during pyrolysis.
2. *Catalysis*—Research in catalysis centers on the use of fused salts in catalysts, the fundamental understanding of fused-salt catalysis, and heterogeneous catalysis.
3. *Process and Separations*—This research includes the study of materials problems related to coal conversion and methods for isolating various components of coal conversion effluents.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
1.3	2.0	2.9	3.5	4.0	4.3	4.5	4.5

Fission Energy

Neutron Reactor Studies—A traditional area of strength at ORNL is the neutronics program in support of fission technology, aimed at developing accurate evaluated information on neutron cross sections critical to the fission reactor process.

Materials Research—Basic research on neutron-induced radiation damage and the simulation of this damage by alpha particles and heavy ions will continue; fundamental studies of radiation-induced creep, fracture, and corrosion in metals at high temperatures will expand.

Chemistry Research—Basic chemistry research will be in areas relevant to fuel reprocessing and waste isolation. Critical properties of the actinides and the chemistry of fission products will be studied intensively.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
3.1	3.6	4.2	4.5	4.8	4.9	5.0	5.0

Conservation

Research areas in support of the conservation program will include hydrogen production by thermochemical cycles, behavior of hydrogen in metals, fused-salt battery research, and low-temperature ac power transmission.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
0.2	0.8	1.1	1.3	1.4	1.4	1.5	1.5

Total support of energy technology progress by Basic Energy Sciences programs (millions of dollars)

	'76	'77	'78	'79	'80	'81	'82	'83
Fusion	2.2	2.7	3.7	4.0	4.3	4.5	46.	4.6
Solar	0.4	1.0	1.6	1.9	2.0	2.1	2.2	2.3
Geothermal	0.1	0.5	0.6	0.6	0.7	0.7	0.7	0.7
Fossil	1.3	2.0	2.9	3.5	4.0	4.3	4.5	4.5
Fission	3.1	3.6	4.2	4.5	4.8	4.9	5.0	5.0
Conservation	0.2	0.8	1.1	1.3	1.4	1.4	1.5	1.5
Total	7.3	10.6	14.1	15.8	17.2	17.9	18.5	18.6

AAA. PROPOSED NEW PROGRAMS AND MAJOR FACILITIES

Several studies have been completed in recent years that have resulted in proposals for new programs and/or major facilities. The objectives of these proposals are summarized here, and funding requirements and schedules for start and completion of the construction items are indicated.

Holified Heavy Ion Research Facility—Phase II

When completed in FY 1979, phase I of the HHIRF will provide a national center for heavy-ion research utilizing ions of lighter and medium-weight nuclei. The goal of the phase II addition is to expand the capabilities of the facility to include acceleration of all ions (up to uranium) to energies in excess of 10 MeV per nucleon. In addition, the expansion will make available lighter heavy ions with significantly higher energies. Facility expansion centers on the design and construction of a large separated-sector cyclotron to serve as a second stage of acceleration for beams from either the 25-MV tandem accelerator or the ORIC. The booster cyclotron will produce heavy-ion beams with energies up to 400 q^2/A. For example, U^{42+} beams will be accelerated to 3000 MeV (12 MeV per nucleon), and beams of C^{6+} will be accelerated to 1200 MeV (100 MeV per nucleon). Special attention will be given to optimizing accelerator design to provide energy definition, energy variability, and beam quality equivalent to beams directly from the tandem. The new facility will be designed as a national facility having the capacity to support a large user organization. New experiment areas totaling 3800 ft^2 and an extensive and flexible beam-transport system will provide six experiment stations initially, and later additions to provide more stations within the same areas will be possible. The building addition will consist of a high-bay structure approximately 172 ft long and 33 ft high adjacent to the existing Building 6000, plus a 60- by 30-ft counting room contiguous with the south walls of the new experiment areas.

Cost (FY 1977)	Start	Completion
$22.4 million	FY 1979	FY 1983

Pulsed Neutron Booster at ORELA

A pulsed neutron source consisting of a subcritical fission booster assembly would be constructed adjacent to the ORELA in a new experiment facility for scattering studies on condensed matter. Successive electron pulses from ORELA would be shared as desired between the new facility and the existing one used for neutron cross-section studies. Analysis (in ORNL/TM-4987) suggests that a booster of simple design gain of about 50 is feasible at an attractive cost per neutron. The available intensity would be 100 to 1000 times that of existing productive scattering facilities at Tokoku, Japan, and Harwell, England. The facility would excel for neutron energies above 0.2 eV. ORNL is developing a formal proposal and conceptual design to submit to ERDA if the Argonne National Laboratory (ANL) proposal for the extremely powerful IPNS-2 should not be funded.

Cost (FY 1977)	Start	Completion
$14.0 million	FY 1979	FY 1982

The Carbon Dioxide (CO_2) Problem

The burning of fossil fuel has increased the concentration of CO_2 in the atmosphere from the preindustrial value of about 295 ppm to the present value of about 330 ppm. Since the beginning of accurate measurements in 1957, the amount of this increase has remained equivalent to about 50% of the cumulative release of fossil carbon as CO_2. If this trend were to continue until the entire reserve of economic fossil fuel were burned, the atmospheric concentration of CO_2 would rise to about six times the preindustrial value. Current estimates suggest that the resulting warming ("greenhouse effect") would raise the average temperature of the earth's surface about 6°C. The purpose of the present program will be to reduce the large uncertainties inherent in such projections in order for the impact of CO_2 from fossil fuel to be properly anticipated.

First, it is necessary to learn more about the carbon cycle and how it will respond to an increasing flux of CO_2 from fossil fuel; for example, will the airborne fraction remain near 50%, will it increase, or will it decrease? This work will involve (1) learning more about ocean circulation, which presently limits the takeup of CO_2; (2) better estimating the effect of increased CO_2 on photosynthesis; and (3) studying the effects of land use, agriculture, and the cultivation of biomass as fuel.

Most uncertain are the regional climatic effects produced by a given increase in atmospheric CO_2. A broad program of climate study is proposed that would include (1) numerical modeling, (2) physical modeling, (3) basic studies of fluid dynamics, (4) studies of cloud formation and interactions, and (5) analysis of meteorological (including satellite) data.

Finally, it is necessary to estimate the ecological, economic, and social aspects of a projected climate change. These predictions must come from a highly interdisciplinary analysis that will include (1) the collection, compilation, and analysis of diverse data for each geographical

region considered; (2) development of a model that will yield quantitative impacts of an assumed climate change; and (3) validation of such models.

Climate changes of the magnitude and rate presently projected for the next 100 years range from possibly acceptable to catastrophic; hence, there should be greatly increased efforts to foresee the effects of anthropogenic carbon dioxide more clearly.

Proposed program funding (millions of dollars)

'77	'78	'79	'80	'81	'82	'83
1.0	2.0	2.5	3.0	3.5	3.7	4.0

Electronuclear Breeding

The abundant energy reserves represented by the world's supply of uranium-238 and thorium-232 can be tapped only if this material can be converted into fissile isotopes for use in reactors. At present, the neutrons needed for this conversion can be most economically produced by burning existing, but much less abundant, fissile material in a breeder reactor. However, if the cost of fissile material continues to rise and if the breeder program is seriously delayed, the use of accelerator-produced neutrons could prove to be more attractive economically. This concept, known as electronuclear breeding, has been studied by various groups during the past 25 years, the most important work being associated with the Materials Testing Accelerator (MTA) program at Livermore in the 1950s and the Canadian Intense Neutron Generator (ING) proposal in the late 1960s.

The major components of an electronuclear breeder are

- a linear accelerator capable of producing a continuous beam of protons (or perhaps deuterons) with an intensity of at least 300 mA and an energy of about 1 GeV,
- a heavy-metal target in which neutrons are produced by spallation reactions,
- a breeding blanket in which the fertile material is produced and heat is generated for subsequent conversion to electricity.

While there is little doubt that such a device is feasible, the overall economics are very uncertain. In assessing the economics, the most important questions are (1) the balance of the system, (2) the rate of production of fissile material, and (3) the capital cost of the device. In order to answer these questions, further studies are needed in certain key areas. These are

- the neutronics of the production target and the breeding blanket,
- the design of the neutron production target,
- the design of the breeding blanket,
- high-power, high-efficiency rf power systems,
- accelerator design,
- engineering cost estimates.

A program to investigate these areas should have as its goal the completion of a design study for the whole facility. Such a program would require an effort of 15 to 20 man-years per year for several years. The early emphasis would be on the neutronics of various target-blanket concepts and the development of high-power, high-efficiency klystrons for 200-MHz operation. At a later stage, the emphasis would shift to more detailed engineering design studies, upon which reliable cost estimates would be based.

Proposed program funding (millions of dollars)

'77	'78	'79	'80	'81	'82	'83
0.2	1.3	1.8	2.0	0	0	0

Institute for the Study of Materials at Elevated Temperatures (ISMET)

The importance of materials research to the successful development of new energy technologies is stressed repeatedly in this Plan. The multidisciplinary materials research program is an area of particular strength and growth at ORNL. In order to develop sufficient understanding of the behavior of structural materials in adverse environments, it will be necessary to make measurements on a scale and to a precision beyond any capabilities available in the United States. We propose to build a laboratory specifically designed for large-scale high-precision measurements of materials behavior at very high temperatures and under extreme stresses. The building is designed to be approximately 77,000 ft^2. It will contain equipment that would allow studies of materials at extremely high temperatures that would include high-precision evaluation of fracture surfaces on very large samples, high-precision measurements of the time evolution of creep phenomena, and high-precision measurements of fracture behavior in small ceramic samples.

Cost (FY 1977)	Start	Completion
$17.5 million	FY 1979	FY 1982

Very-High-Flux Reactor

The family of ERDA research reactors has played an important role in the development of fission power reactors, in the study of radiation-induced defects, in isotope production, and in the development of neutron scattering into one of the most valuable techniques for studying fundamental properties of solids and liquids. The youngest of these reactors is now ten years old and will face technological obsolescence in the next decade. ORNL believes that the materials problems associated with the development of magnetic fusion energy, the unsolved fundamental problems of radiation damage, and the continuing importance of neutron scattering as a research tool require a long-range commitment to first-quality research reactors.

Preliminary estimates indicate that it should be possible to build a 200-MW reactor of the flux-trap type with deuterium oxide as coolant and reflector. The thermal flux should be up by a factor of 4 over that of the HFIR, and the fast flux up by a factor of 2. The design should include a central irradiation facility useful for materials irradiations and isotope production, horizontal beam tubes for neutron scattering, a cold source, and a low-temperature irradiation facility in the reflector region.

Work on a conceptual design should begin now in order to have an operational reactor in the late 1980s. The estimated cost of such a facility is $120.0 million in current dollars.

Cost (FY 1977)	Start	Completion
$120.0 million		

B. Biomedical and Environmental Sciences

An ORNL environmental scientist collects a sample from the "rain maker," a rain simulator system used to study the effects of atmospheric pollutants in rain on vegetation and soil systems (far upper left). At far lower left a microbial geneticist uses an automatic colony counter to quantitate genetic damage induced in fungal cells by environmental effluents from the synthetic fuel technologies. At left a research biologist inspects the offspring of treated fruit flies (Drosophila) for genetic effects induced by environmental mutagens. Adult flies as seen under a dissecting microscope are shown in insert.

B. BIOMEDICAL AND ENVIRONMENTAL SCIENCES

The biomedical and environmental sciences program at ORNL is primarily concerned with the identification, understanding, and reduction of health and environmental impacts of energy production and utilization. Research activities in this program include biological, ecological, health, and assessment studies on the transport and effects of both nuclear and nonnuclear energy technology products and by-products at the molecular, cellular, organism, population, and total-system level. Specific objectives in these studies include development of a basic understanding of interactions of specific products and by-products with biological systems, application of this understanding to evaluation and assessment of observed transport and effects phenomena, and prediction of potential beneficial and detrimental impacts of energy production and utilization through an integration of available information and mathematical simulations. A recent innovation in the biomedical and environmental sciences program that will prove valuable in a total evaluation of energy-effluent impacts is the Environmental Policy Analysis activity, which will serve to integrate the available scientific information concerning a particular practice or pollutant with current and future social, economic, and political climates in order to minimize health and environmental insults while maximizing the orderly development of this nation's energy resources.

There are a number of agencies outside ERDA that support the research in this area. In order to avoid complex tables, these sources are simply identified as Work for Others (WFO) in the funding summaries for individual program elements. At the end of Section B, a table is shown listing these supporting agencies and the level of funding at ORNL for each agency.

B.1 Environmental Research

The unique contribution of ORNL in environmental research derives from its capabilities for an integrated total-system approach to problems. By developing and maintaining a critical mass of scientists, it is possible to (1) conduct strategic research on basic ecosystem processes; (2) utilize the resulting insights to structure research on characterization, transport, and effects of effluents from specific energy technologies; and (3) synthesize the information into a comprehensive assessment through advanced information handling and analysis techniques. This integrated approach permits us to progress beyond evaluating isolated effects on particular organisms and apply predictive methodologies to total environmental systems.

B.1.1 Environmental Transport and Fate of Energy-Related Materials

There is a continuing need to understand the processes governing the rates and magnitude of movement of energy-related contaminants in the environment if we are to minimize the exposure of man and the environment to fuel-cycle effluents. Activities in this program include experimental analyses of specific elements, sites, or fuel-cycle components; development of analytical models of environmental transport and fate of potentially hazardous substances; and generic and specific assessments of integrated environmental transport and fate of potentially hazardous substances. The program encompasses coal fuel cycles (combustion and conversion) and nuclear-fission fuel cycles (LWR, GCR, and LMFBR) and will include research into transport and behavior of effluents from geothermal energy production and nuclear fusion as these technologies are developed.

Research on transport of effluents from coal combustion has progressed rapidly. Overall rates of movement of trace elements and sulfur and associated environmental sinks have been identified. The research emphasis will shift over the next few years to evaluating the physical, chemical, and biological processes in terrestrial and aquatic environments that control the movement of trace elements and their concentration in the biota. Major portions of this task will be completed by 1979. In the coal conversion fuel cycle, rates of transport, accumulation, and degradation of organic effluents will be determined in terrestrial and aquatic environments. Essential measurements of atmospheric transport and deposition processes and absorption mechanisms will be obtained to evaluate and revise the capabilities of transport models. Future model development will improve capabilities for simulation over longer distances and complex terrain. ORNL will complete experiments on transport of sulfate under conditions of the expected increased atmospheric sulfate input in the next two years. In collaboration with other research units, we will study (within the next two to three years) the geographic variability of transport of coal-mining and combustion effluents attributable to climatic, biotic, and source-strength differences.

Previous research on transport and fate of contaminants from the nuclear fuel cycle has emphasized case studies to determine the transport and distribution of radionuclides. Our research now

places emphasis on interpreting environmental transport and fate in terms of the environmental chemistry of specific radionuclides (e.g., fission and activation products) and nonradiological contaminants (e.g., HF and nitrates) discharged in the nuclear fuel cycle. During the 1977-1979 period, the Laboratory will complete characterization of the influence of the environmental chemistry of major contaminants, particularly transuranic nuclides, on transport processes. For the thorium fuel cycle, we will complete research needed to evaluate the fraction of native thorium and uranium available to vegetation and determine the fate of uranium contamination in soil. These results will be integrated into radiological transport and dose assessment models. Because sediments are a major environmental sink for radionuclides, we will determine the rates of release and bioaccumulation of radionuclides from this source through critical pathways.

Research will be initiated to provide input for future environmental impact studies related to environmental statements and impact assessments for fusion technology. Information on the environmental behavior of tritium and several long-lived activation products (including aluminum-26, vanadium-49, niobium-93, and niobium-94) will be obtained. Similar research is required for inorganic salts released to the atmosphere and to surface waters from the geothermal energy cycle. Innovative methods of disposal of energy technology residuals will be evaluated. In particular, the efficacy of land composting of coal fly ash and sewage sludge as part of land reclamation will be determined.

Accurate assessment of environmental transport and fate of contaminants requires analytical models that are continually improved as additional understanding of the biogeochemical behavior of ecosystems is acquired. Building on previous experience, ORNL plans to initiate specific experimental manipulations on intact terrestrial and aquatic ecosystems. These include an analysis of the impacts of land use on the transport and fate of contaminants in reservoirs, establishment of experimental ponds and streams amenable to transport research, and experimental manipulation of components and processes of terrestrial biogeochemical cycles to determine their significance to overall transport processes.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 03	1.4	1.2	1.3	1.4	1.5	1.6	1.7	1.8
WFO	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Total	1.6	1.5	1.6	1.7	1.8	1.9	2.0	2.2

B.1.2 Environmental Effects of Energy Technology

Energy-related environmental-effects research at ORNL is currently focusing on a broad range of potential impacts to aquatic and terrestrial systems resulting from both existing and developing energy technologies. These efforts encompass both field and laboratory research and include problems related to nuclear (LWR, LMFBR, and MFE) and nonnuclear (coal combustion and conversion) energy processing facilities.

Research on aquatic systems is concerned with the problems associated with both power plant cooling systems (discharge of heated water, mechanical impacts and impingement, and the effects of cooling system biocides) and direct releases of contaminants to the aquatic environment. Terrestrial studies deal with the impact on vegetation of a range of atmospheric pollutants, including sulfur dioxide, ozone, acid precipitation, uranium fluorides, and chromium, produced by coal combustion, nuclear fuel processing plants, or power plant cooling towers. In addition to stresses derived from existing technologies, those associated with newly developing coal conversion technologies are leading to important new research on the effects of a variety of expected organic effluents on aquatic organisms and terrestrial vegetation and soils.

In future studies, the objectives of individual research programs will differ widely and will be determined by the developmental status of the specific technology under study. With existing technologies, research will be directed toward defining the subtle stresses to biochemical and physiological processes that underlie changes in the diversity, stability, and productivity of living systems. These studies will range from observations of individual species to microcosm and field experiments in which definition of system-level effects is the ultimate aim. Results of these experiments will ultimately be interfaced with transport and/or population-level models to predict the spatial and temporal scale over which terrestrial and aquatic systems respond to specific energy-related environmental stresses. As the technologies develop, primary emphasis will be placed on identifying and screening the associated atmospheric and aquatic effluents to determine levels of toxicity and the range of effects produced on selected species of aquatic or terrestrial organisms. After specific toxicants have been identified and tested for acute effects, research will be directed toward determining chronic impacts and the transfer coefficients for transport of toxicants to higher organisms, including man.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 03	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
WFO	0.8	0.9	0.9	1.1	1.1	1.1	1.2	1.3
Total	1.2	1.3	1.3	1.5	1.5	1.6	1.7	1.8

B.1.3 Assessment of the Impact of Energy Production and Use on Local, Regional, and National Scales

The analysis and assessment programs are aimed at developing methodologies and information for integrated cost-risk-benefit accounting and applying these assessments to the comparison of various energy technologies and systems. The work is in progress in several ORNL divisions as required by the multidisciplinary nature of the studies, involving consideration of social, economic, health, and environmental effects. The results are utilized in preparing environmental impact statements, setting research priorities, identifying impediments to technology development, and reconciling national goals with problems, constraints, and aspirations at the state and regional level. This activity includes the Regional Studies program, information integration, and analysis of the potential risks of increasing levels of atmospheric carbon dioxide.

The Regional Studies program is directed explicitly at analyzing the regional implications of energy technology development. The approach involves estimating the spatial distribution of future energy supply facilities on the basis of forecasts of energy demand and, from that spatial arrangement, estimating the likely range of social, economic, and environmental effects. Using this approach, ORNL is collaborating with five other ERDA laboratories in the National Coal Assessment Program. This two-year effort constitutes an examination of the regional and national consequences of increased coal production and use. Future assessments by the same group of laboratories will be focused on other fuels.

Information integration involves the work of the Information Center Complex (ICC) and other ORNL information activities. A primary function of ICC is to develop and correlate the information activities of energy and related environmental research projects at ORNL and to systematize operations to achieve maximum response to the information needs of funding agencies and the user community. The development of new data bases and information services as need arises is a major responsibility. Interactions among various ORNL information centers provide for a wide range of analysis and synthesis of knowledge, resulting in a synergistic effect. The emphasis of information integration activities in the future will be to develop and maintain current numerical data bases on energy demand and supply (by fuel and by region) and on associated social, economic, and environmental variables. Such data are needed for the development and use of realistic models for estimating the likely range of effects of energy futures.

In the next few years, the Laboratory will consider the issue of increased atmospheric carbon dioxide and its potential impact on the development of fossil fuel, nuclear, or solar energy technologies. Anticipating the ecological, economic, and social aspects of a projected climate change is essential. These predictions must come from a highly interdisciplinary analysis that will include (1) the collection, compilation, and analysis of data for the geographical regions considered; (2) the development of a sequence of models of the geochemical carbon cycle that relate global exchanges, continental data (and subcontinental models), and estimates of acceptable additions of carbon dioxide and carbon-14 to the atmosphere (projected completion by FY 1979); and (3) the projection of large-scale and long-range consequences and risks of global modification of climate, ecology, and oceans to relevant energy technology scenarios.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 05	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.8
HE 02	0.1	0.4	0.5	0.5	0.5	0.6	0.6	0.7
KG	0.1	0.4	0.5	0.5	0.6	0.6	0.6	0.7
KK	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
WFO	2.9	2.3	2.1	2.3	2.4	2.5	2.7	2.8
Total	4.4	4.4	4.5	4.8	5.1	5.4	5.7	6.1

B.1.4 Environmental Control Technology

The specific goals of the environmental control technology program are to determine the quantities of radionuclides discharged to ground and surface waters from buried radioactive waste and other sources at ORNL, to find ways of reducing these discharges, and to establish improved sampling and monitoring methods. The characterization of the transport of radionuclides and other pollutants in groundwater and the formulation of engineering methods to control this transport will be utilized in the development of recommendations for shallow burial of low-level radioactive wastes. The characterization of pollutant transport will also be used in the development of predictive models for determining the long-term consequences of these releases to the White Oak drainage and the Clinch River and for

applications to other sites. Waste management practices developed in this program will be evaluated for their potential use in other energy technologies, including combustion and conversion of coal. Related control technology activities are described also in Section B.5 of this Plan.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 04	0.1	0.3	0.4	0.4	0.4	0.4	0.5	0.5
KK	0.2	0.6	0.7	0.7	0.7	0.8	0.8	0.9
RW 03	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	0.4	1.0	1.2	1.2	1.2	1.3	1.4	1.5

B.1.5 Radiological Assessment of the Nuclear Fuel Cycle

Potential radiological impacts from environmental releases of radioactivity are associated with all stages of the LWR, HTGR, and LMFBR nuclear fuel cycles. One goal of the radiological assessment program is to integrate fragmented information on the release of radioactive materials by facilities required for the production, use, and reprocessing of the nuclear fuels for each type of reactor so that the overall impact of each fuel cycle may be assessed. Attainment of this goal is important because there are statutes relating to permissible radiological exposures of the public that must be met by individual facilities and by the entire nuclear fuel cycle. Radiological assessments of the nuclear fuel cycles can be used to guide further research and engineering development of equipment and processes related to control of radioactive effluents.

A second major goal of the program is to use a sensitivity analysis approach to identify the uncertainties that must be minimized to maximize the accuracy of the radiological assessments. A third goal of this research is to maintain a state-of-the-art calculational methodology in a form that can be made available to qualified users outside ORNL. The elements of this methodology are the environmental transport and dosimetry models and physical and biological data bases. Although most of the data used are taken from published literature, some information is obtained from direct collaboration with researchers at other installations. In the case of our studies on uranium mining and milling, where adequate data are not available, measurements of radioactivity are made on site by the use of equipment in mobile laboratory trailers. The information gained in such field operations is used to refine the predictive assessment methodology and to control population exposures from environmental releases of radioactivity from nuclear fuel cycle facilities.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 05	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3
RW 03	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5

B.1.6 Ecosystem Analysis

The ecosystem analysis program emphasizes integrated interdisciplinary research efforts directed toward understanding the functional dynamics of the landscape. Over the last ten years, the environmental research program has developed considerable expertise in this area, partially through participation in the U.S. contribution to the International Biological Program. The research emphasizes total ecosystem analyses, including basic information on solar energy conversion, nutrient cycles, mineral utilization, and hydrologic cycles of total ecosystems.

New research projects in this program will be in four areas. (1) Process research on the basic physiological mechanisms that underlie and explain ecosystem function will be continued. Experience has shown that detailed research on processes is needed to provide a mechanistic foundation for theory development. (2) Efforts in testing our insights and predictions in field experiments will be increased. This will involve a series of field manipulation experiments in both terrestrial and aquatic environments. (3) The effects of spatial patterning on the function of ecosystems will be explored. A series of theoretical studies will examine the effects of spatial distribution on system properties such as stability and resiliency. (4) Development of laboratory microcosms as experimental ecosystems will be continued. In addition to developing the potential of microcosms as test systems for screening toxic materials, ORNL is developing these laboratory ecosystems to test predictions made by our ecosystem models.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 03	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
WFO	1.3	1.1	1.3	1.4	1.4	1.5	1.6	1.7
Total	1.4	1.2	1.4	1.5	1.5	1.6	1.7	1.8

B.1.7 Emergency Technology

The goal of the emergency technology program is to minimize the vulnerability of individuals and society to accidental or malevolent misuse of new

energy sources, especially nuclear energy. The research develops technology by which the credibly warned individual can protect himself and his family from potential catastrophic manifestations of nuclear energy using only materials at hand. The research considers a broad spectrum of problems including sabotage, terrorism, nuclear war, and hypothetical reactor accidents.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 05	0.5	0.5	0.7	0.7	0.7	0.8	0.8	0.9
Total	0.5	0.5	0.7	0.7	0.7	0.8	0.8	0.9

B.2 Health Effects of Energy Products and By-Products

This research program is based on the concern that physical and chemical agents to which people may be exposed as a result of the operation of energy technology may have deleterious effects on health. Four major kinds of effects are of concern: (1) genetic effects—inherited effects on future generations resulting from mutations and other chromosomal alterations; (2) teratogenic effects—effects on embryos and fetuses exposed *in utero;* (3) carcinogenic effects on the exposed individual; (4) toxic effects on the exposed individual. Many of the techniques used to study these effects were developed over the last 30 years to study the risks to human well-being from exposure to radiation and radioactive isotopes; these techniques are also applicable to estimating the risks from chemicals. However, there are some special problems, such as identifying the chemicals and mixtures of chemicals of interest, determining the methods of exposure to them, and determining doses received. These problems will require development of new procedures.

The goal during the next few years will be to bring about shifts in emphasis in these programs to deal effectively with the great number of chemicals involved, to develop better methods for evaluating exposure and estimating dose, to develop the programs in toxicology and teratogenesis from their small preexisting base, and to develop the general knowledge that will be so important for dealing more effectively with the great variety of agents that are involved in estimating risks to humans.

B.2.1 Genetic Effects of Energy Technology Products and By-Products

The primary goal of the genetic effects study is to identify substances arising from energy technology that could cause genetic damage to humans and, once they are identified, to obtain a quantitative estimate of the potential risk. For this purpose, tests for mutations and chromosomal aberrations in mouse gonads will be conducted. This is the method that has been used successfully to estimate the genetic risks to humans from radiation. Simultaneously, a tier-system approach using a variety of tests with lower organisms will be used to provide rapid and relatively inexpensive information for identification of potential risks and as a basis for selecting materials to be tested more extensively in the mouse.

A major goal of this program must be continued development, improvement, and evaluation of testing methods. Existing tests still leave much to be desired in rapidity and in relevance to humans. A clear understanding of why different tests sometimes give discordant results is essential for drawing inferences for humans from laboratory results. Among other things, a true dosimetry of the chemicals involved needs to be developed. Fairly simple tests that could be used for screening human populations for increased mutation rates must also be developed. Modern developments in the biochemistry of gene products give some promise for this, and work to develop such tests is part of this program.

A primary difficulty in applying the results of laboratory tests to humans and in generalizing from the results with one chemical to those with related chemicals is the relatively primitive state of our understanding of the process by which mutations arise. Thus, part of the program will be directed toward understanding this process, especially at the molecular level. Existing evidence suggests that DNA repair, through the errors that it makes, may be quite important for mutation induction.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 01	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
RT 02	3.4	3.5	3.9	4.1	4.3	4.6	4.9	5.2
WFO	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
Total	3.7	3.8	4.2	4.4	4.8	5.1	5.4	5.7

B.2.2 Teratogenic Effects of Energy Technology Products and By-Products

The possibility of damage to developing embryos from environmental agents that will be generated in the production and consumption of energy is a subject of serious human concern. Earlier work with radiation and various chemicals

has shown that certain embryonic stages are exceedingly sensitive to even small amounts of disturbance, and there is reason to believe that environmental pollutants of various kinds could also cause maldevelopment. At a time when different energy technologies are being explored and compared, investigating this type of risk seems particularly important.

An empirical screening of many agents for possible teratogenic effects will be needed to answer questions of human risk. By itself, such a screening would have only limited value, despite its importance. Concurrent exploration of basic questions concerning developmental mechanisms is needed to predict the effects of unexplored compounds on various developmental stages and processes. The study of basic and experimental embryology should therefore contribute to the proposed work.

All environmental agents must exert their effects against a background of developmental sequences that are already programmed by an individual's genetic makeup. The nature of the genetic background has been shown to have a pronounced influence on the quality and quantity of the teratogenic effects due to radiation. Moreover, certain gene substitutions produce major teratogenic effects, the study of which is highly instructive for the understanding of development pathways, gene action, and the action of external agents. For these reasons, developmental genetics is one of the disciplines to be included in the program. Particularly valuable in such investigations will be the inclusion of experimental systems in which the pathways between gene and character have already been well explored, so that deviations can be described in detail.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 01		0.1	0.1	0.1	0.1	0.1	0.1	0.1
RT 02	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6
Total	0.3	0.5	0.5	0.6	0.6	0.6	0.7	0.7

B.2.3 Carcinogenic Effects of Energy Technology Products and By-Products

The aim of the work on carcinogenic effects is to predict the risk of human cancer from occupational or environmental exposure to energy sources and their by-products through studies in animals and mammalian cells. The goals are to determine which substances are carcinogenic, how carcinogenic they are, what routes of exposure are important, and what host factors (such as pregnancy or allergies) increase man's susceptibility to cancer. The work necessarily includes various supporting biological studies because rational recommendations on permissible exposures of man must be based on (1) knowledge of the effects of route of exposure; (2) the transport, storage, metabolism, and excretion of energy-related compounds; (3) the effects of continued exposure over a long time; and (4) the ability of the body to repair the damage.

In addition, the role of energy products and by-products as cocarcinogens is being investigated. Because exposure of man to large amounts of carcinogens is an unlikely event, the ability of other energy-related substances (which, by themselves, do not cause cancer) to act together with small amounts of carcinogens to cause cancer is a major component of the research. The interactions of carcinogens (such as tobacco smoke and radionuclides) are also under investigation.

Methods will be developed to measure constituents of specific importance to inhalation exposure. New approaches to assigning priority to products for biological study will be developed using multicomponent chromatographic analysis. Inhalation dosimetry methods will be developed that provide information on the quality, as well as quantity, of aerosol constituents retained by the animal. Noninvasive methods, particularly those of use in human dosimetry, will be sought. Modified smokes will be produced by adding biologically active compounds to the aerosol to evaluate the role of smoke as a cofactor in carcinogenesis (see Section B.5).

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 01	3.6	4.6	5.1	5.4	5.7	6.1	6.4	6.7
RT 02	0.4	0.5	0.6	0.7	0.8	0.8	0.9	0.9
RT 04	0.1							
WFO	3.5	3.2	3.5	3.8	3.9	4.2	4.4	4.6
Total	7.6	8.4	9.3	9.9	10.4	11.1	11.7	12.2

B.2.4 Toxicologic Effects of Energy Technology Products and By-Products

Toxic effects may provide the first indications of damage to health that will be detected in man from occupational or environmental exposures to energy sources and their by-products. The aim of this work is to predict the potential hazards to man from exposures to energy by-products through comparative toxicity studies in experimental animals so that a rational basis can be provided for limiting exposures. Moreover, this research could assist in the selection of acceptable energy technology processes.

Although a national effort is under way to test the toxicity and carcinogenicity of some of the more

widely used chemicals and drugs, few studies have been conducted on mixtures of chemicals such as those in liquefied coal products. The goals of such research in progress at ORNL are to determine what the relative toxicities of energy by-products are (with emphasis on fossil fuels), which constituents or fractions are responsible for the toxic effects, what parts of the body are affected, and what kinds of disease are produced. Of the various routes of exposure, ORNL is concentrating on inhalation and on exposure of the skin and eye because these are the routes through which significant occupational exposures are likely to occur. In addition to dose-response and pathologic studies, considerable work is in progress on metabolic activation and detoxification of chemicals and on the importance of persistent body burdens. Chronic toxicity from frequent low-level exposures is also being investigated.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 01		0.3	0.3	0.3	0.4	0.4	0.4	0.4
Total		0.3	0.3	0.3	0.4	0.4	0.4	0.4

B.3 Biophysical Studies

In recent years, certain types of damage caused by ionizing radiation and chemicals to macromolecules, such as nucleic acids, have been observed to be repaired by living systems. The steps following the insult are biochemical in nature, and the repair mechanism is an enzymatic process that appears to be widespread in living organisms. A thorough understanding of the nature of the damage and the chemical reactions leading to repair of the molecules may permit us to arrange conditions so that the potential hazard of various environmental agents will be lessened.

Basic atomic and molecular studies of the interaction of radiation with matter are being pursued to understand the effects of radiation on living systems. Understanding the mechanisms of radiation damage to biological organisms and the nature of the damage at the molecular level continues to be an important part of ORNL's biomedical and environmental sciences program.

B.3.1 Molecular and Cellular Sciences

Research in the molecular and cellular sciences is directly related to acquiring a knowledge of the molecular and cellular mechanisms through which environmental pollutants (radiation and chemicals) arising from energy production cause damage to living systems. Only through unraveling the details of the biochemical and physiological events that ultimately lead to a clinically recognizable pathologic state will it be possible to ameliorate the adverse biological effects of these noxious agents and be able to predict the potential threat of a given pollutant from structural considerations. If the factors that endow a compound with toxic, carcinogenic, mutagenic, or teratogenic activity could be determined at the molecular level, a financial saving could be incurred by dispensing with some of the massive procedures for screening literally hundreds of compounds in experimental animals over long periods of time. At present, knowledge of mechanisms is so limited that essentially every potentially dangerous environmental agent becomes a new research endeavor with respect to evaluating its interaction with biological systems. Because the biological consequences of these compounds depend on how they enter cells, how they interact with intracellular macromolecules, how their induced damage to macromolecules is repaired, and how they are metabolized, the problems are much greater in scope than mere screening and cross many disciplines of biological science.

To answer some of the basic questions posed above, a number of areas should be strengthened during the next few years.

1. *Physical biochemistry* will be expanded, and special emphasis will be placed on methodologies that are used to study interactions of small organic molecules with nucleic acids and proteins. For example, we must have a research capability in nuclear magnetic resonance as applied to biological problems.

2. *Enzyme mechanisms* will be given a greater emphasis in the future because (*a*) enzyme-dependent repair processes provide the cell a means of overcoming some of the damage resulting from exposure to radiation and chemicals and (*b*) cellular differentiation, transformation, and carcinogenesis will not be fully understood without an elucidation of how cells regulate the activity of enzymes involved in replication, transcription, and translation.

3. *Membrane biochemistry and physiology* are important because the cellular membrane can be viewed as a cell's first line of defense against environmental hazards. The program will concentrate on the following questions: (*a*) What determines whether a given agent can enter a cell? (*b*) What kinds of complexes are formed between membranes and known carcinogens and mutagens? (*c*) What repair processes exist for damaged membranes?

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 02	2.9	3.3	3.7	4.0	4.2	4.5	4.7	5.0

B.3.2 Physical Studies

The physical studies associated with radiation chemistry, radiobiology, biology, and health and environmental physics are directed toward long-range goals. Ultimate understanding of the effects of radiation in biological systems rests on knowledge of the atomic and molecular changes that occur and of the number and nature of secondary products produced as a result of exposure to radiation. Thus the deleterious effect and ultimate fate of pollutant molecules in the environment can be confidently predicted only through an understanding of the physical and chemical processes that they induce. This program will continue work on a broad base involving experimental and theoretical investigations of the interactions of radiation with solid, liquid, and gaseous systems.

Emphasis over the next few years will be on areas of low-energy electron and ion collision physics in the energy range that is of interest in radiation chemistry and biology. Studies in the physics of tissue damage, of which the physics of liquids forms an important part, will also receive continued emphasis. Research programs on the interaction of charged particles and photons with solids, in the area of atomic and molecular physics, and in general theoretical radiation physics will be maintained. The latter program encompasses all programs and additional areas of radiation biophysics and health and environmental physics.

During 1977 and 1978, expansion will be made in studies that are associated with fossil fuel pollutant problems. New studies are under way to determine the clustering properties of atmospheric pollutant ions and to investigate ion-molecule reactions that are important in atmospheric physics problems stemming from power generation.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 04	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.3

B.3.3 Dosimetric Analysis and Modeling

The specific objective in ORNL radiation dosimetry programs has centered on studies to improve the physical dosimetry of human radiation exposures and correlations between biological effects of radiation exposures and radiation dose. Emphasis is placed on investigations of depth-dose distributions and dose to specific organs of the body from neutrons and gamma rays as a function of exposure geometry. Information from these studies is of value in analyses of the effects of routine occupational exposures, radiation accident cases, medical exposures, and the medical and epidemiological studies of the atomic bomb survivors in Japan. As attention in energy research focuses on various alternatives for production, similar attention must be given to the development of dosimetry for the attendant pollutants. The ultimate goal of this integrated dosimetry program is continued assessment of needs for specific types of monitoring, adaptation of instruments and procedures for field testing at facilities known to produce potentially harmful pollutants, establishing specific monitoring techniques and detection principles, and initiating a program of intercalibration studies leading to the establishment of standards in measurement techniques.

As part of the program for estimating internal radiation exposure in humans, metabolic models for about 60 elements have been completed. These models and computer codes also developed within this program serve as a basis for revised internal exposure guidelines. In addition to metabolic models for the remaining elements, emphasis has more recently been placed on obtaining age-dependent models for metabolism so that estimates of dose to any population group can be made in a more realistic manner.

This program provides the continuing data base for national and international guides on internal exposure to radioactive materials. For example, the staff at ORNL is actively engaged in the revision of internal dosimetry standards for the International Commission on Radiological Protection (ICRP). In addition, the Laboratory is represented on all of the internal dosimetry committees of the National Council on Radiation Protection. The exposures to be considered include not only occupational exposures but also the exposure of selected population groups resulting from materials associated with nuclear power technology or from the use of radiopharmaceuticals in medical procedures. Much of the general analysis and metabolic modeling that has been developed is also applicable to the initial review and examination of the health protection implications of effluents from the various energy technology options. Increased emphasis in this area, particularly with regard to age-dependent models and trace-element studies, is anticipated over the next five years.

Other items receiving continuing emphasis in FY 1977 and FY 1978 are the development of new dosimetric techniques for the evaluation of absorbed radiation dose to patients in nuclear

medicine applications and the evaluation of new and promising radiopharmaceuticals for diagnostic usefulness.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 04	0.5	0.5	0.6	0.7	0.8	0.8	0.9	0.9
WFO	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	0.6	0.6	0.7	0.8	0.9	0.9	1.0	1.0

B.4 Detection and Treatment of Environmentally Induced Health Problems

In the search for new sources of energy, some previously unknown biological hazards are likely to surface. The hazards must be identified quickly so that alterations can be made in the process. Studies have been initiated to compare public health and demographic data in Tennessee with records of environmental radiation levels in the region around ORNL. These studies will be developed over the next five years.

B.4.1 Analysis and Assessment of Health Effects

The specific objective of this multidisciplinary study is the development of techniques and procedures for analyzing and estimating health effects from by-products of energy systems. In addition, it is necessary to be able to estimate potential health effects on the basis of exposures to known concentrations of potentially harmful pollutants. The ultimate goal of this program is the establishment of analytical methodology and predictive models that may be applied to epidemiological studies as well as to assessments of environmental and health impacts for a variety of energy-related technologies. As new technologies develop, new methodologies are required for studies of potential health problems, some of which may not be fully recognized until a future generation. An important aspect of methodology development is the ongoing collection and analysis of base-line data for a wide variety of pollutants. This information is useful to practitioners and to those who prepare impact statements. In all health effects studies, there is a need for demonstrating that every effort has been made to minimize the risks from any given technology. In order to accomplish this, available vital and health statistics for the entire country by county must be utilized. Techniques need to be developed to compare the frequency of health disorders in communities containing energy-related facilities with that in communities having a similar population and economy but not containing these facilities. Thus, evaluations based on health impacts from attendant pollutants must be carried out to provide input for impact statements and to provide information to assist logical decision-making processes among competing power production and/or conversion technologies.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 04	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
RT 05	0.2	0.2	0.4	0.4	0.4	0.5	0.5	0.5
RW 03		0.2	0.2	0.2	0.2	0.2	0.3	0.3
Total	0.3	0.5	0.7	0.7	0.7	0.8	0.9	0.9

B.4.2 Nuclear Medicine Technology

The objective of the continuing program of nuclear medicine technology is to provide the maximum possible contribution to national health goals through the development of innovative medical radionuclide systems. This objective will be attained by integrating the Laboratory's expertise in the areas of (1) research and development of radionuclides, (2) synthesis of radiopharmaceuticals, (3) elucidation of biological mechanisms of pharmacology and of distribution in the body, (4) immunology, (5) radiation dosimetry to body organs from radiopharmaceuticals, (6) development of instrumentation specific for nuclear medicine applications, and (7) development and dissemination of computing technology (e.g., through the Biomedical Computing Technology Information Center) for clinical operating systems, image enhancement techniques, and information systems for medical applications. Clinical testing of new materials will proceed through close coordination with organizations such as the Oak Ridge Associated Universities (ORAU), University of Tennessee (UT) Memorial Research Hospital, and the East Tennessee Cancer Research Center. The integrated character of the program will accomplish the development of new radiopharmaceuticals from studies of cell physiology to final testing in man.

Specific objectives include development of ^{123m}Te-labeled amino acids for possible pancreatic agents, ^{123m}Te steroids for hormone receptor studies, ^{195m}Pt-labeled chemotherapy agents for pharmacodynamic studies, ^{33}P-labeled agents for radiotherapeutic application, ^{11}C-labeled agents for tumor localization and dynamic function studies, and a torso proportional-counter camera for high-efficiency whole-body scanning. In addition to the focus on nuclear medical applications, the program provides radioisotope preparations for research applications such as radiotracers for environmental and biomedical research.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 01	0.7	0.8	0.9	1.0	1.0	1.1	1.1	1.2
RT 04	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7
RT 05	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	1.2	1.3	1.5	1.6	1.7	1.8	1.8	2.0

B.5 Biotechnology

In some cases, the biotechnology programs are still in the exploratory stages. ORNL hopes to convert these to a more active form during FY 1977. Then, real progress toward evaluation and implementation of long-range goals can be achieved. These are the kinds of programs for which a large multipurpose laboratory is well suited.

The purpose of this research is to study, develop, and exploit new concepts and techniques that will allow the use of biological systems to achieve specific process goals in energy production, resource recovery, conservation, or the abatement of pollution from energy sources.

B.5.1 Bioengineering Research

Bioengineering research will be carried out in support of various biotechnology development efforts. This research will include the development of new bioreactor concepts, new microbiological or immobilized-enzyme processing methods, and specific equipment and facilities for biological research efforts, as well as operation of large-scale equipment to produce biological materials useful for the research. Biochemical separations will also be studied for specific application in biotechnology.

Bioreactor concepts to be investigated include fluidized and fixed beds for both aerobic and anaerobic operation. Investigation of a fluidized-bed system will be emphasized during FY 1977, and various fixed-bed configurations will be studied during the next several years. Photosynthetic systems will be considered, and reactors compatible with two-phase liquids will be developed. Techniques for immobilization of microorganisms or enzymes to be studied will include chemical bonding, entrapment, and natural attachment or sorption. This research will be carried out during the period FY 1977 through FY 1980. New continuous chromatographic systems will be developed, and chromatography coupled with centrifugation will be investigated as a means of isolating and purifying large quantities of useful biochemicals.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 04	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Total	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3

B.5.2 Bioprocess Development

During the next several years, bioprocess development investigations will include activated-sludge reactors for process waste treatment and bioconversion to fuels, particularly in the production of methane or the lower-molecular-weight alcohols. Also during this period and thereafter, several bioprocesses will be studied and developed for pollution abatement. A new bioreactor concept utilizing microorganisms will be studied for the degradation of dissolved organic pollutants in the aqueous effluents of coal conversion processes. Preliminary results from such a system indicate that the hazardous phenolic compounds can be almost completely removed. A similar system will be developed for the removal of dissolved trace heavy metals or resource materials in dilute aqueous streams.

During the latter part of this period, biological coal beneficiation processes for sulfur removal will be studied, and isotope enrichment techniques based on microbiological processing will be investigated.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 04		0.1	0.1	0.1	0.1	0.1	0.1	0.1
KK 03		0.5	0.6	0.6	0.7	0.7	0.8	0.8
BA 01			0.1	0.1	0.1	0.1	0.1	0.1
HE 01	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3
Total	0.1	0.8	1.0	1.0	1.1	1.1	1.3	1.3

B.5.3 Advanced Bioinstrumentation

A significant effort in the biomedical and environmental sciences program involves an interdisciplinary effort to develop advanced measurement technology for biomedical, environmental, and process applications. Energy production and consumption will continue to result in potential biological hazards, and new technology will be needed to measure and monitor such hazards adequately. Biomedical research associated with investigating these effects will also require advanced instrumentation. In addition, bioprocesses developed for pollution abatement will require new analytical concepts and techniques.

Detectors will be developed to improve risk assessment involved in processing coal and oil shale. Several new measurement technologies will be explored in an effort to characterize atmospheric changes. These new methods will include a pulsed-laser resonance-total-ionization method of measuring small concentrations in gas samples, detection by negative-ion mass spectrometry and sensitized photoemission, development of portable detectors for explosives or toxic gases, instruments to detect surface contamination of harmful organic products of coal liquefaction, and development of integrating dosimeters that respond to wavelengths of light known to produce biological or photochemical effects. Efforts related to nuclear technology will include radiological assessment of extraction operations, track-etch methods of neutron-induced autoradiography for the detection of low levels of plutonium, simple nuclear accident dosimeters using both thermally stimulated exoelectron emission and thermoluminescent dosimetry, and a survey instrument capable of measuring the fast-neutron spectrum and a limited gamma-ray spectrum from a reactor.

Continued efforts will attempt to generate the means for early detection, diagnosis, and prognosis of cancer utilizing tumor-associated antigens and antibodies. These efforts include the development of automated systems for production and assay of specific antigens and antibodies, the creation and adaptation of immunosorbents for biospecific separations, and the actual production of pure immunoreagents in large quantities. The development of techniques for rapid automated sensitive computerized tests for clinical chemistry will continue and will expand to provide a more comprehensive clinical evaluation of the individual.

Since the ERDA missions include all energy technologies, advanced systems for the measurement of environmental by-products will be developed. This research will include chromatographic systems, electrophoretic systems, and various systems for photometric and immunologic assays. Capabilities for gas and liquid chromatographic analysis will be extended over the next few years through the implementation of high-resolution capillary column technologies and of element-selective detectors. Bioanalytical methods, particularly electrophoresis and radioimmunoassay, will be developed for use in environmental and fossil-fuels programs; special attention will be given to rapid high-specificity determinations and to characterizing high-molecular-weight organic compounds. A complete capability for the structural identification of organic compounds will be established that combines the use of preparative isolation and common spectroscopic (ultraviolet, infrared, magnetic resonance, fluorescence, and mass) methods. A systematized method for rapid and for preparative-scale chemical class fractionation will be established. The determination of polynuclear aromatic organic compounds, speciation of metal-organic and organic-organic adducts, airborne sampling, and biochemical markers of environmental or biomedical impact will receive additional attention.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 04	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9
WFO	0.4	0.5	0.4	0.4	0.4	0.5	0.5	0.5
Total	1.7	1.8	1.9	1.0	2.0	2.2	2.3	2.4

B.6 Integrated Studies on the Impact of Coal Conversion Technology

The objective of this study is to provide information necessary for ensuring that coal conversion processes for producing synthetic fuels will not result in unacceptable risks to human and environmental health when they are implemented on a large commercial scale.

The technology for the conversion of coal to liquid and gaseous hydrocarbons for fuel and petrochemicals is being actively developed by ERDA and private industry. The development of this technology should proceed in such a way that conversion processes can be optimized not only economically but also for maximum protection of human and environmental health. Therefore, biomedical and environmental research must proceed in concert with technological development. The importance of biomedical and environmental research to this technology is reflected in the rapid growth projected in the Plan. These studies will cut across programs, and close collaborative research including biologists, chemists, ecologists, and health physicists is being conducted to evaluate the potential fate and effects of coal conversion effluents.

Research activities can be divided into two broad classes: those designed to provide information on intact effluents and fractions thereof through use of rapid toxicity screening tests and those that utilize model compounds and are designed to elucidate mechanisms of effects, metabolic degradation pathways, persistence, bioaccumulation potential, and ultimate fate. Research for evaluating the potential hazards to man

and his environment will proceed from initial toxicity screening tests to chronic exposures and environmental transport and fate studies. Links have been established with the Energy Research Centers (Pittsburgh, Laramie, and Morgantown) and with industry. Samples have been obtained for initial chemical and biological screening. To facilitate this research, techniques will be developed for chemical profiling and multicomponent analysis of selected compound types. A production activity will be implemented to provide well-characterized materials for biological and environmental research.

The health effects portion of the program will involve tests for toxicological, carcinogenic, mutagenic, and teratogenic effects of products and effluents using the procedures given in Section B.2 of this report. Efforts will be made not only to identify potentially hazardous materials but also to estimate the magnitude of any deleterious effects on human health.

Characterization and quantification of molecular pollutants will be conducted utilizing liquid and gas chromatographic techniques coupled with identification by mass spectrometry. New methods and techniques will be developed to aid in the study of the composition of diverse and complex materials derived from coal conversion. As hazardous materials are identified, prototype instruments for assessment and monitoring will be developed.

Chronic effects studies on important components of the environment will be conducted at the organism, population, and community level. Studies designed to determine the metabolic pathways and transformation products will be conducted with appropriate model systems. Investigations into the transport and fate of materials in the environment will be conducted in appropriate systems. The purpose of this program is to evaluate the potential impact of various conversion alternatives on man and his environment, to provide such information to design engineers and abatement personnel so that early design changes can be made in the technology alternatives, and to make data available for eventual assessment and determination of a conversion technology most compatible with man and his environment.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
RT 01	0.3	0.7	0.9	1.0	1.5	1.5	1.6	1.7
RT 02	0.4	0.5	0.6	0.6	0.7	0.7	0.7	0.8
RT 03		0.7	0.9	1.0	1.3	1.4	1.4	1.6
RT 04	0.1	0.9	1.1	1.2	1.3	1.4	1.4	1.5
RT 05	0.1	0.7	0.9	1.0	1.0	1.1	1.2	1.2
RW 03		0.1	0.1	0.1	0.1	0.1	0.1	0.1
WFO	1.5	0.7	0.7	0.7				
Total	2.4	4.3	5.2	5.6	5.9	6.2	6.5	6.9

Summary of Work for Others (WFO) funding

Agency	'76	'77	'78	'79	'80	'81	'82	'83
NRC	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8
EPA	4.3	2.1	1.9	2.1	1.4	1.5	1.6	1.7
NCI	2.4	2.5	2.7	2.9	3.0	3.2	3.4	3.6
NIH	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1
NSF	1.6	1.8	1.9	2.0	2.1	2.2	2.3	2.4
EPRI		0.3	0.3	0.3	0.3	0.3	0.3	0.4
FDA	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NASA	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Others	0.3	0.2	0.2	0.3	0.3	0.4	0.4	0.4
Total	10.9	9.3	9.5	10.3	9.9	10.5	11.1	11.7

C. Conservation

ORNL's conservation research and development programs include evaluations of efficiencies of residential water heaters and furnaces (far left) The Annual Cycle Energy System (ACES), now in the demonstration stage, utilizes large ice bins for energy storage, as seen at left.

C. CONSERVATION

The conservation research and development program has concentrated primarily on the identification of methods to reduce energy use in residences and buildings; smaller programs are concerned with improving electric energy transmission, industrial insulation materials, energy storage systems, and computer modeling of energy use. Stronger programs are projected in all these areas, including work on high-temperature fuel cell electrolytes and management for ERDA of programs in low-temperature thermal storage, residential and commercial applications, and the Annual Cycle Energy System (ACES). In addition to the topics covered in this section, conservation-related activities at ORNL also include the development of coal-fired Modular Integrated Utility Systems (MIUS) and the alkali metal vapor topping cycle for power plants (see Sect. V.F.3).

The Laboratory will encourage new ideas in conservation and will explore ways to extend the application of existing cost-effective conservation technology in residences, business, and industry.

End-use energy conservation is concerned with a large number of end uses in each of several diverse sectors of the economy. Research targets have been chosen on the basis of first doing the things that are likely to have the largest and most immediate payoff. Thus the following program descriptions are concerned mainly with near-term implementation goals. As the program proceeds, a continuing series of assessments will determine the most useful areas for follow-up research. We would like to have the conservation program constitute about 3% of the research effort within the Laboratory. We will work to expand our efforts in conservation with this target in mind.

C.1 Energy Conservation in Buildings and Community Systems

ORNL has systematically investigated the more significant uses of energy in buildings to determine sources of energy loss and methods of reducing these losses. Experimental programs have been completed on mobile homes, residential water heaters, and residential gas furnaces. In each case, cost-effective energy savings were identified that could be accomplished through minor changes in design. Analytical work has also indicated that worthwhile energy savings could be made through night setback of heating system thermostats, stronger building insulation standards, and use of efficient air conditioners. Future investigation will center on the efficiency and reliability of electric heat pumps. New systems are being developed such as ACES, a heat pump with thermal storage. In addition, we continue to seek methods of improving the energy efficiency of buildings and energy-intensive appliances.

An interesting alternative to central station electric generating systems is the use of self-contained community systems producing electricity and heat. We are assisting in the demonstration phase of the MIUS to develop the components for a system that would supply all community utilities.

A new waste water treatment process called ANFLOW has been under development at ORNL for more than two years. The process depends on microorganisms attached to specially prepared conventional chemical packing materials, through which liquid wastes flow for treatment. An appropriate system controls the growth rate of the microorganisms. Using this system anaerobically, fuels and fuel gases can be produced directly during waste treatment.

The test of a system for treatment of domestic sewage is now being readied in cooperation with the Chemical Process Product Division of the Norton Company, Akron, Ohio, and the City of Oak Ridge. We also expect to extend the application of the technology to treatment of certain industrial wastes and to other industrial fermentation processes.

A new role for ORNL in conservation RD&D is that of program management. Increasingly, the Laboratory is undertaking to provide technical assistance to ERDA staff by participating in program planning and management. In Buildings and Community Systems, we will manage the ERDA programs on Residential and Commercial Appliances, the ACES, and the Analysis of Advanced Coal Using Community Systems. Additional management assignments may be identified in the future. The exact definition of this activity varies with the program. Typically, it consists of planning the future program (in concert with the ERDA program manager), preparing requests for proposals, contracting for research work, monitoring the progress of the contract, and preparing a final evaluation of results and recommendations for further work. Contracts to be managed will vary from component development to systems analysis and commercialization types. In keeping with the need for rapid commercialization of ERDA conservation programs, the contracts will generally be placed with organizations that are in a position to do production and/or marketing of the technology being developed.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
HD 01	0.9	2.6	3.7	4.5	4.5	4.3	3.7	2.6
WFO								
HUD	0.4	0.2	0.2					
FEA	0.2							
Total	1.5	2.8	3.9	4.5	4.5	4.3	3.7	2.6

C.2 Industrial Energy Conservation

Initial efforts in industrial energy conservation are being placed on insulation materials. Included in these efforts are programs to (1) assess industrial thermal insulation usage, (2) determine the effects of changing from natural gas to alternative fuels on refractories and refractory insulations, and (3) provide data on high-temperature fiber insulations under realistic operating conditions. Funding for these programs is proposed to be increased in FY 1978 to accelerate their near-term impact.

Starting in FY 1978, ORNL proposes to embark on a major expansion of materials RD&D in areas other than insulation. Examples include (1) system, economic, and technical studies of the cycle of energy-intensive materials within the economy; (2) demonstration of the energy conservation potential of optimizing industrial processes involving crushing, grinding, blending, and precipitation operations for minimum energy consumption in subsequent pyroprocessing; (3) development and demonstration of refractory materials for high-temperature recuperators; (4) development of high-strength cost-effective ceramic turbine blades and heat exchangers by vapor deposition of high-density ceramic coatings on low-cost low-density ceramic preforms; (5) development of improved and economic optically absorbing and reflective coatings for window glass; (6) development of low-cost nontoxic brazing alloys and solders for economic waste and process heat exchangers; and (7) development of low-loss transformer materials.

Another program, to be initiated in FY 1977, will evaluate and demonstrate ways in which waste heat from ERDA's gaseous diffusion plants can be used in agricultural and industrial processes and for electricity generation. The demonstration phase of the program, including applications to such facilities as greenhouses and fish farms, will be carried out in an industrial park to be developed adjacent to the Oak Ridge Gaseous Diffusion Plant.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
HG 01	0.2	0.7	1.4	2.0	3.0	3.0	3.0	3.0

C.3 Electric Energy Systems

Conservation options in electrical energy include improved electric energy transmission systems and methods for leveling loads through improved sensing of demand.

The program in energy transmission is directed toward identification of the best liquid and especially the best gaseous materials for use as high-voltage insulators. Our initial work is on gases, since gaseous components seem to provide the best effective combination of electron thermalizing (slowing down) and electron scavenging (forming relatively immobile negative ions) to prevent breakdown by electrons to very high voltages. Investigations on gaseous components have focused on sulfur hexafluoride, fluorocarbons such as perfluorocyclobutane, perfluoroisobutylene, perfluorobutadiene, and hexafluorobenzene, and binary mixtures of the listed gases, some of which are up to 100% more effective than the reference sulfur hexafluoride.

Technical and project management assistance is being provided for ERDA-EPRI-utility-industry projects in load management. Initially, this support is for field tests of six commercial communication systems that could provide utilities with a capability for remote sensing and control of the loads on the system.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
HA 01	0.1	0.3	0.3	0.3	0.5	0.4	0.3	0.2
HA 02	0.1	0.3	0.3	0.5	0.5	0.4	0.3	0.2
WFO								
EPRI	0.0	0.0	0.1	0.2	0.2	0.0	0.0	0.0
Total	0.2	0.6	0.7	1.0	1.2	0.8	0.6	0.4

C.4 Energy Storage and Peaking Power Systems

Energy storage has several promising applications. (1) The economic use of some of the alternative energy sources may require the availability of energy storage systems. (2) Energy use in some industrial processes could be reduced by energy storage. (3) The flattening of electrical demand by energy storage (e.g., storing heat in homes during off-peak hours) would reduce the use of less efficient peaking units.

ORNL has been assigned the responsibility for managing the low-temperature program on thermal energy storage (to temperatures of about 250°C). Storage technology to be investigated includes sensible heating and phase-change modes for a wide range of potential applications. The bulk

of the effort will be carried out through industrial and university subcontracts. Activities at ORNL will include (1) the development of a computer program to study the response of a thermal energy storage (TES) unit charged with a phase-change material and testing of this mathematical model against the performance of a physical simulation, (2) a survey of TES subsystems for solar energy applications in the heating and cooling of buildings, (3) an evaluation of potential benefits of TES devices, and (4) the experimental determination of physical and chemical properties of phase-change materials.

Investigation of the physical chemistry of high-temperature fuel-cell electrolytes, especially molten carbonates, is directed toward improving the efficiency and lifetime of fuel cells for peaking power applications. Proposed measurements of chemical equilibria and of mass transport and charge transport in molten alkali-carbonate mixtures at 450 to 600° C should contribute to an understanding of the limits of performance of molten-carbonate fuel cells.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
HC 01	0.1	1.2	2.0	2.8	2.6	2.2	2.0	1.3
HF 01	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total	0.1	1.3	2.2	3.0	2.8	2.4	2.2	1.5

C.5 Energy Use Conservation Models and Information

A set of computer models and data bases are being developed and used to evaluate a variety of energy conservation policies, technologies, and strategies affecting energy use in all sectors of the economy. The models incorporate relevant demographic, economic, and technological factors to produce conditional forecasts of patterns of energy use through the year 2000. A detailed model of residential energy use was developed in FY 1976 and is now in use by the project sponsors. This model will be improved in FY 1977; regional residential-energy-use models will be constructed, and similar models will be constructed for commercial buildings and possibly for the paper industry. Plans for later years include construction of detailed end-use models for other manufacturing sectors, for agriculture, and for transportation. These models will be used to analyze conservation opportunities and technology alternatives for federal and state energy agencies.

A Transportation Data Book has been prepared that contains comprehensive data on energy use in transportation along with associated demographic data. Future work is expected to include updating this volume and preparing similar data bases covering the use of energy in other sectors of final demand.

A comprehensive computerized bibliographic data base on energy conservation and consumption has been developed by the ORNL Energy Information Center (EIC). Publications of particular interest to consumers or students have been identified so that special bibliographies for these types of users can be prepared easily. EIC's goals are to provide a response service for both technical and popular conservation information and to participate in public education through ERDA's contemplated energy outreach program.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
HB 01	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HF 01		0.1	0.2	0.3	0.3	0.3	0.3	0.3
WFO								
FEA	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	0.5	0.3	0.4	0.5	0.5	0.5	0.5	0.5

BASIC ENERGY SCIENCES SUPPORT OF CONSERVATION TECHNOLOGY

In this section, we summarize the research at ORNL that directly contributes to conservation technology and is funded by the Division of Physical Research. All money summarized here has already been included in Section A, "Basic Energy Sciences."

Conservation research in the Basic Energy Sciences is devoted mainly to the study of the production and storage of hydrogen and to the study of high-temperature batteries and fuel cells, although a proposed program is directed toward achieving improvements in electric power transmission. A promising tack is the identification and characterization of new chemical reactions and reaction sequences for thermochemical cycles for the production of hydrogen, because such cycles may lead to the usage of thermal energy at high efficiency. Another hydrogen production technique being pursued is that of producing hydrogen by means of enzyme-catalyzed reactions. Two processes are being investigated: the first involves the chemical reduction of water using a recyclable substrate (e.g., sodium dithionite), while the second involves a photo-oxidation process. Both processes use the ferredoxin-hydrogenase catalyst system.

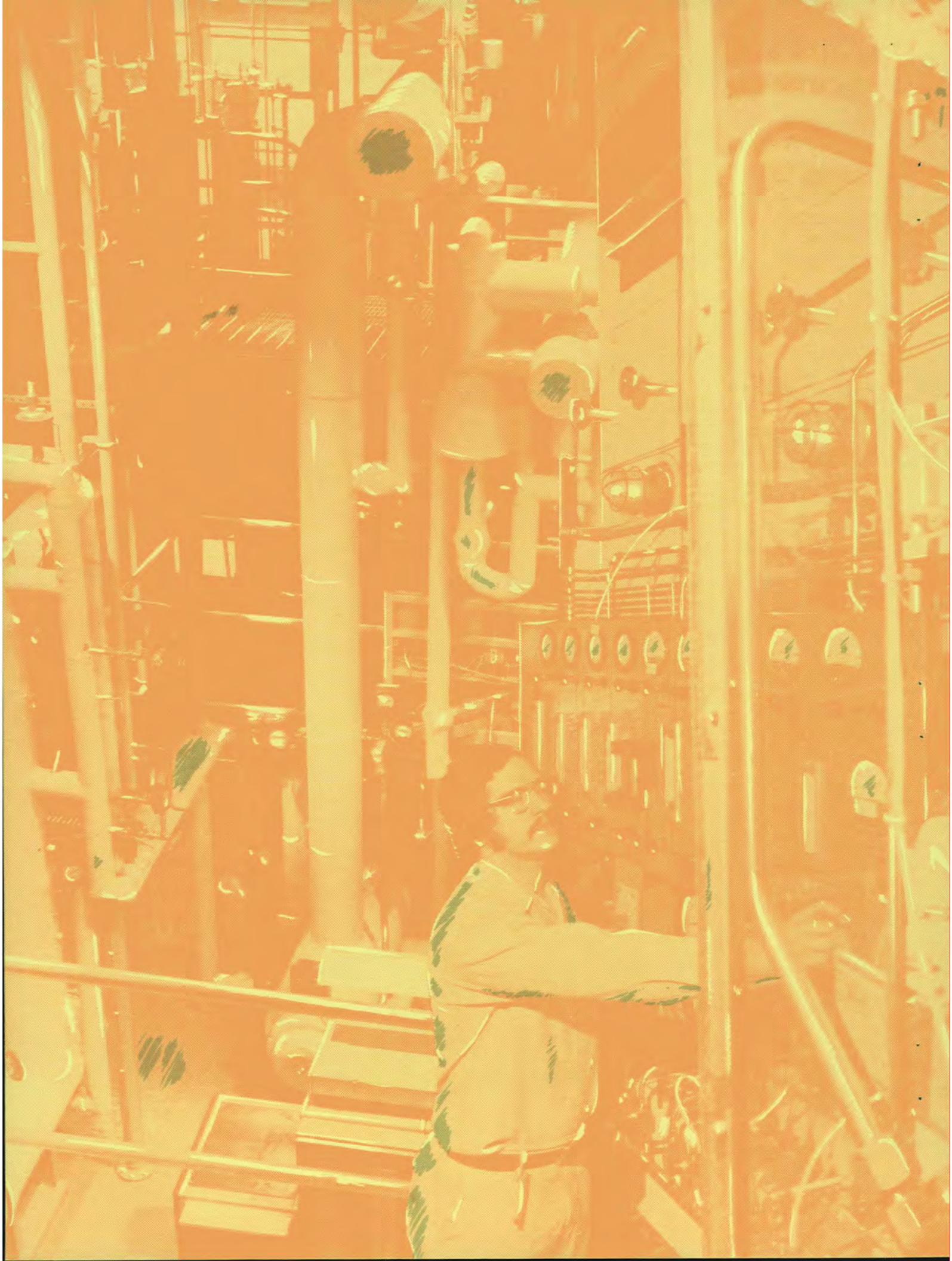
Because of the possible use of hydrogen as a fuel, certain metals and alloys that can hold large quantities of hydrogen and be made to absorb and release the hydrogen rapidly under different conditions of temperature and pressure have assumed increased importance. In order to help develop these materials as storage systems, research into hydrogen bonding and hydrogen diffusion in metals that form hydrides will be carried out.

The development of optimum storage battery systems requires detailed information on the behavior of lightweight substances of high electrochemical activity for electrode materials, on the corrosion resistance of container materials and insulators, and on the electrical and chemical behavior of suitable electrolytes, both liquid and solid. A proposed program in molten-salt battery research is designed to help provide this information and supply the quantitative information needed for the development of high-performance high-temperature fuel cells. An ongoing study of the superionic conductivity shown by certain crystals and ceramics is designed to help realize the potential of these materials as technologically very important solid electrolytes in advanced energy storage systems.

Resistive losses in electric power transmission by cables decrease as the temperature of the conductor is lowered. However, at the present time, determining the optimum conditions for transmission cable operation is impossible; a major reason for this is the lack of fundamental knowledge concerning skin effects (restriction of the alternating current to a small portion of the conductor close to the surface of the cable). We hope to begin a study in the near future to determine the low-temperature transport properties of reasonably pure materials in order to provide reliable engineering data that could be used in systems analyses to provide a more accurate design of ac cryogenic transmission lines than is now possible.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
0.2	0.8	1.1	1.3	1.4	1.4	1.5	1.5



D. Nuclear Energy Development

The Fluorocarbon Selective Absorption Pilot Plant, located at the Oak Ridge Gaseous Diffusion Plant, is used for decontamination of LMFBR fuel reprocessing plant off-gas (far left). Another part of the LMFBR/LWR fuel reprocessing program is an engineering demonstration of the IODOX (iodine oxidation) process (left) which uses bubble cap absorption for removal of iodine from air streams for use in the off-gas system of LMFBR fuel reprocessing plants.

D. NUCLEAR ENERGY DEVELOPMENT

In spite of the severe criticism offered by some, fission systems are expected to have a significant role in the energy economy for at least several decades, and this Plan recognizes both short-term and longer-term program objectives.

ORNL has major basic technology programs in support of the LMFBR and gas-cooled reactor concepts. Nuclear fuel recycle development efforts are being rapidly expanded and include major involvement in LMFBR reprocessing and HTGR recycle and a supporting role in LWR recycle. Other important programs include (1) evaluation of waste management alternatives, (2) studies and evaluations of alternative reactor concepts and of advanced concepts such as process heat applications, (3) reactor safety studies, and (4) development of isotopic fuels and special materials for space applications.

D.1 Liquid-Metal Fast Breeder Reactor Technology

The principal objective of the LMFBR effort is to provide base technology and engineering support to the high-priority National LMFBR Program in technical and management areas where ORNL has a demonstrated expertise.

The format used in the eight-year projection presented below is based on that which has been established at ERDA/RDD Headquarters for the National LMFBR Program. This program is intended to provide the technical base for the Administrator's decision on commercialization of LMFBRs in 1986. Preliminary recommendations provided by ERDA RDD regarding funding projections to achieve this goal have served only as a guide in the plan set forth below.

The LMFBR technology support and safety program at the Laboratory will peak in 1980 at a level about 80% greater than that in 1976. This projection relates to the national LMFBR plan, which is geared to these projects: the Fast Flux Test Facility (FFTF), the Clinch River Breeder Reactor Plant (CRBRP), the prototype large breeder reactor (PLBR), and the first commercial breeder reactor (CBR). These plants are scheduled to be operational in 1979, 1984, 1989, and 1994 respectively. The very small amount of confirmatory analysis being performed for the FFTF will be completed in 1978. For the CRBRP, key milestones to which design-oriented development tasks are geared include testing of the prototype steam generator, 1977; delivery of the last steam generator unit, 1979; establishment of technical base for the Final Safety Analysis Report (FSAR), 1979; sodium fill, 1982. For the PLBR, relevant milestones include selection of PLBR concept and beginning of detailed design, 1978; fabrication of large steam generator moles, 1979; establishment of technical base for Preliminary Safety Analysis Report (PSAR), 1979; finalization of core design, 1982; freezing of component designs, 1983. For CBR-1, milestones include final verification of high-temperature design, 1982; safety technical base for conceptual design, 1983; and beginning of construction, 1986.

The technical areas in which ORNL is involved are the following: Technology—Materials, Advanced Fuels and Absorbers, Physics, and Reactor Analysis; Engineering—Materials Engineering, Structures Engineering (High-Temperature Structural Design), and Codes and Standards; and Safety—Safety Analysis and Safety Experiments (Sections D.4.1 and D.4.2).

The Clinch River Breeder Reactor Plant will be constructed on the Oak Ridge site and is scheduled for operation in 1983. The Laboratory's relationship to the CRBRP project has been and will continue to be both significant and important. Although our LMFBR work is oriented more toward technology than direct design, the result of it will be applied to the design, operating philosophy, and licensing considerations for the CRBRP. The principal areas of involvement of ORNL are in nuclear analysis support, shielding analysis and experiments, reliability support, flux monitoring systems, thermometry, steam generator design and materials development, transition joint technology, thermal hydraulics under normal and abnormal conditions, piping and fitting development, and nondestructive examination.

D.1.1 Technology—Materials

The goal here is to develop the materials and processes that are inherent to a safe, economical, and reliable LMFBR industry through

- establishment of operational limits on current component alloys and development of alternative structural alloys with longer life at higher stresses,
- definition of the compatibility of steam generator alloys in normal and off-normal aqueous environments, and
- development of more sensitive nondestructive examination methods, including remote automated operating techniques for use in fabrication and in-service inspection of plant components.

D.1.1.1 Structural Alloys. Development work will be performed on a continuing basis on steam generator materials, joining technology, alternative

structural materials, and mechanical properties of structural alloys. Data will be generated and then accumulated, evaluated, and stored in an easily accessible and usable form for use by designers, metallurgists, manufacturers, and systems analysts.

A broader mechanical-property, welding, and characterization data base for steam generator alloys will be established. Improved alloys for advanced concepts will also be developed. The welding program will seek to develop improved alloys and techniques for joining austenitic stainless steels and alternative alloys such as high-chromium ferritic steels for high-temperature LMFBR service. There is interest in the potential use of ferritic steels throughout the entire reactor circuit for the PLBR and CBRs. In order to ensure American Society of Mechanical Engineers (ASME) Code acceptance in time for these concepts, a greatly increased effort will be required in this area starting in FY 1978.

Nondestructive evaluation techniques will be developed for use by industry based on radiography, ultrasonics, eddy currents, holography, and acoustic emission, with emphasis on remote automated computer-controlled inspection methods for in-service and postoperative situations. The need for an accelerated national nondestructive evaluation program was identified by an ORNL study and acknowledged by RDD. Increased funding has been projected starting in 1979 to accomplish this end.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 08	2.4	2.4	2.9	3.7	4.6	4.6	4.5	4.5

D.1.2 Technology—Advanced Fuels and Absorbers

The goal of this program segment is to develop and qualify advanced fuels, structural materials, and neutron absorbers that are capable of providing the option for introducing LMFBR core systems having enhanced breeding performance. Extensive irradiation experiments in EBR-II and FFTF will be needed to qualify these materials in time for use in advanced LMFBRs.

D.1.2.1 Cladding and Ducts. The goal of this effort is to develop and qualify improved fuel-pin cladding and subassembly duct materials that can withstand commercial LMFBR exposures to high-temperature flowing sodium and fast neutrons for times corresponding to fluences of at least 2.5×10^{23} n/cm^2 with total swelling less than 5% and creep strains less than 1%. (The large increase in costs shown below results primarily from an increase in irradiation testing costs.)

Alloys meeting these criteria will be developed through optimization of microstructure in iron-base austenitic systems and in both solid-solution and precipitation-hardenable nickel-base systems.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 09	0.5	0.6	0.7	0.9	1.6	1.6	1.5	1.5

D.1.2.2 Fuel Material and Absorbers. Uranium-plutonium carbide and nitride (or carbonitride) fuels provide the potential for high fuel-system performance in the long term because of their inherent thermal and nuclear advantages relative to oxide fuels. Shorter doubling times and higher breeding ratios should be attainable because the thermal conductivities of these fuels allow operation at higher specific powers and because the higher heavy-metal atom densities give higher fuel fractions in the core.

Economic synthesis and fabrication techniques amenable to fuel recycle situations will be developed. A parametric study of the synthesis of advanced fuels from oxide feed using a small converter will be completed in FY 1977, and a prototypic fuel converter will be operating in FY 1978. This will be followed by engineering scale-up studies and by demonstration of the scaled-up synthesis process. Transfer of the advanced fuel synthesis technology to industry should be completed in FY 1984.

Advanced absorber materials based on europium will be developed that can enhance breeding performance and be cost-effective in replacing boron carbide as a control material in LMFBRs because of their longer control life, lack of helium and tritium generation, and associated design advantages. Principal consideration will be given to europium oxide cermets and europium hexaboride.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 09	0.4	0.4	0.7	0.9	1.1	1.1	1.0	0.9

D.1.3 Technology—Physics

The goal of the physics program segment is to determine nuclear cross sections and develop analytic techniques for radiation transport and core physics analysis and to provide experimental data on integral shielding for testing the shielding methodology that is necessary to assure the safe and economic performance of commercial fast breeder reactors.

D.1.3.1 Nuclear Data. Direct mesurements at ORELA and evaluations of cross sections will be

made for fissile, fertile, coolant, structure, control, transuranic radioactive waste, and shielding materials to support CRBR analysis and performance studies as well as design of safe and economical commercial LMFBR plants. The work will be guided by the results of sensitivity analyses coupled with analyses of uncertainties in existing data generated largely within this program segment. (This work is coordinated with the neutron cross-section program of the ORNL basic energy sciences program; see Sections A.6.1 and A.8.)

	Operating cost (millions of dollars)							
Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 07	0.8	0.8	0.9	1.0	1.0	1.0	0.9	0.8

D.1.3.2 Core Analysis and Methods. Computer codes and analytical models sufficiently validated for calculations of the reactor physics parameters in LMFBR design and safety will be provided. Emphasis will continue on the development of three-dimensional static and depletion analysis codes, development of nuclear data sensitivity codes, and the application of sensitivity methods to the determination of nuclear data needs and the utilization of integral experiment data. The three-dimensional neutronics and depletion effort will provide methods to obtain information on power distribution, control rod effects, sodium voiding, fuel depletion, and fuel management. Reactor physics calculations will be performed in support of CRBRP and PLBR design, including a task to determine the effects of advanced heterogeneous core design on the materials research and development program. Sensitivity analyses will be performed to guide basic data and integral experiment efforts and to determine the uncertainties in current designs. Validated neutronics, depletion, and sensitivity codes and data will be distributed and promoted within the LMFBR community.

	Operating cost (millions of dollars)							
Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 07	0.5	0.6	0.8	0.8	0.8	0.8	0.8	0.8

D.1.3.3 Shielding. Nuclear data, calculational methods and analysis, integral experiments, and information services will be provided in the shielding program. Integral shielding experiments provide benchmark experiments for specific shielding materials, and prototypic experiments will be performed in support of FFTF, CRBRP, and PLBR designs. The analytical efforts will provide data processing methods development and library generation; radiation transport and shield-design code development and verification; design support analyses for FFTF, CRBRP, and PLBR; design and analysis of integral experiments; and development of shielding methodology suitable for transfer to industry. The Radiation Shielding Information Center (RSIC) provides shielding codes, data, and literature bibliography and abstracts.

	Operating cost (millions of dollars)							
Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 07 and KG 02	1.1	1.2	1.7	2.0	2.1	2.0	1.9	1.8

D.1.4 Technology—Reactor Analysis

The goal of the national effort on LMFBR reactor analysis is to identify, develop, and demonstrate on a planned and integrated basis the technology that will be required by reactor engineers for designing reliable and economical LMFBR core components. An important segment of this effort is on instrumentation and controls, for which ORNL has a central role.

D.1.4.1 Instrumentation and Controls. The specific goal here is to develop proven technology in the areas of core power and coolant system monitoring, plant surveillance and diagnostics, signal transmission, and plant power control for CRBRP, PLBR, and CBR applications. Manufacturers' designs for control and protection systems will be examined and evaluated, utilizing ORNL's analysis capabilities. Analysis of systems dynamics will be included where appropriate or required, and assistance will be provided to reactor system designers in developing control and protection systems that enhance plant safety and availability. Also to be developed are measurement methods and instrumentation for surveillance and diagnostics. Specific goals include the development of (1) advanced neutron detectors for LMFBRs; (2) accurate and reliable thermometers for temperature measurements for reactor fuels, coolants, core components, power plants, and fuel-recycle processes; (3) advanced techniques and components that will later be evaluated for use in design of high-performance control and protection systems of high reliability; (4) accurate and reliable process sensors (flow, level, pressure, etc.) having special capabilities for use in reactor control systems; and (5) continuing and increasing support of the CRBRP and PLBR reliability programs.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 11 and KG 02	0.9	1.0	1.3	1.6	1.7	1.7	1.5	1.4

D.1.5 Engineering—Materials

The goals of the materials program are to develop fabrication methods and manufacturing processes suitable for the production of reactor plant components in sizes required for large LMFBR plants such as CRBRP and PLBR. The metallurgical effects of these fabrication methods and manufacturing processes on the high-temperature time-dependent properties of the materials of construction of LMFBR components must be evaluated to assure the attainment of an adequate component service life.

Primary emphasis is on development of fabrication methods for large-diameter thin-walled stainless steel welded and seamless pipe and fittings and of welding procedure specifications for transition joints between stainless steel and ferritic steel for the CRBRP.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 06	0.3	0.5	0.7	0.7	0.7	0.7	1.0	1.0

D.1.6 Engineering—Structures

D.1.6.1 High-Temperature Structural Design Methods. The objective of this program is to develop the design technology that is needed to demonstrate structural adequacy and to assure safe and reliable operation of LMFBR components on a practicable and verified basis. Emphasis will be placed on development and validation of both rigorous and simplified design analysis methods and criteria applicable to complex (multiaxial) loadings at elevated temperatures. The technology developed will be applicable to components operating at temperatures in the creep range of the structural materials. The effort will include analytical descriptions of elastic-plastic and time-dependent (creep) behavior of materials and tests to form the basis of structural design analysis. The national effort on high-temperature design will continue to be coordinated by ORNL.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 06	1.7	1.7	2.2	2.2	2.2	2.2	2.1	1.9

D.1.7 Engineering—Codes and Standards

The primary goal of this segment is to develop and document codes and standards for LMFBR technology that reflect sound engineering and quality assurance practices. Such codes are needed to support the development of LMFBRs, their successful introduction to the commercial environment, and the safe and economic growth of the program. The Laboratory's strong technology base and Union Carbide Corporation Nuclear Division's engineering organization are combined to develop codes and standards that govern the design and construction of safe reliable facilities. The Reactor Development and Technology (RDT) Standards Program will be managed by utilizing pertinent development work in support of codes and standards, providing physical standards where needed, providing expert assistance to government standards activities, participating in the management of the activities of national voluntary standards organizations and in standards writing, and encouraging and implementing the use of appropriate applicable codes and standards in ORNL programs.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 06	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0

D.2 Gas-Cooled Reactor Programs

The Laboratory conducts a major effort in support of the development of gas-cooled reactors, including the high-temperature gas-cooled reactor (HTGR), advanced versions of HTGRs, and the gas-cooled fast breeder reactor (GCFR).

The HTGR shows promise of extending uranium resources. Further, higher temperature operation is feasible, which permits increased thermal cycle efficiency through use of topping and bottoming cycles (gas turbine plus ammonia turbine) and also permits the use of HTGRs as a source of high-temperature energy for process heat application. The ORNL HTGR programs include heavy involvement in HTGR fuel recycle technology (Section D.3.3), HTGR basic technology (Section D.2.1), and HTGR safety studies (Section D.4.3).

The GCFR shows potential as an economic high-performance breeder; commercialization near the end of the century appears possible.

The withdrawal of the General Atomic Company from the commercial HTGR market has had severe ramifications on the whole gas-cooled reactor program. A number of evaluations by industry and ERDA are under way to determine whether and under what conditions HTGRs can be

commercialized. As a result, the long-term support and emphasis to be given to the various GCRs have not yet been determined. GCFRs could not be developed as early as HTGRs. At the same time, HTGRs and GCFRs have similar component technologies so that development of one helps the other. It will probably take another year before the detailed directions and emphasis concerning GCR development programs will be determined. Thus, any projection on future work is fraught with more than the usual uncertainties regarding program direction. The program outlined below is based on the questionable assumptions that the steam-cycle HTGR will be emphasized after an evaluation period and supported appropriately in future years, that the GCFR program will be given second priority after the steam-cycle HTGR, and that advanced thermal gas-cooled reactors (gas-turbine, combined-cycle, and very-high-temperature systems) will be given increasing support as the success of the steam-cycle HTGR becomes assured.

D.2.1 HTGR Basic Technology

The ORNL program emphasizes areas of technology development that are generic to all HTGR systems. A major problem relative to steam-cycle HTGRs is commercialization. Important technology development areas related to commercialization are those associated with qualification of fuels, materials, and components and with improving the fuel utilization characteristics of the reactor system. A major potential problem with respect to implementation of important phases of the ORNL program relates to the availability of the Oak Ridge Research Reactor (ORR). The ORR has funding problems, which, if not resolved, may result in its becoming unavailable for critical irradiation experiments.

With advanced HTGRs such as the gas-turbine HTGR and the very-high-temperture reactor (VHTR), the major efforts will be on development of fuels and materials for high-temperature operation and on improved fuel conversion ratios. The present HTGR base program should gradually shift from the steam-cycle HTGR to advanced HTGRs in future years; most of the work after 1980 is expected to be on the advanced systems.

D.2.1.1 Fueled-Graphite Development. The development, testing, and qualification of safe, reliable, and economic fuels for the steam-cycle HTGR will proceed over the next five years. Over the next ten years, safe, reliable, and economic fuels for the gas-turbine HTGR and the VHTR will be developed and tested. HTGR fuel rods containing weak-acid-derived fissile particles and thoria fertile particles will be qualified, and fuel designs permitting higher conversion ratios in the reactor will be developed. Mechanisms of fuel failure and of fission product release from fuel structures will be studied and solutions sought to limiting problems. In future years, development of advanced fuels with improved loading capability for heavy metals will be emphasized.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 02	2.4	1.5	1.7	1.7	1.7	1.7	1.6	1.5

D.2.1.2 Metallic and Ceramic Materials Development and Graphite Characterization. Materials behavior relations for the steam-cycle HTGR will be determined and completed. Materials (including turbine-blade materials and reformer materials) will be tested and developed for use at the higher temperatures in the gas-turbine HTGR and the VHTR.

With regard to graphite development, creep coefficients and related mechanical properties of candidate HTGR core graphites will be determined as they relate to core design, behavior, and safety. Related dimensional and mechanical-property behavior will also be investigated. Graphites for VHTR use are to be included.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 02	0.8	0.9	1.0	1.1	1.1	1.1	1.1	1.1

D.2.1.3 HTGR Chemistry Studies. Fission product transport and interaction, fuel failure mechanisms, fuel stability, core tolerance to steam, and materials interactions with coolant will be described and means devised for controlling or mitigating undesirable effects. Fission product transport and interaction data for operating reactors will be obtained from postirradiation examination of fuel elements and structural materials.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 02	0.7	0.5	0.6	0.8	0.9	1.1	1.2	1.2

D.2.1.4 Prestressed-Concrete Reactor Vessels. The study of confinement components in gas-cooled reactors involves prestressed-concrete reactor vessels (PCRVs) and associated items such as liners, thermal insulation, cover plates, and closure. All of these are included in the term PCRV. Components will be built, tested, and modeled to

determine failure modes and to devise means of mitigating undesirable effects. Analytic studies and instrument development are also included in this task area.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 02	0.6	0.7	0.7	1.0	1.7	1.7	1.7	1.7

D.2.2 GCFR Technology

The GCFR is a promising alternative and backup to the LMFBR. Because of the importance of developing a safe and economic breeder as a long-term solution to our energy problems, the GCFR deserves increased support. The principal technical areas that need resolution for this reactor concept are associated with GCFR behavior following loss of core cooling. Thus, our near-term effort in the GCFR program is concerned with the design, construction, and operation of the Core Flow Test Loop (CFTL), which is to be built at ORNL. The GCFR program also includes materials studies, reactor physics (with principal emphasis on solving the difficult shielding problems of this reactor concept), instrumentation and control systems, and reactor safety. The cost projections for the major tasks are summarized below.

D.2.2.1 Heat Transfer and Fluid-Flow Relations in a GCFR Core. The objectives of this program are to determine the practicality of the present core design under steady-state and expected transient conditions and under certain abnormal conditions. Associated with the above, ORNL will construct and operate the CFTL (estimated cost of $10.5 million) for studying the behavior of fuel bundles under transient conditions and will analyze test results and evaluate control requirements. The test loop is to operate initially in FY 1981, and the experimental program should be completed in FY 1984. The increased effort in FY 1977 will be in development and testing of components in support of the CFTL design.

Mathematical models and computer simulations of GCFR primary loop components will be developed to ensure that accurate predictive capabilities are available for the proper development and design of GCFRs.

Operating cost (millions of dollars)[a]

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 01	0.8	2.0	3.5	5.5	7.2	3.5	3.0	2.5

[a]Includes $10.5 million for design and construction of CFTL.

D.2.2.2 GCFR Fuels and Materials and PCRV Studies. Materials properties under GCFR conditions will be determined, materials technology requirements will be developed, and design data for GCFR core and primary system structural materials will be provided. This work includes the study of properties of materials used in components, the influence of fission products on their behavior, and the effects of irradiation on properties of ribbed cladding (ribbed to provide enhanced heat transfer characteristics).

The Laboratory will complete studies of fuel and fission product behavior in vented and pressure-equalized prototype fuel element systems and will study tritium behavior in detail.

The objectives of the PCRV closure program are to (1) conduct a review of GCFR containment, penetration, and closure designs and evaluate their adequacy; (2) perform associated analytical studies; and (3) develop and conduct a model-testing program to provide further understandng of PCRV failure modes.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 01	0.2	0.2	0.4	0.5	0.8	1.0	1.2	1.2

D.2.2.3 GCFR Physics and Reactor Control. The analytical shielding program will be expanded, and an experimental program will be initiated to determine the adequacy of shield design methods. Physics analyses for GCFR cores will also be undertaken to study the performance of various designs and to obtain reactivity coefficients.

Studies will be initiated in FY 1979 to determine the proper control and protection systems needed for GCFRs. Diagnostic methods will be applied to monitoring component behavior relative to indications of incipient failure.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 01	0.1	0.2	0.3	0.6	1.0	1.2	1.4	1.4

D.3 Nuclear Fuel Recycle

The Laboratory has extensive experience in the development of fuel recycle technology and is involved in major studies in the ERDA fuel recycle development programs in support of the various reactor types. ERDA's recognition of the increasing importance of "closing the fuel cycle" is resulting in rapid growth of these programs.

D.3.1 LWR Fuel Reprocessing and Recycle

A major development program was initiated during FY 1976 to improve LWR fuel reprocessing and recycle technology. This program, for which the Savannah River Laboratory (SRL) is the lead contractor, is part of ERDA's national program to ensure establishment of a viable LWR fuel reprocessing industry. Much of the ORNL reprocessing effort in the LWR program is closely associated with the ongoing LMFBR fuel reprocessing program, and both programs are under common management. Work is also being done at the Oak Ridge Gaseous Diffusion Plant in conjunction with this program. The LWR program is directed at the anticipated problems associated with processing fuels that have much higher burnup than have been processed previously. A major effort will be hot-cell studies of the various processing steps, such as voloxidation, dissolution, and feed preparation, using fully irradiated LWR fuels. Emphasis is being given to development of off-gas treatment processes to provide effective retention of krypton, tritium, iodine, and carbon-14 in the processing plant. The program provides for construction and testing in FY 1977 of a 0.5-ton/day voloxidizer model for tritium retention. Methods will be developed for converting the gaseous wastes to forms suitable for storage.

Improvement of the solvent extraction (Purex) process will also be stressed, particular attention being given to known problem areas such as the effects of insoluble fission products, solids formation during processing, and solvent degradation. Major goals are to minimize losses of fissile material, decrease the amounts of waste, and improve solvent recycle. In FY 1977, a small solvent extraction system will be installed in a hot cell to permit tests with fully irradiated fuel (30,000 MWd/ton).

Processes for converting uranyl nitrate to uranium hexafluoride and then to uranium dioxide will be examined, with emphasis on development of equipment and techniques for handling these operations remotely. Studies of the economics and environmental problems of LWR fuel reprocessing will also be given attention.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KK (through Savannah River Laboratory)	1.5	3.1	3.6	4.0	4.0	4.0	4.0	4.0

D.3.2 LMFBR Fuel Reprocessing

The objective of this high-priority program is to develop and demonstrate the technology for reprocessing LMFBR fuels for application in full-scale commercial plants (expected to be operational in the late 1990s). Safety, reliability, and economics will be emphasized. The program is an essential element of the overall ERDA program to develop the technology for LMFBR systems. As such, the program goals must be achieved as planned in order to mesh the schedule of this program element with the schedules of the other elements.

Specific and detailed objectives are to develop and demonstrate (1) overall mechanical and chemical flowsheets for processing LMFBR fuels that provide high plutonium and uranium recoveries and effective decontamination from fission products; (2) confinement techniques that will meet future regulatory requirements and that will be applicable for reprocessing short-cooled fuel; (3) flowsheets that emphasize maximum liquid and chemical recycle and minimize waste volumes; (4) ventilation and containment systems that drastically reduce off-gas rates, thus minimizing the potential for release of radionuclides in accident situations; (5) remote operating and maintenance techniques as needed to adequately demonstrate the facility concepts and containment systems; and (6) reliable process equipment that can be remotely operated and maintained. As was stated in the preceding section, this program is closely coupled with the LWR fuel reprocessing program, because much of the technology is common to both systems.

The LMFBR program provides for an Integrated Prototype Equipment Test Facility (IPET), which will begin operation about 1981, and for a hot pilot plant (HPP), to be operable beginning in 1986–1988. The IPET will provide a system for integrated testing of previously developed processes and equipment components. It will also provide a major test facility for development of remote operating and maintenance procedures and will be needed to identify and correct any deficiencies in equipment and process coupling steps prior to final design of the equipment for the HPP.

To meet all these program schedules, major expansion of the program is required in FY 1977. A large effort in process component development and laboratory and hot-cell studies will provide data needed for design and support of the IPET and HPP facilities. In these studies, particular attention will be given to certain difficult head-end processing steps, including deshrouding, shearing of the fuel rods, voloxidation, and dissolution. Efficient off-gas treatment systems for removing tritium, krypton, iodine, and particulates will be defined, and the

A technician loads ceramic pellets into steel tubes to be made into LMFBR prototypes needed to test mechanical reprocessing equipment.

effects of liquid and gas recycle on these systems will be determined.

Conceptual design of the hot pilot plant will be done in FY 1977 and FY 1978, and operation of this facility will conclude the research and development phase of the program by processing spent fuel from the CRBRP and the FFTF.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KK 02	4.2	8.8	20.0	25.0	25.0	25.0	25.0	25.0

Because of the high priority of this program and the need for early information, consideration is being given to accelerating the program outlined above in order to permit hot operation of the HPP prior to FY 1988. Costs for the accelerated program would be appreciaiy higher than those shown.

D.3.3 HTGR Fuel Recycle (Thorium Utilization Program)

The Laboratory has been delegated the overall technical responsibility for the HTGR fuel recycle program, through designation of UCCND as the principal contractor. Under this program, the Laboratory is responsible for overall technical direction of the U.S. program and the conceptual design of a planned HTGR fuel recycle demonstration facility (HRDF). ORNL will also be directly involved in fuel refabrication development and in hot engineering testing of key processes and equipment for both fuel reprocessing and refabrication.

The objective of the program is to develop and demonstrate the technology for recycle of HTGR fuels using the thorium-uranium-233 fuel cycle. This is a cooperative program of ORNL, General Atomic Company (GAC), and Allied Chemical Corporation (ACC). Work at ORNL covers (1) technical management of the National Recycle Program; (2) reprocessing development, particularly with regard to performing laboratory-scale hot-cell studies, engineering-scale off-gas cleanup development, and development of carbon-14 retention methods; (3) hot engineering tests of reprocessing—to design, construct, and operate a hot engineering test facility to obtain information on equipment and processes that are likely to be affected by uranium-232 daughter products and fission products, including the process steps of fuel burning, off-gas treatment, fuel dissolution, and limited solvent extraction capability; (4) refabrication process development—perform R&D associated with recycle fuel requirements, preparation of uranium-loaded resin-based fuels, fuel carbonization and particle handling, fuel assay development, instrumentation and material handling, and preparation of fuels for irradiation testing; (5) hot engineering tests of refabrication—design, install, and operate processes and equipment with uranium-232 daughter products, including preparation of fuel kernels, coating of fuel, and minimal fuel rod fabrication and inspection procedures; (6) recycle fuel irradiations—irradiate recycle fuels made in prototype refabrication equipment and perform postirradiation examinations and evaluations of the fuels; (7) program analysis—conduct analytical functions necessary to assure efficient and timely execution of the program, including planning, scheduling, budgeting, and reporting, and assess fuel cycle options, processes, environmental impact, safeguards requirements, transportation, and waste management requirements; (8) conceptual design of an HTGR fuel recycle demonstration facility.

The hot engineering tests indicated above will be carried out mainly in the Thorium Uranium Recycle Facility (TURF); limited operations will be performed in Building 3019.

The above is consistent with operation of the demonstration facility in the middle 1990s.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KK 02	7.2	6.4	6.4	7.0	11.0	18.0	20.0	20.0

D.3.4 Uranium-233 Storage, Purification, Distribution, and Scrap Recovery

This program will provide uranium-233 for various research programs and recover uranium-233 from scrap generated by these programs. ORNL serves as the national repository for this material. The uranium-233 facilities are equipped with storage facilities (for solids and liquids), dissolution and purification equipment (solvent extraction and ion exchange), and conversion facilities (uranyl nitrate to ceramic-grade uranium dioxide powder).

The increased level of expenditures for FY 1977 and 1978 provides for conversion of Consolidated Edison fuel (now stored as a nitrate solution) to an inert solid by the end of FY 1978.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KK 07	0.5	1.0	2.2	0.6	0.6	0.6	0.6	0.6

D.3.5 Fuel Cycle Safeguards Development and Demonstration

If the monetary and strategic value of special nuclear materials (SNM) were not a sufficient incentive to develop highly reliable methods of accounting for and protecting them, then recent terrorist attacks on government and industry on a worldwide basis would be. It is absolutely essential that adequate, rapid, and highly reliable accountability methods, as well as sophisticated and reliable physical protection methods, be developed and proven for SNM.

Because of the developmental nature and flexibility of both reprocessing and fuel conversion equipment available at ORNL, the Laboratory expects to provide an exceptionally versatile facility in which to prove safeguards concepts and methods under the types of conditions found in a number of plants in the nuclear fuel cycle. The work will initially involve applying existing fast-chemical-analysis technology (which the Laboratory has already developed) to process solutions found in a fuel reprocessing plant, thereby developing a fast, reliable method of making a material balance around the plant. In addition, in-line transducers will be installed in an operating chemical processing plant to aid in maintaining a continuous plant inventory. The information will be fed directly to a dedicated computer for evaluation and analysis. The instrumentation, equipment, and techniques will therefore be integrated and proven in the severe environment found in a remotely operated fuel processing facility. Only then will such integrated systems become acceptable to NRC and private industry.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KK	0.0	0.1	0.3	0.8	1.0	1.0	1.0	1.0

D.4 Reactor Safety

D.4.1 LMFBR Safety Analysis

This program was started in FY 1976 to provide an assessment of a disrupted LMFBR core using two- and three-dimensional analysis techniques. A major objective is development of a transient code that has the feedback necessary for accident analysis and that can interface with existing thermal-hydraulic codes. A central computerized data base for LMFBR safety codes is also being developed and maintained.

New tasks include evaluation of models for radioactivity releases, establishment of a proposed safety analysis center for major national LMFBR safety experiments, establishment and maintenance of a reliability data center, studies on inherently safe cores, and evaluation of fast-fission decay heat.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 05	0.4	1.2	1.8	2.1	2.0	1.8	1.7	1.7

D.4.2 LMFBR Safety Experiments

In this segment, the ORNL role is to define core thermal hydraulics under normal and accident conditions. Determination of the thermal-hydraulic behavior of LMFBR core segments will be made in the Thermal Hydraulics Out-of-Reactor Safety (THORS) facility, formerly known as the Fuel Failure Mockup (FFM), for a wide range of off-normal conditions, as well as for normal operating conditions. Of particular importance will be the establishment of fuel failure limits for a range of conditions of flow, power, and temperature. Specific off-normal conditions being studied for fast-reactor safety assessment are flow blockages, transients due to loss of pump power, and transients due to loss of pipe integrity. Intentional boiling under transient and steady-state conditions will be effected to determine void growth patterns and the limits of boiling stability during off-normal conditions. Low-flow and free-convection tests (with and without boiling) will be conducted to determine core coolability after reaction shutdown. Experiments will be done with 61-rod and 217-rod assemblies to determine the effect of size on predictions drawn from previously tested 19-rod assemblies. This will require expansion of the present facility between 1977 and 1980. Experiments with parallel assemblies will be performed to establish interassembly heat transfer and parallel channel stability under wide off-design conditions, including boiling. Similar thermal-hydraulic investigations of advanced fuel will be performed. In addition, anomaly detection techniques such as monitoring of acoustic or temperature noise will be developed. Development of electrical fuel-pin simulators for use in the THORS facility will continue.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KG 05	1.5	1.8	2.2	2.5	2.6	2.6	2.5	2.4

D.4.3 GCFR Safety

The objectives of these studies are to determine GCFR safety characteristics relative to depressurization accidents, possible fuel melting, and associated reactivity accidents. The conditions that might lead to loss of circulation, associated core heat-up fuel melting, and associated reactivity changes and consequences will be evaluated. An understanding of heat transfer and fluid-flow characteristics of GCFRs under transient conditions will be obtained in order to carry out the above. Both analytical and experimental studies will be included; the latter will involve use of the CFTL at ORNL and of an in-pile loop (not at ORNL) to examine the transient response of a fuel bundle under various flow and power conditions. Fission product behavior under accident conditions will also be studied and evaluated.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 01	0.0	0.0	0.1	0.3	0.7	1.3	2.0	2.5

D.5 Waste Management

Waste management has had a mixed history in the ERDA laboratories. Different laboratories have occupied positions of prominence when the various stages of waste management development work favored one or another process. Until recently, ORNL had prime responsibility for the geologic disposal program. This program, which now has been given ERDA's highest priority, is being rapidly expanded and has been placed under UCCND management as the Office of Waste Isolation (OWI).

The partitioning of wastes, while potentially a major step in solving the waste isolation problem, promises to be expensive and very difficult technically. Oak Ridge National Laboratory has unique separation experience applicable to waste partitioning, arising from its extensive work in the transuranium element program and in the development of fission product recovery processes. Waste partitioning, if implemented, is a long-term program involving major manpower commitments and facilities. In any event, ORNL is committed to a long-range program on terminal waste storage.

A program of local concern is the effort to upgrade ORNL's waste management complex. A key factor is the use of hydrofracture of shale for storage of low- and intermediate-level waste, but a determination to allow use of hydrofracture has not yet been made by ERDA and is in doubt. Tank storage, while purely of a provisional nature, is the only practical stopgap alternative to hydrofracture.

D.5.1 Commercial Waste Management Research and Development

This program will assist ERDA in developing the technologies that are needed to meet federal responsibilities for managing the wide variety of radioactive wastes from the nuclear fuel cycles of both present and future commercial power reactors. Experimental work, as well as analysis and evaluation studies, will be provided to develop and demonstrate technically sound and publicly acceptable methods for the treatment, packaging, shipment, and terminal storage of these materials. An important near-term goal is a cost-risk-benefit analysis of separating actinide elements from wastes and burning them to fission products in power reactors. This task is to be completed by the end of FY 1979. Other goals scheduled for the next few years include developing a method for removing iodine from evaporator condensates for use in a commercial reprocessing plant by 1980, developing a suitable method for incorporating iodine concentrates in cement grouts by 1980, specifying criteria for packaging gaseous wastes that can be recommended to NRC by 1979, and developing biological techniques for treating low-level aqueous wastes to remove metal contaminants and nitrate.

The program, in which other ERDA laboratories will participate, will be funded through ERDA-ORO. The costs shown below are ORNL costs.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KK 03	0.5	2.1	3.6	3.7	3.6	3.6	3.4	3.2

D.5.2 Management of ORNL Wastes

This program encompasses both routine operational and R&D activities concerning the management of radioactive wastes generated at ORNL.

The main objectives in the management of solid radioactive waste are to reduce the volume of wastes going into storage and to ensure that wastes that have been buried in the past, as well as currently generated wastes, will not at some future date become a hazard to the public. Volume reduction will be achieved by installing compaction and incineration equipment and equipment decontamination facilities. A compactor for low-radiation-level wastes is expected to be in operation early in FY 1977, and a central waste processing and decontamination facility that will handle all types of solid

contaminated wastes is currently being planned for operation in FY 1982. Studies of the behavior of buried wastes in both the old and current burial grounds have been in progress for the past three years and are excepted to continue at an increased pace for at least the next four years. These studies include such things as the effects of gradual waste decomposition, soil type, and hydrology on the migration of radionuclides, changes in underground water flows as a result of burial operations, development of methods to minimize the infiltration of surface rainwater into buried wastes, and methods of controlling or preventing radionuclide migration. These studies will continue to lead to recommendations for improvements to burial grounds. An extensive groundwater monitoring system in the current and old burial grounds is presently under construction and will be complete in FY 1978; surface sealing, grading, and installation of drainage culverts in selected areas of the burial grounds to control surface water runoff will be a continuing activity. Depending on the results of burial ground studies, there could be a recommendation that the wastes in selected areas of old burial grounds be exhumed and reburied under more closely controlled conditions. There is not expected to be enough information available to decide whether this is necessary before FY 1982.

Modifications to the liquid radioactive waste systems at ORNL are currently in progress and will continue through FY 1980. The objective of these modifications is to provide additional assurance that an accident or equipment failure will not result in the release of activity to an uncontrolled environment and to provide more flexibility for future operations. A new low-level waste treatment plant went into operation in FY 1976. Work has started on additions to the intermediate-level waste system; these include new waste collection and storage tanks, a waste evaporator, and doubly contained waste transfer lines and are expected to be completed late in FY 1978. A new hydrofracture disposal facility is planned for operation in FY 1980. Development of a method to remove sludges that have accumulated in liquid waste storage tanks over the past 30 years is continuing on a schedule that will permit removal operations to start in FY 1980. A new program begins in FY 1977 on development of an electrolytic method for concentrating tritium from low-level aqueous effluents.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KZ 03	1.3	2.6	3.9	4.1	4.1	4.2	4.7	4.7

D.6 Studies, Evaluations, and Advanced Concepts

ORNL has traditionally provided studies of all aspects of nuclear and other power systems. The presence of a large body of people at the Laboratory who are skilled in this work, the technical staff available for consultation and input, and the major computer complex and its support staff make ORNL a resource of great capability and value in this area. As the complexities of the energy program continue to manifest themselves, the importance of this work will increase. ERDA will gradually assign increased program management responsibilities to ORNL in this area, and the percentage of the work done outside the Laboratory under subcontracts will probably increase from the present level of about 30% to about 50%.

General Studies and Evaluations. The goal of this program is to provide broad assessments of the technology and economics of nuclear power systems and alternatives in relation to national goals. Recommendations must be made to ERDA and ORNL management concerning rational RD&D goals and strategy. Personnel engaged in this program will also seek to provide a data base for ERDA studies and participate in ad hoc ERDA and ORNL task groups, as required.

Analysis of Power-Reactor Fuel-Cycle Alternatives. Cost-benefit studies and evaluations will be made of various reactor designs and fuel-cycle options in LWR, heavy water reactor (HWR), HTGR, GCFR, and advanced LMFBR systems. The thorium fuel cycle assessment will be carried out to determine effective options for use of thorium in the nuclear industry. Power cost, impact on resources, and interaction with introduction of the LMFBR will be determined. This assessment will be followed by evaluations of fuel management systems to be used in the LMFBR-LWR economy. In implementing these studies, close interaction is maintained with the UCCND Strategic Planning and Analysis Group, which is studying all aspects of the nuclear fuel cycle to develop recommendations for UCCND and ERDA policy decisions.

Siting and Environmental Factors. In studying siting, the Laboratory must provide broad assessments of alternative siting and utility strategy, such as use of power parks, and determine limitations on power-park size imposed by thermal and radiological discharges. Working with regional groups and utilities, a potential power-park site will be selected and evaluated, and documentation will be developed for licensing such a site. ORNL will manage a national program to develop methods of predicting the atmospheric effects of large heat

releases. Attention is also focused on the potential desirability of siting LMFBRs in energy centers.

Use of Thermal Energy from Power Reactors. Future uses of thermal energy from power reactors in industry, in residential and commercial space conditioning, and in desalting will be evaluated and developed. Utilization of waste heat will also be studied. ORNL will work cooperatively with potential users in industry and government to develop plans, feasibility studies, and demonstration projects and to properly integrate uses of nuclear and fossil fuels. During the planning period, emphasis will shift from studies to support of demonstrations. Thermal energy supply is potentially a very important market for nuclear fuels.

Assessment of Advanced Applications of HTGRs. The technology and cost of very-high-temperature gas-cooled reactors will be evaluated, and determinations will be made of RD&D requirements as applied to gas turbine and process heat applications. Process use in coal gasification, hydrogen production, steelmaking, etc., will be analyzed and compared with alternative sources of energy, in cooperation with industrial and governmental users and process developers. Energy storage concepts will be investigated. RD&D program proposals to implement these technologies will be developed for work to be performed at ORNL or elsewhere.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 09	1.8	2.5	3.4	3.6	3.7	3.7	3.7	3.7

D.7 Technology and Space Applications

In support of radioisotopic power, efforts are being directed to both the fuels and materials of containment to provide safe, reliable, and cost-effective applications to space and terrestrial uses.

Efforts were initiated in FY 1976 to support the Low-Cost High-Performance Generator program in the area of containment and thermal protection materials. Starting in FY 1977, an additional effort will include studies of potential compounds of cesium as fuel forms for terrestrial applications.

Ongoing programs include development and qualification of fuel cladding materials based on precious metals such as iridium and platinum, with increasing effort on lighter weight rhodium alloys. Work on materials of construction for isotope Brayton systems, initiated in FY 1976, is expected to expand in FY 1977 and 1978. Similarly, work on curium-244 fuel development is expected to expand in these years. Production of iridium for flight system hardware is expected to be transferred to industry by FY 1981. However, we expect to fabricate at least initial quantities of hardware for future missions that require advanced materials.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
KJ 06	1.2	1.6	1.8	2.0	2.0	2.1	2.1	2.1
KJ 07	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0
Total	1.3	1.8	1.9	2.1	2.1	2.1	2.1	2.1

BASIC ENERGY SCIENCES SUPPORT OF NUCLEAR ENERGY DEVELOPMENT TECHNOLOGY

In this section, we summarize the basic energy sciences research at ORNL that contributes directly to nuclear energy technology and that is funded by the Division of Physical Research. All the money summarized here has already been included in Section A, "Basic Energy Sciences."

NEUTRON REACTION STUDIES

Most of the neutron physics program in basic energy sciences can be said to support fission energy technology development. Various neutron cross sections are essential to reactor core design, safety evaluations, structural materials development, questions of hydrogen and helium production, shielding design, and waste management.

The continuing objective of the neutron physics program is to develop and maintain evaluated files of cross sections and other nuclear data that are needed for reactor systems design, optimization, and evaluation. ORNL will continue to try to anticipate which cross sections are most needed so that the reactor program will not be delayed and to provide this information in the most convenient form. Recently, significant progress has been made in the application of sensitivity analysis to the determination of what cross sections are most important and what accuracy is required for a particular design problem. These analyses will be used to determine the cross sections that will be measured in the future. The program is a continuation of an established program, and we do not anticipate a significant change in the level of funding over the next five to seven years.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1

MATERIALS RESEARCH

Materials research support of the fission energy systems at present focuses on establishing the base for work on advanced materials as practical alternatives to reference reactor materials. Particular areas are modeling of the behavior of existing alloys and the use of nickel-ion bombardment for the simulation of neutron irradiations of potential fuel-cladding alloys.

In the near and middle term, alpha particles will be used to simulate neutron-induced creep in austenitic stainless steel and similar alloys. There will be close collaboration between theorists and experimentalists in studies of radiation damage production rates and damage structure to develop models that will allow laboratory results to be extrapolated.

A major long-term goal is to develop a better understanding of the correlation between heavy-ion-induced radiation damage and neutron-induced damage.

The materials research program will continue to provide the well-characterized high-quality metals and alloys needed in this program and in complementary efforts on measuring and understanding the structure, diffusion, surface properties, transport processes, and physical properties of potential reactor materials.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
1.5	1.7	2.1	2.2	2.3	2.4	2.5	2.6

E. Nuclear Regulatory Commission Programs

Thick-walled carbon steel vessels representative of the design, material, fabrication, and inspection requirements for current light-water reactor vessels are tested for failure as part of the Heavy Section Steel Technology Program. After a planned flaw is machined at external or internal locations on the vessel, it is subjected to intense internal liquid pressure until it bursts. This one failed at approximately three times the design pressure.

E. NUCLEAR REGULATORY COMMISSION PROGRAMS

The NRC sponsors all of the LWR safety research programs at ORNL and smaller programs in LMFBR and HTGR safety. (Reactor safety research programs sponsored by ERDA are described in Sect. D.4.) Emphasis is on obtaining experimental data that can be used to help assess the safety of nuclear power plants. These data provide a basis for verifying the complex computer codes used in safety evaluations, as well as a more fundamental understanding of the physical phenomena expected to be encountered in a hypothetical accident.

Oak Ridge National Laboratory has expertise and experimental facilities that are uniquely suited to conducting studies in thermal hydraulics, the chemistry and physics of fission products, and the strength of materials used in high-pressure systems.

ORNL is continuing to provide assistance to NRC in the area of preparing environmental impact statements for energy facilities and the supporting social and environmental assessments. The emphasis in these support activities will be on research to facilitate the licensing process.

E.1 LWR Safety

E.1.1 Primary System Integrity

The purpose of this program is to define failure limits of structural components associated with the primary coolant system of LWRs under both steady-state and transient operating conditions. Emphasis will be placed on developing and verifying analytical methods that can be used to evaluate the margin of safety inherent in the heavy-section steel pressure vessels used in PWRs. Present studies of the effects of thermal shock will be expanded and extended to include study of the effects on pressure vessel integrity of irradiation, fatigue cycling, and flaw propagation. By the end of FY 1978, work on validating the analytical methods needed to assess effects of thermal shock should be completed, and experimental evaluations of irradiated weld specimens from commercial reactors will be available. In the period after FY 1978, emphasis will be on developing advanced analytical techniques for studying complex geometries (such as nozzle corner cracks) and on expanding the data base for determining the arrest properties of reactor pressure-vessel steel. Emphasis in the program is expected to be shifted to evaluating the new higher-strength steels that are likely to be used in reactor vessels around 1985 to 1990. Design rules, stress indices, flexibility factors, and other analytical tools that can be used to assess the safety of piping systems will be developed.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83*
WFO								
NRC	2.5	2.2	2.2	2.5	2.5	3.0	3.0	3.0

E.1.2 Thermal Hydraulics

The critical thermal-hydraulic parameters associated with a hypothetical loss-of-coolant accident (LOCA) in a PWR will be evaluated.

Experimental data are being obtained in a large pressurized-water loop where 49 electric heaters are used to mock up a core subassembly. The presence of flow reversal and re-reversal, the time delay to critical heat flux, the rate at which dryout will progress radially and axially within a core, and similar time-related functions that are important to accident analysis will be examined. Emphasis will be placed on interpreting and correlating test results to provide a firm basis for evaluating the degree of conservatism in current PWR safety analyses. The program effort over the next few years will increase, owing to the importance of early verification of the safety analysis methods.

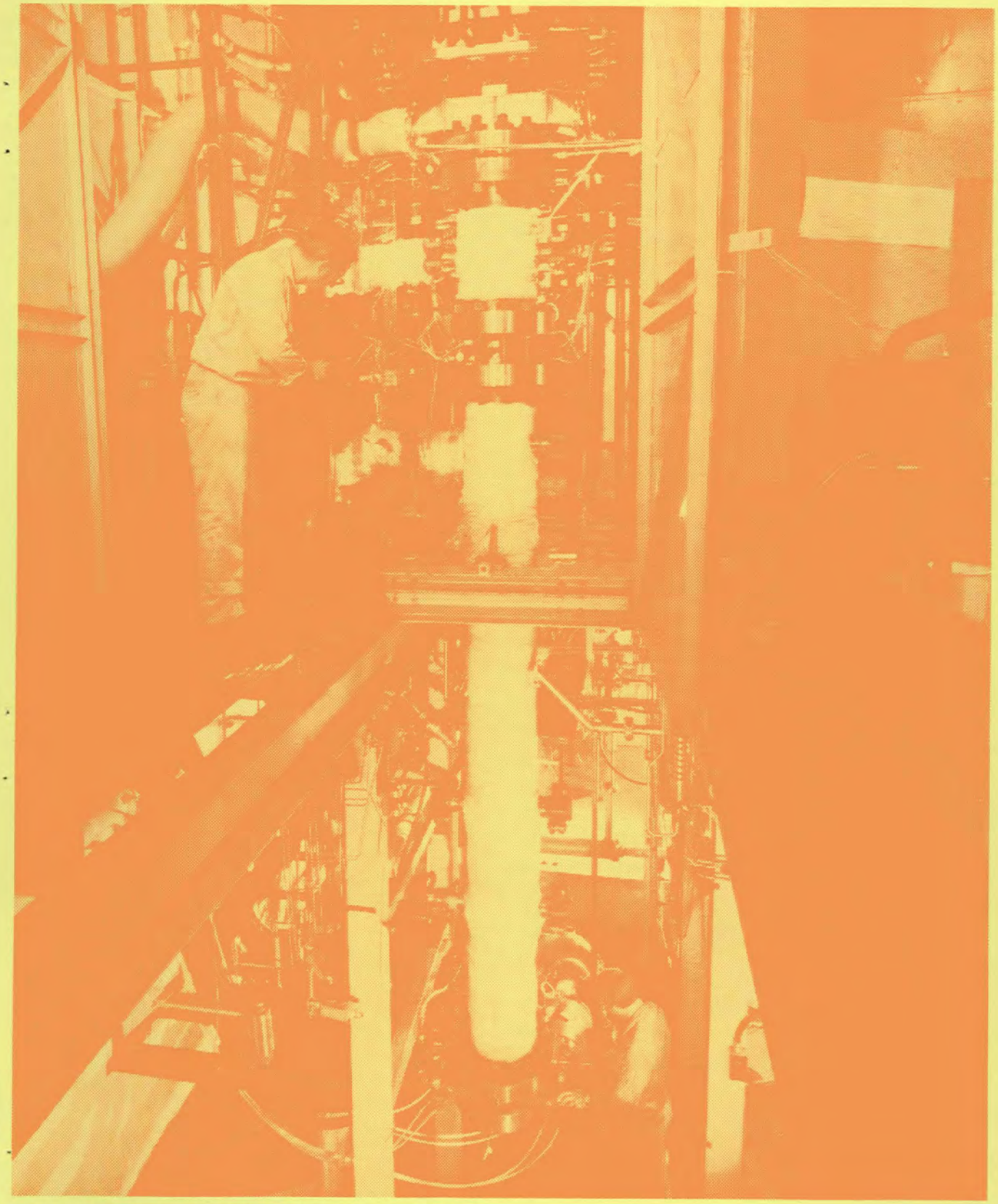
In addition, a support program now under way has as its goal the development of advanced instrumentation for measuring two-phase flow parameters. Such measurements are needed by many experimenters in the field who are evaluating the physical phenomena expected to be encountered in a hypothetical LOCA.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
WFO								
NRC	2.5	3.6	4.4	4.5	4.5	4.0	4.0	2.0

E.1.3 Zircaloy-Cladding Studies

These studies, which will be essentially completed in FY 1980, will investigate the behavior of Zircaloy cladding under conditions expected to be encountered during normal operation and in various hypothetical off-design and accident situations. The studies will provide baseline experimental data for use in assessing the extent of cladding damage anticipated in reactor fuel assemblies subjected to similar conditions. Primary focus will be given to determination of (1) methods of predicting oxygen consumption by Zircaloy during transient temperature oxidation,



The Thermal Hydraulic Test Facility (THTF) is an integral part of the PWR blowdown heat transfer separate effects program. The THTF is a large nonnuclear pressurized-water loop containing a test bundle of 49 rods, 12 feet of which are electrically heated to simulate nuclear fuel pins.

(2) the effect of steam pressure on the oxidation rate of Zircaloy, (3) the creep collapse performance of cladding, (4) the effects of anisotropy on the mechanical behavior of Zircaloy, and (5) the extent of cladding deformation and associated flow channel blockage expected during a LOCA. Data from all these tasks will be used by NRC to assess the margin of safety in the fuel pin cladding.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
WFO								
NRC	1.3	1.5	1.8	2.0	1.9	0.2	0.0	0.0

E.1.4 Fuel Behavior and Safety Information Center

The studies in fuel behavior will emphasize experimental work on fission product characterization, energy release, and dispersion. Data for use in evaluations of the consequences of release of radiologically toxic species due to LWR operational upset and spent-fuel transportation accidents will be obtained. Precise measurements of the fission product beta- and gamma-decay energy release vs time for thermal fission of uranium-235 and plutonium-239 will be made by the end of FY 1977. In addition, ORNL has continuing responsibility for obtaining first-hand knowledge of the German Safety Research Programs on Fuel Behavior by having a resident engineer at the Karlsruhe Laboratories, West Germany.

Also, as part of this task, ORNL will continue to operate the Nuclear Safety Information Center (NSIC). (ERDA contributes about 17% of the funds for operating the NSIC.) The NSIC serves as a focal point for the collection, evaluation, storage, and dissemination of safety information and publishes the bimonthly journal *Nuclear Safety*.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
WFO								
NRC	1.0	1.3	1.3	1.4	1.3	1.0	0.9	0.9

E.2 LMFBR Safety

The objective of this program is to develop and verify analytical models that can be used to assess the safety of LMFBRs. Specific goals are to provide fundamental information and analytical techniques that can be used to predict the quantity of fuel that would be vaporized during a hypothetical core-disruptive accident and the ultimate disposition of the fuel and fission products—that is, will they be retained in the sodium coolant, will they be carried away by the cover gas in the vessel containment, or how will they be dispersed throughout the reactor containment structure?

These activities will be expanded over the next few years to include in-pile tests on the transition-phase postaccident heat-removal problem. This will include investigations in the ORR into the behavior of LMFBR fuel during a meltdown sequence. The goal of this work is to determine how molten cladding and fuel will behave, with emphasis on determining whether or not resolidification or blockages might occur. The large increase in costs reflects our progress into this expensive stage of experimentation.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
WFO								
NRC	1.6	1.6	2.5	3.0	4.7	4.7	4.4	3.2

E.3 GCR Safety

The purpose of these studies is to determine and verify the safety characteristics of GCRs under various operating and accident conditions and to perform research and development to assure that GCR systems will operate safely. This work includes the development of (1) predictive methods, (2) predictions of the consequences of reactor transients on the primary system and on reactor components, (3) system response studies, and (4) assistance with problems arising from the licensing process.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
WFO								
NRC	0.4	0.2	0.4	0.5	0.5	0.5	0.5	0.3

E.4 Environmental Statements Project

The Environmental Statements Project provides technical assistance to NRC and ERDA in the preparation of impact statements for both nuclear and nonnuclear energy systems. During the current year, 12 statements were prepared, almost all of which dealt with the issuance of construction-stage permits. Future work will be expected to deal increasingly with operating permits and with generic reports on topics of concern to all power-reactors. A second aspect of the program deals with assessment of consumer products containing radioactive source materials and by-products.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
WFO								
NRC	1.8	2.1	2.1	2.0	2.0	2.0	2.0	2.0

E.5 Nuclear Fuel Cycle

Three programs relate to activities in the commercial fuel cycle: (1) assistance in safety reviews for the licensing of fuel reprocessing plants, (2) preparation of "as low as reasonably achievable" (ALARA) guides for the release of radioactive materials, and (3) development of adequate safeguards for special nuclear materials (SNM) through an automated-vault storage system. ORNL will develop and demonstrate a vault system for adequate protection of SNM. This program will provide industry with design, fabrication, and operating information for automated vaults which will be applicable to the LMFBR, HTGR, and LWR fuel cycles.

Minor activities include safety reviews for the licensing of shipping casks, components tests of shipping casks, and the revision of environmental reports on recycling plutonium and the HTGR fuel cycle.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
WFO								
NRC	1.3	1.7	1.5	1.5	1.0	1.0	0.5	0.5

E.6 Research

Several research programs are being carried out for NRC in areas other than reactor safety. These programs are intended to enhance the NRC's ability to perform the assessments and reviews that are a necessary part of the licensing process. The areas presently under study include (1) behavior of striped bass, (2) unified transport modeling, (3) evaluation of technical specifications data, (4) social impact assessment, (5) electricity demand forecasts, and (6) waste management studies. Other areas of research will probably be added as specific needs are identified in the licensing process.

Operating cost (millions of dollars)

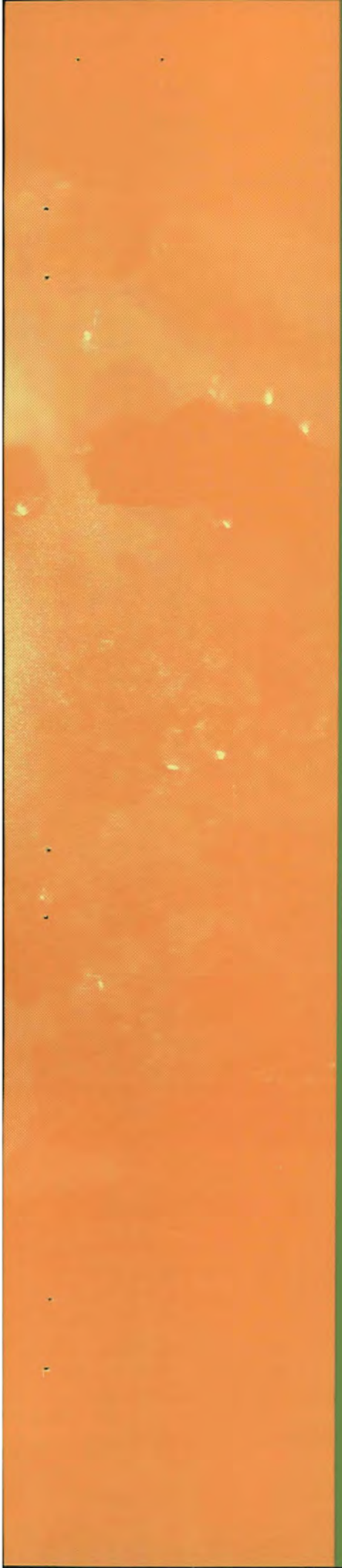
Funding source	'76	'77	'78	'79	'80	'81	'82	'83
WFO								
NRC	1.3	1.8	1.8	1.8	1.8	1.8	1.8	1.8

E.7 Miscellaneous Activities

In addition to the programs specifically identified above, a number of other technical support activities are carried out for the NRC. For example, these additional activities include (1) review of the behavior of reactor materials and components and of standards for structural alloys, (2) radiation exposure analyses, (3) shielding studies, (4) operator licensing review, (5) assistance in evaluation of control systems for power plants and in reactor surveillance and diagnostics, and (6) power plant cost estimates.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
WFO								
NRC	1.5	2.1	1.6	1.5	1.0	1.0	1.0	1.0



F. Fossil Energy

The dark rounded features shown at left are non-combustible mineral inclusions in highly volatile bituminous coal. The area shown in this transmission electron photomicrograph (approximately 47,000x) is composed principally of the coal macerals (components) vitrinite and inertinite.

F. FOSSIL ENERGY

ORNL has an aggressive research and development program on fossil fuels—particularly coal—with emphasis on the chemistry and chemical engineering of coal conversion, development of advanced systems for combustion and power generation, development and testing of materials and components, and engineering studies and evaluations. The base program described here, which is sponsored primarily by the ERDA Fossil Energy Organization, is interfaced with the ORNL program in basic energy sciences to make use of the latest applicable scientific developments and materials, with the ORNL program in life sciences to assure appropriate attention to health and environmental effects, and with the ORNL information center activities. The relation of these programs to fossil energy is discussed briefly at the end of this section. Levels of funding are presented there for information only and are compiled separately within the appropriate program activity. Our program is coordinated with similar programs at other national laboratories and energy research centers and stresses interactions with private industry that will tend to promote early commercialization of the technologies.

F.1 Coal Conversion Laboratory Development

The goal of the applied coal conversion research program is the development of technology for advanced coal conversion processes (particularly liquefaction) and improvement of current processes. Specific activities include (1) research on the chemical structure of coal and its implications with respect to conversion processes, (2) support for the development of coal conversion processes that utilize homogeneous catalysts, (3) development of improved methods for the analysis and monitoring of coal and coal-derived materials, and (4) provision of background information for improving methods for solids-liquid separations. This work draws upon more fundamental investigations that are carried on in many of these areas under ERDA's basic energy sciences program.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
BA 06	0.0	0.2	1.1	1.7	2.5	2.5	2.5	2.5

F.2 Coal Conversion Engineering Development

The objective is to support the national program of advanced coal conversion process development (particularly liquefaction) through the engineering development of certain key unit operations and components (e.g., liquefaction reactors and solids-liquid and solids-gas separations) and through the operation of versatile bench-scale systems to develop data as a function of process parameters for use in process design and optimization studies. We will continue the present bench-scale development of (1) a fluidized-bed hydrocarbonization process, (2) a fluidized-bed process for carbonization of residue streams from hydroliquefaction processes, (3) a method for utilizing coal as a precoat in rotary drum filtration of coal-derived liquids, (4) an agglomeration-settling process for solids-liquid separations, (5) advanced contactors for non-catalytic hydroliquefaction, and (6) the pyrolysis of coal under conditions that simulate in-situ gasification. Also, in FY 1977, ORNL plans to initiate bench-scale development of (7) an advanced coal liquefaction process, (8) processes for the recovery and recycle of solid wastes from coal conversion processes, and (9) bioprocesses for the treatment of aqueous effluents from coal conversion plants. The latter activity builds on research that is a part of the ORNL life sciences program.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
BA 01	0.8	1.1	0.6	0.6	2.0	2.0	2.0	2.0
BA 06	0.2	0.4	0.8	1.5	2.5	2.5	2.5	2.5
BA 07	0.0	0.0	1.3	2.9	3.5	3.5	3.5	3.5
BC 03	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0
Total	1.2	1.8	3.0	5.0	8.0	8.0	8.0	8.0

F.3 Alkali Metal Vapor Cycle

The alkali metal vapor project is to develop an advanced system for converting heat to electricity with an overall thermal efficiency approaching 50%. The concept entails boiling potassium or cesium at high temperature, expanding the vapor through a turbine, and condensing the vapor and using the waste heat to generate steam at about 550° C to drive a conventional modern steam plant. The system is applicable to oil- or gas-fired and fluidized-bed coal combustion plants.

During the past two years, ORNL designed and built a gas-fired potassium boiler; testing of the boiler is beginning. We expect to design, build, and test a potassium condenser that is also a steam generator. In addition, we expect to design, build, and test a coal-fired alkali metal boiler using a fluidized-bed furnace. These steps constitute phase I of the project and will require about five years to complete. Beyond phase I, the Laboratory would be

A technician removes some char by-product from the experimental coal hydrocarbonization pilot plant located at ORNL. The project is designed to convert coal to useable liquid and gaseous fuels.

responsible for assisting in technology transfer, program management, and consultation services.

In phase II, a fluidized-bed coal combustion pilot plant would be designed and built to drive a 4-MW(e) potassium or cesium vapor turbine. If the design can begin in 1979, the pilot plant could be ready for operation in 1984. Finally, the phase II module is intended to be the basis for a 200-MW(e) demonstration plant. Construction could begin in 1985 and operation in 1989. Both the pilot plant and the demonstration unit are likely to be located at an existing utility station as part of the commercialization process.

The following cost estimate includes only development funds and excludes design and construction costs for both the pilot plant and demonstration plant. Approximately $45 million of the money shown here will be used for RD&D subcontracting.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
BA 04	0.6	2.0	4.0	6.0	14.0	19.0	16.0	10.0

F.4 Coal-Burning Gas-Turbine Technology Test Unit

This program is to design, build, and operate a technology test unit to investigate the feasibility of a fluidized-bed coal combustion system coupled to a closed-cycle gas turbine for potential commercial and industrial applications.

Construction of a 0.3-MW(e) experimental unit consisting of a fluidized-bed furnace coupled to a closed-cycle gas turbine for power generation is scheduled for completion in September 1978. ORNL would be responsible for the transfer of technology from this unit to the construction of a commercial plant in the size range of 5 to 20 MW(e).

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
BA 05	1.3	1.5	2.8	2.0	1.5	1.3	1.0	1.0

F.5 Materials Engineering

Materials engineering assistance will be provided for coal conversion and utilization systems. Particular activities include (1) pressure vessels and piping investigation, including the applicability of prestressed-concrete vessels, (2) development and inspection of erosion-resistant coatings, and (3) welding and inspection techniques for the fabrication of gasifiers and heat exchangers.

Because of the diversity of processes and environments in coal conversion systems, a wider range of materials must be characterized properly at scales ranging from modeling and pilot-plant levels through future full-size demonstration-plant levels. Failure prevention analyses will be performed, and prototypic components and parts of all size ranges will be examined after being tested. The extension of current technology to facilitate highly reliable field fabrication and inspection of the extremely large components needed for coal conversion systems is a major aim of this effort.

Major growth is planned in this program in FY 1978 and FY 1979 as ORNL begins to participate substantially in supporting the detailed engineering and construction of fossil-fuel demonstration plants.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
BA 06	0.4	0.7	1.7	2.0	2.0	2.0	2.5	2.5
BA 07	0.0	0.0	0.7	2.0	3.0	4.0	4.5	5.0
Total	0.4	0.7	2.4	4.0	5.0	6.0	7.0	7.5

F.6 Components Testing

The objective of this program is to test and develop performance data on critical components for fossil-fuel demonstration plants. The testing and development of key components in parallel with the design, testing, and operation of demonstration plants is considered an essential part of the strategy of maximizing the probability of success of the accelerated demonstration-plant program. The type of components to be tested—under service conditions that will approximate those to be encountered in demonstration-plant operations—include coal preparation equipment, coal feed systems, pressure vessels, valves, compressors, turbines, pumps, and gas cleanup equipment. A module for testing large lock-hopper valves is scheduled to be in operation in the third quarter of FY 1977. By the end of FY 1981, the Laboratory proposes to complete a line-item construction project to refurbish an existing decommissioned power plant for general-purpose use as the Critical Components Test Facility (CCTF). Approximately 30% of the operating expenses in this program will be used for construction costs.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
BA 07	0.0	3.7	5.0	7.0	9.0	9.0	9.0	9.0

F.7 Engineering Studies and Evaluations

The objective of this subprogram is to prepare and document engineering evaluations, conceptual designs, environmental assessments, and cost estimates of coal conversion, utilization, and production processes. This information will be used to evaluate alternatives and develop goals for the nation's coal research and development program. The development of new techniques for conducting these studies will be included when appropriate.

We will serve as lead laboratory in environmental assessments and information dissemination, assisting ERDA by (1) coordinating environmental assessments, (2) preparing environmental statements for major facilities, (3) performing generic studies, (4) preparing an environmental monitoring handbook for conversion processes, (5) reviewing monitoring data, and (6) preparing social impact assessments. The high level of funding in 1977 represents planning and analysis assistance to ERDA in its evaluation of the overall fossil energy program.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
BA 06	0.0	1.5	0.4	0.4	0.4	0.4	0.4	0.4
BA 07	0.9	1.7	2.3	2.3	2.5	2.5	2.5	2.5
Total	0.9	3.2	2.7	2.7	2.9	2.9	2.9	2.9

F.8 Supporting Research for Enhanced Oil Recovery

Technical support will be provided for the development of the class of tertiary oil recovery methods called micellar flooding, which involve injection of surfactants to release oil from formations and injection of viscosity-modifying polymers to promote flow of the released oils to producing wells. Specific activities include (1) identification and evaluation of the usefulness of cheap chemicals (potentially producible in large quantities from waste streams or naturally occurring materials) as suitable surfactants, polymers, and coagents; (2) identification and testing of elements and ions that can be used as flow tracers for the development of tertiary recovery systems; (3) development of an understanding of the complex interactions that occur between the micellar floods and the natural geologic formations; and (4) determination of the factors that govern the flow of liquids through porous media. The latter three elements are related to fundamental studies in the ORNL basic energy sciences program.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
BB 01	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0
BB 02	0.0	0.0	0.5	0.6	0.6	0.4	0.4	0.4
EE 04	0.3	0.2	0.2	0.2	0.3	0.4	0.4	0.4
Total	0.4	0.6	0.9	0.8	0.9	0.8	0.8	0.8

BASIC RESEARCH IN SUPPORT OF FOSSIL ENERGY TECHNOLOGY PROGRAMS

In the next two subsections, the basic research at ORNL in the physical and life sciences that contributes directly to the fossil energy technology program is described. This research is funded by the Division of Physical Research and the Division of Biomedical and Environmental Research. All money discussed here has been included in Sections A and B of this Plan.

The Laboratory's physical research on the problems likely to be encountered in coal conversion technology ranges from basic studies on the structure and composition of the coal itself, through problems related to chemical reactivity and materials compatibility that are encountered in the conversion processes, to the identification and separation of the conversion products.

STRUCTURE AND SEPARATION

The goal of the work in coal structure is to obtain enough information at the molecular level to assist in the development of economic coal liquefaction processes. Through the use of carbon-14-labeled reagents, estimations of double and triple bonds and of tertiary hydrogens in coals will be made. The structural chemistry group at ORNL will look at the structure of coal-derived or coal-related compounds using neutron and x-ray diffraction techniques. The distribution of microconstituents in coal is being studied by transmission electron and optical microscopy and by small-angle x-ray scattering. This last technique is also applied to the characterization of electron density variations in coals and pyrocarbons.

The latent energy contained in coal can be utilized by direct combustion of the coal or by conversion to a more convenient form such as liquid or gas. The elementary reactions of combustion will be studied at ORNL with crossed atomic and molecular beams and by photochemical techniques. Electron-spin-resonance techniques will be used to study free radicals produced pyrolytically in order to gain a greater understanding of the chemistry of

pyrolytic processes, a field that is highly underdeveloped but is of fundamental importance to coal conversion processes.

CATALYSIS

Molten salts are finding applications as homogeneous catalysts for the steam-coal reaction and for cracking and hydrogenating carbonaceous materials such as coal, tars, and petroleum residues to produce high-quality hydrocarbon fuels.

The thermochemical data needed to determine the most appropriate salt processing techniques, the compatibility of salts with materials of construction, and the safety hazards that may arise when molten salts are mixed with other fluids will be obtained. A further objective of our molten-salt research is to achieve a mechanistic understanding of molten-salt catalysis as it relates to the conversion of low-grade carbonaceous materials into fuels and chemical feed stocks. Here, the chemical reactions that take place within the catalytic liquid phase, the species formed in the melt by dissolution of substrates, the reaction steps by which these species are converted into useful products, the reaction steps by which the catalyst is destroyed, and the relationships that these reactions and processes have to the composition and structure of the liquid catalyst are to be investigated.

A twofold study of heterogeneous catalysis is applied to coal conversion problems. One is a rather basic effort to add to our understanding of the science of catalysis by seeking new connections between the science and the art of catalysis so important in present-day industrial practice. The second study, the chemistry of heteroatom removal from coal, is directly concerned with the components of a generalized coal beneficiation process, abstracting from it rationalized, simplified steps that can be attacked through experiments with model compounds, doing such experiments and interpreting them at a chemical kinetic level, and manipulating the information into a better understanding of the integrated process. In addition, because heavy-metal sulfides (molybdenum disulfide, iron disulfide, and cobalt monosulfide) play an important role in the catalytic desulfurization of coal and crude oil, a study of the electrochemical kinetics of sulfide reactions is under way.

PROCESS AND SEPARATIONS

In chemical engineering research, ORNL is looking at three-phase fluidized beds as potentially important devices for coal conversion processes. In FY 1976, an experimental study was initiated to obtain mass transfer, dispersion, and holdup data under conditions of interest to coal conversion reactors. These studies will be extended in the future with the goal of developing correlations that can be used to evaluate, design, and scale up pilot-plant and production systems. Because we expect that severe corrosion problems will occur in coal conversion pilot plants, we are carrying out studies of gaseous corrosion that emphasize the complex reactions that occur on alloys in high-temperature mixed-gas environments. A study of the properties of different ceramics of possible use as liners in coal conversion systems is also under way.

Research is progressing on the separation and identification of products and wastes from coal conversion processes. In separations, the mechanisms for aggregation processes and for separation of solids from viscous fluids (e.g., by hydraulic cyclones or other techniques) are being studied. A method for the removal of ash from solvent-refined coal by contact with a molten-salt eutectic has been developed and will be improved. In identification, there is an effort to develop computer-based analytical instrumentation with which to characterize the organic materials produced by conversion facilities. Multicomponent analysis techniques will be developed, and the research into organic mass-spectrometric and liquid-chromatographic identification of complex organic compounds will be continued and expanded.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
1.3	2.0	2.9	3.5	4.0	4.3	4.5	4.5

LIFE SCIENCES PROGRAMS RELATED TO FOSSIL ENERGY

The technology for the conversion of coal to liquid and gaseous hydrocarbons for fuel and petrochemicals is being actively developed by ERDA and private industry. The development of this technology should proceed in such a way that conversion processes can be optimized not only economically but also for maximum protection of human and environmental health. Therefore, biomedical and environmental research must proceed in concert with technological development. Close collaborative research including biologists, chemists, ecologists, and health physicists is being conducted to evaluate the potential fate and effects of coal conversion effluents.

Research activities can be divided into two broad classes: those designed to provide information on whole effluents and fractions through use

of rapid toxicity screening tests and those that utilize model compounds and are designed to elucidate mechanisms of effects, metabolic degradation pathways, persistence, bioaccumulation potential, and ultimate fate. Research for evaluating the potential hazards to man and his environment will proceed from initial toxicity screening tests to chronic exposures and studies of environmental transport and fate. To facilitate this research, techniques will be developed for chemical profiling and multicomponent analysis of selected compound types. A production activity will be implemented to provide well-characterized materials for biological and environmental research.

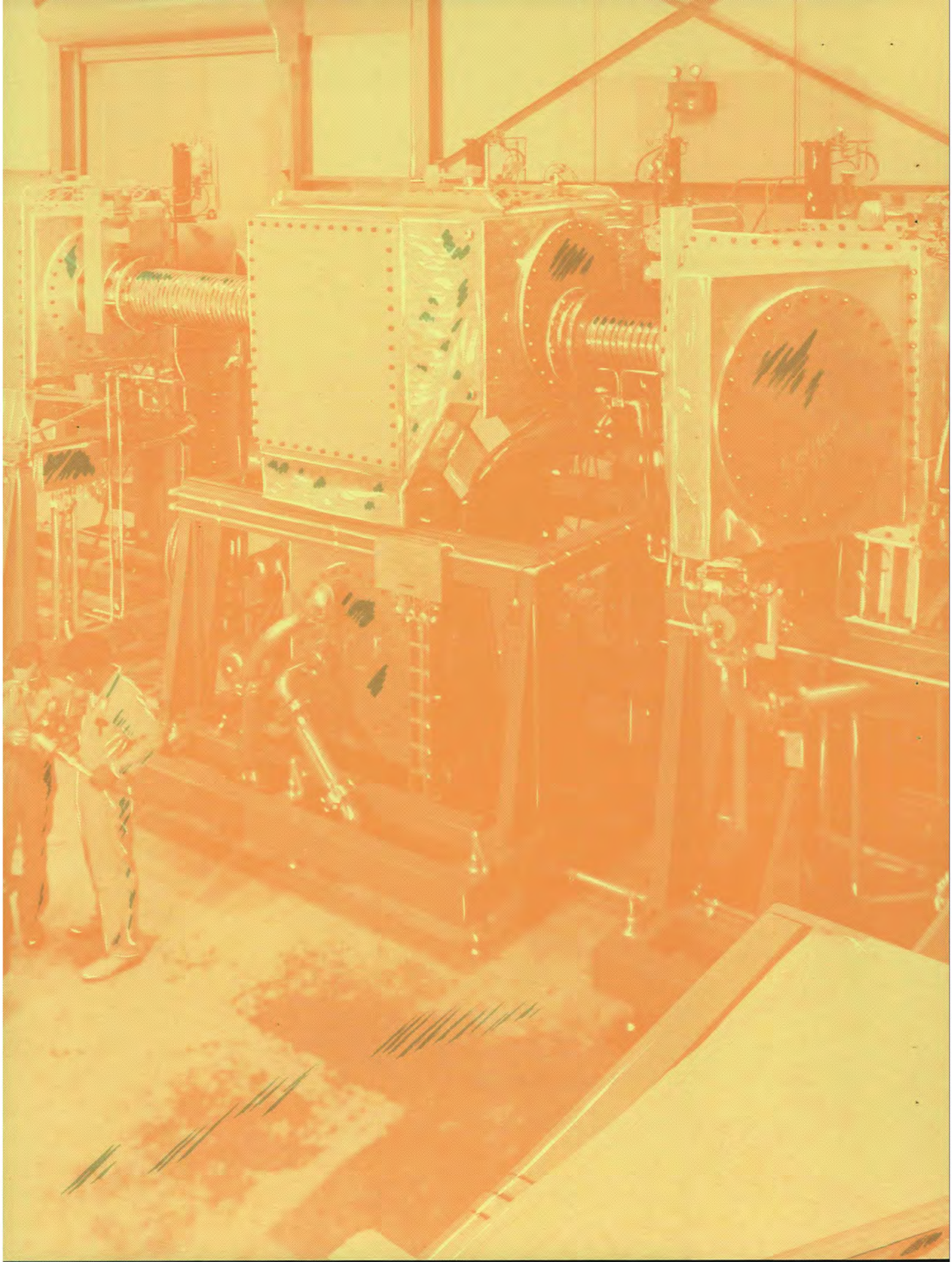
The part of the program dealing with health effects will involve tests for toxicological, carcinogenic, mutagenic, and teratogenic effects of products and effluents. Efforts will be made not only to identify potential hazardous materials, but also to estimate the magnitude of any deleterious effects on human health.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
2.4	4.7	5.9	5.5	6.2	6.9	7.5	8.4

INFORMATION CENTER ACTIVITIES RELATED TO FOSSIL ENERGY

There are more than 20 identified technical information groups in the Laboratory that may be called information centers. The Regional and Urban Studies Information Center is explicitly concerned with analyzing the regional implications of energy technology development. This center is collaborating with five other national laboratories in the National Coal Assessment, a two-year examination of the regional and national consequence of increased coal production and use.



G. Magnetic Fusion Energy

The 150-KeV Neutral Beam Test and Development Facility provides for the testing and development of neutral beam injectors and beam lines of the class that will be needed for the Tokamak Fusion Test Reactor (TFTR) under construction at the Princeton Plasma Physics Laboratory. The test facility can simulate a complete beam line injection system and provides a wide range of experimental operating conditions.

G. MAGNETIC FUSION ENERGY

Magnetic fusion power systems offer several potential advantages over fission power systems: (1) inherent safety against nuclear excursions, (2) reduced radioactive hazards, (3) minimal afterheat cooling problems, and (4) the possible absence of requirements for disposal of long-lived radioactive waste. To realize these potential advantages, the fusion program must attack several formidable research and development problems during the next few years. Our principal emphasis will be on (1) the physics of confinement systems, (2) the development of technology for plasma heating, large superconducting magnets, reactor materials, and tritium containment, and (3) system design and analysis.

G.1 Tokamak Program

The tokamak experimental program seeks to attain sufficient understanding of plasma confinement in the tokamak geometry to design future devices. There are critical questions in the areas of scaling, plasma heating (by means of both radiofrequency power and energetic neutral beams), and the effects of impurities. The ORMAK device is principally aimed toward the questions of plasma heating and confinement. In order to fully exploit the present facilities, the toroidal field and neutral injection power on ORMAK are being extended to the device limits, about 3 T and 500 kW respectively. The experimental program on ORMAK will be finished in April 1977.

In addition, two new experiments have been approved and are being built. ORMAK Upgrade, a medium-sized tokamak (toroidal field about 4 T, major radius 92 cm, minor radius 30 cm, and plasma current greater than 400 kA), is designed to investigate the physics of intensive neutral injection and of confinement at high plasma pressures. For this purpose, an initial injection power of 2 MW will be provided, which will be followed by an additional 2 MW. The goals are machine operation in April 1978 and 2 MW of injection power in October 1978. The experimental program that is currently planned will have a duration of approximately three years.

A smaller device, the Impurity Study Experiment (ISX), will be devoted to studies of wall-plasma interactions and nondiverter impurity control techniques. The experiment is being conducted with the General Atomic Company. We plan to begin device operation by spring of 1977, to begin impurity source experiments and tests of limiter and wall materials and configurations by August 1977, and to operate for approximately two years.

A program of basic surface physics measurements and advanced diagnostic development is carried on to provide the basic data and measurement techniques that are essential to both of the above devices.

	Operating cost (millions of dollars)							
Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA ED 01	8.8	9.8	12.8	13.0	13.0	15.0	15.0	15.0

G.2 Plasma Heating and Fueling

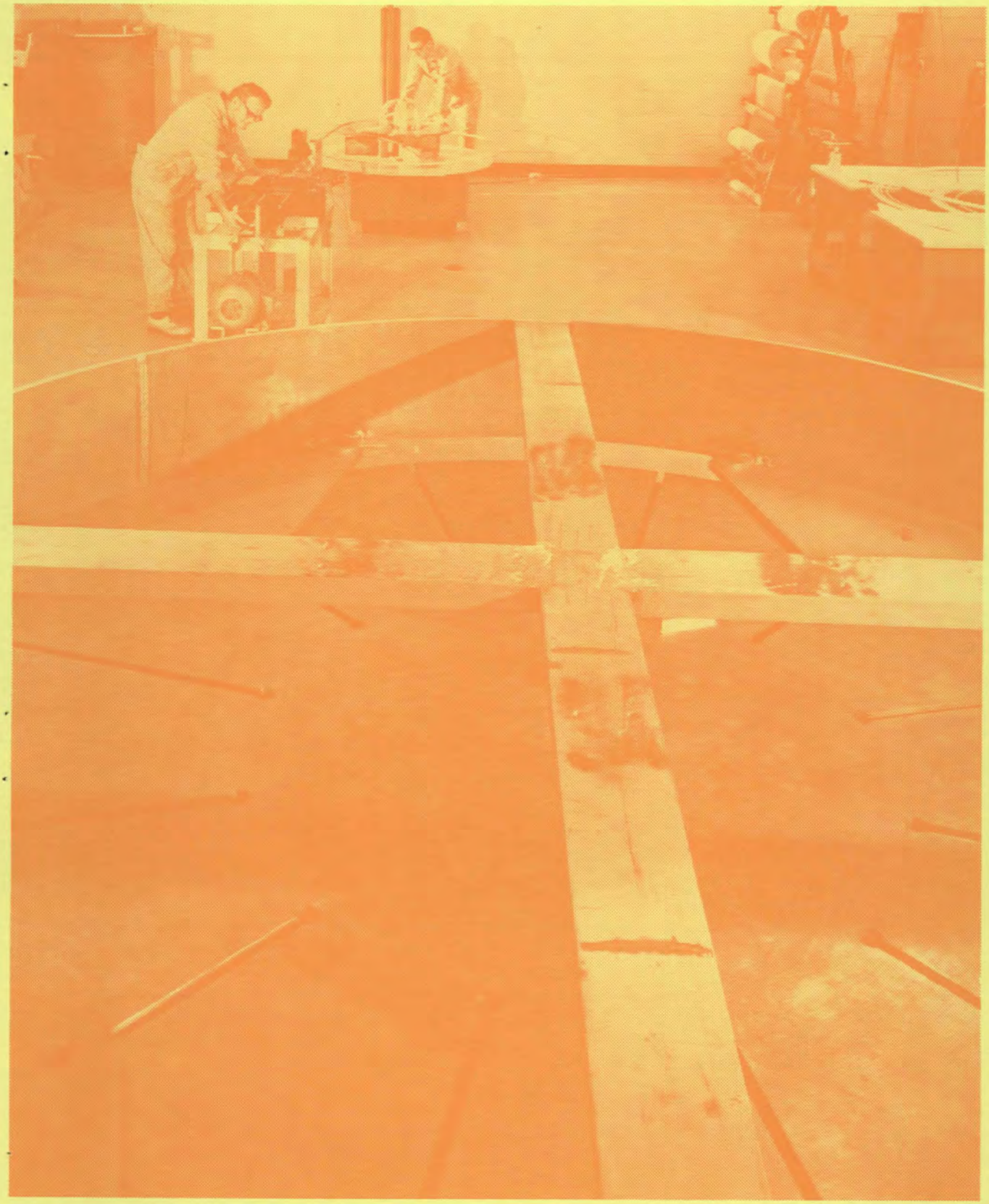
The goal of the plasma heating and fueling program is to provide the capability for heating and fueling the large long-lived plasmas now projected for the U.S. fusion program. ORNL provided pellet fueling and increased neutral-beam heating capabilities for ORMAK in 1976. A pellet fueling system and neutral beams will be provided for the Princeton Large Torus (PLT) in 1977. Pellet fueling and neutral-beam heating capabilities will be supplied for ORMAK Upgrade and for the Poloidal Divertor Experiment (PDX) in 1978 and 1979. We will also develop pellet fueling and neutral-beam equipment for the Toroidal Fusion Test Reactor (TFTR) at Princeton and The Next Step (TNS) at ORNL and supply them when needed in the early 1980s. Developmental programs for heating and fueling subsequent magnetic fusion devices will be well under way in the early 1980s.

Industrialization of plasma heating and fueling technology is expected to proceed during the 1977 to 1983 period. Heavy participation in power system technology by industry will continue, and more participation in large pumping system technology is expected to evolve. Industrial participation in other areas such as power handling technology and ion source manufacturing is also expected during the same period.

	Operating cost (millions of dollars)							
Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA ED 02	5.5	5.0	8.0	11.0	13.0	13.0	12.0	13.0

G.3 The Development of Large Superconducting Magnets

The superconducting magnet development program has the responsibility for providing the technology and the tested designs for the magnet systems of a large tokamak to be built in the early to middle 1980s. The program is organized in two



A 3-m superconducting coil winding facility, located in the Y-12 electric shop, is part of the superconducting magnet development program. Shown in foreground is a round 3-m practice bobbin mounted on a winding table.

major activities, an ongoing program of basic magnet technology development and the Large Coil Program (LCP), which has the specific goal of fabrication of large toroidal field coils for several candidate designs by 1979.

In the LCP, the capabilities of the magnet industry will be utilized, and information generated in the superconducting magnet development program will be disseminated by the involvement of industry in the conceptual design, detailed design, and fabrication of the large coils. A number of coils about 3 m in diameter will be purchased from industrial firms in FY1978 and FY 1979 and will be tested to provide the basis for detailed design of the toroidal magnet for the tokamak.

The base technology program includes conductor selection and testing, coil shielding and protection, structural analysis, coil and system design, cryogenics, developmental fabrication, and testing. Emphasis is on providing information directly applicable to the LCP. Another important function coming to the forefront is the development of pulsed superconducting coils for specific application in the poloidal field systems of the tokamak.

The large increase in funding for the 1978 to 1979 period reflects the purchase of coils from industry and the construction of the coil test facility.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
ED 02	3.6	7.4	19.2	19.8	10.5	9.5	10.0	8.5

G.4 Fusion Reactor Technology Program

The goal of the fusion reactor technology program is to identify, assess, and satisfy the technological requirements associated with the development of nuclear fusion as a safe, reliable, and economic source of power. The scope of this program includes (1) blanket and shielding engineering, (2) neutronics (including calculations, data assessment and procurement, and support by the Radiation Shielding Information Center), (3) tritium processing and control, (4) environment and safety, (5) surface radiation effects, (6) bulk radiation effects, (7) neutron source development, and (8) materials capability. The objectives of the fusion reactor technology program can be divided into (1) short-term objectives to support the design and construction of the Tokamak Fusion Test Reactor (TFTR) in the areas of materials selection, tritium handling, radiation shielding, and remote maintenance; (2) middle-term objectives to develop the technology base for the experimental power reactor and the demonstration power reactor in areas such as thermal-hydraulic design, materials integrity, and tritium breeding and recovery; and (3) long-term objectives to extend the technology base indicated in item 2 for commercial fusion power.

The fusion materials program is severely hampered by the lack of a suitably intense source of energetic neutrons for radiation damage studies. ORNL, with help from the Fermi National Accelerator Laboratory, has recently submitted a 1979 line item proposal to Division of Magnetic Fusion Energy (DMFE) for the construction of an Intense Neutron Generator for Radiation Induced Damage (INGRID) based on the deuterium-lithium concept. The purpose of this program is to provide conceptual design, development, and operating support to the INGRID project. The large increase in funding starting in FY 1978 is due to the assumption that this project will be funded at ORNL.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
ED 02	1.7	2.1	6.7	7.3	8.4	10.4	13.1	16.5

G.5 Theoretical Research on Controlled Thermonuclear Fusion

The theoretical research program goal is to develop functional theories of plasma confinement and heating in close collaboration with the ORMAK, ISX, ORMAK Upgrade, and Elmo Bumpy Torus (EBT) experimental programs and to apply these theories to the choice and conceptual design of future experiments aimed at achieving net power from controlled thermonuclear fusion. Specific research tasks include (1) assessing the impact of magnetohydrodynamic (MHD) fluctuations on plasma confinement in tokamaks; (2) experimenting to find feasible ways of increasing the resulting limits on plasma pressure; (3) assessing the impact of kinetic instabilities in enhancing the transport of particles and energy in tokamaks; (4) developing the capability of making detailed comparisons between theoretical transport models and experimental parameters, both in tokamaks and in the EBT; (5) achieving a working understanding of the processes governing the reflux of plasma particles at the boundary layer between hot confined plasma and the metallic chamber walls; and (6) applying theoretical techniques in reactor design projects to determine feasibility, characteristics, and operating parameters for various concepts. This activity will continue to grow as new experiments are operated and TNS is designed.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
ED 03	2.0	2.3	2.8	3.3	3.7	4.0	4.5	4.5
ED 02	0.0	0.3	0.7	1.0	1.3	1.5	1.5	1.5
Total	2.0	2.6	3.5	4.3	5.0	5.5	6.0	6.0

G.6 Design and Construction of Advanced Fusion Systems

The goal of the advanced fusion systems program is to identify, evaluate, and satisfy the requirements for integrated system experience before the Demonstration Reactor Plant is built. Device-oriented analysis and synthesis are carried out in the multidisciplinary areas of plasma physics and engineering, fusion device technology and engineering, and reactor technology and engineering. This work provides the conceptual design used to support detailed design and subsequent construction.

Beginning in 1979, program tasks will include component development for the device, and in 1981, the tasks will include preparation for experimental research and facilities operation. On the basis of past studies, a set of objectives for TNS, the intermediate system experiment between the TFTR and the Experimental Power Reactor Demonstration (EPR-Demo) facilities, has been chosen. Conceptual design for TNS will begin in FY 1977 and 1978. The TNS plan is directed at the operation of a fusion reactor core, that is, a long-lived ignited deuterium-tritium plasma with necessary support technologies, by the mid 1980s.

The TNS conceptual design will form one of the key inputs to the ERDA decision point on implementing the overall program plan. Assuming that ORNL and an industrial participant are then identified as the contractor team for TNS, we would expect to submit a line item proposal in excess of $0.5 billion for the approximate time period 1979 to 1985.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
ED 02	0.5	2.0	4.0	7.0	10.0	20.0	25.0	30.0

G.7 High-Beta Plasma Program

The goal of the high-beta plasma program is to demonstrate the fusion plasma relevance of the EBT plasma confinement scheme and to evaluate its fusion reactor feasibility. During 1977, the Laboratory will continue detailed documentation of EBT-I parameters and then transfer the studies to investigation of EBT with increased microwave power, referred to as EBT-Scale (EBT-S), to be in operation by September 1977. The information developed should corroborate confinement models suitable for scaling to EBT-II, which is tentatively conceived as a 48-coil superconducting 3-m-radius torus that will be heated by 2 MW of millimeter-wavelength continuous-wave (CW) microwave power. EBT-II construction is expected to be completed in late 1981, enabling the evaluation of the EBT confinement concept during 1982 and 1983 in the relevant density and temperature regime required for extrapolation to reactor conditions. The subcontract part of this program represents a considerable microwave development effort at Varian Associates, Palo Alto, California, aimed at providing the high-frequency power (200 kW CW at 28 GHz by August 1977) for the scale modification of EBT to EBT-S.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
ED 01	1.8	2.0	7.0	7.7	8.0	5.5	5.5	5.5
ED 02	0.8	1.5	1.4	1.4	1.6	1.6	1.6	1.6
Total	2.6	3.5	8.4	9.1	9.6	7.1	7.1	7.1

BASIC ENERGY SCIENCES PROGRAM SUPPORT OF MAGNETIC FUSION ENERGY TECHNOLOGY

In this section, the basic energy sciences research at ORNL that contributes directly to the magnetic fusion energy technology program, is described. This research is funded by the Division of Physical Research. All money summarized here has already been included in Section A, "Basic Energy Sciences."

TRITIUM BEHAVIOR AND CONTAINMENT

The fundamental chemical and engineering research being done at ORNL in order to be able to predict and control tritium behavior is applicable to both fusion and fission reactor systems, but the low tritium pressures and concentrations that must be maintained in fusion systems present particularly difficult process and handling requirements. This research seeks (1) information needed to evaluate and develop processes for recovering tritium from fusion reactor blankets; (2) techniques for removing tritium from fusion reactor plasmas, purifying the fuel, and recycling fuel to the plasma; and (3) data on methods for containing tritium to prevent release to the environment or to the reactor steam system.

Items 2 and 3 will receive the major attention until 1980 because the information will be important to fusion projects that will be designed during the next few years. Item 1 will attract increasing interest well into the 1980s; fusion reactor experiments with breeding blankets are likely to be designed during the middle 1980s. Development of blanket recovery processes will require fundamental physical-chemical data on the distribution of tritium between liquid lithium and potential sorbent or extraction media and fundamental engineering data on the mass transfer steps involved in these processes. A better understanding of the sorption processes that appear most promising for fusion reactor vacuum pumps will be developed. These are low-temperature processes, and little quantitative mass transfer information is available. Studies of tritium containment will investigate permeation and oxidation-sorption processes. Present studies of permeation through metals that are potential steam-generator materials, such as stainless steel or Incoloy-800, with oxide or impurities on their surfaces are particularly important, because a better understanding of these processes under realistic conditions is greatly needed.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7

RADIATION DAMAGE AND MATERIALS RESEARCH

The effect of radiation on metals and alloys is of obvious importance to fusion reactor technology, and ERDA's fusion program benefits greatly from the multidirectional approach of the DPR materials research programs. Since irradiations in reactors and other neutron sources at fluences characteristic of reactor lifetimes are impractical, near-term emphasis will be placed on developing an understanding of methods for simulating the neutron damage that causes swelling in structural materials. Primary attention will be directed to obtaining a quantitative relationship between heavy-ion and neutron irradiations. Concurrently, facilities will be developed for high-voltage electron microscope, Van de Graaff, and cyclotron irradiation of samples to simulate the MFE radiation environment, where both displacement damage and transmutation reactions (helium production) occur.

Light-ion irradiation facilities will be used for in-situ measurement of irradiation creep in a defect flux to obtain creep rates that are almost impossible to obtain in reactor experiments. Techniques have been developed and will be employed to measure damage production rates as a function of ion penetration depths, to view the full range of ion-produced microstructures, and to measure cavity parameters rapidly by means of small-angle x-ray scattering.

The effects of energy of the bombarding particle for various ions and neutrons with energies from thermal to about 40 MeV are being established by experiments evaluating damage production rates in metals and insulators. The use of specially prepared pure metals provided by the Research Materials Center makes interlaboratory comparison of radiation effects much easier by removing much of the uncertainty in material parameters. Continual refinement of the theory and modeling of the damage process also aids in the evaluation of results and the extrapolation to conditions under which the materials will be applied.

The eventual implementation of practical fusion energy will very likely be dependent on the successful development of superconducting magnets for plasma confinement. ORNL is trying to develop a better understanding of fluxoid behavior in superconductors, because the interaction of fluxoids with one another and with pinning sites determines the bulk magnetic properties of the material. The influence of mechanical stresses on superconducting behavior is being investigated, because such effects can impose serious limitations on materials for high-field generation. The effects of small metallurgical modifications of potentially useful materials on important superconducting parameters such as transition temperature, critical current density, and critical field will be determined.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
0.9	1.0	1.2	1.3	1.3	1.4	1.4	1.5

ATOMIC AND SURFACE PHYSICS

An understanding of the interaction of MFE plasmas with impurity ions and with containment vessel first walls is prerequisite to the successful design of a practical device. (The impurity ions arise from impurities in the injected neutral deuterium beam used to heat the plasma.) Plasma interactions with surfaces are simulated in the laboratory by directing an energetic beam of particles or electromagnetic radiation onto surfaces of materials to be used as first walls. By using beams of known mass and energy and analyzing the composition, energy, and spatial distribution of particles leaving the surface, fundamental information on sputtering, desorption, surface-particle chemical reactions, surface damage, and surface impurities may be attained.

At plasma energies, impurity ions lose many electrons (become highly stripped) and represent a serious source of energy loss by electron-capture radiation and bremsstrahlung. The interactions of these ions with the plasma constituents must be studied and understood in order to minimize radiative energy losses in practical MFE devices; a substantial fraction of the heavy-ion atomic physics research at ORNL is dedicated to this task. A knowledge of the cross sections for charge exchange, electron ionization, electron excitation, and radiative and dielectronic recombination will provide a basis for estimating plasma cooling by radiative losses and particle loss, for interpreting diagnostic observations, and for modeling plasma transport properties.

Another first-wall study under way is that of determining the drift of plasma ions and charge-exchanged neutrals to the first wall and their subsequent return to the plasma region. Such recycle can have a controlling effect on plasma dynamics and confinement times. If the recycle times are comparable with burn times, the plasma densities will be dependent on the wall conditions to some extent. If recycle rates are isotope-dependent, the isotopic composition of the plasma will be time-dependent during a burn.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
0.6	0.7	1.1	1.2	1.4	1.4	1.4	1.5

NUCLEAR CROSS SECTIONS

A large part of the physical sciences neutron cross-section measurement and evaluation program is of strong value to fusion technology. Structural materials damage by fast neutrons in MFE devices depends on neutron scattering cross sections and on cross sections for transmutations, particularly those that produce hydrogen and helium. Also, for magnetic confinement systems, the heat production in the superconducting coils will depend on the neutron penetration through the shield and on the gamma-ray production cross sections and spectra near the coils. Much of the neutron cross-section program already measures cross sections and does evaluations of prime interest to these problems, but increasing attention in the future will be paid to materials, energy regions, and reactions that are more pertinent to MFE needs.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
0.2	0.4	0.7	0.8	0.9	0.9	1.0	1.0

H. Solar and Geothermal Energy

An investigator in ORNL's Solid State Division examines a transmutation nuclear doped polycrystalline silicon solar cell, shown in the photographic enlargement at left. The actual size of the solar cell is about 1 cm x 2 cm.

H. SOLAR AND GEOTHERMAL ENERGY

H.1 Solar Energy

Our role in the development of solar energy is limited to specific areas where our skills and experience are likely to contribute to significant progress. Accordingly, the activities that we are now engaged in or propose undertaking include the pursuit of less expensive photovoltaic converters, development of heat exchangers for ocean thermal energy conversion, exploration of advanced concepts for central receivers, development of biophotolysis and efficient production of algal biomass, investigation of the agricultural and industrial uses of solar heat, and assessments of economic and environmental impacts of solar conversion technologies.

H.1.1 Thermal Conversion

Our role in the thermal conversion program is to develop technology to improve the efficiency and lower the cost of systems that convert solar heat into electricity and to help identify the most promising applications. The larger part of this activity involves the development of advanced heat transfer concepts that are applicable to the requirements of the ocean thermal energy conversion systems. A specific goal is to develop high-performance, low-cost heat exchangers that will contribute to the successful demonstration of a full-size system. Our role will involve materials selection and fabrication, heat transfer experimentation, and aid to ERDA in program planning and analysis.

Another program in thermal conversion applies laboratory expertise in molten-salt systems to achieving much higher temperatures than can currently be obtained in concentrating solar collectors using central receivers. In addition, we will attempt to devise economic energy storage systems for use with these collectors.

Finally, we are providing continuing technical support to ERDA on solar electric applications.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EA 03	0.4	0.6	1.2	2.5	3.5	4.0	4.0	4.0

H.1.2 Photovoltaic Conversion

Photovoltaic conversion of solar energy to electricity has already been demonstrated on a very small scale. Unfortunately, converters are more costly by factors of 10 to 100 than other electrical generators, because sufficient purity of materials has not been achieved. Materials research capabilities in several divisions of the Laboratory will be applied to the problems of preparing high-purity polycrystalline silicon, rendering the purified material into sheets of solar-cell quality, and controlling solar-cell properties through nuclear doping, ion implantation, and other techniques.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EA 03	0.0	0.1	0.6	2.0	3.0	4.0	4.0	4.0

H.1.3 Agricultural and Industrial Uses, Biophysical Processes, and Environmental Impacts

ORNL is assisting ERDA and the U.S. Department of Agriculture in guiding and evaluating the attempts of other contractors to apply solar heat economically in agriculture. In addition, we will explore the use of solar heat for carrying out energy-intensive industrial processes. We propose in the near future to initiate process development and associated biophysical studies for the conversion of solar energy to fuels.

Finally, the Laboratory proposes to perform a management role for ERDA in environmental matters related to solar energy alternatives. The specific areas of involvement will include programmatic environmental assessments and statements and providing guidance for environmental studies.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EA 01	0.0	0.1	0.3	1.0	1.2	1.5	1.5	1.5
EA 04	0.0	0.3	1.0	2.0	3.0	4.0	4.0	4.0
EA 02	0.0	0.2	0.3	0.4	0.4	0.5	0.5	0.5
Total	0.0	0.6	1.6	3.4	4.6	6.0	6.0	6.0

H.2 Geothermal Energy Development

Our efforts in this program reflect the areas in which the Laboratory has special expertise and skills to contribute to the overall ERDA geothermal program. The four areas of our participation are (1) low-temperature power systems, (2) scale formation, (3) corrosion, and (4) environmental assessments and statements.

The work in power systems will include the development and testing of better methods of collecting heat, transferring heat from one fluid to another, converting the heat to useful work in Rankine-type engines, and transporting heat from the source to users.

Studies on control of corrosion encountered with the use of high-temperature brines will be performed. The mechanics and control of scale

formation by silica and other aqueous precipitates are being investigated under controlled conditions in a closed titanium loop at the Laboratory. In addition, field testing on a well in California will be undertaken.

In the area of environmental assessment of geothermal programs, ORNL will perform environmental analyses of ERDA Division of Geothermal Energy (DGE) geothermal programs, specific projects, and geothermal loan guarantee projects on nonfederal land, resulting in environmental impact assessments or environmental impact statements.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EB 01	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
EB 06	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0

BASIC ENERGY SCIENCE SUPPORT OF SOLAR AND GEOTHERMAL ENERGY TECHNOLOGY PROGRAMS

SOLAR ENERGY

A broad-based program of fundamental research is being developed with the objective of finding methods for increasing the efficiency of photovoltaic, photothermal, and photochemical conversion of solar energy into forms suitable for terrestrial applications. Initially, the study was concentrated on neutron-transmutation-doped silicon, but it is now being extended to the generation, transfer, and storage of energy in solids by photoinitiated electronic and ionic processes. This research will lead directly to studies of photovoltaic materials other than silicon, to the study of the degradation of photothermal and photovoltaic materials by the action of sunlight, and to investigations of the conversion of sunlight directly into stored energy. Another ongoing study is concerned with the direct conversion of solar energy through a catalytic photochemical process that results in a reduced product that is (1) immediately storable and (2) directly or indirectly usable as a portable fuel. Since photosynthesis is the natural model for such a process, the behavior of absorbed quanta, or excitons, is being studied in the lamellar chlorophyll arrays of photosynthetic organisms.

Basic research is also being done on materials important to solar energy conversion. One program examines crystal-growth mechanisms and techniques in order to develop processes that could meet the size requirements and growth rates needed for large-scale application. Techniques for material purification and for the preparation of promising polycrystalline semiconducting materials will also be under study.

We also propose to study the physical properties of selective absorber coatings for solar thermal conversion by preparing and characterizing a number of multiphase structural absorbing films. Film properties will be determined as a function of time, temperature, and environment.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
0.4	1.0	1.6	1.9	2.0	2.1	2.2	2.3

GEOTHERMAL ENERGY

In the extraction of energy from geothermal reservoirs, salt effects, temperature and pressure effects, and compositional changes can lead to material transport and deposition that result in reservoir porosity changes, in the plugging of drill holes, in the scaling of equipment, and, ultimately, in reduction of the lifetime and value of the resource. At ORNL, research to determine the thermodynamic and physical-chemical parameters of geochemical and geophysical processes is being carried out. Potentiometric, isopiestic, conductance, calorimetric, and theoretical modeling studies on the properties of brines and on characteristic brine-mineral interactions will be made. Results of these studies will be used to characterize practical systems and will, in particular, be applied to the concentrated brines found in the Imperial Valley.

Because magmas can, in principle, provide our nation with a virtually limitless source of energy, ORNL proposes in the near future to develop a program to investigate the thermochemical behavior of magmas. This program will provide the data to predict the chemical reactivity and phase equilibria of magmas, as well as their heat capacities and volumetric properties. Another proposed program is directed toward providing a systematic study of the interaction of aqueous media with constituents of natural formations as a function of ionic strength and composition. This inquiry would be designed to supply the equilibrium and kinetic information needed to describe the transport of elements through natural formations. An understanding of this transport is important in determining the impact of brine reinjection into natural formations and in assessing the severity of hot rock (silica) dissolution problems in potential hot dry rock processes for extracting geothermal heat.

Funding (millions of dollars)

'76	'77	'78	'79	'80	'81	'82	'83
0.1	0.5	0.6	0.6	0.7	0.7	0.7	0.7

OAK RIDGE NATIONAL LABORATORY
ORGANOCHLORINE
HEMICAL MUTAGENESIS
IN LABORATORY MAMMALS
ABSTRACTS
OF DIGITAL COMPUTER CODE PACKAGES
ADAMSON, SMELING INFORMATION CENTER
MIRIX
AN OVERVIEW
ABSTRACTED LITERATURE COLLECTION
1947–1976
RUSTIC
ENERGY
ABSTRACTS
FOR
POLICY
ANALYSIS

J. Information, University Relations, and Commercialization

The rise of large, broad-based research efforts and the explosion of technical information have demanded the creation of specialized groups which effectively combine technical staff, information experts, and information processing software. Such groups digest the masses of technical data to concise reports which are useful to diverse segments of society.

I. INFORMATION, UNIVERSITY RELATIONS, AND COMMERCIALIZATION

An important element of the total Laboratory program is the interaction with many types of agencies and organizations outside the Laboratory, including local and state governments, educational and research institutions, and private industry. Such interactions are vital to the health of the Laboratory's research and development programs. Equally important, the existence of national laboratories is justified primarily by the extent to which the results of laboratory research are transferred to society. Two well-established programs at ORNL that focus directly on this transfer are the information center and university relations programs. An expanding program in the transfer of technology to private industry is planned. Much of the support for these programs comes from small WFO contracts. In the budget summaries, only those agencies which contribute more than $200,000 in any one year are specifically identified.

I.1 Technical Information

Information centers (including response centers and analysis centers) have been evolving at ORNL over the last 20 years. They represent, on the one hand, extensions of the traditional role of the reference librarian, the library specialists, and the special collection and, on the other hand, extensions of the information activities of scientists and technologists. The rise of large, broad programmatic research efforts and the explosion of technical literature have demanded the creation of specialized information-oriented groups that are frequently, but not always, associated with the computerized processing of bibliographic and numerical information elements. ORNL, in cooperation with the Computer Sciences Division of UCCND, has developed a most effective and efficient combination of information specialists and information-processing software. The Laboratory intends to continue to maintain an aggressive position with respect to the continued development of information processing for its own staff and for ERDA and the energy community broadly.

More than 20 identified technical information groups at the Laboratory may be called information centers. They have been classified into four program elements to indicate the major functions of our programmatic information work.

I.1.1 Basic Science Information Centers

These include the following centers or projects: Nuclear Data Project, Controlled Fusion Atomic Data Center, Research Materials Information Center, Radiation Shielding Information Center, Biomedical Computing Technology Information Center, and the Analytic Dosimetry Program. The Nuclear Data Project maintains the Evaluated Nuclear Structure Data File, a standard source of established nuclear structure data, and communicates the most reliable data and best techniques to the general physics community as well as the applied programs. The Controlled Fusion Atomic Data Center collects, evaluates, compiles, and distributes atomic cross sections pertinent to fusion research and the understanding of high-temperature plasma. The Research Materials Information Center functions as an international exchange center for information concerning ultrapure inorganic research materials. The Radiation Shielding Information Center (RSIC) specializes in the evaluation, repackaging, and distribution of shielding computer codes and maintains and distributes evaluated and processed cross-section libraries. The Biomedical Computing Technology Information Center represents an extension of the RSIC methodology to the area of nuclear medicine. The Analytic Dosimetry Program serves primarily the researchers and the research programs of the Health Physics Division of ORNL.

The increased funding in the near term shown here reflects an accelerated effort to revise and maintain the *Nuclear Data Sheets* and the start of new projects in heat transfer data collected in loss-of-coolant accident experiments and in criticality-computing technology.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 01	0.6	0.8	1.0	0.9	0.8	0.8	0.8	0.8
EE 02	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
EE 03	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
KG 10	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
RT 04	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4
WFO	0.3	0.4	0.5	0.5	0.6	0.6	0.6	0.6
Total	1.5	1.9	2.3	2.2	2.3	2.3	2.3	2.3

I.1.2 Energy-Related Research, Policy, and Safety

Included in this element are the Energy Information Center, the Energy Research, Development, and Demonstration Inventory, the Information Center for Energy Safety, and the Nuclear Safety Information Center. The Energy Information Center collaborated with ERDA's Technical Information Center in the monthly publication of *Energy Abstracts for Policy Analysis*. Future plans for the center include continued analysis and synthesis of

I.2 University Relations

manpower for the accomplishment of energy research and development programs through activities that complement those of academic institutions. These programs, while providing unique opportunities for cooperative research with the university community, fit within the Laboratory's programmatic goals and simultaneously effect a transfer of scientific and technical information. To achieve the program objectives, a multifaceted approach is employed, dependent on the academic level of the participants from the university community.

Undergraduate Programs. The Great Lakes Colleges Association (fall) science semester will be expanded to approximately 35 students and 4 faculty members, incorporating increased participation by students and faculty from the social sciences for work on projects in the energy-related areas of cost-benefit analyses and power plant siting. The Southern Colleges and Universities Union (spring) science semester is expected to continue at the present expanded level. The CoOp and Pre-CoOp programs will continue to provide on-the-job experience to engineering students who work during alternate terms of their university study. Further discussions will be held with Furman University and the University of Wisconsin at Stevens Point to explore expansion of the Environmental Sciences Cooperative Curriculum Program. The Carnegie Foundation's minority training program in biological sciences will continue. The Reactor Training Cooperative Experiments will continue at an increased level of participation to accommodate the continuing additional requests from universities seeking to take advantage of the Laboratory's unique reactor facilities.

Graduate Programs. The Massachusetts Institute of Technology (MIT) School of Chemical Engineering Practice will continue to produce first-rate chemical engineers while contributing to programmatic objectives; further discussions will be held with MIT to explore the feasibility of expanding the scope of the Practice School to include materials science, process engineering, and nuclear engineering. The summer employment programs for exceptional new graduates and graduate students will continue. Students in the University of Tennessee graduate program in ecology will employ the Environmental Sciences Division's unique facilities for research on their theses, and industrial hygiene interns engage in on-the-job training in the Health Division. The University of Tennessee Oak Ridge Graduate School of Biomedical Sciences will continue to train graduate students in the biological sciences and will initiate expansion of the curriculum to include aspects of environmental science. The Laboratory will enter into a national consortium to increase the number of minority engineering students by combining efforts with other major laboratories, graduate engineering departments, and national foundations.

Postdoctoral Programs. The Eugene P. Wigner Fellowship program will be expanded from five to ten postdoctoral fellows during its second year. The University of Tennessee Oak Ridge Graduate School of Biomedical Sciences will continue its postdoctoral programs in basic and applied biological sciences.

Faculty Participation Programs. The Laboratory's staff, together with its unique facilities (e.g., the ORIC, Aquatic Laboratory, ORMAK, Walker Branch Watershed instrumented drainage basin, ORELA, and the Biology Division's animal and virus containment facilities) will continue to accommodate the large number of faculty who participate as visiting scientists and engineers and to direct summer and sabbatical employees in cooperative research efforts. Construction of the planned heavy-ion accelerator will augment these opportunities. The summer program for training small groups of college-level instructors in health physics programs on their campuses will be continued.

Operating cost (millions of dollars)

Funding source	'76	'77	'78	'79	'80	'81	'82	'83
ERDA								
EE 04	0.1	0.1	0.3	0.4	0.5	0.6	0.7	0.8
RT 04	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
RT 02	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5
WFO								
NIH	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Others	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Total	0.9	1.0	1.4	1.4	1.6	1.7	1.9	2.0

I.3 Commercialization and Technology Transfer

An important theme of *A National Plan for Energy Research* (ERDA-76) is that private industry and market forces are the most efficient means of achieving the nation's energy goals. Through jointly funded or jointly planned programs with private industry, ERDA's aim is to establish working relationships at the earliest possible development stage of new energy technologies. ERDA-76 specifically cites the importance of interaction with small business and with the general public through public hearings, speeches, and publications.

A diverse research facility such as ORNL can interface with industry in several ways. One way is that in the process of conducting an experiment,

equipment may be developed that has commercial value. A second interface is through the involvement of private companies in the early stages of design and development of "big" technology. ORNL has been involved successfully with these types of interactions for some years.

Two examples of successful commercialization of spin-offs from ORNL research are the zonal gradient centrifuge, which is now used extensively in the development of most of the U.S. flu vaccine, and the GEMSAEC fast analyzer, which is now in wide use in clinical laboratories around the world. Several ideas or processes are now being, or may be, developed for commercial application. These include electrolytic processes for industrial waste treatment and embryo-freezing techniques that may have potential for increasing meat production. The commercialization of programs such as these will continue to be promoted through the Office of Technology Utilization/Commercialization. Most of the ideas pursued in this program have not been primarily in the area of energy and might be characterized as small technology.

On the other hand, ORNL is now involved in many big technology energy projects where there is considerable involvement by private companies. Some of these projects are in the areas of development of large superconducting magnets in the MFE program, a potassium vapor topping cycle steam generation system, and a fluidized-bed coal combustion facility. The number of these large development projects that will involve private industry cooperation is expected to increase over the next five years, especially in the areas of LMFBR fuel cycle demonstration, fossil fuel, and magnetic fusion energy. The size of these projects and others like them, along with space and personnel limitations at the Laboratory, makes Laboratory-industrial cooperation mandatory as well as highly desirable. Many of these projects will be on cost-sharing arrangements. There will be problems in this area with respect to patent rights, conflicts of interest, equitable cost sharing, and private use of government facilities. These are general problems to which we will be able to contribute because of our experience, but many of them can best be solved on a national level, and they deserve close attention by ERDA.

There remains a third area where ORNL will play a more active role over the next five years. This is with regard to ERDA's new programs—particularly in energy conservation and solar energy—wherein specific end-use energy-saving technologies and information are being developed for use in residences, appliances, small industries, and commercial enterprises. These programs are aimed specifically at the development of commercializable energy technology from which results are already, or almost, available. This includes ideas such as the ACES concept, various modes of solar-assisted heating and cooling systems, and applications of end-use conservation. Many of the problems of technology transfer here are concerned with information transfer and education. Programmatic funding may be needed to provide the specialized talents in marketing and communication necessary for successful transfer of these technologies. In the absence of programmatic funding, we will increase our efforts in commercialization. Emphasis will be given to identification, during the preparation of 189s, of programs that are soon to be ready for commercial exploitation. Increased programs for the exchange of personnel between ORNL and potential commercial developers in a given area will be established. Small pilot programs of application of engineering studies of good conservation practice in small businesses will be established. Wherever possible, these programs will be carried out in cooperation with the University of Tennessee, local governments, and economic development agencies. Much of this small technology transfer could be effectively managed through an energy extension service directed by an energy agent in a fashion analogous to the well-established Agriculture Extension Service. A pilot plan for such an extension service will be implemented by 1978.

Summary of Future Needs

In order to meet the goals outlined in this Plan, consideration will have to be given to the Laboratory's needs for major construction items, personnel, and computer capabilities. The Energy Systems Research Laboratory (ESRL), proposed for FY 1979, is shown in an architect's model at far left.

VI. SUMMARY OF FUTURE NEEDS

In this chapter, we present a realistic estimate of the resources ORNL will need to meet the goals set forth in the previous chapters of this Plan. Tabular information is given here on our required operating costs, support for facilities, major construction items, and manpower. We also discuss briefly ORNL's space and computer requirements. This section should not be viewed in any sense as a budget document. The purpose of the section is to give an approximate picture of the magnitude of various program needs.

OPERATING COSTS

In Table VI.1, a summary of the operating costs for programs at the Laboratory is given by ERDA subprograms. The information in this table is shown graphically in Figure 1 (in "Executive Summary"). The figures for FY 1977 are consistent with our best present knowledge of the FY 1977 Financial Plan for ORNL. All figures shown are in constant FY 1977 dollars. The figures here are not the sums of the budgets shown in Chap. V. As we have already pointed out, the budgets in Chap. V reflect the aspirations of individual research groups. In compiling the figures presented in this chapter, the Laboratory management has tried to make realistic estimates of the amount of these programs that will finally be approved and to impose some constraints on the total growth of the Laboratory effort in various areas.

In the past, ORNL has typically been funded at a level which is 77% of the level requested in our budget proposals. The figures shown in Table VI.1 very roughly represent that fraction of the total budgets presented in Chap. V. We have arbitrarily assumed that ORNL's research efforts in the basic energy sciences and biomedical and environmental sciences will remain constant during the period covered in this Plan. This assumption is made because, as yet, we have not been given firm guidance from ERDA on the projected trends of these programs.

The growth in budgets shown in Table VI.1 will not translate directly into growth in staff. At an increasing rate over the next few years, the national laboratories will assume a management role in ERDA's RD&D program. Large fractions of some programs will be put out on subcontracts to private industry and universities. We estimate that by FY 1983, $60 to $70 million of our operating budget will be spent outside the Laboratory.

FACILITIES

In Table VI.2, the estimates of adequate funding for the maintenance and development of ORNL's plant and equipment are presented.

Programmatic Equipment

We believe that reasonable levels of support for programmatic capital equipment are 10% of the operating funds for established programs and 20% of the operating funds for new programs. In the past, ORNL's capital funds have been well below these levels. In FY 1976, our programmatic equipment budget was 6.5%. We strongly recommend a more liberal policy with respect to programmatic capital funds. Our needs are estimated in Table VI.2.

General-Purpose Equipment

Because of inadequate funding for general-purpose equipment (GPE), much of our equipment is obsolete, and we have been forced to expend operating funds for maintenance on equipment that should have been replaced. The GPE funding has not allowed us to comply with ERDA criteria for replacement of equipment. Our estimated GPE needs are also shown in Table VI.2.

General Plant Projects

In addition to providing funds for the needed expansion of office space, General Plant Project (GPP) funds are needed for improvements and minor additions to existing research facilities, for general plant improvements, and to provide adequate utility services. The need to increase funding for General Plant Projects has been described in the Hack Report.[1] Our GPP funds have been inadequate for a number of years, and a significant increase in the funding level is urgently needed. The estimated GPP needs for the Laboratory are given in Table VI.2.

In a large plant such as ORNL, there is a large potential for reduced operating cost and reduced fuel consumption through good energy conservation projects. ORNL has made significant progress in the last few years in conservation through lowered thermostats, reduced lighting, etc. The greatest potential savings now are available through the installation of automated energy systems controls. We estimate that ORNL can make cost-effective improvements to our energy system through the use of GPE and GPP funds at the rate of

1. *Review of General Support Facilities for ORNL Research Programs (FY 1976-FY 1981)*, May 16, 1975.

Table VI.1. Summary of operating cost (millions of dollars [a])

		1977	1978	1979	1980	1981	1982	1983
B. Fossil energy								
BA	Coal	8.0	14.0	24.0	34.0	40.0	45.0	50.0
BB	Petroleum and natural gas	0.6	0.7	0.6	0.6	0.4	0.4	0.4
BC	In-situ technology	0.2	0.3					
		9.0	15.0	25.0	35.0	40.0	45.0	50.0
E. Solar, geothermal, and advanced energy systems								
EA	Solar energy	0.6	0.8	1.2	1.5	1.7	1.9	2.0
EB	Geothermal energy	1.1	1.3	1.4	1.5	1.5	1.5	1.5
EC	High energy physics	0.4	0.4	0.4	0.4	0.4	0.4	0.4
ED	Magnetic fusion energy	31.0	40.0	50.0	55.0	60.0	62.0	62.0
EE	Basic energy sciences [b]	34.0	34.0	34.0	34.0	34.0	34.0	34.0
		67.0	77.0	87.0	92.0	98.0	100.0	100.0
H. Conservation								
HA	Electric energy systems	0.5	0.6	0.7	0.8	0.9	0.9	0.9
HB	Transportation energy conservation	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HC	Energy storage systems	0.7	1.3	1.9	2.0	2.2	2.4	2.4
HD	Buildings and community systems	2.5	3.0	3.5	3.8	4.1	4.3	4.3
HE	Interprogram activities		0.8	0.8	0.9	1.0	1.1	1.1
HF	Conservation research and technology	0.1	0.7	0.7	0.8	0.9	0.9	0.9
HG	Industrial systems	0.3	0.7	1.0	1.9	2.1	2.3	2.3
		4.0	7.0	9.0	10.0	11.0	12.0	12.0
K. Nuclear energy development								
KG	LMFBR	12.0	13.0	16.0	16.0	15.0	14.0	12.0
KJ	Nuclear research and applications	10.0	11.0	13.0	16.0	14.0	13.0	13.0
KX	Fuel cycle R&D	18.0	28.0	33.0	36.0	39.0	39.0	37.0
KZ	Special nuclear materials	3.6	6.0	6.0	5.0	4.0	4.0	4.0
		44.0	58.0	68.0	74.0	72.0	70.0	66.0
R. Biomedical and environmental sciences [b]								
RT	Biomedical and environmental research	23.0	23.0	23.0	23.0	23.0	23.0	23.0
RU	Environmental control technology	0.8	0.8	0.8	0.8	0.8	0.8	0.8
RW	Operational safety	1.2	1.2	1.2	1.2	1.2	1.2	1.2
		25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Total ERDA	149.0	182.0	214.0	236.0	246.0	252.0	253.0
	Total work for other agencies	38.0	38.0	37.0	35.0	31.0	28.0	27.0
		187.0	220.0	251.0	271.0	277.0	280.0	280.0

[a] All budgets are in constant FY 1977 dollars.

[b] Budgets assumed to be constant, pending further guidance from ERDA.

Table VI.2. Facilities

	1977	1978	1979	1980	1981	1982	1983
Programmatic capital equipment	13.0	21.0	24.0	26.0	27.0	28.0	28.0
General plant projects[a]	3.7	5.8	5.6	6.2	6.4	7.3	6.5
General-purpose equipment[a]	2.2	3.9	4.1	4.2	4.2	4.2	4.3
Computers			12.0			12.0	
Experiments constructed on expense	13.0	26.0	30.0	29.0	24.0	22.0	21.0

[a]Includes $0.5 million/year designated for plant energy conservation projects.

$0.5 million/year. The budget projections for both GPE and GPP funds in Table VI.2 include $0.5 million/year designated funds for energy conservation.

Computer Equipment

During the past year, an ad hoc committee was established to formulate a long-range plan for computing facilities at ORNL.[2] The committee consisted almost entirely of computer users. They first surveyed as many computer users as possible from the Laboratory staff to determine their estimates of computer requirements over the next five years. From the survey results, a projection of the total computer needs over the next five years was constructed. The projection of the total batch computing capability needed by all Union Carbide Corporation Nuclear Division operations in Oak Ridge is shown in Figure 3. The projected total UCCND needs for interactive computing capability are shown in Figure 4. The ORNL fraction of the total batch computing use in FY 1976 is 60%, and it increases to 86% in FY 1982. The ORNL fraction of interactive computing in FY 1976 is 39%, and it increases to 86% in FY 1982. The existing batch computing facilities were essentially saturated at the end of calendar 1976. The interactive capability has been greatly oversaturated. The addition of a PDP-10 KL-10 central processor early in FY 1977 is expected to provide adequate interactive computing in FY 1977.

The largest users of the batch computing facilities at ORNL in FY 1976 were Neutron Physics Division (35%) and Fusion Energy Division (17%). These same groups will be the largest users in FY 1982; Neutron Physics Division will generate 27% and Fusion Energy Division will generate 51% of the total batch computing need for FY 1982. For interactive computing, the Fusion Energy Division will play an even more dominant role. It is estimated that they will generate 80% of the interactive computing demand by FY 1982. Perhaps the largest uncertainty in these projects is the impact of relatively young programs in environmental sciences or information processing, which have a large potential for growth.

Based on these projected needs, an acquisition schedule for computing facilities has been recommended. The biggest items on the acquisition schedule are an interactive computer in the class of the IBM 370/168 in FY 1977 and a next-generation batch computer, such as the CRAY-1 machine, in FY 1979. In Figures 3 and 4, the dashed lines show the available computer capacity as a function of time, if this acquisition schedule is met. These figures show that if the new facilities are added on schedule, there will be computing capacity adequate to meet our needs over the next few years. However, the computer specified for FY 1977 has already been moved to the FY 1979 budget request, and the FY 1979 computer will be pushed back at least until FY 1982. There will be a significant computer shortage over the next several years. A temporary solution will be to shift some of the load to computers at other installations not yet saturated.

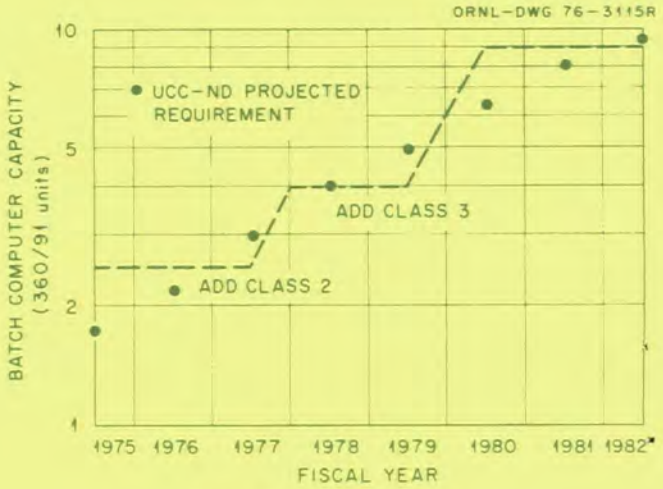


Figure 3. Batch Computing.

2. *Computing Facilities Long Range Plan—Oak Ridge National Laboratory 1976-1982*, March 1976.

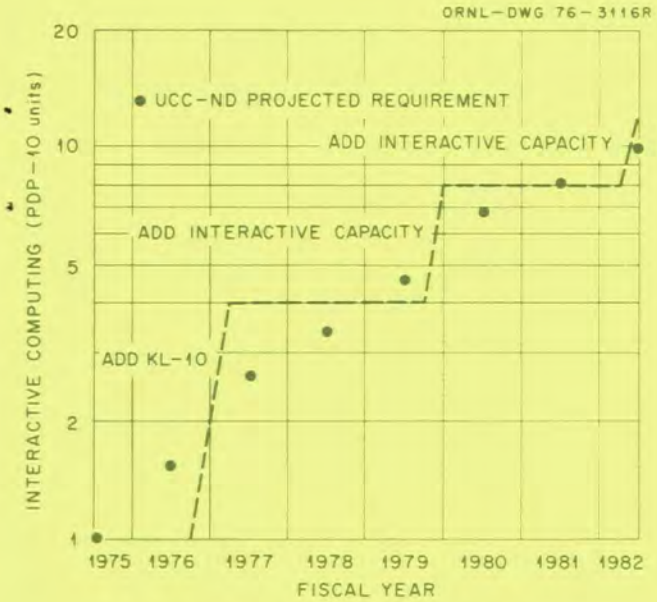


Figure 4. Interactive Computing.

Each of the proposed new computers will cost approximately $12 million.

Experiments Constructed on Operating Expense

There are several projects at ORNL that involve the construction of large equipment on operating expense. These include particularly the nuclear fuel cycle program, the Fusion Energy Division program, and potentially the fossil energy program. Our estimates of these expenditures are given in Table VI.2. This is additional operating money, which will not result in personnel growth.

Major Construction Line Items

The implementation of our new and expanded research and development programs will depend on the availability of new facilities. Our current planning on major facilities is detailed in Table VI.3. The projects are listed according to the year in which authorization will be requested. This list is highly speculative in the later years. However, the list includes projects we believe we are competent in and would like to undertake. Because the prospects for any one project are so uncertain, it is necessary to include them all.

Personnel and Space

The projected number of regular full-time employees at ORNL for the period FY 1977 to FY 1983 is shown in Table VI.4. The information in this table is shown graphically in Figure 2 (in "Executive Summary"). The personnel are projected for each ERDA program with the exception of Solar, Geothermal, and Advanced Energy Systems. In that case, the personnel are projected by subprogram because several of our major programs are in this one ERDA program. In addition to the personnel included in these projections, there are a large number of employees of UCCND's Computer Sciences and Engineering Divisions, temporary employees, and guests who are housed at ORNL. In FY 1977, there are about 1000 people in these categories at ORNL.

The projections shown in Table VI.4 are realistic estimates of the personnel growth in the indicated programs. An average overall Laboratory staff growth of 2% has been assumed between FY 1978 and FY 1983. We have taken into account the fact that significant parts of some programs, primarily fusion and nuclear energy development, will be subcontracted outside the Laboratory or significant fractions of their operating funds will be for construction.

The personnel projections show a relatively modest increase in staff at ORNL by FY 1983. However, there already exists a serious space problem at ORNL. There is a shortage of offices, and many of the offices now in use are in antiquated buildings that must be replaced. Consideration is being given to renting private office space in downtown Oak Ridge to obtain some immediate relief from the space problem. We plan to obtain ultimate relief from space problems by constructing modular office buildings through GPP funding and some construction line items as discussed below.

At present, roughly 20% of the ORNL staff is housed at the Y-12 site. The remaining 80% is at the X-10 site. We review briefly here our plans for space development at each site.

Y-12 Site

The Biology, Fusion Energy, and Engineering Technology Divisions are housed at the Y-12 site; and the Chemical Technology, Analytical Chemistry, and Energy Divisions are partially housed at that site. An analysis[3] of the facility requirements for ORNL in the Y-12 area through FY 1979 indicated that programmatic growth in the Biology Division through FY 1979 can be accommodated by proposed modification, rehabilitation of facilities,

3. Letter from R. F. Hibbs (UCCND) to R. J. Hart (ERDA, ORO), August 22, 1974.

Table VI.3. Major construction line items (millions of dollars)

Project	Funds						Total estimated cost
	Pre 1976	FY 1976	FY 1977	FY 1978	FY 1979	After FY 1979	
Holifield Heavy Ion Research Facility	7.4	10.1					17.5
Upgrade laboratory facility—9207	0.7	1.4					2.1
Intermediate-level waste facility	4.6	5.9					10.5
Chemical mutagenesis test facility	0.3	0.6					0.9
Environmental Sciences laboratory	1.2	7.3					8.5
Improvements to ORELA		0.4					0.4
Biomedical laboratory		1.2					1.2
Safeguards and security upgrading		5.9					5.9
Conversion of steam plant facilities			10.2				10.2
Energy pollutant control system, Biology Division				1.9			1.9
New hydrofracture facility				5.4			5.4
LMFBR integrated prototype equipment test facility				3.0	13.0		16.0
Addition to aquatic ecology laboratory				1.5			1.5
Toxicology laboratories				1.5			1.5
Improvements in thermonuclear research supporting facilities					10.8		10.8
Energy Systems Research Laboratory (ESRL)					28.0		28.0
Addition to the Oak Ridge Isochronous Cyclotron building					1.3		1.3
Modifications aimed at compliance with OSHA					3.0		3.0
Holified Heavy Ion Research Facility—Phase II					27.0		27.0
Modification of facilities for energy conservation					1.5		1.5
LMFBR—FR Hot Pilot Plant					50.0		50.0
Thermal shock test facility					3.4		3.4
Solid waste/decontamination facility					20.0		20.0
HTGR fuel recycle hot engineering test facility					13.6		13.6
Coal equipment test facility						20.0	20.0
Additions to cafeteria						3.0	3.0
Stores facility modifications						3.4	3.4
Toxic substance laboratory and animal facility						11.5	11.5
Pulsed neutron source—ORELA						15.7	15.7
Transplutonium isotopes separations facility						6.3	6.3
Engineering technology building						6.8	6.8
High-temperature materials laboratory						10.0	10.0
Information center complex						10.0	10.0
High-level alpha engineering facility						12.0	12.0
Renovation of 3504 transuranics research facility						1.0	1.0
Mammalian genetics facility addition to 9210						4.5	4.5
Materials science building						9.0	9.0

Table VI.4. Full-time equivalent manpower[a]

Program	1977	1978	1979	1980	1981	1982	1983
B. Fossil	190	350	500	650	750	820	880
E. Solar, geothermal, and advanced energy systems	1570	1650	1730	1790	1800	1810	1810
EA Solar energy	20	25	35	40	50	55	55
EB Geothermal energy	30	35	40	40	40	40	40
EC High energy physics	10	10	10	10	10	10	10
ED Magnetic fusion energy	560	630	695	750	750	755	755
EE Basic energy sciences[b]	950	950	950	950	950	950	950
H. Conservation	80	100	120	130	140	150	150
K. Nuclear energy development	1130	1180	1200	1150	1100	1050	1030
R. Biomedical and environmental sciences[b]	730	730	730	730	730	730	730
Total ERDA	3700	4010	4280	4450	4520	4560	4600
Total work for others	700	630	570	530	510	510	500
	4400	4640	4850	4980	5030	5070	5100

[a]Full-time equivalent manpower includes all regular full-time employees on ORNL payroll. In 1977, there are at ORNL an additional 1000 people who are guests, temporary employees, or personnel from the Union Carbide Corporation Nuclear Division Computer Sciences and Engineering Divisions.

[b]Assumed to be constant, pending ERDA guidance.

and planned new facilities entirely within the present biology complex at Y-12. The expansion of programs in the Fusion Energy Division will require modification and considerable renovation of Buildings 9201-2 and 9204-1 to provide needed laboratory and office space. The Engineering Technology Division needs can be met with the proposed Engineering Technology Laboratory and the upgrading of existing space in Buildings 9201-3 and 9204-1. Anticipated new space requirements of the other ORNL divisions at Y-12 are relatively modest and can probably be accommodated in existing facilities.

X-10 Site

A serious shortage of office space at ORNL will exist if our GPP funds are not adequate and if our line items are not given timely approval. A major facility, the Environmental Sciences Building, is now under construction and should meet our most pressing needs. We have proposed an Energy Systems Research Laboratory (ESRL) as a line item in FY 1979, and we will propose an Information Center Complex building sometime after FY 1979. The Laboratory's space needs should be met with these three buildings, plus the rental of some private offices, as discussed previously.

CL 2

Coastal Research Library

MAY 3 - 1977