DOE/US-0002-2

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Energy Materials Coordinating Committee (EMACC)

Fiscal Year 1979

Annual Technical Report

U.S. Department of Energy

Materials Sciences Division

The Materials Sciences Division reports to the Director of the Office of Energy Research through the Associate Director for Basic Energy Sciences. The objective of the Materials Sciences program is to conduct fundamental research aimed at increasing the understanding of materials and materials related phenomena of interest to the Department of Energy. Research is conducted primarily at DOE laboratories, universities and to a lesser extent in industry.

This program is basic or long range in nature and is intended to provide the necessary base of materials knowledge ultimately needed to advance our energy technologies. Emphasis is placed on areas where problems are known to exist or are anticipated and on generic areas of fundamental importance. Another aspect of the program is the development and utilization of unique facilities used not only by DOE contractors but also by other laboratory, university and industry scientists. Among these facilities are several which will begin operation in mid-FY 1981, the Intense Pulsed Neutron Source-I (IPNS-I) at Argonne, the National Synchrotron Light Source (NSLS) at Brookhaven and the nation's highest voltage electron microscope (1.5 MeV) at Lawrence Berkeley Laboratory. These facilities and others are set up as user-type facilities where qualified scientists from outside the Materials Sciences program at that laboratory can take advantage of equipment and expertise developed.

Some of the research is directed at a single energy technology (e.g., photovoltaic materials for direct conversion of solar energy into electricity), whereas other research is applicable to many technologies simultaneously (e.g., the embrittlement of structural materials due to the presence of hydrogen) and still other has more fundamental implications underpinning all materials research (e.g., mechanisms of atomic transport in solids).

At the DOE laboratories, technology and information transfer takes place between the basic and applied programs co-sited there. The Materials Sciences subprogram also supports research at universities and to a lesser extent industrial laboratories, taking advantage of the unique expertise of researchers at each of the different types of institutions. Coordination of DOE's applied materials development efforts with the Materials Sciences program takes place primarily through the DOE Energy Materials Coordinating Committee (EMaCC), but also through Materials Sciences Research Assistance Task Forces and less formal contacts among staff members. The program utilizes workshops and reports of its Council on Materials Science (a non-governmental body with representatives from academia, industry and DOE laboratories) to help focus on critical issues.

For example, in FY 1981, the Council reviewed research needs and opportunities in the areas of amorphous materials and nondestructive evaluation; in FY 1980, corrosion and novel materials were examined. A relatively large portion of program funds (called contact research) is set aside to support unsolicited proposals.

The following program description is separated into three major categories which represent the separation by major disciplines involved and the administrative units in the program: A) Metallurgy and Ceramics, B) Solid State Physics and C) Materials Chemistry.

Further information can be obtained by contacting Dr. D. K. Stevens, Director, Division of Materials Sciences (301-353-3427), Dr. M. C. Wittels, Branch Chief, Solid State Physics and Materials Chemistry or Dr. L. C. Ianniello, Branch Chief, Metallurgy and Ceramics. A more complete description of the 392 projects is given in an annual publication of the Materials Sciences Division - the most recent is Materials Sciences Programs, FY 1980, DOE/ER-0064. The FY 1980 operating level of the Materials Sciences Division was $78.0 million.

Overall funding levels by contractor are given in Table I, and a summary of funding by selected topical areas is given in Table II. It should be noted that Table II is not meant to be inclusive with regard to subjects under study in the program and also the subjects listed are not mutually exclusive. Table III provides a breakdown of the funding by universities, laboratories and industry. In Table IV, an estimate of funding associated with various technologies is given.

TABLE I - Funding by Contractor

	Total Program (%)
Ames Laboratory	7.8
Argonne National Laboratory	21.6
Brookhaven National Laboratory	10.8
Idaho National Engineering Laboratory	0.6
Illinois, University of (Materials Research Laboratory)	2.8
Lawrence Berkeley Laboratory	7.0
Lawrence Livermore Laboratory	1.5
Los Alamos Scientific Laboratory	2.6
Mound Laboratory	0.3
Oak Ridge National Laboratory	20.7
Pacific Northwest Laboratory	2.2
Sandia Laboratory	2.5
Solar Energy Research Institute	0.3
Contract Research	19.3
	100.0

TABLE II - Funding by Selected Areas of Research

	Number of Projects (Total=392) (%)	Total Program $ (%)
(a) Materials		
Polymers	5.6	1.8
Ceramics	31.4	17.2
Semiconductors	12.5	7.9
Hydrides	8.9	5.2
Ferrous Metals	18.1	10.9
(b) Technique		
Neutron Scattering	8.7	16.5
Theory	18.6	9.0
(c) Phenomena		
Catalysis	8.4	4.9
Corrosion	9.4	13.1
Diffusion	16.1	6.6
Superconductivity	11.2	7.4
Strength	21.7	9.9
(d) Environment		
Radiation	14.0	12.5
Sulphur-Containing	5.9	3.0

TABLE III - Funding by Economic Sector

	Percent
Universities (Including those DOE university laboratories where graduate students are involved to a large extent, e.g., LBL and AMES.......	36.1
DOE Laboratories....................................	63.3
Industry and Other..................................	0.6
	100.0

TABLE IV - Funding by Technology (Estimates Only)

Technology Area	Percent
Conservation and Storage	8.0
Fossil Energy	9.2
Solar Energy	6.8
Geothermal Energy	1.7
Fission	7.2
Fusion	8.3
Environment and Safety	1.1
Multitechnology	30.7
Long-Term Science	27.0
	100.00

A. Metallurgy and Ceramics

The objective of research conducted under the metallurgy and ceramics category is primarily to better understand how metallic and ceramic materials behavior/properties are related and controlled by structure and processing conditions. By processing is meant the methods and techniques used to prepare, form or fabricate materials. Important properties of materials such as fracture, plastic flow, superconductivity, corrosion resistance, radiation resistance, and transport phenomena all depend on structure. As a consequence of this improved understanding, better materials and a greater ability to predict behavior of materials in energy systems will eventually be possible. Although basic in nature, the program is centered around research areas deemed to be of greatest interest for energy systems. For example, there is within the metallurgy and ceramics category a strong emphasis on hydrogen effects, radiation effects, corrosion, creep and high temperature deformation, high temperature ceramics, and superconductivity.

There are five budget areas under the Metallurgy and Ceramics category: structure of materials, mechanical properties, physical properties, radiation effects and engineering materials.

The structure of materials area supports research designed to enhance our understanding of the atomic, electronic, defect and microstructure of materials, how they are affected by chemical composition and processing, and how they relate to material properties.

The budget area of mechanical properties is concerned with material behavior related structural integrity requirements of all energy systems. Research addresses the understanding of strength at high and low temperatures, creep, fatigue, elastic constants, micro- and macrostrain, fracture, and mechanical-chemical effects in hostile environments.

Research under the physical properties area is directed toward understanding the fundamental phenomena controlling thermal, optical, mass transport, and electrical properties of materials, how they can be altered by various heat treatments or other processing steps, and how they are affected by external variables such as temperature and pressure.

The radiation effects area encompasses research delineating radiation induced changes of materials properties important to fusion and fission energy concepts. The effect of irradiation, both neutron and ion, on mechanical properties, structure and electrical properties is studied in this area.

In the engineering materials area, research is aimed at understanding more fully the complex materials and phenomena generally associated with real world materials problems. Some of the topics under study include: erosion, friction and wear, engineering corrosion and fracture, welding and joining, nondestructive evaluation, and the forming and processing of materials.

B. Solid-State Physics

The solid-state physics category is directed toward fundamental research on matter in the condensed state, wherein the interactions of electrons, atoms, and defects are tracked with the purpose of determining the critical properties of solids. These interactions are the ultimate source of all materials properties. Research under this category includes a broad spectrum of experimental and theoretical efforts, which contribute basic solid-state knowledge important to all energy technologies. Accelerated progress is made in this field through the rapid advancements in unique experimental tools and their coupling with high-speed computer systems. Through these efforts, fundamental understanding of matter in the condensed state contributes broadly to characterizing material properties and processes important for all energy technologies.

There are five budget areas within the solid-state physics category: neutron scattering, experimental research, theoretical research, particle-solid interactions, and engineering physics.

The neutron scattering area supports research of a unique kind, namely the use of the neutron as an analytical probe of the properties of solids and liquids. With this probe, fundamental parameters of superconductors, magnets, hydrides, and solid imperfections are determined in a manner that cannot be accomplished by any other technique. The exploitation of this probe is being advanced by recent development of more efficient monochromators and wider use of longer wavelength probes. The bulk of the Nation's efforts in this important area has historically been supported at DOE laboratories, where the advanced research reactors are in operation.

The experimental research area is very broad and includes all fundamental investigations, experimental in concept, on liquids and solids of metals, alloys, semiconductors, insulators, and compounds. The area of high-temperature materials in both metals and nonmetals, for all high-temperature energy systems is being pursued. Ion implantation and backscattering research is being used to learn how to improve superconductor and photovoltaic performance. Hydrogen and hydrides are under study through ultrahigh-pressure and spectroscopic techniques. Synchrotron radiation is utilized in characterizing surfaces with particular relation to catalytic response.

With nearly all these experimental areas, a highly advanced theoretical research program is closely coupled. A large part of the theoretical effort is directed towards dynamic processes in solids and liquids and requires extensive use of DOE's most advanced computer complexes.

Under particle-solid interactions, a major effort is under way to correlate the complex effects of particles of different mass, energy, and charge, not only on surfaces but in bulk materials as well.

The engineering physics area supports research to fulfill the much needed goal of utilizing solid state physics expertise in engineering research for which it has a unique capability. Typical of the work initiated are research laboratory investigations of novel processing techniques with mass spectrometer-computer control for complex material preparation, such as solar materials and superconducting alloys. Another area is the extension of cryogenic and refrigeration techniques to new fluid systems that hold promise for the utilization of low-grade heat.

C. Materials Chemistry

The materials chemistry category provides support for research directed toward developing our understanding of the chemical properties of materials as determined by their composition, structure, and environment (pressure, temperature, etc.) and to show how the laws of chemistry may be used to understand physical as well as chemical properties and phenomena. Included, for example, are studies of energy changes accompanying transformations, the influence of varying physical conditions on rates of transformations, and the manner in which the structure of atomic groupings influences both properties and reactivity.

Chemical concepts coupled with physical experimental techniques are used to study the kinetics of reactions of solids and liquids, the interaction and/or penetration of species in adjacent media, corrosion, phenomena and the stability of high-temperature materials of interest to fossil and geothermal technologies. The program also includes research on the chemical thermodynamics of fission products and their interactions with fuels and cladding materials. Electrochemical is an important aspect of research supported under this category. Research involving elastomers and polymers is also being pursued.

There are three budget areas in the materials chemistry category: structural chemistry, engineering chemistry, and high-temperature and surface chemistry.

Structural chemistry involves studies of a wide variety of problems where a knowledge of the relationship between the atomic structures of materials and their reactivity is required. Important examples of these effects include the influence of difference chemical environments on the catalytic properties of metals. Changes in both the crystal and magnetic structures of compounds are correlated with their specific roles in fuel synthesis, for example.

The methods of engineering chemistry are applied to problems that are currently limiting the efficiency of energy conversion systems. Examples of research underway include: structural and morphological changes that arise during the charge-discharge cycles of the high-temperature battery and studies of tritium permeation of oxide films.

The high temperature and surface chemistry area includes programs on fundamental studies of the influence of surface properties on reactivity. The correlation of mass transport and thermodynamic properties of molten salts in high-temperature battery systems and chemical studies of the influence of micro-inclusions such as sulfides on the formation of pits and crevices to determine whether these inclusions play a significant role in the initiation of stress-corrosion cracking are examples of research underway.

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INTRODUCTION

This report contains information on the Department of Energy's FY 1979 materials research and development programs. It was compiled by the Energy Materials Coordinating Committee (EMaCC). The previous report in this series contained the FY 1978 programs (DOE/US-0002).

The Energy Materials Coordinating Committee (EMaCC) is an internal Department of Energy committee set up to assist coordination of materials research and development activities. It functions primarily by means of the information exchange mechanism and by sponsoring certain activities such as this compilation. Table I contains the membership roster responsible for the various writeups in this report. Table II summarizes the funding levels for each of 25 programs concerning materials research in the Department of Energy (DOE). The report is separated into sections, each containing programs reporting to one of six Assistant Secretaries of DOE: Environment, Defense Programs, Nuclear Energy, Fossil Energy, Conservation & Solar Energy and Resource Applications, and one section reporting to the Director of the Office of Energy Research. In the appendix is a brief index for major programmatic topics of interest to EMaCC members.

Arnold P. Litman of the Advanced Nuclear Systems & Projects Division was elected EMaCC Chairman for FY 1980.

Louis C. Ianniello
FY 1979 EMaCC Chairman

TABLE I
EMaCC MEMBERS
SEPTEMBER 1979

MAIL STOP		NAME	ALTERNATE	DIVISION/OFFICE	PHONE
EV-32	E-201	1. G. Goldstein		Health & Envir. Res.	353-5348
CS-40	2221C	2. Collins, J.	Natof, S.	Industrial Programs	252-2366
EV-13	E-201	3. Counts, J.		Envir. Control	353-5487
ET-62	C-156	4. Dapkunas, S.		Planning & Sys. Eng. (FE)	353-2784
ET-58	2203	5. Eaton, R.		Electric Energy Sys.	376-4727
ET-67	E-178	6. Fairbanks, J.	Neal, J.	Fuel Utilization	353-2816
ET-761	B-107	7. Fox, J. E.		Nuclear Power Devel.	353-5839
CS-30	2221C	8. Freeman, E.		Bldgs. & Community Sys.	376-4888
ET-56	400 600 E	9. Gutstein, M.		SolarTechnology	376-1937
DP-282	A-362	10. Hughes, F. (CDR)		Military Appl.	353-5494
ET-786	B-107	11. Hunter, J.		React. Res. & Tech.	353-5233
RC-603	A-362	12. Jenson, N.		Solid Fuel Mining	353-2722
RA-221	6521	13. Jones, R. A.		Uranium Enrichment	633-9093
ET-771	B-107	14. Litman, A.	Tarr, C. O.	Adv. Nuc. Sys. & Projects	353-5777
CS-63	2221C	15. Maybaum, M.		Solar Applications	376-9642
ET-68	F-338	16. Raring, L.		MHD	353-5915

MAIL STOP		NAME	ALTERNATE	DIVISION/OFFICE	PHONE
ET-57	3122C	17. Reeber, R. R.		Geothermal	376-4899
DP-43	C-404	18. Rossi, C. E.		Laser Fusion	353-3531
ET-59	404 600 E	19. Ruby, S.		Energy Storage	376-9311
CS-810	2221C	20. Schulz, Robert		Transportation Programs	376-4684
ET-75	NR 4E38	21. Steele, R. H.		Naval Reactors	557-5561
ER-15	J-309	22. Stevens, D. K.	Ianniello, L. C.	Materials Sciences	353-3428
ET-87	G-234	23. Zwilsky, K. M.	Dalder, E.	Fusion Energy	353-4961

TABLE II

FY 1979 MATERIALS R&D FUNDING LEVELS, EMaCC ANNUAL TECHNICAL REPORT

ASSISTANT SECRETARIAL DIVISION/OFFICE	(M$)		Corrosion
Environment		1.00	
Environmental Control Technology	1.00		0
Health & Environmental Research	0		0
Energy Research		80.61	
Advanced Technology Projects	0.35		0
Magnetic Fusion Energy	10.36		0
Materials Sciences	69.90		5,400
Defense		73.90	
Inertial Confinement Fusion	6.50		0
Military Application	67.40		250
Nuclear		94.13	
Reactor Research & Technology	31.98		1000
Advanced Nuclear Systems	5.50		0
Naval Reactors	38.00		2000
Nuclear Power Development	8.65		500
Nuclear Waste Management	10.00		1000
Fossil		32.05	
Fuel Utilization	20.00		2000
MHD	3.00		500
Planning & Systems Engineering	7.35		2000
Solid Fuel Mining	1.70		
Conservation and Solar Energy		76.06	
Solar Technology	50.65		1500
Transportation	11.18		
Industrial Programs	1.70		
Energy Storage	10.40		2000
Buildings & Community Systems	1.06		
Solar Applications	1.07		500
Resource Applications		13.64	
Geothermal	7.14		500
Uranium Enrichment	2.10		
Electric Energy Systems	4.00		19,150
TOTAL		371.39	

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ENVIRONMENT

ENVIRONMENTAL CONTROL TECHNOLOGY

This division is located in the Office of Environmental Compliance and Overview under the Assistant Secretary for Environment. The materials related activity supports an independent assessment of the adequacy of shipping container systems for radionuclides. Projects are simulating impact accident conditions (at the drop pad test facility at ORNL), developing computer codes (LASL) and scale models (BNL), and describing material deformation behavior using endochronic plasticity (ANL). Materials studied are Pb, Al, U-238 and steels. In addition, an assessment of materials for handling liquid hydrogen is being considered. The FY 1979 materials related effort is about 1.0 million dollars.

HEALTH AND ENVIRONMENTAL RESEARCH

The Office of Health and Environmental Research reports to the Assistant Secretary for Environment. The Environment program is concerned with effects of energy technologies on the environment. It conducts research on environmental, health and safety. Materials R&D in the Office of Health and Environmental Research is limited to CdTe and Si semiconductors used for detectors.

ENERGY RESEARCH

ADVANCED TECHNOLOGY PROJECTS DIVISION

The Advanced Technology Projects Division reports to the Director of the Office of Energy Research through the Associate Director for Research Policy. The objective of the Advanced Technology Projects program is to initiate novel and innovative projects which are either not completely within the purview of one of the DOE mission-oriented programs or have too high a risk factor for DOE mission-oriented programs to consider. After a few years' development, if successful, projects are turned over to DOE engineering development programs or, possibly, to industry. Research is conducted in industry, both large and small, in universities, and in DOE laboratories. Some projects are co-funded with other DOE divisions, where appropriate, some projects are co-funded with other government agencies, while still other projects are cost-shared with industry.

The ATP Project funded presently for FY 79 follows.

ORNL
Technology Development of Ordered Alloys for Advanced Energy Systems
(A.C. Schaffhauser, C. F. Liu, H. Inoye) $350

Improve properties of Fe and Co-based LRO alloys by varying alloy composition. Extend the high-temperature mechanical property data base including tensile, creep, fatigue, and impact properties and study deformation mechanisms by electron microscope. Determine the corrosion behavior of selected alloys in neutral, carburizing, oxidizing, and sulfidizing environments.

Materials Development for Fusion Reactors

The primary objectives of the Materials Program of the Office of Fusion Energy, DOE, are: (a) development of materials and the understanding of materials behavior which will assure plasma integrity and the structural integrity of the first wall of a fusion reactor; (b) development of special purpose materials that are required for magnetic confinement, heat transport, energy conversion and storage, and other functions of specific fusion systems; and (c) materials engineering support for the continuing development program.

Successful economic operation of commercial fusion reactors depends on the development of materials capable of withstanding the severe radiation environment resulting from the deuterium-tritium (D-T) fusion reaction. The first wall of a fusion reactor will be subjected to bombardment by neutrons, charged and neutral particles, electrons, and photons. Although the total neutron flux in fusion reactors may be less than in fission reactors, high energy neutrons produce from 3-4 times the damage of fission neutrons and result in high transmutation rates which lead to helium and hydrogen contents in structural materials 20-180 times as great as those produced in fission reactors; this results in greatly accelerated materials degradation.

The Fusion Materials Program is made up of six key areas:

Alloy Development for Irradiation Performance is the largest element of the Program and includes the development of materials which must operate reliably in the fusion reactor environment. The objective of this is to provide the materials development for those structural materials that will be subject to significant radiation damage, including the first wall and structural elements for the blanket and shield of a commercial fusion power reactor. The FY 79 operating budget level is $2.26M.

Contractors: ANL, HEDL, MIT, McDonald-Douglas, ORNL, and NRL

Radiation Facilities Operation - The objectives of this area are to define the radiation environment of fusion reactors and to pursue the development of neutron and plasma sources to simulate this environment for materials testing. Since fusion reactors are not now available for testing, high-energy neutron and plasma sources are needed to develop materials for commercial fusion power. The two principal irradiation facilities utilized are the Oak Ridge Research Reactor (ORR) - a thermal reactor facility - and the Rotating Target Neutron Source (RTNS-II) - a 14 MeV irradiation facility captive to the Fusion Program. Other facilities include the Experimental Breeder Reactor (EBR-II) and the High Flux Isotope Reactor (HFIR). The Fusion Materials Irradiation Test Facility (FMIT), a high flux, high-energy, broad-spectrum neutron source will be utilized when it becomes available in FY 84. The FY 79 operating budget level is $2.07M.

Contractors: ANL, LLL, ORNL

Damage Analysis and Fundamental Studies supports the alloy development work. The objectives of the Damage Analysis and Dosimetry area are to characterize available irradiation test environments and to establish a basis for predicting materials performance under irradiation in a fusion reactor environment. This will be accomplished by materials irradiation data obtained in fission reactors, accelerator-based neutron test environments, and charged particle irradiations. The FY 79 operating budget level is $2.0M.

Contractors: ANL, AI, BNL, HEDL, LLL, LASL, ORNL, PNL, Westinghouse, University of California (SB), University of Virginia, University of Wisconsin

Plasma-Materials Interaction relates primarily to processes occurring at the surface of the first wall including interaction with hydrogen, helium, photons, electrons, residual gases, metallic ions, and neutrons. The objectives of the Plasma/Materials area are to minimize the damage to surfaces exposed to plasmas, to minimize the associated release of metallic and gaseous impurities, to control hydrogen re-cycle between plasma and wall, and to control surface processes occurring in the components and sub-systems of fusion experiments and reactors. Included in this work is the development of improved limiter and beam dump materials. The FY 79 operating budget level is $2.28M.

Contractors: ANL, General Atomic, ORNL, SLA, SLL, Columbia University, Georgia Institute of Technology, University of Wisconsin

Special Purpose Materials, is primarily concerned with materials development outboard of the first wall, including: (i) insulators in structural applications, (ii) insulators for components such as neutral beams and superconducting magnets, (iii) moderator and breeding materials, (iiii) materials for heat transfer systems and power-conversion (secondary) systems. The FY 79 operating budget level is $545K.

Contractors: LLL, LASL, ORNL, PNL

Materials for Magnet Systems are being studied for the development of superconducting magnets. Most of the work is intimately tied to magnet development for plasma containment. The FY 79 operating budget level is $1.2M.

Contractors: NBS, BNL, ORNL

Information Available

- *Program plans in the areas of Alloy Development for Irradiation Performance, Damage Analysis and Dosimetry, Special Purpose Materials, and Plasma-Materials Interactions are available, call 353-4565.*

o *Technical Assessments in the areas of Alloy Development for Irradiation Performance and Special Purpose Materials have been published and are available by calling 353-4565.*

o *Six Materials Program Bulletins have been published and are available on request. The titles are as follows:*

Bulletin 1: Overview of Fusion Materials Program
Bulletin 2: First Wall Structural Goal for Economic Fusion Power
Bulletin 3: Alloy Development to Meet First Wall Structural Goals for Economic Fusion Power
Bulletin 4: Plasma-Materials Interactions
Bulletin 5: Neutron Radiation Facilities
Bulletin 6: Special Purpose Materials

These are also available by calling 353-4565.

o Further information may be obtained by calling the following individuals:

Alloy Development for Irradiation Performance	- T. C. Reuther	353-5160
Damage Analysis and Dosimetry	- M. M. Cohen	353-4253
Plasma-Materials Interaction	- C. R. Finfgeld	353-4962
Special Purpose Materials	- C. R. Finfgeld	353-4962
Radiation Facilities	- M. M. Cohen	353-4253
Materials for Magnet Systems	- E. N. C. Dalder	353-4364

MATERIALS SCIENCES DIVISION

The Materials Sciences Division reports to the Director of the Office of Energy Research through the Associate Director for Basic Energy Sciences. The objective of the Materials Sciences program is to conduct fundamental research aimed at increasing the understanding of materials and materials phenomena of interest to the Department of Energy. Research is conducted primarily at DOE laboratories and universities and to a lesser extent in industry. Some of the materials research in the program is aimed at one or another energy technology (e.g., photovoltaic materials research for solar energy or erosion/corrosion of materials for coal conversion), some of the research is applicable to many technologies simultaneously (e.g., studies of constitutive equations for materials deformation or superconducting materials research), while other research is for long range fundamental studies with no immediate technological application (e.g., development of new surface science investigation techniques or theoretical studies of defects in materials). An aspect of the materials sciences program that requires considerable funding is the responsibility to utilize certain unique DOE facilities for the conduct of materials research (e.g., research reactors, high voltage electron microscopes and synchrotron light sources). These are considered national facilities.

In shaping the direction of the research, extensive use is made of workshops bring together both basic and applied scientists. A relatively large portion of program funds is set aside to support unsolicited proposals. If possible basic research is co-located at the same laboratory with applied research to maximize the technology transfer.

The following program description is separated into three major cateogries which represent the separation by major disciplines involved and the administrative units in the program: A) Metallurgy and Ceramics B) Solid State Physics and C) Materials Chemistry. Further information can be obtained by contacting Dr. D. K. Stevens, Director, Division of Materials Sciences (301-353-3427). A more complete description of the 377 projects is given in an annual publication of the Materials Sciences Division - the most recent is Materials Sciences Programs FY 1979, DOE/ER-0031. The FY 1979 operating level for the Materials Sciences Division is $69.9 million in budget authority.

An overall summary of the funding by contractor is given in Table I, and a summary of funding by selected topical areas is given in Table II. In Table III an estimate of the relationship to various energy technologies is provided. This latter table was developed with data provided by the program monitors or the laboratory project directors and is subjective to a large extent.

TABLE I

	Total Program (%)
Ames Laboratory	9.7
Argonne National Laboratory	22.0
Brookhaven National Laboratory	11.0
Idaho National Engineering Laboratory	0.5
Illinois, University (Materials Research Laboratory)	3.2
Lawrence Berkeley Laboratory	7.2
Lawrence Livermore Laboratory	1.6
Los Alamos Scientific Laboratory	2.8
Mound Laboratory	0.3
Oak Ridge National Laboratory	21.3
Pacific Northwest Laboratory	2.4
Sandia Laboratory	2.1
Solar Energy Research Institute	0.3
Contract Research	15.6
	100.0

TABLE II

By Selected Areas of Research	Total Program (%)
(a) Materials	
Polymers	1.0
Ceramics	12.0
Semiconductors	5.9
Hydrides	2.0
Ferrous Metals	7.3
(b) Technique	
Neutron Scattering	12.7
Theory	8.2
(c) Phenomena	
Catalysis	3.7
Corrosion	7.7
Diffusion	4.2
Superconductivity	5.7
Strength	9.4
(d) Environment	
Radiation	10.8

TABLE III

MATERIALS SCIENCES DIVISION

FY 1979 DISTRIBUTION BY TECHNOLOGY

	%
Solar	7.1
Fusion	10.5
Fission	9.7
Fossil	10.1
Geothermal	1.9
Environment & Safety	1.3
Conservation	11.3
Multitechnology	25.0
Long-term Science	23.1
	100.0

A. Metallurgy and Ceramics

Research in metallurgy and ceramics is aimed at understanding the relationship between materials properties, structure and processing. Understanding this relationship is the key to improving present materials and creating new materials to meet the demanding needs of future energy systems. Important properties of materials such as fracture, plastic flow, superconductivity, corrosion resistance, radiation resistance, and transport phenomena all depend on structure. As our understanding becomes more complete and our ability to create the beneficial structures increases, it will be possible to design materials to meet engineering requirements - a task not always possible at the present time. This research will ultimately enable designers to more accurately predict the behavior of materials and changes in material properties as a function of time, stress, and exposure to a variety of environments. Although basic in nature, the program is centered around research areas deemed to be of greatest interest for energy systems. For example, there is within the metallurgy and ceramics category a strong emphasis on hydrogen effects, radiation effects, high-temperature ceramics, refractory metals, and superconductivity, all important topics for energy systems.

There are five budget areas under the Metallurgy and Ceramics category: structure of materials, emchanical properties, physical properties, radiation effects, and engineering materials.

The structure of materials area supports research designed to enhance our understanding of the atomic, electronic, defect and physical structure of materials, how they are affected by composition and processing, and how they relate to material properties.

The budget area of mechanical properties is concerned with material behavior related to structural integrity requirements of all energy systems. Research in this detail addresses the understanding of strength at high and low temperatures, creep, fatigue, elastic constants, micro- and macrostrain, fracture, and mechanical-chemical effects in hostile environments.

Research under the physical properties area is directed toward understanding the fundamental phenomena controlling thermal, optical, mass transport, and electrical properties of materials, how they can be altered by various heat treatments or other processing steps, and how they are affected by external variables such as temperature and pressure.

The radiation effects area encompasses research delineating radiation-induced changes of materials properties important to fusion and fission reactors. Research problems are centered on materials, phenomena and techniques of interest to DOE. Improvement of radiation resistant materials and the prediction of their properties will depend on better theoretical and experimental understanding of defect production, interaction, diffusion, agglomeration, and annihilation at microstructural features, and the resulting structural stability and mechanical properties.

In the engineering materials area, research is aimed at understanding more fully the fundamental materials science on which engineering systems should be based. Some of the topics under study or planned include: erosion, friction and wear, engineering corrosion & fracture, joining and welding, nondestructive evaluation, and the forming and processing of materials. In general, this detail will provide the link to engineering systems by studying more complex materials systems and phenomena.

The major research contractors include: Ames, Argonne, Brookhaven, U. of Illinois, Mound, LASL, LBL, LLL, INEL, ORNL, PNL, SERI, Sandia, Rockwell Science Center, General Electric Co., Varian Associates and various Universities.

B. Solid-State Physics

The solid-state physics category is directed toward fundamental research on matter in the condensed state, wherein the interactions of electrons, atoms, and defects are tracked with the purpose of determining the critical properties of solids. These interactions are the ultimate source of all materials properties. Research under this category includes a broad spectrum of experimental and theoretical efforts, which contribute basic solid-state knowledge important to all energy technologies. Accelerated progress is made in this field through the rapid advancements in unique experimental tools and their coupling with high-speed computer systems. Through these efforts, fundamental understanding of matter in the condensed state contributes broadly to characterizing material properties and processes important for all energy technologies.

There are five budget areas within the solid-state physics category: neutron scattering, experimental research, theoretical research, particle-solid interactions, and engineering physics.

The neutron scattering area supports research of a unique kind, namely, the use of the neutron as an analytical probe of the properties of solids and liquids. With this probe, fundamental parameters of superconductors, magnets, hydrides, and solid imperfections are determined in a manner that cannot be accomplished by any other technique. The exploitation of this probe is being advanced by recent development of more efficient monochromators and wider use of longer wavelength probes. The bulk of the Nation's efforts in this important area has historically been supported at DOE laboratories, where the advanced research reactors are in operation.

The experimental research area is very broad and includes all fundamental investigations, experimental in concept, on liquids and solids of metals, alloys, semiconductors, insulators, and compounds. The area ofhigh-temperature materials in both metals and nonmetals, especially in relation to MHD electrodes and insulators as well as other high-temperature energy systems, is being pursued. Ion implantation and backscattering research is being used to learn how to improve superconductor and photovoltaic performance. Hydrogen and hydrides are under study through ultrahigh-pressure and spectroscopic techniques. Synchrotron radiation will be utilized in characterizing surfaces with particular relation to catalytic response.

With nearly all these experimental areas, a highly advanced theoretical research program is closely coupled. A large part of the theoretical effort is directed towards dynamic processes in solids and liquids and requires extensive use of DOE's most advanced computer complexes.

Under particle-solid interactions, a major effort is under way to correlate the complex effects of particles of different mass, energy, and charge, not only on surfaces but in bulk materials as well.

The engineering physics area supports research to fulfill the much needed goal of utilizing solid state physics expertise in engineering research for hwich it has a unique capability. Typical of the work initiated are research laboratory investigations of novel processing techniques with mass spectrometer-computer control for complex material preparation, such as solar materials and superconducting alloys. Another area is the extension of cryogenic and refrigeration techniques to new fluid systems that hold promise for the utilization of low-grade heat.

The major research contractors include: Ames, Argonne, Brookhaven, U. of Illinois, LASL, LBL, LLL, ORNL, PNL, Sandia, General Electric Co., and various Universities.

C. Materials Chemistry

The materials chemistry category provides support for research directed toward developing our understanding of the chemical properties of materials as determined by their composition, structure, and environment (pressure, temperature, etc.) and to show how the laws of chemistry may be used to understand physical as well as chemical properties and phenomena. Included, for example, are studies of energy changes accompanying transformations, the influence of varying physical conditions on rates of transformations, and the manner in which the structure of atomic groupings influences both properties and reactivity.

Chemical concepts coupled with physical experimental techniques are used to study the kinetics of reactions of solids and liquids, the interaction and/or penetration of species in adjacent media, corrosion and scaling, and the stability of high-temperature materials of interest to fossil and geothermal technologies. The program also includes research on the chemical thermodynamics of fission products and their interactions with fuels and cladding materials. Electrochemical research important aspects of research supported under this category. Research involving elastomers and polymers is also being pursued.

There are three budget areas in the materials chemistry category: structural chemistry, engineering chemistry, and high-temperature and surface chemistry.

Structural chemistry involves studies of a wide variety of problems where a knowledge of the relationship between the atomic structures of materials and their reactivity is required. Important examples of these effects include the influence of different chemical environments on the catalytic properties of metals. Changes in both the crystal and magnetic structures of compounds are correlated with their specific roles in fuel synthesis, for example.

The methods of engineering chemistry are applied to problems that are currently limiting the efficiency of energy conversion systems. Examples of research underway include: structural and morphological changes that arise during the electrochemical incorporation of lithium into aluminum during charge-discharge cycles of the high-temperature battery; measurement of equilibria between tritium and candidate blanket materials; and studies of tritium permeation of oxide films.

The high-temperature and surface chemistry area includes programs on fundamental studies of the influence of surface properties on reactivity and for the correlation of mass transport and thermodynamic properties of molten salts in high-temperature battery systems. Chemical studies of scaling in geothermal environments and the influence of micro-inclusions such as sulfides on the formation of pits and crevices to determine whether these inclusions play a significant role in the initiation of stress-corrosion cracking are examples of research underway.

The major research contractors include: Ames, Argonne, Brookhaven, INEL, LBL, LLL, LASL, ORNL, and various Universities.

DEFENSE PROGRAMS

OFFICE OF INERTIAL FUSION

The Office of Inertial Fusion is under Defense Programs. The major goals of the Inertial Confinement Fusion program are to (1) understand and demonstrate the burning of deuterium-tritium fuel in a small pellet when it is compressed and heated using pulsed laser and particle beam sources, (2) demonstrate near-term weapons technology applications, (3) evaluate and select the most promising driver approach for fusion energy applications, and (4) develop a technology base for the fusion energy engineering phase of the program. Materials research performed as part of the Inertial Confinement Fusion program consists of (1) work to develop and characterize advanced optical materials for use in high power lasers, (2) work to develop and characterize high quality microspheres of various compositions for use as fusion fuel pellets, (3) analyses of the irradiation effects in structural materials which might be used in commercial inertial confinement fusion power plants, and (4) work to develop fabrication and quality control techniques for miscellaneous electronic and optical components required for inertial confinement fusion experiments. The FY 1979 operating budget for the Intertial Confinement Fusion program is $104 million. Following is a list of materials related projects:

Preparation and Characterization of Thin Metal and Polymer Films
(K. W. Bieg, T. D. Hund) $ 30
Sandia Laboratories
Preparation and characterization of free standing, high strength planar seamless cylindrical thin foils. Metals and polymers of various compositions. (key words: thin films, strength)

Preparation and Characterization of Polymer Coatings for Particle Beam Fusion Targets
(K. W. Bieg, T. D. Hund) $ 60
Sandia Laboratories
Preparation and characterization of polymer coatings and shells by plasma polymerization and pyrolysis vapor deposition. Chemical characterization and diffusion properties of polymers. (key words: polymer deposition, diffusion)

Particle Beam Fusion Target Fabrication
(K. W. Bieg, T. D. Hund) $ 40
Sandia Laboratories
Fabrication and characterization of particle beam fusion targets using polymers, metals, and ceramics. (key words: ICF target fabrication)

Damage Resistant Sputtered Coatings for Laser Components
(N. Laegried, W. T. Pawlewicz)
Battelle Memorial Institute
Investigate the relation of laser damage resistance of sputter-deposited optical coatings to their material or metallurgical properties for the purpose of increasing the laser damage threshold of coatings presently available for high energy laser applications. (key words: sputtering techniques, optical coatings)

CO_2 Laser Absorption and Saturation Studies of Molecular Impurities in Alkali Halide Crystals
(A. J. Sievers) $ 45
Cornell University
The objective of this study is to determine the static and dynamic IR properties of tetrahedral molecules embedded in alkali halide lattices. (key words: saturable absorbers, CO_2 technology)

Research and Development of Fluoride Glasses for Laser Fusion
(L. J. Clark) $250
Corning Glass Works
Develop BeF glass to be used for ultraviolet laser windows. Objectives are to demonstrate capability to produce large (30 cm) pieces with good optical quality and to minimize two-photon absorption in the near UV. (key words: BeF glass, UV optical material)

Development of Fluorides for High Power Laser Optics
(E. Bernal G.) $199
Honeywell
Study hot forging techniques to increase strength and size of various crystalline material for use as optical windows and lenses for ultraviolet laser systems. (key words: hot forge techniques, optical material)

Investigation on the Damage Threshold of Films Coated on Various Compositions of Silicate, Fluorophosphate and Phosphate Laser Glasses
(T. Izumitani) $150
Hoya Optics U.S.A., Inc.
Study the relationship between coating materials and substrate materials to improve laser damage thresholds at 1 micron. (key words: optical coating, neodymium glass laser technology)

Phase Conjugation for Fusion Lasers
(C. R. Guiliano) $ 99.8
Hughes Research Laboratory
Demonstrate experimentally the feasibility of nonlinear optical phase conjugation at 10.6 μm using a laser having a pulse duration between 0.5 and 10 nsec. Use one or two nonlinear optical phenomena to demonstrate phase conjugation, either degenerate 4-wave mixing or stimulated Brillouin scattering (SBS), and measure the degree of correction obtained for different degrees and types of intentionally introduced aberrations (e.g., astigmatism, tilt). (key words: phase conjugation, CO_2 laser system)

Development of Glassy-Optical Coating with Gradient Index
(W. Haller) $ 60
National Bureau of Standards
Develop method to deposit glass thin film coatings with a continued gradation in index to improve laser damage thresholds. (key words: optical coatings, gradient index, glassy coating)

Development of Ferromagnetic Spinels for Optical Isolation at 10.6 μm
(K. J. Teegarden) $ 41
University of Rochester
Fabricate high purity, hot-pressed samples of $CdCr_2S_4$ and $CdCr_2Se_4$ to determine intrinsic absorption level for this material at 10.6 μm. These materials are planned to be used as the active elements in Faraday rotators. (key words: Faraday rotators, CO_2 laser technology)

High Power Laser and Materials Investigation
(R. Folweiler) $100
Sanders Associates, Inc.
Growth of Faraday rotator materials (KTb_3F_{10} and others) up to 100mm diameter by the Czochralski technique. (key words: Faraday rotators, laser technology)

Role of Photochemical Defect Production in Optical Breakdown of Halides
(P. Braunlich) $ 27
Washington State University
Model various mechanisms which lead to breakdown of optical materials when irradiated by high power laser beams. (key words: Nonlinear optical theory, laser damage)

Irradiation Effects to Materials in Laser Fusion Reactors
(G. L. Kulcinski, R. W. Conn) $ 70
University of Wisconsin
Parametric analysis of various particle debris and photon outputs to determine the effects on reactor cavity first wall materials. The effects of gas and other protective schemes on the modification of first wall response is also investigated. (key words: irradiation effects, fusion first wall)

Fabrication of Isotopically-Substituted Ammonia-Borane Microballoons
(R. A. Geanangel) $ 25
University of Houston (Under contract to LASL)
Development of processes to produce microballoons from H_3N of a quality suitable for use as inertial confinement fusion targets. After processes are developed these microballoons will be prepared from D_3NBT_3 and T_3NBD_3. (key words: ammonia-borane microballoons, ICF targets, isotopic substitution)

Microporous Polyolefins
(C. Castro, A. Castro) $ 50
Armak Research Laboratory (Under contract to LASL)
Development of process to produce very low density (less than 0.05 g/cc) uniform cell (less than 1.0 micro meter) size CH foams for use in ICF targets. (key words: ICF targets, low density foam)

Formation of Low Density-High Atomic Number Metallic Foams
(J. W. Patten) $ 65
Battelle-Pacific Northwest Laboratories (Under contract to LASL)
Development of low density (less than 20 per cent of theoretical), fine pore size (less than 10 micro meters), metal foams by process of trapping large amount of gas in structure during sputter deposition and subsequent heat treatment. These metal foams to be used in future ICF targets. (key words: metal foam, sputtering, ICF targets)

Development of Methods for Application of Cryogenic (Solid) DT Layers in ICF Targets
(J. Miller, E. Grilly) $220
Los Alamos Scientific Laboratory
Development of methods of freezing solid, uniform, DT layers in ICF targets inside the target chamger. Effort involves computer simulation of freezing process, characterization of frozen DT layers and development of mechanical transport and freezing apparatus. (key words: cryogenics, solid DT shells, ICF targets)

Formation of High Quality Organic Coatings for ICF Targets
(R. Liepins, M. J. Campbell, J. S. Clements) $ 55
Los Alamos Scientific Laboratory
Development of techniques to coat ICF targets with plastic films to thickness variations of plus or minus one per cent and surface smoothness to plus or minus 1000 angstroms. Processes based on vapor phase pyrolysis and low pressure plasma coating technology. (key words: ICF targets, plastic coatings, vapor phase pyrolysis low pressure plasma deposition)

Development of Organometallic Coatings for ICF Targets
(R. Leipins, M. J. Campbell, J. S. Clements) $ 60
Los Alamos Scientific Laboratory
Processes for deposition of plastic coatings highly loaded with metal are being developed for possible ICF target applications. Metal contents achieved to date are approximately 30 weight per cent lead and 10 weight per cent iron. (key words: organometallic films, ICF targets)

Metallic Coatings Development for ICF Target Applications
(D. S. Catlett, et al., A. T. Lowe, S. M. Butler) $275
Los Alamos Scientific Laboratory
Development of metal coating processes for use in fabrication of ICF targets. Processes used are electroplating, electrolessplating, CVD, PVD, and sputter deposition. State of the art in these technologies is applied to forming extremely high quality coating of a wide variety of metals in micro-spherical geometry. (key words: ICF targets, metallic coatings, electroplating, CVD, PVD, sputtering)

Low Density Metallic Structures
(J. V. Milewski) $ 50
Los Alamos Scientific Laboratory
Development of low density, highly uniform metallic foam or felt shells for possible use in ICF targets. Sub-micron fiber technology is basic of development effort. (key words: ICF targets, low density metals, sub-micron metallic fibers)

Neodymium Laser Glass
(R. A. Saroyan, S. E. Stokowski, M. J. Weber) $225
Lawrence Livermore Laboratory
Optical spectroscopy of Nd-doped glasses. Measurements of absorption and fluorescence spectra, fluorescence lifetimes, and quantum efficiencies of Nd^{3+} ions in oxide, fluoride, and oxyfluoride glasses. Evaluation of Nd:glasses for use as amplifying media in lasers for inertial confinement fusion experiments. (key words: laser glass, neodymium, optical spectroscopy)

Laser-Induced Damage in Optical Materials
(T. Deaton, W. H. Lowdermilk, D. Milam, F. Rainer, W. L. Smith) $500
Lawrence Livermore Laboratory
Determination of thresholds for laser-induced damage in transmitting optical materials and thin film coatings used in high-power lasers. Effects of surface physics and chemistry on damage thresholds. Gradient index materials for antireflection coatings. Measurements at wavelengths from 1.06 to 0.226 μm and pulse durations from 0.1 to 10 ns. (key words: laser damage thresholds, optical materials)

Hard Coatings
(S. Meyer, R. J. Burt, E. Hseih) $400
Lawrence Livermore Laboratory
Coatings of various metals (Au, Pt, Ta, W, Be, etc.) and various inorganic materials (SiO_2, AlN, BN, etc.) are deposited by evaporation, sputtering and secondary ion deposition on shells for use as laser fusion targets. Material geometry and physical properties must be controlled to produce layers which are uniform both in bulk and thickness. Surface roughness must be in the 100-300 A range. (key words: coatings, laser fusion targets)

Electrodeposition
(J. Illige, C. W. Hatcher, W. Johnson) $175
Lawrence Livermore Laboratory
Techniques are developed to deposit high quality coatings of electrodepositable materials on hollow shells and flat substrates (discs) for use as laser targets. Surface quality and material and thickness uniformity are critical parameters. Layer thicknesses to a hundred micrometers are required. (key words: electrodeposited coatings, laser fusion targets)

Lead Glass Spherical Shells
(J. Koo) $200
Lawrence Livermore Laboratory
Development of spherical, hollow, target quality shells of lead glass. The composition is primarily a silicate glass with lead oxide concentration from a few percent to seventy-five percent (by weight). The quality is sufficiently high so that the shells can be used as laser fusion targets. In weight percents of lead oxide below 50%, the shells can be readily filled with D-T gas. (key words: lead glass, laser fusion targets)

Polymeric Coatings
(W. Johnson, J. Illige, J. Crane, D. Myers, S. Letts) $500
Lawrence Livermore Laboratory
By using various plasma polymerization techniques, coatings of polymerized fluorocarbons and hydrocarbons are deposited on shells of various materials (e.g., glass, metal) to be used as laser fusion targets. Coating thicknesses may be varied from a few hundred Angstroms to more than one-hundred micrometers. The coating quality is exceptionally good: thickness uniformity is better than 1% and surface roughness is less than 300 A. (key words: plasma polymerization, plastic coatings)

Molecular Beam Levitator - Coater
(J. Crane, W. Johnson) $150
Lawrence Livermore Laboratory
Development of techniques by which spheres can be levitated and coatings applied in the absence or contact with surfaces which may give rise to imperfections in the coatings. The levitation beams are not generally the coating materials. Thus, integration of materials deposition techniques with levitator techniques must be accomplished. Surface finish, layer uniformity, and achievable thickness are critical parameters. (key words: levitation, molecular beam deposition)

Cryogenic ICF Fuel and Target Development
(T. Bernat, LLL; K. Kim, University of Illinois) $375
Lawrence Livermore Laboratory and University of Illinois
Cryogenic fuels (DT, CD_2T_2, etc.) required for inertial confinement targets pose problems in filling of targets, materials compatibility at cryogenic temperatures (as low as 4^oK), and materials handling at cryogenic temperatures. In particular, adhesives and polymers which do not fracture spontaneously at such low temperatures are required. Properties of other target materials are also to be determined. (key words: cryogenic targets)

Glass Shells Development
(R. Woerner, V. Draper) $400
Lawrence Livermore Laboratory
Development of glass composition and techniques by which ultra-high quality glass shells may be produced for use as inertial confinement targets. Composition compatible with droplet generator and power techniques are necessary. Shell thicknesses should be uniform to better than 1%, sphericity to better and 1% surface roughness less than 100 A. Yields are important in the processes and should approach 100% as closely as possible. Yields of target quality spheres of 98% have been achieved. (key words: glass composition, laser fusion targets)

Ion Beam Coating Techniuqes
(M. B. Denton) $ 75
University of Arizona (Tucson)
Development of techniques for production of ion beams suitable for high-rate deposition of coatings on target spheres. A wide variety of materials must be available in beam form to provide the required layers on the targets.

Materials and Surface Analysis
(M. Ward) $350
Lawrence Livermore Laboratory
Development techniques, methods, and instrumentation for characterization of the material and surface properties of various ICF target materials. The important parameters include surface composition and geometry, material uniformity and bulk composition. Non-standard techniques are required because of sample size (50 micrometers in many cases) and the parameter quality required. (key words: surface analysis, scanning electron microscopy)

Polymer Development for Molding of Hemishells
(L. Lorensen, C. W. Hatcher) $200
Lawrence Livermore Laboratory
Molding of polymers into hemishells which can be assembled into spherical ICF targets requires development of polymers with unusual properties. Shells of a few hundred micrometers diameter and a few tens of micrometers thick are necessary. To achieve uniformity of surfaces and material properties, careful control of polymerization properties, surface characteristics, and stability is necessary. (key words: polymeric coatings, laser fusion targets)

Microradiography
(R. Singleton, B. Weinstein, J. Weier) $150
Lawrence Livermore Laboratory
The requirements for multilayer spherical ICF targets with various material layers necessitates characterization and measurements of opaque structures. To measure thickness and uniformity of the various layers and material properties we are developing microradiographic techniques with very high resolution. (key words: microradiograph, laser fusion targets)

DT Fill of Laser Fusion Targets
(L. D. Christensen, J. Weir, I. Moen, B. Weinstein) $225
Lawrence Livermore Laboratory
Development of techniques by which laser fusion can be filled with DT fuel. Permeation rates of D_2, T_2, and DT through various glass target spheres are determined as functions of temperature, ultimate pressure and glass composition. (key words: laser fusion targets)

OFFICE OF MILITARY APPLICATION

The Office of Military Application, under the Assistant Secretary of Defense Programs, directs the research and development, testing, and production of nuclear weapons. Weapon research and development is conducted primarily at the Department of Energy's three nuclear weapon laboratories: Lawrence Livermore Laboratory (LLL), Livermore, California; Los Alamos Scientific Laboratory (LASL), Los Alamos, New Mexico; and Sandia Laboratories at Albuquerque, New Mexico (SLA) and Livermore, California (SLL). Weapons production is conducted at seven government-owned, contractor-operated plants.

The objectives of the program are to develop materials and materials technology for national security uses. The research is directed toward basic material science, the understanding and development of advanced materials and fabrication technology, and the development of materials and processes required to produce nuclear and nonnuclear parts. The program is conducted as a portion of the following budget output categories:

1. Supporting Research.
2. Materials and Fabrication Technology.
3. Process Development.

1. Supporting Research

The objective of the Supporting Research area is to pursue basic and applied research which is fundamental to weapon development. Work is directed toward development of analytical procedures and nondestructive test methods to support ongoing weapons development programs and toward development and characterization of materials. Supporting materials research is required where the design engineer's ability to apply materials is limited to lack of understanding of basic materials phenomena. This category of research is performed at the three nuclear weapon laboratories--LASL, LLL, and Sandia.

2. Materials and Fabrication Technology

The objectives of the Materials and Fabrication Technology area are to provide well characterized materials that have physical and mechanical properties compatible with current and advanced weapon designs and that enable the weapon complex to keep abreast of and to respond promptly to new process and fabrication methods required to fabricate systems components and to complement the advanced materials developments. The advanced materials development and characterization efforts include the support of metallurgy, chemistry, metallography, scanning electron microscopy, electron and ion microprobes, thermal and pressure dilatometry, and the most modern analytical techniques, and involve the determination of thermal properties, elastic-plastic properties, mechanical properties, phase equilibria, and chemical characterization. Process and fabrication development efforts include the use of technological capabilities of the laboratories in a wide variety of materials in conventional metal-working processes and in the welding and joining of materials. These capabilities are augmented by extensive computer modeling, systems analysis, and design engineering. This program is carried out at the three nuclear weapon laboratories--LASL, LLL, and Sandia.

3. Process Development

The objective of the Process Development area is the development of the material processes required to produce nuclear and nonnuclear parts. Development work is performed by the production plants on new materials and production processes for weapons concepts in advanced development, engineering development, and production phases. This area also includes manufacturing research and development work to improve existing processes for efficiency and safety. This program is conducted by the seven production contractors--Bendix, Rockwell International, Monsanto, General Electric, Mason and Hanger, Union Carbide, and du Pont--working closely with the three nuclear weapon laboratories.

The total MA materials program is estimated at $67.4 million in FY 1979 which includes both classified and unclassified research projects. The following listing of projects includes only unclassified projects or unclassified descriptions of projects which involve classified work. More detailed information about the MA materials program can be requested through the Research Branch of the Office of Military Application (Telephone--301-353-5494).

Lawrence Livermore Laboratory

Surface Self-Diffusion on Covalent Materials
(D. Makowiecki, J. Holt) $181

Analysis of mass transport mechanisms on crystal surfaces allows improved understanding of sintering of covalent materials. (Key words: surface analysis, ceramics)

Soft Ferromagnetic Metallic Glasses
(C. Cline) $168

Ferrous base metallic glasses open new vistas in magnetic performance. (Key words: metallic glass, amorphous material)

Reactions in Shock Waves
(W. Von Holle, C. Tarver, L. Green, E. Lee) $200

More energetic and safer explosives will result from understanding the mechanisms of chemical energy release that occur in shock waves. (Key words: insensitive high explosives)

Safe High Energy Explosives
(M. Finger) $242

Safe high energy explosives (SHEE) will significantly advance explosives technology for LLL's nuclear weapons program. (Key words: insensitive high explosives)

Crack Growth in Polymers & Composites
(R. Christensen, E. Wu) $165

The crack growth program will provide the means of quantitatively characterizing damage accumulation under time-load history in engineering materials. (Key words: fracture toughness)

Cryogenic Heavy Hydrogen Technology
(P. Souers) $147

Electrical conductivity of solid DT should be an extreme function of tritium concentration. (Key words: physical properties of hydrogen)

Spectroscopic Analysis of Surface Passivation
(F. Milanovich, R. Meisenheimer, C. Colmenares, W. Siekhaus) $141

Vibrational analysis of monolayers of molecular species on passivated surfaces of actinides will significantly contribute to the understanding of the basic phenomena that control passivation. This knowledge will have considerable impact on prolonging the lifetime of weapons. (Key words: surface chemistry)

Atomization Processes for Multielemental Analysis Systems
(R. Bystroff) $ 56

Sensitive elemental analyses support critical materials characterization for weapon systems. Atomization is the key limiting process for precision and sensitivity. (Key words: chemical instrumentation)

Measurement of the Half-Life of Rhenium-187
(R. Borg) $ 87

Accurate determination of $t_{1/2}$ of ^{187}Re will allow the isotopic couple ^{187}Re-^{187}Os to be used as a cosmo-chronometer to date the formation of the heavy elements and, hence, the age of the universe. (Key words: nuclear chemistry)

Metallic Alloy Glasses
(R. Hopper) $392

Alloy glass project aims at new materials having properties obtainable only with rapid quenching. (Key words: amorphous material, metallic glass)

Transplutonium Element Research
(E. Hulet, R. Lougheed, J. Wild, J. Landrum, R. Dougan, M. Mustafa) $360

Nuclear and chemical information obtained in our research is being used by the weapons program and other programs. Nearly all of our research is aimed at testing some major aspects of nuclear and atomic theory. (Key words: nuclear chemistry)

Nuclear Structure - In-Beam Spectroscopy
(G. Struble, L. Mann, R. Lanier) $449

In-beam nuclear spectroscopy benefits the Lawrence Livermore Laboratory scientifically and programmatically. (Key words: nuclear structure)

Neutron Capture Gamma Measurements
(R. Hoff, R. Lougheed) $ 60

Our program of neutron capture gamma measurements on actinide targets is producing useful nuclear spectroscopic data. (Key words: nuclear cross-sections)

Hydrogen Equation of State
(M. Costantino, R. Schock, J. Richardson) $106

Equation of state and molecular spectra measurements are made on solid H_2 to 10 GPa to test theoretical molecular potentials. (Key words: hydrogen equation of state)

Laser Applications to Chemical Analysis
(J. H. Richardson, G. R. Haugen) $361

This work represents the application of lasers as tools for chemical analytical measurements. Techniques are being developed which utilize the special properties of the laser; e.g., monochromaticity; intensity and spatial coherence, to provide measurement capabilities unattainable by conventional analytical methods. (Key words: chemical analysis, laser applications)

Single Photon Absorption Reaction Chemistry in the Solid State
(E. Catalano) $172

This work involves the use of low energy (∿1000 cm^{-1}), low power (∿1 watt) lasers to induce single-photon reactions between host and guest molecules residing in low temperature (∿12°K) matricies. The experiments are part of the bases for understanding a process of photochemistry of reactants in fixed relative configuration; a general matrix phenomena in which spatial configurations dramatically affect potential energy surfaces for reaction. (Key words: laser induced chemistry)

Development of Control Algorithms for Process Control and Characterization (J. W. Frazer) $402

Parameter identification algorithms which identify a system model from actual operating data have been developed for the enzyme system. Using the identified model both proportional plus integral plus derivative and time optimal control algorithms employing the Smith Predictor has been tested. (Key words: chemical process instrumentation and modeling)

Flash X-Ray Diffraction
(Q. C. Johnson) $111

Experiments are conducted to determine the microscopic behavior of materials undergoing shock-wave compression. Shock waves travel up to at least 1 Mbar and are produced in single crystal materials by the impact of a projectile from a light-gas gun. At the instant the shock emerges from the front of the crystal, a very powerful x-ray source is used to probe, by diffraction, the arrangement of atoms within the compressed crystal. (Key words: equation of state)

Diamond-Anvil Cell
(J. Akella) $ 79

The diamond-anvil high pressure x-ray diffraction cell is being used to determine the compessibility and the structure relationships of the actinide metals. The cell is capable of pressures to ∿1 Mbar. Americium has been found to undergo two structural modifications at pressures below 100 kbar. (Key words: equation of state)

Plutonium Research & Development (Sputtering, Joining, Hydride Kinetics, and Chemical/Physical Properties) (R. E. Kelley) $910

The purpose of the Plutonium Research and Development Program is to support technological development for the nuclear weapons program in areas that do not receive direct programmatic support. The programs include superplasticity of delta-Pu, diamond-anvil cell high pressure studies, hydride kinetics, plutonium sputtering, and alpha-Pu joining. (Key words: material research)

Los Alamos Scientific Laboratory

Surface Chemistry, Metallurgy, and Physics
(D. J. Sandstrom) $300

The general area of thin and thick film technology is currently a subject of considerable effort at Los Alamos. We have established a capability to do physical vapor deposition by electron beam evaporation, sputtering, ion plating, and resistance heating under highly controlled and reproducible conditions. Our equipment is complemented with diagnostic capabilities which include a scanning Auger spectrometer, ESCA, and SIMS. Additionally, we are supported with an SEM which is equipped with EDAX (energy dispersive analysis by x-ray) and conventional microscopy.

The objective of this area of activity is to develop and characterize classes of materials with mechanical and physical properties that are different from those obtainable by conventional processing techniques. To date we have developed such a class of materials, which are created by physically evaporating layers of high purity material with alternating layers of an impurity, which is introduced into the system in a highly controlled and reproducible fashion. Examples of this are aluminum foils with tensile strengths up to ~350 MPa and tantalum foils with strengths to ~860 MPa. We are also developing the ability to deposit these materials in highly uniform layers onto spherical shapes.

We also have a very strong program in surface coating processes by chemical vapor deposition(CVD) for a variety of shapes. We do this both statically and dynamically (fluid-beds). We are currently capable of depositing W, Mo, Mo_2C, Ni, and W-Re alloys from the pyrolysis of carbonyls and the hydrogen reduction of halides and carbonyls. (key words: thin films, thick films, surface analysis, CVD, PVD.)

Surface Studies
(W. P. Ellis, T. N. Taylor, H. L. Barker) $200

Studies of surface structures, gas-solid reactions and catalysis. Low energy electron diffraction (LEED), ion scattering spectroscopy (ISS), inelastic secondary electron spectral analyses (Auger/Loss), and photoelectron spectroscopy (PES), used to characterize surface structures, detect and identify surface impurities, and obtain information about valence band electrons. (key words: surface structures, gas-solid reactions, catalysis, LEED, ISS, Auger, PES.)

Mechanical Metallurgy of Pu
(R. N. R. Mulford) $200

Mechanical properties of Pu and Pu alloys are determined over a strain rate range from 10^{-5} to 100 per second. (key words: plutonium, plutonium alloys, mechanical properties)

Transformation Behavior
(R. N. R. Mulford) $200

Transformation of selected low-alloy content materials is investigated by high-pressure dilatometry, x-ray diffraction, and optical metallurgy. (key words: plutonium, high-pressures, x-ray diffraction, metallography)

Rapid Quenching of Plutonium Alloys
(R. N. R. Mulford) $80

Splat cooling, arc smashing and irradiation methods to produce glassy Pu alloys are investigated. (key words: plutonium, glassy metals)

Neutron Diffraction on Plutonium
(R. N. R. Mulford) $100

Time-of-flight neutron diffraction on pure Pu at pressure and temperature to determine the structure of Pu phases is conducted. (key words: plutonium, neutron diffraction, high pressures)

Physical Metallurgy of U-6 Nb Alloys
(R. N. R. Mulford) $100

Phase transformations in U-6 Nb and their relation to high rate biaxial deformation capability are investigated. (key words: uranium-niobium alloys, biaxial deformation)

Actinide Metal Physics
(R. N. R. Mulford) $150

Electronic structures and physical properties of actinide metals are investigated by examination of superconducting and magnetic behavior. (key words: actinide metals, superconductivity, magnetism)

Thermophysical Properties of Pu and Its Alloys
(J. F. Andrew, D. R. Harbur) $80

Measurements of resistivity, thermal expansion and differential thermal analysis are made on Pu-Ga alloys to access fabrication processing and stability of existing and new alloys. (key words: thermophysical properties, alloy development)

Characterization of Pu_3Ga
(S. D. Soderquist, D. R. Harbur) $80

The transformation behavior between the cubic and tetragonal phases of Pu_3Ga and relative stability of each in the presence of other plutonium phases. (key words: transformation, diffusion)

Process Development of Polymeric Materials
(D. J. Sandstrom) $75

A variety of polymeric materials is required for all phases of energy, safeguards, and defense-related work. We are conducting a continuing program aimed at materials and process improvements for elastomers, adhesives, and structural plastic materials.

Our continued study of the use of various curing agents as replacements for MOCA in polyurethanes has resulted in a suitable candidate. Apocure 601E [1,2-bis (2-aminophenylthio) ethane] can be used in our applications which previously required MOCA. An additional benefit is the extended potlife provided by the Apocure. Development will continue on the technology of large polyurethane castings using modern reaction injection molding (RIM) techniques as well as high-speed mixing/metering equipment.

A very significant area of ceramic-polymer technology development is currently being pursued. We have developed ceramic-silicone polymer formulations which can be injection molded, or transfer molded using plastics industrial procedures to yield highly complex ceramic shapes. These materials differ from commercially available injection moldable ceramic formulations in that they exhibit shrinkage on firing of less than 6% and the formulation of the body is greater than 95% Al_2O_3. Commercial materials usually shrink more than 15% on maturing. These materials have been used in prototype production of two components of a detonator assembly. The molding characteristics have been found to be quite good. Short runs of 150-200 parts were made to evaluate achievable dimensional tolerances. Consistency from part to part was found to be within 0.25% for small (10 mm) parts, and would be significantly better for larger parts. Development will continue to expand the process to more complex geometries and variable chemical composition. (key words: injection moldable ceramics, injection molding, curing agents, elastomers, adheseives, structural plastics)

Metal Casting Processes
(D. J. Sandstrom) $75

There are four major ongoing programs in casting development to improve the quality and efficiency of metal casting processes.

We are using molds made from castable ceramics in an attempt to reduce or eliminate the amount of carbon picked up during the normal uranium casting process. The initial uranium casting, a simple cylinder, showed no increase in carbon content, and it appears the program will be very successful.

Using the lost wax process, we have fabricated ceramic molds and used them to cast complex-shaped thin-walled uranium alloy parts. We are investigating casting parameters using these molds and are able to cast parts with thinner walls and more complex shapes than has been possible using graphite molds.

Computer simulation of the casting process has been developed and utilized as a development tool. By simulating the metal solidification process, we are able to evaluate casting processes and mold design at a lower cost and with faster turnaround time between design and process changes. The results are plotted as color motion pictures, thereby decreasing post computation analysis time and increasing our understanding of the complex heat transfer conditions which exist.

Process improvements are being investigated related to casting SNM. These improvements are aimed at reducing the amount of machine stock and riser material currently required. Such improvements will reduce material recovery costs and also require less SNM material be held in inventory. (key words: castable molds, investment casting, computer simulation)

Ceramic and Powder Metallurgy Technology Development
(D. J. Sandstrom) $150

We are conducting an ongoing program in ceramics and powder metallurgy technology development. This work includes the preparation of ceramic and powder metallurgy materials using communution, consolidation, and sintering processes. An extensive powder characterization is an important part of our operation.

Specific programs underway in ceramic technology include the development of spinel components as an inexpensive substitute for expensive weapons components for use in hydrodynamic tests and the development of some boron carbide-graphite composites as a replacement material for certain weapons components. Development of composite materials has been continued and tungsten alloy-boron composites were fabricated for use as a collimator material for the WNR, tungsten-coated graphite cloths were evaluated and carbon-bonded zirconium moderators for critical assemblies were formed. The technology for fabrication of co-sintered ceramic-cermet detonators has been developed to the extent that permits limited production of prototype parts.

Development of a process for controlling porosity of materials has led to the fabrication of a porous gadolinium wheel for use in a magnetic cryogenic refrigerator. Glass development activities have resulted in a variety of glasses used for metal coating, ceramic joining, and sealing. Bulk glasses for use as materials replacement in weapons are being investigated. (key words: characterization, sintering, composites, cermets, bulk glasses, controlled porosity)

Welding and Joining Development
(D. J. Sandstrom) $150

Activities in the welding and joining areas have mostly been with electron beam and laser welding.

An upgraded high voltage electron beam system has not been fully operational for several months and has realized numerous benefits compared to the old system. Beam current and focus control are improved as a result of the new gun and bias control systems; our experimental work currently includes beam power modulation. Joint programs with other DOE contractors are designed to compare various approaches to improved control design, and make some quantitative and qualitative measurements of the benefits of these systems with respect to the standard systems typical of production agency usage.

A new 400-watt Nd-YAG laser processing system is also now operational and the development work includes mini-joining applications, braze welding, welding in various gaseous atmospheres, and a comparison study with low heat input electron beam welding. (key words: process control, electron beam welding, laser welding)

Metal Fabrication Development
(D. J. Sandstrom) $125

We have been conducting several continuing programs which are aimed at improving processing techniques for various uranium alloys and several new structural materials. We have recently undertaken a basic evaluation of the high energy rate forming characteristics of a variety of materials used in weapons applicatio Additionally, we intend to determine the effects such high forming rates have on the ultimate mechanical properties of these materials. Several uranium alloys and other structural materials used in weapons applications such as Ti-6 Al-4 V, and 2219 Al alloys are being evaluated.

Studies involving the use of explosives in metalworking were also continued. The explosion welding process is being used whenever a need arises to fabricate dissimilar metal transition joints for subsequent fusion welding. (key words: explosive metalworking, high energy rate forming, dissimilar metal bonding)

Electrochemistry and Electroforming
(D. J. Sandstrom) $100

We have an ongoing development effort in the area of electrolytic and electroless deposition of metals and alloys. Specifically, most of our effort is directed toward developing electroforming processes and techniques for fabricating structural components for specific experimental weapon designs. We are evaluating high strength electrodeposits of pure materials and alloys for possible applications in weapons hardening. We are investigating the properties, particularly hydrodynamic response, of amorphous metals and alloys deposited by either electrolytic or electroless plating techniques. (key words: electrolytic or electroless plating amorphous deposited materials)

Mechanical Properties of Conventional Construction Metals and Alloys
(D. J. Sandstrom) $75

For the past few years we have been evaluating a variety of common structural alloy steels which are used extensively at the Nevada Test Site. The materials in question have been evaluated using nil-ductility tests, dynamic tear tests, and other valid fracture mechanics techniques.

Currently, we are applying fracture mechanics concepts to the design and evaluation of a variety of structures at LASL to ensure fracture safeness. These structures span the range from liquid CO_2 storage tanks and experimental explosive containment vessels to laser windows. In many instances, the material requirements are at the present technological limit and require special attention to attain the design properties. (key words: fracture mechanics, fracture toughness)

Optical Coatings
(D. J. Sandstrom) $150

A program has been initiated to investigate problems associated with the development and fabrication of state-of-the-art optical coatings. The work is focused on the optimization of deposition processes and coating designs for high energy infrared lasers and solar energy applications. Later work will extend the laser coatings effort into the ultra-violet and visible portions of the spectrum. The capability to produce instrumental coatings in the various spectral regions will become available with the start of the laser coating work in the same region. (key words: deposition, ultraviolet coatings, IR coatings, solar energy applications)

Superconducting Materials Research
(A. L. Giorgi, E. G. Szklarz, G. Stewart) $305

Preparation of new superconducting materials in a search for better materials; careful characterization of these materials to see how stoichiometry and purity influences the transition temperature (Tc). Measurement of low temperature heat capacity to determine energy gaps; discovery of anomalously large energy gaps. Superconductivity of radioactive elements. (key words: superconducttivity, high Tc, heat capacity, energy gaps)

Studies of Optical Spectra of the Actinides and Other Elements
(G. R. Waterbury, D. W. Steinhaus) $283

The optical spectra of selected actinides and other specific elements are being studied to provide atomic data useful in weapons design and effects calculations, laser weapons applications, isotope enrichment processes, opacity calculations, analytical applications, and calculations of thermodynamic properties. From the highly precise measurements of more than 100,000 lines of neutral and singly ionized uranium, isotope shifts, Zeeman patterns, hyperfine structures, wavenumbers, more than 1600 U I and 700 U II energy levels, and transition probabilities for some U I lines have been derived. Some of these measurements will be extended to thorium, plutonium, and multiply ionized uranium spectra.

The ability to handle and produce spectra of difficult materials has led to studies of the absorption spectrum of PuF_6 and preliminary work on the spectrum of triatomic tritium. The spectra of various molecules, including CS_2, SO_2

and UF_6, have been studied for application to isotope separation processes. Non-classical, optogalvanic spectroscopy studies using a tunable dye laser, have resulted in a better understandin of discharges and may have applications in isotopic or other types of analysis. The very rare and radioactive actinide element, actinium, also will be studied to determine its atomic level structure. (key words: optical spectra, actinides, tritium, uranium wavenumbers, isotope shifts)

Development of Chemical Characterization Equipment
(G. R. Waterbury) $135

An advanced, state-of-the-art, direct-reading, dual-grating spectrograph was designed at LASL and is being constructed for spectrochemical analyses. It will have over 200 photo detectors and will measure more than one spectral line of each metallic and several nonmetallic elements simultaneously. This spectrograph will accept signals from sources in plutonium and uranium glove boxes, and from several other sources on a time-sharing basis. With an inductively-coupled-plasma source, detection limits are in the mg/m^3 (ppb) range, much better than the g/m^3 (ppm) detection limits for unprocessed samples with conventional spectrographs. This direct-reading spectroscopic system includes a computer to record, process, and report the results and will provide more timely and accurate analyses with less manpower effort.

PDP-11 mini computer system, infrared detectors, and associated equipment and interfaces were installed to automate the analyses of plutonium, uranium, and other materials for oxygen contents. The equipment, now undergoing final testing, will operate up to four analyzers concurrently, and measure oxygen contents in the low g/m^3 (ppm) range. The equipment should provide equal or better accuracy than manual analyses and promises to be cost-effective in reducing manpower requirements.

An automated spectrophotometer was designed, built, and fully tested for determining 0.1 to 12 mg of uranium and/or 1 to 12 mg of plutonium at a rate of 8 to 12 samples per hour. Solutions of the samples containing the appropriat amounts of uranium or plutonium are transferred to 24 special cells in the apparatus, and the analyses proceed unattended. Automatic operations include dispensing of necessary reagents, liquid-liquid extraction of the actinide elements, measuring the optical absorbances of the extracted actinides, and printing of the sample identifications and analytical results. Measurement precisions are within the range of 0.5 to 3% relative standard deviation.

The speed and reliability of electron microprobe and ion microprobe analyses of plutonium, uranium, and/or other materials were improved by modifications in the two instruments and in the associated computer software. Modifications included interfacing to a strip chart recorder and software to provide rapid scans to identify elements present in a material, software to set wavelength (energy) and pulse height analyzer to measure an element by just typing in the elemental symbol, improved computer programming to make interelement corrections and produce quantitative results, and a multichannel scaler added to the ion microprobe to improve isotope abundance and depth profiling analyses. (key words: dual-grating spectrograph, computer-control, oxygen determinations, automated spectrophotometer, computer software, microprobe)

<u>Development of Chemical Characterization Methods</u>
(G. R. Waterbury) $50

To maintain chemical analysis capabilities at highly proficient and reliable levels for materials characterizations, new or improved methods are continually being developed. An emission spectrographic method for determining low concentrations of iridium and yttrium in plutonium was developed. The samples are partially dissolved, and the soluble and insoluble portions are analyzed separately for each element. An emission spectrographic method also was develope for determining traces of beryllium and lithium in powdered samples. A programmable calculator is used to record, process, and report the results. Methods have been developed for determining small amounts of tritium and deuterium and total gas contents of plutonium, plastics and lithium materials. Samples are either burned in air to produce T_2O and D_2O, or heated with chromium powder to release the elemental gases for volume, mass spectrometric, and radiochemical counting measurements. The assay of PuO_2 for plutonium was improved by modifyinc an existing method. The PuO_2 samples are dissolved and then reacted with zinc to reduce all higher oxidation states of plutonium to Pu^{+3} which is titrated with ceric sulfate solution to a photometric endpoint. New standards were prepared and put into use for electron microprobe and ion microprobe analyses. These standards include well characterized UO_2, PuO_2, and ThO_2. (key words: analysis methods, iridium, yttrium, beryllium, lithium, tritium, PuO_2 assay)

Sandia Laboratories

Electrochemical Fabrication of Metal Structures
(J. W. Dini, H. R. Johnson) $125 K

Electrodeposition from aqueous solutions of Au, Cu, Ni focusing on the relationship between the critical process variables and the mechanical and physical properties. (key words: electrodeposition, gold, copper, nickel, mechanical properties)

Physical Aging of Glassy Polymers
(R. R. Lagasse) $100 K

Techniques are being developed for the prediction of long term aging effects on glassy polymers due to purely physical relaxation processes. Materials studied are crosslinked glasses (epoxies), as well as thermoplastic glasses (acrylics). (key words: aging, glassy polymers, epoxies, acrylics)

Radiation Hardening of Integrated Circuits
(W. R. Dawes, Jr., G. F. Derbenwick, J. R. Adams, C. F. Gibbon, P. V. Dressendorfer) $300 K

Characterizing and improving the effects of radiation on integrated circuits and integrated circuit materials. (key words: integrated circuits, radiation hardening, LSI)

Pulsed Laser Welding of Molybdenum
(J. L. Jellison) $54 K

Evaluation of improvements in fracture toughness of molybdenum welds afforded by pulsed-mode welding and in situ gettering of oxygen by titanium and boron. Analyses to identify segregates responsible in intergranular cleavage. (key words: molybdenum, laser, welding)

NUCLEAR ENERGY

REACTOR RESEARCH AND TECHNOLOGY DIVISION

Introduction:

The 47 materials program tasks described below are directed at supplying the necessary technical support in the materials area to assure that reliable, safe and economic plant designs can be identified and developed. The materials programs fall into the two general support areas listed below and are funded at the levels indicated:

	FY 1979 ($K)
Plant Systems and Components Materials (Non-Core)	6,528
Fuel and Cladding/Duct Materials (Core)	25,452

The funding at various contractors, national laboratories and government laboratories is as follows:

	FY 1979 ($K)
Argonne National Laboratory	1,278
Combustion Engineering	470
General Electric	2,410
Hanford Engineering Development Laboratory	13,504
Idaho National Engineering Laboratory	750
Los Alamos Scientific Laboratory	5,350
Naval Research Laboratory	250
Oak Ridge National Laboratory	2,930
Rockwell International	535
Westinghouse Advanced Reactors Division	4,503
TOTAL	31,980

Reactor Research and Technology Division

I. Plant Systems and Components Materials (Non-Core)

A. Argonne National Laboratory

1. Mechanical Property for Structural Materials

(R. W. Weeks) $550K

Provide information required to develop a verified design basis for LMFBR structural components; develop design failure criteria; provide mechanical properties data on LMFBR structural materials including weldments in both air and sodium; determine the effect of thermal aging on mechanical properties; evaluate the carburization/decarburization kinetics of 9 Cr-1 Mo steel in sodium.

(Key words: structural materials, design basis, mechanical properties)

2. NDT Development and Engineering Support

(R. W. Weeks) $110K

Develop reliable and economic nondestructive test methods for in-service inspection of coarse grain welds in reactor components at both room temperature and elevated temperature; develop NDT techniques for in-service inspection of duplex tubes; develop three-dimensional radiography for fuel subassembly examination without disassembly.

(Key words: welds, duplex tubes, three-dimensional radiography)

B. General Electric

1. Steam Generator Materials Qualification (P. J. Ring)

$540

Provide material and fabrication control and qualified manufacturing and inspection procedures for materials used in LMFBR steam generators; characterize 2¼ Cr-1 Mo tubing and tubesheet forgings, tube/tubesheet welds, shell plate, nozzles and heavy section welds for CRBR steam generators;

apply advanced NDE techniques and water chemistry technology to assure system integrity and reliability; develop stainless steel to 2¼ Cr-1 Mo transition joint capable of serving design life of FBR plant.

(Key words: transition welds, steam generator materials.)

2. Steam Generator Materials Engineering (P. Roy)

$424

Establish the properties and behavior of steam generator materials used for CRBR under prototypic conditions; tasks include measuring the mechanical properties of 2¼ Cr-1 Mo steel under various environmental conditions and after thermal aging, determining the decarburizing effect of sodium on 2¼ Cr-1 Mo steel, evaluating the stress-corrosion behavior of 2¼ Cr-1 Mo steel in a caustic environment.

C. Hanford Engineering Development Laboratory

1. Radiation Effects on Structural Materials (R.L. Knecht)

$485K

Provide mechanical property data on irradiated and unirradiated materials to support the design, performance and safety analysis, and operation of out-of-core breeder reactor components and structures by: (a) conducting irradiation experiments, (b) performing property measurements, and (c) analyzing, interpreting and documenting test results. Provide technical coordination for national program on radiation effects in structural materials.

(Key words: radiation effects, structural materials.)

2. Nondestructive Testing (T.E. Michaels)

$227K

Develop technology to solve existing and anticipated NDT application problems using the following methods:

x-ray and neutron radiography, ultrasonics, eddy currents, electrothermal, acoustic emission, and liquid penetrants. These primary current emphasis are being directed toward techniques for the ultrasonic inspection of FFTF piping.

(Key words: Inspection, NDT, FFTF.)

3. Materials for Friction, Wear and Self Welding

(R. N. Johnson) $72K

Coordinate the development of improved hardsurfacing alloys for reactor mechanical interfaces, and technically direct the National Friction, Wear, and Self-Welding Program.

(Key words: wear, friction, hardfacing alloys.)

4. Materials Information Documentation (J. Spanner, R. A. Moen) $250

Develop the Nuclear Systems Materials Handbook (NSMH) through a coordinated effort involving all major DOE/RRT Breeder Reactor Program contractors and other representatives from related nuclear industries; provide the NSMH and revised/updated contents to organizations involved in DOE/RRT's advanced nuclear systems programs.

(Key words: materials handbook.)

D. Idaho National Engineering Laboratory

1. Welding Technology Development (P. W. Turner) $200

Advance welding technology as applied to commercial and developmental nuclear power plants by developing improve pipe welding techniques and procedures which minimize effects on stress intensification; improve ease of nondestructive examination, and improved weldment quality and reproducibility.

(Key words: pipe welding, improved weld joints.)

2. <u>Alloy 718 Mechanical Properties</u> (G.E. Korth)

$550

Provide mechanical properties data (tensile, fatigue, creep rupture, thermal-aging, toughness, etc.) on Alloy 718, given a heat treatment that assures adequate engineering properties for the design needs of FBR plants and to supplement existing data needed for acceptance in an ASME Code Case.

(Key words: Alloy 718 properties, Alloy 718 heat treatment.)

E. <u>Naval Research Laboratory</u>

1. <u>Neutron Effects on Structural Materials</u>

(L. E. Steele, D. J. Michel) $190K

Provide guidelines for producing improved and radiation resistant structural materials for the assurance of structural integrity through the investigation of the performance of FBR structural materials irradiated under prototypical reactor operating conditions.

(Key words: structural materials, radiation effects, FBR.)

F. <u>Oak Ridge National Laboratory</u>

1. <u>Piping and Fittings Development</u> (J. W. McEnerney, C. R. Brinkman) $400

Develop fabrication methods for large diameter stainless steel pipe and fittings and determine effects of fabrication methods on elevated temperature behavior of the materials. Develop transition joint welding materials and inspection data for design and fabrication of high reliability FBR pipe joints between dissimilar materials.

(Key words: transition welds, transition joint materials, pipe fabrication.)

2. Joining Development (G. M. Goodwin)

$205

Continue to develop and commercialize austenitic stainless steel welding materials with improved high-temperature mechanical properties; determine creep, tensile, impact, and fatigue design data for critical prototypical weldments, evaluate advanced transition joints and recommend optimum materials and processes.

(Key words: austenitic stainless steel weldments, advanced transition joints.)

3. Development of Ferritic 9% Cr Alloy (V. K. Sikka)

$615

Develop a modified 9 Cr-1 Mo alloy for pressure-boundary and structural material applications, tasks include alloy development to determine a specification for chemistry and heat treatment; establish melting practices suitable for large ingots and manufacturing capability for a range of product forms, developing fabrication capability through welding development studies; determining the properties of commercial material relative to LMFBR applications.

(Key words: alloy development, 9 Cr-1 Mo, commercialization.)

4. Mechanical Properties of Reference Materials

(C. R. Brinkman) $870

Provide mechanical properties data in support of the development of codes, standards, and constitutive equations; tasks include coordinating the national mechanical properties testing program, conducting tensile, creep, fatigue, creep-fatigue, crack-growth and complex interaction tests and evaluating heat-to-heat and thermal-aging effects on mechanical properties.

(Key words: coordination, codes, mechanical properties data.)

5. Nondestructive Testing (R. W. McClung)

$280

Determine and address the high-priority needs for NDT methods and techniques through coordination of the LMFBR national program and the development of advanced methods of NDT; tasks include developing volumetric examination methods for austenitic stainless steel welds and for manufacturing examination of steam generator tube-to-tubesheet joints and in-service inspection of steam generator tube-to-tubesheet joints and tubing.

(Key words: coordination, austenitic stainless steel welds, steam generator.)

G. Westinghouse Advanced Reactors Division

1. Friction, Wear, and Self-Welding (W. E. Ray)

$175

Support the national LMFBR tribological program; tasks include self-welding tests in support of CRBR Secondary Shut-Down System and Subassembly/ Upper Internal Interface, friction and wear tests in argon on PCRS interfaces, and long-term compatability tests of diffusion coatings in sodium.

(Key words: self-welding, friction and wear, sodium.)

2. Mechanical Properties of Structural Materials (W.E. Ray)

$385

Experimentally determine the effect of a flowing sodium environment on the mechanical properties of LMFBR structural materials; tasks include determining the creep rupture, creep fatigue, low- and high-cycle fatigue and notch effects on creep rupture of types 304 and 316 stainless steel, type 316 stainless steel welds and Alloy 718.

(Key words: sodium, mechanical properties, structural materials.)

II. Fuel and Cladding/Duct Materials (Core)

A. Argonne National Laboratory

1. Alloy Development (L. Walters) $150K

Perform analysis on alloy specimens to determine the effect of stress on swelling and creep.

(Key words: stress, swelling, creep.)

2. Alternative Fuels Properties (H. Kittel) $168K

Determination of the compatibility of metal fuels and candidate cladding alloys, and development of improved Th-Pu-U alloys with higher solidus temperatures.

(Key words: metal fuels.)

3. Advanced Fuels - Transient (L. Neimark, H. Kittel)

Design, irradiate and evaluate advanced fuels transient tests; develop fuel and blanket pin performance codes, validate codes with pin irradiation data.

(Key words: transient, TREAT, modelling, lifetime.)

B. Combustion Engineering

1. Advanced Fuels/Blanket - Steady State (R. Noyes)

$470

Design, irradiate and evaluate advanced blanket fuel tests.

(Key words: carbide, blanket, assembly design.)

C. General Electric

1. Alloy Development (K. Appleby) $530K

Perform examinations and analysis of creep-in-bending test, and assess post-irradiation ductility of advanced alloys.

(Key words: creep-in-bending, ductility.)

2. Fuel Rod Test and Analysis (K. Appleby) $481K

   Determination of fuel rod behavior under specific conditions of fast neutron irradiation. Tests are focused on providing data for design and licensing in the areas of thermal performance, mechanical performance, chemical effects, and run to and beyond cladding breath.

   (Key words: fuel rod behavior, neutron irradiation.)

3. Fuels Properties (M. Adamson) $435K

   Support the national program on fuels properties measurements and evaluation by performing property evaluations and developing correlations for the Nuclear Systems Materials Handbook (NSMH); performing mechanical, physical (melting) and thermodynamic property measurements on ThO_2 and ThC; study cesium transport behavior and effects in oxide systems; study and evaluate fuel-cladding chemical interaction (FCCI) in oxide and carbide systems; and develop sodium-fuel reaction swelling (SFRS) model and study blanket fuel dispersal in sodium.

   (Key words: properties, NSMH, FCCI.)

D. Hanford Engineering Development Laboratory

1. In-Reactor Deformation (J. Holmes, B. Chin) $600K

   Characterize the in-reactor deformation behavior of breeder reactor cladding and duct materials by the use of both instrumented and non-instrumented reactor tests on mechanically loaded and non-fueled specimens as well as analysis of reactor core components which were mechanically loaded during service.

   (Key words: creep, creep rupture.)

2. Swelling and Microstructure (J. Straalsund, M. Korenko, T. Bierlein) $890K

   Characterize the swelling behavior of breeder reactor cladding and duct materials, and assess, through study of microstructural evolution under irradiation, mechanisms which exert a controlling influence on the in-reactor deformation characteristics of these materials. Identify appropriate means for control of compositional and processing parameters for optimum alloy performance.

(Key words: swelling, phase stability, microstructure.)

3. Mechanical Properties (J. Holmes, G. Wire, G. Johnson) $401K

Determine the effects of fast reactor neutron irradiation and environment on the postirradiation mechanical properties of breeder reactor cladding and duct materials by performing ductility screening tests, tensile tests, fracture toughness tests and transient burst tests.

(Key words: ductility, tensile, fracture toughness, transient burst.)

4. MOTA Design and Development (J. Holmes, B. Chin, M. Paxton) $804K

Conduct design, development, fabrication and assembly of Materials Open Test Assemblies for irradiation of non-fueled materials tests in FFTF.

(Key word: MOTA)

5. Reference Fuels - Steady State (FFTF) (C. Cox) $2587K

Design, fabricate, irradiate, examine and evaluate standard FFTF driver fuel in FFTF, special tests of standard driver fuel (such as high power, power-to-melt, backup spacers and FOTA's) in FFTF and tests of improved driver fuel in FFTF and PFR to meet design lifetime (e.g., using advanced alloys) and extended lifetime.

(Key words: FFTF driver fuel.)

6. Reference Fuel - Transient (J. Hanson) $1605K

Conduct experimental and analytical program for establishing transient performance limits and for design bases confirmation of FFTF driver fuel and other FBR fuel systems.

(Key words: transients, confirmation.)

7. Reference Fuels - Steady State (EBR-II)

(C. Cox) $1604K

Design, fabricate, irradiate, examine and evaluate FFTF driver fuel irradiation tests in EBR-II and GETR.

(Key words: EBR-II, GETR.)

8. Advanced/Alternative Oxide Fuel (C. Cox) $1634K

Design, fabricate, irradiate, examine and evaluate fuel irradiation tests of: (1) alternative (Pu, Th and ^{233}U) oxide FBR fuels in EBR-II, and advanced (U, Pu) oxide fuels in EBR-II and FFTF.

(Key words: alternative oxides, advanced oxides.)

9. Technical Support - Fuel Properties (R. Gibby)

$ 244K

Obtain by laboratory measurements properties data required for design, performance analyses and fabrication of fuel and blanket materials. Develop analytical relationships for experimental data compatible with performance codes and models. Prepare reports on results and recommendations for fuel/blanket materials properties. Review, evaluate and recommend properties data for non-metallic fuel/blanket materials.

(Key words: data, analytical relationship.)

10. Oxide Blanket Testing (C. Cox) $175K

Design, fabricate, irradiate, examine and evaluate blanket fuel irradiation test, and provide blanket fuel irradiation program coordination.

(Key words: oxide blankets.)

11. Absorbers (K. Birney) $1015K

Design and develop breeder reactor absorber components which provide economic advantages and enhanced performance relative to current technology, demonstrate the performance capability of absorber components by irradiation testing and appropriate ex-reactor characterization, verify the performance of FTR control elements by testing and periodic surveillance examinations, and provide fabrication engineering support and develop industrial suppliers of absorber components.

(Key words: absorber components.)

12. Carbide Fuel - Steady State (C. Cox) $243K

Design and code calculational support for a FFTF carbide fuel tests and analysis of carbide fuel from EBR-II tests.

(Key words: carbide fuel.)

13. FFTF Driver Fuel (C. Cox) $668K

Analysis and test engineering for FFTF driver fuel, including analysis for bundle/duct interaction and design and test engineering of modified wire wrap.

(Key words: bundle/duct interaction.)

E. Los Alamos Scientific Laboratory

1. Advanced Fuels Fabrication and PIE (J. L. Green, W. T. Wood) $5350

Fabricate carbide fuel test pins, analysis of data from EBR-II advanced fuels and post-irradiation examination of reference and advanced fuels.

(Key words: carbide fuel. PIE, fuel tests.)

F. Naval Research Laboratory

1. Alloy Development (F. Smidt and L.E. Steele)

$ 60K

Conduct examinations of ferritic alloy specimens and perform fracture toughness evaluation of ferritic alloy samples.

(Key words: ferritic alloys, fracture toughness.)

G. Oak Ridge National Laboratory

1. Alloy Development (A. Rowcliffe) $560K

Conduct examinations and analysis of selected advanced alloy specimens for swelling and phase stability. Perform post irradiation tensile tests and microstructural exams of advanced alloys, and conduct analysis of creep test results.

(Key words: creep, swelling, phase stability, tensile tests.)

H. Rockwell International

1. Fuels Development (L. Jones, B. Ostermier) $535K

Fabricate advanced fuel blanket pellets for carbide blanket fuel assembly testing.

(Key words: blanket fuel fabrication, uranium carbide.)

I. Westinghouse Advanced Reactors Division

1. Advanced Alloy Analysis (M. Bleiberg) $400K

Characterize the swelling behavior and phase stability of selected advanced alloy specimens, and conduct tensile tests and examinations of advanced alloys to determine the mechanisms of ductility loss.

(Key words: swelling, phase stability, ductility.)

2. Design Equation Development and Creep/Swelling Analysis (A. Boltax, P.F. Fox) $225K

Develop fuel pin cladding performance predictions, and perform steady state and transient damage analysis as well as property correlations. Conduct analysis and post-irradiation examinations of creep/swelling opposition test.

(Key words: design equations, creep/swelling opposition.)

3. Fuel Element Irradiation Testing (A. Boltax) $786K

Support national activities on fuel element irradiation testing including: EBR-II and FTR tests on oxide and carbide fuel and blanket pins.

(Key words: irradiation testing, carbide, oxide.)

4. Test Element/Vehicle Fabrication (A. Boltax, J. Theilacker) $1717K

Support national activities on test element and vehicle fabrication including: fuel and pins for FTR and EBR-II carbide fuel tests, and grid spaced assembly hardware for the FTR MFTA tests and RTCB-4.

(Key words: MFTA, RTCB, fabricate.)

5. Blanket Design and Development (B. Minushkim)

$815K

Perform design, analysis, testing and development work in the area of thermal-hydraulics, irradiation, flow control, mechanical performance and feature development for breeder reactor blanket assemblies and assembly components.

(Key word: blankets.)

Advanced Nuclear Systems and Projects Division

The Advanced Nuclear Systems and Projects (ANSP) Division reports to the Assistant Secretary for Energy Technology through the Office of Nuclear Energy Programs. The Division is composed of three branches: (1) Space and Terrestrial Systems, responsible for developing radioisotope thermoelectric generators, heat and irradiation sources for use in space/earth applications, (2) Advanced Isotope Separation, which is developing and evaluating novel uranium enrichment, other isotope separation processes, and evaluating advanced concepts relating to applications of nuclear power, and (3) Nuclear Processing and Projects, which provide management and technical coordination of the nuclear processing programs, including the Fluorinel program, at Idaho Chemical Processing Plant. In FY 1979, approximately $5.5 million was funded by ANSP on research, development and processing of fuel, cladding and thermoelectric materials for the Space and Terrestrial Systems Branch. Further information can be obtained by contacting Dr. N. Goldenberg, Director, ANSP (301-353-5006).

General Purpose Heat Source

(R. D. Baker, S. E. Bronisz) $2120
Los Alamos Scientific Laboratory

Development of materials, selection, design and prototype fabrication of plutonium-238 fueled heat sources. Preparation and testing of $^{238}PuO_2$ fuel bodies, testing of iridium alloy claddings, 2-D and 3-D composite graphites. Heat source compatibility. High temperature, high strain rate impact studies. Launch abort and/or reentry fire, blast overpressure, sequential testing. Component qualification. (Key words: Pu-238, processing, iridium, mechanical properties, physical properties, compatibility, heat sources.)

Advanced Isotope Power Fuels

(E. Lamb) $ 100
Oak Ridge National Laboratory

Compatibility, mechanical property tests of candidate $^{244}Cm_2O_3$ isotopic heat sources. Chemical reprocessing, recovery, and characterization of $^{244}Cm_2O_3$ bodies. Program completed. (Key words: Cm-244, physical properties, compatibility, recovery.)

Irradiator Fuels Technology

(B. T. Kenna) $ 100
Sandia Laboratories

(J. R. Keiser) $ 200
Oak Ridge National Laboratory

Development of $^{137}CsAlSi_2O_6$ as an insoluble sewage sludge and potential food gamma irradiator fuel. Processing, hot pressing parameters, physical properties, stability tests. (Key words: Cs-137, processing, properties.)

Materials Technology Support
(A. C. Schaffhauser) $ 300
Oak Ridge National Laboratory

Iridium alloy development, mechanical properties as function of strain rate, metallurgical characterization. Creep and stability testing in gaseous environments. Conventional and laser welding development of iridium alloys. (Key words: iridium, mechanical properties, welding.)

Iridium Alloy Processing and Fabrication
(A. C. Schaffhauser) $ 580
Oak Ridge National Laboratory

Batch melting, rolling and fabrication of iridium alloys for isotopic heat source components. (Key words: iridium, metallurgical processing, fabrication.)

Strontium-90 Heat Source Development
(H. H. Van Tuyl, H. T. Fullam, D. G. Atteridge, F. A. Simonen) $ 350
Pacific Northwest Laboratory

Chemical and physical properties of $^{90}SrF_2$ as heat source fuel. High temperature compatibility with container materials. Heat source capsule design, qualification and licensing. (Key words: Sr-90, heat sources, properties, compatibility.)

Heat Source Component Evaluation
(E. Foster, I. Grinberg, E. Hulbert, R. Whitacre) $ 200
Battelle Columbus Laboratories

Analytical evaluations using 2-D and 3-D models of space heat source performance under abort and reentry modes. Graphite ablation, spallation. (Key words: graphite, ablation, modeling.)

Thermoelectric Conversion Materials
(J. D. Hinderman) $ 950
3M Company

Development of high efficiency selenide base thermoelectric materials of p-type, Cu 1.97 Ag 0.03 Se 1.0045; n-type, GdSe 1.49. Doping mechanisms for nonstoichiometric selenide lattices. Alloy synthesis, processing; element, couple and power module fabrication. Thermodynamic stability, compatibility, mechanical property characterization. Couple and power module performance evaluation. (Key words: thermoelectrics, processing, selenides, properties, fabrication.)

Thermoelectric Materials Evaluation
(N. B. Elsner) $ 250
General Atomics Company

Development and evaluation of thermoelectric bonding materials and processing methods. Thermodynamic properties. Sublimation suppression coatings. (Key words: thermoelectrics, processing.)

Gadolinium Preparation
(K. A. Gschneidner, Jr.) $ 340

Processing and refining gadolinium metal for use in selenide n-leg thermoelectric couples. Investigation of new rare earth thermoelectric materials, e.g., sulfides, Nd_2Se_{3-x}. Pilot production of very high purity Gd. (Key words: Gd, processing, refining.)

Fluorinel Fuel Storage & Processing
(R. E. Mizia) $ 45
Idaho Chemical Processing Plant

Evaluation of Hastelloy C-4 weld wire and weldments exposed to dissolved and complexed Fluorinel fuel solutions. (Key words: Hastelloy C-4, weld pitting, corrosion.)

DIVISION OF NAVAL REACTORS

The Materials Research and Development Program in the Division of Naval Reactors is in support of the development and operation of improved and longer life reactors and pressurized water reactor plants for naval nuclear propulsion. In addition, this program supports the Light Water Breeder Reactor (LWBR) currently operating in the Shippingport Atomic Power Station and the Advanced Water Breeder Activity to develop technical information that will assist U.S. industry in evaluating the LWBR for commercial scale applications.

The objective of the materials program is to develop and apply in operating service materials capable of use in the high power density and long life required of naval ship propulsion systems. This work includes irradiation testing of reactor fuel, poison, and cladding materials in the Advanced Test Reactor at the Idaho National Engineering Laboratory. This testing and associated examination and design analysis demonstrates the performance characteristics of existing materials as well as defining the operating limits for new materials.

Corrosion, mechanical property, and wear testing is also conducted on reactor plant structural materials under both primary reactor and secondary steam plant conditions to confirm the acceptability of these materials for the ship life. This testing is conducted primarily at two Government laboratories - Bettis Atomic Power Laboratory in Pittsburgh and Knolls Atomic Power Laboratory in Schenectady, New York.

One result of the work on reactor plant structural material is the issuance of specifications defining the processing and final product requirements for materials used in naval propulsion plants. These specifications also cover the areas of welding and nondestructive testing.

The materials program effort applied to the Water Breeder Reactor program includes irradiation testing of fuel rods utilizing the thorium-uranium-233 fuel cycle, which has the potential for providing appreciably more energy than the current design of water reactors. This testing provides the basis for the development of analytical models for use in calculating the performance of fuel rods in pressurized water reactors.

Funding for this materials program is incorporated in naval projects jointly funded by the Department of Defense and the Department of Energy and the Water Breeder Reactor program funded by the Department of Energy. This funding amounts to approximately $38 million dollars in FY 1979, including about $15 million as the cost for irradiation testing in the Advanced Test Reactor.

NUCLEAR POWER DEVELOPMENT DIVISION

The Division of Nuclear Power Development (NPD) reports to the Director of the Office of Nuclear Energy Programs (ETN). This division is responsible for technology development in four major program areas: Light Water Reactors (LWR); High Temperature Gas Reactors (HTGR); Gas-Cooled Fast Reactors (GCFR);, and Nuclear Fuel Cycle (NFC). Descriptions and extended plans for these programs are given in an annual publication of the Nuclear Energy Program Office entitled, "Fission Energy Program of the U.S. Department of Energy." The most recent issue is DOE/ET-0089, dated April 1979.

The majority of the materials research and development programs supported by this division are funded by the HTGR Branch. The FY 1979 budget outlay for this branch is $33.5 million and a major portion of that funding is allocated for the following programs:

A. General Atomic Company

o Fuel Development $2580

(T.D. Gulden, O. M. Stansfield)

Development of high-temperature coated-particle fuels and fuel rods. Ceramic fuel kernel preparation and coating process development. Irradiation testing, performance demonstration and specification preparation. (Key words: fuel, coated particles, irradiation)

o Materials Technology $1840

(D. I. Roberts, S. N. Rosenwasser)

Development of high-temperature metallic and ceramic structural materials. Evaluation of mechanical properties and corrosion effects after extended exposures in simulated reactor helium environments. (Key words: elevated temperature, properties, corrosion) o Graphite Materials Development

(G. B. Engle, R. J. Price)

Evaluation and development of graphites for reactor applications as fuel and reflector blocks and core support blocks and posts. Characterization of strength, density and purity of production-grade logs. Determination of oxidation rates and effects on strength and effects of irradiation on dimensional changes and mechanical and physical properties. (Key words: graphite, property characterization, oxidation, irradiation.

B. Oak Ridge National Laboratory

o Fueled Graphite $1640

(F. J. Homan, E. L. Long)

Development, preparation and demonstration testing of coated-particle fuels and fuel bodies in ORNL test reactor. Preparation of fissile and fertile fuel kernels, applications of multi-layer ceramic coatings, preparation of fuel rods, fabrication and testing of irradiation capsules, and analysis and reporting of results. (Key words: fuel, coated particles, irradiation)

o Structural Materials Studies $690

(H. E. McCoy, J. P. Strizak, H. Inouye)

Development of high-temperature metallic and ceramic structural materials. Evaluation of mechanical properties and corrosion effects after extended exposures in simulated reactor helium and steam environments. Evaluation of weldability and weld properties. (Key words: elevated temperature properties, corrosion, weldability)

o HTGR Graphite Studies $550

(W. P. Eatherly, J. A. Colin)

Determination of effects of irradiation on creep properties and dimensional changes of HTGR candidate graphites. Design, fabrication and operation of irradiation experiments to test specimens at service temperatures and under constant stress. (Key words: graphite, irradiation creep, dimensional stability) o Graphite Oxidation Studies $200

(W. P. Eatherly, R. W. Wishner)

Determination of oxidation rates and the effects on strength of HTGR candidate graphites. Exposure of samples to produce predicted microstructural changes for expected burnoff levels. Characterization of samples and determination of effects on mechanical properties. (Key words: graphite, oxidation, burnoff, strength)

C. General Electric Company

o Advanced Materials Evaluation Program $1335

Evaluation and development of high-temperature alloys for applications in advance gas-cooled reactor systems, i.e., the direct cycle (gas turbine) and process heat designs. Testing of available candidate alloys in simulated reactor coolant environments and determination of the effects of extended exposures on mechanical properties. (Key words: high-temperature alloys, corrosion, thermal stability, mechanical properties)

NUCLEAR WASTE MANAGEMENT

There are three technical divisions in this program: Waste Isolation (commercial waste), Waste Products (commercial and defense including interim storage), and Fuel Storage and Transfer. No separately identified materials program exists within the organization. However, materials testing and development work is underway connected with the various processes being examined. Materials work is conducted related to waste forms suitable for radioactive waste containment, canister materials testing and corrosion/materials compatibility studies. The estimate for materials studies is about 10.0 million dollars and was administered by the SR, RL and ID operations offices.

During FY 1979 an Office of Nuclear Waste Management Materials Steering Committee, chaired by C. A. Heath, was established which has a responsibility for planning and coordinating the testing and qualification of materials to be used in the long term waste management programs. A primary concern will be to assure that materials needs are integrated and considered from a total office viewpoint.

A Waste Materials Characterization Center was also established during FY 1979 at Pacific Northwest Laboratory. The Center will be responsible for establishing standard materials tests which will be used throughout the waste management program.

FOSSIL ENERGY

DIVISION OF FOSSIL FUEL UTILIZATION

The Division of Fossil Fuel Utilization (FFU) has responsibilities for displacing the use of petroleum and natural gas with synthetic fuels in energy conversion equipment at the earliest time. This multi-fuel capability must be obtained with an advantageous durability and efficiency trade-off and acceptable emissions. Materials are intimately involved in the development of advanced concepts and enhancing the durability of current and modified equipment to operate in the more aggressive corrosion/erosion environment of some of the synthetic fuels.

The Division of Fossil Fuel Utilization is comprised of three branches. The Heat Engines and Heat Recovery Branch is responsible for the development of high efficiency engine cycles, intermediate and baseload utility power generation, advanced cogeneration technologies and technology for cost effective recovery of reject heat. The Combustion Systems Branch is developing combustion technology to improve conventional and fluidized-bed combustion of coal and to develop combustion of alternate fuels. This branch also has responsibilities for improving combustion equipment efficiency such as engine combustors, space heaters and industrial furnaces. The Fuel Cell Branch is developing fuel cell powerplants for electric power generation, in a variety of simple cycle, cogeneration and waste heat conversion configurations.

The materials technology being developed in the Division's programs are strongly applications oriented. Thus, coating development involves mechanical integrity with component, composition and microstructure optimization for thermal excursions and corrosion environment. Component cooling and operating conditions influence material development. Heat engine efficiencies are related to materials high temperature properties cooling requirements and flow path surface conditions. Engine durability is dependent on fuel characteristics, fuel handling and the resulting combustion zone corrosion/erosion environment as well as the operational steady state and ramp conditions and engine water wash effectiveness.

Historically, materials development is an integral part of heat engine development. Advanced materials technology directly supporting advanced engine development is also integrated with respect to the demanding series of hot-corrosion, high temperature strength, creep and fatigue requirements, often in an interelative design effort with changes in component geometry and alloy composition and microstructure. Therefore, materials R&D funding does not appear as a budget line item in the Division's programs. Materials development costs presented represent estimates by the cognizant Program Managers.

The total funding level for materials development for the Division in FY79 is approximately $20 million. The materials development work of the Division's programs is summarized as follows:

I. Heat Engines and Heat Recovery

A. Ceramic Coating Development for Heat Engine Combustion Zones

The objectives of the ceramic coating, or thermal barrier coating program are to first significantly enhance utility/industrial gas turbine and diesel engine durability with multi-fuel capability and then to obtain the insulative advantages which result in improved engine efficiency. A competitive process resulted in awards to two engine manufacturers to develop ceramic coatings in Phase I and to engineer these coatings to hot-section components in Phase II. Also there are ten supporting technology efforts focusing additional talents on specific ceramic coating problems. The ceramic coating-development program with the engine manufacturers is being managed by the National Aeronautics and Space Administration/Lewis Research Center (NASA/LeRC). Battelle-Pacific Northwest Labs (PNL) are managing the support technology.

(1) Contractor--Solar Turbines International, $240 K

Contract was awarded in February 1979. Four ceramic coating $ZrO_2 8Y_2O_3$, $M_gAl_2O_4$, $CaTiO_3$ and $ZrO_2 24MgO$ are being screened using selected bond and intermediate layers for hot-corrosion resistance. Twenty-one systems will be screened under cyclic oxidation conditions and ballistic impact. Selected coatings will be screened in high velocity burner rig tests on air-cooled specimens. Diagnostics will be performed to assess the corrosion resistance and stress accommodation. Iterations on the coating composition and microstructure and a 1000 hour high velocity burner rig test will be conducted. This work is directed at provided data justifying a Phase II effort involving engineering a ceramic coating to hot-section components. Promising candidate coatings will be independently tested.

(2) Contractor--Westinghouse, $800 K

Contract awarded May 1979. Initial work will screen approximately 70 candidate coating systems. Variations include composition, microstructure and alternate layers. Burner rig test, iterations and analytical stress analysis will follow a similar format as described above under the Solar program.

B. Ceramic Coating Support Technology

(1) Contractor--Battelle-PNL, FY79, $90 K

PNL is developing sputter-deposited multilayered ceramic/metallic coatings. Combined mode DC/RF sputtering is used to make deposits consisting of alternate layers of Ni/ZrO_2+Y or Ni-50Cr/ZrO_2+Y with systemmatic variations in layer thicknesses and component gradients between layers. Cyclic thermal shock testing and bend testing is encouraging.

(2) Contractor--Battelle-PNL, FY79, $90K

PNL is improving the adherence and stress accommodation of sputtered ZrO_2 ceramic coatings by developing high aspect ratio cones on the metallic bond layer surface. This approach distributes thermal mismatch stresses over a greater area as well as enhancing columnar formation in the ZrO_2 outerlayer. This columnar structure appears in early testing to reduce microcrack initiation and crack propagation. Cone formation has been obtained on the CoCrAlY surface but has not been optimized. Work is continuing on improving cone formation and variations in the sputter deposition process to obtain a stress accommodating, impermeable ZrO_2 outerlayer.

(3) Contractor--Linde Division of Union Carbide, FY79, $70 K

Linde is investigating the structural effects obtained through variations of the plasma spray deposition parameters.

The metallic bond coat used in all depositions is a NiCoCrAlY. Deposition parameter variations are done with $ZrO_2Y_2O_3$ and $MgOZrO_2$ with and without a Cr intermediate layer. Depositions were achieved with percent theoretical densities between 84 and 90. Currently thermal fatigue testing is being done. Candidate test specimens will be delivered for burner rig tests.

(4) Contractor--General Electric, FY78, $60 K

Hot-corrosion attack investigation is being conducted with NASA supplied plasma sprayed $ZrO_2Y_2O_3$ coatings with NiCrAlY bond layers. Salt deposits containing Na_2SO_4 with V and Pb impurities were studied by means of crucible and sprayed salt laboratory tests. Salt deposits containing V at 900^{o}C formed a YVO_4 on the surface which lead to destabilization and rapid failure of the zirconia layer.

(5) Contractor--United Technologies, FY79, $60 K

The mechanism of hot-corrosion attack on several candidate ceramic coatings is being investigated under a series of conditions known to initiate hot-corrosion attack of metallic systems. Specifically, hot-corrosion attack of Na_2SO_4, NaCl, V_2O_5 and SO_3 on ceramic coatings was investigated at 700^{o} and $982^{o}C$. The ceramics studied were SiO_2, Si_3N_4, mullite ($3Al_2O_3$ $2SiO_2$), zircon ($ZrSiO_4$), Al_2O_3 and ZrO_2+Y_2O_3. Results obtained indicate ceramic coating systems require testing of both basic and acidic salt fluxing reactions to determine hot-corrosion resistance. This is different than metallic systems which undergo protective oxide scale breakdown in a distinct initiation stage followed by a propagation stage. Preferential removal of Y_2O_3 from Y_2O_3 stablized ZrO_2. The Y_2O_3 removal increases with decreasing temperature and increasing Y_2O_3 content. Thus, increasing the Y_2O_3 content is not a means of inhibiting Y_2O_3 removal. This result is particularly significant as the primary candidate ceramic coating is the yttria stablized zirconia system.

(6) Contractor--Naval Research Laboratory, FY78, $70K

The Naval Research Lab (NRL) is providing characterization and fracture mechanics analysis support for candidate ceramic coatings developed in DOE programs. Consultation is also provided on DOE programs using ceramics in heat engine and heat recovery programs. NRL is currently conducting mechanical property analysis of Norwegian diesel engine coatings.

(7) Contractor--Central Institute for Industrial Research, FY79, $50K

The Central Institute for Industrial Research in Oslo, Norway was tasked to develop coatings resistive to the hot-corrosion encountered in diesel engines due to poor quality residual fuels around the world after the 1973 War. Coatings developed have tripled exhaust valve and piston crown life by a factor of 3. The Central Institute is applying some of their most promising plasma sprayed ceramic coatings to burner rig and mechanical specimens and exhaust valves for test and evaluation in the U.S. This work may have direct applicability to U.S. diesel engines and may provide input for the development of ceramic coatings for gas turbines.

(8) Contractor--Deposits and Composites, FY79, $62 K

This program involves investigation of the chemical vapor deposition (CVD) process to deposit smooth, dense ceramic coatings or thin outerlayers over plasma sprayed ceramic coating. The aerodynamic advantages of the smooth CVD coating on turbine airfoils and the resistance to diffusion of corrosion agents because of porosity along with excellent erosion resistance are potential advantages of the CFD process. Current work has been primarily involved with deposition equipment development.

C. Metallic Coating Development for Heat Engine Combustion Zones

The objectives of the metallic coating program is to obtain improved engine durability with multi-fuel capability. This program is competitive with the ceramic coating. The decision to undertake a major metallic coating development program is dependent on successes in these support programs, EPRI and NAVSEA programs and the ceramic coating program.

Metallic Coating Support Technology

(1) Contractor--Battelle Northwest, FY79, $90 K

Sputter deposited MCrAlY type coatings are being optimized to be resistive to both the low and high temperature hot-corrosion attack Cr and Al concentration gradients are obtained through the coating thickness with the highest Cr concentrations at the surface. Also Pt underlayers and graded Pt additions were deposited. Fifteen types of coating systems involving composition, compositional gradients and post-deposition treatment have been developed. All candidates have been scheduled for burner rig testing.

(2) Contractor--AIRCO Temescal, $60 K

Development MCrAlY coating systems deposited by electron-beam physical vapor deposition (PVD) with additional elements and compositional gradients is being pursued.

MCrAlY coatings with Y, Si, Ti, Zr and Hf, either singularly or in combination have been developed. Dual source evaporation was used in this development and for compositional grading. These specimens are in burner rig tests or in the PFB test at Leatherhead. A highly significant development in this program was the successful PVD deposition of yttria stablized zirconia. This success will be exploited in FY80 as it appears to provide significant advantages over the early plasma sprayed $ZrO_2+Y_2O_3$ coatings.

(3) Contractor--Battelle-Columbus, FY79, $60 K

Developing model for advanced coating alloy development based on Peierls Stress synthesis. The objective is to improve the erosion resistance of hot-corrosion resistant coating alloys by enhancing hardness through increased modulus. NbC and NbB_2 were selected as the dispersed phase in Nb coatings to isolate and study the effects of local thermal effects on the mechanical behavior of the coating.

(4) Contractor--United Technologies, FY79, $40 K

The Pratt & Whitney Division is developing Cr, Si and NiCrSi coating systems to provide improved protection with dirty petroleum and synfuels. Screening tests will be done with Na_2SO_4 alone and with V_2O_5 and SO_3 environments. Work started in August 1979.

II. Heat Engines

A. Contractor--Westinghouse & Garrett Airesearch, FY79, $2 M

Both contractors have completed Phase I of the Ceramics Technology Development Program. This phase included work on developing innovative baseline gas turbine designs utilizing ceramic materials for intermediate and baseload utility applications using coal-derived fuels. Each contract has also selected and is providing samples of several candidate materials for a corrosion/erosion screening test to be conductd at METC. The contractors also developed program plans for the follow-on phases of the program.

III. Ceramic Support Technology, FY79, $2 M

A. METC is in the process of fabricating, installing and checking out test hardware (combustor and test section) in preparation for conducting corrosion/erosion screening tests of composite and monolithic ceramic specimens provided by Garrett and Westinghouse. These tests will include both dynamic (2000 ft/sec) and soak tests at temperatures of 1850, 2200 and 2600^{o}F. for up to 1000 hours duration. Initial testing is to begin in March-April 1980 time period.

B. NASA-LeRC, FY79, $600 K

The material objectives of this effort include development of a corrosion data base for materials exposed to combustion products of coal-derived fuels and to correlate this to a corrosion life prediction model. Doped fuel tests have been completed and actual fuel tests are to begin in September. A second objective of this program is to develop ceramic coating approaches which have acceptable life in combustion products of coal-derived fuels. NASA and DOE have been notified that the corrosion-resistant Ca_2SiO_4 thermal barrier coating has been selected for an IR-100 award in 1979.

C. Contractor--IIT Research Institute, FY79, $50 K

IIT Research Institute (IITRI) through an existing contract with the Air Force Materials Laboratory, is responsible for all pre- and post-test characterization and analyses of the test specimens for the METC corrosion/erosion screening tests. These specimens are at present being delivered to IITRI by Garrett and Westinghouse for baseline characterization including:

- Four point flexural strength
- X-ray phase identification
- Optical fractography
- SEM tractography/EDX

D. Contractor--National Bureau of Standards, FY79, $50 K

The program objective is to determine the physical and chemical conditions that limit the applicability of proof testing as a method of improving the reliability of silicon nitride and silicon carbide for use as structural components in turbine engines; to investigate the effect of high temperature on the strength of these materials; and to characterize the environmental conditions that result in strength impairing flaw generation in these materials. Two test assemblies have been modified for testing at high temperature under constant load and static fatigue tests for times up to 1000 hours have been initiated.

IV. Combustion

A. Fireside Corrosion Projects

(1) Evaluation of Gas Turbine and Heat Exchanger Alloys in Fluidized Bed Combustion Applications (Fireside II)

(a) Contractors--General Electric, Westinghouse, Exxon, Battelle-Columbus Labs

The first portion of this program was to investigate the corrosion/erosion of heat exchanger alloys in an atmospheric fluidized bed coal combustor. Data from test times up to 1500 hours was gathered and indicated that at temperatures approaching that of the bed (1650^{o}F) corrosion could be a serious problem. Erosion was seen at all test temperatures with the most severe attack noted at very low temperatures in bed (Tm 500^{o}F).

The second portion of this program consist of testing heat exchanger and turbine materials in a pressurized fluidized bed combustor for times up to 1000 hours. Results to date suggest that hot-corrosion may be the most significant problem and that erosion can conceivably be controlled by adequate cleanup.

(2) Evaluation of Advanced Heat Exchanger Alloys in Pulverized Coal Application (Fireside III)

(a) Contractor--Combustion Engineering, FY79 $0

The objective of this program is to examine alloys for use as heat exchangers at metal temperatures up to 1700^{o}F in pulverized coal boilers. Test times up to 8000 hours have been gathered on four coals burned in four different boilers. Testing is underway using more corrosive high chloride coal.

V. Fuel Cells

A. Platinum Properties, Brookhaven National Laboratory, Stonehart Associates, Inc., FY79 - $400 K, FY80 - $400 K

Objective: Investigate the deposition of platinum catalyst and sintering (loss of surface area) phenomenon to determine the mechanisms. Sintering of small platinum catalyst crystals on carbon fuel cell electrodes reduces powerplant efficiency.

B. Platinum Substitutes, National Bureau of Standards, ECO, Inc., Stonehart Associates, FY79 - $300 K, FY80 - $300 K

Objective: Investigate fuel cell catalyst materials to find a cost-effective alternative to platinum in terms of cost and electrode activity. Possible alternative include tungsten carbide and cobalt tetraazannulene.

C. Electrode Development for Phosphoric Acid Fuel Cells, Stonehart Associates, Engelhard Industries, Energy Research Corporation, Westinghouse, United Technologies Corporation, FY79 - $500 K, FY80 - $500 K

Objective: Determine the suitability of various carbon substrates for fabrication into fuel cell electrodes with supported platinum catalysts. Evaluate electrochemical activity, resistance to corrosion, strength, density, porosity and conductivity of substrates made from different fabrication procedures.

D. Molten Carbonate Fuel Cell Electrodes, Institute of Gas Technology, General Electric Company, United Technologies Corporation, FY79 - $1000 K, FY80 - $3000 K

Structural Materials Corrosion Rates. Cell components fabricated from stainless steel sheet metal are being assessed. Corrosion - resistant bipolar separators are being fabricated and tested. Nickel and nickel alloys are being fabricated into high-surface area electrodes that are stable and resistant to contaminants in the fuel streams.

E. Fabrication & Development of Molten Carbonate Fuel Cell Electrolytes Materials, Institute of Gas Technology, General Electric Company, United Technologies Corporation, FY79 - $1000 K, FY80 - $3000 K

Stable or renewable electrolyte structures are being developed in an effort to reduce cell decay due to loss of electrolyte (including effect of lost corrosive electrolyte on other components). The core of this work is to define and test optimal electrolyte compositions.

F. Solid Oxide Electrolyte Fuel Cells (1000°C), Westinghouse, Brookhaven National Laboratory, Montana State University, Montana Energy and MHD Research and Development Institute, Inc., National Bureau of Standards, FY79 - $300 K, FY80 - $500 K

Evaluate electronic and ionic conductivities of solid oxide electrolyte materials (ZrO_2, CeO_2), develop fabrication techniques, determine stability and performance in fuel cell application.

G. Interconnector Materials, Westinghouse, Montana Energy and MHD Research and Development Institute, Inc., and Brookhaven National Laboratory, FY79 - $400 K, FY80 - $300 K

Evaluate pertinent chemical and electronic properties of interconnector materials used to provide the cell-to-cell series connection in the solid oxide fuel cell.

H. Porous Support Tube, Westinghouse, FY79 - $100 K

Refine fabrication techniques for extrusion of zirconia porous support tubes to the following specification:

- Tensile strength of 5,000 - 10,000 psi,
- open porosity of 20-30 volume percent, and
- no surface pore larger than 10 microns in diameter.

MAGNETOHYDRODYNAMICS

MHD materials development efforts fall into two principal categories, viz: (a) research which is relatively independent of the mainstream component development work; and (b) development and engineering in direct support of, and inseparable from, component development work.

Work in the first category is concerned mainly with generator and airheater materials, slag properties studies, and relevant high temperature chemical kinetics. Principal contractors are Battelle Northwest, Fluidyne Engineering, National Bureau of Standards, Mass. Institute of Technology, Montana State University, Westinghouse Electric, and Argonne National Laboratory. Annual funding is in the $2.5-3.0 million range.

Development activities in the second category have mainly to do with performance evaluation under true or closely simulated design conditions. This requires pre- and post-test analyses of test materials, measurement and control of design and operating conditions, and engineering interpretation of the test results. Most of the work in this category is being carried out in connection with generator development work. Activities in connection with boiler components (the so-called HRSR or heat and seed recovery system) is expected to greatly accelerate within the next two years.

The principal contractors involved in materials work in this second category are: AVCO-Everett Research Laboratories, Inc., the University of Tennessee Space Institute, Fluidyne Engineering Corporation, Rockwell International, TRW, and Babcock and Wilcox. It is difficult to separate specific materials activities from overall development and test costs in closely integrated engineering development work of this kind. A rough estimate of between $2.5 and $3.5 million would, however, seem reasonable in this case.

Programs

Coal fired MHD power systems present a broad spectrum of material applications. Three are particularly noteworthy, viz:

(A) Channel electrode and insulator elements,
(B) Ceramic heat transfer elements, and
(C) metallic heat exchange tubing.

The design environment in each case differs to a considerable degree from conditions encountered in conventional power conversion technology. The principal design requirements for each of these material applications are reviewed below.

(A) Electrode and Insulator Elements

The electrodes of an MHD generator connect the plasma charge with the external load. Currents flow from the anodes, through the inverter and external load, back to the cathodes. The distinguishing feature is the unique design environment which exists at the electrode-plasma interface, i.e., the combined electrical, thermal, fluidynamic, and chemical conditions under which the electrodes must function. For example: heat fluxes up to 300 w/cm^2, temperaures up to 2000C, and current densities up to 1 amp/cm^2 may be experienced at electrode surfaces in the presence of a 2500C plasma moving at sonic velocities and carrying a considerable fraction of strongly alkali chemical species in a magnetic field of 50,000 to 60,000 Gauss. In addition, strong voltage gradients exist in both the transverse and longitudinal directions.

The chemical constituents carried by the working fluid (plasma) arise from two sources: first, gaseous or liquid species derives from the volatilization of mineral matter (ash) present in the coal; and, second, K_2CO_3 and K_2SO_4, in ionic or molecular states, produced by the injection of these "seeding" compounds into the combustor to enhance electrical conductivity.

Power is extracted from the plasma as it flows through the generator channel and the temperature and pressure consequently fall from approximately 2500C and 5 atmospheres at the inlet to less than 2100C and 1 atmosphere at the diffuser entrance. If the electrode walls are externally cooled to below approximately 1800C, a mixture of "slag" and seed species, transported to the walls, will condense to form a thin, flowing liquid coating on the wall. If the electrode walls are cooled further, a thin solidified substrate of seed-slag product forms under the liquid film. The thickness of the slag-seed coating, generally around 1 mm, is relatively insensitive to wall temperature.

The chemical species present at the electrode surface are determined not only by the specific chemical composition of the coal and seed, but also by electrochemical effects. Iron and potassium compounds, for example, tend to concentrate at the cathodes while oxygen and sulfur are most active at anode surfaces. Electrode materials selection must be adjusted accordingly.

In coal burning MHD systems, there is a considerable degree of design freedom in the selection of the electrode surface temperature. This is because effective cooling can be provided without imposition of excessive thermal losses (and, concommitantly, efficiency penalties).

The duplex solid-liquid slag blanket, which forms on electrode surfaces, prevents major thermal losses. Heat transfer calculations indicate that "electrode" surface temperature as low as 200 or 300C can be sustained without significantly penalizing overall plant efficiency. Of course, under these conditions the current exchange function of the electrode is transferred to the liquid slag surface directly above the solid electrode structure.

The unique thermal design freedom which coal fired MHD electrodes provide permits consideration of a wide spectrum of materials. Early British investigators recognized this fact (Haywood and Womack, Open Cycle MHD Power Generation, Pergamon Press, Oxford, 1969) in their evaluation of a wide variety of ceramic and metallic materials under conditions simulating the thermal and electrodynamic stresses of an MHD channel. The U.S. program has extended the British work and, to a remarkable degree, confirmed many of the important tentative conclusions of the earlier effort.

In the U.S. program, experimental studies have bracketed a wide range of metallic and ceramic materials, from copper to doped hafnia and zirconia. Among the metals Ni, Co, Cr, Fe, W, Ti, Ta, Nb, and their alloys have been evaluated, some to a greater extent than others. A number of electrically conducting spinels based upon Al, Fe, La, Cr, and Mn have been carried through synthesis and consolidation development to engineering evaluation in operating MHD generators. Ultra high temperature ceramics based upon rare earth doped ZrO_2 and HfO_2 and other additions to enhance electronic conductivity, have been tested in operating generators.

Test evaluation experience, so far, strongly favors a lower temperature, metallic electrode design rather than a higher temperature, ceramic design. The important trade-off consideration is chemical reactivity. The high temperature ceramic systems have shown considerable susceptibility to alkali attack, especially at cathode surfaces. Ionic transfer problems have been encountered, also, at the interface of the ceramic body with the current lead out. Ceramic anodes (oxides) have stood up considerably better than cathodes, as would be expected.

In contrast to ceramic oxides, metallic systems have shown more distress at anode surfaces than at cathode surfaces, again as could be expected in view of the preponderance of negative sulfur and oxygen ions at anodic surfaces.

Development progress in overcoming problems associated with metal electrode durability illuminates the importance of thermal design and material properties selection. Test experience shows clearly that electrode durability can be improved by lowering electrode surface temperatures. This had led, after many tests of nickel, cobalt, and iron base alloys, to the selection of copper as the standard "reference" electrode material. Copper is the only practical candidate capable of providing heat transfer rates necessary to the maintenance of surface temperatures below the 500-600C range. The most efficient cooling designs in nickel or cobalt base alloys (∿540C) fail to completely suppress erosion at anode surfaces. Copper is necessary to reduce temperatures to within the 200-300C range.

Extensive testing of copper electrodes has led gradually to material improvements whicn, on the basis of 250 and 500 hour tests, give clear evidence of providing MHD generator lifetimes of at least 2000 hours. The most important improvements have been, first, an adjustment of the electrode width (in the flow direction) to reduce a tendency towards electrical lvoerloading, and, second, the adoption of electrode caps to reduce degradation at the electrode surface. In the case of the anode, the current "reference" capping material is unalloyed platinum. This effectively suppresses oxidation-induced erosion. A Cu-W cathode surface inhibits slight erosion effects which are experienced with bare copper.

Insulator material selection is similarly influenced strongly by thermal property considerations. Test experience with MgO, Al_2O_3, castable ceramics, Mg-Al spinels, and BN has clarified two characteristics of particular design importance. The first is thermal conductivity and the second, slag "wettability". BN was selected for test on the basis of the high conductivity. Combined with copper electrodes, it provides maximum thermal diffusivity which, as indicated by direct experience, is necessary to dissipate the thermal energy released by arc impact at anode surfaces, particularly at edges. The BN, however, was found to be less effective than Al_2O_3 in retaining a continuous slag blanket. Recent tests, combining Pt capped Cu electrodes with Al_2O_3 capped BN insulators, demonstrated full slag coverage with high erosion resistance.

Current work, at the engineering design level, is aimed towards further optimization of electrode configurations, improved methods for fabricating the composit capped copper electrodes (from both cost and mechanical integrity standpoints), and further optimization of capping materials in relation to cost and performance. At the research level, work is continuing along two parallel paths. The first is attempting to develop advanced ceramic compositions, electronically conductive and structurally stable at the high temperatures and under the electrochemical conditions that exist in an MHD generator. The other principal effort involves experimental studies of the degradation mechanisms of metal electrode surfaces under power generating conditions.

Both of these efforts have necessitated the development and improvement of specialized experimental apparatus required to simulate the electrodynamic, thermal, and chemical conditions which obtain under assumed design conditions.

The importance of the contribution of analytical modeling studies to these efforts should not be overlooked. Theoretical analyses of boundary effects, current transfer mechanisms, fluidynamic conditions, and heat transfer have provided a valuable backgrop to planning and execution of the materials research effort. The importance of such close coordination of materials research with analytical, design, and test engineering is clearly apparent in these programs.

Contractors

Materials Engineering and Evaluation

AVCO Everett Research Laboratories, Inc.
University of Tennessee Space Institute
Westinghouse Electric Company.

Materials Research and Development

Westinghouse Electric Company
Battelle Northwest Laboratories
National Bureau of Standards
Stanford University
Montana State University
Massachusetts Institute of Technology
General Electric Company
Argonne National Laboratory

B. Ceramic Heat Transfer Elements

The importance of air preheat to MHD power generation has been modified to a considerable extent by system studies of oxygen enrichment alternatives. These analyses strongly suggest that the few percentage points efficiency advantage, potentially available in high temperature preheated combustion air, may not be worth the accompanying cost and development complexity in a "first generation" commercial power system. Extensive trade-off studies indicate that a low cost oxygen generating plant, based upon available technology, is cost-competitive and does not significantly compromise efficiency.

Nevertheless, work is being continued to evaluate candidate ceramic materials under conditions which could be expected in both directly-fired and indirectly-fired air heaters. Test apparatus has been designed, constructed, and operated to simulate the thermal profiles, fluidynamic conditions, chemical environments, and, to some extent, structural stresses which are projected for both firing conditions. Both regenerative checker brick and continuous moving pebble bed designs are being evaluated at temperatures up to 3000°F. Total accumulated test times exceed 1000 hours under directly fired conditions and 2000 hours under indirectly fired conditions. In "clean," indirectly-fired systems, principal attention has been given to industrial grades based on Al_2O_3, MgO, and SiO_2. Chrome magnesia and magnesia bonded magnesia-alumina spinels have performed well under the more punishing corrosive/erosive conditions of direct firing. This class of material is considered as the leading candidate for 2800°F directly fired regenerative air heaters.

Concurrently with the materials evaluation work, compressive creep testing is being conducted to provide essential background design data. Studies are also being conducted on valving design and materials, structural design, and systems configuration. The work is being closely coordinated with general systems studies of performance and cost effects.

As noted before, these air heater technology efforts are considered mainly relevant to advanced MHD power systems since oxygen enrichment provides a more practical approach to the "first generation" system.

Materials Test Contractors

- Fluidyne Engineering Corporation
- General Electric Company
- Montana State University
- Institute of Nuclear Research, Swierk, Poland (under the joint U.S.-Polish Republic Program)
- Argonne National Laboratory
- National Bureau of Standards

C. Metallic Heat Exchange Tubing

These applications apply to the convection heat transfer surfaces in the bottoming plant main boiler. The specific applications of most concern are the superheaters, reheaters, and air recouperators.

The principal differences between the design environments in these applications and the design environmenta normally encountered in industrial boilers arise from differences in the chemical and physical conditions of the hot gas stream. The MHD gas stream is heavily loaded with condensible species derives from the nearly 2% mass fraction of K_2CO_3/K_2SO_4 and additional condensible species derives from volatilized ash constituents. The main materials engineering concerns are, of course, alkali corrosion, erosion, and fouling. Of these, corrosion is clearly of most importance to materials evaluation and selection. It will be necessary, in the interest of achieving a commercially competitive cost-of-electricity (COE) to strike a proper balance between material costs, plant size, efficiency, and maintanance costs.

The principal design requirements necessary to minimize the need for stainless steel and nickel base alloys will be to avoid gas conditions that produce liquid pyrosulfates ($K_2S_2O_7$) and complex potassium sulfates and pyrosulfates at boiler tube surfaces. Thus, the principal objective of the experimental work is to determine the influence of gas conditions on the nature and quantity of deposites formed on tube surfaces. A realistic range of gas and metal temperatures is being investigated to establish the thermal boundary conditions necessary to suppress the formation of corrosive alkali sulfates and sulfides under various gas conditions. Critical chemical variables include the K/S ratio and stoichiometry.

Major materials development efforts are thus directed, first, towards a determination of the sensitivity of formation of corrosive liquid species at metal surfaces to specific gas chemistry and heat transfer design conditions. These data will then be applied, after performance and cost implications are fully assessed, to the corrosive endurance testing of candidate heat transfer tubing materials. Obviously, final materials selection will be based upon the preferred compromise between initial material costs, plan performance, plant cost, efficiency, and projected C.O.E. The work requires a rigorous materials enigneering and test effort, closely coordinated with design, performance, and economic analyses.

Contractors

Materials Engineering and Evaluation

Babcock and Wilcox Co.
University of Tennessee Space Institute

Laboratory Research and Test Support

Argonne National Laboratory
Mississippi State University
National Bureau of Standards

D. Other Applications

Superconducting Magnet Materials: Principal technology support efforts for SCM applications are being pursued by the Francis Bitter Magnet Laboratory at MIT and the Argonne National Laboratory. The work closely parallels research being conducted in support of the Nuclear Fusion program. Engineering fabrication and assembly development studies are also being conducted by the general electric Co. and by General Dynamics in conjunction with the design and fabrication of experimental SCMs.

Coal Combustors: Coal combustor design, in common with channel and diffuser design, is based essentially on a "slagging wall" concept. This approach is well founded in conventional boiler technology. The higher temperature and different chemical conditions posed by MHD systems have not introduced any singificant "new" material problems. The AVCO-Everett Research Laboratory, Inc. and TRW are applying the cold (slagged) wall design in their combustor development work. Rockwell, on the other hand, is investigating a ceramic lined coal combustor with a view towards lowered heat losses. Commercially available spinels are again considered to be the lead candidates for this application.

<u>Other</u>: No significant materials "problems" have been identified in power inversion, seed recovery, or other processes or auxiliaries necessary to the MHD system.

FOSSIL ENERGY PROGRAM
ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT
MATERIALS PROGRAM

I. Introduction

Objectives

The objective of the AR&TD materials program in FE is to provide mission oriented, but long-range materials R&D, which will result in significant increases in reliability and service life and decreases in capital costs of emerging fossil energy technologies.

Organization

The AR&TD materials program is managed by the Materials Planning and Development Section of the Planning and Systems Engineering Division within the fossil energy program. Management of most major projects will be carried out by the Oak Ridge National Laboratory in FY 80. Headquarters responsibilities are:

- Program management
- Technology transfer activities
- Materials program planning of all FE programs
- Initiation of exploratory projects
- Supervision of ORNL project management team

ORNL responsibilities are:

- Management of assigned projects
- Assistance to Headquarters for program planning
- Initiation and procurement of projects in approved program areas

Total FY 1979 Funding - $7,350K

The attached table shows a further breakdown of the funding pattern.

FY 79 ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT MATERIALS PROGRAM

Budget Allocations ($M)

A. BY TECHNOLOGY END USE

EXTRACTION	0.30
UTILIZATION	0.67
GASIFICATION	1.95
LIQUEFACTION	1.33
MHD	0.47
GENERAL	2.63
TOTAL	7.35

B. DISTRIBUTION OF FUNDS

NATIONAL LABS	1.69
GOVERNMENT LABS	1.26
UNIVERSITIES	1.30
INDUSTRY AND NFP LABS	3.11
TOTAL	7.35

EMACC Contact   W. T. Bakker, Room C-157 Germantown, Telephone 353-2789

Reference Publication

Proceedings Third Annual Conference on Materials for Coal Conversion and Utilization, DOE report Conf. 781018 (An updated report - 4th Annual Conference - will be issued in October 1979)

II. List of Projects

A list of projects is attached.

NATIONAL LABORATORIES

Contract No.	Contractor	Title
7318	Ames Lab	Alloy Evaluation for Fossil Fuel Process Materials (Liquefaction)
7106	Argonne	Materials Technology for Coal Conversion Processes a. Evaluation of Refractories under Slagging Conditions b. Acoustic Emission Analysis of Refractory Concrete c. Development of Erosive Wear Detection Systems d. On-line Acoustic Valve Leak Detection Development e. Corrosion of Alloys in CGA f. Erosive Wear Studies g. Failure Analysis h. PFB Corrosion/Erosion
7336	INEL	Bi-Axial Creep and Fatigue of Materials for Coal Gasificatic Conversion of Materials for In situ Gasification
	LBL	Erosion in Liquefaction Systems
7166	Sandia	Development of Alloys for CGA
7146	ORNL	Liquefaction Failure Analysis
7145A	ORNL	Evaluation of Fracture Toughness of PV Steels

Contract No.	Contractor	Title
7145B	ORNL	Development of Techniques for Cladding and Welding of Low Alloy and Cr Mo Steels
	ORNL	Materials for ZnCl Process*
	ORNL	Liquefaction Materials Research*
	ORNL	9Cr-1Mo Alloy Development for Coal Conversion*
	ORNL	Analysis of AFC Corrosive Samples**

* FFP Funding
** Joint Program with FFU

UNIVERSITIES

Contract No.	Contractor	Title	PI
EY-76-S-03-0034 Task 274	University of California (Berkeley)	Development of Wear Resistant Alloys for Coal Handling Equipment	Professor V. Zackay U. of CA (Berkeley) Berkeley, CA 94720
EF-77-S-01-2678	Penn State	Analysis of Fracture Behavior of Refractory Concretes	Dr. Richard C. Bradt Ceramic Science Section Department of Material Sciences College of Earth and Mineral Sciences University Park, PA 16802
EY-76-S-03-0034	University of California (Los Angeles)	Study of Effect of Coal Char on Corrosion in CGA	Dr. D. L. Douglass U. of CA (LA) Material Department School of Engineering and Applied Science Los Angeles, CA 90024
EX-76-S-01-2407	University of Utah	Manufacture of Sialon Refractories from Clay and Coal	Dr. I. B. Cutler Department of Material Sciences and Engineering University of Utah Salt Lake City, Utah 84112
EY-76-S-02-2904	University of Missouri (Rolla)	Chemical and Physical Stability of Refractories in CGA	Dr. Delbert E. Day University of Missouri Rolla, Missouri 65401
EF-77-S-02-4246	University of Notre Dame	Effects of Alloy Microstructure on Abrasive Wear	Mr. N. F. Fiore University of Notre Dame Department of Metallurgical Engineering and Materials Sciences Box E Notre Dame, Indiana 46556

Contract No.	Contractor	Title	PI
EX-76-S-01-2527	Lehigh University	Fracture Mechanics of Steel for GC Application	Mr. R. P. Wei Lehigh University Department of Mechanical Engineering & Mechanics Building No. 19 Bethlehem, PA 18015
EX-76-S-01-2484	University of Pittsburgh	Hot Corrosion of Gas Turbine Alloys in Low-Btu Gas Combustion	Dr. Gerald H. Meier University of Pittsburgh School of Engineering Department of Metallurgical and Materials Engineering 848 Benedum Hall Pittsburgh, PA 15261
EF-77-S-01-2631	Virginia Polytechnical Institute	Investigation of CO Disintegration of Refractories in Coal Gasifiers	Professor J. J. Brown Ceramic Engineering Virginia Polytechnic Institute and State University Department of Materials Engineering Blacksburg, VA 21061
EX-76-A-01-2295	Massachusetts Institute of Technology	A Numerical Thermomechanical Model for Refractory Concrete Liner-Anchor Intersectors	Mr. O. Buyukozturk Massachusetts Institute of Technology 77 Massachusetts Avenue Cambridge, MA 02139
EF-77-S-01-2708	Penn State	Stability of Si Base Refractories in Slagging Gasifier Environment	Dr. Arnuf Muan Pennsylvania State Univer. College of Earth and Mineral Science University Park, PA 16802

Contract No.	Contractor	Title	PI
EY-76-S-03-0034	University of California (Berkeley)	Development of Low Alloy Steels for Thick Wall Pressure Vessels	Professor V. Zackay U. of CA (Berkeley) Berkeley, CA 94720
ET-78-S-01-2873	Iowa State University	Creep Behavior of Monolithic Refractory Materials	Professor T. McGee Materials Sciences and Engineering Department Iowa State U. 110 Engineering Annex Ames, Iowa 50011
ET-78-S-01-0765	Massachusetts Institute of Technology	Fatigue in Pressure Vessel Steels	Mr. Robert O. Ritchie Associate Professor Mechanics and Materials Division Department of Mechanical Engineering Massachusetts Institute of Technology Cambridge, MA 02139
ET-78-S-01-3299	Cornell University	H_2 Attack in Cr-Mo Steel at Elevated Temperatures	Professor Chi-Ye Li Cornell University Department of Science and Engineering Cornell University Bard Hall Ithaca, New York 14853
ET-78-S-01-3129	Colorado School of Mines	Electroslag Welding of Pressure Vessel Steels	Glen Edwards Associate Professor Colorado School of Mines Department of Metallurgical Engineering Goldon, Colorado 80401

Contract No.	Contractor	Title	PI
ET-78-S-01-3313	University of California (Santa Barbara)	H_2 Attack of Pressure Vessel Steels	Professor G. Robert Odette Department of Chemical and Nuclear Engineering U. of CA (Santa Barbara) Santa Barbara, CA 93106
EX-76-S-01-2241	University of Missouri	Alkali Degradation of Refractories in Coal Gasification	Dr. G. Lewis University of Missorui Rolla, Missouri 65401
E-(49-18)-2465	University of Cincinnati	Erosion Study in Turbo-Machinery Affected by Coal and Ash Particles	Dr. W. Tabakoff University of Cincinati Cincinnati, Ohio 45221
ET-78-G-013318	University of Washington	Processing of Structural Ceramic Compounds	Dr. A. E. Gorum University of Washington Seattle, Washington 98195
ET-78-G-01-3319	Univeristy of Washington	Thermal Stability of Ferritic Alloys	Dr. D. H. Polonis University of Washington Seattle, Washington 98195
ET-78-G-01-3320	University of Washington	Exploratory Research on Composites	Dr. D. B. Fischback University of Washington Seattle, Washington 98195

INDUSTRY AND GOVERNMENT

Contract No.	Contractor	Title
EY-76-C-02-0092 092.A001	Battelle	Correlation of CGA Conditions with Corrosion
PO-76-04	Standard Oil of Indiana	Refractory Design and Evaluation Services
EX-76-C-01-2210	Battelle	Analysis of Heat Transfer through Refractory Walls
EX-76-C-01-2218	Babcock & Wilcox	Improvement of Reliability of Monolithic Refractory Walls
EX-76-C-01-2299	Lockheed	Development and Processing of Low Cr Alloy for CGA
EF-77-C-01-2716	Battelle	M&C Newsletter
EF-77-C-01-2556	Solar Division of Int'l Harvester	Development of Ceramic Tube Heat Exchangers
EF-77-C-01-2775	Solar	Development of Coatings for CGA
EF-77-C-01-2592	Lockheed	Development of Coatings for CGA
EF-77-C-01-2606	Babcock & Wilcox	Development of Automated Welding for Heavy Wall P.V.
EF-77-C-01-2621	INCO	Evaluation of Weld Overlays for CGA Corrosion Resistance
EX-76-C-01-1765	General Electric *	Evaluation of Gas Turbine Alloys in Coal Derived Fuels
EX-76-C-01-2325	Battelle	Evaluation of Heat Exchanger Materials in an AFB
EX-76-C-01-2326	General Electric *	Evaluation of Gas Turbine Materials in a PFB

Joint Program with FFU

Contract No.	Contractor	Title
EX-76-C-01-2327	Westinghouse*	Evaluation of Heat Exchanger Materials in a PFB
EX-76-C-01-2452	Exxon *	Operation of EPA PFB
E(49-18)-2045	C-E Combustion Systems*	Evaluation of Heat Exchanger Materials in P.C. Applications
EX-76-C-01-1784	Metals Properties Council	Evaluation of Materials for High Btu Gas II. Pilot Plant Exposure IV. Corrosion Erosion V. Mechanical Properties
ET-78-C-01-2785	IITRI**	Refractories for Slagging Gasifiers
ET-78-C-01-3050	Westinghouse	Optimize Cr-Mo Steels for Resistance to H_2 Embrittlement
ET-78-C-01-2771	Westinghouse	Automated Welding of Thick Wall P.V.
EA-77-A-01-6010	NBS	Materials of Construction Test Methods, Information System and Failure Data Bank for Clean Utilization of Coal 1. Test methods for stress corrosion susceptibility 2. Mechanical properties of refractories

* Joint Program with FFU
** Joint Program with FFP

Contract No.	Contractor	Title
EA-77-A-01-6010 (continued)	NBS	3. In-situ real-time chemical degradation of ceramics 4. Failure Information Data Center 5. Materials of Construction Properties Information Center 6. Mechanical Failure Prevention Group
EX-76-A-01-2219	Bureau of Mines Albany	Testing of Wear Resistant Valve Materials
	Tuscaloosa	Testing of Ceramic Liners for Coal Gasification Process Vessels

SOLID FUEL MINING

The solid fuel mining program is part of the fossil fuel extraction office under the Assistant Secretary for Fossil Energy. The objective of the office is to facilitate safe mining and preparation of coal and to advance mining technology. It supports four technologies: underutilized hydrocarbons, and coal preparation. Materials research and development is focused on evaluating factors affecting service life of large diameter wire rope (Pacific Northwest Lab.), internal friction as an NDE monitor to signal replacement of the rope before failure (Dadalean Associates), dragline boom stress analysis (Michigan Technological University), constraints on front end loaders (Skally and Loy), simulation of hydrowinning of coal (University of Missouri), and reuseable coal crete (Southwest Research Institute). Other efforts being considered address drill bits and cutters. The materials effort for FY 1979 equals about 1.7 million dollars, all part of component development and not separate materials projects.

CONSERVATION AND SOLAR ENERGY

SOLAR THERMAL POWER SYSTEMS BRANCH
ENERGY MATERIALS RESEARCH PROGRAM OVERVIEW

The Thermal Power Systems Branch of DOE sponsors solar materials research on collector, transport and storage subsystems. SERI has been assigned the lead role in coordinating these research and development activities for TPS. They are presently completing individual program plans for absorber, reflector and transmitter materials, which will lead to the eventual commercialization of optical materials for solar energy conversion. An important part of all programs is the development of measurement techniques and quality assurance standards.

Selective absorbers for receivers are being studied which will be stable in the 300-700°C range. Several production techniques are being investigated, including chemical vapor deposition and vacuum deposition. Analysis by comparative profiling of materials is done with Auger Electron Spectroscopy and Electron Spectroscopy for Chemical Analysis. Other efforts are underway to develop low cost solar receiver coatings that can be applied using conventional paint spraying and that also can be repaired "in place." The coating must have high absorbance and mechanical and optical stability up to 700°C.

Metals, alloys and composite materials are being investigated which will be suitable for absorber and reflector applications. An efficient high temperature cermet solar absorber is also being developed.

For thermal storage applications, various fluids are studied with respect to their stability, compatibility and surface fouling.

A listing of the contracts follows:

Materials R&D, SERI (Bulter), $430K

Chemical Vapor Deposition of Refractory Metal Reflectors for Spectrally Selective Solar Absorbers, U. of Arizona (Seraphin), $136K

Development of Reflective Surface Protective Coatings, Dow Chemical Corp (Dennis), $70K

Optimization of EXXON's High Temperature Coating For Solar Applications, EXXON (Muenker), $98K

R&D In Solar Mirror Quality Assurance, PNL (Lind), $275K

Improved Absorber Coatings for Thermal Utilization of Solar Energy, Englehard Industries (Farrauto), $132K

Comparative Profiling of Solar Coatings & Materials with AES and ESCA, U. of Minnesota (Wehner), $58K

Optical Properties of Metallic Surfaces, Small Particles and Composite Coatings, Cornell U. (Sievers), $156K

Development of Granular Semiconductors as Selective Absorbers, RCA (Gittleman), $100K

Stability of Oil, Caloria HT-43, at High Temperatures, Martin-Marietta, $200K.

Thermal Storage Fluid (Media) Tests, MDAC (Hallet), $173K

Surface Morphologies of Efficient Solar Energy Absorbing Materials, U. of Houston (Ignatiev), $88K.

Evaluation of Vacuum Deposition or Chemical Vapor Deposition as Techniques for the Production of Solar Receiver Coatings, SERI, $205K

PHOTOVOLTAIC SYSTEMS BRANCH
ENERGY MATERIALS RESEARCH PROGRAM OVERVIEW
(FY 1979)

There are numerous activities, programs and projects under the purview of the Photovoltaic Systems Branch that relate to energy materials research. These efforts are part of either the Advanced Research and Development (AR&D) or Technology Development (TD) subprograms. The respective responsible lead field centers are the Solar Energy Research Institute (SERI) and the Jet Propulsion Laboratory (JPL). The AR&D subprogram, in turn, can be broken down into three subelements: 1) Advanced Materials/Cell Research, 2) High Risk Research, and 3) Research Support/Fundamental Studies. During fiscal year 1979 there have been a number of initiatives undertaken by the AR&D subprogram which relate to energy materials research:

- Funding of additional Program Research and Development Announcement (PRDA) proposals

  1) Amorphous Materials
  2) Polycrystalline Silicon Cells
  3) Emerging Photovoltaic Materials
  4) Basic Photovoltaic Mechanisms

- Innovative Concepts Program Initiation

- Low-Cost Substrate Research Initiation

Within the TD subprogram, the Low-Cost Solar Array Project supports a number of research efforts primarily involving silicon material research. The principal contact at SERI is Dr. Donald Feucht ((303) 231-1000) and at JPL Mr. Robert Forney ((213) 577-9431).

The following is a brief overview of the type of energy materials research supported by the Photovoltaic Systems Branch along with a full listing of key participants. For a more detailed summary, see the Photovoltaic Systems Program Summary.

Advanced Materials/Cell Research

Cadmium sulfide, polycrystalline silicon, amorphous silicon, and gallium arsenide are the thin film technology materials being studied under the Advanced Materials/Cell Research effort.

1. Cadmium Sulfide — Investigations currently involve researching sputtering and multi-source evaporation to deposit $CuInSe_2$ films on CdS; multiple cathode reactive sputtering for thin film Cu_2S/CdS cell fabrication, and structural characteristics of the Cu_2S/CdS interface.

   Participants: Aerospace Corporation; Brown University; University of Delaware; Westinghouse; Lawrence Livermore/Berkeley Labs; et al.

Photovoltaic Systems Branch Energy Materials
Research Program Overview (FY 1979) (Continued)

Page two

2. Polycrystalline Silicon — New efforts include research of: electrodeposition from nonaqueous solvents and molten salt electrolytes; electron-beam evaporation on low-cost glass substrates; CVD growth on low-cost substrates; control of nucleation.

Participants: Johns Hopkins University; Rockwell International; EIC Corporation, Sandia Labs; RCA; Columbia University, et al.

3. Amorphous Silicon — New efforts include research of: growth conditions; reactive sputtering and resultant film properties for α - Si cells; electrodeposition of α - Si from organic solutions.

Participants: RCA; Mobil-Tyco; Xerox, University of Delaware; Howard University; Lockheed; Batelle Columbus Labs; Pennsylvania State University; University of Southern California; et al.

4. Gallium Arsenide — Investigations include study of: anodic oxidation to mask grain boundaries; laser recrystallization to produce large grains and transport across grain boundaries.

Participants: MIT-Lincoln Labs; Rennselear; Jet Propulsion Lab; Rockwell; et al.

High Risk Research

Photovoltaic energy materials research in this area covers emerging materials and amorphous materials other than silicon.

1. Emerging Materials — The emerging materials are promising new materials and device concepts for photovoltaic conversion which have potential in the long-term future. Zn_3P_2, CdTe, $ZnSiAs_2$, Cu_2O, CdS/InP, $Cu_{2-x}Se$, BAs, polyacetylene and InP/ITO (Indium Tin Oxide) are the materials which are presently being investigated.

Participants: Hughes; Rockwell; Westinghouse; University of Delaware; VPI; Boeing Monosolar; Pennsylvania State University; et al.

2. Amorphous Materials — Amorphous materials other than amorphous silicon are also being investigated to find suitable materials with good photovoltaic properties. Present candidate materials include: GaAs, boron, II-IV-V_2 compounds and chalcogenide semiconductor glasses.

Participants: Duke University; EIC Corporation; Harvard University; MIT; et al.

Photovoltaic Systems Branch Energy Materials
Research Program Overview (FY 1979) (Continued)

Page three

Research Support/Fundamental Studies

Activities in this area include study of basic mechanisms and development of test and measurement techniques.

1. Basic Mechanism Studies — Studies are being performed to identify those mechanisms that limit the conversion efficiency of new technology solar cells; procedures to eliminate or passivate these mechanisms will be specified. Studies include life-times, grain boundaries and general theory. These efforts are expected to contribute to the understanding and advancement of the Advanced Material/Cell Research and High Risk Research efforts and assist in achieving the goals in each area.

Participants: University of Florida; NBS; et al.

Low-Cost Solar Array Project

As the name of this project implies the principal aim is to develop the technology required to produce low-cost long-life silicon arrays. Materials research as part of the Silicon Material and Encapsulation Tasks are a key part of the effort.

1. Silicon Material/Encapsulation Tasks — Materials research efforts include the study of: silicon composition measurement by analytical photon catalysis; silicon impurity effects; low-cost mullite substrates; encapsulant degradation; crystallographic structure defects in impurity doped silicon.

Participants: Materials Research, Incorporated; Dow Corning Corporation; Cornell University; Coors Procelain Company; Case Western Reserve University; et al.

OCEAN SYSTEMS BRANCH

ENERGY MATERIALS RESEARCH PROGRAM OVERVIEW

The Ocean Systems Branch (DOE) has programs in several areas of energy production from the oceans, these being Ocean Thermal Energy Conversion (OTEC), ocean wave energy conversion, ocean current energy conversion, power from salinity gradients and power from electrodialysis.

Ocean Thermal Energy Conversion is the most important in terms of energy output potential. Its continental U.S. area of usefulness is the Gulf Coast which is adjacent to tropical waters. Puerto Rico, Hawaii and Guam have excellent tropical warm water and deep cold water resources close to them.

Ocean wave energy is presently evaluated at about 1/10 of the OTEC potential and is expected to have particular potential in the Northwest and Northeast U.S.

Ocean current energy conversion is being studied as are salinity gradients and electrodialysis. Ocean current power is estimated to have about 1/100 the potential power output of OTEC.

The materials related research in the Ocean Systems program falls into areas involving qualification of metals for heat exchanger use with seawater and ammonia, materials useful in biofouling and corrosion countermeasures, and identification of membranes useful in power generation from salinity gradients and electrodialysis.

Funding details are as follows:

OCEAN SYSTEMS FY'79 FUNDING

TOTAL FUNDING	$43M
Apportioned as follows:	
1. Engineering Test & Evaluation	16.6M
2. Technology Development	11.6M
3. Definition Planning	6.7M
4. Advanced Research & Development	3.3M
5. Reprogrammed from FY'78	4.8M

Materials related funding within the first four areas in the breakdown above are shown below:

Argonne National Laboratory (Materials) Principal Investigator - V.E. Draley & G.F. Popper	FY'79 - $.53M
Applied Physics Lab/JHU (Lightweight Concrete) Principal Investigator - R.W. Blevins	FY'79 - $2M
Civil Engineering Lab/CB Center (Anti-fouling Concrete) Principal Investigator - T.B. O'Neil	FY'79 - $.05M
The Research Corporation of the Univ. of Hawaii (Corrosion Resistance Materials) Principal Investigator - L.W. Hallanger	FY'79 - $.5M
Dow Chemical (Ammonia/Seawater Corrosion Metal) Principal Investigator - W.F. McIlhenny	FY'79 - $.27M
University of Puerto Rico (Biofouling & Corrosion Measurements) Principal Investigator - S. Sasscer	FY'79 - $.05M
International Nickel Company (Corrosion of CA706, 722 CU-IONI-85n, 5052 Al Principal Investigator - T.S. Lee	FY'79 - $.09M
Temple University (Select Materials for Protonic Conductors) Principal Investigator - R.E. Salamon	'79 - $0M
Bend Research (Evaluate Membranes for Salinity Gradient Power) Principal Investigator - H.K. Lonsdale	FY'79 - $.03M

OCEAN SYSTEMS FY'79 FUNDING (Continued)

Clarkson College of Technology (Evaluate Membranes for Salinity Gradient Power) FY'79 - $0M
Principal Investigator - H.G. Jellinek

InterTechnology/Solar Corporation (Investigate Increasing Water Permeation Coefficient) FY'79 - $.01M
Principal Investigator - M.D. Fraser

Office of Transportation Programs
Heat Engine Systems Branch
Contact: R. B. Schulz

The Office of Transportation Programs has established a number of broad programs aimed at reducing highway vehicle fuel consumption. One such program, Heat Engine Highway Vehicle Systems, addresses gas turbine and Stirling propulsion systems. These propulsion systems have the potential of achieving significant improvements in fuel consumption over the conventional spark ignition powerplant. A major program is underway to develop advanced gas turbine and Stirling propulsion systems and to demonstrate their potential for future automotive applications. Project management responsibility for the gas turbine and Stirling engine development has been delegated to the NASA-Lewis Research Center. Program management is the responsibility of the Office of Transportation Programs.

The success of these advanced propulsion systems is strongly dependent on the development of new or improved materials. Ceramic materials are key to the gas turbine development. Ceramic hot-flow-path components (turbine and heat exchanger) are required to meet both cost and operating temperature requirements. Low cost, iron-base alloys capable of operating at high temperatures in high pressure hydrogen are required for the Stirling system. Materials technology development programs for each of these propulsion systems are underway. Key elements of each materials program are described briefly in the following listings. As indicated, most of the materials activities are being conducted by contract program with industry.

I. Materials Technology Program for Automotive Gas Turbine Engine Applications

A. Ceramics for Advanced Turbine Engines (CATE) $8200K

Detroit Diesel Allison, H. E. Helms
NASA Project Manager, R. C. Evans

The primary objective of the CATE Program is to apply ceramic components to a highway vehicular gas turbine engine. This objective is being accomplished by the application of ceramic components to the DDA 404/505 IGT engine. Replacing existing metal turbine parts in this engine with ceramics permits increased operating temperatures which improves engine efficiency. Ceramic material characterization, ceramic process development, and ceramic design technologies are included. (ceramics, turbine engines, silicon carbide, silicon-nitride)

B. Ceramic Regenerator Systems Development Program $635K

Ford Motor Company, C. J. Rahnke
NASA Project Manager, T. J. Miller

Program emphasizes ceramic regenerator design and development for automotive/industrial gas turbine engines. Regenerator core materials include aluminum silicate and magnesium aluminum silicate. A major program objective is to demonstrate 10,000 hour engine durability of ceramic regenerator cores at operating temperatures of 1800°F. (ceramics, heat exchangers, aluminum silicate)

C. Ceramic Stator Evaluation $400K

Ford Motor Company, E. A. Fisher
NASA Project Manager, G. K. Watson

Silicon nitride and silicon carbide ceramics are being evaluated for potential use in automotive turbine stator applications. Program includes integral stator fabrication development by four ceramic component suppliers and property characterization of the candidate materials. Durability testing of the stators in a simulated engine environment is being conducted to assess overall potential of the ceramic materials. (ceramics, turbine engines, silicon nitride, silicon carbide)

D. Ceramic Durability Evaluation $180K

AiResearch Manufacturing Company, K. W. Benn
NASA Project Manager, W. A. Sanders

Four commercially available ceramic materials are being evaluated under extended thermal exposures up to 2500°F for 3500 hours.

Silicon carbide and silicon nitride ceramics are included. An overall assessment of the capability of these types of materials to perform satisfactorily at the temperatures and times required for automotive turbine engine applications will be made. (ceramics, silicon carbide, silicon nitride)

E. High Density Reaction Sintered Silicon Nitride (RSSN) $100K

Ford Motor Company, E. A. Fisher
NASA Project Manager, S. Dutta

Process parameters are being developed to optimize silicon powder preparation and nitriding schedules to achieve high density (>2.8) RSSN for injection molded components. Significant improvements in strength and oxidation resistance are anticipated. (ceramics, silicon nitride, reaction sintering)

F. Sinterable Silicon Nitride Ceramics $165K

Army Materials and Mechanics Research Center, R. N. Katz

Program includes evaluation of sintering additives and development of sintering process parameters with the objective of achieving hot pressed material properties in a sinterable product. Both oxide and non-oxide additives are being evaluated. (ceramics, silicon nitride, sintering)

G. Life Prediction Methodology $185K

Army Materials and Mechanics Research Center, E. M. Lenoe

A methodology is being developed for life prediction in the use of brittle materials such as ceramics for structural applications. Time, temperature, stress dependencies are being statistically treated and comparisons made of silicon nitride behavior in test bar and simple component geometries. (ceramics, structural mechanics, fracture mechanics)

H. Ceramic Component Technology $200K

NASA-Lewis, R. L. Davies

Project includes development and evaluation of advanced techniques for fabrication and evaluation of ceramic components. Ceramic fabrication by hot isostatic pressing and NDE techniques such as acoustic microscopy are featured. (ceramics, fabrication, NDE)

II. Materials Technology Program for Stirling Automotive Engine Applications

A. Hydrogen Permeability $75K

IIT Research Institute, G. Horne
NASA Project Manager, J. R. Stephens

Hydrogen permeability data are being obtained for candidate alloys/coatings under Stirling engine operating conditions. Permeability characteristics are measured at temperatures up to 1500°F and at hydrogen pressures up to 3000 psi. (hydrogen permeability, Stirling engine)

B. Material Characterization $440K

NASA-Lewis, J. R. Stephens

Candidate Stirling engine alloy types are being subjected to a simulated engine environment to assess the combined effects of high pressure hydrogen, high temperature, and combustion products on material properties. Iron-, nickel-, and cobalt-base alloys are included with emphasis on the lower cost iron alloys. (oxidation, hydrogen embrittlement, material properties)

5

C. <u>Alloy Development</u> $600K

Contractors to be selected
NASA-Lewis, J. R. Stephens

Advanced iron-base alloys are to be developed specifically to meet Stirling engine requirements. Cast alloys will be emphasized for the piston-cylinder housing and wrought-alloys for the heat tube application. (iron alloys, Stirling engine materials)

OFFICE OF INDUSTRIAL PROGRAMS

The Office of Industrial Programs is responsible for the stimulation of energy conservation in the industrial sector. The potential for this is quite high, since this sector accounts for an estimated 37 percent of overall U.S. energy consumption and most existing industrial processes are extremely inefficient in their use of energy. The objectives of the program are three-fold:

- To achieve maximum penetration of existing and new energy conservation technologies in as short a period as possible;
- To substitute, where possible, abundant fuels for scarce fuels; and
- To minimize the energy loss embodied in waste streams of all types (discarded products, materials, and energies).

Details of the background, funding, management approaches, and ongoing projects of the Office of Industrial Programs are spelled out in the Industrial Energy Conservation Multi-Year Program Plan of July 13, 1979 and the earlier Program Descriptions (January 1979) and Industrial Energy Conservation Strategic Plan (July 1978).

The materials R&D being carried out in Industrial Programs is in the Division of Conservation Research and Development's Alternative Materials Utilization Branch (Contact: Jerome Collins, 252-2366) and High Temperature Processes Branch (Contact: Michael McNeil, 252-2080). Descriptions of materials projects, together with their FY '79 funding levels, are provided below.

ALTERNATIVE MATERIALS UTILIZATION BRANCH

(Total FY '79 obligation for materials R&D = $350,000.)

Automobile Life Cycle Study, performed by Mr. Sam Napolitano of Cornell University; FY '79 obligation of $20,000.

This work broadly examines the prevention of automobile corrosion from an energy perspective. The characteristics and magnitude of the corrosion problem are discussed. The technology available and the technology actually utilized to prevent rust are examined. Then analysis of the potential energy savings from extending vehicle life through better corrosion protection is provided. Other factors such as economic implications of the corrosion problem are addressed. In conclusion, a set of recommendations for federal government action on the corrosion problem is advanced.

Blended Cement Study, performed by the National Bureau of Standards. Of $150,000 spent on this project in FY '79, about $50,000 is estimated to be for materials R&D.

The objective of this program is to facilitate the use of granulated blast furnace slag and coal fly ash as partial replacements for Portland cement. In other countries, extensive use of slag and fly ash saves significant amounts of energy. This project involves laboratory testing to bolster efforts of the American Society for Testing Materials and other standards and specifying organizations to facilitate greater use of these two materials.

Kiln Dust - Fly Ash Systems for Pavement Bases and Subbases, performed by the Department of Transportation; FY '79 obligation of $150,000.

The objective of this program is to evaluate the effectiveness of substituting kiln dust (KD) collected during the production of lime and cement for hydrated lime in lime-fly ash stabilization systems. Laboratory studies will identify those kiln dusts which are suitable as substitutes for lime in the lime-fly ash-aggregate system; their suitability will be ascertained relative to their chemical, mineralogical and physical properties. The laboratory study will establish the benefits and limitations of the KD-fly ash system relative to its use as a binder in base courses or sub-bases for highway pavements. The laboratory research will also establish the optimum relative proportions of KD and fly ash for various systems.

A field study will also be conducted to obviate any unusual or unanticipated behavior of the kiln dust-fly ash-aggregate system relative to construction operations. The field study will also provide a comparison of the performance of pavement sections featuring a lime-fly ash-aggregate layer with sections featuring kiln dust-fly ash-aggregate layer.

Glass Composite Pipe, performed by Brookhaven National Laboratory; FY '79 obligation of $30,000.

This project studies the feasibility of the use of urban solid waste components as aggregates in the development of structurally strong and durable composite materials. A glass polymer composite (CPC) is produced by mixing crushed waste glass with monomer (either methyl methacrylate or polyesterstyrene) and polymerizing by chemical initiation techniques. With ungraded crushed bottle glass, monomer concentrations are 13 to 16 percent by weight; graded sieved glass results in monomer loadings of 9 to 10 percent. The strength of GPC is 2 to 4 times higher than ordinary concrete. The durability, especially the resistance to chemical attack, far exceeds concrete. The application of GPC for sewer pipes is especially attractive because of the availability of waste glass in urban communities. Specifically, this project will provide several test results derived from experimentation with the conversion from glass to GPC sewer pipe. GPC pipe will be compared with concrete pipe for (1) embodied energy (2) cost, and (3) service life.

Energy Conservation in the Ethylene Polymer Industry, performed by Brookhaven National Laboratory; FY '79 obligation of $100,000.

The objectives of this project are to develop useful energy-conserving copolymers of ethylene and sulfur dioxide of the polysulfone type and a process for their production for the plastics industry.

It was shown previously at Brookhaven National Laboratory (BNL) that SO_2 can be copolymerized with ethylene to form polysulfone polymers by a high energy radiation technique. These polysulfone copolymers offer a major potential in conserving valuable petrochemical feedstock (for ethylene supply) for the plastics industry while at the same time converting SO_2, a waste material from the power and metallurgical industry, into a useful product. The use of high energy radiaiton, either machine or Co^{60} may be preferred because of the unique process chemistry and resulting product characteristics. Machine radiation may be preferable because of the safety, availability, and investment. The project focuses on the following two major items: (1) establishement of the uniqueness of the radiation process for polysulfone synthesis and (2) determination of the processability and marketability of the substitute polysulfone copolymers. This effort is being performed in cooperation with the International Nickel Company (INCO) because of the availability to INCO of large waste quantities of SO_2 from its metallurgical operations and its potential position in the copolymer market. BNL provides the scientific and technical means and experimental facilities for preparation of the copolymer while INCO provides the analysis and characterization and market expertise for development of an acceptable polymer product.

Gypsum in Cement, performed by the Portland Cement Association, Skokie, Illinois; no obligation of funds in FY '79 - supported with prior year funds at an annual rate of $70,000.

The objective of this project is to develop comprehensive data on:

- Potential alternatives to gypsum for controlling set in commercial concretes;
- Additives to deter sulfate-induced expansion; and
- The influence of clinker manufacture on expansion potential in cements.

Chemical, microscopic, and X-ray diffraction analyses are performed to characterize samples, and calorimetric and compressive strength measurements are made. This data will provide a basis for reconsidering the limitations currently imposed on sulfate contents in cements for reasons of soundness. If limitations on sulfate content could be made less restrictive, it should prove possible to use kiln fuels with higher sulfur contents and to employ energy efficient modern preheater kiln technology without risk of exceeding sulfate specifications in the finished product. The use of high sulfur fuels is desirable in that it allows high quality, low sulfur fuels to be reserved for key applications where substitution is technically impossible, and the use of modern kiln technology is desirable from the point of view of saving energy.

Alkali - Silica Reactions in Concrete, performed by Purdue University; no obligation of funds in FY '79 - supported with prior year funds at an annual rate of $35,000.

This project involves the study of the reactions between alkali (from cement) and silica (from aggregate) in concrete. The work is directed toward developing a better understanding of the mechanism of the alkali-silica reaction and toward evaluating an approach (the use of pozzolans) toward mitigating the problem. Microstructural details of the reaction processes at local attack sites are being studied with ZAF-corrected EDXA. A new x-ray diffraction apparatus with improved precision and sensitivity is also being utilized to investigate the correlation of the rate of alkali-silica attack with the source of the alkali in the cement. Finally, the influence of a range of pozzolanic materials on the course of the reaction is being studied in an effort to define the common characteristics that mark successful pozzolanic treatment, and to shed more light on the physical chemistry of the response.

<u>Characterization of Paper Pulp Fibers</u>, performed by the National Bureau of Standards; no-cost extension in FY '79.

The objective of this project is to demonstrate an on-line pulp and paper industry control system based on automated morphological characterization of pulp fibers. Scanning measurements and the necessary systems to integrate these measurements into on-line process controls are being developed and laboratory-tested. This control system could reduce energy use in the pulp and paper industry by permitting more use of waste paper as secondary pulp fiber, less bleaching of certain mechanical pulps, and less paper machine waste. About 25 million barrels of oil equivalent are expected to be saved annually by the year 2000, if this control technology is proved effective and economical.

<u>Maximizing the Life-Cycle of Plastics</u>, performed by the Plastics Institute of America, Inc. at Stevens Institute of Technology; no-cost extension in FY '79.

This project is aimed at developing methods for extending the useful life of plastics through the preparation, characterization, and measurement of properties of a variety of polymeric materials, including those incorporating recycled materials. Research projects include studies of: improved stabilization, separation of plastic blends with solvents or by grinding; compatibilizing of mixtures of plastic scrap through the addition of compatibilizing agents or thorugh hydrogen bonding; and controlled degradation of plastic scrap.

<u>HIGH TEMPERATURE PROCESSES BRANCH</u>

(Total FY '79 obligation for materials R&D = $1,180,000.)

Direct Reduction of Aluminum, performed by Alcoa, with Koppers Company, Inc., Carnegie - Mellon University, and Professor Julian Szekely as subcontractors; FY '79 obligation of $650,000.

The primary objective of this three-year program, begun in September 1977, is to demonstrate the technical feasibility of a pilot sized direct carbothermic reduction process to produce commercially pure aluminum from available ores. This is done by reducing a mixture of bauxite and aluminum silicate ore with coke in a shaft furnace, producing an aluminum-silicon alloy which is then refined. The effects of process operating and design variables have been established in bench scale units, the pilot units have been designed, and pilot reactor operation is underway.

Energy Savings Through the Use of an Improved Aluminum Reduction Cell Cathode, performed by Kaiser Aluminum; FY '79 obligation of $530,000.

The potential benefits of using titanium diboride (TiB_2) as a cathode face material in aluminum reduction cells have been recognized for over twenty years. Energy savings of 15 - 25%, which result from reducing the anode-cathode distance (ACD) have been demonstrated. However, past attempts to apply TiB_2 cathodes to full-size reduction cells have been frustrated by short-lived TiB_2 parts. The objectives of this project are to develop specifications for TiB_2 materials that have an acceptable life in a reduction cell; to develop cathode designs that can accommodate the inherent properties of the material; and to evaluate the process economics of an industrial retrofit.

The program is an integrated materials characterization and cathode design effort. At this point several significant advances have been made. The materials evaluation program has established relationships between microstructure (grain size, porosity, etc.) and mechanical properties, and has distinguished those characteristics that promote intergranular disintegration in a reduction cell. Fractography techniques, developed to determine failure modes and temperatures of failure, suggest that TiB_2 may be subject to slow crack growth in the reduction cell environment. However, this needs to be explored further and techniques to do this have been developed. Methods have also been developed to inspect and detect defective materials by nondestructive means. Heat transfer theory and experiments have been applied to the thermal shock problems.

The materials evaluation and cathode design activities are being augmented by an extensive proof testing program, in which candidate materials and shapes are exposed to simulated and actual cell environments. TiB_2 parts weighing up to several pounds have been successfully inserted into a large test cell, left in place for 20 - 40 days, and removed without failure. Similar parts have been exposed for 60 days in a large laboratory furnace containing molten aluminum at 950^{o} C.

DIVISION OF ENERGY STORAGE

The principal function of energy storage technology is to permit more efficient and more economic use of intermittent energy sources. The development of new and improved materials is a vital part of the energy storage R&D effort.

The energy storage activities include materials development, fabrication, characterization and data base compilation. Because most of these activities are part of the component development projects, materials R&D does not appear as a line item in the budget.

The total funding level for materials R&D in FY 79 is approximately $10.4 million.

Described below are the materials R&D efforts of the six subprograms of the Division.

1. THERMAL STORAGE

FY 79 FUNDING: $6.0 million

CONTRACTORS: Rocket Research, Sandia Livermore, University of Delaware, Institute of Gas Technology, Suntek, Dow Chemical, NRL, Brookhaven, ORNL, Inst. of Energy Conversion, Honeywell, Inc., Gen. Electric, Comstock and Wescott, Inc., Grumman Aerospace Corp., U. of Houston.

Heat energy is stored through sensible heat in materials, phase changes in materials (mainly melting and solidification), and reversible chemical reactions. Molten salt mixtures and fusible metal alloys are being investigated as both sensible and phase-change thermal storage media. Thermal properties, expansivity, and corrosivity are all important properties. A major thrust of the program is the incorporation of constituents that change phase near ambient temperature in materials of construction for buildings. Reversible chemical reactions such as SO_3 decomposition and steam reforming of methane are attractive for long-term storage combined with heat transmission. The materials problems are catalyst development and performance and corrosion of container materials.

2. CHEMICAL AND HYDROGEN STORAGE

FY 79 FUNDING: $1.1 million

CONTRACTORS: Sandia Livermore, Brookhaven, Virginia Polytechnic, NASA Ames, Pratt and Whitney, GE, University of Georgia, Energy Concepts Co., U. of Wisconsin, Denver Research Inst., Teledyne Energy Systems, International Nickel, Westinghouse Electric Corp., R. J. Teitel Associates, General Atomics, ANL, JPL

Work on the behavior of hydrogen in materials includes structural steels for the containment of hydrogen gas, hydrides as storage media, direct reduction of iron-titanium ores to produce hydride forming alloys, solid polymer electrolytes for producing hydrogen from water, and catalysts for both thermochemical and electrolytic hydrogen production. In other projects in chemical energy storage, sensitizers and catalysts are being developed for the storage of solar energy through phase changes in organic compounds. Also molten-salt systems are being evaluated for separating oxygen from air.

3. MECHANICAL ENERGY STORAGE

FY 79 FUNDING: $1.1 million

CONTRACTORS: LLL, Sandia (Albuquerque), PNL, U. of Wisconsin, LSU, Serata Geomechanics, U. of Minnesota, Re/Spec. Inc., Wm. Brobeck & Assoc., Garrett Air Research Rochetdyne Div., Rockwell Int.

The primary emphasis is on flywheels for regenerative braking. Of particular interest is the use of high strength-to-weight materials such as "Kevlar" and "tire wire." POtential problem areas are stress rupture, creep and vacuum outgassing. Both advanced magnetic and low-loss conventional bearings are also being investigated. Other materials properties research is directed at characterization of rock and individual mineral properties at elevated temperature and pressure.

4. SUPERCONDUCTING MAGNETIC ENERGY STORAGE

FY 79 FUNDING: $0.3 million

CONTRACTORS: LASL, University of Wisconsin

The overall objective is to develop technology for both large scale (1000 MWh) diurnal energy storage plants and small scale (10 KWh) utility system stabilization devices. The major emphasis is on low-cost polyester-glass support structure for cryogenic service and high-purity aluminum stabilized conductor.

5. BATTERIES AND ELECTROCHEMISTRY

FY 79 FUNDING: $1.8 million

CONTRACTORS: Argonne, Ford, University of Utah, Ceramatec, EDA, Diamond Shamrock, Stanford University, M.I.T.

Lithium-iron sulfide and sodium sulfur batteries operate at temperatures of several hundred degrees Celsius. Corrosion of container materials is a concern, as are materials for current collectors, separators, and seals. Of special importance is the development of processing techniques to make beta-alumina parts with reproducible properties for use in sodium-sulfur batteries. Improvements in lead-acid batteries are being made, and new zinc-chlorine and more advanced batteries are under study. Materials R&D for these includes electrode materials and new solid electrolytes. New materials for an air electrode are also being investigated.

6. TECHNICAL AND ECONOMIC ANALYSIS

FY 79 FUNDING: $0.1 million

CONTRACTOR: LLL

A project to collect and develop evaluation data on properties of energy storage materials will be completed in FY 78 for flywheel, battery, electrolyzer and thermal energy storage technologies.

OFFICE OF BUILDINGS AND COMMUNITY SYSTEMS

The Office of Buildings and Community Systems (BCS) works to develop methods for using energy more efficiently in: the design and operation of buildings; the design and operation of appliances and other energy consuming products used in buildings; systems that supply energy to buildings and communities; the design and functioning of communities; and the energy consuming practices of consumers and the institutional factors affecting these practices. Since most existing buildings were constructed in an era when energy was thought to be plentiful and inexpensive, it is estimated that 40 percent of the energy supplied to buildings is now wasted. BCS programs encourage the implementation of energy conserving technologies that will reduce this waste, and also substitute more abundant fuels and renewable resources for oil and gas used in buildings and community energy consumption. The BCS program objectives are:

- To provide supporting research; development, demonstration and required implementation to increase the efficiency of energy utilization in community systems, buildings, and consumer products;
- To maximize the effectiveness of energy use;
- To minimize adverse socio-economic and/or environmental impacts;
- To accelerate/complement private sector efforts; and
- To foster acceptance of energy-saving technology.

Details of the background, funding, management approaches, and ongoing projects of the Office are spelled out in the BCS FY 1980 Annual Operating Plan and Multi-Year Program Plan of August 1979.

Materials R&D is being carried out in three areas of BCS: (1) R&D on thermal insulating materials is supported in the Buildings Division as part of the National Program for Building Thermal Envelope Systems and Insulating Materials (Contact: Ernest Freeman, 376-4888); the Urban Waste and Municipal Systems Branch has an ongoing project on corrosion (Contact: Donald Walter, 376-1964); and the Technology and Consumer Products Branch supports three materials R&D projects (Contact: Kurt Riegel, 376-4590). Descriptions of the projects, together with their FY'79 funding levels, are provided below.

NATIONAL PROGRAM FOR BUILDING THERMAL ENVELOPE SYSTEMS AND INSULATION MATERIALS

(FY'79 obligation for materials R&D = $580,000)

The objective of this program is to provide technical data, test procedures, guidelines, and consensus standards needed by manufacturers, designers, builders, and government to produce buildings of high efficiency while concurrently meeting safety, durability, habitability, and economic requirements. It is broken into three tasks: an Implementation Task that provides overall planning and guidance and informal coordination; a Thermal Insulating Materials Task; and a Thermal Envelope Systems Task. The materials R&D is in the Thermal Insulating Materials Task, and includes:

- Evaluation of building insulation at Oak Ridge National Laboratory;
- Development of standard reference materials at NBS - Boulder;
- Corrosiveness testing and chemical analyses of large numbers of commercially produced insulations at the Naval Weapons Support Center;
- Corrosion research aimed at determining the relevance of established materials tests in real buildings situations at Stevens Institute of Technology;
- Studies of air convectioneffects at SUNY-Stony Brook;
- Laboratory and field studies of emissions from urea-formaldehyde (UF) foams by the University of Iowa;
- Research on the strength and shrinkage of UF foams by Dynatech R/D Company;
- Thermal performance studies at NBS - Gaithersburg; and
- Research on smoldering combustion at Princeton University.

URBAN WASTE AND MUNCIPAL SYSTEMS BRANCH

(FY '79 obligation for materials R&D = $90,000)

These funds are supporting a project entitled "Research on the Mechanisms of Corrosion in Materials Used in Municipal Waste-to-Energy Incinerator Systems," performed by the National Bureau of Standards. This project is aimed at filling the gap that presently exists in knowledge of the detailed mechanism for and effects of corrosion in materials used in muncipal waste-to-energy incinerator systems. This lack of knowledge is one of the current inhibitors to using waste material as a fuel. A series of characterization tests are being performed, including: water table tests; combustion gas analysis; air pollution control equipment tests and evaluation of the input municipal waste stream. This series of tests, coupled with detailed corrosion test data, will provide a comprehensive correlation of the interaction of all the system parameters and its effect on the materials used. Specific activities include:

- Metallographic examination of the candidate materials before and after exposure to the harsh environment;
- Sample surface evaluation before and after exposure
- Determination of degradation due to exposure;
- Identification of types of corrosion involved;
- Weight loss, pit depth, reduction in wall thickness or other physical measurements to evaluate the effects of the environment on the tube corrosion;
- Weld analysis;
- Analysis of corrosion products (rusts or other oxides); and
- Particle and gradient analysis.

TECHNOLOGY AND CONSUMER PRODUCTS BRANCH

(FY '79 obligation for materials R&D - $195,000)

Advanced Insulation for Appliances, performed by Arthur D. Little, Inc.; FY '79 obligation of $50,000.

This project is aimed at the development and evaluation of innovative conceptual designs that would provide dramatic decreases in the energy loss through insulation in appliances. A thermal resistance per inch of thickness of 20 hr. ft.^{2} $^{\circ}$F/BTU is the threshold considered for improved insulation. Initially, a survey of "best" thermal insulation practice for 1980 model water heaters, refrigerators, freezers, ovens, etc. is being carried out. The potential annual energy savings that would result from substitution of greatly improved insulation is being assessed. Then conceptual designs will be developed that consider technical feasibility, manufacturing practicability, durability, cost, barriers to commercialization, energy savings, and needed RD&D (including a detailed RD&D plan). In a later phase RD&D projects may be begun on specific promising concepts.

Selective Reflective Solar Control Coatings, performed by Kinetic Coatings, Inc.; FY '79 obligation of $55,000.

The objective of this project is to develop a window glazing unit that contains an external thin-film layer to reject short-wave infrared radiation while maintaining daylight transmittance. This film is to be applied and protected in such a manner that it will maintain its properties under prolonged exposure in an outdoor environment.

Advanced Materials Survey, performed by Hughes Aircraft; FY '79 obligation of $40,000.

This is a survey of aerospace and military technology and developments to identify materials, products, processes, analysis, and instrumentation relevant to improved thermal control in window systems.

Aerial Measurement of Heat Loss, performed by Calspan Corporation, Buffalo, N.Y.; FY '79 obligation for materials R&D of $50,000.

The objective of this project is to develop a general technique for predicting 8 - 14μ IR-band emissivities for building surfaces arbitrairly chosen from aerial IR thermographs. Development of such a technique is a necessary first step if aerial IR imagery is to be used in a definitive way to express the hotness or coldness of arbitrary building surfaces on either an absolute or relative basis. The materials part of the project is the development of a library of 8 - 14μ emissivities for a variety of common roofing materials.

OFFICE OF SOLAR APPLICATIONS

(Under the Assistant Secretary for Conservation and Solar Applications)

The general objective of the research and development program of the Office of Solar Applications is to provide the solar industry with the materials, components, and information needed for cost-effective solar heating and cooling systems. Materials research and development is conducted in connection with the development of solar collectors, thermal energy storage, and passive solar heating or cooling techniques for buildings. The material requirements for all these applications are characterized by the need for good thermal and structural properties, long term stability in environments that include solar radiation, high temperatures and corrosive fluids, and, above all, by the need for light weight and/or low cost in order to achieve economic viability of solar components and systems. Many of these requirements are similar to those needed by materials used in solar thermal applications, but generally there is less emphasis on high temperature limits and a greater emphasis on low cost.

The present materials program is part of the directed research and development program that was initiated in 1975 with a far reaching broad-based assessment of the status and needs of solar heating and cooling technology, formalized in 1976 in the first "National Plan for Research and Development in Solar Heating and Cooling", ERDA77-144 (now DOE/CS-0008), and implemented in 1977 through a series of solicitations for work in over 60 categories. Most of the 26 projects that constitute the FY79 materials program were initiated in late FY77 or FY78 as fixed price contracts and many have pursued their goals through FY79 without additional funding. Therefore, both the FY79 funding and the total funds are indicated for each project listed below in order to more accurately reflect the amount of effort. The FY79 funding of SA materials projects totaled 1M$, but the total effort over the past 2-2 1/2 years represents a 4M$ expenditure.

The major material efforts are related to solar collector and passive building needs and are subdivided into five subelements: Heat Transfer Fluids and Corrosion; Absorbers and Selective Coatings; Glazing and Glazing Coatings; Insulation; and Sealants. Projects in these five areas are described briefly below. For more details on the projects and their accomplishments the interested reader is referred to "Solar Heating and Cooling Research and Development Project Summaries," DOE/CS-0010, May 1979 and "Proceedings of the 3rd Annual Solar Heating and Cooling Research and Development Branch Contractors Meeting," CONF-780983.

A. HEAT TRANSFER FLUIDS AND CORROSION:
6 Projects: FY79 - 289K, Total - 917K.

The principal objectives of these projects are (1) to survey and evaluate the characteristics of superior, cost-effective liquid coolants; (2) to elucidate the corrosion problems and their cures for aqueous coolants with inhibitors and antifreezes in multi-metallic collectors and systems, and (3) to enumerate the various techniques of freeze protection and their costs.

1. "Survey of Available Heat Transfer Fluids,"
Monsanto Research Corporation, FY79 - 76K, Total - 155K.

The objectives of this project are: (1) to quantify the required design and handling properties of heat transfer fluids for solar collector applications, (2) to collect data and pertinent information for all fluids presently used or envisioned as potentially useful in solar energy applications based on the current state of the art, and (3) to organize the latter information to allow the designers of solar collection systems to select optimum fluids for their particular needs.

Two broad surveys have been conducted. One encompassed the designers and manufacturers of solar collectors and collection systems to establish the data base for the required fluids properties. The second survey was addressed to the manufacturers of heat transfer fluids. The results of these surveys are summarized in the Semiannual Report ALO/45356-1 which also contains a list of commercially available heat transfer fluids.

Further analysis of collected information, the determination of ignitability characteristics of the heat transfer fluids, and their screening for mutagenic effect on bacteria are in progress.

2. "Development of Superior Liquid Coolants,"
Dow Corning Corporation, FY79 - 30K, Total - 120K.

The specific objective of this work is to establish the most cost-effective solar heat transfer fluid through a comprehensive one year study of the four most common fluids being used. Criteria for making the assessment will be the relative results of F.H.S.A. toxicological studies, fire hazards testing, thermal performances efficiency, corrosion studies, collector stagnation testing, and physical property comparison data of various fluids. Contributing to cost effectiveness shall be the simplification of solar collector systems by the elimination of devices and premium metals used to protect against freezing, over-heating and corrosion.

Physical property measurements and toxicity testing have been completed. A report covering all flammability studies is now being finalized. Stagnation testing in solar collectors at New Mexico State University is continuing with the four selected fluids: Syltherm™444, Uniroyal PAO-LV, Ethylene Glycol/H_2O, Propylene Glycol/H_2O. The cost effectiveness analysis is in progress.

3. "Vegetable Oils as Coolants,"
University of Florida, FY79 - 0, Total - 50K.

The objectives of this program are: (1) the collection of and/or measurement of the pertinent thermophysical properties of vegatable oils - (a) cottonseed oil, (b) corn oil, (c) peanut oil, and (d) soybean oil, (2) the evaluation of the potential use of these oils as coolants in solar energy systems, and (3) the recommendations for the use of these oils in solar applications with the limitations specified for each oil in such applications.

Most of the necessary thermophysical property determinations have been completed. The stability experiments in simulated solar systems will be continued as long as possible since the feasibility of using vegetable oils depends upon agreeable results for these experiments. The stability is probably the dominant factor in the cost effectiveness analysis.

4. "Corrosion Problems with Aqueous Collants," Battelle Memorial Institute, FY79 - 76K, Total - 206K.

A principle objective is to elucidate the corrosion problems and their cures for aqueous coolants with inhibitors and antifreezes in multi-metallic collectors and systems. The work is divided into three major tasks: (1) review of the state-of-the-art collector corrosion processes, (2) study corrosion in multi-metallic systems, and (3) determine the interaction between different waters and chemical antifreeze additives.

A report "Review of the State of the Art of Collector Corrosion Processes" was completed and was recommended for publication. This report was compiled from the data bank which was developed for cataloging basic corrosion information pertinent to various solar systems. This data bank was used to plan the experiments to study corrosion in multi-metallic systems and study the interaction between different waters and chemical antifreeze additives. These experiments have been in progress since January 1979.

5. "Aluminum Corrosion Studies for Solar Collectors," Giner, Inc. FY79 - 50K, Total - 180K.

This project aimed at determining the requisite conditions under which aluminum solar collectors, operating with a water/glycol heat transfer fluid, can be safely used for a reasonable period of time without encountering catastrophic corrosion problems.

The use of a scavenger to remove deleterious contaminants from the solution was studied. Zinc metal proved effective as a heavy-metal ion scavenger and, when used in powder form, it also protected aluminum against pitting. A final program objective wll be the creation of a corrosion handbook for aluminum collectors.

6. "Corrosion Protection using Electrochemically Deposited Films," EIC Corporation, FY79 - 57K, Total - 202K.

The objectives of this project are to select electrochemically deposited polymeric coatings for solar-collector heat exchangers, to define conditions for their application, to test their effectiveness for inhibition of corrosion and to characterize them in terms of the other important properties that will determine their ultimate cost effectiveness. Such properties include thermal stability, effect on heat transfer, abrasion resistance, expected life and ease of reconditioning.

Films have been formed on Al, Fe, and Cu, and these films do inhibit corrosion. The films are inexpensive and they can be applied and repaired in situ, inside heat exhangers, and on complex surfaces. The major problems are the adhesion of the film to the substrate and the defects (pinholes) in the films. The primary effort is now focused on forming protective films on aluminum.

B. ABSORBERS AND SELECTIVE COATINGS:
5 Projects: FY79 - 215K, Total - 681K.

Selective absorbers, having high solar absorptance and low thermal emittance, have a wide range of applications varying from passive solar buildings to sophisticated two-axis tracking concentrators. The objectives of this program are to develop, optimize, and determine performance durability and economic viability of absorber coatings for the various applications.

1. "Commercial Selective Surfaces,"
Berry Solar Products, Inc., FY79 - 36K, Total - 148K.

Berry is investigating means of improving selective surfaces on copper, aluminum, and stainless steel. The program is divided into three phases: evaluation of existing coatings, investigation of improvement processes for black chrome, and testing of developed coatings. The project should provide a better understanding of coating properties, limits, durability and economics. In addition, funding will provide direct industry stimulation.

2. "Selective Paint & Black Chrome Coatings,"
Honeywell, Inc., FY79 - 103K, Total - 258K.

The objective of this project is to improve the performance of the black chrome and selective paints. Techniques will be developed to apply the coatings to foil. Testing techniques and breakdown mechanisms will be analyzed in detail. One of the outgrowths of the program will be to create a platers and painters handbook describing the techniques.

3. "Optical Performance and Stability of Selective Absorbers,"
Lockheed Missiles & Space Co., FY79 - 59K, Total 125K.

The objectives of this project are to study the techniques of making certain selective absorbers, study the stablity of selective surfaces in various environments, and compare optical performance and costs for different types of surfaces.

A survey has been conducted to establish a compendium of potential commercial and research sources of candidate absorber selective surfaces. Emphasis is on optical properties and their stability. Appropriate materials have been selected and procured for evaluation. Final program results will provide degradation and stability information for all solar applications.

4. "Black Germanium Selective Absorber Surfaces," Pennsylvania State University, FY79 - 0, Total - 67K.

The purpose of this research is to develop the basic and applied understanding of the preparation, characterization, and properties of black germanium films so as to determine, if feasible, the conditions necessary for large-scale production of these films as optimized selective absorber surfaces in solar collectors. The project will determine if this is a viable concept for a practical selective coating.

5. "Selective Surfaces by DC Sputtering," Telic Corporation, FY79 - 17K, Total - 83K.

Recent advances in sputtering technology using magnetically confined plasmas permit coatings to be deposited over large areas with significantly increased deposition rates. This technology is already being used for various production applications. This project extends its use to solar selective coatings.

One phase will examine a sputter-deposited substitute for the graded oxide-metal coating (black chrome) that is formed by electroplating. A second phase will illustrate the multilayer capabilities of sputtering by depositing an Al_2O_3-Mo-Al_2O_3 coating that has been found to have excellent thermal stability and therefore is suitable for concentrating collectors. This could be an economically viable process for large scale production, particularly when deposited on continuous foil.

C. GLAZINGS & COATINGS: 9 Projects: FY79 - 386K, Total - 1800K.

Glazing materials must have high transmittance, low absorptance and low reflection to be desirable for solar heating applications. Other properties, such as emittance, can be varied to obtain enhanced performance. Glazings and coatings must be durable, weatherable, UV and temperature tolerant, and above all, economical. The objectives of the program are to study, develop and stimulate commercialization of various glazing materials and coatings.

1. "Exposure Testing and Evaluation and Solar Collector Materials," ITT Research Institute, FY79 - 0, Total - 445K.

The overall objective of the project is to determine, by direct exposure to sunlight and ambient weather, those collector materials that are most satisfactory because they are solar and weather-resistant and hence can be expected to provide long, reliable collector life. To monitor material performance by means of appropriate optical and mechanical tests, to investigate accelerated testing with sunlight concentrated about eight times, and to investigate material deterioration at temperatures above ambient.

The testing program includes glazing, absorber, and reflector materials. The final program results will provide degradation and durability information for designee, manufacturers, and users of solar equipment.

2. "Selective IR Coatings Development," Honeywell, Inc., FY79 - 29K, Total - 142K.

The objective of this program is the development of a cost-effective method of coating thin plastic foils with a solar transparent, infrared reflective coating, i.e., a heat mirror. The optical properties goals are 85%-90% solar transmission and 90%-95% infrared reflectance at the peak of the room temperature black body spectrum. Coated plastic substrates with these optical properties can be used to enhance the performance of solar collecting systems, to reduce heat loss through building windows, and reduce the losses from passive systems.

3. "Low-Cost Solar Anti-Reflection Coatings," Honeywell, Inc., FY79 - 32K, Total - 134K.

The overall objective of this project is to develop large scale production processes for low-cost organic and anti-reflection (AR) coating and etched AR coating on glass.

This program's emphasis is on the improvement of mechanical durability and the development of coating thickness control for large glass panes. The stability of coating solution will also be improved to meet the requirement of a continuous operation. The coating will finally be scaled up to a sample size of 3 by 6 feet.

4. "Non-Glass Glazings and Surface Coatings," Hughes Aircraft Co., FY79 - 35K, Total - 162K.

The objective of this project is to develop a non-glass glazing material for solar collectors, which has optimum optical and physical properties, and is cost effective. Modifications of a polycarbonate, the best plastic glazing material available, will be made by co-polymerizing two diphenols into a polycarbonate that has a glass transition temperature high enough to be usable at 300^{o}F. These copolymers will be evaluated for thermal, physical, and optical properties before and after environmental exposure.

5. "Improved Collector Efficiency Through the Use of Anti-Reflective Coatings & Improvement of Solar Selective Coating Stability," Owens-Illinois, Inc., FY79 - 50K, Total - 266K.

In an evacuated, all-glass tubular collector, three surfaces can utilize an anti-reflective coating: two surfaces of the cover tube and the selective coating itself. The purpose of this project is to analyze the cost effectiveness of coatings for these surfaces, given that the greatest incremental benefit could be realized by coating the solar selective surface of the absorber tube.

First, anti-reflective coating materials for the solar selective surface will be evaluated; second, optimal application techniques will be assessed; and, finally, prototype collectors will be prepared and evaluated for performance and stability.

6. "Non-Glass Glazings,"
Research Triangle Institute, FY79 - 0, Total - 154K.

The optical and thermal properties of plastic glazings are sensitive to prolonged exposure to solar ultraviolet radiation/weathering. It is the purpose of this project to evaluate several types of organosilicones as glazing materials. These are in the form of commercially available, reinforced and non-reinforced silicone elastomer membranes, optically clear silicone rubbers, reinforced silicone rubber sheets, and reinforced, low-temperature curing, transparent potting compounds. The final outgrowth of the program will be a report describing the material evaluations and economic analyses.

7. "Non-Glass Glazings and Surface Coatings,"
Springborn Laboratories, Inc., FY79 - 88K, Total - 176K.

The objectives of the project are to: (1) survey and evaluate the potential of a range of polymeric and other non-glass materials resistant to weathering, UV radiation, and high temperatures (300°F), suitable for mass-produced collector glazings and housings; (2) survey the state of develoment of surface etching processes for reducing reflectivity of plastics; (3) evaluate the potential of IR reflection coatings for non-glass glazings; (4) investigate means for applying IR and/or anti-reflection coatings uniformly in large volume production; and (5) evaluate durable coatings for UV protection of plastic glazings.

8. "Studies for Predictably Modifying the Optical Constants of Doped Indium Oxide Films," Tufts University, FY79 - 27K, Total - 73K.

The objectives of this research are to correlate the wavelength dependence of the optical constants of polycrystalline films of doped indium oxide with structure, composition, and thermal history and to arrive at a useful model of the electromagnetic behavior of doped indium oxide so that one could predictably modify its optical constants and those of related metal oxides.

9. "Polymer Surface Coatings for Downconversion of UV Radiation and Inhibition of Photodegradation," University of Wisconsin, FY79 - 125K, Total - 248K.

This project focuses on the development and optical evaluation of surface coatings on polymeric substrates which will downconvert the UV component of solar radiation into the visible region and will simulataneously inhibit photodegradation of the plastic glazings. Experimental testing, economic analyses and scale-up studies will be reported.

D. INSULATION:
3 Projects: FY79 - 121K, Total - 389K

The requirements for thermal insulation materials in solar collectors are often quite different and frequently more stringent than for materials used in building construction or in industrial applications. Solar collectors require back insulation and manifold insulation that is effective, light weight, stable in environments that include solar radiation, high temperature, high humidity and atmosphere pollutants, fire resistant or retardant, and, above all, that are economical to manufacture, install, and maintain. In most cases, the relevant information for selecting materials for solar collector application is not available so the first thrust of the program is to determine the information requirements and to collect as much as is available for commercial materials. Additional work will fill in information gaps and pursue the development of materials to meet special needs.

1. "Development of Improved Insulation Materials,"
Dow Corning Corporation, FY79 - 33K, Total - 141K.

The objective of this work is to develop an improved silicone elastomeric foam for both in-situ and prefabricated applications and to evaluate its cost effectiveness. A number of different types of low-density silicone foams have been developed. These foams tend to retain the intrinsic silicone properties of thermal and physical stability at moderately high temperatures as verified by laboratory scale evaluations. Some testing on flat plate collectors has been done. Laboratory scale evaluations have demonstrated that silicone foams can be effectively used as a protective covering over polyurethane foams.

2. "Survey of Thermal Insulation Materials,"
Versar Inc., FY79 - 56K, Total - 116K.

The ultimate objective of this program is to produce a comprehensive tabulation and evaluation of suitable materials. with specific recommendations on which materials are most suitable for particular applications and temperature ranges.

The survey will include insulation materials that have actually been used in solar heating and cooling systems as well as other suitable candidate materials that have not yet been tried. This includes fibrous insulations, plastic foams and foam glass (i.e., cellular material), etc. Relevant information includes (a) apparent thermal conductivity, (b) moisture absorption, (c) out gassing and dimensional and thermal stability, (d) fire resistance and composition of the products of decomposition, (e) ease of installation or application, (f) lifetime, and (g) costs.

3. "Polyimide Foam Insulation,"
Solar Turbines International, FY79-32K, Total - 132K.

Polymide foams are light, strong, and fire resistant. They have good thermal insulation qualities and are stable at high temperatures. The objective of this project is to optimize foams for solar applications to achieve the best combination of thermal properties, cost, manufacturability, durability, and fire resistance. Foams are tested for resistance to environment, including sunlight and high humidity at elevated temperatures. A pilot plant scale process will be developed in order to assess the cost effectiveness of the product.

E. SEALANTS:
2 Projects: FY79 - 63K, Total - 246K

The objectives of the sealants program are to survey and elucidate the pertinent characteristics of collector sealants and how they effect collector life and collector efficiency, to identify superior sealants, and develop a sealant that can survive a thermal environment of 400°F. A future objective will be to take the identified best sealants for low-, medium-, and high-temperature applications and improve them to provide truly superior performance.

1. "Collector Sealants and Breathing,"
Westinghouse, FY79 - 46K, Total - 186K.

The objectives of the work are to survey and evaluate the pertinent characteristics of a variety of collector sealants, and to study the effects of, and the control of, breathing in collectors. An improved understanding of available sealants will be the deliverable of this contract, but the results of the testing indicate that today's "on the shelf" sealants are not ideal. Development of superior sealants is indicated to eliminate the collector degradation presently caused by inadequate sealants.

2. "Development of 400°F Sealants,"
Product Research & Chemical Corporation, FY79 - 17K,
Total - 60K.

The objective of this project is to evaluate elevated temperature-resistant sealants based upon silicones, fluorocarbons, acrylic elastomers and ethylene propylene terpolymers. Fluoroelastomers have been identified as the most viable candidate for 400° resistant sealants.

RESOURCE APPLICATIONS

Division of Geothermal Energy

The Division of Geothermal Energy (DGE) reports to the Assistant Secretary for Energy Technology through the Program Director for Solar, Geothermal, Electric and Storage Systems. The majority of the materials work in this Program is combined under geochemical engineering and materials. R.R. Reeber, DOE/Washington, (telephone (202) 376-4899), coordinates this subprogram. Field implementation is carried out through two DOE Operations Offices (Materials, Ms. B. Mueller, DOE/Chicago; geochemical engineering, A. Adduci, DOE/San Francisco). Technical support for major subdivisions are provided by the following DOE National Laboratories:

A) Geothermal Cements; Brookhaven National Laboratory, L. Kukacka (516) 345-3065

B) Alternate Materials for Geothermal Systems; Brookhaven National Laboratory, L. Kukacka

C) Metallic Materials for Geothermal Systems; Brookhaven National Laboratory, D. Van Rooyen (516) 345-4050

D) Geothermal Cable Development, Sandia National Laboratory, A. Veneruso (505) 264-9162

E) Water Chemistry Control Instrumentation; Battelle Northwest Laboratories, G. Jensen (509) 946-2779

F) Sampling, Analysis and Plant Monitoring; Battelle Northwest Laboratories, D. Shannon (509) 946-3139

G) Geothermal Fluid Handling Technology; Los Alamos Scientific Laboratory, R. Feber (505) 667-4181

H) Geochemical Engineering, A. Adduci, DOE/SAN

I) Materials Activity in other DGE Projects

The objective of the materials work is to increase the acceptability of geothermal energy by lowering life cycle costs.

Projects in each major area are reviewed by industrial/university task groups such as the American Petroleum Institute or The American Society for Testing and Materials. These national technical societies provide the interfaces for Industry/university/government interactions and cooperation.

In addition to projects already mentioned, the Program supports work with a broader scope. These projects, with estimates of materials and materials related chemistry activity, are included in this listing and have funding equal to $7,141,200. The approximate amounts of funding for different sectors are:

Industry - $3,338,700, National Laboratories - $3,173,800
Universities $392,100 and other government agencies $236,600

Major reports published to date include:

(1) Materials Selection Guidelines for Geothermal Power Systems. Radian Corporation Report No ALO-3904-1, September 1978.

(2) Sampling and Analysis Methods for Geothermal Fluids and Gases. Battelle Pacific Northwest Laboratory Report No PNL-MA-572.

(3) Cementing of Geothermal Wells Quarterly Progress Reports for Contract EY-76-C-02-0016, Brookhaven National Laboratory and Subcontracts.

(4) Alternate Materials of Construction Quarterly Progress Reports for Contract EY-76-C-02-0016, Brookhaven National Laboratory and Subcontracts.

(5) The Application of a Non-destructive Evaluation Technique Utilizing Internal Friction for Detecting the Incipient Failure of Drill Pipes. Final Report Daedalean Associates Contract No EG-77-C-01-4045, December 1978.

(6) American Society for Testing and Materials Task Group on Geothermal Seals. Proceedings of Technical Seminar CONF 78-6141, April 1979.

(7) Proceedings of a Workshop/Symposium on Materials in Geothermal Energy Systems, Radian Corporation, Contract No EG-77-C-04-3904.

(8) Geothermal Materials Review. Radian Corporation P.O. Box 9948, Austin, Texas 78766.

(9) Geothermal Elastomeric Materials (GEM) Program, L'Gardē Corporation Final Report, October 1976-30 June 1979, Contract No. DE-AC03-77ET28309.

(10) Economic Assessment of Using Non-Metallic Materials in the Direct Utilization of Geothermal Energy, Burns & Roe Industrial Services Corporation (Brookhaven National Laboratory Contract No. 442252-5), February,1979.

Geothermal Cements

Title: Cementing of Geothermal Wells

Principal Investigator(s): L.E. Kukacka

Institution: Brookhaven National Laboratory

FY 79 Funding (thousands): $200

Description:

The objective of this program is to organize, manage, and perform research in order to develop high-temperature organic and inorganic cementing materials for use in geothermal well completion systems.

Key Words: Cements, geothermal, high temperature, polymers, wells.

Title: Geothermal Cement Screening

Principal Investigator(s): E.R. Fuller, Jr.

Institution: National Bureau of Standards

FY 79 Funding (thousands): $65

Description:

The objectives of the program are 1) to assess the strength and durability of cementing materials after exposure to high-pressure, high-temperature geothermal saline fluids; 2) to develop techniques and test procedures for evaluating high-pressure, high-temperature permeability; and 3) to develop techniques and test procedures for measuring high-pressure, high-temperature fracture toughness and shear strength of cement-metal and cement-rock interfaces.

Key Words: Cements, strength, corrosion, durability, stress corrosion cracking, permeability, interface fracture toughness, interface shear, bond strength, standards.

Title: Cementing of Geothermal Wells

Principal Investigator(s): D.M. Roy

Institution: Pennsylvania State University (Brookhaven subcontract)

FY 79 Funding (thousands): $55

Description:

The goal of the research is to develop new cements utilizable for geothermal wells at temperatures up to 400°C (725°F). Two aspects are involved: 1) determination of the hydrothermal stability of new potential cementing compositions, of optional preparation methods, and of the detailed characterization of the compositions, and 2) determination of the mechanical and physical properties of the materials and of their chemical and physical durability in the presence of saline solutions or vapors under high temperature and pressure. Systems studied include $CaO-Al_2O_3-SiO_2-H_2O$ (high alumina-silica compositions), $CaO-MgO-SiO-H_2O$, and $CaO-MgO-SiO_2-K_2O-Al_2O-H_2O$.

Key Words: Cements, temperature, pressure, composition phase equilibria, calcium magnesium aluminum silicates, stability, durability, mechanical properties, physical properties, permeability.

Title: Cementing of Geothermal Wells; Phosphate-Blended Cements

Principal Investigator(s): T.J. Rockett

Institution: University of Rhode Island (Brookhaven subcontract)

FY 79 Funding (thousands): $33.3

Description:

The object was to develop and test a phosphate cement that can be used for completion of geothermal wells, by determining the phosphate phases that are stable at geothermal conditions and that are capable of cementing grains with high aluminum or silica content.

Key Words: Phosphate cement, phosphate-bonded glasses, hydrothermal stability of phosphates, geothermal cement, the system $CaO-Al_2O_3-P_2O_5-H_2O$

Title: High Temperature Materials for Cementing of Geothermal Wells

Principal Investigotor(s): D.K. Curtice

Institution: Southwest Research Institute (Brookhaven subcontract)

FY 79 Funding (thousands): $57.6

Description:

The purpose of the research is to develop improved cementing materials for use in the completion of geothermal wells. The work will involve selecting one or more formulations for use in geothermal wells at temperatures up to 750°F.

Key Words: Silica polymer cements, hydrothermal, high temperature, geothermal.

Title: Cementing of Geothermal Wells

Principal Investigator(s): R.S. Kalyoncu

Institution: Battelle Columbus Laboratories (Brookhaven subcontract)

FY 79 Funding (thousands) $50

Description:

The objective is to develop high-temperature cementing materials for use in the completion of geothermal wells that will meet the requirements of durability, thickening time, minimum strength loss, and minimum permeability.

Key Words: Silica polymer cements, hydrothermal, high temperature, geothermal.

Title: Development of Geothermal Well Completion Systems

Principal Investigator(s): B.E. Simpson

Institution: Dow Chemical Company, Dowell Division

FY 79 Funding (thousands): $145

Description:

The purpose of this project is to develop and evaluate a suitable geothermal-well cementing material through stability measurements, placement measurements, and chemical measurements. Work will center around three areas: portland and modified portland systems, silicate and/or aluminate systems, and "polymer" systems.

Key Words: Portland cement, modified portland, calcium silicates, polymer cements, lightweight cement, phase transformations, strength retrogression, brine erosion, steam erosion, well completions, high temperature, geothermal energy.

Alternate Materials for Geothermal Systems

Title: Alternate Materials of Construction for Geothermal Applications

Principal Investigator(s): L. E. Kukacka

Institution: Brookhaven National Laboratory

FY 79 Funding (thousands): $200

Description:

The program includes tests to determine the feasibility of using non-metallic materials in geothermal environments and studies to identify cost-effective applications. The program at BNL involves in-house research on polymers, polymer concretes, and refractory cements and includes full management of an integrated program involving subcontract efforts and industrial participation.

Key Words: Plastics, cements, polymer cements, ceramics, seals, cost effectiveness, electric power generation, direct utilization.

Title: Materials Analysis and Selection Handbook

Principal Investigator(s): Marshall Conover

Institution: Radian Corporation

FY 79 Funding (thousands): $325

Description:

The objectives are to prepare and maintain a Materials Selection Design and Operational Guideline Handbook for geothermal energy conversion systems. Fluid chemistry and materials corrosivity data will be evaluated for each major KGRA. Principal proposed conversion systems will be assessed as to materials needs and availability of subsystem components. Standardized testing procedures and operating procedures will be developed from a data base of utility failure analysis reports and smaller public and private non-electric systems.

Key Words: Materials Handbook, geothermal systems, materials analysis.

Title: Polymer Concrete Pipe Manufacture

Principal Investigator(s): J. Schroeder

Institution: Lindsay Industries (Brookhaven subcontract)

FY 79 Funding (thousands): $10

Description:

The program will optimize the manufacture of polymer concrete pipe developed by Brookhaven National Laboratory. In FY 1980, this pipe will be installed in a non-electric geothermal demonstration plant for long term field testing.

Key Words: Non-metallic components, geothermal energy, polymer concrete pipe.

Title: Geothermal Seals Screening

Principal Investigator(s): E. A. Kearsley

Institution: National Bureau of Standards

FY 79 Funding (thousands): $55

Description:

The objectives of the program are to 1) evaluate existing standards for applicability to geothermal uses; 2) develop short term tests indicative of longer term service life; and 3) screen polymer families for hydrolytic and temperature stability in reductive environments.

Key Words: Seals, hydrolytic stability elastomers, test methods, standards.

Title: Alternate High Temperature Seal Materials

Principal Investigator(s): Al Hirasuna

Institution: L'Garde, ExFluor Corporation (Brookhaven subcontract)

FY 79 Funding (thousands): $75

Description:

The work includes the development of high temperature sealing materials for use in drill bit seals, packers, logging equipment, and blow-out preventors and Technology Transfer of Elastomers developed under an earlier effort. These materials have successfully sealed for 24 hours at 300°C.

Key Words: Sealing methods, materials, geothermal, drilling tools, logging equipment.

Title: Polymer Coating Report

Principal Investigator(s): L. E. Lorensen

Institution: Lawrence Livermore Laboratory

FY 79 Funding (thousands): $70

Description:

Polymer coatings previously tested in flowing, aerated brine for total flow turbine applications will be examined metallographically and with the electron microscope to evaluate their stability.

Key Words: Brine, coatings, durability, materials selection handbook.

Title: ASTM Seals Conference

Principal Investigator(s): D. Hertz

Institution: American Society for Testing Materials (Brookhaven subcontract)

FY 79 Funding (thousands): $5

Description:

A 1-day conference of research groups, major industrial suppliers and users of geothermal seal materials will discuss the current state-of-the-art of geothermal seal materials. Conference proceedings will be published as DOE/ASTM report.

Key Words: Geothermal applications, high temperature, elastomers, polymers, hydralytic stability, seals, drill bits, packers, logging devices.

Metallic Materials for Geothermal Systems

Title: Pitting Resistant Alloys Development and Materials Management

Principal Investigator(s): D. VanRooyen

Institution: Brookhaven National Laboratory

FY 79 Funding (thousands): $150

Description:

The objective of the work is to develop and commercialize metallic alloys and steels that possess improved properties and are cost-effective; they are intended to reduce life-cycle costs and increase plant availability. R&D is underway on pitting resistant alloys. The project also manages subcontracts with steel and alloy developers in industry, non-profit laboratories and universities.

Key Words: Localized corrosion, nitrogen, stainless steels

Title: Internal Friction NDE Technique for Drill Pipe

Principal Investigator(s): L. Yeager

Institution: Daedalean Associates, Inc.

FY 79 Funding (thousands): $100

Description:

The objectives of this program are to develop internal friction NDE drill string technology for field testing drill pipe used in geothermal well drilling. An integral part of the program would use analytical and data processing techniques to enable the operator to distinguish the various modes of drill pipe failure.

Key Words: Drill pipe, non-destructive testing, internal friction, fatigue failure prediction.

Title: Materials Needs for the Geothermal Industry Till The Year 2000

Principal Investigator(s): D. Groves

Institution: Brookhaven National Laboratory subcontract, National Academy of Sciences

FY 79 Funding (thousands): $75

Description:

The objective of this work is to identify methods for significantly increasing productivity in the geothermal industry through specific materials developments.

Key Words: Productivity, geothermal, materials

Title: Clad Pipe for Non-Electric Heat Exchangers

Principal Investigator(s): V. H. Baldwin

Institution: Research Triangle Institute (Brookhaven subcontract)

FY 79 Funding (thousands): $20

Description:

The objective of this project is to ensure the durability and availability of non-electric heat exchangers immersed in geothermal fluid. A definition study is underway to examine the feasibility of eliminating waterline corrosion by using HIP Ticlad steel or other materials.

Key Words: Waterline corrosion, clad pipe, down-hole heat exchangers.

Title: Materials with Improved Hot Fracture Toughness for Drill Bits

Principal Investigator(s): R. Hendrickson

Institution: Terra Tek (Brookhaven subcontract)

FY 79 Funding (thousands): $45

Description:

The objective of this work is to develop the basic concepts of improving hot hardness and fracture toughness in materials for applications such as drill bits for geothermal well drilling.

Key Words: Geothermal drill bits, hot fracture toughness, hot hardness.

Title: Materials With Resistance to Wear in Geothermal Brines

Principal Investigator(s): D. P. Huey

Institution: Solar Turbines, International

FY 79 Funding (thousands): $45

Description:

The objective of this program is to develop durable materials that will resist wear and deterioration when used as bearings in pumps for geothermal fluids. The resistance to galling, corrosion, wear, and localized attack is being developed. The goal is to improve pump lifetimes and increase the efficiency of heat extracted from geothermal wells. Materials (metallic or non-metallic or combination) will be developed and laboratory tested to determine the best candidates for field testing in components under separate contracts.

Key Words: Geothermal pump bearings, resistance to deterioration.

Title: Localized Corrosion Studies

Principal Investigator(s): D. McCright

Institution: Lawrence Livermore Laboratory

FY 79 Funding (thousands): $160 (additional $20 subcontract)

Description:

The goal of this program is to determine the time dependence of localized corrosion rate under anaerobic Niland brine condition of API, AISI, and ASTM carbon steels. Pitting corrosion damage (number, distribution, depth of pits) will be determined, following ASTM STP G-46 after time intervals of 15 days, 1 month, 2 months, 4 months, and 6 months of exposure.

Key Words: Niland brine, carbon steel, alloy steel, pitting, localized corrosion.

Title: Localized Corrosion of Casing

Principal Investigator(s): A. Troiano, R. Hehemann, J. Peterson

Institution: Case Western Reserve (Armco Steel Subcontract)

FY 79 Funding (thousands): $100

Description:

This project aims to reduce localized corrosion of geothermal casing by composition and heat treatment. The goal is to eliminate incipient corrosion centers without large increases in materials and fabrication costs. Suitable specimens for testing will be prepared under simulated geothermal conditions, using new techniques to reduce tedious evaluations of samples.

Key Words: Geothermal casing, local corrosion, steel composition, heat treatment.

Title: Corrosion Field Test Data

Principal Investigator(s): J. P. Carter

Institution: Bureau of Mines

FY 79 Funding (thousands): $40

Description:

This project will provide documentation of extensive corrosion tests performed by U.S. Bureau of Mines at Niland/San Diego Gas & Electric Geothermal Test Facility. Approximately 1,700 samples from seven T.P. environments will be cleaned, weight loss and pit depth analyzed. This includes 20 alloy compositions.

Key Words: Geothermal materials, field test, U.S. Bureau of Mines, corrosion.

Title: In-situ Borehole NDE Definition

Principal Investigator(s): D. D. Emerson, R. H. Bossi

Institution: Lawrence Livermore Laboratory

FY 79 Funding (thousands): $40

Description:

The objective of this project is to review the state-of-the-art of nondestructive well inspection methods used in the oil and gas industry, to review Russian and Plowshare literature and to identify methods for insite testing useful for cement and casing standards development.

Key Words: NDE testing, borehole cement, geothermal wells.

Title: In-site Borehole NDE Definition (Subcontract)

Principal Investigator(s): C. K. Knutson, C. R. Boardman

Institution: GeoEnergy Corporation (Livermore subcontract)

FY 79 Funding (thousands): $30

Description:

See original Livermore contract.

Title: Alternative Materials for Well Casings

Principal Investigator(s): D. McCright

Institution: Lawrence Livermore Laboratory

FY 79 Funding (thousands): $230 (with an additional $30 subcontract)

Description:

The objective is to determine if certain grades of AISI, ASTM, or specially designed low to intermediate alloy steels offer the potential of significantly improving casing lifetime. A composite 1800 ft. well casing string will be exposed three months in a Salton Sea KGRA production well. The exposed casing string sections will be examined for generalized and localized effects.

Key Words: Well casing, geothermal, alternate material, AISI, ASTM, carbon steel.

Geothermal Cable Development

Title: Sandia High Temperature Cable Subcontracts

Principal Investigator(s): A. Veneruso, Sandia Coordinator

Institution: Unknown (Sandia subcontracts)

FY 79 Funding (thousands): $200

Description:

Geothermal cable development by industry will be funded to stimulate commercial application of new materials and fabrication techniques, as well as innovative design with existing materials. Additionally, the program will support industrial development of a promising new cable concept--an armored cable with a thin-walled metal tube core or impermeable coating, within which high temperature insulators and conductors are protected from the corrosive environment.

Key Words: Cables, coatings, high temperature, impermeability, corrosive resistance.

Water Chemistry Control Instrumentation

Title: Development of a High Temperature CO_2 Sensor for Operation in Geothermal Brines

Principal Investigator(s): R. Taylor

Institution: Leeds and Northrup (Battelle Northwest Subcontract)

FY 79 Funding (thousands): $40

Description:

Carbon dioxide is the major dissolved gas in solution in geothermal fluids. It affects turbine design and performance and drastically influences calcium carbonate scale development. The objective of this project is to develop, fabricate, and laboratory proof test a carbon dioxide sensor for in-situ measurement of pH in geothermal fluids at a minimum temperature of 250°C and 5000 psi both in down-hole and above ground systems. Field tests will begin when laboratory proof testing is completed.

Key Words: Geothermal fluid, carbon dioxide sensor

Title: Reservoir and Inline Monitoring Instrument R&D and Management

Principal Investigator(s): M. Danielson, G. Jensen

Institution: Battelle Northwest Laboratory

FY 79 Funding (thousands): $150

Description:

The objective of this project is to develop electrical and electrochemical probes that can measure the chemical environment of geothermal water and steam. This is accomplished through a three phase program of research, subcontract R&D and instrument field tests.

Key Words: Redox electrode, CO_2 and sulfide ion sensor, corrosion monitoring instruments.

Title: Development of a High Temperature pH Electrode for Operation in Geothermal Brines

Principal Investigator(s): G. Jensen, PNL Coordinator

Institution: Leeds & Northrup, Owens-Illinois, Beckman Instruments, Anaheim, California. (3 Projects), (Battelle Northwest Subcontract)

FY 79 Funding (thousands): $201

Description:

The objective of this project is to develop, fabricate, and laboratory proof test a glass pH electrode for in-situ measurement of pH in geothermal fluids at a minimum temperature of 250°C and pressures to 5000 psi both in down-hole and above ground systems. An electrode design was to have been available by May 1979 and sensors which have been proof tested in the laboratory were to be available seven months later. Field tests will begin when laboratory proof tests are complete.

Key Words: Geothermal fluids, pH electrode.

Title: Geochemistry Monitor and Instrument R&D

Principal Investigator(s): G. Jensen, PNL Coordinator

Institution: Battelle Northwest Subcontract (University)

FY 79 Funding (thousands): $20

Description:

The objective is to carry out R&D essential for in-situ probe and instrument development, and to create the technology needed for monitoring chemistry processes that can cause precipitation, scaling, and non-optimum efficiency as well as catastrophic reservoir failure.

Key Words: Geothermal fluids, probes, monitor, instrumentation specific ion electrodes.

Sampling, Analysis and Plant Monitoring

Title: Sampling and Analysis Technology

Principal Investigator(s): D. Shannon

Institution: Battelle Northwest Laboratory

FY 79 Funding (thousands): $125 ($50 subcontracts)

Description:

The objective is to improve geothermal data reliability/comparability, improve geothermal analytical capability, provide a basis for standard sampling and analysis method selection, eliminate irrelevant analyses, and establish an ASTM group to develop consensus standards. The work includes round robin comparisons between industrial, university, EPA, USGS, and National Laboratory Chemists. This will survey available methods of analysis, identify elements of interest, relate end uses of data to an analytical program, and test best methods at East Mesa.

Key Words: Geothermal fluids, analytical capability, standards, sampling.

Title: Geoplant Fluid Case Studies

Principal Investigator(s): D. Shannon

Institution: Battelle Northwest Laboratory

FY 79 Funding (thousands): $625 (est. 10% materials-oriented)

Description:

The objective is to operate a fluid monitoring system for documenting corrosion, scaling, injection and production well performance and plant operability. The program will concentrate primarily on a study at the Magma Electric Co., 10 MW binary cycle plant at East Mesa, California. A number of monitoring methods will be utilized to document fluid characteristics that affect scaling, corrosion of plant materials, particulates and suspended solids, and injectability of fluids. Data will be obtained from in-line probes, fluid samples, and an on-time data logger.

Key Words: Geothermal fluid, corrosion, scaling, injection, production well performance.

Geothermal Fluid Handling Technology

Title: Hydrodynamic/Kinetic Reactions and Morphology Changes of Scale Forming Materials

Principal Investigator(s): A.B. Metzner, J.W. Edington, C.E. Birchenall

Institution: University of Delaware (Los Alamos Subcontract)

FY 79 Funding (thousands): $30.4

Description:

Hydrodynamic effects on scale formation kinetics and morphology were experimentally determined. An applied R&D effort evaluated the potential for beneficial waste product recovery from geothermal fluids.

Key Words: Scale control, hydrodynamics morphology.

Title: Hydrodynamic/Kinetic Reactions in Liquid Dominated Geothermal Systems

Principal Investigator(s): P. Neswich

Institution: Aerojet Conversion Co. (Los Alamos Subcontract)

FY 79 Funding (thousands): $375

Description:

This project will evaluate how geothermal scale buildup occurs, and what hydrodynamic/kinetic mechanisms are operant during the scaling process. It identifies methods of controlling or modifying solids deposition in order to expand the utility of hydrothermal energy conversion systems. A mobile test unit will be built and operated to perform a systematic evaluation of the interaction between hydrodynamics and the precipitation kinetics and morphology of solids.

Key Words: Geothermal scale control, scaling mechanisms, mobile test unit scale morphology.

Title: Calorimetry of Geothermal Fluids and Related Materials

Principal Investigator(s): A. Navrotsky

Institution: Arizona State University (Los Alamos Subcontract)

FY 79 Funding (thousands): $58.7

Description:

The objective of this report is to modify and apply an existing high-temperature, high-pressure calorimeter to measurements of enthalpies of dilution in concentrated $NaCl-H_2O$ solutions, and enthalpies of mixing, solution, and precipitation of solid phases in the systems $NaCl - CaCl_2 - CaSO_4 - H_2O$ and $NaCl - CaCl_2 - CaCO_3 - H_2O$.

Key Words: Geothermal fluids, calorimetry

Title: Gibbs Free Energies of Formation of Scale Minerals

Principal Investigator(s): R. A. Robie

Institution: U.S. Geological Survey-Reston (Los Alamos Subcontract)

FY 79 Funding (thousands): $76.6

Description:

The heat capacities of chalcopyrite ($CuFeS_2$), siderite ($FeCO_3$), rhodochrosite ($MnCO_3$), fayalite ($Fe\ Si\ O_4$), and tephroite ($Mn\ Si\ O_4$), between 5 and 600K were measured by combined adiabatic calorimetry and differential scanning calorimetry. Also measured were the enthalpies of formation of siderite and rhodochrosite by HCl solution calorimetry. Thermodynamic scrubbing products were derived as a function of temperature and limits to scrubbing products for iron-rich amorphous silica were set.

Key Words: Geothermal fluids, scale minerals, heat capacities.

Title: The Solubility and Kinetics of Precipitation of Minerals of Importance in Geothermal Applications

Principal Investigator(s): George H. Nancollas

Institution: State University of New York at Buffalo (Los Alamos Subcontract)

FY 79 Funding (thousands): $45

Description

Thermodynamic solubilities and kinetics of minerals such as the calcium carbonate polymorphs, calcium sulfate hydrates, barium sulfate and the silicates, of importance in geothermal scale formation will be studied at temperatures up to 300°C using a highly reproducible seeded growth technique. The kinetic studies will be made in the presence of potential scale inhibitors, and the influence of trace heavy metal ions on precipitation will be considered.

Key Words: Thermodynamics, solubilities, geothermal fluid, growth kinetics, sulfate, silicates.

Geochemical Engineering

Title: H_2S Control, $CuSO_4$ Scrubbing

Principal Investigator(s): G. Allen

Institution: Pacific Gas & Electric Co.

FY 79 Funding (thousands): $800 (est. 10% materials)

Description:

Equipment and auxiliaries were installed at The Geysers, for an integrated, complete test facility designed to remove at least 90 percent of the hydrogen sulfide from 100,000 lb/hr of geothermal steam.

Key Words: Sulfide scrubbing, The Geysers, copper sulfate, geothermal, titanium cladding.

Title: Silica Scale Inhibitors

Principal Investigator(s): J. Harrar

Institution: Lawrence Livermore Laboratory

FY 79 Funding (thousands): $190

Description:

This report concerns test state-of-the-art chemical additives as scale inhibitors for Niland brines. The goal of this project was to identify any existing materials that could cost-effectively control scale from Niland brines. Approximately 13 proprietary scale inhibitors and 28 generic chemicals will be field tested at the Niland facility. The tests will rank additives as to scale inhibitor effectiveness.

Key Words: Geothermal, scale inhibitors.

Title: Injection Well Stimulation Chemistry

Principal Investigator(s): O. Vetter

Institution: Vetter Research

FY 79 Funding (thousands): $325 (est. 15% materials)

Description:

The objective of this project is to identify chemical procedures and chemicals that remove or reduce scaling in injection wells. The goal is to significantly extend the life of injection wells by developing appropriate maintenance procedures for periodic well stimulation. The project will use novel techniques to determine particulates entering geothermal wells. Chemicals, chemical procedures, and rock/chemical interactions will be laboratory tested under simulated near-well-bore reservoir conditions.

Key Words: Scale reduction, injection wells, geothermal, corrosion inhibitors.

Title: Hydrogen Sulfide Applied R&D

Principal Investigator(s): Unknown

Institution: San Francisco RFP (August 1979)

FY 79 Funding (thousands): $200 (10% materials oriented)

Description:

This consists of work to support existing project-oriented programs dealing with H_2S removal. The goal is to generate a new, more cost-effective approach for H_2S control in geothermal systems. Research and development will be done to investigate factors influencing rate processes for H_2S removal from geothermal fluids, and to review and supplement H_2S solubility data for static and dynamic systems where such information is weak or non-existent.

Key Words: Hydrogen sulfide, abatement, geothermal systems

Materials Activity in Other DGE Projects

Title: Jet Drilling

Principal Investigator(s): Sam Varnado, Sandia Coordinator

Institution: Flow Industries

FY 79 Funding (thousands): $5

Description:

The purpose is to study the potential of high pressure water jet coring for geothermal exploration. The project includes the design, fabrication, and laboratory testing of a water jet coring device applicable to coring in granitic and basaltic rocks.

Key Words: Waterjet, drilling, geothermal wells

DOE Contact: A. Follett

Title: External Drilling & Completions Technical Development

Principal Investigator(s): San Varnado, Sandia Coordinator

Institution: Sandia Laboratories Subcontracts

FY 79 Funding (thousands): $3,324 (est. 17% materials oriented)

Description:

The purpose is to develop and commercialize the technology required to reduce the cost of drilling and completing geothermal wells. The objective is to reduce the cost of wells by 25% by 1982 and 50% by 1986. Areas of potential cost reduction include: drill bits, drilling fluids, down-hole motors, well completions and advaced drilling techniques.

Key Words: Cost reduction, geothermal well drilling, bits, fluids, down-hole motors, new techniques, well completion.

DOE Contact: A. Follett

Title: Internal Technical Support

Principal Investigator(s): Sam Varnado

Institution: Sandia Laboratories

FY 79 Funding (thousands): $675 (est. 17% materials-oriented)

Description:

This study is intended to develop, test, demonstrate and transfer to industry, new concepts in drilling and completions. The objective is to transfer new technologies in drill bit hydraulics, synthetic diamond cutters and drill stem corrosion. A prototype down-hole replaceable drill bit will be designed, fabricated, and tested. A bit hydraulic laboratory will be established with the capability to observe, study and understand the cleaning and cooling functions of the drilling fluid, leading to innovative and optimized bit design. Research will be carried out to support stratapax and fluid testing of stratapax applications. Corrosion modes of drill stem material and changes of drill stem materials will be investigated. Exploration of the effect of changes in steel chemistry on corrosion, hydrogen embrittlement and corrosion fatigue properties will be undertaken.

Key Words: Drilling, completions, geothermal wells, hydraulics, diamond cutters, drill stem, corrosion fatigue, toughness, hydrogen embrittlement.

DOE Contact: A. Follett

Title: Compax Drill Bit

Principal Investigator(s): L.E. Hibbs

Institution: General Electric Co.

FY 79 Funding (thousands): $100

Description:

The goal is to increase drill-bit penetration rates and/or bit life, and to develop and demonstrate drill-bit utilization of high-pressure, sintered polycrystalline diamond compacts for cutting edges to increase penetration rate and/or bit life. The project will include instrumented rock-cutting experiments, diamond compact wear and failure analysis, rock removal modeling studies, bit design and construction, full scale laboratory testing, and field testing.

Key Words: Drill bits, diamond compacts.

DOE Contact: A. Follett

Title: High Temperature, High Pressure Mud Test Instrumentation

Principal Investigator(s): K. Walter

Institution: N. L. Baroid

FY 79 Funding (thousands): $200

Description:

The objective is to develop a laboratory instrument to measure properties of drilling mud under 20,000 psi and 700°F. The properties to be measured include rheology, density, plugging tendency and corrosion characteristics of drilling muds.

Key Words: Drilling muds, properties, high temperature and pressure.

DOE Contact: A. Follett

Title: Cavitation Cleaning HT/HS Facility

Principal Investigator(s): L. Yaeger

Institution: Daedalean Associates

FY 79 Funding (thousands): $147 (10% est. materials)

Description:

The objective is to develop cavitation cleaning techniques and components and field test a descaling system, for in-line cleaning of high temperature/high scaling geothermal piping and vessels. At the Niland Geothermal Loop Experimental Facility (GLEF), rigidly mounted or rotating cleaning heads will be installed in components and pipe sections for in-line cleaning during the 1000 hour operational cycle of the facility. The cleaning heads will be engineered to withstand the in-pipe environment during operation of the facility and will use the spent geothermal fluids as the source of cavitating liquid. Scale build-up at the GLEF occurs at the rate of 1 inch per month as the brine travels through the facility. The methods currently employed for overall scale removal are time consuming, costly, and cause deterioration with each use. In-line cavitation cleaning has the potential of eliminating these problems.

Key Words: Cavitation cleaning, geothermal, components, scale removal.

DOE Contact: M. Scheve

Title: Geothermal Test Facility (GCTF)

Principal Investigator(s): K. Newman, R. Jones

Institution: Westec Services, Inc.

FY 79 Funding (thousands): $532 (10% materials-oriented)

Description:

This facility is to provide high temperature moderate-to-low salinity geothermal fluid and supporting services to experimenters for R&D testing of equipment and components to be used in advanced geothermal systems. This involves the operation and maintenance of the facility including support of the BUREC geothermal well operation and providing all supporting services to the experimenters who use the test stations.

Key Words: Geothermal Test Facility

DOE Contact: R. LaSala

Title: Test Modifications to Down-Well Pumps

Principal Investigator(s): K. Nichols

Institution: Barber-Nichols Engineering

FY 79 Funding (thousands): $75 (est. 20% materials-oriented)

Description:

The purpose is to design and test proposed modifications to a currently available geothermal pump, enabling it to operate in a 450°F environment with a lifetime of 10,000 hours. It is proposed to modify a submersible pump to increse its temperature capability and reliability. The pump is intended to operate at a setting depth of 1500-2000 feet at a flow rate of 500-2000 gpm over a pressure difference of about 200 psi with an efficiency of 75 percent.

Key Words: Downwell Pumps, geothermal brine

Title: Geothermal Well Logging Development and Demonstration

Principal Investigator(s): A. Veneruso

Institution: Sandia Laboratories

FY 79 Funding (thousands): $691 (est. 5% materials-oriented)

Description:

The purpose is to provide near-term geothermal well logging capability through a joint DOE laboratory-industry effort to develop critically needed components and prototype logging tools for operation in temperatures up to 275°F in the nearterm and 325°C as a longer range goal. Facilities will be developed, including a computer truck, for performing geothermal logging on a production basis by the industry, and for field testing of new tools, procedures, and interpretation techniques.

Key Words: Geothermal wells, logging

DOE Contact: L. Ball

Title: Geothermal Well Logging Development Subcontracts

Principal Investigator(s): A. Veneruso, Sandia Coordinator

Institution: Sandia Laboratories Subcontractors

FY 79 Funding (thousands): $484 (est. 5% materials-oriented)

Description:

The objective is to provide near-term and long-term well logging capability through the utilization of innovative well logging technology. The major goal is to stimulate industry developed measurement tools and transmission techniques capable of functioning in the high temperature and corrosive environment of geothermal wells. Southwest Research Institute has studied the possible applications of optical fiber transmission lines and optical transducers for well logging applications at temperatures up to 600°C. IRT corp. is studying the feasibility of using nuclear techniques, such as Advanced Neutron Activation Analysis (NAA) for improving the well logging capability in harsh environments.

Key Words: Geothermal wells, logging

DOE Contact: L. Ball

Title: Active Electronic Circuits for High Temperature Instrumentation

Principal Investigator(s): B. McCormick

Institution: Los Alamos Scientific Laboratory

FY 79 Funding (thousands): $300 (est. 10% materials-oriented)

Description:

Down-hole logging of geothermal wells requires temperature-hardened instruments, to determine temperature, pressure, porosity, and permeability of a geothermal reservoir. The objective is to design, fabricate, and test active electronic circuit elements which can be used in instruments required to operate in high temperature environments, and to determine the feasibility of using integrated thermionic circuits (ITC) at high temperatures. ITCs were designed and their performance was simulated. Selected designs will be fabricated, and prototypes will be tested to compare theoretical against real performance.

Key Words: Geothermal environments, high temperature electronic elements, integrated thermionic circuits

DOE Contact: A. Jelacic

Title: Hot Dry Rock Program

Principal Investigator(s): B. Dennis

Institution: Los Alamos Scientific Laboratory

FY 79 Funding (thousands): $11500 (11% materials tests and testing facilities)

Description:

The objectives of the Hot Dry Rock Program are 1) to establish the technical feasibility of the LASL HDR heat extraction system by the end of FY 1981; 2) to confirm the technical and economic feasibility of commercial-site HDR systems by FY 1986; and 3) to support HDR commercialization by the early 1990's.

DOE Contact: A. Jelacic

Title: Test and Evaluation of API Casing Material Strings

Principal Investigator(s): D. McCright

Institution: Lawrence Livermore Laboratory

FY 79 Funding (thousands): $96 (with an additional $15 subcontract)

Description:

The objective is to determine the API grade of carbon steel best suited for well casings as well as to determine the composition-dependent variations within API specifications that influence corrosion lifetime. This will lead to API specifications for maximum well casing lifetime. To meet this objective a 1-1/4 inch, 1800-foot long well casing string was emplaced in the Woolsey 1 well in January 1979 with scheduled removal of the string in April. The string is composed of 30-foot sections of API J-55, N-80, and C-75 steels. After removal, the corrosion performance of each section will be determined. Metallographic analyses will be performed on appropriate sections to determine what influence the microstructure exerts on the corrosion behavior.

Key Words: Casing, geothermal, carbon steel, API specifications.

DOE Contact: M. Scheve

Title: Evaluation of Tested Metallic Materials for Plant Application

Principal Investigator(s):

Institution: Lawrence Livermore Laboratory

FY 79 Funding (thousands): $56

Description:

The objective of this project is to complete corrosion evaluation of materials tested in FY 78. USBM and LLL results were to be compared and recommendations made for further work, if warranted. Analysis of 32 commercial alloys exposed to acidified geothermal brine for 30 days has been completed. Work continued on analyses of the stress corrosion and weldment coupons and was scheduled for completion in April.

Key Words: Metallic Materials, geothermal, plant applications.

DOE Contact: M. Scheve

URANIUM ENRICHMENT

The uranium enrichment program is a very large and, in many respects, unique public enterprise wherein the Government itself is the purveyor of goods and services to both domestic and foreign customers. Revenues from the sale of these services will exceed one billion dollars this fiscal year. The Office of Uranium Resources and Enrichment (OURE) directs and administers those Government programs that assess uranium resources and provides uranium enrichment services to national and international customers.

The DOE has now underway an extensive effort to develop and use the gas centrifuge process which will dramatically reduce power demand for enriching uranium. This effort will lead to the construction of centrifuge enrichment facilities at Portsmouth, Ohio. The initial production from this plant will begin in 1987, with a capacity of 2.2 million separative work units in operation by 1988. This plant can be completed sequentially by adding enrichment capacity in blocks of 1.1 million separative work units as dictated by enrichment demand.

The long range goal of the gas centrifuge development program is to develop the centrifuge technology required for installation in the Portsmouth Gas Centrifuge Enrichment Plant (GCEP) and to continue to improve the efficiency of this new technology for incorporation in the long-term operation of this plant as well as any subsequent plants.

Specifically, OURE intends to continue the establishment of centrifuge materials, components, and systems manufacturing industries and subsequently procure products from these industries for installation in both operating centrifuge facilities and facilities under construction.

During FY 1979, about $2.1 million was committed to materials development in the gas centrifuge development activities.

DIVISION OF ELECTRIC ENERGY SYSTEMS

Electric Energy Systems (EES) Division manages their funds in two subprogram areas, namely

(a) Power Delivery, and
(b) Power Supply Integration.

The combined budget managed is $40.0M.

The portion of the effort that is judged to be materials research and development corresponds to a budget of approximately $4.0M.

The vast quantity and numerous types of materials required for the production of electrical equipment to meet expanding electrical energy demands poses a major long-lead-time problem area for electrical energy systems. Coupled with other driving forces - such as esthetics and scarcity of land for transmission rights-of-way, among others - materials research has become an integral part of many development projects of the Electric Energy Systems Division.

Program Content

Descriptions of current or planned EES projects, which are either materials R&D or contain significant amounts of materials R&D, are given in the following format:

TITLE OF RESEARCH

Contractor	Project ID Number
Location	Period of Performance
	Total Estimated Project Value

Project Description

Titles to research projects are typed in all capitals except those projects which are being managed by a national laboratory. Funding levels refer to the total negotiated or anticipated value of the contract.

DEVELOPMENT OF A LOW LOSS MAGNETIC COMPOSITE MATERIAL

General Electric Company	ET-78-C-01-3205
Schenectady, New York	9/78 - 5/80
	EV - $417,300

Develop and optimize the process necessary to produce a magnetic material made of amorphous metal flakes. The resultant technology when applied to the magnetic circuits of electric power equipment should provide potential benefits of increasing efficiency.

DEVELOPMENT OF FUTURE INSULATING SYSTEMS

National Bureau of Standards
Washington, D.C.

EX-77-A-01-6010/A053
9/77 - 9/80
EV - $616,350

Develop advanced diagnostic techniques, test procedures and statistically valid models for monitoring and identifying aging or degradation processes in compressed gas electrical insulating systems under normal or near normal operating conditions.

NON-CELLULOSIC INSULATION FOR TRANSFORMERS

Planned

AC01-79ET2-9343
12-months
EV - $199,000

Determine the potential for economic utilization of non-cellulosic solid insulation to reduce size, weight and electrical losses in transformers.

HIGH VOLTAGE BREAKDOWN STRENGTHS OF INSULATING GAS

Oak Ridge National Laboratory
Oak Ridge, Tennessee

W-7405-ENG-0026
10/76 - 10/79
EV - $1,648,461

Analyze, from a physiochemical point of view, the factors influencing the breakdown strength of gaseous dielectrics and seek gases with superior performance.

STUDY OF GAS DIELECTRICS AS CABLE INSULATORS

Massachusetts Institute of Technology
Cambridge, Massachusetts

ET-76-C-01-2295-T019
8/76 - 12/79
EV - $437,256

Fundamental study of gas dielectrics for insulation purposes to cover four areas of applied research: basic gases and mixture studies, particle trap studies, large system performance, and insulating surface studies.

AGING PROCESS IN SOLID DIELECTRICS

Battelle-Columbus Laboratories
Columbus, Ohio

EC-77-C-01-5010
9/77 - 9/81
EV - $2,732,865

Development of an understanding of insulation aging characteristics of solid dielectrics used for underground transmission cable systems. Development and verification of a short-term cable test procedure which will accurately predict insulation life for its rated service.

SYNTHETIC TAPE DEVELOPMENT

Brookhaven National Laboratory
Upton, Long Island, New York

ET-77-C-02-0016
10/77 - 9/79
EV - $900,000

Development of optimized polymeric film tapes for ambient temperature taped cable use.

MECHANISMS OF WATER TREE GROWTH IN EXTRUDED CABLES

Phelps Dodge Cable and Wire Corporation
Yonkers, New York

ET-78-C-01-3034
6/78 - 11/80
EV - $175,293

Analysis and comparison of observed laboratory and field data with the various theories regarding water tree growth mechanisms in polymeric insulations will be pursed. In particular, a novel new theory involving electro-osmotic pressure effects will be investigated. Experimental verification of the new theory will be attempted.

TRANSIENT BREAKDOWN VOLTAGES IN SOLID DIELECTRIC CABLES

Cable Technology Laboratories
Edison, New Jersey

ET-78-C-01-3062
8/78 - 9/80
EV - $442,577

Development of a physical model of voltage aging of solid dielectrics used for high voltage underground transmission cable systems. Development of a procedure for a short-term voltage test on solid dielectric full reel cables.

INVESTIGATION OF INTERCALATED GRAPHITE FIBERS

Naval Research Laboratory
Washington, D.C.

ET-78-I-01-2897
2/79 - 2/81
EV - $225,000

Determine the feasibility of developing a practical, lightweight, high strength, highly conductive cable material from intercalated graphite fibers suitable for use in future power transmission and distribution systems.

DEVELOP AN INTERCALATED GRAPHITE COMPOSITE WIRE

Westinghouse Electric Corporation
Pittsburgh, Pennsylvania

AC01-79ET2-9044
5/79 - 7/81
EV - $340,000

Feasibility demonstration of fabricating lightweight, highly conductive, intercalated graphite composite wires suitable for use in future transmission and distribution systems.

AC SUPERCONDUCTING POWER TRANSMISSION
CABLE DEVELOPMENT

Brookhaven National Laboratory Upton, Long Island, New York	ET-76-C-02-0016 7/73 - 9/84 EV - $12,961,900

Development of a flexible ac Superconducting cable system based on Nb_3SN conductor and a tape dielectric. The project includes management of all supporting research on materials and refrigeration.

MATERIALS RESEARCH FOR HYDROGEN-COOLED
SUPERCONDUCTING POWER TRANSMISSION LINES

Westinghouse Electric Corporation Pittsburgh, Pennsylvania	DE-AC02-79ET29354.A000 9/79 - 10/82 EV - $687,000

Investigation of materials which can be used in future superconducting powe transmission lines with performance characteristics superior to Brookhaven National Laboratory's liquid helium cooled superconducting line. The investigation consists of two parts: (1) dielectric studies of liquid hydrogen, and (2) investigation of superconducting materials with transition temperatures in the liquid hydrogen range.

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