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Metals and Ceramics Division Annual Progress Report for Period Ending June 30, 1981

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FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Contents

Foreword

This progress report covers the research and development (R&D) activities of the Metals and Ceramics Division for the period July 1, 1980, through June 30, 1981. In keeping with past custom, the format of the report follows rather closely the organizational structure of the division. Short summaries of technical work in progress in the various functional units are grouped and presented in five parts. Chapter 1 deals with the technical activities of the Engineering Materials Section, Chap. 2 with the Fuels and Processes Section, Chap. 3 with the Materials Science Section, Chap. 4 with Other Research Activities, and Chap 5 with Specialized Research Facilities and Equipment operated in user's mode to promote collaboration and joint research with the U.S. industrial sector and the university community.

The past year was characterized by restricted financial support for materials research activities and a reduction in the staff to accommodate the reduced budget anticipated for FY 1982. The financial decreases of divisional support for the fission energy and Nuclear Regulatory Commission (NRC) programs were essentially offset by corresponding increases in the fossil energy and nuclear waste programs. Overall, operating funds rose a mere 0.8% and hence failed to keep pace with inflation. The size of the staff was reduced from 279 permanent employees on roll as of July 1, 1980, to 258 employees on roll as of July 1, 1981. Further details are presented in Appendix A, Budget and Support Distribution, and in Appendix B, Personnel Summary.

The organizational structure of the division was realigned in selected areas to accommodate evolving changes in the mix and thrust of R&D activity and to upgrade technical management. These adjustments and staff member appointments in the past year are announced in Appendix C on Organizational Structure and Chart. On April 1, the division began reporting to Alexander Zucker, Laboratory Associate Director for Physical Sciences.

Greater attention is currently being focused on discerning trends and seeking opportunities for exploratory research needed in materials science and engineering. Numerous ideas for exploratory research have been submitted to the laboratory seed money committee, and seven proposals have been approved for investigation. The nature and scope of these research investigations are described under "New Research Initiatives" in Chap 4.

Descriptive information on Honors and Awards, Seminar Program, Advisory Committee, Publications, and Presentations at Technical Meetings appears in summary form in Appendixes D through H, respectively.

Previous reports issued in this series are listed on the next page.

Reports previously issued in this series are as follows:

ORNL-28	Period Ending March 1, 1948
ORNL-69	Period Ending May 31, 1948
ORNL-407	Period Ending July 31, 1949
ORNL-511	Period Ending October 31, 1949
ORNL-583	Period Ending January 31, 1950
ORNL-754	Period Ending April 30, 1950
ORNL-827	Period Ending July 31, 1950
ORNL-910	Period Ending October 31, 1950
ORNL-987	Period Ending January 31, 1951
ORNL-1033	Period Ending April 30, 1951
ORNL-1108	Period Ending July 31, 1951
ORNL-1161	Period Ending October 31, 1951
ORNL-1267	Period Ending January 31, 1952
ORNL-1302	Period Ending April 30, 1952
ORNL-1366	Period Ending July 31, 1952
ORNL-1437	Period Ending October 31, 1952
ORNL-1503	Period Ending January 31, 1953
ORNL-1551	Period Ending April 10, 1953
ORNL-1625	Period Ending October 10, 1953
ORNL-1727	Period Ending April 10, 1954
ORNL-1875	Period Ending October 10, 1954
ORNL-1911	Period Ending April 10, 1955
ORNL-1988	Period Ending October 10, 1955
ORNL-2080	Period Ending April 10, 1956
ORNL-2217	Period Ending October 10, 1956
ORNL-2422	Period Ending October 10, 1957
ORNL-2632	Period Ending October 10, 1958
ORNL-2839	Period Ending September 1, 1959
ORNL-2988	Period Ending July 1, 1960
ORNL-3160	Period Ending May 31, 1961
ORNL-3313	Period Ending May 31, 1962
ORNL-3470	Period Ending May 31, 1963
ORNL-3670	Period Ending June 30, 1964
ORNL-3870	Period Ending June 30, 1965
ORNL-3970	Period Ending June 30, 1966
ORNL-4170	Period Ending June 30, 1967
ORNL-4370	Period Ending June 30, 1968
ORNL-4470	Period Ending June 30, 1969
ORNL-4570	Period Ending June 30, 1970
ORNL-4770	Period Ending June 30, 1971
ORNL-4820	Period Ending June 30, 1972
ORNL-4870	Period Ending June 30, 1973
ORNL-4970	Period Ending June 30, 1974
ORNL-5579	October 1, 1978–June 30, 1979
ORNL-5670	Period Ending June 30, 1980

1. Engineering Materials

G. M. Slaughter

This section is responsible for determining and evaluating the suitability of engineering materials for use in various energy systems, for developing new alloys, and for determining and developing improved joining and nondestructive testing techniques to assure the structural integrity of materials and components in specific applications. It comprises a staff of approximately 75, about 60% of whom are professionals. Research and development activities are carried out in five different laboratories, which carry the functional names Materials Compatibility, Mechanical Properties, Nondestructive Testing, Pressure Vessel Technology, and Welding and Brazing. Additionally, divisional support for the Heavy Section Steel Technology (HSST) and the High-Temperature Gas-Cooled Reactor (HTGR) Structural Materials programs is administered through this section. Brief descriptions of work performed by and major accomplishments of these groups are presented.

MATERIALS COMPATIBILITY

J. H. DeVan

The Materials Compatibility Group conducts corrosion studies for fusion energy, gas-cooled reactor, fossil energy, nuclear fuel reprocessing, nuclear waste management, conservation, and advanced technology projects.

In March unexpected cutbacks in financial support for two projects necessitated reassignment of personnel. The base technology program for space and terrestrial nuclear power systems (development and characterization of refractory and noble metals for isotopic fuel containment) was terminated; the remaining funds were transferred to the production of iridium alloy canisters. Funding of solvent refined coal (SRC) liquefaction plants was also reduced, curtailing studies of high corrosion rates in the fractionation area of SRC plants. Nevertheless, we have maintained an effective corrosion program on direct coal liquefaction processes, and the group has identified the mechanisms responsible for corrosion during hydrogenation of coal and fractionation of coal-derived liquids. For example, we have traced the movement of chloride-containing impurities through the liquefaction process and categorized the corrosion effects from them.

We have also maintained an active program on the fireside corrosion of heat exchanger materials in atmospheric fluidized-bed combustors (AFBCs). We are currently determining solid state reactions between the heat exchanger alloy and dense $CaSO_4$ deposits formed during the combustion process. We have determined the phase stability relationships between $CaSO_4$ and Fe, Cr, Ni, and Co, respectively, up to 1100°C. Closely related is a recently initiated program undertaken to assess the state of the art of heat exchanger alloys for high-temperature heat recuperation, a part of a conservation-supported program to develop metallic and ceramic heat exchanger materials for recovering heat in industrial ceramic processes.

Studies of the corrosion and mass transport of austenitic, ferritic, and long-range-ordered alloys by liquid lithium and lead-lithium solutions are being conducted for the Fusion Alloy Development for Irradiation Performance (ADIP) Program. Candidate fusion first-wall alloys are exposed in static melts and in naturally convective lithium. Our studies provide understanding of the kinetics of iron, nickel, and chromium transport from high to low temperatures in lithium heat transfer circuits. They also include a study of the compatibility of Fe-Cr-Ni-Mo and ordered Fe-Ni-V alloys with Li_2O, a candidate tritium-breeding solid. Thermal-convection loops are also used to study the mass transfer of types 304 and 316 stainless steel and alloy 800 in mixed nitrate-salt ($NaNO_3$-KNO_3) for the solar thermal energy conversion program sponsored by Sandia National Laboratory.

Environmental interactions of Hastelloy X and alloy 800 with ppm amounts of H_2, H_2O, CH_4, and CO in helium are important in developing HTGR reactors. Accordingly, gas-metal reaction studies of these alloys in helium with closely controlled impurity levels are being conducted at 600 to 1100°C. Current results demonstrate that dilation from carburization can produce a volume increase of up to 1% and can complicate interpretation of mechanical property behavior.

We have continued to support the Consolidated Fuel Reprocessing Program in the selection and corrosion testing of containment materials for advanced fuel reprocessing plants. The experimental part of this program has been conducted under subcontract, but, beginning in FY 1982, we will assume corrosion testing.

A new investigation, started in FY 1981, examined two 33-cm-diam carbon steel pipes that had resided in a dry domal salt deposit for about 36 months. The pipes simulated the casing of a burial shaft for nuclear waste storage and contained internal electric heaters that generated thermal energy equivalent to that released by spent fuel. The pipes and the carbon steel specimens attached to their outside surfaces were significantly pitted. However, companion austenitic stainless steels, 26 Cr-1 Mo steel, and titanium were unaffected.

MECHANICAL PROPERTIES

C. R. Brinkman

The Mechanical Properties Group develops and analyzes data, qualifies new materials, and provides materials engineering support for ongoing national energy-related programs. During the past year, we received support from the following programs: breeder reactor, 40%; breeder reactor foreign exchange, 3%; gas-cooled reactor, 25%; fossil, 9%; service, 8%; conservation, 5%; defense, 2%; fusion, 5%; waste, 2%; and space, 1%. The overall effort for these programs was in characterizing the elastic, plastic, creep, and fatigue behavior of base metals, ceramics, polymers, and weldments. After statistical and parametric analyses of the data, we present them in a form useful to engineers or code developers for design.

Fast breeder reactor work continued on obtaining various mechanical properties such as long-term creep and fatigue data on types 304 and 316 stainless steel, alloy 718, and $2^1/_4$ Cr-1 Mo and modified 9 Cr-1 Mo steels. Elastic-plastic and toughness properties of annealed and aged material were also studied. Investigation continues on the influence of combined stress and temperature on subsequent mechanical properties of thin-wall large-diameter prototypic piping with welds for type 316 stainless steel. This work is based on differences in the microstructure between stressed and unstressed regions of long-term creep specimens and the degradation of room-temperature toughness properties by prolonged exposure to elevated temperatures. Our heat-to-heat variations program continues to generate data on the austenitic stainless steels, both for defining the magnitude of inherent data scatter in various properties and for providing the basis for revised chemical specifications to decrease data scatter. One of our greatest recent experimental successes was the development of a biaxial fatigue extensometer. This unit allows us to conduct time-dependent fatigue tests by combined push-pull and torsional loading on tubular specimens for breeder reactor development. About 30 tests were successfully completed on $2^1/_4$ Cr-1 Mo and type 304 stainless steel.

Several utilities, steel suppliers, and design organizations have shown considerable interest in the recent development of modified 9 Cr-1 Mo ferritic steel. This is a new structural material for use at elevated temperatures, which offers several advantages, including increased strength and chromium conservation compared with some austenitic stainless steels. Considerable new data were obtained, and an ASTM specification was submitted for consideration. One foreign and three domestic utilities and several foreign laboratories are cooperating in the evaluation of this material.

Several pages of updates prepared by our Data Analysis Center were entered in the *Nuclear Systems Materials Handbook*. A creep-fatigue design procedure for 2¼ Cr-1 Mo steel based on our analysis was accepted by the ASME for ASME Code Case N-47. Test matrices from the national breeder reactor structural materials program were computerized for inclusion in a national plan for mechanical properties design data.

Data development and analysis for the materials technology to design and license HTGR cogeneration and reformer systems emphasized obtaining information on mechanical properties, thermal stability, and behavior of weldments. Structural alloys included Hastelloy X, Inconel 617, and alloy 800H, and ceramic materials included silicon nitride.

We conducted materials and components assessments on, and provided materials engineering services to, the coal gasification pilot plants and process development units managed by the Morgan-town Energy Technology Center (METC). Our continuing assessments will provide an engineering data base for future design use and will identify gaps in the technology. We also participate in surveillance testing of metals and ceramics programs in several gasification pilot plants.

We initiated work on a conservation program to develop a high-voltage gas-cooled transformer. Our objective is to develop mechanical properties of candidate polymers and to investigate long-term degradation in the presence of anticipated transformer materials in SF_6 at elevated temperatures. This work will supplement efforts of others to establish the optimum polymer for use in sheet-wound transformers and shunt reactors and to establish the compatibility of proposed materials of construction.

In fusion development, 20% cold-worked type 316 stainless steel was irradiated to damage levels of up to 9 dpa and helium contents of 450 at. ppm, which are prototypic of first-wall levels currently envisioned. Fatigue experiments on this material irradiated and tested at 550°C showed no adverse effects on fatigue life compared with unirradiated material. At lower temperatures (430°C), however, a deleterious effect of irradiation was noted.

In our waste container development program, compatibility is being tested on 15 potential canister materials contacted with 7 forms of simulated high-level waste. After 3500 h of exposure at 100 and 300°C (postulated storage temperatures), glass and Fuetap (concrete) evolved detectable amounts of sulfur. The low-temperature penetration was very shallow, and exposures are continuing to determine the penetration rate with time.

NONDESTRUCTIVE TESTING

R. W. McClung

The Nondestructive Testing Group develops new or improved methods of nondestructive testing (NDT) and provides technical support for nondestructive examination (NDE). The activities range from long-term studies of physical mechanisms and theory for development of advanced techniques and equipment to near-term development and technical support for various applied programs. The effort is broad-based, in terms of both the technologies involved (including penetrating radiation, eddy-current, ultrasonic, thermal, and penetrant techniques) and the varied interests of sponsoring agencies, especially those of the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC).

The major activity for DOE has been on the Breeder Reactor Program (BRP). We performed ultrasonic studies with improved transducers on austenitic stainless steel welds at temperatures up to 200°C with both machined discontinuities (e.g., notches and holes) and fatigue cracks. Studies began on ultrasonic inspectability as a function of weld design. Ultrasonic frequency analysis, diffraction, and other signal processing techniques were investigated for improved flaw characterization in the steel welds. Eddy-current studies emphasized multiparameter multifrequency techniques, and a special computer-controlled scanner was developed for use with modular instrumentation in studies on stainless steel welds. For the Clinch River Breeder Reactor steam generator we developed prototype ultrasonic techniques and equipment for in-service inspection (ISI) of the tube-to-tubesheet (T/TS) joints including microcomputer controls for ultrasonic scanning and continued development of eddy-current techniques for ISI of the tubing.

Development and technical support were begun for both ultrasonic and eddy-current ISI techniques for double-wall tubing for a Westinghouse alternate steam generator design. Preliminary techniques were applied for ISI of a few-tube model. We provided technical support to Westinghouse-Tampa Division for their acquisition of a microfocus rod-anode x-ray unit and peripheral equipment for radiography of T/TS joints.

In our long-range NDT studies for the DOE Office of Basic Energy Sciences we developed an analytical model for acoustic propagation across solid-solid interfaces emphasizing isotropic-to-anisotropic boundaries (e.g., for the base metal-weld metal interface in austenitic stainless steel); investigated advanced signal processing for flaw characterization; and developed a method for accurate eddy-current measurement of electrical conductivity. Other DOE programs included studies in x rays and ultrasonics for research reactor fuel, eddy-current examination of reactor control rods, radiographic and ultrasonic developments for graphite, and technical support for examining alloys and graphite components for space nuclear systems.

Technical consultation and support was provided to the program management staffs for the BRP and Fossil Energy Materials Development programs. Special ultrasonic and eddy-current studies were performed for Brookhaven National Laboratory on techniques for evaluating welds in stainless steel tubing.

The largest activity for the NRC was on improved ultrasonic standards for ISI of light-water reactor (LWR) pressure vessels, including consultation, interaction with ASME Code committees, assistance in development of a regulatory guide, and confirmatory laboratory experiments. We also provided consultation in evaluating nondestructive examinations on commercial nuclear reactors. For reactor safety research, we continued to develop improved eddy-current techniques (with the aforementioned multiparameter technology) for the ISI of LWR steam generators. We also conducted experimental studies for ultrasonic techniques to monitor gas bubbles in aerosol release from BRP fuels.

PRESSURE VESSEL TECHNOLOGY

R. K. Nanstad

The Pressure Vessel Technology Group investigates the fracture resistance of structural materials, particularly steels for pressure vessel applications. This requires expertise in experimental fracture mechanics and metallurgy. Programs are sponsored by both NRC and DOE. We are currently emphasizing the materials property needs for the HSST, Fossil Energy Materials, and High-Temperature Gas-Cooled Reactor programs.

Fracture toughness testing of prestressed concrete reactor vessel (PCRV) liner and penetration steels have continued with specific examination of weldments. We are analyzing data in order to apply candidate PCRV liner steels and weldments to a reference fracture toughness framework as in Appendix G of the *ASME Boiler and Pressure Vessel Code*. Weld metal and heat-affected zone studies are included, and results are compared with previous information from base material tests. Information for all materials will be assessed for establishment of a reference fracture toughness for PCRV liner steels.

Under the HSST program, material property data were obtained for thermal shock experiment 5A (TSE-5A). Results from TSE-5 and TSE-5A indicated that a large variability in fracture toughness data should be expected when testing laboratory specimens in the transition temperature regime and that vessel behavior occurred at or below the lower bound toughness results from laboratory testing. Additional testing with thicker specimens and side-grooved compact specimens and testing in a machine with variable compliance (i.e., spring in series with load train) did not reduce the toughness variation or the lower bound toughness. These investigations are continuing with thermal shock vessels 2 and 3.

The remaining Charpy V-notch (CVN) impact specimens from the second and third 4T-CTS irradiation experiments were tested in the HSST irradiation program. Analyses of force-time traces are being performed, and all results will be analyzed for fast neutron fluence and irradiation temperature. The fourth Bulk Shielding Reactor (4th BSR) experiment was started in December 1979, and irradiation of capsule A was completed in October 1980. Preliminary CVN impact data for HSST plate 02 steel, irradiated at 288°C to an estimated fast neutron fluence of 2×10^{19} neutrons/cm^2 ($E > 1$ MeV), indicated a transition temperature shift near that predicted by *Regulatory Guide 1.99*, but the upper-shelf energy loss was only one-third of that predicted. Capsule B completed irradiation in March 1981 with most of the specimens receiving an estimated fast neutron fluence of 2×10^{19} neutrons/cm^2 ($E > 1$ MeV). Capsule C, which began irradiation in May 1981, contains specimens of "current practice" submerged arc welds having copper contents of 0.046 and 0.056%. Capsule D assembly, to begin July 1981, will contain specimens from the Federal Republic of Germany.

Studies on the Fossil Energy Materials Program have emphasized mechanical property characterization of thick-section carbon and low-alloy steels for liquefaction and gasification pressure vessels. Tensile properties and CVN impact toughness have been determined over a wide temperature range for A-516, grade 70; A-533, grade B, class 1; A-387, grade 22, class 2; and weldments of those steels. The materials have been postweld heat treated (PWHT) for varying times to determine the effects of extended PWHT times on mechanical properties. Additionally, various heats of 2¼ Cr-1 Mo steel with chemical compositions modified to increase hardenability have been obtained from the Japan Steel Works and U.S. Steel and are being similarly characterized. Future testing will include fracture toughness determinations by elastic-plastic analyses such as the *J*-integral.

WELDING AND BRAZING

G. M. Goodwin

The Welding and Brazing Group continues to conduct materials joining research and development for light water reactor, reactor safety, fossil energy, fusion energy, basic energy sciences, gas-cooled reactor, space-nuclear, and fast breeder reactor projects.

Light water reactor and reactor safety activities have centered around the Advanced Instrumentation for Reflood Studies (AIRS) Program. Over 100 complex ceramic-to-metal instrumentation subassemblies have been successfully fabricated and delivered to facilities in the Federal Republic of Germany and Japan.

The Fossil Energy Program has emphasized evaluating heavy section weldments and weld overlay cladding. Analysis of a 300-mm-thick (12-in.) submerged arc weld in 2¼ Cr-1 Mo plate from an industrial supplier was completed, and additional plates and weldments are being procured. Weld overlay specimens have been corrosion tested here and at the SRC-I Pilot Plant.

Work on fusion energy consisted of welding assistance to the Large Coil Program.

The basic energy sciences welding study has continued investigating the solidification of austenitic stainless steels and iron-chromium-nickel alloys. A significant contribution involved the identification and characterization of four distinct morphologies of the δ-ferrite phase.

Gas-cooled reactor efforts have developed laser and electron beam welding procedures for a number of advanced alloys, including cast austenitics and mechanically alloyed materials such as International Nickel Company's MA-956.

For space-nuclear applications, we have continued to characterize the weldability of thorium-doped iridium alloys by several processes, including continuous-wave laser welding.

The breeder reactor programs have demonstrated commercialization of controlled residual element (CRE) stainless steel filler metals. The evaluation of large commercial heats has been completed, and the characterization of pipe produced by centrifugal casting and spin-forging has been reported. Graded transition spoolpieces are being produced by vacuum arc melting; the weldability of advanced 9 Cr alloys is being evaluated. Mechanical properties comparable to base metal values can be achieved by use of matched-composition filler metal with the gas tungsten arc process.

2. Fuels and Processes

R. G. Donnelly

The diversification from complete dependence on nuclear fuels research and development (R&D) toward a more balanced mix of nuclear and nonnuclear energy activities has continued over the past few years to the point that no single program currently accounts for more than about 17% of the section's support. Specialized manufacturing production, including fabrication of cermets for the Nuclear Regulatory Commission (NRC) Advanced Instrumentation for Reflood Studies (AIRS) Program and iridium disks and carbon fiber insulation for the Space Power Program, has increased and now represents 20% of the section's activities. This year, however, decreases in programmatic R&D were not fully offset by new initiatives. This and anticipated reductions in FY 1982 support resulted in a reduction of nine staff members (seven technicians) and consolidation of two former groups into the new Fuel Cycle and Engineering Analysis Group.

Section-managed programs continue to include the space power program, the graphite programs, and the national Building Thermal Envelope Systems and Insulating Materials (BTESIM) Program. Management of the remaining work on the irradiation testing task of the proliferation-resistant research and test reactor fuel element development program was transferred to the Engineering Technology Division of ORNL for completion.

Research activities and accomplishments of the functional groups reporting through this section during the past year are summarized below.

CERAMIC TECHNOLOGY

D. R. Johnson

Ongoing studies of pyrolytic SiC coatings for High-Temperature Gas-Cooled Reactor (HTGR) fuel have clarified relationships among properties, microstructural characteristics, and process variables. Recent transmission electron microscopy (TEM) studies are directed toward interactions with fission products and effects of radiation damage. Candidate structural ceramics for the HTGR core support are being evaluated. Characterization of several silicon nitrides before and after creep testing has identified dominant creep mechanisms. This is necessary to extrapolate the results of accelerated creep testing for predicting 30- to 40-year behavior.

A new program to develop improved solid electrolytes for sodium-sulfur batteries includes characterization of β''-Al_2O_3 electrolyte tubes. This program, which will emphasize the use of ceramic-metal composites as solid electrolytes, has the potential for creating an entirely new class of materials.

We continued development and production of carbon-bonded carbon-fiber (CBCF) insulation for use in the General Purpose Heat Source for the space program. Parts have been fabricated, characterized, and delivered for various testing programs. A quality assurance program was developed to control the fabrication and characterization processes.

We supported the Department of Energy (DOE) Brayton cycle waste heat utilization program by characterizing flue-gas particulates from operational industrial glass furnaces. We also contributed to materials testing through identification of candidate materials and test conditions; managed a subcontract for development of a thermal analysis code for glass furnace regenerators; and fabricated monolithic refractory specimens, which were tested and evaluated as potential recuperator materials in a glass furnace exhaust atmosphere.

Cordierite recuperators, representing a type used in DOE demonstrations of industrial waste heat recovery, were tested in the Refractory Test Facility to determine the effects of combustion products of both No. 6 oil and coal-oil mixtures on performance. We concluded that these particular recuperators are not suitable for use with dirty fuels unless a method of ash removal from the recuperator is provided. Materials support has been provided to a DOE contractor conducting demonstration tests of a stainless steel reradiant recuperator on an industrial furnace for melting aluminum scrap. Severe corrosion was determined to be caused by chlorides and or sulfur in hot flue gases. Rigid ceramic fiberboard was recommended as an alternative material.

A new testing program was started to identify the best commercially available devices for measuring oxygen in coal-burning fluidized-bed combustors. We are testing ceramic electrolytes and other devices to determine which types are capable of making the required measurements.

Electron and optical microscopy studies of coal have continued. We observed and identified a possible mechanism for the transformation of pyrite to pyrrhotite during electron beam heating in a high-voltage electron microscope. Our use of the near-infrared microscope was broadened to include subbituminous and low-volatile bituminous coals, and we expanded our coal structure program to include differential thermal analysis (DTA) of whole coal and separated macerals.

We continued development and production of Al_2O_3-Pt cermets for electrical insulators with high thermal shock resistance for the AIRS program. Insulators of Al_2O_3-Cr with equivalent thermal shock resistance were developed.

A series of experiments was completed to determine the oxidation characteristics of ThC, $(Th_{0.69}U_{0.31})C$, and (for comparison) UC fuel materials. Information on the oxidation behavior of these carbide fuels is needed to establish the requirements for fabricating and reprocessing them.

We initiated a new program to characterize and test commercial materials used as trim in severely erosive service and as high-pressure letdown valves in coal liquefaction pilot plants. Various techniques, such as optical and electron microscopy and x-ray and electron diffraction, are used in these characterization studies to gain a better understanding of the erosion mechanisms experienced in the synfuel pilot plants.

Another activity initiated this year is the study of atmospheric exposure effects on the performance of photovoltaic cells under concentrated (~40×) insolation. This work is intended specifically to improve the technical understanding of in-service photovoltaic cell behavior of concentrated insolation in nonarid, forested-agricultural or industrial areas typical of U.S. population centers.

The determination of physical property changes in graphite irradiated in various reactors was continued, and the effects of steam oxidation and neutron irradiation on the fracture mechanics of graphite were determined. A series of graphite specimens containing a dispersion of metal carbide particles (WC, TaC, and ZrC) was fabricated for the Navy, and examination of these composites has begun. The mechanical properties of several charcoals were evaluated for possible use as filters in the primary coolant loop of naval submarine reactors.

FUEL CYCLE AND ENGINEERING ANALYSIS

W. J. Lackey

This group develops processes and equipment for radioactive waste disposal and nuclear reactor fuels fabrication and performs engineering analyses in these areas and in the areas of materials for fossil energy applications and energy conservation. The high-level waste effort uses sol-gel and coating technology for preparing spheres of crystalline ceramic waste forms. Concrete waste forms for solidification of high-level and transuranic wastes are being characterized. New work in low-level waste management focuses on disposal or reclamation of contaminated metal scrap. Our fuels work is divided into two areas: (1) fabrication of breeder reactor pellet fuels by pressing gel-derived spheres (the sphere-cal process) and (2) fuel particle preparation and coating for HTGR fuels. Task management and materials design reviews are performed as part of the Fossil Energy Materials Program. The group also performs task management and experimentation for the materials project of the Energy Conversion and Utilization Technology Program and also for the Residential Conservation Service Program.

Sol-gel and fluidized-bed coating processes were successfully applied in producing highly inert, leach-resistant alternative high-level waste forms. The internal gelation process was emphasized in making dense spheres of Synroc containing commercial or defense waste. All particles were successfully coated with pyrocarbon and silicon carbide at temperatures as low as 1000 and 900°C, respectively. A generic cesium-bearing coated-waste form has been developed, which can be applied to any waste form, including glass. Aqueous leach contaminant test data of the coated-waste forms were below the detection limits of analytical techniques.

A new low-level waste task has the objective of formulating a comprehensive management program for contaminated metal scrap generated at sites managed by the DOE Oak Ridge Operations Office (DOE-ORO). A metal smelting facility to be located at the Oak Ridge Gaseous Diffusion Plant was identified as a necessary complement to existing capabilities, and conceptual design of the facility has begun. Development efforts supporting the facility will include uranium recovery from slag, slag disposal, and aluminum decontamination.

Concretes formed under elevated temperatures and pressures offer excellent possibilities as containment for radioactive wastes. We began studies to identify phases and partitioning of radionuclides in such concretes. About ten separate phases have been identified. Phase identification and radionuclide partitioning data will help us prepare concrete with greater leach resistance and will provide a better understanding of concrete that should increase the overall confidence in this waste form.

We successfully prepared fuel pellets from UO_2 and $(U,Pu)O_2$ gel-derived microspheres and achieved the desired pellet densities and microstructures.

Dense UC_xO_y is one of four kernel compositions being evaluated as HTGR fuel, and we are working jointly with the General Atomic Company to optimize the sphere-forming, calcining, and sintering processes. Significant progress was made in reducing the sintering time and temperature.

We are working jointly with the Fuel Recycle Division to develop, design, construct, test, and evaluate a welding system that can remotely repair piping systems within a fuel reprocessing facility.

We continued our lead roles in the materials design review and monitoring of research and development for the Solvent Refined Coal (SRC) demonstration plant projects and in the preliminary design of the H-Coal commercial plant project. An assessment of foreign activities in the selection and development of materials for use in coal liquefaction plants was completed. We also continued coordination and control activities for the Fossil Energy Materials Program; a program plan was completed, and a program-wide quarterly technical progress reporting system was devised and initiated. Coordination of the determination of causes of and solutions for severe corrosion of SRC pilot plant components is continuing.

We were selected by DOE to manage the materials project of the Energy Conversion and Utilization Technology (ECUT) Program, which was established to conduct applied research to develop base technologies for energy conservation. We prepared a preliminary annual operating plan for FY 1981 and a long-range project plan for FY 1981 through FY 1987. The project plan provides the basis for selecting future experimental projects from the following areas: (1) materials for high-temperature waste heat recovery, (2) materials for low-temperature waste heat recovery, (3) insulation, (4) materials for heat engines, (5) materials processing, (6) tribology, (7) recycle of waste materials, and (8) lightweight materials for ground transportation.

We continued to provide technical support to the Residential Conservation Service (RCS) Program in three principal areas of program implementation: rulemaking, technical assistance to states, and R&D. We completed an RCS auditor training manual, validated approximately 35 audit procedures for states and utilities, and supervised completion of a number of auditor-training activities. We continued our in-house research and development on (1) settling of loose-fill attic insulation, (2) thermal performance of attic insulation, and (3) seasonal furnace efficiency; data acquisition and analysis were the principal efforts on tasks 1 and 2, and a final report was prepared on the results of task 3.

FUELS EVALUATION

F. J. Homan

The HTGR Base-Technology Program continues to support most of the Fuels Evaluation Group. However, during the past year some support was provided by the Magnetic Fusion Energy and the High-Temperature Applications of Solar Energy programs. In HTGR-related work, the group continues to specialize in unique postirradiation examination (PIE) capabilities emphasizing quantitative measurements of fission product inventories by use of the irradiated microsphere gamma analyzer (IMGA) and the postirradiation gas analyzer (PGA) systems. These techniques are highly regarded by others in the HTGR community, such as the General Atomic Company and Kernforschungsanlage (KFA) Jülich who regularly send samples to ORNL for analysis.

The IMGA system has operated for the entire year examining coated-particle fuels from a number of irradiation tests. Results have shown significant releases of metallic fission products (e.g., ^{137}Cs) from Biso-coated ThO_2 at temperatures and burnups typically envisioned in a commercial HTGR. Radioactive silver release from SiC-coated particles is still being examined, and preliminary results show a dependence on temperature, fast neutron damage, and SiC properties. Recognizing this dependence, we fabricated and irradiated a capsule test. Detailed examination of the capsule began in June.

The PGA system routinely measured gaseous fission product inventories in coated particles. We found that the permeability characteristics of the pyrocarbon on Biso-coated ThO_2 varies widely from particle to particle within any one batch irradiated under the same conditions. Concern over the gaseous and metallic fission product release from Biso coatings led to a decision to replace the Biso design with a Triso design on the fertile particles.

Cooperative work with the KFA is continuing under the HTGR "Umbrella Agreement" between the United States and the Federal Republic of Germany. Work was completed and a final report written on fission gas permeability of pyrocarbon coatings (mentioned above). Work was also completed on comparison of the PIE techniques of ORNL and KFA to assess particle irradiation performance. Consequently, KFA has stopped development of its postirradiation annealing technique in favor of the IMGA.

Because of our experience in thermal analysis of our own irradiation capsules, we perform the service function of thermal design for irradiation capsules for the Radiation Effects and Microstructural Analysis Group. The work, supported by our Fusion Energy Materials Program, tests candidate materials for fusion reactors.

Work was completed and final reports written for two tasks on materials for high-temperature applications of solar energy. We found that silicon carbide materials were the leading candidates for use at high temperatures under anticipated fuel and chemical processing environments. We also assessed current ceramic fabrication technology for solar receivers to be used in fuel and chemical processes. We found that, although the fabrication technology is adequate, operational experience with hazardous chemicals does not currently justify solar-powered chemical production.

METALS PROCESSING

R. L. Heestand

Activities supporting space and terrestrial power systems continued to center on fabricating iridium containment for General Purpose Isotopic Heat Sources. Production levels were initially set at 600 forming disks for the year but were increased to 725 forming disks in the last quarter. An iridium production task force was formed early in the year to evaluate fabrication problems and forming defects that arose in changing from a hemisphere for the Multihundred-watt Heat Source to a deep-drawn cup for the General Purpose Heat Source. The task force recommendations were investigated on an experimental basis, and many were incorporated into the fabrication procedure. A reallocation of development funds precluded completion of several of the tasks. An iridium management plan was developed and implemented for control of inventories, refining, and financial plans for ORNL and all subcontractors for the Space and Terrestrial Systems Program. Under this system, ORNL has responsibility for managing and refining all program iridium.

The Waste Management Program on the "Volume Reduction of Low-Level TRU Contaminated Metals by Melting" was continued to complete experiments on the removal of plutonium by slagging reactions. Experiments indicated that plutonium could be removed to the same levels as uranium. An engineering-scale demonstration for uranium decontamination is being conducted in conjunction with Paducah Operations. This consists of melting and slagging a 100-ton contaminated melt, followed by determining residual contamination on the resultant 1-ton ingots. In another program a survey of the existing contaminated DOE-ORO scrap inventory is being conducted and plans made for melt-slag decontamination.

Efforts were continued on the fabrication of large heats of radiation-resistant D-9 stainless steel for use in fusion energy alloys. Similarly, a large heat of modified 9 Cr-1 Mo steel was procured for breeder reactor experimental use. Mechanical properties of these heats were found to be superior to commercial alloys. In addition to the modification of commercial alloys for radiation resistance, the scale-up of semiproduction quantities of long-range-ordered alloys was initiated. These high-temperature high-strength alloys, developed at ORNL, will be prepared commercially by both electron beam and electroslag melting to provide material for neutron irradiation, mechanical property, and compatibility tests.

The effort on fabricating experimental molybdenum heat pipes for Los Alamos National Scientific Laboratory in support of the Space Reactor Electric Power Supply (SPAR) was expanded to include molybdenum-rhenium alloys. This includes fabrication of both heat pipe tubing and wire for capillary screens.

3. Materials Science

J. O. Stiegler

Research in the Materials Science Section is directed toward understanding structure-property relationships in terms of processes occurring at the atomic level. Such an understanding can lead to the development of principles for the design of improved materials. The work ranges from efforts to control the composition and microstructure of conventional austenitic and ferritic steels for applications in breeder and fusion reactor systems to the exploration of novel processing techniques for synthesizing new metals and ceramics for possible use in advanced energy systems.

About 65% of our support comes from the Division of Materials Sciences of the Office of Basic Energy Sciences. This work, which is generic in nature, is aimed toward providing a technology base for addressing materials problems 10 to 15 years from now. Nearly 20% of our support is directed toward development of structural materials for high-flux regions of breeder and fusion reactors. Additional programs are funded by the Offices of Fusion Energy on Plasma-Surface Interactions, Fossil Energy on Structural Ceramics, and Conservation on Thermal Insulation.

The success of determining structure-property relationships rests on our ability to define structure precisely and quantitatively. We have therefore devoted substantial effort and resources in recent years to developing a state-of-the-art capability in techniques for characterizing materials. Facilities for these techniques, which are available for use by members of the university and industrial communities, are described more fully in Chap. 5 on Specialized Research Facilities and Equipment. During the past year our small-angle x-ray scattering laboratory was transferred to the National Center for Small-Angle Scattering Research, which is managed by the Solid State Division.

Descriptions of activities and accomplishments of groups in the section are given in the following paragraphs.

ALLOYING BEHAVIOR AND DESIGN

C. C. Koch

The primary goal of the Alloying Behavior and Design Group is the development and understanding of the principles of alloying behavior and of structure-property relationships and their application to the creation of new materials to meet energy technology needs. The group focuses on three major programs: (1) metastable materials, (2) deformation and mechanical properties, and (3) high-temperature alloy design.

The metastable materials program has emphasized the development of facilities to produce amorphous alloys by rapid quenching from either the liquid or vapor state. The formation, structure, stability of the amorphous phase, and selected property measurements of several amorphous alloy systems have been studied. Molybdenum-base amorphous alloy superconductors are studied as prepared by vapor quenching (in argon or N_2) or liquid quenching alloys containing metalloids such as phosphorus, boron, or silicon. Superconductivity also provides useful information on the structure of metallic glasses. Small-angle x-ray scattering on the ORNL 10-m Small-Angle X-Ray Scattering Facility (SAXS) is being used to help define the defect structure and compositional homogeneity of metallic glasses. We have used rapid solidification to modify the microstructure of several long-range-ordered (LRO) alloys of the $(Fe,Co,Ni)_3V$ type.

The immediate goal of the deformation and mechanical properties program is to understand the physical mechanisms of deformation and fracture in model systems (nickel and nickel-base binary alloys) and commercial alloys (austenitic stainless steels and nickel-base superalloys) at elevated temperatures under low applied stresses. Effects of trace elements on grain boundary cavitation under creep and fatigue test conditions are investigated by Auger spectroscopy. Use of the 30-m Small Angle Neutron

Scattering (SANS) Facility to study grain boundary cavitation has been initiated. The 1-MV High-Voltage Electron Microscope (HVEM) is used to provide direct microstructural information to aid the SANS study. Recent theoretical progress includes modeling of impurity-induced microvoid formation and effects of internal stress on grain boundary crack initiation.

The alloy design program has been concerned with the LRO alloys in the $(Fe,Co,Ni)_3V$ system for applications (including magnetic fusion first wall material) and with the iridium-base alloys for space power applications. Plans have been formulated and a seed money proposal funded for partial support of an alloy design program based on LRO alloys and intermetallic compounds for potential use at elevated temperatures in energy technology systems.

PHYSICAL PROPERTIES

D. L. McElroy

Physical properties are measured and analyzed to obtain an understanding of charge and heat transport behavior. These efforts on research and engineering materials are principally supported by the Division of Materials Sciences, the Building and Industrial Conservation programs, and the Breeder Reactor Program.

Experimental determinations were made of the phonon and electron components of the thermal conductivity of elemental iron, niobium, and tantalum. The phonon conductivity includes scattering terms caused by electron-phonon and phonon-phonon interactions. The former is large for niobium and tantalum and provides an important test of electron-phonon interaction theory. The electronic Lorenz functions of niobium and tantalum approach the Sommerfeld value. Similar studies are in progress for nickel. The electrical resistivity of a series of dilute palladium-base alloys was measured because these values may be calculated theoretically. Different theoretical models were verified as being capable of predicting thermal conductivity on (1) AXM-5Q1 graphite within 3% from 200 to 950 K and (2) microspheres of UO_2 or ThO_2 in helium. An apparatus for property measurements to 2600 K is being tested with a graphite standard.

The Conservation Program supports evaluations of properties, test methods, and the influence of operating environments on building and industrial thermal insulations. We are involved in developing standards and in cosponsoring conferences with ASTM Committee C-16 on Thermal Insulations and Subcommittee C-16.30 on Thermal Measurements. Research to improve the technical data base on insulating materials is performed both in house and by subcontract.

The physical properties of standard and modified 9 CR-1 Mo steels in the normalized and tempered states show the thermal stress factor to be twice as good as that of Inconel 718.

RADIATION EFFECTS AND MICROSTRUCTURAL ANALYSIS

E. E. Bloom

The primary objective of the Radiation Effects and Microstructural Analysis Group is to elucidate the role of microstructure, composition, and service environment on the behavior of materials and to develop materials with microstructures and compositions tailored for specific applications. Two mission-oriented or applied alloy development programs (supported by the Office of Fusion Energy and the Division of Reactor Research and Technology) are complemented by programs on radiation effects and analytical and high-voltage electron microscopy (supported by the Division of Materials Sciences). Electron microscopy (transmission, analytical, and high voltage) and surface analysis techniques (Auger spectroscopy) are used to characterize structure and composition on a microscale. The Oak Ridge Reactor (ORR), High Flux Isotope Reactor (HFIR), Experimental Breeder Reactor-II (EBR-II), Oak Ridge Isochronous Cyclotron (ORIC), and dual-beam Van de Graaff Facility are used in irradiation damage studies.

Analytical and High-Voltage Electron Microscopy

Research during the last year focused on development and evaluation of instrumentation, new methods and techniques of materials characterization, and application to a wide range of materials. Some of the applications involved collaboration with non-ORNL staff on the Shared Research Equipment (SHaRE) Program.

High-resolution-imaging techniques have been applied to the characterization of the interface structure of precipitates in austenitic stainless steels. Although reliable methods for revealing the interface boundary dislocation structure by weak-beam and lattice imaging have been successfully identified, the determination of Burgers vectors requires a more detailed investigation. Such work is in progress.

Detailed observations and dynamical calculations have provided a quantitative understanding of thickness fringe contrast at grain boundaries in transmission electron microscope (TEM) and scanning transmission electron microscope (STEM) modes and its relationship to the top-bottom effect.

A postspecimen scanning system on the field emission gun analytical electron microscope has been developed, which allows us to obtain energy-filtered intensity profiles of images or diffraction patterns. Uses include on-line computer analysis of "rocking curve" profiles in convergent-beam electron diffraction (CBED) patterns, from which accurate values of foil thickness can be obtained rapidly (<1 min). The characterization of complex ordered or modulated structures from diffuse elastic electron intensity profiles is also under way.

A number of improvements to the two electron energy-loss spectrometers were made. We continued our evaluations of the reliability of quantitative analysis made on a wide range of specimens by use of both *K* and *L* ionization edges. Some discrepancies were found, but the overall results were encouraging. A new, improved background-fitting procedure was developed for spectra involving *M* edges of transition metals.

In situ experiments in the high-voltage electron microscope continued. Dislocation motion and details of the propagation of shear cracks, such as ligament formation, were observed by in situ deformation of precipitation-hardened Al-4 wt % Cu and 2024 aluminum alloys. Little strain localization in precipitate-free zones was observed. Further studies are under way on alloys in their maximum hardness condition, where ductile intergranular failure is most likely to occur. Experiments on in situ oxidation of vanadium and vanadium-titanium alloys have continued. A detailed determination of the structure of the different phases that form (depending on foil thickness) also involved analytical and lattice imaging experiments. The disorder commonly observed arises from the low transformation temperature and the rapidity of the oxidation process.

Many applications employing state-of-the-art techniques were made on materials science problems during the year. In nickel-bonded TiB_2 ceramics (intended for use as hard wear-resistant materials) an intergranular phase was identified and characterized in detail as nonstoichiometric boron-deficient Ni_3B. A successful correlation was made of unusual strain softening behavior with deformation cell size and other microstructural features in ferritic 9 Cr-1 Mo alloys. The characterization of defect structures in annealed ion-implanted GaAs necessitated the use of high-resolution weak-beam techniques. An important finding was the presence of Frank dislocation loops as the major damage component, and a model correlating electrical activity with such microstructural details is being developed. The deformation substructure as a function of the composition of the binder phase in deformed cemented WC was investigated with the HVEM. Details of faulting, hexagonal close-packed phase formation, and twinning were investigated and interpreted for the expected deformation modes of the binder.

Radiation Effects

The mechanistic understanding of the processes by which irradiation changes physical and mechanical properties of metals and alloys is the primary objective of the Radiation Effects task. The program is focused on the phenomena and conditions encountered or anticipated in fission and fusion reactors. Results of this work provide guidance to the alloy development programs. The current scope includes cavity swelling, irradiation creep and embrittlement. An integrated theoretical and experimental approach is brought to bear on major problem areas.

Simultaneous nickel and helium ion bombardments have led to an improved understanding of the role of helium in microstructural development. Ferritic materials irradiated with neutrons or bombarded with simultaneous iron and helium beams are being studied. Both high-purity iron and iron-chromium alloys as well as commercial steels are included. The irradiation behavior of the LRO alloys developed elsewhere in this division is being studied. The first phase of a program of pulsed ion beam bombardment of a high-purity stainless steel was completed. This area is also of interest in connection with the pulsed environment of planned fusion reactors. The effects of irradiation-induced phase instability on swelling and the related effects of helium on phase instability are being pursued in close cooperation with the alloy development programs.

The theory of radiation effects is a major area of development. In the past, emphasis was on establishing the framework of the rate theory description and on modeling the effects of charged particle bombardment, including the large increase in damage rate and the marked spatial variation in swelling. More recently, impurity effects have been emphasized, and this resulted in the development of the theory of point defect trapping and its influence on cavity nucleation, cavity growth, and irradiation creep. The effects of impurity segregation on cavity nucleation and growth were explored by determining the changes in sink capture efficiencies with segregation. In alloys, second phase precipitates are also often a major feature of the microstructure. In the past year an important extension of the theory was to treat mechanisms affecting swelling in alloys with precipitates. This led to an improved understanding of swelling kinetics in complex alloys, especially the often observed increase in swelling from precipitation. In the past year an additional important result was achieved, the application of our cascade diffusion theory to establish the theory that cascade-induced point defect concentration fluctuations and the consequent dislocation climb excursion response can lead to significant irradiation-induced creep rates. This work led to the identification and quantitative evaluation of a mechanism of irradiation creep.

Fast Breeder Reactor Cladding and Duct Alloy Development Program

This work forms part of a national program to develop alloys with improved resistance to high-temperature irradiation damage for fast reactor core applications. Three major elements are (1) development of modified type 316 stainless steels with improved resistance to void swelling, (2) assessment of the effects of irradiation on the high-strain-rate deformation and fracture behavior of advanced alloys, and (3) fabrication development.

Previous irradiation with 4-MeV nickel ions showed that the swelling behavior of type 316 stainless steel could be substantially reduced through modifications to the composition, principally through the addition of silicon and titanium. Based on these initial studies, a series of austenitic stainless steel alloys with systematic compositional variations were neutron irradiated in EBR-II, and their radiation response was examined by analytical electron microscopy. Some 13 phases have been identified and their crystal structure and chemical composition characterized. Irradiation does not produce completely new phases. However, as a result of radiation-induced segregation (principally of nickel and silicon) and of enhanced diffusion rates, several major changes in phase relationships were found to occur during irradiation. First, phases characteristic of remote regions of the phase diagram appear unexpectedly and dissolve during postirradiation annealing (radiation-induced phases). Second, the compositions of some phases are significantly altered during development by the incorporation of nickel or silicon (radiation-modified phases). Several phases also develop at significantly lower temperatures during neutron irradiation (radiation-enhanced phases).

These phase instabilities are coupled to swelling behavior by three mechanisms: (1) helium trapping at particles and direct void-particle association, (2) modifications to the dislocation structure, and (3) depletion of matrix solute or solvent concentrations. Based on this understanding, commercial heats with improved compositions are being procured for irradiation testing in the Fast Flux Test Facility.

The successful application of the titanium-modified stainless steels to the manufacture of cladding and duct components necessitates some modification to existing type 316 stainless steel fabrication technology. A basic understanding of the fabrication technology of these alloys has been developed on flat products. The principles developed are being implemented in the production of thin-walled fuel pin cladding in the tube-drawing and continuous-hydrogen-annealing facilities in the Metals Processing Group.

Alloy Development for Irradiation Performance

An extensive effort was undertaken to develop alloys capable of withstanding the fusion reactor environment long enough to achieve economical fusion power production. With this as a long-range goal, the program must also provide design data for alloys to be used in near-term experimental fusion reactors such as the Fusion Engineering Device (FED).

To reach both these goals, five alloy paths are being investigated. The first and most developed path consists of austenitic steels and is followed by ferritic steels, high-strength Fe-Ni-Cr alloys, reactive and refractory metal alloys, and innovative concepts, which currently consist of only LRO alloys. Austenitic and ferritic steels are being considered for both the FED and the long-term applications; the remaining alloys are being considered for only the long term.

Helium produced by transmutation is a primary factor in determining radiation-induced swelling, microstructural evolution, and mechanical property degradation. Because the helium effects tend to limit lifetime, they are the focus of much of our research. In nickel-containing alloys, helium may be introduced simultaneously with displacement damage through irradiation in mixed-spectrum reactors such as HFIR and ORR.

A rather complex experiment is being conducted in the ORR to produce the same helium-to-displaced-atom ratio in an austenitic stainless steel as that which will be produced in a fusion reactor. The research has led to the development of a prime candidate austenitic stainless steel with improved radiation damage resistance. Several thermomechanical conditions have been developed, which result in desirable microstructures. Materials in these conditions are being irradiated to investigate their response to displacement damage and helium. The improved properties result from additions of titanium that result in precipitation of TiC particles. When the alloy is treated to produce a homogeneous fine distribution of TiC, the precipitate particles trap helium and prevent its migration to grain boundaries and its aggregation to form large bubbles. Phase stability during irradiation and the use of microstructural features such as dislocation substructures and precipitates to trap helium are under investigation.

Significant work was done on swelling of austenitic alloys, which led to the discovery of a low-temperature swelling peak. Further studies on swelling mechanisms led to the development of an equation to describe swelling in type 316 stainless steel on the basis of a fundamental understanding of microstructural evolution.

Irradiation in HFIR at 550°C to damage levels of up to 15 displacements per atom (dpa) and 850 at. ppm He showed little influence on the fatigue life of type 316 stainless steel at 550°C. The only notable effect was a decrease in the strain range of the endurance limit from 0.35 to 0.30%. This strain range corresponds to a thermal strain induced by a wall loading of 5 MW/m^2 in a 3-mm stainless steel wall, which is within the acceptable design envelope.

Experiments on ferritic alloys (mostly Fe–12% Cr–1% MoVW and Fe–9% Cr–1% MoVNb) focused on low temperatures, primarily 50°C. Fracture properties such as Charpy impact, crack growth, and fracture toughness must be addressed in these materials. Because the FED will operate below 300°C, low temperatures were selected to represent a relevant worst-case situation. Specimens of these alloys, both at their nominal composition and doped with up to 2% Ni to form helium, were irradiated in the HFIR. Tensile tests revealed very significant radiation hardening but no discernible effect of helium. Future research will extend this work to higher temperatures and examine Charpy impact specimens now being irradiated.

For LRO alloys emphasis is being shifted from ion bombardment to neutron irradiation. The first neutron-irradiated material became available this year. Swelling measurements on material irradiated in the ORR to approximately 5 dpa demonstrated the value of titanium additions to control swelling. Specimens irradiated to higher fluences are now available and are being examined. This research will lead to tailoring the composition of this class of alloys for irradiation resistance.

Smaller emphasis is being placed on refractory metals, titanium alloys, and high-nickel alloys. Tensile, fatigue, and transmission microscopy specimens of these materials from neutron irradiation experiments are being examined on a secondary priority basis. Cyclotron implantation of helium in vanadium alloys followed by fast reactor irradiation has shown a very significant effect of helium on mechanical properties. Further research is being conducted to validate the cyclotron implantation method of helium doping in vanadium alloys.

Structure and Properties of Surfaces

Surface analytical techniques are being used to study the influence of the structure and composition of surfaces on plasma-wall interactions in fusion devices and, conversely, the effects of such interactions on surfaces.

We are monitoring changes in the surface composition and structure of small samples of wall and limiter materials exposed in the Impurity Study Experiment-B (ISX-B) tokamak and the Elmo Bumpy Torus (EBT) torroidal confinement device to study impurity transport and to optimize impurity control. These studies are supplemented with studies in a small laboratory device wherein plasma-wall interactions can be studied under a wide range of controlled conditions.

Laboratory studies are currently concentrated in the area of hydrogen recycling and hydrogen-metal interactions. Recycling from the walls and limiters of tokamaks is the major source of hydrogen to the plasma. The composition and structure of the surface play strong roles in recycling, but the mechanisms involved are neither well characterized nor understood. We are studying these processes empirically to determine which are most important and the extent to which they can be controlled by materials selection and surface treatment. Isotope exchange experiments under conditions simulating ISX-B operation show that recycling from oxygen-contaminated stainless steel walls changes to 70% of the new isotope in five 200-ms pulses. Clean walls change much more quickly. The rate of change can be used to separate surface effects from bulk properties and to separate ion-bombardment-induced processes from thermal processes. Each can be important, depending on temperature and ion fluxes as well as on surface conditions.

Unipolar arcing occurs in all tokamaks and may be an important source of metallic impurities in the plasma. Our previous studies correlated arcing with surface cleanliness and plasma instabilities. High-speed photographic techniques are being used to study the details of the plasma-wall interactions on the main limiters in ISX-B. Correlation of arcing with magnetohydrodynamic (MHD) activity and major disruptions shows that particles and vapor resulting from arcing on the limiters can cause major plasma disruptions and thus terminate the plasma pulse. Titanium carbide coatings on POCO graphite limiters are badly damaged by arcing and the extremely high-energy fluxes but gradually become conditioned and provide good service. Bare graphite limiters will be tested for comparison. The various types of arcing on the limiters have been categorized, and we are trying to correlate them with plasma and materials properties to provide a means of protecting the limiters and keeping plasma impurity levels as low as possible. Studies of transport of materials into the plasma from natural arcs and artificially triggered arcs in the plasma edge are continuing; this work will help assess the importance of arcing in the plasma edge as a source of impurities for the core plasma.

STRUCTURAL CERAMICS

V. J. Tennery

The work of this group has emphasized several principal areas. One is the synthesis, fabrication, and characterization of hard ceramics, with the objective of achieving an understanding of how the microstructure and microcomposition determine the macrobehavior of these materials under highly erosive and high-stress conditions.

A second area involves studies of the behavior of selected structural ceramics in high-temperature fossil fuel combustion environments such as those anticipated for heat exchangers in direct coal-fired and other advanced fossil energy systems. The objective of this activity is to determine if structural ceramics based on SiC, Si_3N_4, or Al_2O_3 have the requisite stability to function as heat exchanger surfaces in the highly corrosive and erosive environments anticipated in certain advanced fossil energy systems and to identify important degradation mechanisms and the means for impeding them.

A third area involves the mechanical behavior of ceramic dielectric windows in gyrotron tubes to be used for microwave heating of the plasma in fusion reactors. The objective is to understand the relationship between thermal stresses and externally applied stresses in the windows of these tubes under operating conditions and to correlate the stress state with the fracture behavior of the ceramics. An Exploratory Studies Project included a study of the fracture toughness of ceramic materials containing a dispersion of a metastable phase such as tetragonal ZrO_2 in a matrix of Al_2O_3. This work identified the relationships among the geometry of the dispersed phases, its structural form, its concentration, and the temperature dependence of fracture toughness of the ceramic material.

Our work on hard ceramics this year was concentrated primarily on TiB_2 caused by the reported high hardness and electrical conductivity of this compound. We determined that, when correctly sized TiB_2 powders are blended with nickel powder and hot pressed, a near-theoretical density microstructure can be achieved under relatively modest temperature and pressure conditions. This process allows rapid densification of TiB_2 with minimal grain growth of the boride. These ceramics, when properly fabricated, contain relatively low concentrations of elemental nickel (<1 wt %), and we established by analytical electron microscopy that the nickel is primarily present as Ni_3B. Several properties of the TiB_2-based ceramics were determined as a function of the processing conditions; at 25°C, flexure strengths of 700 MPa, fracture toughness of 8 $MPa{\cdot}m^{1/2}$, and Young's moduli of 570 GPa were typical. Microhardness values of about 22 GPa were observed at 25°C with a decrease to about 8 GPa at 800°C. The thermal diffusivity of these nickel-sintered TiB_2 ceramics is essentially identical to that of theoretically dense find-grained TiB_2 from 25 to 1200°C. The thermal diffusivity at 600°C is about half that at 25°C. Engineering tests of these materials, including high-velocity particulate erosion, hot coal-oil slurry erosion, and metal cutting, suggest that these ceramics have promising potential for use as linings in valves and as metal-cutting tools.

Two first-of-a-kind high-temperature coal combustion experiments were conducted with structural ceramics this year. One included a 496-h exposure of a set of ceramic tubes and flexure bar specimens to the combustion products of an acidic ash bituminous coal at material temperatures of about 1250°C. The second included a 238-h exposure of the same type of structural ceramics to combustion products of a basic ash subbituminous coal at $T \cong 1250°C$. The same nominal amount of coal was burned in both experiments. Results from these experiments, which included SiC, Si_3N_4, and Al_2O_3-based ceramics, are providing insight into the practicality of using these materials in high-temperature heat exchangers in fossil energy systems. Surface corrosion of some of these ceramics by the liquid silicate sl[illegible] resulting from melting of the coal ash was four[illegible] to have a major influence on their fracture strength. Diffusion of certain elements from the slags into the ceramics at high temperatures caused appreciable increases in the thermal expansion in some cases. Ceramics based on SiC were relatively resistant to degradation by the coal combustion products.

Successful growth of some new hard refractory eutectics was accomplished. These included eutectics based on the ZrO_2-ZrB_2 and Y_2O_3-TiB_2 systems. Crack propagation through these eutectic structures was found to be much more difficult when the crack is moving across the secondary-phase lamallae. Quantitative measurements of the mechanical properties of these composite materials are in progress.

Single crystals of a ternary compound in the Ni-Ti-B system having a nominal composition of $Ni_{20.3}Ti_{2.7}B_6$ and referred to in the literature as a tau phase were successfully grown by the Czochralski method from the melt as part of our studies on hard ceramics based on TiB_2. On the basis of available phase equilibria data, this compound was anticipated to form as a secondary phase within the TiB_2-Ni ceramics discussed previously. Because this phase has not been observed, studies were initiated to determine why Ni_3B forms in preference to the tau phase and how the form of these secondary phases affects the flexure strength and fracture toughness of the TiB_2-based ceramics.

Consideration of Al_2O_3, BeO, and other ceramics for use in the output windows of high-power microwave tubes (called gyrotrons) for heating plasma in fusion reactors resulted in a critical analysis of available data required for lifetime predictions of these windows as well as initiation of experimental measurement of the static fatigue behavior of the candidate ceramic materials. Concurrent measurements of the dielectric losses in these ceramics at the Massachusetts Institute of Technology to frequencies to 300 GHz are being used to correlate electrical losses of the ceramics with the mechanical and microstructural properties.

Studies of the toughening of a normally brittle ceramic material such as Al_2O_3 by use of a dispersed metastable second phase consisting of ZrO_2 resulted in an improved understanding of the dispersion toughening process. Second-phase particles located along the Al_2O_3 grain boundaries with a diameter considerably smaller than the Al_2O_3 grain size are most effective in impeding crack propagation and thereby increasing the fracture toughness. The chemical process employed in forming the precursors of both the Al_2O_3 and ZrO_2 are very important in controlling the microstructure and thereby the mechanical properties of the resultant ceramics.

SURFACE AND SOLID STATE REACTIONS

J. V. Cathcart

Individual research projects of this group are designed to address the problems of diffusion and mass transport in high-defect solids, to investigate ways of modifying transport kinetics in these materials through the addition of impurities, and to examine the general question of stress generation and scale adherence during the growth of such high-defect scales on metals and alloys. The work is aimed specifically toward understanding sulfidation mechanisms and, in particular, transport in $Fe_{1-x}S$ and other transition metal monosulfides. However, because of emphasis on factors affecting point-defect mobility, results of much of this research are generally applicable to a range of phenomena including diffusion-controlled creep in metals and ceramics, the electrical and thermal properties of ceramic materials, and radiation damage.

We have continued to emphasize parallel theoretical and experimental programs. Theoretical studies utilize our previously developed concept of *defect* diffusion to treat the defect interactions so frequently important in high-defect solids. These ideas were used to generalize the Nernst-Einstein equation so as to make it applicable to self-diffusion in high-defect solids. The phenomenon of atomic and ionic transport via interstitial defects in which interstitial pairing occurs was treated. In collaboration with Dr. P. W. Tasker, Atomic Energy Research Establishment, Harwell, solute distribution was investigated for systems exhibiting both substitutional and interstitial defects, with special attention being given to calculations of the stability of interstitial-vacancy pairs.

Experimental work includes studies of the sulfidation kinetics of iron as a function of sulfur pressure;

diffusion in $Fe_{1-x}S$, also as a function of sulfur pressure and, hence, defect concentration; an x-ray study of the point defect structure of $Fe_{1-x}S$ single crystals (in collaboration with B. S. Borie and C. J. Sparks of the X-ray Research and Application Group); the effect of zirconium and chromium additions on the sulfidation rate of iron; mechanical stress development during sulfidation; and computer modeling of sulfide scale growth processes.

THEORY

J. S. Faulkner

A book reviewing the development of a first-principles theory of the electronic states in substitutional alloys entitled *The Modern Theory of Alloys* (*Progress in Materials Science*, to be published by Pergamon Press) was completed during the year by J. S. Faulkner.

We have used our alloy theory to explain the results of modern experiments that are specifically designed to measure the electronic states in alloys. These experiments are angle-resolved photoemission, soft x-ray spectroscopy, and positron annihilation. We have also explained some of the classic experimental measurements on alloys t' ... have been in the materials science literature for many years. For example, the electrons in a metal or alloy contribute a component to the specific heat that is linear in the temperature. The coefficient of T, called γ, is proportional to the product of the density of electronic states at the Fermi energy $\rho(E_F)$ and an electron enhancement $1 + \lambda$. We showed that the experimental values for γ as a function of concentration for the Hume-Rothery alloy copper-zinc can be reproduced exactly by our theory. We calculated the density of electronic states at the Fermi energy for pure copper with our band theory programs and for alloys of copper containing 10, 20, and 30% zinc with our coherent-potential approximation (CPA) programs. We obtained the electron-phonon enhancement factor for pure copper λ_0 from some of our first-principles calculations and estimated λ for the alloys by use of resistivity data. These calculations demonstrate that the CPA gives the correct values for $\rho(E_F)$ for alloys and that the older theory that has historically been used for alloys, the rigid-band model, is wrong.

In the paper that described our new equations for calculating the properties of random alloys within the CPA, we demonstrated algebraically that the equations suggested by other authors are incorrect. We have now demonstrated this numerically by showing that, for an exactly solvable one-dimensional model, their equations lead to such manifestly unphysical results as negative densities of states but that ours do not.

Our ability to calculate the total energies of pure metals and ordered compounds has been enhanced by developing a new set of band-theory equations, the quadraticized Korringa-Kohn-Rostocker (QKKR) equations. Calculations can be done with these equations that have almost the same accuracy as ordinary KKR calculations, but they are much faster. We will use these equations to study the thermodynamic properties of iron and iron-base alloys.

We calculated the thermal and electrical resistivities of niobium and palladium with realistic KKR energy bands and wave functions, experimental phonon frequencies, and rigid-muffin-tin electron-phonon interactions. The agreement with experiment is excellent, considering the fact that our theory has no adjustable parameters. The older *s-d* model is not too bad for palladium, but it is not supported by our calculations on niobium.

The rigid-muffin-tin approximation has proved to be a useful way to calculate electron-phonon interactions for many systems, but we would like to do better. This will require the self-consistent change in crystal potential caused by the displacement of an atom. To calculate this, we have developed computer programs for the crystal Green's function, a quantity that is also useful for calculating the formation energies of vacancies and heats of solution of impurities.

Our capability for studying atomic interactions of interfaces and surfaces has been enhanced by the development of an improved cluster technique for performing self-consistent, spin-polarized total energy calculations. We are using the technique to calculate the forces on atoms in larger clusters. Our results indicate that a sensitive balance of electron and nuclear forces of both stabilizing (net attractive) and destabilizing (net repulsive) character exists. Such analyses are valuable for deriving simplified conceptual frameworks for atomic interactions in complex systems.

The basis of all total energy calculations today is density functional theory. We analyzed the applicability of the Hellman-Feynman and virial theorems within this theory. A new exchange-correlation potential was also derived within density functional theory. This new result is of such accuracy that the effects of nonlocality can be considered.

X-RAY RESEARCH AND APPLICATION

C. J. Sparks, Jr., and H. L. Yakel

The diffraction of x rays by matter is the most widely used technique to determine the geometrical arrays of atoms and molecules. X rays also photoeject electrons to form the basis for studying electron energy levels and their charge distributions. These parameters determine the basic physical and chemical behavior of materials. Except in a few instances, theorists are unable to calculate material properties entirely from first principles. Most materials of interest consist of two or more elements in varying concentrations; therefore, the number of conceivable combinations makes detailed measurements an incredible task. Our goal is a synthesis of our experimental results with the calculations of the theorists to sort out the more promising trends and to lead the way to tailoring the physical and chemical properties of materials to our needs.

With the construction of large dedicated storage rings, intense x-ray sources are now available with a brilliance approaching electron sources and with a broad energy spectrum from which specific energies can be selected. Matching x-ray energies with resonances of specific elements permits improved location of their atoms in crystals containing elements of nearly the same atomic number and also permits exciting electrons for a host of spectroscopic probes. We are involved in a major commitment to using the National Synchrotron Light Source to improve our capabilities for studying advanced materials. This program complements our large effort in electron microscopy and provides a balanced and high capability probe for unraveling the geometrical arrays of atoms.

Our activities this past year included both small- and high-angle diffraction studies of a host of materials ranging from liquid-like polymers to crystalline metal alloys. Synchrotron radiation experiments were conducted at Stanford Synchrotron Radiation Laboratory to highlight specific atoms in some iron-base transition metal phases containing cobalt and to study the resonance interaction of x-rays near absorption edges for electronic excitation. Further insights into the interactions of x rays with matter were obtained by calculations of surface roughness and crystal perfection (extinction) on diffracted intensity. Our modeling of the geometrical structure of atoms and molecules by scattering is greatly enhanced by our improved understanding of how other x-ray interactions affect the scattered intensities. Experiments conducted at the Cornell High Energy Synchrotron Source proved our design of a crystal bending device, which for the first time provides for sagittal focusing of the horizontal divergence of the radiation for a continuously selectable range of x-ray energies to 30 keV. Crystal focusing provides an x-ray flux 4 to 20 times that obtained with mirrors.

Our x-ray laboratory provides services for other projects. Over 500 x-ray analyses are performed annually on a variety of samples. Most originate in the division and require that phase identifications, preferred orientation determinations, fluorescent analyses, crystal orientation determinations, and lattice parameter measurements be routinely performed.

4. Other Research Activities

In addition to the research activities presented previously in this report, this chapter includes Metallography, High-Temperature Materials Laboratory, and New Research Initiatives.

METALLOGRAPHY

R. S. Crouse, R. J. Gray, and B. C. Leslie

The Metallography Group provides technical assistance in general metallography, postirradiation metallography, and electron beam microanalysis (scanning electron microscopy and microprobe of both irradiated and unirradiated materials). Highlighted below are the results of failure analysis and other metallographic findings not covered elsewhere in this report.

An investigation of type 347 stainless steel tubing used in the apparatus to transfer neutron activation samples into and out of the High Flux Isotope Reactor (HFIR) was completed. The tubes had been subjected to a thermal fluence of approximately 7×10^{22} neutrons/cm^2 in the centerline of the reactor. They were compared with the upper portion of the assembly that had not been subjected to irradiation. Microhardness and bend tests revealed an expected increase in hardness and a loss in ductility for the irradiated tubing compared with the unirradiated tubing. Comparative tensile tests also showed a loss in ductility for the irradiated tubes. Yield and ultimate tensile strengths, however, did not increase to the level one would have expected from comparison with previous work conducted on this particular steel. This anomalous behavior was believed to be caused by erratic testing of the tubes in the hot cell. Scanning electron microscopy was used to a distinct advantage to show ductility characteristics of the tensile fractures. In addition, transmission electron microscopy was employed to show dislocation characteristics of the unirradiated and irradiated tubes.

The need to increase the U.S. domestic production of liquid fuels has required a more intensified study of the production of this vital fuel from coal. The H-Coal liquefaction process is one of several methods now under study. On September 20, 1980, the H-Coal Pilot Plant at Catlettsburg, Kentucky, experienced a failure of three tubes of a heat exchanger, which shut down the entire system and created an urgent need to determine the cause(s) of failure. An investigation team was assembled from ORNL; the Institute for Mining and Minerals Research (IMMR), Lexington, Kentucky; Hydrocarbon Research, the plant designer; Kobe Steel, the fabricator of the heat exchanger; and Mobil and Standard Oil of Indiana (AMOCO) to make this determination and to offer remedial suggestions. Three days later the operators of the pilot plant were notified that the tubes had failed from stress-corrosion cracking caused by the presence of chlorides or caustic. Corrosion fatigue could also have played a role in the failure.

The Metallography Group continues to provide on-site surveillance of the Department of Energy's (DOE's) solvent refined coal (SRC) plants. On demand, a team of three metallographers goes to the SRC plant and performs the necessary in situ metallographic examinations for monitoring the performance of the various components (fractionating columns, piping, etc.).

HIGH-TEMPERATURE MATERIALS LABORATORY

J. V. Cathcart

High-temperature materials problems impose significant limitations on advanced energy-generating or -converting systems (reduced efficiency and lack of reliability or, in some instances, of feasibility). Problems such as sulfur attack in a fluidized-bed combustor for coal or the high-temperature corrosion of ceramic recuperators involve rather complex phenomena. Effective solutions are most readily achieved by a multidisciplinary research staff housed in a central, specially equipped laboratory. Best results can, we believe, be obtained through integrated programs of basic and applied research. We have therefore continued our efforts to establish a High-Temperature Materials Laboratory (HTML) at Oak Ridge; our sponsor in this effort is the DOE Office of Basic Energy Sciences.

As discussed in last year's annual progress report, budgetary constraints forced a reduction in the size of the proposed HTML from about 7800 m^2 (84,000 sq ft) to about 3900 m^2 (42,000 sq ft), and a new conceptual design for the smaller building was developed. Consequently, of the six areas of functional expertise originally identified as necessary in an HTML staff, only four (structural characterization, physical properties, materials synthesis and preparation, and mechanical behavior) will be represented in the reduced HTML. However, work in high-temperature chemistry and environmental interactions will be performed in laboratories immediately adjacent to the HTML, thus ensuring that effective communications are maintained among investigators in all six research areas.

During the past year a major effort was made to establish closer ties between the HTML and the industrial research community. An Industrial Users Committee, chaired by W. D. Manly, Senior Vice President, Cabot Corporation, was formed. At the suggestion of the committee, a symposium entitled "Materials Research Highlights at ORNL" was organized, which was attended by about 25 corporate executives from U.S. companies whose products involve high-temperature materials. The symposium was well received and contributed significantly to a greater industrial awareness of ORNL-HTML programs and facilities.

Development of the integrated High-Temperature Materials Program continued during the past year. Active research programs exist in all six functional research areas of the HTML, and progress is being made in developing interfaces between basic and applied research efforts. Typical of the latter are two investigations of deformation and fracture processes, one mechanistic, the other a classical study of creep and rupture in support of the Liquid-Metal Fast Breeder Reactor (LMFBR) Pressure Vessel Program. The basic work emphasizes the role of interfaces in crack initiation processes, and in it we are utilizing the small-angle neutron scattering (SANS) facility to characterize the number and size distribution of cavities formed under stress at grain boundaries. Auger electron spectroscopy (AES) techniques provide a basis for measuring the effect of grain boundary impurities on the fracture process, and all these results are correlated with data from the applied study. These new mechanistic insights are proving useful in developing rationalizations for features of the applied data (such as a heat-to-heat variation of properties of a given steel) and in providing new techniques for identifying the causes of anomalous behavior for a particular set of test samples. Even more important is the guidance that these detailed understandings of damage accumulation mechanisms provide during the inevitably necessary extrapolation of the results of one- to five-year creep tests to the 50-year life expectancy of structural components.

NEW RESEARCH INITIATIVES

Numerous exploratory research ideas that are essentially free from constraints imposed by existing programmatic efforts and that would advance materials science and technology were generated by the professional staff during the year. These ideas were submitted to the Laboratory Seed Money Committee for support, and the following proposals were approved for investigation:

Design of Intermetallic Compounds for High-Temperature Applications

The objective of this investigation is to develop a new class of structural materials for advanced energy conversion systems. Intermetallics offer potential advantages over conventional alloys for high-temperature structural applications. However, the critical characteristic limiting the use of intermetallics is their tendency toward brittle fracture and low ductility at ambient temperatures. An exploratory study will be conducted on the design of *ductile* intermetallics through microalloying processes.

Characterization of the Mineralogy and Microchemistry of Fly Ash

Coal-fired power plants produce large amounts of fly ash, which must be used or disposed of in an environmentally acceptable way. Knowledge of the physical and chemical properties of fly ash will aid in reducing its environmental impact, enhance the potential recovery of valuable resource materials, and increase the understanding of the combustion process of coal. This study will use electron microscopy to characterize the microstructure and mineral content of two types of ash. The observed properties of the ash will be compared with the original structure and mineral distribution of the coal that produced the ash. Specimens of sintered fly ash compacts will also be examined to relate fly ash properties to the behavior of the ash in various chemical processes for resource recovery being studied at ORNL.

Applicability of Small Specimens for Determination of Qualitative Material Toughness Properties

The use of small specimens for predicting materials toughness properties could assist in assessing the integrity of components fabricated from thin-wall materials (such as the N Reactor pressure tubes) and the effects of irradiation of candidate first-wall materials for fusion reactors or light-water reactor pressure vessels. This study will test subsize fracture toughness specimens by recommended procedures and will compare the data with results obtained from standard specimens.

Ceramics-Metal Solid Electrolytes

The sodium-sulfur battery, which may be used in future electric vehicles, is limited by degradation of the electrolyte's mechanical properties by repeated cycling. In this project the existing technology for producing shock-resistant insulators based on alumina-metal composites will be adapted to β-alumina compositions in an effort to make shock-resistant sodium ion conductors. Fabrication of specimens of an electrolyte that contain small amounts of finely dispersed metal particles yet retain the desired electrical properties will be demonstrated.

Synthesis and Characterization of Dispersion-Toughened Structural Ceramics

High-temperature structural ceramics are promising for use in advanced energy conversion systems because of their refractory nature and corrosion resistance. However, the brittle behavior of these materials limits their structural applicability. This project will implement the concept of dispersing a second phase (such as ZrO_2 or HfO_2) within alumina so that an advancing crack will be slowed or arrested when it contacts a particle of the second phase. The potential of sol-gel synthesis processes for preparing powders suitable for fabrication of dispersion-toughened structural ceramics will be identified. These prepared ceramics will then be characterized to relate the dispersed particle's size, shape, and concentration to the resultant mechanical properties.

Ceramic Powder Preparation by Chemical Vapor Deposition

A new method for preparing fine-grained SiC powder by chemical vapor decomposition is proposed. Such powder should allow fabrication of dense bodies by sintering without the use of sintering aids; it would allow processing at lower temperatures and would result in an improved fine crystalline microstructure and improved mechanical strength and toughness. Current SiC fabrication practice is to use sintering or hot-pressing aids, such as metallic silicon, which bond the SiC grains. This can result in glassy phases between SiC grains or multiphasic boundaries, which lead to reduced high-temperature strength and greater tendency to creep. Our theory of using a silane as the decomposition gas could result in improved powders. The durability of dense bodies formed to final net shape will be evaluated.

The last two proposals resulted from our study to identify possible research opportunities for conserving and replacing critical materials.

5. Specialized Research Facilities and Equipment

In recent years the division has promoted the establishment of selected research facilities with unique capabilities to be operated in the user-dedicated mode. The underlying aim is to advance materials science on a broad national front by making this one-of-a-kind equipment available for collaborative and joint research with the industrial sector and the university community. The effort involves three specialized facilities: Shared Research Equipment Program (SHaRE), ORNL-Oak Ridge Associated Universities (ORAU) Synchrotron Radiation X-Ray Sources, and the National Center for Small-Angle Scattering Research (NCSASR). A brief status report on each activity is presented.

SHARED RESEARCH EQUIPMENT PROGRAM

E. A. Kenik

The past year was a productive period for the SHaRE program, both in the breadth of research conducted and the number of participants. The program has expanded beyond the Southeastern region to include university and industrial participants from other regions of the country. The program facilitates research in areas pertinent to the U.S. Department of Energy (DOE) mission and emphasizes areas under current research in the Materials Science Section of the Metals and Ceramics Division. Members of SHaRE outside ORNL are provided access to research equipment (especially for electron microscopy) much more sophisticated than that available at their own laboratories. Research involving Auger surface analysis, ion implantation, and nuclear microanalysis is also included in the SHaRE program.

As during FY 1980, the Division of Materials Sciences, Office of Basic Energy Science, provided funds through ORAU to support the SHaRE activity. Program funds are used for travel and living expenses of SHaRE participants while at ORNL and for the support of G. L. Lehman, an electron microscope engineer. His responsibility is to familiarize SHaRE participants with the electron microscope and computer facilities and to participate in SHaRE research when appropriate. The presence of Lehman has greatly facilitated a high level of SHaRE participation that has interfered minimally with in-house programs. The program policy for SHaRE is defined by a steering committee, whose members are:

- William Felling, Assistant Director, ORAU
- E. A. Kenik, ORNL
- C. L. White, ORNL
- J. J. Wert, Professor and Chairman, Department of Mechanical and Materials Engineering, Vanderbilt University, Nashville, Tennessee
- E. A. Starke, Professor and Director, School of Chemistry and Metallurgy, Georgia Institute of Technology, Atlanta

The following ten active research projects were continued in FY 1981:

1. K. R. Lawless, University of Virginia, with E. A. Kenik: High-voltage electron microscopic in situ oxidation of vanadium and vanadium-titanium
2. J. B. Benson, Jr., North Carolina State University, with J. Bentley and G. L. Lehman: Defect analysis in ion-implanted GaAs
3. P. J. Reucroft, University of Kentucky, with J. Bentley and E. A. Kenik: Chemical and physical characterization of dispersed metal particles in porous media
4. J. J. Wert, Vanderbilt University, with P. S. Sklad: The role of structure in the wear process
5. R. Sisson, Virginia Polytechnic Institute and State University, with M. B. Lewis: Nuclear microanalysis of hydrogen in oxides formed by steam oxidation
6. E. Schulson, Dartmouth University, with C. T. Liu and C. L. White: Collaborative experiments on the brittle to ductile transition in polycrystalline

7. H. Anderson, University of Missouri-Rolla, with J. Bentley: Lattice imaging studies of donor-doped transition metal oxides
8. D. Northwood, University of Windsor, Canada, with E. A. Kenik: High-voltage electron microscopic studies of hydrogen and hydrides in zirconium and its alloys
9. A. Krawitz, University of Missouri-Columbia, with E. A. Kenik: Deformation substructures in cemented tungsten carbide-cobalt composites
10. J. J. Hren, University of Florida, with J. Bentley, K. Farrell, and E. A. Kenik: High-resolution studies in radiation effects, image simulation calculations

The following six new SHaRE projects were initiated during FY 1981:

1. S. Hack, Southwest Research Institute, and H. Marcus, University of Texas, with E. A. Kenik: Influence of hydrogen on in situ deformation behavior of titanium alloys
2. E. A. Starke, Georgia Institute of Technology, with E. A. Kenik: In situ deformation of aluminum-lithium alloys
3. R. Davis, North Carolina State University, with J. Bentley: Transmission electron microscopy of deformed niobium carbide and deformed α-silicon carbide
4. R. W. Carpenter, Arizona State University, with J. Bentley and A. Fisher: Convergent-beam electron diffraction with coherent illumination
5. M. M. Kersker, Alcoa Technical Center, with J. Bentley and G. L. Lehman: Convergent-beam electron diffraction in multiphase alloys
6. W. Clark, Ohio State University, with J. Bentley: Analytical electron microscopy of wear deformation structures in copper

Results from research on some of the SHaRE programs listed above are described in Chap. 3 of this report.

The following guests outside the SHaRE program are participating in collaborative research.

R. J. Bayuzick, Vanderbilt University
H. Liu and T. Mukai, Case Western Reserve University
M. J. Goringe, Oxford University
L. L. Horton, University of Virginia
J. Mullins, Alcoa Technical Center
L. B. Coons and B. Tarnowski, Memphis State University
R. Keller and L. Schoenlien, Case Western Reserve University
J. R. Leteutre, CEN, Saclay
J. Spruiell, University of Tennessee

ORNL-ORAU SYNCHROTRON RADIATION X-RAY SOURCES

C. J. Sparks, Jr.

Our decision to use the powerful x-ray generator under construction at Brookhaven National Laboratory has involved us significantly in the design and engineering construction of the necessary instrumentation. We will use the x-radiation from the National Synchrotron Light Source (NSLS) to probe the structure of materials. We have identified several materials science programs at ORNL that will benefit from the unique properties of this radiation source. These research areas involve personnel from the Chemistry, Solid State, Metals and Ceramics, and Analytical Chemistry divisions. Through organizational meetings held at ORAU in 1979, we formed a consortium with university and industrial researchers with similar interests in materials science. This collaboration is directed by an interim steering committee consisting of R. DeAngelis, Department of Materials Science, University of Kentucky; S. C. Moss, Department of Physics, University of Houston; C. J. Sparks, Jr., ORNL; and R. Young, Engineering Experiment Station, Georgia Institute of Technology. Several consortium members are engaged in software development for our recently acquired PDP 11/34 computer, which will be used to control experimental equipment, collect data, and provide for data reduction. DeAngelis' stay at ORNL produced many worthwhile contributions to our software development in association with A. Habenschuss, who is supported by DOE funding through ORAU to manage our computer system and to do research on liquid and amorphous materials.

SMALL-ANGLE X-RAY SCATTERING RESEARCH FACILITIES

C. J. Sparks, Jr.

Our small-angle x-ray-scattering research facilities are heavily used and attract a large number of outside researchers.

Much of the research is centered on polymers. Dynamic small-angle investigations of the crystallization of polymers continues to provide unique information on the structural characteristics that control the mechanical properties of these materials. Stacks of alternating crystalline and amorphous layers have been observed in semicrystalline polymers. This crystallinity changes reversibly with temperature and explains the observed pyroelectric response of polarized, Phase I polyvinylidene fluoride films. Industrial processes of fiber and film spinning, injection molding, and film blowing produce crystallized polymers at high rates of extension. Small-angle x-ray scattering has shown the fibrous crystals to be modulated axially from spinodal decomposition of the material into crystalline and amorphous regions. Such information is leading to a better understanding of the high density and high moduli of these polymers.

The small-angle x-ray scattering research will henceforth be administered and reported by the Solid State Division.

Appendix A

BUDGET AND SUPPORT DISTRIBUTION

As with most U.S. Department of Energy (DOE)-supported organizations, the Metals and Ceramics Division received less than the needed cost-of-living increases in FY 1981 and anticipates a greater financial shortfall in FY 1982. Compared with FY 1979 and FY 1980, the division began FY 1981 at a low level, gained substantial support in the second and third quarters, and now at the three-quarter mark is at a constant-dollar support level slightly above that of the previous two years. Our financial plan continues to undergo changes, however, in funds allocated to individual projects as well as total divisional support.

Table A.1 is a comparison by project of the funds currently approved for FY 1981 with the actual figures for FY 1980 and the anticipated funding for FY 1982. Of the twelve major elements in the FY 1981 financial plan, seven reflect increases compared with the FY 1980 final budget, whereas five show decreases. The change in total divisional support is only $197,000, or an increase of 0.8%, which is well below the current inflation rate. The Fission and related Nuclear Regulatory Commission programs received less money, continuing the downward trend of less support for the nuclear effort. All other major programs received greater support, and fairly large increases were registered in three cases.

Funding for subcontracting DOE work to organizations outside the laboratory by program managers within the division is decreasing significantly. However, this change has no direct impact on divisional programs; in most instances, this pass-through money cannot be spent within the division.

The division budget traditionally changes within a given year as well as from one year to the next, and coping with this added dimension of variability presents a challenge to efficient management. Fig. A.1 illustrates the degree of annual fluctuations encountered in divisional support over the past three years. Each year funding starts at a low level and increases during the year. The problem recurs each fiscal year, when beginning support drops significantly. Because the division is required to start operating each year on money provided by Congressional continuing resolution, this situation presents a serious problem to management annually.

Although anticipated support for FY 1982 shows a decrease from that of FY 1981, the decrease does not appear to be nearly so large as that estimated earlier this year and is less than encountered in past years. However, none of the increases proposed for FY 1982 are great enough to offset expected cost-of-living increases. Such a situation demands a reduction in personnel on practically all programs.

Table A.1. Division financial support by project, FY 1980 through FY 1982[a]

Project	Actual FY 1980	Current FY 1981	Change FY 1980 to FY 1981	Anticipated FY 1982	Change FY 1981 to FY 1982
Advanced Technology	124	36	−88	0	−36
Basic Energy	5,269	5,397	+128	5,944	+547
Conservation	1,310	1,808	+498	1,990	+182
Fission	6,845	5,119	−1,726	5,287	+168
Fossil	1,453	2,911	+1,458	2,520	−391
Fusion	2,053	2,356	+303	2,564	+208
NRC	2,233	1,742	−491	1,335	−407
Solar	145	207	+62	0	−207
Space	1,874	2,205	+331	1,980	−225
Waste	708	1,236	+528	843	−393
Other	994	288	−706	360	+72
Service	1,300	1,200	−100	1,400	+200
Division support	24,308	24,505	+197	24,223	−282
Outside subcontracts	8,783	6,345	−2,438	4,800	−1,545
Division total	33,091	30,850	−2,241	29,023	−1,827

[a]Thousands of dollars.

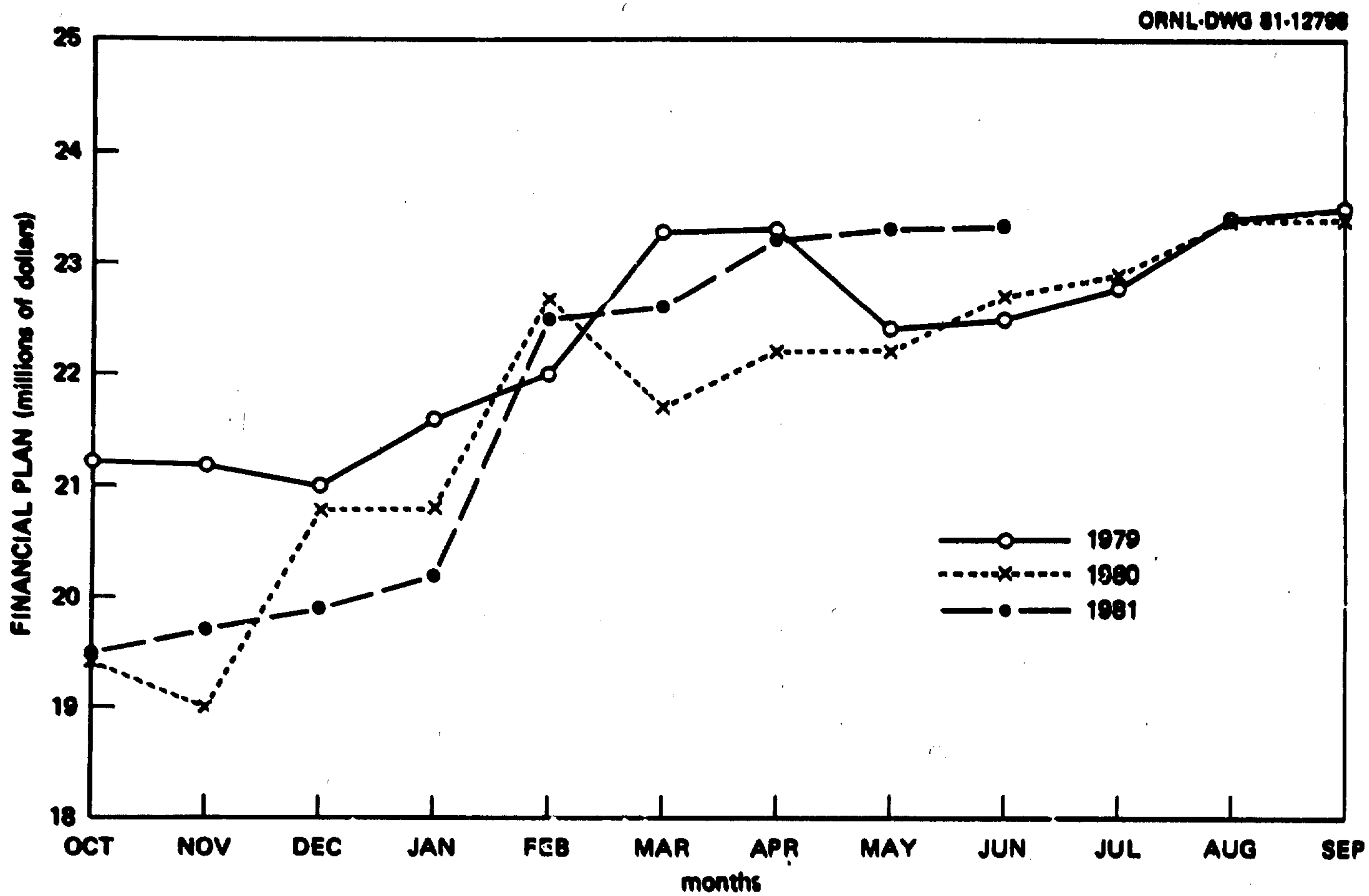


Fig. A.1. Monthly variation in divisional financial plan over the indicated three years.

Appendix B

PERSONNEL SUMMARY

In the second quarter of the year, the division embarked on an aggressive retrenchment program to reduce the staff to a level consistent with anticipated financial support for FY 1982. Table B.1 presents the status of professional and technical support personnel as of July 1 for 1980 and 1981. The table indicates that considerable success has already been achieved in reducing the staff and that the reduction has affected both the technical and the support staffs, with a reduction of 6% in the former and 9% in the latter. Because of current budget uncertainties, the reductions are expected to continue into next year. As shown in Appendix A, the budget for FY 1981 has now been increased to the level of last year, but earlier in the year it was much lower. If the FY 1982 budget remains the same as that for FY 1981 in constant dollars, which is likely, the high inflation rate will require a considerable reduction in the staff. The fact that the budgets generally start low and increase during the year makes management of manpower difficult.

To supplement our skills and to obtain fresh viewpoints, we have continued to encourage research visits from guests supported by outside sources. During the past year, 54 guests worked in the division, 15 on a full-time and the others on an intermittent basis. Of these, 12 were from foreign countries; 11 were assigned through the Oak Ridge Associated Universities, largely from American universities; 29 were on direct assignment from universities; and 2 were from other DOE laboratories.

During the year July 1, 1980, through June 30, 1981, five people were added to the technical staff, consisting of three new employees and two returning from assignments to other ORNL divisions. Two of the new employees were recent Ph.D.'s, and the other was a B.S. with considerable industrial experience. No new people were added to the technician roll, and only one new secretary was employed. A second secretary (a loanee) returned to the division.

Most of those who left the technical staff resigned from the laboratory to accept higher salaried postions with outside companies. Of those leaving the division support staff, only two left the laboratory—a technician did not return from maternity leave, and a secretary accepted other employment. All others have been transferred to other assignments within Union Carbide Corporation, Nuclear Division.

Table B.1. Composition and changes in division staff as of July 1, 1980 and 1981

	Technical			Support			Total		
	1980	1981	Change	1980	1981	Change	1980	1981	Change
Permanent employees	149	140	−9	130	118	−12	279	258	−21
Temporary employees, >ten months	6	6	0	0	0	0	6	6	0
Loanees from other divisions	0[a]	0	0	4[a]	3	−1	4[a]	3	−1
Loanees to other divisions	2	1	−1	1	1	0	3	2	−1
Part-time employees	7	6	−1	5	6	+1	12	12	0
Long-time guests	12[b]	12	0	1[b]	1	0	13[b]	13	0
Coops (one-half time)	0	0	0	6	2	−4	6	2	−4

[a]These numbers have been corrected from last year because some assigned personnel are no longer shown as direct manpower.
[b]These numbers have been changed from last year because only long-time guests are now included in this summary.

Appendix C

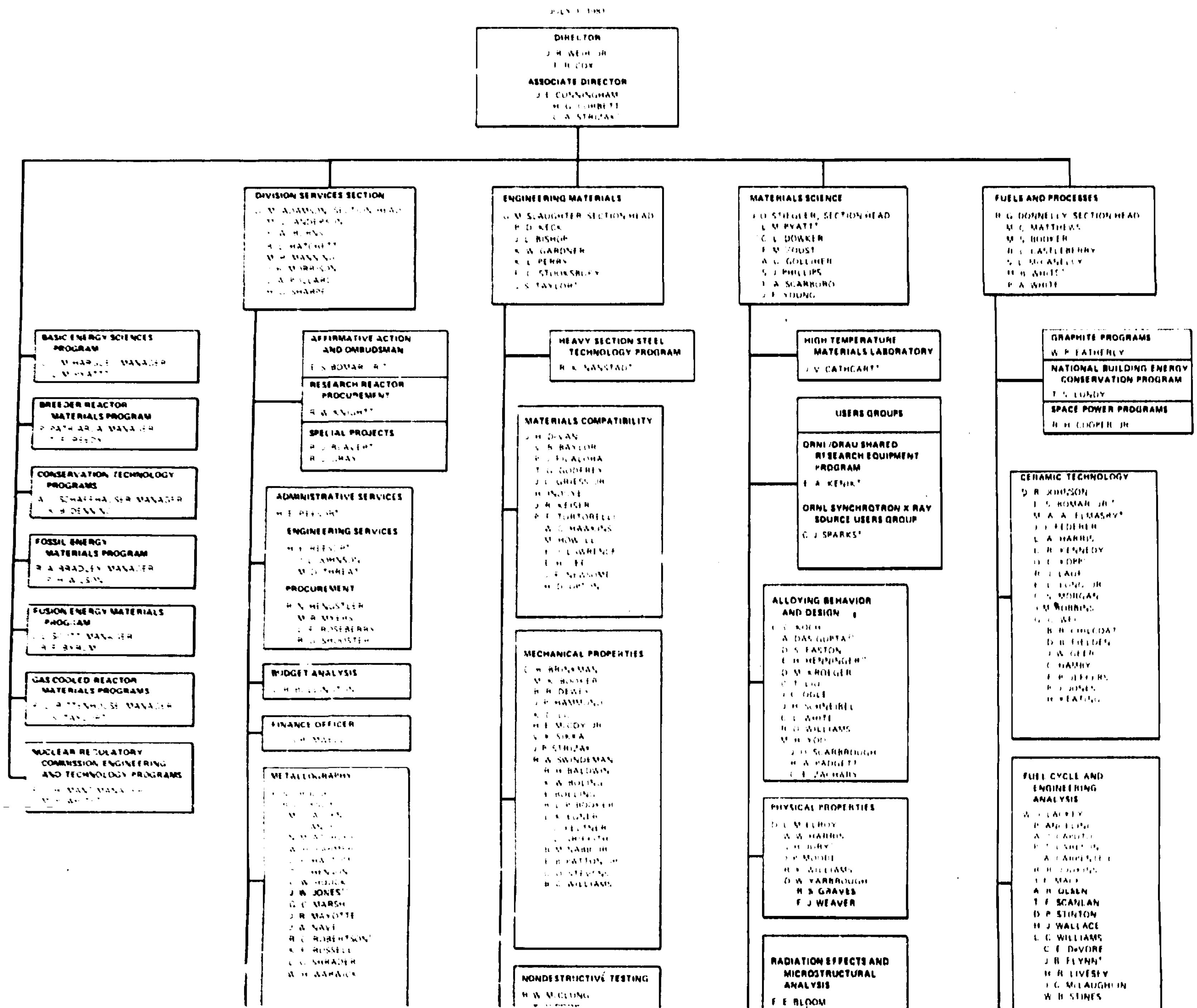
ORGANIZATIONAL STRUCTURE AND CHART

During the past year, the organizational structure of the division was realigned in selected areas to accommodate changes in the research and development thrust and direction and to upgrade management efficiency. Fuel Cycle Technology was combined with Engineering and Evaluation to form a new group entitled Fuel Cycle and Engineering Analysis in the Fuels and Processes Section. W. J. Lackey was appointed leader of this new group. An office of Nuclear Regulatory Commission Engineering Technology Programs was created, and F. J. Homan was appointed manager. In turn, P. L. Rittenhouse was appointed to the position of manager of Gas-Cooled Reactor Materials Programs vacated by Homan. The Small-Angle X-Ray Scattering Laboratory, formerly operated in the division under the direction of R. W. Hendricks, was recently transferred to the Solid State Division for joint management in consort with the Small-Angle Neutron Scattering Facility. Otherwise, the division continued to operate in a stable matrix mode to handle the dual administration of line organization by functional discipline and management of large, complex, multidisciplinary, and high-technology projects.

Several openings occurred during the past year that allowed younger staff members to advance and assume positions of greater responsibility. In January, C. J. Sparks, Jr., became leader of the X-ray Research and Applications Group. In March, D. R. Johnson was appointed leader of the Ceramics Technology Group, replacing R. L. Beatty who resigned to accept a position with Exxon. Finally, in April R. K. Nanstad advanced to leader of the Pressure Vessel Technology Group, replacing D. A. Canonico who accepted the position of Research Director of Operations at Combustion Engineering in Chattanooga.

The division organization chart reflecting these changes is attached for reference.

METALS AND CERAMICS DIVISION



R. C. ROBERTSON[1]
[illegible] RUSSELL
C. G. SHRADER
W. H. WARWICK

QUALITY ASSURANCE
R. J. BEAVER[6]

REPORTS OFFICE
M. R. HILL
[illegible]

SAFETY, RADIATION, ENVIRONMENTAL, AND SNM CONTROL
[illegible]

TECHNICAL EDITOR
[illegible]

ON LOAN/LEAVE
[illegible]

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K. V. COOK
W. E. DEEDS[1]
C. V. DODD
R. E. FOSTER
G. W. SCOTT
W. A. SIMPSON, JR.
J. H. SMITH
[illegible] CHITWOOD
R. A. CUNNINGHAM, JR.
[illegible] DAVIS
[illegible] LEWIS

PRESSURE VESSEL TECHNOLOGY
[illegible] NANSTAD[1]
R. G. BERGGREN
W. R. CORWIN
[illegible] HOBSON
[illegible] LONG, JR.
W. J. STELZMAN
[illegible]
[illegible] SWAIN

WELDING AND BRAZING
[illegible] GOODWIN
S. A. DAVID
[illegible]
[illegible] McDONALD
[illegible]
T. D. OWINGS, JR.
R. W. REED, JR.
J. J. WOODHOUSE

SPECIAL PROJECTS
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J. T. HUTTON[1]

RADIATION EFFECTS AND MICROSTRUCTURAL ANALYSIS
E. E. BLOOM
J. BENTLEY
D. N. BRASKI
W. H. CARTER[6]
R. E. CLAUSING
W. A. COGHLAN
C. K. H. DuBOSE
L. C. EMERSON
K. FARRELL
M. L. GROSSBECK
[illegible]
[illegible] LEE
[illegible] LEWIS
[illegible] MAZIASZ
[illegible] PACKAN
[illegible] ROWCLIFFE
[illegible] SPEAD
[illegible] WIFFEN
[illegible] GIBSON
[illegible] HEATHERLY
[illegible] HOUSTON
[illegible] McKAMEY
G. A. POTTER
[illegible] ROUSE
[illegible] SMITH
[illegible] TURNER

STRUCTURAL CERAMICS
[illegible] TENNERY
P. F. BECHER
G. W. CLARK
M. K. FERBER
C. R. FINCH
C. S. YUST
[illegible] HALL
S. B. WATERS
J. E. WILLMERING

SURFACE AND SOLID STATE REACTIONS
J. V. CATHCART[1]
R. E. DRUSCHEL
R. A. McKEE
R. E. PAWEL
G. F. PETERSEN
J. J. CAMPBELL
L. C. MANLEY, JR.

THEORY
J. S. FAULKNER
W. H. BUTLER
G. S. PAINTER
G. M. STOCKS

X-RAY RESEARCH AND APPLICATION
[illegible] SPARKS, JR.[1]
[illegible] BORIE
[illegible] CAVIN
A. HABENSCHUSS[1]
[illegible] HAUBOLD[1]
[illegible]
[illegible] YAKEL

C. E. DeVORE
J. R. FLYNN[1]
R. R. LIVESEY
J. C. McLAUGHLIN
W. B. STINES

FUELS EVALUATION
F. J. HOMAN[1]
M. J. KANIA
[illegible] KRAUTWASSER
[illegible] TIEGS

METALS PROCESSING
[illegible] HEESTAND
[illegible] COPELAND
[illegible] HESHMATPOUR
[illegible] KNIGHT[1]
[illegible] MARTIN
[illegible] McDONALD
[illegible] ROCHE
[illegible] ANGEL
[illegible] BEAVERS
[illegible] DAVIS
[illegible]
[illegible] HOLLAND
[illegible] MARTIN
[illegible]

SPECIAL PROJECT
[illegible]

[illegible]
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[illegible] MANAGEMENT [illegible]
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ON ASSIGNMENT FROM KFA, JULICH
ON LOAN FROM FINANCE AND MATERIALS DIVISION
ON ASSIGNMENT FROM PLANT AND EQUIPMENT DIVISION
LABORATORY GRADUATE PARTICIPANT PROGRAM FROM GEORGIA TECH
ON ASSIGNMENT TO KFA, JULICH
ON LOAN FROM INFORMATION DIVISION
ON LOAN FROM QUALITY ASSURANCE AND INSPECTION DEPARTMENT
ON ASSIGNMENT FROM COMPUTER SCIENCES DIVISION
ON ASSIGNMENT FROM INSTRUMENTATION AND CONTROLS DIVISION
ON ASSIGNMENT FROM ENGINEERING TECHNOLOGY
GUEST, OAK RIDGE ASSOCIATED UNIVERSITIES
GUEST, DEPAUW UNIVERSITY, GREENCASTLE, INDIANA
ON LOAN TO CMO BREEDER REACTOR PROGRAM
GUEST, JAPAN ATOMIC ENERGY RESEARCH INSTITUTE
GUEST, CENTRE D'ETUDE NUCLEAIRE, FRANCE
GUEST, UNIVERSITY OF VIRGINIA
ON ASSIGNMENT TO INSTITUT FUR PHYSIK DER UNIVERSITAT, BASEL, SWITZERLAND

Appendix D

HONORS AND AWARDS

Division staff members continue to be cited and rewarded for exhibiting outstanding talent and ability in fulfilling their professional roles within the scientific and engineering community. The type of recognition received or professional achievement attained tends to fall into one of the following six specific categories: honors, awards, commendations, elected officers and members, certification and registration, and appointments. A chronological listing of citations in each of these categories during the past year follows.

Honors

August 1980

Ken C. Liu's work, "Biaxial Materials Testing for Nuclear Reactor System Integrity," was cited in the August 1980 issue of *Metal Progress* in an article, "Mechanical Testing in the 80s."

October 1980

James L. Scott was elected a Fellow of the American Society for Metals.

February 1981

Domenic A. Canonico presented the Clarence E. Jackson Honorary Lecture, "Review of Heavy Section Steel Technology," at the American Welding Society Washington, D.C., Section Meeting.

Awards

August 1980

Peter Angelini, David P. Stinton, W. Jack Lackey, Tom J. Henson, Larry G. Shrader, Nobel H. Rouse, and *Charles E. DeVore* (with E. Leon Smith of Graphic Arts) received the first-place award in the class on Unique, Unusual, or Other Techniques for their entry on "Alpha Autoradiography Identifies the Partitioning of Plutonium into the Desired Synroc Phases" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

David P. Stinton, Peter Angelini, W. Jack Lackey, and *Nobel H. Rouse* (with E. Leon Smith of Graphic Arts) received the first-place award in the class on Color Micrographs for their entry on "Transmitted Light Microscopy Allows Identification of Synthetic Minerals Able to Immobilize Nuclear Wastes" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

Nick H. Packan, Ken Farrell, and *John T. Houston* received the first-place award in the class on Electron Microscopy—Transmission for their entry on "Depth Profile of Swelling in Ion-Bombarded Nickel" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

Ron L. Klueh, C. W. (Pete) Houck, and *Rosemary C. Robertson* received the second-place award in the class on Optical Microscopy—Iron, Steel, Stainless Steel, Nickel, and Nickel Alloys for their entry on "Dissimilar-Alloy (Austenitic Stainless Steel-Ferritic Steel) Weld Joint Failures" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

Stan A. David, C. Paul Haltom, and *Rosemary C. Robertson* received Honorable Mention in the class on Optical Microscopy—Iron, Steel, Stainless Steel, Nickel, and Nickel Alloys for their entry on "A Comprehensive Insight into the Ferrite Morphology" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the Amerian Society for Metals.

Stan A. David and *C. Paul Haltom* received Honorable Mention in the class on Optical Microscopy—Metals and Alloys Not Listed in Class I for their entry on "Modification of Fusion Zone Structure by Laser Welding: A Solution to Hot Cracking" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

September 1980

Peter Angelini, Anthony J. Caputo, Robert R. Suchomel (now with IBM), Donald Kiplinger (Plant and Equipment Division), and Melvin G. Willey (Engineering Division) won an I·R-100 Award from

Industrial Research for their design and development of the Continuous-Ring Particle-Blender-Dispenser.

October 1980

Dewey S. Easton, Don M. Kroeger, and *Carl C. Koch* (with W. Specking, Karlsruhe, Germany) received the Department of Energy's 1980 Metallurgy and Ceramics Award for their research paper "A Prediction of the Stress State in Nb_3Sn Superconducting Composites," which was judged highest in the Follow-Up category.

The *Oak Ridge Section* of The American Society for Nondestructive Testing received the 1979–1980 President's Award. *Jim H. Smith* was Chairman of the Oak Ridge Section at that time.

November 1980

James L. Scott and *Jack E. Cunningham* received American Nuclear Society Exceptional Service Awards on the occasion of the Society's 25th anniversary in recognition of their exceptional and outstanding contributions to the Society.

April 1981

Arthur J. Moorhead and *Robert W. Reed* received the A. F. Davis Silver Medal Award by the American Welding Society for their paper "Development of Techniques for Joining Fuel Rod Simulators to Test Assemblies" as the best contribution to the progress of welding in the field of machine design.

May 1981

Philip S. Sklad and *Jim Bentley* received Best in Show for their display on Analytical Electron Microscopy of TiB_2-Ni Ceramics in the metallographic competition at the American Ceramic Society Meeting in Washington, D.C., May 3–6, 1981.

June 1981

Everett E. Bloom received the 1981 American Nuclear Society Young Members Engineering Achievement Award.

David P. Stinton and *Alice Richardson* (Information Division) were one of the six winners of the contest to design a new logo for the American Ceramic Society.

Commendations

December 1980

Dom A. Canonico and *Rey G. Berggren* received a Letter of Commendation from the Nuclear Regulatory Commission on their materials characterization work for the Heavy Section Steel Technology program.

Jim R. Keiser received a Letter of Commendation from Solvent Refined Coal International, Inc., for his work on corrosion studies of fractionation column by coal-derived liquids.

Jim R. Keiser and *Ron A. Bradley* received a Letter of Commendation from DOE for the corrosion work being performed by the ORNL Fossil Energy Materials Program staff.

E. Sloan Bomar received a Letter of Appreciation from ORNL for his diligent and highly competent service on the Radioactive Operations Committee for the past year.

January 1981

Wilbur H. Warwick received a Letter of Appreciation from General Atomic Division for his assistance in SiC etching.

March 1981

Carl C. Koch received a Letter of Appreciation from the Council on Materials Science of DOE for his contributions to the panel report on amorphous materials to identify the needs and opportunities for research on disordered or amorphous solids.

Larry A. Harris received a Letter of Commendation from G. E. Moore (Coordinator, Professional Education Program) for teaching "Topics in Geology," ORNL Technical Continuous Education Course C-600 in the In-House Continuing Education Program for Scientific and Technical Personnel, during the fall 1980 term.

April 1981

Bill E. Foster received a Letter of Appreciation from Westinghouse Electric Corporation for his participation in its rod anode positioner final design review.

May 1981

Vivian B. Baylor and *Jim R. Keiser* received a Letter of Appreciation from the Oak Ridge Chapter of the American Society for Metals for their substantial contributions to the success of the Symposium on Elevated-Temperature Materials Considerations in Coal Liquefaction and Gasification Service.

Ralph G. Donnelly, received a Certificate of Appreciation from the American Society for Metals for his ASM seminar on "Metallurgical Technology of Uranium and Uranium Alloys."

Elected Officers and Members

May 1981

Ralph G. Donnelly was elected Vice Chairman of the Energy Conservation Society, Knoxville–Oak Ridge Chapter, for 1981–82.

June 1981

David L. McElroy was elected Chairman of the Governing Board of the International Thermal Conductivity Conference for a two-year term.

Certification and Registration

August 1980

Rhonda L. Castleberry achieved the rating of Certified Professional Secretary (CPS).

Appointments

July 1980

James L. Scott was appointed to the Publications Steering Committee of the American Nuclear Society for a three-year term.

Pete Patriarca was appointed Chairman of the Joining Division of the American Society for Metals for a three-year term.

Jack E. Cunningham was appointed to the Books, Monographs, and Handbooks Committee of the American Nuclear Society for a three-year term ending in 1983.

Helen G. Corbett was appointed Certified Professional Secretary Service and Education Chairman of the Oak Ridge Chapter, National Secretaries Association (International).

Gene M. Goodwin was selected to serve as a member of the new American Welding Society Welding Academy Committee.

November 1980

Jack E. Cunningham was appointed Chairman of the American Nuclear Society Planning Cycle Subcommittee.

Jack E. Cunningham was appointed Past Chairman of the American Society for Metals Engineering Materials Achievement Award Selection Committee for one year.

Gerald M. Slaughter was appointed a member of the American Society for Metals Technical Divisions Board for three years.

January 1981

Harry L. Yakel was appointed Associate Editor of the *Journal of Applied Crystallography*.

Robert W. Hendricks was appointed a member of the Solid State Sciences Committee Advisory Panel of the National Research Council of the National Academy of Sciences for a three-year term ending December 31, 1983.

Bill E. Foster was appointed for a five-year term as a member of the Subgroup on Radiography (SC V) of the Boiler and Pressure Vessel Committee of The American Society of Mechanical Engineers.

March 1981

Calvin L. White was appointed a member of the Materials Science Division Council and was named program chairman of the Materials Science Technical Division of the American Society for Metals.

Jim R. Weir was appointed to the Speakers' Bureau of the American Society for Metals for one year, 1981–82.

May 1981

W. Jack Lackey was appointed chairman of the Program Committee of the Nuclear Division of the American Ceramic Society for a one-year term, 1981–82.

D. Ray Johnson was appointed chairman of the Research Committee of the Nuclear Division of the American Ceramic Society for a one-year term, 1981–82.

David P. Stinton was appointed a member of the Membership Committee of the Nuclear Division of the American Ceramic Society for a one-year term, 1981–82.

Charles S. Yust was appointed a member of the Nomination and Fellows Committee of the Nuclear Division of the American Ceramics Society for a one-year term, 1981–82.

Gene M. Goodwin was appointed Chairman of the Welding Subcommittee of the Electric Power Research Institute Boiling Reactor Owners Group.

June 1981

James L. Scott was appointed Vice Chairman of the Publications Steering Committee of the American Nuclear Society for a one-year term.

Jack E. Cunningham was appointed Vice Chairman of the Honors and Awards Committee of the American Nuclear Society for a one-year term.

Arthur J. Moorhead was appointed Vice Chairman of the C3-D Subcommittee on Education of the American Welding Society.

Appendix E

SEMINAR PROGRAM

Because effective communication is vital to technological advancement, the division sponsors and maintains an active seminar program to promote the exchange of ideas and discussion of common problems among researchers working in the field of materials science and technology and allied disciplines. Most of the talks deal with scientific and engineering subjects and are presented by invited speakers from various organizations in the United States and abroad. The actual number of talks scheduled in any given week varies but over the year averages about two per week.

The Seminar Program is administered by a committee appointed by division management. The Seminar Committee for calendar years 1980 and 1981 consists of D. O. Hobson (Chairman), N. H. Packan, and G. C. Wei.

The speakers and topics of seminars presented during the past year are listed below. It is interesting that 17 of the 94 talks scheduled were made by individuals affiliated with institutions located outside the United States. An alternative breakdown shows 42 talks by university faculty members and graduate students, 6 by representatives fr n industrial firms, and the balance from governmental and other research institutions. In function, the program achieves the desired objectives of maintaining close relationships with the university community and of enhancing the diffusion of knowledge.

R. J. Gray, Metals and Ceramics Division, ORNL, "Basic and Unusual Techniques in Metallography Extend Our Understanding of Microstructures," July 9, 1980.

S. K. Sinha, Argonne National Laboratory, "Charge and Spin Fluctuations in Mixed Valence Systems," July 9, 1980.

M. H. Yoo, Metals and Ceramics Division, ORNL, "From Deformation and Fracture to Strength and Ductility A BES Way," July 11 1980.

A. T. Fromhold, Jr., Auburn University, "An Overview of Metal Oxidation Theory," July 23, 1980.

M. L. Grossbeck, Metals and Ceramics Division, ORNL, "Fatigue of Irradiated Stainless Steel," July 25, 1980.

L. L. Horton, University of Virginia, "Defect Structures in Neutron-Irradiated Iron," July 31, 1980.

P. J. Alberry, Marchwood Engineering Laboratories, England, "Welding Research at the Central Electricity Generating Board, Marchwood Engineering Laboratories," August 4, 1980.

H. Mecking, Institut für Allgemeine Metallkunde and Metallphysik, Rheinisch-Westfalische Technische Hochschule Aachen, West Germany, "Different Stages of Work Hardening and Dynamic Recovery," August 8, 1980.

R. W. Hendricks, Metals and Ceramics Division, ORNL, "Opportunities for Materials Science Research Utilizing the ORNL Small Angle Scattering Facilities," August 8, 1980.

Brian Ralph, Cambridge University, "Recrystallization of High-Performance Materials," August 10, 1980.

R. J. Arsenault, University of Maryland, "Computer Simulation Studies on Solid Solution Strengthening of BCC Metals," August 13, 1980.

D. Richerson, AiResearch Manufacturing of Arizona, "Contact Stress Effects at Ceramic Interfaces," August 19, 1980.

J. Schelten, Kernforschungsanlage, Jülich, West Germany, "Studies of Polymer Conformations in Solid Polymers by Small-Angle and Wide-Angle Neutron Scattering," August 21, 1980.

Charles W. Murphy, Rockwell International, "Where Is Our Space Transportation System?," August 21, 1980.

M. B. Lewis, Metals and Ceramics Division, ORNL, "Direct Measurement of Diffusion and Trapping of Deuterium," August 22, 1980.

Sindo Kou, Carnegie-Mellon University, "Heat Flow Analysis of Fusion Welds," August 25, 1980.

J. H. Schneibel, Massachusetts Institute of Technology, "Anelasticity in Superplastic Alloys," August 28, 1980.

M. K. Booker, Metals and Ceramics Division, ORNL, "The Complex Time-Dependent Fatigue Behavior of 2 $^{1}/_{4}$ Cr-1 Mo Steel: Is Life Prediction Possible?," September 3, 1980.

Sunggi Baik, Cornell University, "Creep Fatigue Interaction," September 4, 1980.

G. E. Ice, Metals and Ceramics Division, ORNL, "Current Design of the ORNL Synchrotron

Radiation Beam Line and How It Affects the Kinds of Experiments We Can Do." September 5, 1980.

P. B. Allen, State University of New York, Stony Brook, "Resistivity of Metals: Exploring the Breakdown of Bloch-Boltzmann Theory," September 12, 1980.

W. C. Luth, Sandia National Laboratories, "A Magnificent Crucible - The 1959 Kilauea Iki Lava Lake," September 16, 1980.

R. E. Clausing, Metals and Ceramics Division, ORNL, "Materials Problems Due to Plasma-Wall Interactions in Fusion Energy Research," September 19, 1980.

E. L. Haase, Kernforschungszentrum, Karlsruhe, West Germany, "New Phases in the Nb-Ge-Si Ternary System," September 22, 1980.

R. W. Matolka, Johnson and Johnson Company, "Evaluation of the Porcelain-Metal Interface for Nickel Chrome Dental Alloy," September 25, 1980.

David B. Williams, Lehigh University, "Microanalysis in the Scanning Transmission Electron Microscope," September 26, 1980.

T. Mura, Northwestern University, "Micromechanics of Solids," October 1, 1980.

Georges Martin, Ce[illegible] d'Etudes Nucléaires de Saclay, Paris, France, "The Stability of Solid Solutions Under Irradiation," October 3, 1980.

R. W. Hendricks, Metals and Ceramics Division, ORNL, "A Materials Science Section Data Acquisition Computing Network," October 3, 1980.

A. J. Minchener, Coal Research Establishment, National Coal Board, England, "Research Activities at CRE on Materials for Fossil Energy Applications," October 10, 1980.

R. G. Faulkner, University of Technology at Loughborough, Leicestershire, England, "Non-equilibrium Segregation in Austenitic Steels," October 10, 1980.

R. J. Gray, Metals and Ceramics Division, ORNL, "Basic and Unusual Techniques in Metallography Extend Our Understanding of Microstructures," Octobe. 13, 1980.

Adrian Roberts, Electric Power Research Institute, "The Search for a More 'Forgiving' Material," October 15, 1980.

J. Halbritter, Kernforschungszentrum, Karlsruhe, West Germany, "Low-Temperature Oxidation of Niobium and Niobium-Niobium Pentaoxide Interfaces," October 17, 1980.

Rosemary MacDonald, National Bureau of Standards, "Molecular Dynamical Calculations of Energy Transport in Solids," October 21, 1980.

J. S. Faulkner, Metals and Ceramics Division, ORNL, "Iron," October 31, 1980.

R. Kamo, Cummins Engine Company, Columbus, Indiana, "The Adiabatic Diesel," November 3, 1980.

Warren E. Pickett, Naval Research Laboratory, "Influence of the Electronic Structure of Complex Crystals on Metallic Properties: Theory and Application to Nb_3Sn," November 5, 1980.

B. J. Busovne, Pennsylvania State University, "Precipitation-Hardening Behavior of Titanium-Doped Sapphire," November 6, 1980.

G. R. Leverant Southwest Research Institute, "Materials Research at Southwest Research Institute," November 18, 1980.

R. W. Balluffi, Massachusetts Institute of Technology, "Current Research in Grain Boundary Structure and Properties," November 19, 1980.

R. E. Prange, University of Maryland, Department of Physics, "Ferromagnetism in Iron and Nickel," December 3, 1980.

R. E. Clausing, Metals and Ceramics Division, ORNL, "Materials Problems Due to Plasma-Wall Interactions in Fusion Energy Research," December 5, 1980.

Ian G. Wright Battelle-Columbus Laboratories, "Evaluation of Materials for Liquefaction Letdown Valves," December 9, 1980.

Husam Gurol, University of California, Santa Barbara, "Calculations of the Effect of Radiation Pulsing on Irradiation Creep," December 16, 1980.

W. L. Worrell, University of Pennsylvania, "Corrosion of Nickel in SO_2 Atmospheres," December 15, 1980.

R. Stoltz, Sandia National Laboratories, "Hydrogen Embrittlement Studies: Low Carbon Pipeline Steels Versus Austenitic Stainless Steels," December 18, 1980.

C. C. Koch, Metals and Ceramics Division, ORNL, "Research Opportunities in Amorphous Alloys," January 9, 1981.

J. W. Hutchinson, Harvard University, "Void Growth in Metals," January 14, 1981.

Lih-Shyng Tsai, Cornell University, "Measurement of High-Temperature Kinetics and Applications on Time-Dependent Deformation of Silicon Nitride Polyphase Systems," January 19, 1981.

F. Spaepen, Harvard University, "Atomic Transport in Amorphous Materials" (joint with Solid State Division), January 20, 1981.

Judith Ann Todd, University of California, Berkeley, "Design of Low-Alloy Steels for Thick-Walled Pressure Vessels," January 20, 1981.

R. A. Penty, Hague International, Inc., South Portland, Maine, "Ceramic Heat-Exchanger Materials and Applications," January 21, 1981.

P. J. Maziasz, Metals and Ceramics Division, ORNL, "Helium Trapping at TiC Precipitates," January 23, 1981.

J. L. Whitten, University of New York, Stony Brook, "Chemisorption Theory Based on Orbital Localization," February 4, 1981.

R. A. McKee, Metals and Ceramics Division, ORNL, "Defect Structures and Diffusion in Sodium- and Lithium-Base Alloys," February 6, 1981.

T. D. Ketcham, Massachusetts Institute of Technology, "Toughening Thoria Zirconia and Alumina," February 9, 1981.

J. J. Hren, University of Florida, "Applications of Field Ionization and Field Desorption Microscopy," February 10, 1981.

M. L. Torti, Norton Company, Worcester, Massachusetts, "Advanced Ceramics for Energy Conversion Applications," February 10, 1981.

N. S. Stoloff, Rensselaer Polytechnic Institute, "Advanced Nickel- and Cobalt-Base Alloys for Gas Turbine Applications," February 17, 1981.

T. V. Ramakrishnan, Bell Laboratories, "Electron Localization: Fact and Theory," February 18, 1981.

H. Inhaber, Industrial Safety and Applied Health Physics Division, ORNL, "Risk Assessment in Energy Production," February 20, 1981.

B. D. Marsh, Johns Hopkins University, "Mechanics and Petrology of Island Arc Volcanism," February 24, 1981.

R. W. Derby, Massachusetts Institute of Technology, "Magnet Structural Materials Problems for Fusion Reactors," March 3, 1981.

P. B. Visscher, University of Alabama, "Discrete Hydrodynamics: Transport Coefficients via Renormalization," March 4, 1981.

W. D. Kingery, Massachusetts Institute of Technology, "MgO as a Solvent-Conductivity; Diffusion; Reactions" (joint with Solid State Division), March 5, 1981.

R. A. McKee, Metals and Ceramics Division, ORNL, "Defect Structures and Diffusion in Sodium- and Lithium-Base Alloys," March 6, 1981.

Michael J. Bennett, Atomic Energy Research Establishment, Harwell, England, "Recent Work at Harwell on Ceramic Coatings for Oxidation Protection," March 9, 1981.

Gene Lucas, University of California, Santa Barbara, "Fundamental Studies for Fusion Reactor Materials," March 20, 1981.

Roger Stoller, University of California, Santa Barbara, "Modeling of Microstructural Evolution," March 23, 1981.

Peter Weinberger, Technical University of Vienna, Austria, "The Relativistic KKR-CPA Method and Its Application to Au_xPt_{1-x} and Ni_xPt_{1-x}," March 25, 1981.

D.R.K. Brownrigg, Tennessee Technological University, "Computer Simulation of the Dynamics of Galaxies," March 31, 1981.

J. V. Cathcart, Metals and Ceramics Division, ORNL, "A High-Temperature Materials Laboratory Update," April 3, 1981.

Greg Gruzalski, Solid State Division, ORNL, "A Solid State Division Project: A Study of Transition Metal Carbides," April 3, 1981.

R. B. Griffiths, Carnegie-Mellon University, "Soluble Ising Models on Crazy Lattices," April 8, 1981.

D. J. Dingley, University of Bristol, England, "A New Theory of Grain Boundary Structure Based on Bollmann's O-Lattice Theory," April 13, 1981.

Hermann Winter, Kernforschungszentrum, Karlsruhe, West Germany, "Ab Initio Calculations of Supeconducting Transition Temperatures and Some Mechanisms Limiting T_c's," April 29, 1981.

Arthur J. McEvily, University of Connecticut, "Low-Cycle Fatigue Behavior of Ferritic Steels at Elevated Temperatures," April 29, 1981.

Norman Peterson, Argonne National Laboratory, "Diffusion Mechanisms in Transition Metal Oxides," May 1, 1981.

Gerd Willmann, Dornier System, Inc., West Germany, "Oxidation of Silicon Carbide Tubes for a High-Temperature Heat Exchanger," May 1, 1981.

G. H. Gilmer, Bell Laboratories, "Computer Models of Crystal Growth," May 6, 1981.

Hermann Winter, Kernforschungszentrum, Karlsruhe, West Germany, "Some Mechanisms Depressing the Superconducting Transition Temperatures of Refractory Compounds. Can One Get Around Them?," May 8, 1981.

M. J. Gillan, Atomic Energy Research Establishment, Harwell, England, "Diffusion Theory and Defect Structures in Crystals," May 15, 1981.

John Mundy, Argonne National Laboratory, "Mechanisms of Self-Diffusion in Metals," May 22, 1981.

David M. McClachlan, Research Corporation, St. Louis, Missouri, "Ion Sputtering and Ion Etching in Materials Research," May 28, 1981.

D. R. Nelson, Harvard University, "Theory of Melting in Two and Three Dimensions," June 3, 1981.

W. C. Oliver, Stanford University, "Deformation Mechanisms in Dispersion-Strengthened Solid Solution and Pure Metals," June 5, 1981.

J. H. Schneibel, Metals and Ceramics Division, ORNL, "Diffusional Creep: The Role of Grain Size Distribution," June 5, 1981.

Nils Christensen, Colorado School of Mines, "Methods of Characterizing Hydrogen Embrittlement in Welding," June 8, 1981.

Herbert Stephan, Director of Electron Beam Research, Leybolt-Heraeus, Hanau, West Germany, "Update on Electron Beam Use Over the Last Five Years," June 8, 1981.

E. R. Thompson, United Technologies Laboratories, Hartford, Connecticut, "High-Temperature Alloys," June 15, 1981.

M. A. A. El-Masry, Metals and Ceramics Division, ORNL, "Fabrication, Microstructure Control, and Characterization of Hard Ceramic and Cermet Bodies for Valve Inserts," June 18, 1981.

Michael Ball, University of Liverpool, England, "Generalized Pseudo Atom and Its Application to Lattice Dynamics," June 24, 1981.

Wolfgang Losch, Federal University of Rio de Janeiro, Brazil, "On the Physical Basis of Impurity-Induced Intergranular Fracture," June 29, 1981.

Appendix F

ADVISORY COMMITTEE

The Advisory Committee to the Metals and Ceramics Division currently consists of six members appointed by the laboratory director. The size of the committee was restored to a six-person body in 1981. The tenure of appointment remains at four years as previously requested by the committee. Such action was considered prudent because of rising costs and pending reductions in programmatic support. Attainment of th· six-person committee will be accomplished by appointing one new member in odd calendar years (1981, 1983, etc.) and adding two new members in the even calendar years (1982, 1984, etc.). The main function of the committee is to review ongoing research and development activities and to render independent judgments on the general state and welfare, ability of staff, and progress being made in various operations and missions of the division. Members are chosen from governmental, industrial, educational, and research institutions in the United States and are selected on the basis of demonstrated ability in management, research, and technology. Members of the 1981 Advisory Committee are listed below.

Dr. Arden L. Bement, Jr. (Committee Chairman)
Vice President of Technical Resources
TWR, Inc.
23555 Euclid Avenue
Cleveland, Ohio 44117

Dr. Edward H. Kottcamp, Jr.
Director of Research
Homer Research Laboratories
Bethlehem Steel Corporation
Bethlehem, Pennsylvania 18016

Professor Alan Lawley
Department of Materials Engineering
Drexel University
Philadelphia, Pennsylvania 1S 104

Professor Tadeusz B. Massalski
Department of Metallurgy and Materials Science
Carnegie-Mellon University
5000 Forbes Avenue
Pittsburgh, Pennsylvania 15213

Dr. Richard H. Redwine
Technical Director,
Kimble Products Division
Owens-Illinois, Inc.
Post Office Box 1035
Toledo, Ohio 43666

Appendix G

PUBLICATIONS

Compiled by Alice Rice

L. Adler, K. V. Cook, and D. W. Fitting, "Ultrasonic Characterization of Austenitic Welds," pp. 533-40 in *Ultrasonic Materials Characterization, NBS Spec. Publ.* 596, National Bureau of Standards, Washington, D.C., November 1980.

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Appendix H

PRESENTATIONS AT TECHNICAL MEETINGS

Compiled by Alice Rice

Fourth International Conference on Liquid and Amorphous Metals, Grenoble, France, July 7–11, 1980:

D. M. Kroeger,* D. S. Easton, C. C. Koch, and J. O. Scarbrough, "Critical Cooling Rates for Formation of Metallic Glasses Made in an Arc-Hammer Apparatus."

27th Sagamore Army Materials Research Conference, Bolton Landing, New York, July 14–18, 1980:

C. R. Brinkman, "Creep-Fatigue Effects in Structural Materials Used in Advanced Nuclear Power Generating Systems."

Fifth International Conference on Zirconium in the Nuclear Industry, Boston, August 4–7, 1980:

D. O. Hobson,* K. R. Thoms, and Theo van der Kaa, "Effects on Temperature and External Pressure on the In-Reactor Creepdown of Zircaloy Fuel Cladding."

R. E. Pawel* and J. J. Campbell "A Comparison of the High-Temperature Oxidation Behavior of Zircaloy-4 and Pure Zirconium."

Gordon Conference on Solid State Studies in Ceramics, Kimball Union Academy, Meriden, New Hampshire, August 4–8, 1980:

P. F. Becher,* C. C. Wu, and R. W. Rice, "Fracture Toughness Behavior in Al_2O_3–ZrO_2 Composites."

38th Annual Meeting of the Electron Microscopy Society of America, Reno, Nevada, August 4–8, 1980:

J. Bentley, "Advantages of a Field Emission Gun for a Combined Analytical and High-Resolution Transmission Electron Microscope."

J. Bentley,* L. L. Horton, and K. Farrell, "Defect Structures in Neutron-Irradiated Iron."

S. G. Caldwell,* J. J. Wert, and R. W. Carpenter, "Influence of Stacking Energy of Wear of Cu Alloys."

R. W. Carpenter,* J. J. Wert, and S. G. Caldwell, "Metal Surface Deformation and Subsurface Defect Structure: A Microscopy Correlation Study."

L. A. Harris,* R. Raymond, Jr., and R. Cooley, "A New Improved Standard for Electron Probe Determination of Organic Sulfur in Fossil Fuels."

E. A. Kenik* and R. W. Carpenter, "In Situ HVEM Deformation of Aluminum Alloys."

E. A. Kenik,* K. R. Lawless, and R. W. Carpenter, "Low Pressure In Situ Oxidation of Vanadium and V-20 Ti."

M. M. Kersker,* E. A. Aigeltinger, and J. J. Hren, "Crystallographic Differences of Metastable Ni_2Mo in an Ni-Mo-Al Superalloy."

R. J. Lauf* and H. Keating, "Preparation of Ceramic Particulates for Transmission Electron Microscopy."

E. H. Lee* and A. F. Rowcliffe, "Phase Identification in Neutron Irradiated Stainless Steel" (presented by P. J. Maziasz).

P. J. Maziasz* and R. W. Carpenter, "MC Precipitate Characterization in Austenitic Stainless Steel."

P. S. Sklad, "Observations of Gas Bubbles in an Austenitic Stainless Steel Charged with ^3H."

L. J. Sykes* and J. J. Hren, "Comparison of Dislocation and Precipitate Strain Fields."

J. J. Wert,* R. W. Carpenter, and S. G. Caldwell, "The Effect of Stacking Fault Energy of Sliding Wear Behavior of Copper-Aluminum Alloys."

*Speaker.

N. J. Zaluzec,* E. A. Kenik, and P. J. Maziasz, "On the Limitations of X-Ray Microanalysis of Heterogeneous Specimens Using Analytical Electron Microscopy."

N. J. Zaluzec,* J. J. Hren, and R. W. Carpenter, "The Influence of Diffracting Conditions on Quantitative Electron Energy Loss Spectroscopy."

89th Annual Meeting, American Institute of Chemical Engineers, Portland, Oregon, August 17–20, 1980:

G. L. Copeland,* B. Heshmatpour, and R. L. Heestand, "Melting Metal Waste for Volume Reduction and Decontamination."

American Crystallographic Association Summer Meeting, Calgary, Alberta, Canada, August 17–22, 1980:

J. E. Epperson,* J. Faber, R. W. Hendricks, and J. S. Lin, "On the Decomposition and Ripening of an Ni–12.7 at. % Al Alloy."

13th Annual Technical Meeting of the International Metallographic Society, Brighton, England, August 18–22, 1980:

R. J. Gray,* D. A. Canonico, and L. C. Bate, "An Integrity Study of Type 347 Stainless Steel Tubes After a Five-Year Service in a High Flux Nuclear Reactor."

International Conference, "Physics of Transition Metals," Leeds, England, August 18–22, 1980:

W. H. Butler, "The Electron-Phonon Interaction in Transition Metals and Their Compounds."

G. M. Stocks* and B. L. Györffy, "The 2γ Momentum Distribution in Random Ag_cPd_{1-c} Alloys."

G. M. Stocks* and W. H. Butler, "Residual Resistivities of $Ag_cPd_{(1-c)}$ Alloys."

Seventh European Congress on Electron Microscopy, The Hague, The Netherlands, August 24–29, 1980:

D. N. Braski* and K. Farrell, "Radiation Damage Structure in Ordered $(Co_{0.78},Fe_{0.22})_3V$ Alloy."

International Conference, "X-Ray Process and Innershell Ionization," Stirling, England, August 25–29, 1980:

G. M. Stocks, "Electronic States in bcc $Li_cMg_{(1-c)}$ Alloys: Soft X-Ray Emission Spectra."

Third International Conference on "Effect of Hydrogen on Behavior of Materials," Jackson Lake Lodge, Wyoming, August 26–31, 1980:

M. B. Lewis* and K. Farrell, "Deuterium Depth Profiles and Diffusion Coefficient in Electrocharged Stainless Steel."

Basic Engineering Sciences National Welding Conference, Berkeley, California, September 4–5, 1980:

J. M. Vitek* and S. A. David, "Microstructural Analysis of Austenitic Stainless Steel Laser Welds."

International Conference on Engineering Aspects of Creep, Sheffield, England, September 15, 1980:

M. K. Booker, "Progress Toward Analytical Description of the Creep Strain-Time Behavior of Engineering Alloys" (presented by S. Majumdar of Argonne National Laboratory).

Joint U.S.-French Seminar on Small-Angle X-Ray and Neutron Scattering from Polymers, Strasbourg, France, September 16–19, 1980:

D. W. Schaefer,* R. W. Hendricks, and J. S. Lin, "Static Correlations in Semidilute Solutions: Marginal Solvents."

G. D. Wignall,* R. W. Hendricks, and W. C. Koehler, "Current Instrumentaion Developments and Polymer Research at the United States National Center for Small-Angle Scattering Research."

Advisory Technical Awareness Council, American Society for Metals, Cleveland, September 30, 1980:

J. E. Cunningham, "Solidification Behavior and Ferrite Morphology in Austenitic Stainless Steel Welds."

22d Meeting of the Joint Working Group on Uranium Alloys, Oak Ridge, Tennessee, September 30–October 3, 1980:

R. A. Vandermeer,* J. C. Ogle, and W. G. Northcutt, Jr., "Influence of Aging at $M_s(A_f)$ on the Deformation and Shape Memory Behavior of U-Nb α'' Martensite."

ADIP Program Review Meeting, DOE-OFE, Materials and Radiation Effects Branch, Germantown, Maryland, September 30–October 1, 1980:

D. N. Braski, "Resistance of $(Fe,Ni)_3V$ Long-Range-Ordered Alloys to Radiation Damage."

M. L. Grossbeck, "Status of ORR Spectral Tailoring and HFIR Irradiation Experiments."

R. L. Klueh* and J. M. Vitek, "Characterization of Nickel-Doped Ferritic Steels for Helium Production Through HFIR Irradiation."

P. J. Maziasz, "Swelling and Microstructure of HFIR Irradiated Austenitic Stainless Steels."

P. J. Maziasz, "Microstructural Design and Development of Path A Prime Candidate Alloy."

M. P. Tanaka,* E. E. Bloom, and J. A. Horak, "Tensile Properties and Microstructure of Helium-Injected and Reactor-Irradiated V-20 Ti."

F. W. Wiffen,* J. A. Horak, D. P. Edmonds, and J. F. King, "The Influence of Irradiation on the Tensile Properties of Austenitic Stainless Steel Weldments."

TMS-AIME Fall Meeting, Metallurgical Society of AIME, Pittsburgh, Pennsylvania, October 5–9, 1980:

V. B. Baylor,* J. R. Keiser, and E. H. Lee, "Alloy Evaluation in High-Temperature Oxygen-Chloride Environment."

J. R. Keiser,* V. B. Baylor, J. F. Newsome, and M. Howell, "Study of Fractionation Area Corrosion at Solvent Refined Coal Pilot Plants."

E. A. Kenik* and E. H. Lee, "Influence of Injected Helium on the Phase Instability of Ion-Irradiated Stainless Steel."

E. H. Lee,* P. J. Maziasz, and A. F. Rowcliffe, "The Structure and Composition of Phases Occurring in Austenitic Stainless Steels in Thermal and Irradiation Environments."

E. H. Lee,* P. J. Maziasz, and A. F. Rowcliffe, "Identification of Precipitate Phases Occurring in Austenitic Stainless Steels in Thermal and Irradiation Environments."

L. K. Mansur and M. R. Hayns, "Basic Mechanisms Affecting Swelling in Alloys with Precipitates."

P. J. Maziasz,* J. A. Horak, B. L. Cox, and M. L. Grossbeck, "The Influence of Both Helium and Neutron Irradiation on Precipitation in 20% Cold-Worked Austenitic Stainless Steel."

P. J. Maziasz, "Helium Trapping at Ti-Rich MC Particles in Ti-Modified Austenitic Stainless Steel."

A. F. Rowcliffe, E. H. Lee,* L. K. Mansur, and P. J. Maziasz, "Precipitation in Austenitic Stainless Steels During Irradiation."

W. A. Simpson,* L. Adler, and T. K. Bolland, "Boundaries Between Isotropic and Anisotropic Solids and Their Effect on Quantitative NDE."

C. L. White* and R. A. Padgett, "Effects of Antimony Additions on the Fracture of Nickel at 600°C."

M. H. Yoo, "Trace Element Effects on Vacancy Clustering and Heterogeneous Nucleation of Microvoids During Various Thermomechanical Treatments."

Electrochemical Society Autumn Meeting, Hollywood, Florida, October 5–10, 1980:

R. W. Carpenter, "Microdiffraction Studies on Semiconductor Materials."

Fifth Annual Conference on Materials for Coal Conversion and Utilization, Gaithersburg, Maryland, October 6–8, 1980:

V. B. Baylor,* J. R. Keiser, and J. H. DeVan, "Materials for CONOCO Zinc Chloride Hydrocracking Process."

G. M. Goodwin* and D. P. Edmonds, "Fossil Energy Welding and Cladding Program."

J. R. Keiser,* V. B. Baylor, and J. H. DeVan, "Corrosion in Coal Liquefaction Systems."

V. K. Sikka, "Potential Use of Modified 9 Cr-1 Mo Steel for Fossil Utility Boiler Applications" (presented by R. A. Bradley).

American Nuclear Society International Conference on Materials for Nuclear Steam Generation, St. Petersburg, Florida, October 6–8, 1980:

J. P. Hammond,* J. C. Griess, and W. A. Maxwell, "Effects of Chromium, Silicon, Stabilization of Carbides, and Surface Condition on the Steam Corrosion of Cr-Mo Ferritic Alloys."

Fifth International Conference on Small Angle Scattering, Berlin, Germany, October 6–10, 1980:

R. W. Hendricks,* B. S. Borie, and F. W. Stallman, "Small-Angle Scattering from a Misoriented Stack of Lamellae."

R. W. Hendricks,* P. A. Seeger, J. W. Scheer, and S. Suehiro, "The LASL-ORNL Fast Digital Data Acquisition System."

R. W. Hendricks* and S. Suehiro, "Dynamic Deformation Device for Small-Angle X-Ray and Neutron Scattering."

P. LaBarbe,* A. C. Wright, J. S. Lin, R. W. Hendricks, and J. Zarzycki, "SAXS and SANS Studies of Silica Glasses Prepared by Hot-Pressing of Silica Gel."

G. A. Wallace and R. W. Hendricks,* "A High Intensity Mirror-Focussed X-Ray Source for Small Angle Scattering."

Annual Contractors' Review Meeting for Thermal and Chemical Energy Storage, McLean, Virginia, October 13–16, 1980:

J. H. DeVan and P. F. Tortorelli, "Mass-Transfer Characteristics of Nitrate-Based Salt Mixtures." Paper not presented. Summary published in proceedings.

American Nuclear Society Meeting on the Technology of Controlled Nuclear Fusion, King of Prussia, Pennsylvania, October 14–17, 1980:

C. J. Long, "Structural Materials for Large Superconducting Magnets: An Assessment Based on the Large Coil Program."

J. L. Scott,* E. E. Bloom, J. J. Holmes, R. E. Gold, S. M. Rosenwasser, M. L. Grossbeck, T. C. Reuther, Jr., and F. W. Wiffen, "Progress in the Development of the Blanket Structural Material for Fusion Reactors."

International Fuel Rod Simulator Symposium, Gatlinburg, Tennessee, October 22–24, 1980:

A. J. Moorhead* and R. W. Reed, "Fuel Rod Simulator Fabrication Requires Creative Joining Techniques."

American Ceramic Society 33d Pacific Coast Regional Meeting, San Francisco, October 26–29, 1980:

W. K. Alexander, W. P. Eatherly, and C. R. Kennedy,* "Irradiation of TSX Graphite: A Comparison of Highly Accelerated Tests with Reactor Performance."

J. H. Bottcher,* D. A. Donahue, and E. L. Long, Jr., "Sphere-Pack Versus Pellet Mixed-Oxide Fuel to 10 at. % Burnup."

A. J. Caputo,* P. Angelini, and D. P. Stinton, "Drying and Characterization of Sol-Gel Produced Synroc Waste Forms."

W. P. Eatherly, C. R. Kennedy,* and R. P. Wichner, "Mechanical Properties of Several Graphites as Affected by Steam Oxidation."

C. R. Kennedy,* W. P. Eatherly, and R. L. Senn, "The Compressive Creep Characteristics of Graphite Under Irradiation."

S. M. Tiegs,* W. B. Stines, and M. H. Lloyd, "Fabrication of $(U,Pu)O_2$ Fuel Pellets Using Gel Microspheres."

G. C. Wei, "Thermophysical Properties of Carbon-Bonded Carbon-Fiber Thermal Insulation for Radioisotopic Heat Source in Space Nuclear Systems."

Mid-West Solid State Symposium, Bloomington, Indiana, October 27–28, 1980:

W. H. Butler, "Calculation of the Superconductivity Transition Temperature: A Review of the State of the Art."

G. M. Stocks, "Electronic States in Random Substitutional Alloys: Energy Bands and Fermi Surfaces."

U.S. Japan Exchange on Fusion Reactor Materials, Tokai, Japan, October, 28–29, 1980:

E. E. Bloom,* M. L. Grossbeck, and K. C. Liu, "Mechanical Properties of Type 316 Stainless Steel at Fusion Reactor Damage Levels."

N. H. Packan, T. C. Reiley, K. Farrell, L. K. Mansur, and E. E. Bloom,* "Summary of Results from the ORNL Ion Irradiation Program."

M. P. Tanaka,* E. E. Bloom, and J. A. Horak, "Tensile Properties and Microstructure of Helium-Injected and Reactor-Irradiated V-20 Ti."

American Society for Metals Materials and Processes Show, Cleveland, Ohio, October 28–30, 1980:

S. A. David, "Solidification Structure of Thorium-Doped Iridium Alloy Welds."

J. R. Keiser,* V. B. Baylor, D. R. Canfield, and W. P. Barnett, "Materials Performance in Coal Liquefaction Pilot Plant."

J. R. Keiser,* V. B. Baylor, D. R. Canfield, and W. P. Barnett, "Failure Analysis Assistance to Solvent Refined Coal Pilot Plant."

J. W. McEnerney,* B. R. Dewey, and S. A. David, "System for Control of Electroslag Casting in a Collar Mold."

R. W. Swindeman, "Failure Analysis Activities at Coal Liquefaction Pilot Plants—An Overview."

National Association of Corrosion Engineers, El Paso, Texas, October 28–30, 1980:

J. H. DeVan,* H. E. McCoy, and J. E. Mack, "Compatibility of Several Waste Forms with Potential Cannister Materials."

Eighth Water Reactor Safety Research Information Meeting, Nuclear Regulatory Commission, Washington, D.C., October 27–31, 1980:

C. V. Dodd, "Improved Eddy-Current Inspection of Steam Generator Tubes."

Synchrotron Radiation Users' Meeting, Stanford, California, October 30–31, 1980

G. S. Brown, M. H. Chen, B. Crasemann,* and G. E. Ice, "Observation of the Auger Resonant Raman Effect."

Workshop on "The Effect of Complex Loads and Irradiation on the Lifetime of Fusion Reactor First Walls," Petten, The Netherlands, November 4, 1980:

M. L. Grossbeck, "Recent Work on Mechanical Properties of Austenitic Stainless Steels for Fusion Reactor Service."

Meeting of the Working Group of ANNEX II of the IEA Implementing Agreement on Radiation Damage to Fusion Materials, Petten, The Netherlands, November 7, 1980:

M. L. Grossbeck, "Mixed Spectrum Neutron Irradiation Experiments on Fusion Reactor Materials."

American Society for Testing and Materials November Committee Week, Bal Harbour, Florida, November 9–14, 1980:

R. W. Swindeman* and D. N. Robinson, "Experimental Determination of State Variables Related to Metallurgical Structure in $2^1/_4$ Cr-1 Mo Steel at High Temperature."

ANL/DOE, International Meeting on Development, Fabrication, and Application of Reduced-Enrichment Fuels for Research and Test Reactors, Chicago, November 12–14, 1980:

G. L. Copeland and M. M. Martin,* "Fabrication of High-Uranium-Loaded U_3O_8-Al Developmental Fuel Plates."

R. L. Senn* and M. M. Martin, "Irradiation Testing of Miniature Fuel Plates fo the RERTR Program."

First Annual Utility Energy Management Conference, New Orleans, November 16–19, 1980:

D. L. McElroy, "Thermal Insulation."

American Society of Mechanical Engineers Annual Winter Meeting, Chicago, November 16–21, 1980:

M. K. Booker, "Analysis of Creep-Rupture Data for Long-Range Life Prediction."

M. K. Booker* and B. L. P. Booker, "New Methods of Analysis of Materials Strength Data for the ASME Boiler and Pressure Vessel Code."

Materials Research Society Third International Symposium on Scientific Basis for Nuclear Waste Management, Boston, November 16–21, 1980:

P. Angelini,* W. D. Bond, A. J. Caputo, J. E. Mack, W. J. Lackey, D. A. Lee, and D. P. Stinton, "Sol-Gel Technology Applied to Crystalline Ceramics."

National Synchrotron Light Source X-Ray Participating Research Team Meeting, Brookhaven National Laboratory, Upton, New York, November 17–18, 1980:

G. E. Ice, "ORNL Beam Line Optics."

C. J. Sparks, Jr., "ORNL Synchrotron Radiation Beam Line."

American Physical Society, Plasma Physics Division, Annual Meeting, San Diego, California, November 17–21, 1980:

L. C. Emerson,* C. E. Bush, R. C. Isler, R. A. Langley, D. M. Mattox, A. W. Mullendore, and J. B. Whitley, "Testing of TiC and B-Coated Limiters in Beam Heated ISX-B Plasmas."

Coal Liquefaction Corrosion Workshop, Baytown, Texas, November 20, 1980:

J. R. Keiser,* R. R. Judkins, V. B. Baylor, M. Howell, and J. F. Newsome, "ORNL Studies of Fractionation Area Corrosion."

Committee of Safety of Nuclear Installation Specialists Meeting on Instrumented Precracked Charpy Testing, Palo Alto, California, December 1–3, 1980:

R. K. Nanstad, "Comparison of Instrumented Precracked Charpy and Compact Specimen Tests with Carbon Steels."

R. K. Nanstad, "Comparison Between Instrumented Precracked Charpy and Compact Specimen Tests of Carbon Steels."

Electron Microscopy: Instruments and Instrumentation (Institute of Physics), London, England, January 7, 1981:

J. Bentley, "The Field Emission Gun TEM/STEM as a Combined Analytical and High-Resolution Electron Microscope."

Golden Gate Metals and Welding Conference, San Francisco, January 21–23, 1981:

R. A. Bradley, "Overview of DOE-Funded Fossil Energy Materials Program."

WATTec Conference, Knoxville, Tennessee, February 18–20, 1981:

R. A. Bradley, "An Overview of DOE-Funded Coal Utilization and Conversion Projects."

C. V. Dodd, "Application of Multiple-Property Eddy-Current Techniques to Steam Generator Tubing Inspection."

T. G. Godfrey, "Materials and Fabrication for Fluidized Bed Combustion."

R. J. Gray,* G. M. Slaughter, J. C. Griess, Jr., and C. W. Houck, "Metallurgical Analysis of Fire-Damaged Piping from a U.S. Strategic Petroleum Reserve Supply Facility."

T. S. Lundy, "Building Thermal Envelope Systems and Insulating Materials."

Meeting, American Institute of Mining, Metallurgical, and Petroleum Engineers, Chicago, February 23–26, 1981:

J. Bentley, "Interphase Boundary Dislocation Structure of Second Phase Particles in Stainless Steel."

D. J. Bradley,* M. McDonald, and J. M. Leitnaker, "The Effect of Silicon on the Composition and Solubility of Laves and Chi Phases in 316 and Titanium-Modified 316 Stainless Steels."

D. A. Canonico* and R. G. Berggren, "Effect of Irradiation on Nuclear Pressure Vessel Weld Metals."

S. A. David* and J. M. Vitek, "Solidification Behavior and Microstructural Analysis of Austenitic Stainless Steel Laser Welds."

K. Farrell, "Radiation Response of Aluminum and Its Alloys After Exposure in the High Flux Isotope Reactor."

L. A. Harris* and E. C. Hise, "The Application of Coal Petrography to the Evaluation of Magnetically Separated Dry Crushed Coal."

L. L. Horton,* J. Bentley, and W. A. Jesser, "Fusion Environment Radiation Damage in High-Purity Iron and Iron Chromium Alloys."

C. T. Liu* and E. H. Lee, "Creep Behavior of Ductile Ordered Alloys Co-16 to 25 Fe–23 V."

P. S. Sklad* and V. K. Sikka, "Microstructural Observations of Strain Softening in Ferritic 9 Cr-1 Mo Alloys."

R. A. Vandermeer,* J. C. Ogle, and W. G. Nothcutt, Jr., "Influence of Aging at $M_s(A_f)$ on the Deformation and Shape Memory Behavior of U-Nb α'' Martensite."

C. L. White* and R. A. Padgett, "Trace Element Effects on the High-Temperature Ductility of Nickel."

M. H. Yoo, "Fracture Initiation at Grain Boundary Inclusions—Internal Stress Effects."

Meeting, Fusion Engineering Device, Technical Management Board, Washington, D.C., February 26, 1981:

J. O. Stiegler, "Strategy for the Use of Irradiation Test Facilities in the Development of Materials for Fusion Power."

International Conference on High-Temperature Corrosion, San Diego, California, March 2–6, 1981:

V. B. Baylor,* J. R. Keiser, and E. H. Lee, "Corrosion Studies in $ZnCl_2$-Air-HCl Environments at 500–1000°C."

R. E. Pawel, "The Oxidation of Zirconium and Zircaloy-4 from 1000 to 1500°C."

R. E. Pawel* and J. J. Campbell, "Reaction Kinetics and Oxygen Diffusion During the Oxidation of Zirconium and Zircaloy-4 from 1000 to 1500°C."

Meeting, American Physical Society, Phoenix, Arizona, March 16–20, 1981:

W. H. Butler, "Lattice Thermal Conductivity of Nb, Mo, and Pd."

J. S. Faulkner, "Pivoted Multiple-Scattering Equations and Band Theory."

R. A. McKee, "Diffusion in a Pure, High Vacancy Content Crystal."

G. S. Painter* and F. W. Averill, "On the Hellmann-Feyman and Virial Theorems Within the Density Functional Formalism: Applications to Molecules."

G. M. Stocks, "Screening Mechanisms in Heterovalent Alloys: Li_cMg_{1-c}."

E. A. Kenik,* C. L. White, and W. E. Felling, "SHaRE: A Collaborative Users Program for Microanalysis in Materials Science" (invited presentation to a Special Session on National Facilities).

American Welding Society, Sixth Annual Rocky Mountain Symposium, Golden, Colorado, March 20, 1981:

S. A. David, "Nature of Ferrite in Stainless Steel."

International Conference on Creep and Fracture of Engineering Materials and Structures, University College of Swansea, United Kingdom, March 24–27, 1981:

C. L. White,* R. A. Padgett, R. W. Swindeman, K. Farrell, and M. H. Yoo, "Impurity Segregation to Creep Cavities in 304 Stainless Steel."

Fifth International Conference on Fracture, Cannes, France, March 29–April 3, 1981:

C. L. White* and R. A. Padgett, "Trace Element Effects in High-Temperature Fracture of Nickel."

Third International Conference on Wear of Materials, San Francisco, March 30–April 1, 1981:

J. J. Wert,* R. W. Carpenter, and S. G. Caldwell, "The Effect of Stacking Fault Energy of Sliding Wear Behavior of Copper-Aluminum Alloys."

National Meeting of American Institute of Chemical Engineers, April 5–9, 1981:

J. R. Keiser, R. R. Judkins, V. B. Baylor, D. R. Canfield, and W. P. Barnett,* "Control of Fractionation Area Corrosion at SRC Pilot Plants."

American Welding Society Conference on Aluminum Weldments, Cleveland, April 6–10, 1981:

S. A. David, "A Study of Ferrite Morphology and Variations in Ferrite Content in Austenitic Stainless Steel Welds."

J. M. Vitek* and S. A. David, "Microstructural Analysis of Austenitic Stainless Steel Laser Weld."

11th Annual Symposium on Electronic Structure of Metals and Alloys, Gaussig, East Germany, April 6–10, 1981:

J. S. Faulkner, "Multiple Scattering Theory of Electrons in Ordered and Disordered Solids."

Meeting, National Association of Corrosion Engineers, Toronto, Canada, April 6–10, 1981:

V. B. Baylor* and J. R. Keiser, "Stress Corrosion Cracking Studies in Coal Liquefaction Systems."

J. C. Griess,* J. H. DeVan, and W. A. Maxwell, "Long-Term Corrosion of Cr-Mo Steels in Superheated Steam at 482 and 538°C."

J. R. Keiser, R. R. Judkins,* V. B. Baylor, D. R. Canfield, and W. P. Barnett, "Corrosion of Solvent Refined Coal Pilot Plant Fractionation Columns."

P. F. Tortorelli,* J. H. DeVan, and R. M. Yonco, "Compatibility of Fe-Cr-Mo Alloys with Static Lithium."

Spring Meeting of Swiss Physical Society, Neuchatel, Switzerland, April 8–10, 1981:

E. Ambruster, A. DasGupta,* H.-U. Kunzi, and H.-J. Guntherodt, "Hydrogen Peaks in Internal Friction of Metallic Glasses."

Meeting, Scanning Electron Microscopy, Dallas, Texas, April 14–18, 1981:

J. Bentley,* M. J. Goringe, and R. W. Carpenter, "Thickness Fringe Contrast at Grain Boundaries in TEM and STEM."

J. Bentley, "Instrumental Problems Affecting X-Ray Microanalysis in the Analytical Electron Microscope: An Update."

L. A. Harris,* E. A. Kenik, and C. S. Yust, "Reactions in Pyrite Framboids Induced by Electron Beam Heating in an HVEM."

P. S. Sklad* and J. Bentley, "Analytical Electron Microscopy of Ni-TiB_2 Composites."

J. M. Vitek* and S. A. David, "Analytical Electron Microscopy Evaluation of Laser-Welded 308 Stainless Steel."

American Ceramic Society Annual Meeting, Washington, D.C., May 3–8, 1981:

P. F. Becher* and V. J. Tennery, "Fracture Behavior in Composites Containing ZrO_2 Particulates" (poster exhibit).

M. K. Ferber* and S. D. Brown, "Delayed Failure Characteristics of Plasma-Sprayed Al_2O_3 Applied to 316L Stainless Steel and Ti–6 Al–4 V ELI Substrates."

C. S. Morgan* and R. J. Lauf, "Thermal Shock Resistant Al_2O_3-Cr Cermets."

D. P. Stinton,* P. Angelini, A. J. Caputo, and W. J. Lackey, "Deposition of Impervious Pyrolytic Carbon and SiC Provide Enhanced Inertness to Crystalline Waste Forms."

P. S. Sklad* and J. Bentley, "Analytical Electron Microscopy of TiB_2-Ni Ceramics" (poster exhibit).

V. J. Tennery,* G. C. Wei, and M. K. Ferber, "High-Temperature Behavior of Silicon Carbide, Sialon, and Aluminum Oxide Ceramics in Coal and Residual Oil Slags."

C. S. Yust* and E. L. Long, Jr., "Transmission Electron Microscopy and Optical Microscopy of Commercial WC-Co Compositions."

Specialists' Meeting on High-Temperature Metallic Materials for Application in Gas Cooled Reactors, Vienna, Austria, May 4–6, 1981:

H. Inouye and P. L. Rittenhouse,* "Relationship Between Carburization and Zero-Applied-Stress Creep Dilation in Alloy 800H and Hastelloy X."

J. F. King, H. E. McCoy, and P. L. Rittenhouse,* "Weldability Evaluations and Weldment Properties of Hastelloy X."

J. P. Strizak, C. R. Brinkman, and P. L. Rittenhouse,* "High-Temperature Low-Cycle Fatigue and Tensile Properties of Hastelloy X and Alloy 617 in Air and HTGR-Helium."

Workshop on Corrosion Erosion in Coal Liquefaction Pilot Plants, Lexington, Kentucky, May 13–14, 1981:

J. R. Keiser,* V. B. Baylor, M. Howell, A. R. Irvine, R. R. Judkins, and J. F. Newsome, "ORNL Studies of Fractionation Column Corrosion."

American Society for Metals, Symposium on Elevated-Temperature Materials Considerations in Coal Liquefaction and Gasification Service, Oak Ridge, Tennessee, May 15, 1981:

V. B. Baylor* and J. R. Keiser, "Corrosion in Coal Liquefaction Processes."

J. R. Keiser,* M. D. Allen, V. B. Baylor, J. H. DeVan, R. J. Gray, B. C. Leslie, and J. R. Mayotte, "Corrosion Failures in Coal Liquefaction Pilot Plants."

International Conference on Fast Ionic Transport in Solids, Gatlinburg, Tennessee, May 18–22, 1981:

R. A. McKee, "A Generalization of the Nernst-Einstein Equation for Self-Diffusion in High Defect Concentration Solids."

Meeting, Mechanical Behavior and Nuclear Application of Stainless Steels at Elevated Temperatures, Varese, Italy, May 20–22, 1981:

V. K. Sikka, "Long-Term Creep Data on Type 304 Stainless Steel."

R. W. Swindeman, "Correlation of Rupture Life, Creep Rate, and Microstructure for Type 304 Stainless Steel."

Presentations in China as part of exchange program between American Society for Metals and Chinese Society of Metals—Tokyo, May 16; Beijing, May 17; Shanghai, June 1; Guangzhou, June 4; and Hong Kong, June 6:

R. J. Gray, "Unusual Metallographic Techniques Help Us to Understand and Evaluate Microstructures."

R. J. Gray, "Failure Analyses of Surgical Implants from the Human Body Can Improve Product and Performance Reliability."

Second US/Japan LMFBR Steam Generator Seminar, Sunnyvale, California, June 1–5, 1981:

R. W. McClung,* R. A. Day, H. H. Neely, and T. Powers, "Techniques for In-Service Inspection of Heat Transfer Tubes in Steam Generators."

International Seminar on Chemistry and Process Engineering for High-Level Liquid Waste Solidification, Kernforschungsanlage, Jülich, West Germany, June 1–5, 1981:

W. J. Lackey,* P. Angelini, W. D. Arnold, W. D. Bond, A. J. Caputo, and D. P. Stinton, "Sol-Gel-Derived Waste Forms."

American Nuclear Society, Miami Beach, Florida, June 7–12, 1981:

G. L. Copeland* and B. Heshmatpour, "Decontamination of TRU-Contaminated Metal Waste by Melt Refining."

B. Heshmatpour and G. L. Copeland,* "Granulation of Metals and Slags for Waste Disposal and Storage."

A. F. Rowcliffe* and J. A. Horak, "Tensile Properties and Fracture Behavior of Irradiated Nickel Alloys."

American Society for Metals, Workshop on Conservation and Substitution Technology, Vanderbilt University, Nashville, Tennessee, June 15–17, 1981:

V. K. Sikka, "Substitution of Modified 9 Cr-1 Mo Steel for Austenitic Stainless Steel."

National Bureau of Standards International Conference on Thermal Conductivity, Gaithersburg, Maryland, June 15–19, 1981:

H. A. Fine, S. H. Jury, D. L. McElroy,* and D. W. Yarbrough, "The Thermal Conductivity of Semitransparent Materials."

J. P. Moore* and R. S. Graves, "The Thermal Conductivity and Electrical Resistivity of a POCO AXM-5Q1 Graphite from 80 to 900 K."

J. P. Moore,* R. S. Graves, and R. K. Williams, "Thermal Transport Properties of Niobium and Some Niobium-Base Alloys from 80 to 1600 K."

J. P. Moore,* D. L. McElroy, and S. H. Jury, "A Technique for Measuring the Apparent Thermal Conductivity of Flat Insulations."

R. K. Williams, R. S. Graves, F. J. Weaver, and D. L. McElroy,* "The Physical Properties of 9 Cr-1 Mo Steel from 300 to 1000 K."

American Society of Mechanical Engineers Pressure Vessel and Piping Conference, Denver, Colorado, June 21–25, 1981:

R. W. Swindeman and C. R. Brinkman,* "Progress in Understanding the Mechanical Behavior of Pressure Vessel Materials at Elevated Temperatures."

R. W. Swindeman* and K. C. Liu, "Creep and Fatigue Resting of Austenitic Stainless Steel Welds and Overlay Cladding."

American Carbon Society 15th Biennial Carbon Conference, Philadelphia, June 22–26, 1981:

W. P. Eatherly, "The Use of Run Statistics to Validate Tensile Tests."

W. P. Eatherly, "Statistical Identification of Disparate Flaws in H451 Graphite."

C. R. Kennedy, "Evaluation of Fracture Strength by Sonic Testing."

C. R. Kennedy* and W. P. Eatherly, "The Flux Effect in Graphite."

American Society of Heating, Refrigerating, and Air-Conditioning Engineers Annual Meeting, Cincinnati, Ohio, June 28–July 2, 1981:

H. A. Fine,* S. H. Jury, D. W. Yarbrough, and D. L. McElroy, "Heat Transfer in Building Thermal Insulation: The Thickness Effect."

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Metals and Ceramics Division Annual Progress Report for Period Ending June 30, 1981

OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Contents

Foreword

This progress report covers the research and development (R&D) activities of the Metals and Ceramics Division for the period July 1, 1980, through June 30, 1981. In keeping with past custom, the format of the report follows rather closely the organizational structure of the division. Short summaries of technical work in progress in the various functional units are grouped and presented in five parts. Chapter 1 deals with the technical activities of the Engineering Materials Section, Chap. 2 with the Fuels and Processes Section, Chap. 3 with the Materials Science Section, Chap. 4 with Other Research Activities, and Chap 5 with Specialized Research Facilities and Equipment operated in user's mode to promote collaboration and joint research with the U.S. industrial sector and the university community.

The past year was characterized by restricted financial support for materials research activities and a reduction in the staff to accommodate the reduced budget anticipated for FY 1982. The financial decreases of divisional support for the fission energy and Nuclear Regulatory Commission (NRC) programs were essentially offset by corresponding increases in the fossil energy and nuclear waste programs. Overall, operating funds rose a mere 0.8% and hence failed to keep pace with inflation. The size of the staff was reduced from 279 permanent employees on roll as of July 1, 1980, to 258 employees on roll as of July 1, 1981. Further details are presented in Appendix A, Budget and Support Distribution, and in Appendix B, Personnel Summary.

The organizational structure of the division was realigned in selected areas to accommodate evolving changes in the mix and thrust of R&D activity and to upgrade technical management. These adjustments and staff member appointments in the past year are announced in Appendix C on Organizational Structure and Chart. On April 1, the division began reporting to Alexander Zucker, Laboratory Associate Director for Physical Sciences.

Greater attention is currently being focused on discerning trends and seeking opportunities for exploratory research needed in materials science and engineering. Numerous ideas for exploratory research have been submitted to the laboratory seed money committee, and seven proposals have been approved for investigation. The nature and scope of these research investigations are described under "New Research Initiatives" in Chap 4.

Descriptive information on Honors and Awards, Seminar Program, Advisory Committee, Publications, and Presentations at Technical Meetings appears in summary form in Appendixes D through H, respectively.

Previous reports issued in this series are listed on the next page.

Reports previously issued in this series are as follows:

ORNL-28	Period Ending March 1, 1948
ORNL-69	Period Ending May 31, 1948
ORNL-407	Period Ending July 31, 1949
ORNL-511	Period Ending October 31, 1949
ORNL-583	Period Ending January 31, 1950
ORNL-754	Period Ending April 30, 1950
ORNL-827	Period Ending July 31, 1950
ORNL-910	Period Ending October 31, 1950
ORNL-987	Period Ending January 31, 1951
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ORNL-1108	Period Ending July 31, 1951
ORNL-1161	Period Ending October 31, 1951
ORNL-1267	Period Ending January 31, 1952
ORNL-1302	Period Ending April 30, 1952
ORNL-1366	Period Ending July 31, 1952
ORNL-1437	Period Ending October 31, 1952
ORNL-1503	Period Ending January 31, 1953
ORNL-1551	Period Ending April 10, 1953
ORNL-1625	Period Ending October 10, 1953
ORNL-1727	Period Ending April 10, 1954
ORNL-1875	Period Ending October 10, 1954
ORNL-1911	Period Ending April 10, 1955
ORNL-1988	Period Ending October 10, 1955
ORNL-2080	Period Ending April 10, 1956
ORNL-2217	Period Ending October 10, 1956
ORNL-2422	Period Ending October 10, 1957
ORNL-2632	Period Ending October 10, 1958
ORNL-2839	Period Ending September 1, 1959
ORNL-2988	Period Ending July 1, 1960
ORNL-3160	Period Ending May 31, 1961
ORNL-3313	Period Ending May 31, 1962
ORNL-3470	Period Ending May 31, 1963
ORNL-3670	Period Ending June 30, 1964
ORNL-3870	Period Ending June 30, 1965
ORNL-3970	Period Ending June 30, 1966
ORNL-4170	Period Ending June 30, 1967
ORNL-4370	Period Ending June 30, 1968
ORNL-4470	Period Ending June 30, 1969
ORNL-4570	Period Ending June 30, 1970
ORNL-4770	Period Ending June 30, 1971
ORNL-4820	Period Ending June 30, 1972
ORNL-4870	Period Ending June 30, 1973
ORNL-4970	Period Ending June 30, 1974
ORNL-5579	October 1, 1978–June 30, 1979
ORNL-5670	Period Ending June 30, 1980

1. Engineering Materials

G. M. Slaughter

This section is responsible for determining and evaluating the suitability of engineering materials for use in various energy systems, for developing new alloys, and for determining and developing improved joining and nondestructive testing techniques to assure the structural integrity of materials and components in specific applications. It comprises a staff of approximately 75, about 60% of whom are professionals. Research and development activities are carried out in five different laboratories, which carry the functional names Materials Compatibility, Mechanical Properties, Nondestructive Testing, Pressure Vessel Technology, and Welding and Brazing. Additionally, divisional support for the Heavy Section Steel Technology (HSST) and the High-Temperature Gas-Cooled Reactor (HTGR) Structural Materials programs is administered through this section. Brief descriptions of work performed by and major accomplishments of these groups are presented.

MATERIALS COMPATIBILITY

J. H. DeVan

The Materials Compatibility Group conducts corrosion studies for fusion energy, gas-cooled reactor, fossil energy, nuclear fuel reprocessing, nuclear waste management, conservation, and advanced technology projects.

In March unexpected cutbacks in financial support for two projects necessitated reassignment of personnel. The base technology program for space and terrestrial nuclear power systems (development and characterization of refractory and noble metals for isotopic fuel containment) was terminated; the remaining funds were transferred to the production of iridium alloy canisters. Funding of solvent refined coal (SRC) liquefaction plants was also reduced, curtailing studies of high corrosion rates in the fractionation area of SRC plants. Nevertheless, we have maintained an effective corrosion program on direct coal liquefaction processes, and the group has identified the mechanisms responsible for corrosion during hydrogenation of coal and fractionation of coal-derived liquids. For example, we have traced the movement of chloride-containing impurities through the liquefaction process and categorized the corrosion effects from them.

We have also maintained an active program on the fireside corrosion of heat exchanger materials in atmospheric fluidized-bed combustors (AFBCs). We are currently determining solid state reactions between the heat exchanger alloy and dense $CaSO_4$ deposits formed during the combustion process. We have determined the phase stability relationships between $CaSO_4$ and Fe, Cr, Ni, and Co, respectively, up to 1100°C. Closely related is a recently initiated program undertaken to assess the state of the art of heat exchanger alloys for high-temperature heat recuperation, a part of a conservation-supported program to develop metallic and ceramic heat exchanger materials for recovering heat in industrial ceramic processes.

Studies of the corrosion and mass transport of austenitic, ferritic, and long-range-ordered alloys by liquid lithium and lead-lithium solutions are being conducted for the Fusion Alloy Development for Irradiation Performance (ADIP) Program. Candidate fusion first-wall alloys are exposed in static melts and in naturally convective lithium. Our studies provide understanding of the kinetics of iron, nickel, and chromium transport from high to low temperatures in lithium heat transfer circuits. They also include a study of the compatibility of Fe-Cr-Ni-Mo and ordered Fe-Ni-V alloys with Li_2O, a candidate tritium-breeding solid. Thermal-convection loops are also used to study the mass transfer of types 304 and 316 stainless steel and alloy 800 in mixed nitrate-salt ($NaNO_3$-KNO_3) for the solar thermal energy conversion program sponsored by Sandia National Laboratory.

Environmental interactions of Hastelloy X and alloy 800 with ppm amounts of H_2, H_2O, CH_4, and CO in helium are important in developing HTGR reactors. Accordingly, gas-metal reaction studies of these alloys in helium with closely controlled impurity levels are being conducted at 600 to 1100°C. Current results demonstrate that dilation from carburization can produce a volume increase of up to 1% and can complicate interpretation of mechanical property behavior.

We have continued to support the Consolidated Fuel Reprocessing Program in the selection and corrosion testing of containment materials for advanced fuel reprocessing plants. The experimental part of this program has been conducted under subcontract, but, beginning in FY 1982, we will assume corrosion testing.

A new investigation, started in FY 1981, examined two 33-cm-diam carbon steel pipes that had resided in a dry domal salt deposit for about 36 months. The pipes simulated the casing of a burial shaft for nuclear waste storage and contained internal electric heaters that generated thermal energy equivalent to that released by spent fuel. The pipes and the carbon steel specimens attached to their outside surfaces were significantly pitted. However, companion austenitic stainless steels, 26 Cr-1 Mo steel, and titanium were unaffected.

MECHANICAL PROPERTIES

C. R. Brinkman

The Mechanical Properties Group develops and analyzes data, qualifies new materials, and provides materials engineering support for ongoing national energy-related programs. During the past year, we received support from the following programs: breeder reactor, 40%; breeder reactor foreign exchange, 3%; gas-cooled reactor, 25%; fossil, 9%; service, 8%; conservation, 5%; defense, 2%; fusion, 5%; waste, 2%; and space, 1%. The overall effort for these programs was in characterizing the elastic, plastic, creep, and fatigue behavior of base metals, ceramics, polymers, and weldments. After statistical and parametric analyses of the data, we present them in a form useful to engineers or code developers for design.

Fast breeder reactor work continued on obtaining various mechanical properties such as long-term creep and fatigue data on types 304 and 316 stainless steel, alloy 718, and $2\frac{1}{4}$ Cr-1 Mo and modified 9 Cr-1 Mo steels. Elastic-plastic and toughness properties of annealed and aged material were also studied. Investigation continues on the influence of combined stress and temperature on subsequent mechanical properties of thin-wall large-diameter prototypic piping with welds for type 316 stainless steel. This work is based on differences in the microstructure between stressed and unstressed regions of long-term creep specimens and the degradation of room-temperature toughness properties by prolonged exposure to elevated temperatures. Our heat-to-heat variations program continues to generate data on the austenitic stainless steels, both for defining the magnitude of inherent data scatter in various properties and for providing the basis for revised chemical specifications to decrease data scatter. One of our greatest recent experimental successes was the development of a biaxial fatigue extensometer. This unit allows us to conduct time-dependent fatigue tests by combined push-pull and torsional loading on tubular specimens for breeder reactor development. About 30 tests were successfully completed on $2\frac{1}{4}$ Cr-1 Mo and type 304 stainless steel.

Several utilities, steel suppliers, and design organizations have shown considerable interest in the recent development of modified 9 Cr-1 Mo ferritic steel. This is a new structural material for use at elevated temperatures, which offers several advantages, including increased strength and chromium conservation compared with some austenitic stainless steels. Considerable new data were obtained, and an ASTM specification was submitted for consideration. One foreign and three domestic utilities and several foreign laboratories are cooperating in the evaluation of this material.

Several pages of updates prepared by our Data Analysis Center were entered in the *Nuclear Systems Materials Handbook*. A creep-fatigue design procedure for 2¼ Cr-1 Mo steel based on our analysis was accepted by the ASME for ASME Code Case N-47. Test matrices from the national breeder reactor structural materials program were computerized for inclusion in a national plan for mechanical properties design data.

Data development and analysis for the materials technology to design and license HTGR cogeneration and reformer systems emphasized obtaining information on mechanical properties, thermal stability, and behavior of weldments. Structural alloys included Hastelloy X, Inconel 617, and alloy 800H, and ceramic materials included silicon nitride.

We conducted materials and components assessments on, and provided materials engineering services to, the coal gasification pilot plants and process development units managed by the Morgan-town Energy Technology Center (METC). Our continuing assessments will provide an engineering data base for future design use and will identify gaps in the technology. We also participate in surveillance testing of metals and ceramics programs in several gasification pilot plants.

We initiated work on a conservation program to develop a high-voltage gas-cooled transformer. Our objective is to develop mechanical properties of candidate polymers and to investigate long-term degradation in the presence of anticipated transformer materials in SF_6 at elevated temperatures. This work will supplement efforts of others to establish the optimum polymer for use in sheet-wound transformers and shunt reactors and to establish the compatibility of proposed materials of construction.

In fusion development, 20% cold-worked type 316 stainless steel was irradiated to damage levels of up to 9 dpa and helium contents of 450 at. ppm, which are prototypic of first-wall levels currently envisioned. Fatigue experiments on this material irradiated and tested at 550°C showed no adverse effects on fatigue life compared with unirradiated material. At lower temperatures (430°C), however, a deleterious effect of irradiation was noted.

In our waste container development program, compatibility is being tested on 15 potential canister materials contacted with 7 forms of simulated high-level waste. After 3500 h of exposure at 100 and 300°C (postulated storage temperatures), glass and Fuetap (concrete) evolved detectable amounts of sulfur. The low-temperature penetration was very shallow, and exposures are continuing to determine the penetration rate with time.

NONDESTRUCTIVE TESTING

R. W. McClung

The Nondestructive Testing Group develops new or improved methods of nondestructive testing (NDT) and provides technical support for nondestructive examination (NDE). The activities range from long-term studies of physical mechanisms and theory for development of advanced techniques and equipment to near-term development and technical support for various applied programs. The effort is broad-based, in terms of both the technologies involved (including penetrating radiation, eddy-current, ultrasonic, thermal, and penetrant techniques) and the varied interests of sponsoring agencies, especially those of the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC).

The major activity for DOE has been on the Breeder Reactor Program (BRP). We performed ultrasonic studies with improved transducers on austenitic stainless steel welds at temperatures up to 200°C with both machined discontinuities (e.g., notches and holes) and fatigue cracks. Studies began on ultrasonic inspectability as a function of weld design. Ultrasonic frequency analysis, diffraction, and other signal processing techniques were investigated for improved flaw characterization in the steel welds. Eddy-current studies emphasized multiparameter multifrequency techniques, and a special computer-controlled scanner was developed for use with modular instrumentation in studies on stainless steel welds. For the Clinch River Breeder Reactor steam generator we developed prototype ultrasonic techniques and equipment for in-service inspection (ISI) of the tube-to-tubesheet (T/TS) joints including microcomputer controls for ultrasonic scanning and continued development of eddy-current techniques for ISI of the tubing.

Development and technical support were begun for both ultrasonic and eddy-current ISI techniques for double-wall tubing for a Westinghouse alternate steam generator design. Preliminary techniques were applied for ISI of a few-tube model. We provided technical support to Westinghouse-Tampa Division for their acquisition of a microfocus rod-anode x-ray unit and peripheral equipment for radiography of T/TS joints.

In our long-range NDT studies for the DOE Office of Basic Energy Sciences we developed an analytical model for acoustic propagation across solid-solid interfaces emphasizing isotropic-to-anisotropic boundaries (e.g., for the base metal-weld metal interface in austenitic stainless steel); investigated advanced signal processing for flaw characterization; and developed a method for accurate eddy-current measurement of electrical conductivity. Other DOE programs included studies in x rays and ultrasonics for research reactor fuel, eddy-current examination of reactor control rods, radiographic and ultrasonic developments for graphite, and technical support for examining alloys and graphite components for space nuclear systems.

Technical consultation and support was provided to the program management staffs for the BRP and Fossil Energy Materials Development programs. Special ultrasonic and eddy-current studies were performed for Brookhaven National Laboratory on techniques for evaluating welds in stainless steel tubing.

The largest activity for the NRC was on improved ultrasonic standards for ISI of light-water reactor (LWR) pressure vessels, including consultation, interaction with ASME Code committees, assistance in development of a regulatory guide, and confirmatory laboratory experiments. We also provided consultation in evaluating nondestructive examinations on commercial nuclear reactors. For reactor safety research, we continued to develop improved eddy-current techniques (with the aforementioned multiparameter technology) for the ISI of LWR steam generators. We also conducted experimental studies for ultrasonic techniques to monitor gas bubbles in aerosol release from BRP fuels.

PRESSURE VESSEL TECHNOLOGY

R. K. Nanstad

The Pressure Vessel Technology Group investigates the fracture resistance of structural materials, particularly steels for pressure vessel applications. This requires expertise in experimental fracture mechanics and metallurgy. Programs are sponsored by both NRC and DOE. We are currently emphasizing the materials property needs for the HSST, Fossil Energy Materials, and High-Temperature Gas-Cooled Reactor programs.

Fracture toughness testing of prestressed concrete reactor vessel (PCRV) liner and penetration steels have continued with specific examination of weldments. We are analyzing data in order to apply candidate PCRV liner steels and weldments to a reference fracture toughness framework as in Appendix G of the *ASME Boiler and Pressure Vessel Code*. Weld metal and heat-affected zone studies are included, and results are compared with previous information from base material tests. Information for all materials will be assessed for establishment of a reference fracture toughness for PCRV liner steels.

Under the HSST program, material property data were obtained for thermal shock experiment 5A (TSE-5A). Results from TSE-5 and TSE-5A indicated that a large variability in fracture toughness data should be expected when testing laboratory specimens in the transition temperature regime and that vessel behavior occurred at or below the lower bound toughness results from laboratory testing. Additional testing with thicker specimens and side-grooved compact specimens and testing in a machine with variable compliance (i.e., spring in series with load train) did not reduce the toughness variation or the lower bound toughness. These investigations are continuing with thermal shock vessels 2 and 3.

The remaining Charpy V-notch (CVN) impact specimens from the second and third 4T-CTS irradiation experiments were tested in the HSST irradiation program. Analyses of force-time traces are being performed, and all results will be analyzed for fast neutron fluence and irradiation temperature. The fourth Bulk Shielding Reactor (4th BSR) experiment was started in December 1979, and irradiation of capsule A was completed in October 1980. Preliminary CVN impact data for HSST plate 02 steel, irradiated at 288°C to an estimated fast neutron fluence of 2×10^{19} neutrons/cm^2 ($E > 1$ MeV), indicated a transition temperature shift near that predicted by *Regulatory Guide 1.99*, but the upper-shelf energy loss was only one-third of that predicted. Capsule B completed irradiation in March 1981 with most of the specimens receiving an estimated fast neutron fluence of 2×10^{19} neutrons/cm^2 ($E > 1$ MeV). Capsule C, which began irradiation in May 1981, contains specimens of "current practice" submerged arc welds having copper contents of 0.046 and 0.056%. Capsule D assembly, to begin July 1981, will contain specimens from the Federal Republic of Germany.

Studies on the Fossil Energy Materials Program have emphasized mechanical property characterization of thick-section carbon and low-alloy steels for liquefaction and gasification pressure vessels. Tensile properties and CVN impact toughness have been determined over a wide temperature range for A-516, grade 70; A-533, grade B, class 1; A-387, grade 22, class 2; and weldments of those steels. The materials have been postweld heat treated (PWHT) for varying times to determine the effects of extended PWHT times on mechanical properties. Additionally, various heats of 2¼ Cr-1 Mo steel with chemical compositions modified to increase hardenability have been obtained from the Japan Steel Works and U.S. Steel and are being similarly characterized. Future testing will include fracture toughness determinations by elastic-plastic analyses such as the *J*-integral.

WELDING AND BRAZING

G. M. Goodwin

The Welding and Brazing Group continues to conduct materials joining research and development for light water reactor, reactor safety, fossil energy, fusion energy, basic energy sciences, gas-cooled reactor, space-nuclear, and fast breeder reactor projects.

Light water reactor and reactor safety activities have centered around the Advanced Instrumentation for Reflood Studies (AIRS) Program. Over 100 complex ceramic-to-metal instrumentation subassemblies have been successfully fabricated and delivered to facilities in the Federal Republic of Germany and Japan.

The Fossil Energy Program has emphasized evaluating heavy section weldments and weld overlay cladding. Analysis of a 300-mm-thick (12-in.) submerged arc weld in 2¼ Cr-1 Mo plate from an industrial supplier was completed, and additional plates and weldments are being procured. Weld overlay specimens have been corrosion tested here and at the SRC-I Pilot Plant.

Work on fusion energy consisted of welding assistance to the Large Coil Program.

The basic energy sciences welding study has continued investigating the solidification of austenitic stainless steels and iron-chromium-nickel alloys. A significant contribution involved the identification and characterization of four distinct morphologies of the δ-ferrite phase.

Gas-cooled reactor efforts have developed laser and electron beam welding procedures for a number of advanced alloys, including cast austenitics and mechanically alloyed materials such as International Nickel Company's MA-956.

For space-nuclear applications, we have continued to characterize the weldability of thorium-doped iridium alloys by several processes, including continuous-wave laser welding.

The breeder reactor programs have demonstrated commercialization of controlled residual element (CRE) stainless steel filler metals. The evaluation of large commercial heats has been completed, and the characterization of pipe produced by centrifugal casting and spin-forging has been reported. Graded transition spoolpieces are being produced by vacuum arc melting; the weldability of advanced 9 Cr alloys is being evaluated. Mechanical properties comparable to base metal values can be achieved by use of matched-composition filler metal with the gas tungsten arc process.

2. Fuels and Processes

R. G. Donnelly

The diversification from complete dependence on nuclear fuels research and development (R&D) toward a more balanced mix of nuclear and nonnuclear energy activities has continued over the past few years to the point that no single program currently accounts for more than about 17% of the section's support. Specialized manufacturing production, including fabrication of cermets for the Nuclear Regulatory Commission (NRC) Advanced Instrumentation for Reflood Studies (AIRS) Program and iridium disks and carbon fiber insulation for the Space Power Program, has increased and now represents 20% of the section's activities. This year, however, decreases in programmatic R&D were not fully offset by new initiatives. This and anticipated reductions in FY 1982 support resulted in a reduction of nine staff members (seven technicians) and consolidation of two former groups into the new Fuel Cycle and Engineering Analysis Group.

Section-managed programs continue to include the space power program, the graphite programs, and the national Building Thermal Envelope Systems and Insulating Materials (BTESIM) Program. Management of the remaining work on the irradiation testing task of the proliferation-resistant research and test reactor fuel element development program was transferred to the Engineering Technology Division of ORNL for completion.

Research activities and accomplishments of the functional groups reporting through this section during the past year are summarized below.

CERAMIC TECHNOLOGY

D. R. Johnson

Ongoing studies of pyrolytic SiC coatings for High-Temperature Gas-Cooled Reactor (HTGR) fuel have clarified relationships among properties, microstructural characteristics, and process variables. Recent transmission electron microscopy (TEM) studies are directed toward interactions with fission products and effects of radiation damage. Candidate structural ceramics for the HTGR core support are being evaluated. Characterization of several silicon nitrides before and after creep testing has identified dominant creep mechanisms. This is necessary to extrapolate the results of accelerated creep testing for predicting 30- to 40-year behavior.

A new program to develop improved solid electrolytes for sodium-sulfur batteries includes characterization of β''-Al_2O_3 electrolyte tubes. This program, which will emphasize the use of ceramic-metal composites as solid electrolytes, has the potential for creating an entirely new class of materials.

We continued development and production of carbon-bonded carbon-fiber (CBCF) insulation for use in the General Purpose Heat Source for the space program. Parts have been fabricated, characterized, and delivered for various testing programs. A quality assurance program was developed to control the fabrication and characterization processes.

We supported the Department of Energy (DOE) Brayton cycle waste heat utilization program by characterizing flue-gas particulates from operational industrial glass furnaces. We also contributed to materials testing through identification of candidate materials and test conditions; managed a subcontract for development of a thermal analysis code for glass furnace regenerators; and fabricated monolithic refractory specimens, which were tested and evaluated as potential recuperator materials in a glass furnace exhaust atmosphere.

Cordierite recuperators, representing a type used in DOE demonstrations of industrial waste heat recovery, were tested in the Refractory Test Facility to determine the effects of combustion products of both No. 6 oil and coal-oil mixtures on performance. We concluded that these particular recuperators are not suitable for use with dirty fuels unless a method of ash removal from the recuperator is provided. Materials support has been provided to a DOE contractor conducting demonstration tests of a stainless steel reradiant recuperator on an industrial furnace for melting aluminum scrap. Severe corrosion was determined to be caused by chlorides and or sulfur in hot flue gases. Rigid ceramic fiberboard was recommended as an alternative material.

A new testing program was started to identify the best commercially available devices for measuring oxygen in coal-burning fluidized-bed combustors. We are testing ceramic electrolytes and other devices to determine which types are capable of making the required measurements.

Electron and optical microscopy studies of coal have continued. We observed and identified a possible mechanism for the transformation of pyrite to pyrrhotite during electron beam heating in a high-voltage electron microscope. Our use of the near-infrared microscope was broadened to include subbituminous and low-volatile bituminous coals, and we expanded our coal structure program to include differential thermal analysis (DTA) of whole coal and separated macerals.

We continued development and production of Al_2O_3-Pt cermets for electrical insulators with high thermal shock resistance for the AIRS program. Insulators of Al_2O_3-Cr with equivalent thermal shock resistance were developed.

A series of experiments was completed to determine the oxidation characteristics of ThC, $(Th_{0.69}U_{0.31})C$, and (for comparison) UC fuel materials. Information on the oxidation behavior of these carbide fuels is needed to establish the requirements for fabricating and reprocessing them.

We initiated a new program to characterize and test commercial materials used as trim in severely erosive service and as high-pressure letdown valves in coal liquefaction pilot plants. Various techniques, such as optical and electron microscopy and x-ray and electron diffraction, are used in these characterization studies to gain a better understanding of the erosion mechanisms experienced in the synfuel pilot plants.

Another activity initiated this year is the study of atmospheric exposure effects on the performance of photovoltaic cells under concentrated (~40×) insolation. This work is intended specifically to improve the technical understanding of in-service photovoltaic cell behavior of concentrated insolation in nonarid, forested-agricultural or industrial areas typical of U.S. population centers.

The determination of physical property changes in graphite irradiated in various reactors was continued, and the effects of steam oxidation and neutron irradiation on the fracture mechanics of graphite were determined. A series of graphite specimens containing a dispersion of metal carbide particles (WC, TaC, and ZrC) was fabricated for the Navy, and examination of these composites has begun. The mechanical properties of several charcoals were evaluated for possible use as filters in the primary coolant loop of naval submarine reactors.

FUEL CYCLE AND ENGINEERING ANALYSIS

W. J. Lackey

This group develops processes and equipment for radioactive waste disposal and nuclear reactor fuels fabrication and performs engineering analyses in these areas and in the areas of materials for fossil energy applications and energy conservation. The high-level waste effort uses sol-gel and coating technology for preparing spheres of crystalline ceramic waste forms. Concrete waste forms for solidification of high-level and transuranic wastes are being characterized. New work in low-level waste management focuses on disposal or reclamation of contaminated metal scrap. Our fuels work is divided into two areas: (1) fabrication of breeder reactor pellet fuels by pressing gel-derived spheres (the sphere-cal process) and (2) fuel particle preparation and coating for HTGR fuels. Task management and materials design reviews are performed as part of the Fossil Energy Materials Program. The group also performs task management and experimentation for the materials project of the Energy Conversion and Utilization Technology Program and also for the Residential Conservation Service Program.

Sol-gel and fluidized-bed coating processes were successfully applied in producing highly inert, leach-resistant alternative high-level waste forms. The internal gelation process was emphasized in making dense spheres of Synroc containing commercial or defense waste. All particles were successfully coated with pyrocarbon and silicon carbide at temperatures as low as 1000 and 900°C, respectively. A generic cesium-bearing coated-waste form has been developed, which can be applied to any waste form, including glass. Aqueous leach contaminant test data of the coated-waste forms were below the detection limits of analytical techniques.

A new low-level waste task has the objective of formulating a comprehensive management program for contaminated metal scrap generated at sites managed by the DOE Oak Ridge Operations Office (DOE-ORO). A metal smelting facility to be located at the Oak Ridge Gaseous Diffusion Plant was identified as a necessary complement to existing capabilities, and conceptual design of the facility has begun. Development efforts supporting the facility will include uranium recovery from slag, slag disposal, and aluminum decontamination.

Concretes formed under elevated temperatures and pressures offer excellent possibilities as containment for radioactive wastes. We began studies to identify phases and partitioning of radionuclides in such concretes. About ten separate phases have been identified. Phase identification and radionuclide partitioning data will help us prepare concrete with greater leach resistance and will provide a better understanding of concrete that should increase the overall confidence in this waste form.

We successfully prepared fuel pellets from UO_2 and $(U,Pu)O_2$ gel-derived microspheres and achieved the desired pellet densities and microstructures.

Dense UC_xO_y is one of four kernel compositions being evaluated as HTGR fuel, and we are working jointly with the General Atomic Company to optimize the sphere-forming, calcining, and sintering processes. Significant progress was made in reducing the sintering time and temperature.

We are working jointly with the Fuel Recycle Division to develop, design, construct, test, and evaluate a welding system that can remotely repair piping systems within a fuel reprocessing facility.

We continued our lead roles in the materials design review and monitoring of research and development for the Solvent Refined Coal (SRC) demonstration plant projects and in the preliminary design of the H-Coal commercial plant project. An assessment of foreign activities in the selection and development of materials for use in coal liquefaction plants was completed. We also continued coordination and control activities for the Fossil Energy Materials Program; a program plan was completed, and a program-wide quarterly technical progress reporting system was devised and initiated. Coordination of the determination of causes of and solutions for severe corrosion of SRC pilot plant components is continuing.

We were selected by DOE to manage the materials project of the Energy Conversion and Utilization Technology (ECUT) Program, which was established to conduct applied research to develop base technologies for energy conservation. We prepared a preliminary annual operating plan for FY 1981 and a long-range project plan for FY 1981 through FY 1987. The project plan provides the basis for selecting future experimental projects from the following areas: (1) materials for high-temperature waste heat recovery, (2) materials for low-temperature waste heat recovery, (3) insulation, (4) materials for heat engines, (5) materials processing, (6) tribology, (7) recycle of waste materials, and (8) lightweight materials for ground transportation.

We continued to provide technical support to the Residential Conservation Service (RCS) Program in three principal areas of program implementation: rulemaking, technical assistance to states, and R&D. We completed an RCS auditor training manual, validated approximately 35 audit procedures for states and utilities, and supervised completion of a number of auditor-training activities. We continued our in-house research and development on (1) settling of loose-fill attic insulation, (2) thermal performance of attic insulation, and (3) seasonal furnace efficiency; data acquisition and analysis were the principal efforts on tasks 1 and 2, and a final report was prepared on the results of task 3.

FUELS EVALUATION

F. J. Homan

The HTGR Base-Technology Program continues to support most of the Fuels Evaluation Group. However, during the past year some support was provided by the Magnetic Fusion Energy and the High-Temperature Applications of Solar Energy programs. In HTGR-related work, the group continues to specialize in unique postirradiation examination (PIE) capabilities emphasizing quantitative measurements of fission product inventories by use of the irradiated microsphere gamma analyzer (IMGA) and the postirradiation gas analyzer (PGA) systems. These techniques are highly regarded by others in the HTGR community, such as the General Atomic Company and Kernforschungsanlage (KFA) Jülich who regularly send samples to ORNL for analysis.

The IMGA system has operated for the entire year examining coated-particle fuels from a number of irradiation tests. Results have shown significant releases of metallic fission products (e.g., ^{137}Cs) from Biso-coated ThO_2 at temperatures and burnups typically envisioned in a commercial HTGR. Radioactive silver release from SiC-coated particles is still being examined, and preliminary results show a dependence on temperature, fast neutron damage, and SiC properties. Recognizing this dependence, we fabricated and irradiated a capsule test. Detailed examination of the capsule began in June.

The PGA system routinely measured gaseous fission product inventories in coated particles. We found that the permeability characteristics of the pyrocarbon on Biso-coated ThO_2 varies widely from particle to particle within any one batch irradiated under the same conditions. Concern over the gaseous and metallic fission product release from Biso coatings led to a decision to replace the Biso design with a Triso design on the fertile particles.

Cooperative work with the KFA is continuing under the HTGR "Umbrella Agreement" between the United States and the Federal Republic of Germany. Work was completed and a final report written on fission gas permeability of pyrocarbon coatings (mentioned above). Work was also completed on comparison of the PIE techniques of ORNL and KFA to assess particle irradiation performance. Consequently, KFA has stopped development of its postirradiation annealing technique in favor of the IMGA.

Because of our experience in thermal analysis of our own irradiation capsules, we perform the service function of thermal design for irradiation capsules for the Radiation Effects and Microstructural Analysis Group. The work, supported by our Fusion Energy Materials Program, tests candidate materials for fusion reactors.

Work was completed and final reports written for two tasks on materials for high-temperature applications of solar energy. We found that silicon carbide materials were the leading candidates for use at high temperatures under anticipated fuel and chemical processing environments. We also assessed current ceramic fabrication technology for solar receivers to be used in fuel and chemical processes. We found that, although the fabrication technology is adequate, operational experience with hazardous chemicals does not currently justify solar-powered chemical production.

METALS PROCESSING

R. L. Heestand

Activities supporting space and terrestrial power systems continued to center on fabricating iridium containment for General Purpose Isotopic Heat Sources. Production levels were initially set at 600 forming disks for the year but were increased to 725 forming disks in the last quarter. An iridium production task force was formed early in the year to evaluate fabrication problems and forming defects that arose in changing from a hemisphere for the Multihundred-watt Heat Source to a deep-drawn cup for the General Purpose Heat Source. The task force recommendations were investigated on an experimental basis, and many were incorporated into the fabrication procedure. A reallocation of development funds precluded completion of several of the tasks. An iridium management plan was developed and implemented for control of inventories, refining, and financial plans for ORNL and all subcontractors for the Space and Terrestrial Systems Program. Under this system, ORNL has responsibility for managing and refining all program iridium.

The Waste Management Program on the "Volume Reduction of Low-Level TRU Contaminated Metals by Melting" was continued to complete experiments on the removal of plutonium by slagging reactions. Experiments indicated that plutonium could be removed to the same levels as uranium. An engineering-scale demonstration for uranium decontamination is being conducted in conjunction with Paducah Operations. This consists of melting and slagging a 100-ton contaminated melt, followed by determining residual contamination on the resultant 1-ton ingots. In another program a survey of the existing contaminated DOE-ORO scrap inventory is being conducted and plans made for melt-slag decontamination.

Efforts were continued on the fabrication of large heats of radiation-resistant D-9 stainless steel for use in fusion energy alloys. Similarly, a large heat of modified 9 Cr-1 Mo steel was procured for breeder reactor experimental use. Mechanical properties of these heats were found to be superior to commercial alloys. In addition to the modification of commercial alloys for radiation resistance, the scale-up of semiproduction quantities of long-range-ordered alloys was initiated. These high-temperature high-strength alloys, developed at ORNL, will be prepared commercially by both electron beam and electroslag melting to provide material for neutron irradiation, mechanical property, and compatibility tests.

The effort on fabricating experimental molybdenum heat pipes for Los Alamos National Scientific Laboratory in support of the Space Reactor Electric Power Supply (SPAR) was expanded to include molybdenum-rhenium alloys. This includes fabrication of both heat pipe tubing and wire for capillary screens.

3. Materials Science

J. O. Stiegler

Research in the Materials Science Section is directed toward understanding structure-property relationships in terms of processes occurring at the atomic level. Such an understanding can lead to the development of principles for the design of improved materials. The work ranges from efforts to control the composition and microstructure of conventional austenitic and ferritic steels for applications in breeder and fusion reactor systems to the exploration of novel processing techniques for synthesizing new metals and ceramics for possible use in advanced energy systems.

About 65% of our support comes from the Division of Materials Sciences of the Office of Basic Energy Sciences. This work, which is generic in nature, is aimed toward providing a technology base for addressing materials problems 10 to 15 years from now. Nearly 20% of our support is directed toward development of structural materials for high-flux regions of breeder and fusion reactors. Additional programs are funded by the Offices of Fusion Energy on Plasma-Surface Interactions, Fossil Energy on Structural Ceramics, and Conservation on Thermal Insulation.

The success of determining structure-property relationships rests on our ability to define structure precisely and quantitatively. We have therefore devoted substantial effort and resources in recent years to developing a state-of-the-art capability in techniques for characterizing materials. Facilities for these techniques, which are available for use by members of the university and industrial communities, are described more fully in Chap. 5 on Specialized Research Facilities and Equipment. During the past year our small-angle x-ray scattering laboratory was transferred to the National Center for Small-Angle Scattering Research, which is managed by the Solid State Division.

Descriptions of activities and accomplishments of groups in the section are given in the following paragraphs.

ALLOYING BEHAVIOR AND DESIGN

C. C. Koch

The primary goal of the Alloying Behavior and Design Group is the development and understanding of the principles of alloying behavior and of structure-property relationships and their application to the creation of new materials to meet energy technology needs. The group focuses on three major programs: (1) metastable materials, (2) deformation and mechanical properties, and (3) high-temperature alloy design.

The metastable materials program has emphasized the development of facilities to produce amorphous alloys by rapid quenching from either the liquid or vapor state. The formation, structure, stability of the amorphous phase, and selected property measurements of several amorphous alloy systems have been studied. Molybdenum-base amorphous alloy superconductors are studied as prepared by vapor quenching (in argon or N_2) or liquid quenching alloys containing metalloids such as phosphorus, boron, or silicon. Superconductivity also provides useful information on the structure of metallic glasses. Small-angle x-ray scattering on the ORNL 10-m Small-Angle X-Ray Scattering Facility (SAXS) is being used to help define the defect structure and compositional homogeneity of metallic glasses. We have used rapid solidification to modify the microstructure of several long-range-ordered (LRO) alloys of the $(Fe,Co,Ni)_3V$ type.

The immediate goal of the deformation and mechanical properties program is to understand the physical mechanisms of deformation and fracture in model systems (nickel and nickel-base binary alloys) and commercial alloys (austenitic stainless steels and nickel-base superalloys) at elevated temperatures under low applied stresses. Effects of trace elements on grain boundary cavitation under creep and fatigue test conditions are investigated by Auger spectroscopy. Use of the 30-m Small Angle Neutron

Scattering (SANS) Facility to study grain boundary cavitation has been initiated. The 1-MV High-Voltage Electron Microscope (HVEM) is used to provide direct microstructural information to aid the SANS study. Recent theoretical progress includes modeling of impurity-induced microvoid formation and effects of internal stress on grain boundary crack initiation.

The alloy design program has been concerned with the LRO alloys in the $(Fe,Co,Ni)_3V$ system for applications (including magnetic fusion first wall material) and with the iridium-base alloys for space power applications. Plans have been formulated and a seed money proposal funded for partial support of an alloy design program based on LRO alloys and intermetallic compounds for potential use at elevated temperatures in energy technology systems.

PHYSICAL PROPERTIES

D. L. McElroy

Physical properties are measured and analyzed to obtain an understanding of charge and heat transport behavior. These efforts on research and engineering materials are principally supported by the Division of Materials Sciences, the Building and Industrial Conservation programs, and the Breeder Reactor Program.

Experimental determinations were made of the phonon and electron components of the thermal conductivity of elemental iron, niobium, and tantalum. The phonon conductivity includes scattering terms caused by electron-phonon and phonon-phonon interactions. The former is large for niobium and tantalum and provides an important test of electron-phonon interaction theory. The electronic Lorenz functions of niobium and tantalum approach the Sommerfeld value. Similar studies are in progress for nickel. The electrical resistivity of a series of dilute palladium-base alloys was measured because these values may be calculated theoretically. Different theoretical models were verified as being capable of predicting thermal conductivity on (1) AXM-5Q1 graphite within 3% from 200 to 950 K and (2) microspheres of UO_2 or ThO_2 in helium. An apparatus for property measurements to 2600 K is being tested with a graphite standard.

The Conservation Program supports evaluations of properties, test methods, and the influence of operating environments of building and industrial thermal insulations. We are involved in developing standards and in cosponsoring conferences with ASTM Committee C-16 on Thermal Insulations and Subcommittee C-16.30 on Thermal Measurements. Research to improve the technical data base on insulating materials is performed both in house and by subcontract.

The physical properties of standard and modified 9 CR-1 Mo steels in the normalized and tempered states show the thermal stress factor to be twice as good as that of Inconel 718.

RADIATION EFFECTS AND MICROSTRUCTURAL ANALYSIS

E. E. Bloom

The primary objective of the Radiation Effects and Microstructural Analysis Group is to elucidate the role of microstructure, composition, and service environment on the behavior of materials and to develop materials with microstructures and compositions tailored for specific applications. Two mission-oriented or applied alloy development programs (supported by the Office of Fusion Energy and the Division of Reactor Research and Technology) are complemented by programs on radiation effects and analytical and high-voltage electron microscopy (supported by the Division of Materials Sciences). Electron microscopy (transmission, analytical, and high voltage) and surface analysis techniques (Auger spectroscopy) are used to characterize structure and composition on a microscale. The Oak Ridge Reactor (ORR), High Flux Isotope Reactor (HFIR), Experimental Breeder Reactor-II (EBR-II), Oak Ridge Isochronous Cyclotron (ORIC), and dual-beam Van de Graaff Facility are used in irradiation damage studies.

Analytical and High-Voltage Electron Microscopy

Research during the last year focused on development and evaluation of instrumentation, new methods and techniques of materials characterization, and application to a wide range of materials. Some of the applications involved collaboration with non-ORNL staff on the Shared Research Equipment (SHaRE) Program.

High-resolution-imaging techniques have been applied to the characterization of the interface structure of precipitates in austenitic stainless steels. Although reliable methods for revealing the interface boundary dislocation structure by weak-beam and lattice imaging have been successfully identified, the determination of Burgers vectors requires a more detailed investigation. Such work is in progress.

Detailed observations and dynamical calculations have provided a quantitative understanding of thickness fringe contrast at grain boundaries in transmission electron microscope (TEM) and scanning transmission electron microscope (STEM) modes and its relationship to the top-bottom effect.

A postspecimen scanning system on the field emission gun analytical electron microscope has been developed, which allows us to obtain energy-filtered intensity profiles of images or diffraction patterns. Uses include on-line computer analysis of "rocking curve" profiles in convergent-beam electron diffraction (CBED) patterns, from which accurate values of foil thickness can be obtained rapidly (<1 min). The characterization of complex ordered or modulated structures from diffuse elastic electron intensity profiles is also under way.

A number of improvements to the two electron energy-loss spectrometers were made. We continued our evaluations of the reliability of quantitative analysis made on a wide range of specimens by use of both *K* and *L* ionization edges. Some discrepancies were found, but the overall results were encouraging. A new, improved background-fitting procedure was developed for spectra involving *M* edges of transition metals.

In situ experiments in the high-voltage electron microscope continued. Dislocation motion and details of the propagation of shear cracks, such as ligament formation, were observed by in situ deformation of precipitation-hardened Al-4 wt % Cu and 2024 aluminum alloys. Little strain localization in precipitate-free zones was observed. Further studies are under way on alloys in their maximum hardness condition, where ductile intergranular failure is most likely to occur. Experiments on in situ oxidation of vanadium and vanadium-titanium alloys have continued. A detailed determination of the structure of the different phases that form (depending on foil thickness) also involved analytical and lattice imaging experiments. The disorder commonly observed arises from the low transformation temperature and the rapidity of the oxidation process.

Many applications employing state-of-the-art techniques were made on materials science problems during the year. In nickel-bonded TiB_2 ceramics (intended for use as hard wear-resistant materials) an intergranular phase was identified and characterized in detail as nonstoichiometric boron-deficient Ni_3B. A successful correlation was made of unusual strain softening behavior with deformation cell size and other microstructural features in ferritic 9 Cr-1 Mo alloys. The characterization of defect structures in annealed ion-implanted GaAs necessitated the use of high-resolution weak-beam techniques. An important finding was the presence of Frank dislocation loops as the major damage component, and a model correlating electrical activity with such microstructural details is being developed. The deformation substructure as a function of the composition of the binder phase in deformed cemented WC was investigated with the HVEM. Details of faulting, hexagonal close-packed phase formation, and twinning were investigated and interpreted for the expected deformation modes of the binder.

Radiation Effects

The mechanistic understanding of the processes by which irradiation changes physical and mechanical properties of metals and alloys is the primary objective of the Radiation Effects Task. The program is focused on the phenomena and conditions encountered or anticipated in fission and fusion reactors. Results of this work provide guidance to the alloy development programs. The current scope includes cavity swelling, irradiation creep, and embrittlement. An integrated theoretical and experimental approach is brought to bear on major problem areas.

Simultaneous nickel and helium ion bombardments have led to an improved understanding of the role of helium in microstructural development. Ferritic materials irradiated with neutrons or bombarded with simultaneous iron and helium beams are being studied. Both high-purity iron and iron-chromium alloys as well as commercial steels are included. The irradiation behavior of the LRO alloys developed elsewhere in this division is being studied. The first phase of a program of pulsed ion beam bombardment of a high-purity stainless steel was completed. This area is also of interest in connection with the pulsed environment of planned fusion reactors. The effects of irradiation-induced phase instability on swelling and the related effects of helium on phase instability are being pursued in close cooperation with the alloy development programs.

The theory of radiation effects is a major area of development. In the past, emphasis was on establishing the framework of the rate theory description and on modeling the effects of charged particle bombardment, including the large increase in damage rate and the marked spatial variation in swelling. More recently, impurity effects have been emphasized, and this resulted in the development of the theory of point defect trapping and its influence on cavity nucleation, cavity growth, and irradiation creep. The effects of impurity segregation on cavity nucleation and growth were explored by determining the changes in sink capture efficiencies with segregation. In alloys, second phase precipitates are also often a major feature of the microstructure. In the past year an important extension of the theory was to treat mechanisms affecting swelling in alloys with precipitates. This led to an improved understanding of swelling kinetics in complex alloys, especially the often observed increase in swelling from precipitation. In the past year an additional important result was achieved, the application of our cascade diffusion theory to establish the theory that cascade-induced point defect concentration fluctuations and the consequent dislocation climb excursion response can lead to significant irradiation-induced creep rates. This work led to the identification and quantitative evaluation of a mechanism of irradiation creep.

Fast Breeder Reactor Cladding and Duct Alloy Development Program

This work forms part of a national program to develop alloys with improved resistance to high-temperature irradiation damage for fast reactor core applications. Three major elements are (1) development of modified type 316 stainless steels with improved resistance to void swelling, (2) assessment of the effects of irradiation on the high-strain-rate deformation and fracture behavior of advanced alloys, and (3) fabrication development.

Previous irradiation with 4-MeV nickel ions showed that the swelling behavior of type 316 stainless steel could be substantially reduced through modifications to the composition, principally through the addition of silicon and titanium. Based on these initial studies, a series of austenitic stainless steel alloys with systematic compositional variations were neutron irradiated in EBR-II, and their radiation response was examined by analytical electron microscopy. Some 13 phases have been identified and their crystal structure and chemical composition characterized. Irradiation does not produce completely new phases. However, as a result of radiation-induced segregation (principally of nickel and silicon) and of enhanced diffusion rates, several major changes in phase relationships were found to occur during irradiation. First, phases characteristic of remote regions of the phase diagram appear unexpectedly and dissolve during postirradiation annealing (radiation-induced phases). Second, the compositions of some phases are significantly altered during development by the incorporation of nickel or silicon (radiation-modified phases). Several phases also develop at significantly lower temperatures during neutron irradiation (radiation-enhanced phases).

These phase instabilities are coupled to swelling behavior by three mechanisms: (1) helium trapping at particles and direct void-particle association, (2) modifications to the dislocation structure, and (3) depletion of matrix solute or solvent concentrations. Based on this understanding, commercial heats with improved compositions are being procured for irradiation testing in the Fast Flux Test Facility.

The successful application of the titanium-modified stainless steels to the manufacture of cladding and duct components necessitates some modification to existing type 316 stainless steel fabrication technology. A basic understanding of the fabrication technology of these alloys has been developed on flat products. The principles developed are being implemented in the production of thin-walled fuel pin cladding in the tube-drawing and continuous-hydrogen-annealing facilities in the Metals Processing Group.

Alloy Development for Irradiation Performance

An extensive effort was undertaken to develop alloys capable of withstanding the fusion reactor environment long enough to achieve economical fusion power production. With this as a long-range goal, the program must also provide design data for alloys to be used in near-term experimental fusion reactors such as the Fusion Engineering Device (FED).

To reach both these goals, five alloy paths are being investigated. The first and most developed path consists of austenitic steels and is followed by ferritic steels, high-strength Fe-Ni-Cr alloys, reactive and refractory metal alloys, and innovative concepts, which currently consist of only LRO alloys. Austenitic and ferritic steels are being considered for both the FED and the long-term applications; the remaining alloys are being considered for only the long term.

Helium produced by transmutation is a primary factor in determining radiation-induced swelling, microstructural evolution, and mechanical property degradation. Because the helium effects tend to limit lifetime, they are the focus of much of our research. In nickel-containing alloys, helium may be introduced simultaneously with displacement damage through irradiation in mixed-spectrum reactors such as HFIR and ORR.

A rather complex experiment is being conducted in the ORR to produce the same helium-to-displaced-atom ratio in an austenitic stainless steel as that which will be produced in a fusion reactor. The research has led to the development of a prime candidate austenitic stainless steel with improved radiation damage resistance. Several thermomechanical conditions have been developed, which result in desirable microstructures. Materials in these conditions are being irradiated to investigate their response to displacement damage and helium. The improved properties result from additions of titanium that result in precipitation of TiC particles. When the alloy is treated to produce a homogeneous fine distribution of TiC, the precipitate particles trap helium and prevent its migration to grain boundaries and its aggregation to form large bubbles. Phase stability during irradiation and the use of microstructural features such as dislocation substructures and precipitates to trap helium are under investigation.

Significant work was done on swelling of austenitic alloys, which led to the discovery of a low-temperature swelling peak. Further studies on swelling mechanisms led to the development of an equation to describe swelling in type 316 stainless steel on the basis of a fundamental understanding of microstructural evolution.

Irradiation in HFIR at 550°C to damage levels of up to 15 displacements per atom (dpa) and 850 at. ppm He showed little influence on the fatigue life of type 316 stainless steel at 550°C. The only notable effect was a decrease in the strain range of the endurance limit from 0.35 to 0.30%. This strain range corresponds to a thermal strain induced by a wall loading of 5 MW/m^2 in a 3-mm stainless steel wall, which is within the acceptable design envelope.

Experiments on ferritic alloys (mostly Fe–12% Cr–1% MoVW and Fe–9% Cr–1% MoVNb) focused on low temperatures, primarily 50°C. Fracture properties such as Charpy impact, crack growth, and fracture toughness must be addressed in these materials. Because the FED will operate below 300°C, low temperatures were selected to represent a relevant worst-case situation. Specimens of these alloys, both at their nominal composition and doped with up to 2% Ni to form helium, were irradiated in the HFIR. Tensile tests revealed very significant radiation hardening but no discernible effect of helium. Future research will extend this work to higher temperatures and examine Charpy impact specimens now being irradiated.

For LRO alloys emphasis is being shifted from ion bombardment to neutron irradiation. The first neutron-irradiated material became available this year. Swelling measurements on material irradiated in the ORR to approximately 5 dpa demonstrated the value of titanium additions to control swelling. Specimens irradiated to higher fluences are now available and are being examined. This research will lead to tailoring the composition of this class of alloys for irradiation resistance.

Smaller emphasis is being placed on refractory metals, titanium alloys, and high-nickel alloys. Tensile, fatigue, and transmission microscopy specimens of these materials from neutron irradiation experiments are being examined on a secondary priority basis. Cyclotron implantation of helium in vanadium alloys followed by fast reactor irradiation has shown a very significant effect of helium on mechanical properties. Further research is being conducted to validate the cyclotron implantation method of helium doping in vanadium alloys.

Structure and Properties of Surfaces

Surface analytical techniques are being used to study the influence of the structure and composition of surfaces on plasma-wall interactions in fusion devices and, conversely, the effects of such interactions on surfaces.

We are monitoring changes in the surface composition and structure of small samples of wall and limiter materials exposed in the Impurity Study Experiment-B (ISX-B) tokamak and the Elmo Bumpy Torus (EBT) torroidal confinement device to study impurity transport and to optimize impurity control. These studies are supplemented with studies in a small laboratory device wherein plasma-wall interactions can be studied under a wide range of controlled conditions.

Laboratory studies are currently concentrated in the area of hydrogen recycling and hydrogen-metal interactions. Recycling from the walls and limiters of tokamaks is the major source of hydrogen to the plasma. The composition and structure of the surface play strong roles in recycling, but the mechanisms involved are neither well characterized nor understood. We are studying these processes empirically to determine which are most important and the extent to which they can be controlled by materials selection and surface treatment. Isotope exchange experiments under conditions simulating ISX-B operation show that recycling from oxygen-contaminated stainless steel walls changes to 70% of the new isotope in five 200-ms pulses. Clean walls change much more quickly. The rate of change can be used to separate surface effects from bulk properties and to separate ion-bombardment-induced processes from thermal processes. Each can be important, depending on temperature and ion fluxes as well as on surface conditions.

Unipolar arcing occurs in all tokamaks and may be an important source of metallic impurities in the plasma. Our previous studies correlated arcing with surface cleanliness and plasma instabilities. High-speed photographic techniques are being used to study the details of the plasma-wall interactions on the main limiters in ISX-B. Correlation of arcing with magnetohydrodynamic (MHD) activity and major disruptions shows that particles and vapor resulting from arcing on the limiters can cause major plasma disruptions and thus terminate the plasma pulse. Titanium carbide coatings on POCO graphite limiters are badly damaged by arcing and the extremely high-energy fluxes but gradually become conditioned and provide good service. Bare graphite limiters will be tested for comparison. The various types of arcing on the limiters have been categorized, and we are trying to correlate them with plasma and materials properties to provide a means of protecting the limiters and keeping plasma impurity levels as low as possible. Studies of transport of materials into the plasma from natural arcs and artificially triggered arcs in the plasma edge are continuing; this work will help assess the importance of arcing in the plasma edge as a source of impurities for the core plasma.

STRUCTURAL CERAMICS

V. J. Tennery

The work of this group has emphasized several principal areas. One is the synthesis, fabrication, and characterization of hard ceramics, with the objective of achieving an understanding of how the microstructure and microcomposition determine the macrobehavior of these materials under highly erosive and high-stress conditions.

A second area involves studies of the behavior of selected structural ceramics in high-temperature fossil fuel combustion environments such as those anticipated for heat exchangers in direct coal-fired and other advanced fossil energy systems. The objective of this activity is to determine if structural ceramics based on SiC, Si_3N_4, or Al_2O_3 have the requisite stability to function as heat exchanger surfaces in the highly corrosive and erosive environments anticipated in certain advanced fossil energy systems and to identify important degradation mechanisms and the means for impeding them.

A third area involves the mechanical behavior of ceramic dielectric windows in gyrotron tubes to be used for microwave heating of the plasma in fusion reactors. The objective is to understand the relationship between thermal stresses and externally applied stresses in the windows of these tubes under operating conditions and to correlate the stress state with the fracture behavior of the ceramics. An Exploratory Studies Project included a study of the fracture toughness of ceramic materials containing a dispersion of a metastable phase such as tetragonal ZrO_2 in a matrix of Al_2O_3. This work identified the relationships among the geometry of the dispersed phases, its structural form, its concentration, and the temperature dependence of fracture toughness of the ceramic material.

Our work on hard ceramics this year was concentrated primarily on TiB_2 caused by the reported high hardness and electrical conductivity of this compound. We determined that, when correctly sized TiB_2 powders are blended with nickel powder and hot pressed, a near-theoretical density microstructure can be achieved under relatively modest temperature and pressure conditions. This process allows rapid densification of TiB_2 with minimal grain growth of the boride. These ceramics, when properly fabricated, contain relatively low concentrations of elemental nickel (<1 wt %), and we established by analytical electron microscopy that the nickel is primarily present as Ni_3B. Several properties of the TiB_2-based ceramics were determined as a function of the processing conditions; at 25°C, flexure strengths of 700 MPa, fracture toughness of 8 MPa·m$^{1/2}$, and Young's moduli of 570 GPa were typical. Microhardness values of about 22 GPa were observed at 25°C with a decrease to about 8 GPa at 800°C. The thermal diffusivity of these nickel-sintered TiB_2 ceramics is essentially identical to that of theoretically dense find-grained TiB_2 from 25 to 1200°C. The thermal diffusivity at 600°C is about half that at 25°C. Engineering tests of these materials, including high-velocity particulate erosion, hot coal-oil slurry erosion, and metal cutting, suggest that these ceramics have promising potential for use as linings in valves and as metal-cutting tools.

Two first-of-a-kind high-temperature coal combustion experiments were conducted with structural ceramics this year. One included a 496-h exposure of a set of ceramic tubes and flexure bar specimens to the combustion products of an acidic ash bituminous coal at material temperatures of about 1250°C. The second included a 238-h exposure of the same type of structural ceramics to combustion products of a basic ash subbituminous coal at $T \cong 1250°C$. The same nominal amount of coal was burned in both experiments. Results from these experiments, which included SiC, Si_3N_4, and Al_2O_3-based ceramics, are providing insight into the practicality of using these materials in high-temperature heat exchangers in fossil energy systems. Surface corrosion of some of these ceramics by the liquid silicate sl·: resulting from melting of the coal ash was four to have a major influence on their fracture strength. Diffusion of certain elements from the slags into the ceramics at high temperatures caused appreciable increases in the thermal expansion in some cases. Ceramics based on SiC were relatively resistant to degradation by the coal combustion products.

Successful growth of some new hard refractory eutectics was accomplished. These included eutectics based on the ZrO_2-ZrB_2 and Y_2O_3-TiB_2 systems. Crack propagation through these eutectic structures was found to be much more difficult when the crack is moving across the secondary-phase lamallae. Quantitative measurements of the mechanical properties of these composite materials are in progress.

Single crystals of a ternary compound in the Ni-Ti-B system having a nominal composition of $Ni_{20.3}Ti_{2.7}B_6$ and referred to in the literature as a tau phase were successfully grown by the Czochralski method from the melt as part of our studies on hard ceramics based on TiB_2. On the basis of available phase equilibria data, this compound was anticipated to form as a secondary phase within the TiB_2-Ni ceramics discussed previously. Because this phase has not been observed, studies were initiated to determine why Ni_3B forms in preference to the tau phase and how the form of these secondary phases affects the flexure strength and fracture toughness of the TiB_2-based ceramics.

Consideration of Al_2O_3, BeO, and other ceramics for use in the output windows of high-power microwave tubes (called gyrotrons) for heating plasma in fusion reactors resulted in a critical analysis of available data required for lifetime predictions of these windows as well as initiation of experimental measurement of the static fatigue behavior of the candidate ceramic materials. Concurrent measurements of the dielectric losses in these ceramics at the Massachusetts Institute of Technology to frequencies to 300 GHz are being used to correlate electrical losses of the ceramics with the mechanical and microstructural properties.

Studies of the toughening of a normally brittle ceramic material such as Al_2O_3 by use of a dispersed metastable second phase consisting of ZrO_2 resulted in an improved understanding of the dispersion toughening process. Second-phase particles located along the Al_2O_3 grain boundaries with a diameter considerably smaller than the Al_2O_3 grain size are most effective in impeding crack propagation and thereby increasing the fracture toughness. The chemical process employed in forming the precursors of both the Al_2O_3 and ZrO_2 are very important in controlling the microstructure and thereby the mechanical properties of the resultant ceramics.

SURFACE AND SOLID STATE REACTIONS

J. V. Cathcart

Individual research projects of this group are designed to address the problems of diffusion and mass transport in high-defect solids, to investigate ways of modifying transport kinetics in these materials through the addition of impurities, and to examine the general question of stress generation and scale adherence during the growth of such high-defect scales on metals and alloys. The work is aimed specifically toward understanding sulfidation mechanisms and, in particular, transport in $Fe_{1-x}S$ and other transition metal monosulfides. However, because of emphasis on factors affecting point-defect mobility, results of much of this research are generally applicable to a range of phenomena including diffusion-controlled creep in metals and ceramics, the electrical and thermal properties of ceramic materials, and radiation damage.

We have continued to emphasize parallel theoretical and experimental programs. Theoretical studies utilize our previously developed concept of *defect* diffusion to treat the defect interactions so frequently important in high-defect solids. These ideas were used to generalize the Nernst-Einstein equation so as to make it applicable to self-diffusion in high-defect solids. The phenomenon of atomic and ionic transport via interstitial defects in which interstitial pairing occurs was treated. In collaboration with Dr. P. W. Tasker, Atomic Energy Research Establishment, Harwell, solute distribution was investigated for systems exhibiting both substitutional and interstitial defects, with special attention being given to calculations of the stability of interstitial-vacancy pairs.

Experimental work includes studies of the sulfidation kinetics of iron as a function of sulfur pressure;

diffusion in $Fe_{1-x}S$, also as a function of sulfur pressure and, hence, defect concentration; an x-ray study of the point defect structure of $Fe_{1-x}S$ single crystals (in collaboration with B. S. Borie and C. J. Sparks of the X-ray Research and Application Group); the effect of zirconium and chromium additions on the sulfidation rate of iron; mechanical stress development during sulfidation; and computer modeling of sulfide scale growth processes.

THEORY

J. S. Faulkner

A book reviewing the development of a first-principles theory of the electronic states in substitutional alloys entitled *The Modern Theory of Alloys* (*Progress in Materials Science*, to be published by Pergamon Press) was completed during the year by J. S. Faulkner.

We have used our alloy theory to explain the results of modern experiments that are specifically designed to measure the electronic states in alloys. These experiments are angle-resolved photoemission, soft x-ray spectroscopy, and positron annihilation. We have also explained some of the classic experimental measurements on alloys t' .. have been in the materials science literature for many years. For example, the electrons in a metal or alloy contribute a component to the specific heat that is linear in the temperature. The coefficient of T, called γ, is proportional to the product of the density of electronic states at the Fermi energy $\rho(E_F)$ and an electron enhancement $1 + \lambda$. We showed that the experimental values for γ as a function of concentration for the Hume-Rothery alloy copper-zinc can be reproduced exactly by our theory. We calculated the density of electronic states at the Fermi energy for pure copper with our band theory programs and for alloys of copper containing 10, 20, and 30% zinc with our coherent-potential approximation (CPA) programs. We obtained the electron-phonon enhancement factor for pure copper λ_0 from some of our first-principles calculations and estimated λ for the alloys by use of resistivity data. These calculations demonstrate that the CPA gives the correct values for $\rho(E_F)$ for alloys and that the older theory that has historically been used for alloys, the rigid-band model, is wrong.

In the paper that described our new equations for calculating the properties of random alloys within the CPA, we demonstrated algebraically that the equations suggested by other authors are incorrect. We have now demonstrated this numerically by showing that, for an exactly solvable one-dimensional model, their equations lead to such manifestly unphysical results as negative densities of states but that ours do not.

Our ability to calculate the total energies of pure metals and ordered compounds has been enhanced by developing a new set of band-theory equations, the quadraticized Korringa-Kohn-Rostocker (QKKR) equations. Calculations can be done with these equations that have almost the same accuracy as ordinary KKR calculations, but they are much faster. We will use these equations to study the thermodynamic properties of iron and iron-base alloys.

We calculated the thermal and electrical resistivities of niobium and palladium with realistic KKR energy bands and wave functions, experimental phonon frequencies, and rigid-muffin-tin electron-phonon interactions. The agreement with experiment is excellent, considering the fact that our theory has no adjustable parameters. The older *s-d* model is not too bad for palladium, but it is not supported by our calculations on niobium.

The rigid-muffin-tin approximation has proved to be a useful way to calculate electron-phonon interactions for many systems, but we would like to do better. This will require the self-consistent change in crystal potential caused by the displacement of an atom. To calculate this, we have developed computer programs for the crystal Green's function, a quantity that is also useful for calculating the formation energies of vacancies and heats of solution of impurities.

Our capability for studying atomic interactions of interfaces and surfaces has been enhanced by the development of an improved cluster technique for performing self-consistent, spin-polarized total energy calculations. We are using the technique to calculate the forces on atoms in larger clusters. Our results indicate that a sensitive balance of electron and nuclear forces of both stabilizing (net attractive) and destabilizing (net repulsive) character exists. Such analyses are valuable for deriving simplified conceptual frameworks for atomic interactions in complex systems.

The basis of all total energy calculations today is density functional theory. We analyzed the applicability of the Hellman-Feynman and virial theorems within this theory. A new exchange-correlation potential was also derived within density functional theory. This new result is of such accuracy that the effects of nonlocality can be considered.

X-RAY RESEARCH AND APPLICATION

C. J. Sparks, Jr., and H. L. Yakel

The diffraction of x rays by matter is the most widely used technique to determine the geometrical arrays of atoms and molecules. X rays also photoeject electrons to form the basis for studying electron energy levels and their charge distributions. These parameters determine the basic physical and chemical behavior of materials. Except in a few instances, theorists are unable to calculate material properties entirely from first principles. Most materials of interest consist of two or more elements in varying concentrations; therefore, the number of conceivable combinations makes detailed measurements an incredible task. Our goal is a synthesis of our experimental results with the calculations of the theorists to sort out the more promising trends and to lead the way to tailoring the physical and chemical properties of materials to our needs.

With the construction of large dedicated storage rings, intense x-ray sources are now available with a brilliance approaching electron sources and with a broad energy spectrum from which specific energies can be selected. Matching x-ray energies with resonances of specific elements permits improved location of their atoms in crystals containing elements of nearly the same atomic number and also permits exciting electrons for a host of spectroscopic probes. We are involved in a major commitment to using the National Synchrotron Light Source to improve our capabilities for studying advanced materials. This program complements our large effort in electron microscopy and provides a balanced and high capability probe for unraveling the geometrical arrays of atoms.

Our activities this past year included both small- and high-angle diffraction studies of a host of materials ranging from liquid-like polymers to crystalline metal alloys. Synchrotron radiation experiments were conducted at Stanford Synchrotron Radiation Laboratory to highlight specific atoms in some iron-base transition metal phases containing cobalt and to study the resonance interaction of x-rays near absorption edges for electronic excitation. Further insights into the interactions of x rays with matter were obtained by calculations of surface roughness and crystal perfection (extinction) on diffracted intensity. Our modeling of the geometrical structure of atoms and molecules by scattering is greatly enhanced by our improved understanding of how other x-ray interactions affect the scattered intensities. Experiments conducted at the Cornell High Energy Synchrotron Source proved our design of a crystal bending device, which for the first time provides for sagittal focusing of the horizontal divergence of the radiation for a continuously selectable range of x-ray energies to 30 keV. Crystal focusing provides an x-ray flux 4 to 20 times that obtained with mirrors.

Our x-ray laboratory provides services for other projects. Over 500 x-ray analyses are performed annually on a variety of samples. Most originate in the division and require that phase identifications, preferred orientation determinations, fluorescent analyses, crystal orientation determinations, and lattice parameter measurements be routinely performed.

4. Other Research Activities

In addition to the research activities presented previously in this report, this chapter includes Metallography, High-Temperature Materials Laboratory, and New Research Initiatives.

METALLOGRAPHY

R. S. Crouse, R. J. Gray, and B. C. Leslie

The Metallography Group provides technical assistance in general metallography, postirradiation metallography, and electron beam microanalysis (scanning electron microscopy and microprobe of both irradiated and unirradiated materials). Highlighted below are the results of failure analysis and other metallographic findings not covered elsewhere in this report.

An investigation of type 347 stainless steel tubing used in the apparatus to transfer neutron activation samples into and out of the High Flux Isotope Reactor (HFIR) was completed. The tubes had been subjected to a thermal fluence of approximately 7×10^{22} neutrons/cm^2 in the centerline of the reactor. They were compared with the upper portion of the assembly that had not been subjected to irradiation. Microhardness and bend tests revealed an expected increase in hardness and a loss in ductility for the irradiated tubing compared with the unirradiated tubing. Comparative tensile tests also showed a loss in ductility for the irradiated tubes. Yield and ultimate tensile strengths, however, did not increase to the level one would have expected from comparison with previous work conducted on this particular steel. This anomalous behavior was believed to be caused by erratic testing of the tubes in the hot cell. Scanning electron microscopy was used to a distinct advantage to show ductility characteristics of the tensile fractures. In addition, transmission electron microscopy was employed to show dislocation characteristics of the unirradiated and irradiated tubes.

The need to increase the U.S. domestic production of liquid fuels has required a more intensified study of the production of this vital fuel from coal. The H-Coal liquefaction process is one of several methods now under study. On September 20, 1980, the H-Coal Pilot Plant at Catlettsburg, Kentucky, experienced a failure of three tubes of a heat exchanger, which shut down the entire system and created an urgent need to determine the cause(s) of failure. An investigation team was assembled from ORNL; the Institute for Mining and Minerals Research (IMMR), Lexington, Kentucky; Hydrocarbon Research, the plant designer; Kobe Steel, the fabricator of the heat exchanger; and Mobil and Standard Oil of Indiana (AMOCO) to make this determination and to offer remedial suggestions. Three days later the operators of the pilot plant were notified that the tubes had failed from stress-corrosion cracking caused by the presence of chlorides or caustic. Corrosion fatigue could also have played a role in the failure.

The Metallography Group continues to provide on-site surveillance of the Department of Energy's (DOE's) solvent refined coal (SRC) plants. On demand, a team of three metallographers goes to the SRC plant and performs the necessary in situ metallographic examinations for monitoring the performance of the various components (fractionating columns, piping, etc.).

HIGH-TEMPERATURE MATERIALS LABORATORY

J. V. Cathcart

High-temperature materials problems impose significant limitations on advanced energy-generating or -converting systems (reduced efficiency and lack of reliability or, in some instances, of feasibility). Problems such as sulfur attack in a fluidized-bed combustor for coal or the high-temperature corrosion of ceramic recuperators involve rather complex phenomena. Effective solutions are most readily achieved by a multidisciplinary research staff housed in a central, specially equipped laboratory. Best results can, we believe, be obtained through integrated programs of basic and applied research. We have therefore continued our efforts to establish a High-Temperature Materials Laboratory (HTML) at Oak Ridge; our sponsor in this effort is the DOE Office of Basic Energy Sciences.

As discussed in last year's annual progress report, budgetary constraints forced a reduction in the size of the proposed HTML from about 7800 m^2 (84,000 sq ft) to about 3900 m^2 (42,000 sq ft), and a new conceptual design for the smaller building was developed. Consequently, of the six areas of functional expertise originally identified as necessary in an HTML staff, only four (structural characterization, physical properties, materials synthesis and preparation, and mechanical behavior) will be represented in the reduced HTML. However, work in high-temperature chemistry and environmental interactions will be performed in laboratories immediately adjacent to the HTML, thus ensuring that effective communications are maintained among investigators in all six research areas.

During the past year a major effort was made to establish closer ties between the HTML and the industrial research community. An Industrial Users Committee, chaired by W. D. Manly, Senior Vice President, Cabot Corporation, was formed. At the suggestion of the committee, a symposium entitled "Materials Research Highlights at ORNL" was organized, which was attended by about 25 corporate executives from U.S. companies whose products involve high-temperature materials. The symposium was well received and contributed significantly to a greater industrial awareness of ORNL-HTML programs and facilities.

Development of the integrated High-Temperature Materials Program continued during the past year. Active research programs exist in all six functional research areas of the HTML, and progress is being made in developing interfaces between basic and applied research efforts. Typical of the latter are two investigations of deformation and fracture processes, one mechanistic, the other a classical study of creep and rupture in support of the Liquid-Metal Fast Breeder Reactor (LMFBR) Pressure Vessel Program. The basic work emphasizes the role of interfaces in crack initiation processes, and in it we are utilizing the small-angle neutron scattering (SANS) facility to characterize the number and size distribution of cavities formed under stress at grain boundaries. Auger electron spectroscopy (AES) techniques provide a basis for measuring the effect of grain boundary impurities on the fracture process, and all these results are correlated with data from the applied study. These new mechanistic insights are proving useful in developing rationalizations for features of the applied data (such as a heat-to-heat variation of properties of a given steel) and in providing new techniques for identifying the causes of anomalous behavior for a particular set of test samples. Even more important is the guidance that these detailed understandings of damage accumulation mechanisms provide during the inevitably necessary extrapolation of the results of one- to five-year creep tests to the 50-year life expectancy of structural components.

NEW RESEARCH INITIATIVES

Numerous exploratory research ideas that are essentially free from constraints imposed by existing programmatic efforts and that would advance materials science and technology were generated by the professional staff during the year. These ideas were submitted to the Laboratory Seed Money Committee for support, and the following proposals were approved for investigation:

Design of Intermetallic Compounds for High-Temperature Applications

The objective of this investigation is to develop a new class of structural materials for advanced energy conversion systems. Intermetallics offer potential advantages over conventional alloys for high-temperature structural applications. However, the critical characteristic limiting the use of intermetallics is their tendency toward brittle fracture and low ductility at ambient temperatures. An exploratory study will be conducted on the design of *ductile* intermetallics through microalloying processes.

Characterization of the Mineralogy and Microchemistry of Fly Ash

Coal-fired power plants produce large amounts of fly ash, which must be used or disposed of in an environmentally acceptable way. Knowledge of the physical and chemical properties of fly ash will aid in reducing its environmental impact, enhance the potential recovery of valuable resource materials, and increase the understanding of the combustion process of coal. This study will use electron microscopy to characterize the microstructure and mineral content of two types of ash. The observed properties of the ash will be compared with the original structure and mineral distribution of the coal that produced the ash. Specimens of sintered fly ash compacts will also be examined to relate fly ash properties to the behavior of the ash in various chemical processes for resource recovery being studied at ORNL.

Applicability of Small Specimens for Determination of Qualitative Material Toughness Properties

The use of small specimens for predicting materials toughness properties could assist in assessing the integrity of components fabricated from thin-wall materials (such as the N Reactor pressure tubes) and the effects of irradiation of candidate first-wall materials for fusion reactors or light-water reactor pressure vessels. This study will test subsize fracture toughness specimens by recommended procedures and will compare the data with results obtained from standard specimens.

Ceramics-Metal Solid Electrolytes

The sodium-sulfur battery, which may be used in future electric vehicles, is limited by degradation of the electrolyte's mechanical properties by repeated cycling. In this project the existing technology for producing shock-resistant insulators based on alumina-metal composites will be adapted to β-alumina compositions in an effort to make shock-resistant sodium ion conductors. Fabrication of specimens of an electrolyte that contain small amounts of finely dispersed metal particles yet retain the desired electrical properties will be demonstrated.

Synthesis and Characterization of Dispersion-Toughened Structural Ceramics

High-temperature structural ceramics are promising for use in advanced energy conversion systems because of their refractory nature and corrosion resistance. However, the brittle behavior of these materials limits their structural applicability. This project will implement the concept of dispersing a second phase (such as ZrO_2 or HfO_2) within alumina so that an advancing crack will be slowed or arrested when it contacts a particle of the second phase. The potential of sol-gel synthesis processes for preparing powders suitable for fabrication of dispersion-toughened structural ceramics will be identified. These prepared ceramics will then be characterized to relate the dispersed particle's size, shape, and concentration to the resultant mechanical properties.

Ceramic Powder Preparation by Chemical Vapor Deposition

A new method for preparing fine-grained SiC powder by chemical vapor decomposition is proposed. Such powder should allow fabrication of dense bodies by sintering without the use of sintering aids; it would allow processing at lower temperatures and would result in an improved fine crystalline microstructure and improved mechanical strength and toughness. Current SiC fabrication practice is to use sintering or hot-pressing aids, such as metallic silicon, which bond the SiC grains. This can result in glassy phases between SiC grains or multiphasic boundaries, which lead to reduced high-temperature strength and greater tendency to creep. Our theory of using a silane as the decomposition gas could result in improved powders. The durability of dense bodies formed to final net shape will be evaluated.

The last two proposals resulted from our study to identify possible research opportunities for conserving and replacing critical materials.

5. Specialized Research Facilities and Equipment

In recent years the division has promoted the establishment of selected research facilities with unique capabilities to be operated in the user-dedicated mode. The underlying aim is to advance materials science on a broad national front by making this one-of-a-kind equipment available for collaborative and joint research with the industrial sector and the university community. The effort involves three specialized facilities: Shared Research Equipment Program (SHaRE), ORNL-Oak Ridge Associated Universities (ORAU) Synchrotron Radiation X-Ray Sources, and the National Center for Small-Angle Scattering Research (NCSASR). A brief status report on each activity is presented.

SHARED RESEARCH EQUIPMENT PROGRAM

E. A. Kenik

The past year was a productive period for the SHaRE program, both in the breadth of research conducted and the number of participants. The program has expanded beyond the Southeastern region to include university and industrial participants from other regions of the country. The program facilitates research in areas pertinent to the U.S. Department of Energy (DOE) mission and emphasizes areas under current research in the Materials Science Section of the Metals and Ceramics Division. Members of SHaRE outside ORNL are provided access to research equipment (especially for electron microscopy) much more sophisticated than that available at their own laboratories. Research involving Auger surface analysis, ion implantation, and nuclear microanalysis is also included in the SHaRE program.

As during FY 1980, the Division of Materials Sciences, Office of Basic Energy Science, provided funds through ORAU to support the SHaRE activity. Program funds are used for travel and living expenses of SHaRE participants while at ORNL and for the support of G. L. Lehman, an electron microscope engineer. His responsibility is to familiarize SHaRE participants with the electron microscope and computer facilities and to participate in SHaRE research when appropriate. The presence of Lehman has greatly facilitated a high level of SHaRE participation that has interfered minimally with in-house programs. The program policy for SHaRE is defined by a steering committee, whose members are:

- William Felling, Assistant Director, ORAU
- E. A. Kenik, ORNL
- C. L. White, ORNL
- J. J. Wert, Professor and Chairman, Department of Mechanical and Materials Engineering, Vanderbilt University, Nashville, Tennessee
- E. A. Starke, Professor and Director, School of Chemistry and Metallurgy, Georgia Institute of Technology, Atlanta

The following ten active research projects were continued in FY 1981:

1. K. R. Lawless, University of Virginia, with E. A. Kenik: High-voltage electron microscopic in situ oxidation of vanadium and vanadium-titanium
2. J. B. Benson, Jr., North Carolina State University, with J. Bentley and G. L. Lehman: Defect analysis in ion-implanted GaAs
3. P. J. Reucroft, University of Kentucky, with J. Bentley and E. A. Kenik: Chemical and physical characterization of dispersed metal particles in porous media
4. J. J. Wert, Vanderbilt University, with P. S. Sklad: The role of structure in the wear process
5. R. Sisson, Virginia Polytechnic Institute and State University, with M. B. Lewis: Nuclear microanalysis of hydrogen in oxides formed by steam oxidation
6. E. Schulson, Dartmouth University, with C. T. Liu and C. L. White: Collaborative experiments on the brittle to ductile transition in polycrystalline

7. H. Anderson, University of Missouri-Rolla, with J. Bentley: Lattice imaging studies of donor-doped transition metal oxides

8. D. Northwood, University of Windsor, Canada, with E. A. Kenik: High-voltage electron microscopic studies of hydrogen and hydrides in zirconium and its alloys

9. A. Krawitz, University of Missouri-Columbia, with E. A. Kenik: Deformation substructures in cemented tungsten carbide-cobalt composites

10. J. J. Hren, University of Florida, with J. Bentley, K. Farrell, and E. A. Kenik: High-resolution studies in radiation effects, image simulation calculations

The following six new SHaRE projects were initiated during FY 1981:

1. S. Hack, Southwest Research Institute, and H. Marcus, University of Texas, with E. A. Kenik: Influence of hydrogen on in situ deformation behavior of titanium alloys

2. E. A. Starke, Georgia Institute of Technology, with E. A. Kenik: In situ deformation of aluminum-lithium alloys

3. R. Davis, North Carolina State University, with J. Bentley: Transmission electron microscopy of deformed niobium carbide and deformed α-silicon carbide

4. R. W. Carpenter, Arizona State University, with J. Bentley and A. Fisher: Convergent-beam electron diffraction with coherent illumination

5. M. M. Kersker, Alcoa Technical Center, with J. Bentley and G. L. Lehman: Convergent-beam electron diffraction in multiphase alloys

6. W. Clark, Ohio State University, with J. Bentley: Analytical electron microscopy of wear deformation structures in copper

Results from research on some of the SHaRE programs listed above are described in Chap. 3 of this report.

The following guests outside the SHaRE program are participating in collaborative research.

R. J. Bayuzick, Vanderbilt University
H. Liu and T. Mukai, Case Western Reserve University
M. J. Goringe, Oxford University
L. L. Horton, University of Virginia
J. Mullins, Alcoa Technical Center
L. B. Coons and B. Tarnowski, Memphis State University
R. Keller and L. Schoenlien, Case Western Reserve University
J. R. Leteutre, CEN, Saclay
J. Spruiell, University of Tennessee

ORNL-ORAU SYNCHROTRON RADIATION X-RAY SOURCES

C. J. Sparks, Jr.

Our decision to use the powerful x-ray generator under construction at Brookhaven National Laboratory has involved us significantly in the design and engineering construction of the necessary instrumentation. We will use the x-radiation from the National Synchrotron Light Source (NSLS) to probe the structure of materials. We have identified several materials science programs at ORNL that will benefit from the unique properties of this radiation source. These research areas involve personnel from the Chemistry, Solid State, Metals and Ceramics, and Analytical Chemistry divisions. Through organizational meetings held at ORAU in 1979, we formed a consortium with university and industrial researchers with similar interests in materials science. This collaboration is directed by an interim steering committee consisting of R. DeAngelis, Department of Materials Science, University of Kentucky; S. C. Moss, Department of Physics, University of Houston; C. J. Sparks, Jr., ORNL; and R. Young, Engineering Experiment Station, Georgia Institute of Technology. Several consortium members are engaged in software development for our recently acquired PDP 11/34 computer, which will be used to control experimental equipment, collect data, and provide for data reduction. DeAngelis' stay at ORNL produced many worthwhile contributions to our software development in association with A. Habenschuss, who is supported by DOE funding through ORAU to manage our computer system and to do research on liquid and amorphous materials.

SMALL-ANGLE X-RAY SCATTERING RESEARCH FACILITIES

C. J. Sparks, Jr.

Our small-angle x-ray-scattering research facilities are heavily used and attract a large number of outside researchers.

Much of the research is centered on polymers. Dynamic small-angle investigations of the crystallization of polymers continues to provide unique information on the structural characteristics that control the mechanical properties of these materials. Stacks of alternating crystalline and amorphous layers have been observed in semicrystalline polymers. This crystallinity changes reversibly with temperature and explains the observed pyroelectric response of polarized, Phase I polyvinylidene fluoride films. Industrial processes of fiber and film spinning, injection molding, and film blowing produce crystallized polymers at high rates of extension. Small-angle x-ray scattering has shown the fibrous crystals to be modulated axially from spinodal decomposition of the material into crystalline and amorphous regions. Such information is leading to a better understanding of the high density and high moduli of these polymers.

The small-angle x-ray scattering research will henceforth be administered and reported by the Solid State Division.

Appendix A

BUDGET AND SUPPORT DISTRIBUTION

As with most U.S. Department of Energy (DOE)-supported organizations, the Metals and Ceramics Division received less than the needed cost-of-living increases in FY 1981 and anticipates a greater financial shortfall in FY 1982. Compared with FY 1979 and FY 1980, the division began FY 1981 at a low level, gained substantial support in the second and third quarters, and now at the three-quarter mark is at a constant-dollar support level slightly above that of the previous two years. Our financial plan continues to undergo changes, however, in funds allocated to individual projects as well as total divisional support.

Table A.1 is a comparison by project of the funds currently approved for FY 1981 with the actual figures for FY 1980 and the anticipated funding for FY 1982. Of the twelve major elements in the FY 1981 financial plan, seven reflect increases compared with the FY 1980 final budget, whereas five show decreases. The change in total divisional support is only $197,000, or an increase of 0.8%, which is well below the current inflation rate. The Fission and related Nuclear Regulatory Commission programs received less money, continuing the downward trend of less support for the nuclear effort. All other major programs received greater support, and fairly large increases were registered in three cases.

Funding for subcontracting DOE work to organizations outside the laboratory by program managers within the division is decreasing significantly. However, this change has no direct impact on divisional programs; in most instances, this pass-through money cannot be spent within the division.

The division budget traditionally changes within a given year as well as from one year to the next, and coping with this added dimension of variability presents a challenge to efficient management. Fig. A.1 illustrates the degree of annual fluctuations encountered in divisional support over the past three years. Each year funding starts at a low level and increases during the year. The problem recurs each fiscal year, when beginning support drops significantly. Because the division is required to start operating each year on money provided by Congressional continuing resolution, this situation presents a serious problem to management annually.

Although anticipated support for FY 1982 shows a decrease from that of FY 1981, the decrease does not appear to be nearly so large as that estimated earlier this year and is less than encountered in past years. However, none of the increases proposed for FY 1982 are great enough to offset expected cost-of-living increases. Such a situation demands a reduction in personnel on practically all programs.

Table A.1. Division financial support by project, FY 1980 through FY 1982[a]

Project	Actual FY 1980	Current FY 1981	Change FY 1980 to FY 1981	Anticipated FY 1982	Change FY 1981 to FY 1982
Advanced Technology	124	36	−88	0	−36
Basic Energy	5,269	5,397	+128	5,944	+547
Conservation	1,310	1,808	+498	1,990	+182
Fission	6,845	5,119	−1,726	5,287	+168
Fossil	1,453	2,911	+1,458	2,520	−391
Fusion	2,053	2,356	+303	2,564	+208
NRC	2,233	1,742	−491	1,335	−407
Solar	145	207	+62	0	−207
Space	1,874	2,205	+331	1,980	−225
Waste	708	1,236	+528	843	−393
Other	994	288	−706	360	+72
Service	1,300	1,200	−100	1,400	+200
Division support	24,308	24,505	+197	24,223	−282
Outside subcontracts	8,783	6,345	−2,438	4,800	−1,545
Division total	33,091	30,850	−2,241	29,023	−1,827

[a]Thousands of dollars.

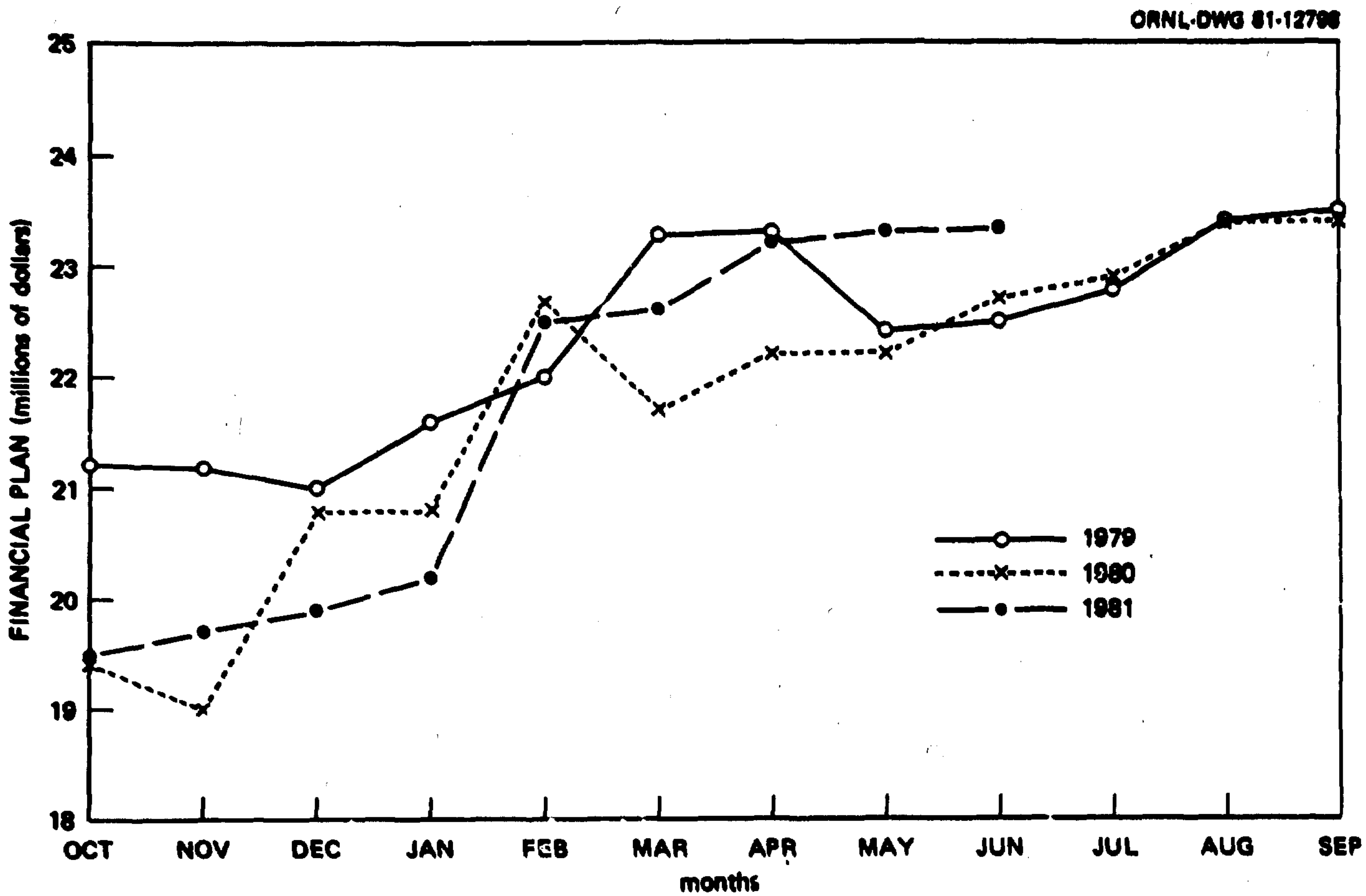

Fig. A.1. Monthly variation in divisional financial plan over the indicated three years.

Appendix B

PERSONNEL SUMMARY

In the second quarter of the year, the division embarked on an aggressive retrenchment program to reduce the staff to a level consistent with anticipated financial support for FY 1982. Table B.1 presents the status of professional and technical support personnel as of July 1 for 1980 and 1981. The table indicates that considerable success has already been achieved in reducing the staff and that the reduction has affected both the technical and the support staffs, with a reduction of 6% in the former and 9% in the latter. Because of current budget uncertainities, the reductions are expected to continue into next year. As shown in Appendix A, the budget for FY 1981 has now been increased to the level of last year, but earlier in the year it was much lower. If the FY 1982 budget remains the same as that for FY 1981 in constant dollars, which is likely, the high inflation rate will require a considerable reduction in the staff. The fact that the budgets generally start low and increase during the year makes management of manpower difficult.

To supplement our skills and to obtain fresh viewpoints, we have continued to encourage research visits from guests supported by outside sources. During the past year, 54 guests worked in the division, 15 on a full-time and the others on an intermittent basis. Of these, 12 were from foreign countries; 11 were assigned through the Oak Ridge Associated Universities, largely from American universities; 29 were on direct assignment from universities; and 2 were from other DOE laboratories.

During the year July 1, 1980, through June 30, 1981, five people were added to the technical staff, consisting of three new employees and two returning from assignments to other ORNL divisions. Two of the new employees were recent Ph.D.'s, and the other was a B.S. with considerable industrial experience. No new people were added to the technician roll, and only one new secretary was employed. A second secretary (a loanee) returned to the division.

Most of those who left the technical staff resigned from the laboratory to accept higher salaried postions with outside companies. Of those leaving the division support staff, only two left the laboratory—a technician did not return from maternity leave, and a secretary accepted other employment. All others have been transferred to other assignments within Union Carbide Corporation, Nuclear Division.

Table B.1. Composition and changes in division staff as of July 1, 1980 and 1981

	Technical			Support			Total		
	1980	1981	Change	1980	1981	Change	1980	1981	Change
Permanent employees	149	140	−9	130	118	−12	279	258	−21
Temporary employees, >ten months	6	6	0	0	0	0	6	6	0
Loanees from other divisions	0[a]	0	0	4[a]	3	−1	4[a]	3	−1
Loanees to other divisions	2	1	−1	1	1	0	3	2	−1
Part-time employees	7	6	−1	5	6	+1	12	12	0
Long-time guests	12[b]	12	0	1[b]	1	0	13[b]	13	0
Coops (one-half time)	0	0	0	6	2	−4	6	2	−4

[a]These numbers have been corrected from last year because some assigned personnel are no longer shown as direct manpower.
[b]These numbers have been changed from last year because only long-time guests are now included in this summary.

Appendix C

ORGANIZATIONAL STRUCTURE AND CHART

During the past year, the organizational structure of the division was realigned in selected areas to accommodate changes in the research and development thrust and direction and to upgrade management efficiency. Fuel Cycle Technology was combined with Engineering and Evaluation to form a new group entitled Fuel Cycle and Engineering Analysis in the Fuels and Processes Section. W. J. Lackey was appointed leader of this new group. An office of Nuclear Regulatory Commission Engineering Technology Programs was created, and F. J. Homan was appointed manager. In turn, P. L. Rittenhouse was appointed to the position of manager of Gas-Cooled Reactor Materials Programs vacated by Homan. The Small-Angle X-Ray Scattering Laboratory, formerly operated in the division under the direction of R. W. Hendricks, was recently transferred to the Solid State Division for joint management in consort with the Small-Angle Neutron Scattering Facility. Otherwise, the division continued to operate in a stable matrix mode to handle the dual administration of line organization by functional discipline and management of large, complex, multidisciplinary, and high-technology projects.

Several openings occurred during the past year that allowed younger staff members to advance and assume positions of greater responsibility. In January, C. J. Sparks, Jr., became leader of the X-ray Research and Applications Group. In March, D. R. Johnson was appointed leader of the Ceramics Technology Group, replacing R. L. Beatty who resigned to accept a position with Exxon. Finally, in April R. K. Nanstad advanced to leader of the Pressure Vessel Technology Group, replacing D. A. Canonico who accepted the position of Research Director of Operations at Combustion Engineering in Chattanooga.

The division organization chart reflecting these changes is attached for reference.

METALS AND CERAMICS DIVISION

JULY 1, 1980

DIRECTOR
J. R. WEIR, JR.
[illegible] COX

ASSOCIATE DIRECTOR
J. E. CUNNINGHAM
[illegible] CORBETT
[illegible] STAGNER

- **DIVISION SERVICES SECTION**
  - [illegible] ADAMSON, SECTION HEAD
  - [illegible] ANDERSON
  - [illegible] BURNS
  - [illegible] HATCHETT
  - [illegible] MANNING
  - [illegible] MORRISON
  - [illegible] POLLARD
  - [illegible] SHARPE
  - **BASIC ENERGY SCIENCES PROGRAM** — [illegible], MANAGER; [illegible]
  - **BREEDER REACTOR MATERIALS PROGRAM** — [illegible], MANAGER; [illegible]
  - **CONSERVATION TECHNOLOGY PROGRAMS** — [illegible] SCHAFFHAUSER, MANAGER; [illegible]
  - **FOSSIL ENERGY MATERIALS PROGRAM** — R. A. BRADLEY, MANAGER; [illegible]
  - **FUSION ENERGY MATERIALS PROGRAM** — [illegible], MANAGER; [illegible]
  - **GAS COOLED REACTOR MATERIALS PROGRAMS** — [illegible], MANAGER; [illegible]
  - **NUCLEAR REGULATORY COMMISSION ENGINEERING AND TECHNOLOGY PROGRAMS** — [illegible], MANAGER; [illegible]
  - **AFFIRMATIVE ACTION AND OMBUDSMAN** — [illegible] BOMAR, JR.
  - **RESEARCH REACTOR PROCUREMENT** — [illegible]
  - **SPECIAL PROJECTS** — [illegible]
  - **ADMINISTRATIVE SERVICES** — [illegible]
    - **ENGINEERING SERVICES** — [illegible]
    - **PROCUREMENT** — [illegible] HENGSTLER; [illegible] MYERS; [illegible] ROSEBERRY; [illegible]
  - **BUDGET ANALYSIS** — [illegible]
  - **FINANCE OFFICER** — [illegible]
  - **METALLOGRAPHY** — [illegible]; J. W. JONES*; G. C. MARSH; J. R. MAYOTTE; J. A. NAVE; R. C. ROBERTSON*; [illegible] RUSSELL; [illegible] SHRADER; [illegible]
- **ENGINEERING MATERIALS**
  - [illegible] SLAUGHTER, SECTION HEAD
  - R. D. NEEK
  - J. L. BISHOP
  - K. W. GARDNER
  - K. L. PERRY
  - [illegible] STOCKSBURY
  - [illegible] TAYLOR*
  - **HEAVY SECTION STEEL TECHNOLOGY PROGRAM** — R. K. NANSTAD*
  - **MATERIALS COMPATIBILITY** — J. H. DEVAN; [illegible] BAYLOR; [illegible]; J. R. KEISER; [illegible] TORTORELLI; [illegible]
  - **MECHANICAL PROPERTIES** — [illegible] BROWNING; [illegible] BOOKER; [illegible] DEAVES; [illegible]; [illegible] McCOY, JR.; [illegible] SIKKA; J. P. STRIZAK; R. W. SWINDEMAN; [illegible] BALDWIN; [illegible]; [illegible] PATTON, JR.; [illegible] WILLIAMS
  - **NONDESTRUCTIVE TESTING** — [illegible] McCLUNG; [illegible]
- **MATERIALS SCIENCE**
  - J. O. STIEGLER, SECTION HEAD
  - [illegible] M. PYATT*
  - C. L. BOWKER
  - F. M. FOUST
  - A. G. GOLLIHER
  - S. J. PHILLIPS
  - [illegible] A. SCARBORO
  - [illegible] YOUNG
  - **HIGH TEMPERATURE MATERIALS LABORATORY** — [illegible] V. CATHCART*
  - **USERS GROUPS**
    - **ORNL/ORAU SHARED RESEARCH EQUIPMENT PROGRAM** — E. A. KENIK*
    - **ORNL SYNCHROTRON X RAY SOURCE USERS GROUP** — C. J. SPARKS*
  - **ALLOYING BEHAVIOR AND DESIGN** — [illegible] KOCH; A. DAS GUPTA*; [illegible] EASTON; [illegible] HENNINGER*; D. M. KROEGER; [illegible]; [illegible] OGLE; [illegible] SCHNEIBEL; [illegible] WHITE; [illegible] WILLIAMS; [illegible] YOO; [illegible] SCARBROUGH; [illegible] PADGETT; [illegible] ZACHARY
  - **PHYSICAL PROPERTIES** — [illegible] McELROY; [illegible] HARRIS; [illegible]; [illegible] MOORE; [illegible] WILLIAMS; D. W. YARBROUGH; H. S. GRAVES; F. J. WEAVER
  - **RADIATION EFFECTS AND MICROSTRUCTURAL ANALYSIS** — E. E. BLOOM
- **FUELS AND PROCESSES**
  - R. G. DONNELLY, SECTION HEAD
  - M. C. MATTHEWS
  - M. S. HOOVER
  - [illegible] CASTLEBERRY
  - [illegible] McCANLESS
  - [illegible] WHITE*
  - R. A. WHITE
  - **GRAPHITE PROGRAMS** — W. P. EATHERLY
  - **NATIONAL BUILDING ENERGY CONSERVATION PROGRAM** — T. S. LUNDY
  - **SPACE POWER PROGRAMS** — R. H. COOPER, JR.
  - **CERAMIC TECHNOLOGY** — D. R. JOHNSON; [illegible] BOMAR, JR.*; M. A. A. ELMASRY*; [illegible] FEDERER; L. A. HARRIS; [illegible] KENNEDY; [illegible] KOPP; [illegible] LAUF; [illegible] LONG, JR.; [illegible] MORGAN; [illegible] ROBBINS; [illegible]; [illegible] CHILCOAT; [illegible] FIELDEN; [illegible]; [illegible] GAMBY; [illegible] JEFFERS; [illegible] JONES; [illegible] KEATING
  - **FUEL CYCLE AND ENGINEERING ANALYSIS** — [illegible] LACKEY; [illegible]; A. R. OLSEN; T. F. SCANLAN; D. P. STINTON; H. J. WALLACE; [illegible] WILLIAMS; C. E. DeVORE; J. B. FLYNN*; R. R. LIVESEY; [illegible] McLAUGHLIN; W. H. STINES

R C ROBERTSON[a]
K F RUSSELL
E G SHRADER
W H WARWICK

QUALITY ASSURANCE

R J BEAVER[a]

REPORTS OFFICE

M R HILL
[illegible]

SAFETY, RADIATION, ENVIRONMENTAL, AND SNM CONTROL

[illegible]

TECHNICAL EDITOR

[illegible]

ON LOAN LEAVE

[illegible]

NONDESTRUCTIVE TESTING

R W McCLUNG
K V COOK
W E DEEDS[a]
C V DODD
R E FOSTER
G W SCOTT
W A SIMPSON JR
J H SMITH
[illegible]
R A CUNNINGHAM JR
[illegible]

PRESSURE VESSEL TECHNOLOGY

[illegible]

WELDING AND BRAZING

[illegible]
T O OWINGS JR
R W REED JR
[illegible] WOODHOUSE

SPECIAL PROJECTS

T L HEBBLE
J T HUTTON

RADIATION EFFECTS AND MICROSTRUCTURAL ANALYSIS

E E BLOOM
J BENTLEY
D N BRASKI
W H CARTER[a]
R E CLAUSING
W A COGHLAN
C K H DuBOSE
L C EMERSON
K FARRELL
M L GROSSBECK
A HISHINUMA
[illegible]
E A KENIK[a]
[illegible]
E H LEE
[illegible]
[illegible] WEATHERLY
[illegible] HOUSTON
[illegible] McKAMEY
[illegible] POTTER
[illegible] ROUSE
[illegible] SMITH
[illegible] TURNER

STRUCTURAL CERAMICS

[illegible]
R F BECHER
G W CLARK
M K FERBER
C R FINCH
C S YUST
[illegible] HALL
S B WATERS
[illegible] WILLMERING

SURFACE AND SOLID STATE REACTIONS

J V CATHCART[a]
R E DRUSCHEL
R A McKEE
R E PAWEL
G F PETERSEN
J J CAMPBELL
[illegible] MANLEY JR

THEORY

[illegible] FAULKNER
W H BUTLER
G S PAINTER
G M STOCKS

X-RAY RESEARCH AND APPLICATION

[illegible] SPARKS JR
B S BORIE
D B CAVIN
[illegible]
[illegible]
[illegible]
[illegible] YAKEL

C F DeVORE
J H FLYNN[a]
R R LIVESEY
J C McLAUGHLIN
W B STINES

FUELS EVALUATION

F J HOMAN[a]
M J KANIA
[illegible] KRAUTWASSER
[illegible]

METALS PROCESSING

[illegible]

SPECIAL PROJECT

[illegible]

[illegible]
ON ASSIGNMENT FROM KFA, JULICH
ON LOAN FROM FINANCE AND MATERIALS DIVISION
ON ASSIGNMENT FROM PLANT AND EQUIPMENT DIVISION
LABORATORY GRADUATE PARTICIPANT PROGRAM FROM GEORGIA TECH
ON ASSIGNMENT TO KFA, JULICH
ON LOAN FROM INFORMATION DIVISION
ON LOAN FROM QUALITY ASSURANCE AND INSPECTION DEPARTMENT
ON ASSIGNMENT FROM COMPUTER SCIENCES DIVISION
ON ASSIGNMENT FROM INSTRUMENTATION AND CONTROLS DIVISION
ON ASSIGNMENT FROM ENGINEERING TECHNOLOGY
GUEST, OAK RIDGE ASSOCIATED UNIVERSITIES
GUEST, DePAUW UNIVERSITY, GREENCASTLE, INDIANA
ON LOAN TO CMO BREEDER REACTOR PROGRAM
GUEST, JAPAN ATOMIC ENERGY RESEARCH INSTITUTE
GUEST, CENTRE D'ETUDE NUCLEAIRE, FRANCE
GUEST, UNIVERSITY OF VIRGINIA
ON ASSIGNMENT TO INSTITUT FUR PHYSIK DER UNIVERSITAT, BASEL, SWITZERLAND

Appendix D

HONORS AND AWARDS

Division staff members continue to be cited and rewarded for exhibiting outstanding talent and ability in fulfilling their professional roles within the scientific and engineering community. The type of recognition received or professional achievement attained tends to fall into one of the following six specific categories: honors, awards, commendations, elected officers and members, certification and registration, and appointments. A chronological listing of citations in each of these categories during the past year follows.

Honors

August 1980

Ken C. Liu's work, "Biaxial Materials Testing for Nuclear Reactor System Integrity," was cited in the August 1980 issue of *Metal Progress* in an article, "Mechanical Testing in the 80s."

October 1980

James L. Scott was elected a Fellow of the American Society for Metals.

February 1981

Domenic A. Canonico presented the Clarence E. Jackson Honorary Lecture, "Review of Heavy Section Steel Technology," at the American Welding Society Washington, D.C., Section Meeting.

Awards

August 1980

Peter Angelini, David P. Stinton, W. Jack Lackey, Tom J. Henson, Larry G. Shrader, Nobel H. Rouse, and *Charles E. DeVore* (with E. Leon Smith of Graphic Arts) received the first-place award in the class on Unique, Unusual, or Other Techniques for their entry on "Alpha Autoradiography Identifies the Partitioning of Plutonium into the Desired Synroc Phases" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

David P. Stinton, Peter Angelini, W. Jack Lackey, and *Nobel H. Rouse* (with E. Leon Smith of Graphic Arts) received the first-place award in the class on Color Micrographs for their entry on "Transmitted Light Microscopy Allows Identification of Synthetic Minerals Able to Immobilize Nuclear Wastes" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

Nick H. Packan, Ken Farrell, and *John T. Houston* received the first-place award in the class on Electron Microscopy—Transmission for their entry on "Depth Profile of Swelling in Ion-Bombarded Nickel" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

Ron L. Klueh, C. W. (Pete) Houck, and *Rosemary C. Robertson* received the second-place award in the class on Optical Microscopy—Iron, Steel, Stainless Steel, Nickel, and Nickel Alloys for their entry on "Dissimilar-Alloy (Austenitic Stainless Steel-Ferritic Steel) Weld Joint Failures" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

Stan A. David, C. Paul Haltom, and *Rosemary C. Robertson* received Honorable Mention in the class on Optical Microscopy—Iron, Steel, Stainless Steel, Nickel, and Nickel Alloys for their entry on "A Comprehensive Insight into the Ferrite Morphology" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the Amerian Society for Metals.

Stan A. David and *C. Paul Haltom* received Honorable Mention in the class on Optical Microscopy—Metals and Alloys Not Listed in Class 1 for their entry on "Modification of Fusion Zone Structure by Laser Welding: A Solution to Hot Cracking" at the International Metallographic Exhibit in Brighton, England, jointly sponsored by the International Metallographic Society and the American Society for Metals.

September 1980

Peter Angelini, Anthony J. Caputo, Robert R. Suchomel (now with IBM), Donald Kiplinger (Plant and Equipment Division), and Melvin G. Willey (Engineering Division) won an I-R-100 Award from

Industrial Research for their design and development of the Continuous-Ring Particle Blender-Dispenser.

October 1980

Dewey S. Easton, Don M. Kroeger, and *Carl C. Koch* (with W. Specking, Karlsruhe, Germany) received the Department of Energy's 1980 Metallurgy and Ceramics Award for their research paper "A Prediction of the Stress State in Nb_3Sn Superconducting Composites," which was judged highest in the Follow-Up category.

The *Oak Ridge Section* of The American Society for Nondestructive Testing received the 1979–1980 President's Award. *Jim H. Smith* was Chairman of the Oak Ridge Section at that time.

November 1980

James L. Scott and *Jack E. Cunningham* received American Nuclear Society Exceptional Service Awards on the occasion of the Society's 25th anniversary in recognition of their exceptional and outstanding contributions to the Society.

April 1981

Arthur J. Moorhead and *Robert W. Reed* received the A. F. Davis Silver Medal Award by the American Welding Society for their paper "Development of Techniques for Joining Fuel Rod Simulators to Test Assemblies" as the best contribution to the progress of welding in the field of machine design.

May 1981

Philip S. Sklad and *Jim Bentley* received Best in Show for their display on Analytical Electron Microscopy of TiB_2-Ni Ceramics in the metallographic competition at the American Ceramic Society Meeting in Washington, D.C., May 3–6, 1981.

June 1981

Everett E. Bloom received the 1981 American Nuclear Society Young Members Engineering Achievement Award.

David P. Stinton and *Alice Richardson* (Information Division) were one of the six winners of the contest to design a new logo for the American Ceramic Society.

Commendations

December 1980

Dom A. Canonico and *Rey G. Berggren* received a Letter of Commendation from the Nuclear Regulatory Commission on their materials characterization work for the Heavy Section Steel Technology program.

Jim R. Keiser received a Letter of Commendation from Solvent Refined Coal International, Inc., for his work on corrosion studies of fractionation column by coal-derived liquids.

Jim R. Keiser and *Ron A. Bradley* received a Letter of Commendation from DOE for the corrosion work being performed by the ORNL Fossil Energy Materials Program staff.

E. Sloan Bomar received a Letter of Appreciation from ORNL for his diligent and highly competent service on the Radioactive Operations Committee for the past year.

January 1981

Wilbur H. Warwick received a Letter of Appreciation from General Atomic Division for his assistance in SiC etching.

March 1981

Carl C. Koch received a Letter of Appreciation from the Council on Materials Science of DOE for his contributions to the panel report on amorphous materials to identify the needs and opportunities for research on disordered or amorphous solids.

Larry A. Harris received a Letter of Commendation from G. E. Moore (Coordinator, Professional Education Program) for teaching "Topics in Geology," ORNL Technical Continuous Education Course C-600 in the In-House Continuing Education Program for Scientific and Technical Personnel, during the fall 1980 term.

April 1981

Bill E. Foster received a Letter of Appreciation from Westinghouse Electric Corporation for his participation in its rod anode positioner final design review.

May 1981

Vivian B. Baylor and *Jim R. Keiser* received a Letter of Appreciation from the Oak Ridge Chapter of the American Society for Metals for their substantial contributions to the success of the Symposium on Elevated-Temperature Materials Considerations in Coal Liquefaction and Gasification Service.

Ralph G. Donnelly, received a Certificate of Appreciation from the American Society for Metals for his ASM seminar on "Metallurgical Technology of Uranium and Uranium Alloys."

Elected Officers and Members

May 1981

Ralph G. Donnelly was elected Vice Chairman of the Energy Conservation Society, Knoxville–Oak Ridge Chapter, for 1981–82.

June 1981

David L. McElroy was elected Chairman of the Governing Board of the International Thermal Conductivity Conference for a two-year term.

Certification and Registration

August 1980

Rhonda L. Castleberry achieved the rating of Certified Professional Secretary (CPS).

Appointments

July 1980

James L. Scott was appointed to the Publications Steering Committee of the American Nuclear Society for a three-year term.

Pete Patriarca was appointed Chairman of the Joining Division of the American Society for Metals for a three-year term.

Jack E. Cunningham was appointed to the Books, Monographs, and Handbooks Committee of the American Nuclear Society for a three-year term ending in 1983.

Helen G. Corbett was appointed Certified Professional Secretary Service and Education Chairman of the Oak Ridge Chapter, National Secretaries Association (International).

Gene M. Goodwin was selected to serve as a member of the new American Welding Society Welding Academy Committee.

November 1980

Jack E. Cunningham was appointed Chairman of the American Nuclear Society Planning Cycle Subcommittee.

Jack E. Cunningham was appointed Past Chairman of the American Society for Metals Engineering Materials Achievement Award Selection Committee for one year.

Gerald M. Slaughter was appointed a member of the American Society for Metals Technical Divisions Board for three years.

January 1981

Harry L. Yakel was appointed Associate Editor of the *Journal of Applied Crystallography*.

Robert W. Hendricks was appointed a member of the Solid State Sciences Committee Advisory Panel of the National Research Council of the National Academy of Sciences for a three-year term ending December 31, 1983.

Bill E. Foster was appointed for a five-year term as a member of the Subgroup on Radiography (SC V) of the Boiler and Pressure Vessel Committee of The American Society of Mechanical Engineers.

March 1981

Calvin L. White was appointed a member of the Materials Science Division Council and was named program chairman of the Materials Science Technical Division of the American Society for Metals.

Jim R. Weir was appointed to the Speakers' Bureau of the American Society for Metals for one year, 1981–82.

May 1981

W. Jack Lackey was appointed chairman of the Program Committee of the Nuclear Division of the American Ceramic Society for a one-year term, 1981–82.

D. Ray Johnson was appointed chairman of the Research Committee of the Nuclear Division of the American Ceramic Society for a one-year term, 1981–82.

David P. Stinton was appointed a member of the Membership Committee of the Nuclear Division of the American Ceramic Society for a one-year term, 1981–82.

Charles S. Yust was appointed a member of the Nomination and Fellows Committee of the Nuclear Division of the American Ceramics Society for a one-year term, 1981–82.

Gene M. Goodwin was appointed Chairman of the Welding Subcommittee of the Electric Power Research Institute Boiling Reactor Owners Group.

June 1981

James L. Scott was appointed Vice Chairman of the Publications Steering Committee of the American Nuclear Society for a one-year term.

Jack E. Cunningham was appointed Vice Chairman of the Honors and Awards Committee of the American Nuclear Society for a one-year term.

Arthur J. Moorhead was appointed Vice Chairman of the C3-D Subcommittee on Education of the American Welding Society.

Appendix E

SEMINAR PROGRAM

Because effective communication is vital to technological advancement, the division sponsors and maintains an active seminar program to promote the exchange of ideas and discussion of common problems among researchers working in the field of materials science and technology and allied disciplines. Most of the talks deal with scientific and engineering subjects and are presented by invited speakers from various organizations in the United States and abroad. The actual number of talks scheduled in any given week varies but over the year averages about two per week.

The Seminar Program is administered by a committee appointed by division management. The Seminar Committee for calendar years 1980 and 1981 consists of D. O. Hobson (Chairman), N. H. Packan, and G. C. Wei.

The speakers and topics of seminars presented during the past year are listed below. It is interesting that 17 of the 94 talks scheduled were made by individuals affiliated with institutions located outside the United States. An alternative breakdown shows 42 talks by university faculty members and graduate students, 6 by representatives from industrial firms, and the balance from governmental and other research institutions. In function, the program achieves the desired objectives of maintaining close relationships with the university community and of enhancing the diffusion of knowledge.

R. J. Gray, Metals and Ceramics Division, ORNL, "Basic and Unusual Techniques in Metallography Extend Our Understanding of Microstructures," July 9, 1980.

S. K. Sinha, Argonne National Laboratory, "Charge and Spin Fluctuations in Mixed Valence Systems," July 9, 1980.

M. H. Yoo, Metals and Ceramics Division, ORNL, "From Deformation and Fracture to Strength and Ductility A BES Way," July 11 1980.

A. T. Fromhold, Jr., Auburn University, "An Overview of Metal Oxidation Theory," July 23, 1980.

M. L. Grossbeck, Metals and Ceramics Division, ORNL, "Fatigue of Irradiated Stainless Steel," July 25, 1980.

L. L. Horton, University of Virginia, "Defect Structures in Neutron-Irradiated Iron," July 31, 1980.

P. J. Alberry, Marchwood Engineering Laboratories, England, "Welding Research at the Central Electricity Generating Board, Marchwood Engineering Laboratories," August 4, 1980.

H. Mecking, Institut für Allgemeine Metallkunde and Metallphysik, Rheinisch-Westfalische Technische Hochschule Aachen, West Germany, "Different Stages of Work Hardening and Dynamic Recovery," August 8, 1980.

R. W. Hendricks, Metals and Ceramics Division, ORNL, "Opportunities for Materials Science Research Utilizing the ORNL Small Angle Scattering Facilities," August 8, 1980.

Brian Ralph, Cambridge University, "Recrystallization of High-Performance Materials," August 10, 1980.

R. J. Arsenault, University of Maryland, "Computer Simulation Studies on Solid Solution Strengthening of BCC Metals," August 13, 1980.

D. Richerson, AiResearch Manufacturing of Arizona, "Contact Stress Effects at Ceramic Interfaces," August 19, 1980.

J. Schelten, Kernforschungsanlage, Jülich, West Germany, "Studies of Polymer Conformations in Solid Polymers by Small-Angle and Wide-Angle Neutron Scattering," August 21, 1980.

Charles W. Murphy, Rockwell International, "Where Is Our Space Transportation System?," August 21, 1980.

M. B. Lewis, Metals and Ceramics Division, ORNL, "Direct Measurement of Diffusion and Trapping of Deuterium," August 22, 1980.

Sindo Kou, Carnegie-Mellon University, "Heat Flow Analysis of Fusion Welds," August 25, 1980.

J. H. Schneibel, Massachusetts Institute of Technology, "Anelasticity in Superplastic Alloys," August 28, 1980.

M. K. Booker, Metals and Ceramics Division, ORNL, "The Complex Time-Dependent Fatigue Behavior of 2 ¼ Cr-1 Mo Steel: Is Life Prediction Possible?," September 3, 1980.

Sunggi Baik, Cornell University, "Creep Fatigue Interaction," September 4, 1980.

G. E. Ice, Metals and Ceramics Division, ORNL, "Current Design of the ORNL Synchrotron

Radiation Beam Line and How It Affects the Kinds of Experiments We Can Do." September 5, 1980.

P. B. Allen, State University of New York, Stony Brook, "Resistivity of Metals: Exploring the Breakdown of Bloch-Boltzmann Theory," September 12, 1980.

W. C. Luth, Sandia National Laboratories, "A Magnificent Crucible - The 1959 Kilauea Iki Lava Lake," September 16, 1980.

R. E. Clausing, Metals and Ceramics Division, ORNL, "Materials Problems Due to Plasma-Wall Interactions in Fusion Energy Research," September 19, 1980.

E. L. Haase, Kernforschungszentrum, Karlsruhe, West Germany, "New Phases in the Nb-Ge-Si Ternary System," September 22, 1980.

R. W. Matolka, Johnson and Johnson Company, "Evaluation of the Porcelain-Metal Interface for Nickel Chrome Dental Alloy," September 25, 1980.

David B. Williams, Lehigh University, "Microanalysis in the Scanning Transmission Electron Microscope," September 26, 1980.

T. Mura, Northwestern University, "Micromechanics of Solids," October 1, 1980.

Georges Martin, Ce[illegible] d'Etudes Nucléaires de Saclay, Paris, France, "The Stability of Solid Solutions Under Irradiation," October 3, 1980.

R. W. Hendricks, Metals and Ceramics Division, ORNL, "A Materials Science Section Data Acquisition Computing Network," October 3, 1980.

A. J. Minchener, Coal Research Establishment, National Coal Board, England, "Research Activities at CRE on Materials for Fossil Energy Applications," October 10, 1980.

R. G. Faulkner, University of Technology at Loughborough, Leicestershire, England, "Non-equilibrium Segregation in Austenitic Steels," October 10, 1980.

R. J. Gray, Metals and Ceramics Division, ORNL, "Basic and Unusual Techniques in Metallography Extend Our Understanding of Microstructures," Octobe. 13, 1980.

Adrian Roberts, Electric Power Research Institute, "The Search for a More 'Forgiving' Material," October 15, 1980.

J. Halbritter, Kernforschungszentrum, Karlsruhe, West Germany, "Low-Temperature Oxidation of Niobium and Niobium-Niobium Pentaoxide Interfaces," October 17, 1980.

Rosemary MacDonald, National Bureau of Standards, "Molecular Dynamical Calculations of Energy Transport in Solids," October 21, 1980.

J. S. Faulkner, Metals and Ceramics Division, ORNL, "Iron," October 31, 1980.

R. Kamo, Cummins Engine Company, Columbus, Indiana, "The Adiabatic Diesel," November 3, 1980.

Warren E. Pickett, Naval Research Laboratory, "Influence of the Electronic Structure of Complex Crystals on Metallic Properties: Theory and Application to Nb_3Sn," November 5, 1980.

B. J. Busovne, Pennsylvania State University, "Precipitation-Hardening Behavior of Titanium-Doped Sapphire," November 6, 1980.

G. R. Leverant Southwest Research Institute, "Materials Research at Southwest Research Institute," November 18, 1980.

R. W. Baluffi, Massachusetts Institute of Technology, "Current Research in Grain Boundary Structure and Properties," November 19, 1980.

R. E. Prange, University of Maryland, Department of Physics, "Ferromagnetism in Iron and Nickel," December 3, 1980.

R. E. Clausing, Metals and Ceramics Division, ORNL, "Materials Problems Due to Plasma-Wall Interactions in Fusion Energy Research," December 5, 1980.

Ian G. Wright Battelle-Columbus Laboratories, "Evaluation of Materials for Liquefaction Letdown Valves," December 9, 1980.

Husam Gurol, University of California, Santa Barbara, "Calculations of the Effect of Radiation Pulsing on Irradiation Creep," December 16, 1980.

W. L. Worrell, University of Pennsylvania, "Corrosion of Nickel in SO_2 Atmospheres," December 15, 1980.

R. Stoltz, Sandia National Laboratories, "Hydrogen Embrittlement Studies: Low Carbon Pipeline Steels Versus Austenitic Stainless Steels," December 18, 1980.

C. C. Koch, Metals and Ceramics Division, ORNL, "Research Opportunities in Amorphous Alloys," January 9, 1981.

J. W. Hutchinson, Harvard University, "Void Growth in Metals," January 14, 1981.

Lih-Sheng Tsai, Cornell University, "Measurement of High-Temperature Kinetics and Applications on Time-Dependent Deformation of Silicon Nitride Polyphase Systems," January 19, 1981.

F. Spaepen, Harvard University, "Atomic Transport in Amorphous Materials" (joint with Solid State Division), January 20, 1981.

Judith Ann Todd, University of California, Berkeley, "Design of Low-Alloy Steels for Thick-Walled Pressure Vessels," January 20, 1981.

R. A. Penty, Hague International, Inc., South Portland, Maine, "Ceramic Heat-Exchanger Materials and Applications," January 21, 1981.

P. J. Maziasz, Metals and Ceramics Division, ORNL, "Helium Trapping at TiC Precipitates," January 23, 1981.

J. L. Whitten, University of New York, Stony Brook, "Chemisorption Theory Based on Orbital Localization," February 4, 1981.

R. A. McKee, Metals and Ceramics Division, ORNL, "Defect Structures and Diffusion in Sodium- and Lithium-Base Alloys," February 6, 1981.

T. D. Ketcham, Massachusetts Institute of Technology, "Toughening Thoria Zirconia and Alumina," February 9, 1981.

J. J. Hren, University of Florida, "Applications of Field Ionization and Field Desorption Microscopy," February 10, 1981.

M. L. Torti, Norton Company, Worcester, Massachusetts, "Advanced Ceramics for Energy Conversion Applications," February 10, 1981.

N. S. Stoloff, Rensselaer Polytechnic Institute, "Advanced Nickel- and Cobalt-Base Alloys for Gas Turbine Applications," February 17, 1981.

T. V. Ramakrishnan, Bell Laboratories, "Electron Localization: Fact and Theory," February 18, 1981.

H. Inhaber, Industrial Safety and Applied Health Physics Division, ORNL, "Risk Assessment in Energy Production," February 20, 1981.

B. D. Marsh, Johns Hopkins University, "Mechanics and Petrology of Island Arc Volcanism," February 24, 1981.

R. W. Derby, Massachusetts Institute of Technology, "Magnet Structural Materials Problems for Fusion Reactors," March 3, 1981.

P. B. Visscher, University of Alabama, "Discrete Hydrodynamics: Transport Coefficients via Renormalization," March 4, 1981.

W. D. Kingery, Massachusetts Institute of Technology, "MgO as a Solvent-Conductivity; Diffusion; Reactions" (joint with Solid State Division), March 5, 1981.

R. A. McKee, Metals and Ceramics Division, ORNL, "Defect Structures and Diffusion in Sodium- and Lithium-Base Alloys," March 6, 1981.

Michael J. Bennett, Atomic Energy Research Establishment, Harwell, England, "Recent Work at Harwell on Ceramic Coatings for Oxidation Protection," March 9, 1981.

Gene Lucas, University of California, Santa Barbara, "Fundamental Studies for Fusion Reactor Materials," March 20, 1981.

Roger Stoller, University of California, Santa Barbara, "Modeling of Microstructural Evolution," March 23, 1981.

Peter Weinberger, Technical University of Vienna, Austria, "The Relativistic KKR-CPA Method and Its Application to Au_cPt_{1-c} and Ni_cPt_{1-c}," March 25, 1981.

D.R.K. Brownrigg, Tennessee Technological University, "Computer Simulation of the Dynamics of Galaxies," March 31, 1981.

J. V. Cathcart, Metals and Ceramics Division, ORNL, "A High-Temperature Materials Laboratory Update," April 3, 1981.

Greg Gruzalski, Solid State Division, ORNL, "A Solid State Division Project: A Study of Transition Metal Carbides," April 3, 1981.

R. B. Griffiths, Carnegie-Mellon University, "Soluble Ising Models on Crazy Lattices," April 8, 1981.

D. J. Dingley, University of Bristol, England, "A New Theory of Grain Boundary Structure Based on Bollmann's O-Lattice Theory," April 13, 1981.

Hermann Winter, Kernforschungszentrum, Karlsruhe, West Germany, "Ab Initio Calculations of Superconducting Transition Temperatures and Some Mechanisms Limiting T_c's," April 29, 1981.

Arthur J. McEvily, University of Connecticut, "Low-Cycle Fatigue Behavior of Ferritic Steels at Elevated Temperatures," April 29, 1981.

Norman Peterson, Argonne National Laboratory, "Diffusion Mechanisms in Transition Metal Oxides," May 1, 1981.

Gerd Willmann, Dornier System, Inc., West Germany, "Oxidation of Silicon Carbide Tubes for a High-Temperature Heat Exchanger," May 1, 1981.

G. H. Gilmer, Bell Laboratories, "Computer Models of Crystal Growth," May 6, 1981.

Hermann Winter, Kernforschungszentrum, Karlsruhe, West Germany, "Some Mechanisms Depressing the Superconducting Transition Temperatures of Refractory Compounds. Can One Get Around Them?," May 8, 1981.

M. J. Gillan, Atomic Energy Research Establishment, Harwell, England, "Diffusion Theory and Defect Structures in Crystals," May 15, 1981.

John Mundy, Argonne National Laboratory, "Mechanisms of Self-Diffusion in Metals," May 22, 1981.

David M. McClachlan, Research Corporation, St. Louis, Missouri, "Ion Sputtering and Ion Etching in Materials Research," May 28, 1981.

D. R. Nelson, Harvard University, "Theory of Melting in Two and Three Dimensions," June 3, 1981.

W. C. Oliver, Stanford University, "Deformation Mechanisms in Dispersion-Strengthened Solid Solution and Pure Metals," June 5, 1981.

J. H. Schneibel, Metals and Ceramics Division, ORNL, "Diffusional Creep: The Role of Grain Size Distribution," June 5, 1981.

Nils Christensen, Colorado School of Mines, "Methods of Characterizing Hydrogen Embrittlement in Welding," June 8, 1981.

Herbert Stephan, Director of Electron Beam Research, Leybold-Heraeus, Hanau, West Germany, "Update on Electron Beam Use Over the Last Five Years," June 8, 1981.

E. R. Thompson, United Technologies Laboratories, Hartford, Connecticut, "High-Temperature Alloys," June 15, 1981.

M. A. A. El-Masry, Metals and Ceramics Division, ORNL, "Fabrication, Microstructure Control, and Characterization of Hard Ceramic and Cermet Bodies for Valve Inserts," June 18, 1981.

Michael Ball, University of Liverpool, England, "Generalized Pseudo Atom and Its Application to Lattice Dynamics," June 24, 1981.

Wolfgang Losch, Federal University of Rio de Janeiro, Brazil, "On the Physical Basis of Impurity-Induced Intergranular Fracture," June 29, 1981.

Appendix F

ADVISORY COMMITTEE

The Advisory Committee to the Metals and Ceramics Division currently consists of six members appointed by the laboratory director. The size of the committee was restored to a six-person body in 1981. The tenure of appointment remains at four years as previously requested by the committee. Such action was considered prudent because of rising costs and pending reductions in programmatic support. Attainment of the six-person committee will be accomplished by appointing one new member in odd calendar years (1981, 1983, etc.) and adding two new members in the even calendar years (1982, 1984, etc.). The main function of the committee is to review ongoing research and development activities and to render independent judgments on the general state and welfare, ability of staff, and progress being made in various operations and missions of the division. Members are chosen from governmental, industrial, educational, and research institutions in the United States and are selected on the basis of demonstrated ability in management, research, and technology. Members of the 1981 Advisory Committee are listed below.

Dr. Arden L. Bement, Jr. (Committee Chairman)
Vice President of Technical Resources
TWR, Inc.
23555 Euclid Avenue
Cleveland, Ohio 44117

Dr. Edward H. Kottcamp, Jr.
Director of Research
Homer Research Laboratories
Bethlehem Steel Corporation
Bethlehem, Pennsylvania 18016

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Appendix G

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W. J. Lackey, R. S. Lowrie, and J. D. Sease, *Gas Scrubbing Liquids* (to U.S. Department of Energy) U.S. Patent 4,276,063, June 30, 1981

Appendix H

PRESENTATIONS AT TECHNICAL MEETINGS

Compiled by Alice Rice

Fourth International Conference on Liquid and Amorphous Metals, Grenoble, France, July 7–11, 1980:

D. M. Kroeger,* D. S. Easton, C. C. Koch, and J. O. Scarbrough, "Critical Cooling Rates for Formation of Metallic Glasses Made in an Arc-Hammer Apparatus."

27th Sagamore Army Materials Research Conference, Bolton Landing, New York, July 14–18, 1980:

C. R. Brinkman, "Creep-Fatigue Effects in Structural Materials Used in Advanced Nuclear Power Generating Systems."

Fifth International Conference on Zirconium in the Nuclear Industry, Boston, August 4–7, 1980:

D. O. Hobson,* K. R. Thoms, and Theo van der Kaa, "Effects on Temperature and External Pressure on the In-Reactor Creepdown of Zircaloy Fuel Cladding."

R. E. Pawel* and J. J. Campbell "A Comparison of the High-Temperature Oxidation Behavior of Zircaloy-4 and Pure Zirconium."

Gordon Conference on Solid State Studies in Ceramics, Kimball Union Academy, Meriden, New Hampshire, August 4–8, 1980:

P. F. Becher,* C. C. Wu, and R. W. Rice, "Fracture Toughness Behavior in Al_2O_3–ZrO_2 Composites."

38th Annual Meeting of the Electron Microscopy Society of America, Reno, Nevada, August 4–8, 1980:

J. Bentley, "Advantages of a Field Emission Gun for a Combined Analytical and High-Resolution Transmission Electron Microscope."

J. Bentley,* L. L. Horton, and K. Farrell, "Defect Structures in Neutron-Irradiated Iron."

S. G. Caldwell,* J. J. Wert, and R. W. Carpenter, "Influence of Stacking Energy of Wear of Cu Alloys."

R. W. Carpenter,* J. J. Wert, and S. G. Caldwell, "Metal Surface Deformation and Subsurface Defect Structure: A Microscopy Correlation Study."

L. A. Harris,* R. Raymond, Jr., and R. Cooley, "A New Improved Standard for Electron Probe Determination of Organic Sulfur in Fossil Fuels."

E. A. Kenik* and R. W. Carpenter, "In Situ HVEM Deformation of Aluminum Alloys."

E. A. Kenik,* K. R. Lawless, and R. W. Carpenter, "Low Pressure In Situ Oxidation of Vanadium and V-20 Ti."

M. M. Kersker,* E. A. Aigeltinger, and J. J. Hren, "Crystallographic Differences of Metastable Ni_3Mo in an Ni-Mo-Al Superalloy."

R. J. Lauf* and H. Keating, "Preparation of Ceramic Particulates for Transmission Electron Microscopy."

E. H. Lee* and A. F. Rowcliffe, "Phase Identification in Neutron Irradiated Stainless Steel" (presented by P. J. Maziasz).

P. J. Maziasz* and R. W. Carpenter, "MC Precipitate Characterization in Austenitic Stainless Steel."

P. S. Sklad, "Observations of Gas Bubbles in an Austenitic Stainless Steel Charged with ^3H."

L. J. Sykes* and J. J. Hren, "Comparison of Dislocation and Precipitate Strain Fields."

J. J. Wert,* R. W. Carpenter, and S. G. Caldwell, "The Effect of Stacking Fault Energy of Sliding Wear Behavior of Copper-Aluminum Alloys."

*Speaker.

N. J. Zaluzec,* E. A. Kenik, and P. J. Maziasz, "On the Limitations of X-Ray Microanalysis of Heterogeneous Specimens Using Analytical Electron Microscopy."

N. J. Zaluzec,* J. J. Hren, and R. W. Carpenter, "The Influence of Diffracting Conditions on Quantitative Electron Energy Loss Spectroscopy."

89th Annual Meeting, American Institute of Chemical Engineers, Portland, Oregon, August 17–20, 1980:

G. L. Copeland,* B. Heshmatpour, and R. L. Heestand, "Melting Metal Waste for Volume Reduction and Decontamination."

American Crystallographic Association Summer Meeting, Calgary, Alberta, Canada, August 17–22, 1980:

J. E. Epperson,* J. Faber, R. W. Hendricks, and J. S. Lin, "On the Decomposition and Ripening of an Ni–12.7 at. % Al Alloy."

13th Annual Technical Meeting of the International Metallographic Society, Brighton, England, August 18–22, 1980:

R. J. Gray,* D. A. Canonico, and L. C. Bate, "An Integrity Study of Type 347 Stainless Steel Tubes After a Five-Year Service in a High Flux Nuclear Reactor."

International Conference, "Physics of Transition Metals," Leeds, England, August 18–22, 1980:

W. H. Butler, "The Electron-Phonon Interaction in Transition Metals and Their Compounds."

G. M. Stocks* and B. L. Györffy, "The 2γ Momentum Distribution in Random Ag_cPd_{1-c} Alloys."

G. M. Stocks* and W. H. Butler, "Residual Resistivities of $Ag_cPd_{(1-c)}$ Alloys."

Seventh European Congress on Electron Microscopy, The Hague, The Netherlands, August 24–29, 1980:

D. N. Braski* and K. Farrell, "Radiation Damage Structure in Ordered $(Co_{0.78},Fe_{0.22})_3V$ Alloy."

International Conference, "X-Ray Process and Innershell Ionization," Stirling, England, August 25–29, 1980:

G. M. Stocks, "Electronic States in bcc $Li_cMg_{(1-c)}$ Alloys: Soft X-Ray Emission Spectra."

Third International Conference on "Effect of Hydrogen on Behavior of Materials," Jackson Lake Lodge, Wyoming, August 26–31, 1980:

M. B. Lewis* and K. Farrell, "Deuterium Depth Profiles and Diffusion Coefficient in Electrocharged Stainless Steel."

Basic Engineering Sciences National Welding Conference, Berkeley, California, September 4–5, 1980:

J. M. Vitek* and S. A. David, "Microstructural Analysis of Austenitic Stainless Steel Laser Welds."

International Conference on Engineering Aspects of Creep, Sheffield, England, September 15, 1980:

M. K. Booker, "Progress Toward Analytical Description of the Creep Strain-Time Behavior of Engineering Alloys" (presented by S. Majumdar of Argonne National Laboratory).

Joint U.S.-French Seminar on Small-Angle X-Ray and Neutron Scattering from Polymers, Strasbourg, France, September 16–19, 1980:

D. W. Schaefer,* R. W. Hendricks, and J. S. Lin, "Static Correlations in Semidilute Solutions: Marginal Solvents."

G. D. Wignall,* R. W. Hendricks, and W. C. Koehler, "Current Instrumentaion Developments and Polymer Research at the United States National Center for Small-Angle Scattering Research."

Advisory Technical Awareness Council, American Society for Metals, Cleveland, September 30, 1980:

J. E. Cunningham, "Solidification Behavior and Ferrite Morphology in Austenitic Stainless Steel Welds."

22d Meeting of the Joint Working Group on Uranium Alloys, Oak Ridge, Tennessee, September 30–October 3, 1980:

R. A. Vandermeer,* J. C. Ogle, and W. G. Northcutt, Jr., "Influence of Aging at $M_s(A_f)$ on the Deformation and Shape Memory Behavior of U-Nb α″ Martensite."

ADIP Program Review Meeting, DOE-OFE, Materials and Radiation Effects Branch, Germantown, Maryland, September 30–October 1, 1980:

D. N. Braski, "Resistance of $(Fe,Ni)_3V$ Long-Range-Ordered Alloys to Radiation Damage."

M. L. Grossbeck, "Status of ORR Spectral Tailoring and HFIR Irradiation Experiments."

R. L. Klueh* and J. M. Vitek, "Characterization of Nickel-Doped Ferritic Steels for Helium Production Through HFIR Irradiation."

P. J. Maziasz, "Swelling and Microstructure of HFIR Irradiated Austenitic Stainless Steels."

P. J. Maziasz, "Microstructural Design and Development of Path A Prime Candidate Alloy."

M. P. Tanaka,* E. E. Bloom, and J. A. Horak, "Tensile Properties and Microstructure of Helium-Injected and Reactor-Irradiated V-20 Ti."

F. W. Wiffen,* J. A. Horak, D. P. Edmonds, and J. F. King, "The Influence of Irradiation on the Tensile Properties of Austenitic Stainless Steel Weldments."

TMS-AIME Fall Meeting, Metallurgical Society of AIME, Pittsburgh, Pennsylvania, October 5–9, 1980:

V. B. Baylor,* J. R. Keiser, and E. H. Lee, "Alloy Evaluation in High-Temperature Oxygen-Chloride Environment."

J. R. Keiser,* V. B. Baylor, J. F. Newsome, and M. Howell, "Study of Fractionation Area Corrosion at Solvent Refined Coal Pilot Plants."

E. A. Kenik* and E. H. Lee, "Influence of Injected Helium on the Phase Instability of Ion-Irradiated Stainless Steel."

E. H. Lee,* P. J. Maziasz, and A. F. Rowcliffe, "The Structure and Composition of Phases Occurring in Austenitic Stainless Steels in Thermal and Irradiation Environments."

E. H. Lee,* P. J. Maziasz, and A. F. Rowcliffe, "Identification of Precipitate Phases Occurring in Austenitic Stainless Steels in Thermal and Irradiation Environments."

L. K. Mansur and M. R. Hayns, "Basic Mechanisms Affecting Swelling in Alloys with Precipitates."

P. J. Maziasz,* J. A. Horak, B. L. Cox, and M. L. Grossbeck, "The Influence of Both Helium and Neutron Irradiation on Precipitation in 20% Cold-Worked Austenitic Stainless Steel."

P. J. Maziasz, "Helium Trapping at Ti-Rich MC Particles in Ti-Modified Austenitic Stainless Steel."

A. F. Rowcliffe, E. H. Lee,* L. K. Mansur, and P. J. Maziasz, "Precipitation in Austenitic Stainless Steels During Irradiation."

W. A. Simpson,* L. Adler, and T. K. Bolland, "Boundaries Between Isotropic and Anisotropic Solids and Their Effect on Quantitative NDE."

C. L. White* and R. A. Padgett, "Effects of Antimony Additions on the Fracture of Nickel at 600°C."

M. H. Yoo, "Trace Element Effects on Vacancy Clustering and Heterogeneous Nucleation of Microvoids During Various Thermomechanical Treatments."

Electrochemical Society Autumn Meeting, Hollywood, Florida, October 5–10, 1980:

R. W. Carpenter, "Microdiffraction Studies on Semiconductor Materials."

Fifth Annual Conference on Materials for Coal Conversion and Utilization, Gaithersburg, Maryland, October 6–8, 1980:

V. B. Baylor,* J. R. Keiser, and J. H. DeVan, "Materials for CONOCO Zinc Chloride Hydrocracking Process."

G. M. Goodwin* and D. P. Edmonds, "Fossil Energy Welding and Cladding Program."

J. R. Keiser,* V. B. Baylor, and J. H. DeVan, "Corrosion in Coal Liquefaction Systems."

V. K. Sikka, "Potential Use of Modified 9 Cr-1 Mo Steel for Fossil Utility Boiler Applications" (presented by R. A. Bradley).

American Nuclear Society International Conference on Materials for Nuclear Steam Generation, St. Petersburg, Florida, October 6–8, 1980:

J. P. Hammond,* J. C. Griess, and W. A. Maxwell, "Effects of Chromium, Silicon, Stabilization of Carbides, and Surface Condition on the Steam Corrosion of Cr-Mo Ferritic Alloys."

Fifth International Conference on Small Angle Scattering, Berlin, Germany, October 6–10, 1980:

R. W. Hendricks,* B. S. Borie, and F. W. Stallman, "Small-Angle Scattering from a Misoriented Stack of Lamellae."

R. W. Hendricks,* P. A. Seeger, J. W. Scheer, and S. Suehiro, "The LASL-ORNL Fast Digital Data Acquisition System."

R. W. Hendricks* and S. Suehiro, "Dynamic Deformation Device for Small-Angle X-Ray and Neutron Scattering."

P. LaBarbe,* A. C. Wright, J. S. Lin, R. W. Hendricks, and J. Zarzycki, "SAXS and SANS Studies of Silica Glasses Prepared by Hot-Pressing of Silica Gel."

G. A. Wallace and R. W. Hendricks,* "A High Intensity Mirror-Focussed X-Ray Source for Small Angle Scattering."

Annual Contractors' Review Meeting for Thermal and Chemical Energy Storage, McLean, Virginia, October 13–16, 1980:

J. H. DeVan and P. F. Tortorelli, "Mass-Transfer Characteristics of Nitrate-Based Salt Mixtures." Paper not presented. Summary published in proceedings.

American Nuclear Society Meeting on the Technology of Controlled Nuclear Fusion, King of Prussia, Pennsylvania, October 14–17, 1980:

C. J. Long, "Structural Materials for Large Superconducting Magnets: An Assessment Based on the Large Coil Program."

J. L. Scott,* E. E. Bloom, J. J. Holmes, R. E. Gold, S. M. Rosenwasser, M. L. Grossbeck, T. C. Reuther, Jr., and F. W. Wiffen, "Progress in the Development of the Blanket Structural Material for Fusion Reactors."

International Fuel Rod Simulator Symposium, Gatlinburg, Tennessee, October 22–24, 1980:

A. J. Moorhead* and R. W. Reed, "Fuel Rod Simulator Fabrication Requires Creative Joining Techniques."

American Ceramic Society 33d Pacific Coast Regional Meeting, San Francisco, October 26–29, 1980:

W. K. Alexander, W. P. Eatherly, and C. R. Kennedy,* "Irradiation of TSX Graphite: A Comparison of Highly Accelerated Tests with Reactor Performance."

J. H. Bottcher,* D. A. Donahue, and E. L. Long, Jr., "Sphere-Pack Versus Pellet Mixed-Oxide Fuel to 10 at. % Burnup."

A. J. Caputo,* P. Angelini, and D. P. Stinton, "Drying and Characterization of Sol-Gel Produced Synroc Waste Forms."

W. P. Eatherly, C. R. Kennedy,* and R. P. Wichner, "Mechanical Properties of Several Graphites as Affected by Steam Oxidation."

C. R. Kennedy,* W. P. Eatherly, and R. L. Senn, "The Compressive Creep Characteristics of Graphite Under Irradiation."

S. M. Tiegs,* W. B. Stines, and M. H. Lloyd, "Fabrication of $(U,Pu)O_2$ Fuel Pellets Using Gel Microspheres."

G. C. Wei, "Thermophysical Properties of Carbon-Bonded Carbon-Fiber Thermal Insulation for Radioisotopic Heat Source in Space Nuclear Systems."

Mid-West Solid State Symposium, Bloomington, Indiana, October 27–28, 1980:

W. H. Butler, "Calculation of the Superconductivity Transition Temperature: A Review of the State of the Art."

G. M. Stocks, "Electronic States in Random Substitutional Alloys: Energy Bands and Fermi Surfaces."

U.S.-Japan Exchange on Fusion Reactor Materials, Tokai, Japan, October, 28–29, 1980:

E. E. Bloom,* M. L. Grossbeck, and K. C. Liu, "Mechanical Properties of Type 316 Stainless Steel at Fusion Reactor Damage Levels."

N. H. Packan, T. C. Reiley, K. Farrell, L. K. Mansur, and E. E. Bloom,* "Summary of Results from the ORNL Ion Irradiation Program."

M. P. Tanaka,* E. E. Bloom, and J. A. Horak, "Tensile Properties and Microstructure of Helium-Injected and Reactor-Irradiated V-20 Ti."

American Society for Metals Materials and Processes Show, Cleveland, Ohio, October 28–30, 1980:

S. A. David, "Solidification Structure of Thorium-Doped Iridium Alloy Welds."

J. R. Keiser,* V. B. Baylor, D. R. Canfield, and W. P. Barnett, "Materials Performance in Coal Liquefaction Pilot Plant."

J. R. Keiser,* V. B. Baylor, D. R. Canfield, and W. P. Barnett, "Failure Analysis Assistance to Solvent Refined Coal Pilot Plant."

J. W. McEnerney,* B. R. Dewey, and S. A. David, "System for Control of Electroslag Casting in a Collar Mold."

R. W. Swindeman, "Failure Analysis Activities at Coal Liquefaction Pilot Plants—An Overview."

National Association of Corrosion Engineers, El Paso, Texas, October 28–30, 1980:

J. H. DeVan,* H. E. McCoy, and J. E. Mack, "Compatibility of Several Waste Forms with Potential Cannister Materials."

Eighth Water Reactor Safety Research Information Meeting, Nuclear Regulatory Commission, Washington, D.C., October 27–31, 1980:

C. V. Dodd, "Improved Eddy-Current Inspection of Steam Generator Tubes."

Synchrotron Radiation Users' Meeting, Stanford, California, October 30–31, 1980

G. S. Brown, M. H. Chen, B. Crasemann,* and G. E. Ice, "Observation of the Auger Resonant Raman Effect."

Workshop on "The Effect of Complex Loads and Irradiation on the Lifetime of Fusion Reactor First Walls," Petten, The Netherlands, November 4, 1980:

M. L. Grossbeck, "Recent Work on Mechanical Properties of Austenitic Stainless Steels for Fusion Reactor Service."

Meeting of the Working Group of ANNEX II of the IEA Implementing Agreement on Radiation Damage to Fusion Materials, Petten, The Netherlands, November 7, 1980:

M. L. Grossbeck, "Mixed Spectrum Neutron Irradiation Experiments on Fusion Reactor Materials."

American Society for Testing and Materials November Committee Week, Bal Harbour, Florida, November 9–14, 1980:

R. W. Swindeman* and D. N. Robinson, "Experimental Determination of State Variables Related to Metallurgical Structure in 2¼ Cr-1 Mo Steel at High Temperature."

ANL/DOE, International Meeting on Development, Fabrication, and Application of Reduced-Enrichment Fuels for Research and Test Reactors, Chicago, November 12–14, 1980:

G. L. Copeland and M. M. Martin,* "Fabrication of High-Uranium-Loaded U_3O_8-Al Developmental Fuel Plates."

R. L. Senn* and M. M. Martin, "Irradiation Testing of Miniature Fuel Plates fo the RERTR Program."

First Annual Utility Energy Management Conference, New Orleans, November 16–19, 1980:

D. L. McElroy, "Thermal Insulation."

American Society of Mechanical Engineers Annual Winter Meeting, Chicago, November 16–21, 1980:

M. K. Booker, "Analysis of Creep-Rupture Data for Long-Range Life Prediction."

M. K. Booker* and B. L. P. Booker, "New Methods of Analysis of Materials Strength Data for the ASME Boiler and Pressure Vessel Code."

Materials Research Society Third International Symposium on Scientific Basis for Nuclear Waste Management, Boston, November 16–21, 1980:

P. Angelini,* W. D. Bond, A. J. Caputo, J. E. Mack, W. J. Lackey, D. A. Lee, and D. P. Stinton, "Sol-Gel Technology Applied to Crystalline Ceramics."

National Synchrotron Light Source X-Ray Participating Research Team Meeting, Brookhaven National Laboratory, Upton, New York, November 17–18, 1980:

G. E. Ice, "ORNL Beam Line Optics."

C. J. Sparks, Jr., "ORNL Synchrotron Radiation Beam Line."

American Physical Society, Plasma Physics Division, Annual Meeting, San Diego, California, November 17–21, 1980:

L. C. Emerson,* C. E. Bush, R. C. Isler, R. A. Langley, D. M. Mattox, A. W. Mullendore, and J. B. Whitley, "Testing of TiC and B-Coated Limiters in Beam Heated ISX-B Plasmas."

Coal Liquefaction Corrosion Workshop, Baytown, Texas, November 20, 1980:

J. R. Keiser,* R. R. Judkins, V. B. Baylor, M. Howell, and J. F. Newsome, "ORNL Studies of Fractionation Area Corrosion."

Committee of Safety of Nuclear Installation Specialists Meeting on Instrumented Precracked Charpy Testing, Palo Alto, California, December 1–3, 1980:

R. K. Nanstad, "Comparison of Instrumented Precracked Charpy and Compact Specimen Tests with Carbon Steels."

R. K. Nanstad, "Comparison Between Instrumented Precracked Charpy and Compact Specimen Tests of Carbon Steels."

Electron Microscopy: Instruments and Instrumentation (Institute of Physics), London, England, January 7, 1981:

J. Bentley, "The Field Emission Gun TEM/STEM as a Combined Analytical and High-Resolution Electron Microscope."

Golden Gate Metals and Welding Conference, San Francisco, January 21–23, 1981:

R. A. Bradley, "Overview of DOE-Funded Fossil Energy Materials Program."

WATTec Conference, Knoxville, Tennessee, February 18–20, 1981:

R. A. Bradley, "An Overview of DOE-Funded Coal Utilization and Conversion Projects."

C. V. Dodd, "Application of Multiple-Property Eddy-Current Techniques to Steam Generator Tubing Inspection."

T. G. Godfrey, "Materials and Fabrication for Fluidized Bed Combustion."

R. J. Gray,* G. M. Slaughter, J. C. Griess, Jr., and C. W. Houck, "Metallurgical Analysis of Fire-Damaged Piping from a U.S. Strategic Petroleum Reserve Supply Facility."

T. S. Lundy, "Building Thermal Envelope Systems and Insulating Materials."

Meeting, American Institute of Mining, Metallurgical, and Petroleum Engineers, Chicago, February 23–26, 1981:

J. Bentley, "Interphase Boundary Dislocation Structure of Second Phase Particles in Stainless Steel."

D. J. Bradley,* M. McDonald, and J. M. Leitnaker, "The Effect of Silicon on the Composition and Solubility of Laves and Chi Phases in 316 and Titanium-Modified 316 Stainless Steels."

D. A. Canonico* and R. G. Berggren, "Effect of Irradiation on Nuclear Pressure Vessel Weld Metals."

S. A. David* and J. M. Vitek, "Solidification Behavior and Microstructural Analysis of Austenitic Stainless Steel Laser Welds."

K. Farrell, "Radiation Response of Aluminum and Its Alloys After Exposure in the High Flux Isotope Reactor."

L. A. Harris* and E. C. Hise, "The Application of Coal Petrography to the Evaluation of Magnetically Separated Dry Crushed Coal."

L. L. Horton,* J. Bentley, and W. A. Jesser, "Fusion Environment Radiation Damage in High-Purity Iron and Iron Chromium Alloys."

C. T. Liu* and E. H. Lee, "Creep Behavior of Ductile Ordered Alloys Co-16 to 25 Fe-23 V."

P. S. Sklad* and V. K. Sikka, "Microstructural Observations of Strain Softening in Ferritic 9 Cr-1 Mo Alloys."

R. A. Vandermeer,* J. C. Ogle, and W. G. Nothcutt, Jr., "Influence of Aging at $M_s(A_f)$ on the Deformation and Shape Memory Behavior of U-Nb α'' Martensite."

C. L. White* and R. A. Padgett, "Trace Element Effects on the High-Temperature Ductility of Nickel."

M. H. Yoo, "Fracture Initiation at Grain Boundary Inclusions—Internal Stress Effects."

Meeting, Fusion Engineering Device, Technical Management Board, Washington, D.C., February 26, 1981:

J. O. Stiegler, "Strategy for the Use of Irradiation Test Facilities in the Development of Materials for Fusion Power."

International Conference on High-Temperature Corrosion, San Diego, California, March 2–6, 1981:

V. B. Baylor,* J. R. Keiser, and E. H. Lee, "Corrosion Studies in $ZnCl_2$-Air-HCl Environments at 500–1000°C."

R. E. Pawel, "The Oxidation of Zirconium and Zircaloy-4 from 1000 to 1500°C."

R. E. Pawel* and J. J. Campbell, "Reaction Kinetics and Oxygen Diffusion During the Oxidation of Zirconium and Zircaloy-4 from 1000 to 1500°C."

Meeting, American Physical Society, Phoenix, Arizona, March 16–20, 1981:

W. H. Butler, "Lattice Thermal Conductivity of Nb, Mo, and Pd."

J. S. Faulkner, "Pivoted Multiple-Scattering Equations and Band Theory."

R. A. McKee, "Diffusion in a Pure, High Vacancy Content Crystal."

G. S. Painter* and F. W. Averill, "On the Hellmann-Feyman and Virial Theorems Within the Density Functional Formalism: Applications to Molecules."

G. M. Stocks, "Screening Mechanisms in Heterovalent Alloys: Li_cMg_{1-c}."

E. A. Kenik,* C. L. White, and W. E. Felling, "SHaRE: A Collaborative Users Program for Microanalysis in Materials Science" (invited presentation to a Special Session on National Facilities).

American Welding Society, Sixth Annual Rocky Mountain Symposium, Golden, Colorado, March 20, 1981:

S. A. David, "Nature of Ferrite in Stainless Steel."

International Conference on Creep and Fracture of Engineering Materials and Structures, University College of Swansea, United Kingdom, March 24–27, 1981:

C. L. White,* R. A. Padgett, R. W. Swindeman, K. Farrell, and M. H. Yoo, "Impurity Segregation to Creep Cavities in 304 Stainless Steel."

Fifth International Conference on Fracture, Cannes, France, March 29–April 3, 1981:

C. L. White* and R. A. Padgett, "Trace Element Effects in High-Temperature Fracture of Nickel."

Third International Conference on Wear of Materials, San Francisco, March 30–April 1, 1981:

J. J. Wert,* R. W. Carpenter, and S. G. Caldwell, "The Effect of Stacking Fault Energy of Sliding Wear Behavior of Copper-Aluminum Alloys."

National Meeting of American Institute of Chemical Engineers, April 5–9, 1981:

J. R. Keiser, R. R. Judkins, V. B. Baylor, D. R. Canfield, and W. P. Barnett,* "Control of Fractionation Area Corrosion at SRC Pilot Plants."

American Welding Society Conference on Aluminum Weldments, Cleveland, April 6–10, 1981:

S. A. David, "A Study of Ferrite Morphology and Variations in Ferrite Content in Austenitic Stainless Steel Welds."

J. M. Vitek* and S. A. David, "Microstructural Analysis of Austenitic Stainless Steel Laser Weld."

11th Annual Symposium on Electronic Structure of Metals and Alloys, Gaussig, East Germany, April 6–10, 1981:

J. S. Faulkner, "Multiple Scattering Theory of Electrons in Ordered and Disordered Solids."

Meeting, National Association of Corrosion Engineers, Toronto, Canada, April 6–10, 1981:

V. B. Baylor* and J. R. Keiser, "Stress Corrosion Cracking Studies in Coal Liquefaction Systems."

J. C. Griess,* J. H. DeVan, and W. A. Maxwell, "Long-Term Corrosion of Cr-Mo Steels in Superheated Steam at 482 and 538°C."

J. R. Keiser, R. R. Judkins,* V. B. Baylor, D. R. Canfield, and W. P. Barnett, "Corrosion of Solvent Refined Coal Pilot Plant Fractionation Columns."

P. F. Tortorelli,* J. H. DeVan, and R. M. Yonco, "Compatibility of Fe-Cr-Mo Alloys with Static Lithium."

Spring Meeting of Swiss Physical Society, Neuchatel, Switzerland, April 8–10, 1981:

E. Ambruster, A. DasGupta,* H.-U. Kunzi, and H.-J. Guntherodt, "Hydrogen Peaks in Internal Friction of Metallic Glasses."

Meeting, Scanning Electron Microscopy, Dallas, Texas, April 14–18, 1981:

J. Bentley,* M. J. Goringe, and R. W. Carpenter, "Thickness Fringe Contrast at Grain Boundaries in TEM and STEM."

J. Bentley, "Instrumental Problems Affecting X-Ray Microanalysis in the Analytical Electron Microscope: An Update."

L. A. Harris,* E. A. Kenik, and C. S. Yust, "Reactions in Pyrite Framboids Induced by Electron Beam Heating in an HVEM."

P. S. Sklad* and J. Bentley, "Analytical Electron Microscopy of Ni-TiB_2 Composites."

J. M. Vitek* and S. A. David, "Analytical Electron Microscopy Evaluation of Laser-Welded 308 Stainless Steel."

American Ceramic Society Annual Meeting, Washington, D.C., May 3–8, 1981:

P. F. Becher* and V. J. Tennery, "Fracture Behavior in Composites Containing ZrO_2 Particulates" (poster exhibit).

M. K. Ferber* and S. D. Brown, "Delayed Failure Characteristics of Plasma-Sprayed Al_2O_3 Applied to 316L Stainless Steel and Ti–6 Al–4 V ELI Substrates."

C. S. Morgan* and R. J. Lauf, "Thermal Shock Resistant Al_2O_3-Cr Cermets."

D. P. Stinton,* P. Angelini, A. J. Caputo, and W. J. Lackey, "Deposition of Impervious Pyrolytic Carbon and SiC Provide Enhanced Inertness to Crystalline Waste Forms."

P. S. Sklad* and J. Bentley, "Analytical Electron Microscopy of TiB_2-Ni Ceramics" (poster exhibit).

V. J. Tennery,* G. C. Wei, and M. K. Ferber, "High-Temperature Behavior of Silicon Carbide, Sialon, and Aluminum Oxide Ceramics in Coal and Residual Oil Slags."

C. S. Yust* and E. L. Long, Jr., "Transmission Electron Microscopy and Optical Microscopy of Commercial WC-Co Compositions."

Specialists' Meeting on High-Temperature Metallic Materials for Application in Gas Cooled Reactors, Vienna, Austria, May 4–6, 1981:

H. Inouye and P. L. Rittenhouse,* "Relationship Between Carburization and Zero-Applied-Stress Creep Dilation in Alloy 800H and Hastelloy X."

J. F. King, H. E. McCoy, and P. L. Rittenhouse,* "Weldability Evaluations and Weldment Properties of Hastelloy X."

J. P. Strizak, C. R. Brinkman, and P. L. Rittenhouse,* "High-Temperature Low-Cycle Fatigue and Tensile Properties of Hastelloy X and Alloy 617 in Air and HTGR-Helium."

Workshop on Corrosion Erosion in Coal Liquefaction Pilot Plants, Lexington, Kentucky, May 13–14, 1981:

J. R. Keiser,* V. B. Baylor, M. Howell, A. R. Irvine, R. R. Judkins, and J. F. Newsome, "ORNL Studies of Fractionation Column Corrosion."

American Society for Metals, Symposium on Elevated-Temperature Materials Considerations in Coal Liquefaction and Gasification Service, Oak Ridge, Tennessee, May 15, 1981:

V. B. Baylor* and J. R. Keiser, "Corrosion in Coal Liquefaction Processes."

J. R. Keiser,* M. D. Allen, V. B. Baylor, J. H. DeVan, R. J. Gray, B. C. Leslie, and J. R. Mayotte, "Corrosion Failures in Coal Liquefaction Pilot Plants."

International Conference on Fast Ionic Transport in Solids, Gatlinburg, Tennessee, May 18–22, 1981:

R. A. McKee, "A Generalization of the Nernst-Einstein Equation for Self-Diffusion in High Defect Concentration Solids."

Meeting, Mechanical Behavior and Nuclear Application of Stainless Steels at Elevated Temperatures, Varese, Italy, May 20–22, 1981:

V. K. Sikka, "Long-Term Creep Data on Type 304 Stainless Steel."

R. W. Swindeman, "Correlation of Rupture Life, Creep Rate, and Microstructure for Type 304 Stainless Steel."

Presentations in China as part of exchange program between American Society for Metals and Chinese Society of Metals—Tokyo, May 16; Beijeng, May 17; Shanghai, June 1; Guangzhou, June 4; and Hong Kong, June 6:

R. J. Gray, "Unusual Metallographic Techniques Help Us to Understand and Evaluate Microstructures."

R. J. Gray, "Failure Analyses of Surgical Implants from the Human Body Can Improve Product and Performance Reliability."

Second US/Japan LMFBR Steam Generator Seminar, Sunnyvale, California, June 1–5, 1981:

R. W. McClung,* R. A. Day, H. H. Neely, and T. Powers, "Techniques for In-Service Inspection of Heat Transfer Tubes in Steam Generators."

International Seminar on Chemistry and Process Engineering for High-Level Liquid Waste Solidification, Kernforschungsanlage, Jülich, West Germany, June 1–5, 1981:

W. J. Lackey,* P. Angelini, W. D. Arnold, W. D. Bond, A. J. Caputo, and D. P. Stinton, "Sol-Gel-Derived Waste Forms."

American Nuclear Society, Miami Beach, Florida, June 7–12, 1981:

G. L. Copeland* and B. Heshmatpour, "Decontamination of TRU-Contaminated Metal Waste by Melt Refining."

B. Heshmatpour and G. L. Copeland,* "Granulation of Metals and Slags for Waste Disposal and Storage."

A. F. Rowcliffe* and J. A. Horak, "Tensile Properties and Fracture Behavior of Irradiated Nickel Alloys."

American Society for Metals, Workshop on Conservation and Substitution Technology, Vanderbilt University, Nashville, Tennessee, June 15–17, 1981:

V. K. Sikka, "Substitution of Modified 9 Cr-1 Mo Steel for Austenitic Stainless Steel."

National Bureau of Standards International Conference on Thermal Conductivity, Gaithersburg, Maryland, June 15–19, 1981:

H. A. Fine, S. H. Jury, D. L. McElroy,* and D. W. Yarbrough, "The Thermal Conductivity of Semitransparent Materials."

J. P. Moore* and R. S. Graves, "The Thermal Conductivity and Electrical Resistivity of a POCO AXM-5Q1 Graphite from 80 to 900 K."

J. P. Moore,* R. S. Graves, and R. K. Williams, "Thermal Transport Properties of Niobium and Some Niobium-Base Alloys from 80 to 1600 K."

J. P. Moore,* D. L. McElroy, and S. H. Jury, "A Technique for Measuring the Apparent Thermal Conductivity of Flat Insulations."

R. K. Williams, R. S. Graves, F. J. Weaver, and D. L. McElroy,* "The Physical Properties of 9 Cr-1 Mo Steel from 300 to 1000 K."

American Society of Mechanical Engineers Pressure Vessel and Piping Conference, Denver, Colorado, June 21–25, 1981:

R. W. Swindeman and C. R. Brinkman,* "Progress in Understanding the Mechanical Behavior of Pressure Vessel Materials at Elevated Temperatures."

R. W. Swindeman* and K. C. Liu, "Creep and Fatigue Resting of Austenitic Stainless Steel Welds and Overlay Cladding."

American Carbon Society 15th Biennial Carbon Conference, Philadelphia, June 22–26, 1981:

W. P. Eatherly, "The Use of Run Statistics to Validate Tensile Tests."

W. P. Eatherly, "Statistical Identification of Disparate Flaws in H451 Graphite."

C. R. Kennedy, "Evaluation of Fracture Strength by Sonic Testing."

C. R. Kennedy* and W. P. Eatherly, "The Flux Effect in Graphite."

American Society of Heating, Refrigerating, and Air-Conditioning Engineers Annual Meeting, Cincinnati, Ohio, June 28–July 2, 1981:

H. A. Fine,* S. H. Jury, D. W. Yarbrough, and D. L. McElroy, "Heat Transfer in Building Thermal Insulation: The Thickness Effect."