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Metals and Ceramics Division Annual Progress Report for October 1, 1978 Through June 30, 1979

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METALS AND CERAMICS DIVISION ANNUAL PROGRESS REPORT FOR OCTOBER 1, 1978, THROUGH JUNE 30, 1979

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Foreword

This progress report covers the research and development activities of the Metals and Ceramics Division for the nine-month period October 1, 1978, through June 30, 1979. 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 four parts. Part 1 deals with the activities of the Engineering Materials Section, Part 2 with the Fuels and Processes Section, and Part 3 with the Materials Science Section. Part 4 highlights the work of the metallographic group and presents the current status of the High-Temperature Materials Laboratory (HTML) and the Materials and Structures Technology Management Center (MSTMC). Background information on financial support and allocation of funds, personnel, organizational structure, seminar program, honors and awards, 1979 Advisory Committee, technical publications, and oral presentations appear in appendices in summary form.

The character and thrust of the materials science and engineering effort of the Division continues to undergo change in step with national program needs in the energy field. An office has been established to manage the National Fossil Energy Materials Program for the underlying purpose of expanding domestic energy supply by increasing extraction and utilization of coal. Providing a sound base of materials technology to permit design and construction of new facilities and equipment for efficient mining, processing, and use of coal is an important objective of the program. In the area of energy conservation, the pace of work has accelerated on the Building Thermal Envelope Systems and Insulating Materials (BTESIM) Program, and the Division has been assigned new management roles in connection with implementation of the national Residential Conservation Service (RCS) program. The merits of the gel sphere-pac fuel process to produce LWR fuel with higher burnup capability and improved service performance is being recognized, and the effort has advanced from the development phase to actual demonstration of performance in utility-owned power plants. A new basic program on material deformation and fracture has been initiated in the Materials Science Section to broaden and integrate the theoretical and experimental applied work under way on mechanical and metallurgical behavior of structural materials. The initial thrust of the effort will be focussed on void nucleation and growth at grain boundaries during creep deformation.

Considerable effort has been devoted to establishing users groups so that university and industrial research people will have access to the specialized facilities and unique equipment available at ORNL for advancing materials research on a broad front. Active groups are in existence for utilizing the Small-Angle X-Ray Scattering (SAXS) Laboratory, which is part of the National Center for Small-Angle Scattering Research, the high-voltage electron microscope and related scanning transmission electron microscopes, and the surface analysis and microstructural analysis facilities. Recently, a consortium of university and ORNL personnel was organized to design, construct, and operate a national x-ray scattering facility at the Brookhaven Synchrotron. In addition, the HTML is being planned as a national facility to promote cooperative investigation of generic science in this important research area.

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

1. Engineering Materials

G. M. Slaughter

This Section has the responsibility 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. The 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. A brief description of the work performed and accomplishments of each functional group during the past year are presented below.

MATERIALS COMPATIBILITY

J. H. DeVan

The Materials Compatibility Group conducts corrosion and alloy development studies in support of fusion energy, gas-cooled reactor, fossil energy, space-nuclear, nuclear fuel reprocessing, and advanced technology projects.

We continue to study thermal-gradient mass transfer processes in small, natural-convection loops circulating liquid lithium, nitrate salt mixtures, and fluoride salt mixtures. These fluids are of interest for tritium-breeding blankets and coolants in fusion reactors. The principal objective of these tests is to characterize the corrosion properties of 300-series stainless steels and higher nickel alloys under the temperature and hydrodynamic conditions of conceptual fusion reactor systems. These studies have led to an effective technique for limiting the corrosion of nickel-bearing alloys in lithium by adding aluminum directly to the lithium.

To support the advancement of the Very High-Temperature Gas-Cooled Reactor concept, we have constructed a small helium loop to study the compatibility of conventional superalloys with systemic impurities in the helium. Helium with fixed levels of CH_4, CO_2, H_2O, CO, and H_2 is recirculated over test specimens heated to temperatures from 600 to 1100°C. The principal effect seen in these tests is grain boundary carburization and an associated embrittlement and dilation of the reference alloys.

Studies in support of space-nuclear power systems are concerned with the development of high-temperature metal claddings for the containment of PuO_2 or Cm_2O_3 decay-heat sources. We have had long-standing alloy development programs to upgrade the mechanical and chemical properties of Pt-Rh and Ir-W alloys to meet extreme temperature and environmental conditions. Key efforts this year were devoted to characterizing the high-temperature impact properties of the iridium-base alloys to ensure that they can survive heat source atmospheric reentry and ground impact. We also studied the effects of selenium on the high-temperature tensile properties of platinum alloys to qualify these alloys for use with selenide-containing thermoelectric generating modules.

The Group's efforts in the area of fossil energy centered around hot-corrosion problems in fluidized-bed coal combustors (AFBCs) and stress-corrosion and acid attack in coal-liquefaction processes. By examining several sets of heat exchanger tubes from operating AFBCs, we have established an initial correlation of oxidation-sulfidation processes with fluidized bed conditions and alloy composition. Our coal liquefaction corrosion studies included metallurgical examinations of surveillance specimens exposed in operating Solvent-Refined Coal pilot plants as well as tensile specimens tested at constant extension rates in laboratory autoclaves.

The Group is supporting the Consolidated Fuel Reprocessing Program at ORNL by qualifying container materials for process fluids. The experimental part of this program is being conducted by subcontracting corrosion studies with Battelle-Columbus and Westinghouse Advanced Reactors Division.

Development of long-range-ordered (LRO) alloys, originally part of the space-nuclear program, is now being supported under DOE's Advanced Technology Program in the Office of Energy Research. The objective is the qualification of the $(Ni,Fe,Co)_3V$ alloy for general applications in high-temperature energy systems. Because of limited cobalt resources, we have concentrated on the development of new compositions in which cobalt is restricted to 10% or less. Such alloys have critical ordering temperatures in the range from 700 to 800°C and appear extremely useful for fusion reactor and fast breeder applications.

MECHANICAL PROPERTIES

C. R. Brinkman

During the past 12 months the staff continued materials research and development support of national programs aimed at energy development. Percentages of our effort directed at various projects within the group were as follows: Liquid Metal Fast Breeder Reactor (44%), High Temperature Gas-Cooled Reactor (15%), Nuclear Regulatory Commission (13%), Fusion Development (8%), and miscellaneous (20%). Highlights from specific programs were as follows:

Elevated-temperature mechanical property measurements continued in support of LMFBR development. Typical property studies included tensile, creep, fatigue, crack growth, and creep-fatigue interaction. These properties were obtained in support of specific component development tasks such as the steam generator, evolving constitutive equations, failure criteria and ASME Code support, and development of the Nuclear Systems Materials Handbook. Experimentally, approximately 125 creep, 7 fatigue, and 7 creep plasticity and relaxation machines were involved in this effort. Long-term creep tests were continued with some tests in progress exceeding 60,000 h at temperatures (428–649°C) in many instances above the range of previous long-term data. Experimental techniques were developed to study the evolution of the "structure-dependent state variables" needed to implement inelastic design.

The chemical composition of 9 Cr-1 Mo steel was optimized to yield a material with elevated-temperature strength properties equal to or better than that of type 304 stainless steel. These modifications were made to obtain a stronger ferritic material with the inherent advantages of high thermal conductivity, low thermal expansion, and immunity to halide-induced stress-corrosion cracking. Work to qualify the material for high-temperature service is continuing.

Nuclear Regulatory Commission sponsored studies of the creepdown of Zircaloy fuel cladding under conditions of external pressure, temperature, and fast neutron flux typical of light-water power reactors are in their final year. A joint irradiation program with the Dutch at ECN-Petten produced unique creep rate data and other information on cladding behavior that were directly applicable to computer modeling of that behavior in actual power reactors.

Fatigue and crack growth behavior are among the most important properties to be considered in the design of the first wall of a magnetic confinement fusion reactor. Towards this end fatigue tests were conducted on irradiated specimens of 20%-cold-worked type 316 stainless steel. Further, another fatigue system was designed and built to conduct scoping tests on unirradiated candidate first-wall alloys such as vanadium- and niobium-base alloys. Accordingly, it is now possible to conduct fatigue and crack growth tests on both irradiated and unirradiated specimens at elevated temperatures and in vacuum.

Mechanical property studies in support of HTGR development involved creep and fatigue studies conducted in an impure helium environment. Structural materials characterized were $2^1/_4$ Cr-1 Mo steel, Hastelloy X, alloy 800H, and associated weld metals. Creep studies run to 25,000 h revealed that Hastelloy X was carburized and $2^1/_4$ Cr-1 Mo steel was decarburized. Changes in strength and ductility were monitored.

NONDESTRUCTIVE TESTING

R. W. McClung

The Nondestructive Testing Group develops new or improved methods of nondestructive testing (NDT) and provides technical support in NDT. The scope of activities ranges from long-range studies of physical mechanisms and theory to development of advanced techniques and equipment and to near-term applied development, technical support, and consultation in the technology of NDT. The program

is broad-based, both from the technologies involved (including penetrating radiation, eddy current, ultrasonic, thermal, and penetrant techniques) and the projects (or agencies) represented, including several projects for both the DOE and the Nuclear Regulatory Commission (NRC).

The major activity for DOE has been on the Breeder Reactor Program (BRP). We have coordinated parallel NDT development at ANL, GE, and HEDL, including issuing periodical progress reports and conducting review meetings. For the examination of austenitic stainless steel welds, we performed ultrasonic calibration studies with both machined discontinuities (e.g., notches and holes) and fatigue cracks toward establishment of correlations between such natural and man-made flaws. Ultrasonic frequency analysis was investigated for improved flaw characterization in the steel welds. Eddy-current studies emphasized multiparameter multiple frequency techniques, and modular instrumentation containing an on-board microcomputer was designed and built. We have begun to apply this technology to the work on stainless steel welds as well as other problems. For the Clinch River Breeder Reactor steam generator we completed the development of microfocus rod-anode radiography for manufacturing inspection of the tube-to-tubesheet (T/TS) joint, developed prototype ultrasonic techniques and equipment for in-service inspection (ISI) of the T/TS joints, and established preliminary eddy-current techniques for the ISI of the tubing. For alternate steam generator designs for BRP we provided technical support to Babcock and Wilcox for radiographic and ultrasonic examination of tube-to-tube and T/TS welds and to Westinghouse Tampa Division for radiographic examination of T/TS welds.

Long-range NDT studies for the DOE Office of Basic Energy Sciences emphasized mechanisms for acoustic propagation across solid-solid interfaces. Other DOE programs include studies in x-ray attenuation for fuel homogeneity for LWRs, investigations for NDT of composites, x-ray and ultrasonic studies for research reactor fuel, radiographic and ultrasonic developments for graphite, and technical support for the examination of alloys for space nuclear systems.

The largest activity for the NRC was directed toward improved ultrasonic standards for ISI of LWR pressure vessels and included consultation, interaction with ASME Code committees, and confirmatory laboratory experiments. For reactor safety research we optimized eddy-current techniques (with the aforementioned multiparameter technology) for the ISI of LWR steam generators, and completed development of eddy-current techniques and equipment for the in-core monitoring of deformation of Zircaloy fuel cladding.

PRESSURE VESSEL TECHNOLOGY

D. A. Canonico

The Pressure Vessel Technology Group is concerned with the fracture resistance of load-bearing materials. The development of such information requires expertise in the areas of fracture toughness testing and interpretation of the data. Both DOE- and NRC-sponsored programs are conducted by this group. Currently, the major emphasis is on the material property needs for the heavy-section steel technology (HSST), fossil energy, HTGR, and fusion energy programs.

The efforts on behalf of the HSST program consist of (1) initiating a fourth irradiation experiment and (2) satisfying the material property needs for the ongoing intermediate test vessel (ITV) program. The fourth irradiation experiment will include 1T compact specimens (CS), Charpy V-notch (C_V) specimens, and tensile specimens. Specimen complement in the fourth experiment was based on the need to statistically assign fracture toughness values to the nuclear pressure vessel materials after irradiation. It was necessary to completely redesign the capsule and modify the specimen geometry for this experiment. This has been completed, and the first capsule is scheduled to be placed in the Bulk Shielding Reactor (BSR) during FY 1979.

Material property data were obtained for the ITV-8 repair weldment. The heat-affected zone of the half-bead weld repair exhibited the highest fracture toughness of any region in ITV-8. The area of the weldment that exhibited the poorest fracture toughness was the original fabrication weld. As a result of the PVT material characterization studies the flaw for the ITV-8 test was placed in the fabrication weldment. The fracture toughness data provided by us and the residual stress values were used in the pretest fracture mechanics analysis. This analysis accurately predicted the fracture behavior of the ITV-8 test vessel. In addition to the testing programs, we also determined the process heat treatment required to develop 110 MPa $\sqrt{m}$ (100 ksi $\sqrt{in.}$) at about −20°C (0°F) for SA-508 class 2 steel. A

4-h treatment at 615°C (1135°F) provided the required toughness.

The research for the prestressed concrete reactor vessel program includes the characterization of the fracture toughness of plain carbon and low-alloy steel liner materials. The SA-508 class la steel exhibited exceptionally good resistance to fracture at extremely low temperatures. This material exhibits a nil-ductility temperature (NDT) at −55°C (−70°F). Even more impressive was the fact that the C_V fracture energy exceeded 68 J (50 ft-lb) at this same temperature. Usually, a plain carbon steel will exhibit about 20 J (15 ft-lb) at this temperature. It appears that the "microalloy," lower carbon and high manganese, permitted in the SA-508 class la specification promotes improved fracture toughness.

The characterization of the fracture toughness of candidate materials for commercial coal conversion pressure vessels is continuing. These studies include an assessment of the effect of high hydrogen pressures at typical operating temperatures on the mechanical properties. Hydrogen attack, based on thermodynamic calculations of carbon-hydrogen interactions, is under way. Early results indicate good agreement between the computer-based predictions and the empirical results shown in a Nelson diagram. An autoclave capable of 14 MPa (2000 psi) and 540°C (1000°F) has been modified and is being used to experimentally assess the results obtained from the thermodynamic calculations.

WELDING AND BRAZING

G. M. Goodwin

The Welding and Brazing Group has conducted materials joining research and development in the Light-Water Reactor, Reactor Safety, Fossil Energy, Basic Energy Science, Gas-Cooled Reactor, Space-Nuclear, and Fast Breeder Reactor Program areas.

Light-Water Reactor and Reactor Safety Programs have involved review of ASME code cases and continuation of a study of lamellar tearing of reactor materials. Additionally, more than a dozen complex instrumentation assemblies for Reflood Studies in the Federal Republic of Germany have been developed and successfully fabricated in a cooperative program with the Instrumentation and Controls Division. This latter project has involved the development of very difficult ceramic-to-metal and metal-to-metal brazing procedures as well as laser welding techniques on small and intricate probes and associated units.

Fossil Energy efforts have developed successful techniques for corrosion-resistant weld overlay cladding of heavy-walled reaction vessels and initiated a characterization of prototypic field welds in thick plate. Prototypic production cladding processes were utilized (e.g. submerged-arc), and the advantage of an intermediate transition layer of a nickel-base alloy was demonstrated.

The Basic Energy Science Program has made significant progress toward determination of the sequences of phase separation during solidification of austenitic stainless steels and iron-chromium-nickel ternary alloys. Microstructural and microprobe analyses indicated both extensive solid-state transformation and solute redistribution during solidification and cooling from the nonequilibrium solidus to room temperature.

Gas-Cooled Reactor work has emphasized characterization of the weldability of a number of relatively new high-temperature nickel-base alloys for advanced applications. Alloys that look particularly promising are alloy 617, HD 556, and alloy 802; mechanical properties of welds in these materials are currently being determined.

Work for Space-Nuclear Related Systems has advanced the state of the art of joining platinum- and iridium-base alloys for isotopic fuel encapsulation. Although modified iridium alloys containing thorium were found to be very susceptible to hot-cracking during welding, the electron beam process showed greater promise of success in welding them.

Breeder Reactor Programs have confirmed the improvement in long-term high-temperature properties achieved with controlled residual element (CRE) stainless steel welds for several weld processes and types of filler metals from commercial suppliers. The applicability of large-diameter pipe fabricated by advanced techniques has been demonstrated in detail. Five formed-and-welded pipes (0.91-m-OD by 12.77-mm-wall) were procured to characterize their time-independent properties; two welding processes and three weld metals were evaluated. Welding procedures for fast breeder reactor dissimilar-metal transition joints have been developed and supplied to the commercial fabricator.

A program funded by Laboratory seed money has shown great progress toward fabrication of pipe by continuous electroslag casting techniques. The results are applicable to many energy systems, current and advanced.

2. Fuels and Processes

R. G. Donnelly

Over the past year losses in support from nuclear fuels programs, particularly the HTGR Recycle Program, were fully offset by increases in advanced LWR and FBR fuel and alternate high-level nuclear waste form technology. Additionally, nonnuclear activities have expanded in the areas of industrial energy conservation, residential energy conservation, and fossil energy. The groups most involved in the nonnuclear diversification are the Ceramic Technology Group and the Engineering Coordination and Evaluation Group, which was retitled from Fuel Cycle Engineering to reflect this more broadening scope of activities. At the same time, we have increased our management role in national and Laboratory programs. These include the Residential Conservation Services Program, which is national in scope, and multidivisional programs at ORNL on solar process heat and proliferation-resistant research reactor fuel elements. A major contribution to management of the National Fossil Energy Materials Program is also being made in the form of technical assistance to the program manager.

Consolidation of irradiation test fabrication services at ORNL has resulted in the transfer of this function and associated personnel previously within the Fuels Evaluation Group to the Engineering Technology Division.

Overall, the Section has come through this past year somewhat understaffed, particularly in the area of Ceramic Technology, where diversification efforts into nonnuclear technologies have been particularly successful.

A brief description of the major activities and annual accomplishments of each functional group in the Section follows.

CERAMIC TECHNOLOGY

V. J. Tennery

During this year, the Ceramic Technology Group started work on several new programs and has continued research and development in most of the programs that were under way last year. Discussion of accomplishments will be grouped roughly by subject to illustrate the supportive nature of several of the programs funded by different sponsors.

Significant new DOE program support was obtained this year from Fossil Energy for work on materials for ceramic heat exchangers (HXs) and from Solar Energy for work on materials for solar process heat systems. Additionally, increased work was accomplished on development and fabrication of ceramic insulators for the Advanced Instrumentation for Reflood Studies (AIRS) program. Electrically insulating ceramics with high thermal shock resistance are needed for use in sensors for the international 2D/3D Reflood Program. The objective of this program is to study loss-of-coolant accidents in pressurized water reactors.

Several of the programs are oriented toward application of structural ceramics and other materials in high-stress and high-temperature applications, which include HXs and HTGR core support structures. Accomplishments in the new Fossil-Energy-supported HX program included completion of assessments of the application potential of advanced ceramics HXs in the steel, glass, and aluminum industries for high-temperature waste heat recovery. Conceptual designs for these recuperators were completed, and ceramic material and HX costs necessary to achieve an attractive return on investment were determined. Construction of the Ceramic Recuperator Analysis Facility (CRAF) was completed for use in testing structural ceramic HX tubes in impure combustion gas environments. The Conservation-supported HX work included completion of analysis and reporting of (1) the behavior of an MAS honeycomb ceramic recuperator from a 2000-h industrial furnace demonstration, (2) candidate structural ceramics from long-term recuperator tests in a glass melting furnace flue gas environment, and (3) the corrosion and failure of a reradiant

recuperator from an industrial aluminum remelting furnace demonstration. A very significant observation from this work was that SiC ceramics exhibit accelerated corrosion at temperatures near 1200°C in the presence of sodium-bearing flue gases, while they exhibit much slower corrosion at 1300 to 1500°C.

The Solar-Energy-supported HX work was directed at identifying candidate ceramic materials suitable for use in high-temperature solar thermal process systems, such as hydrogen production or nitrogen fixation cycles. We identified the best ceramic materials for use in moderate and very high-temperature regimes in solar receivers and started compatibility testing of these ceramics with chemical species from three recommended chemical cycles at high temperatures. The HTGR structural program work focused on nitride and alumina ceramics for use in core supports. We completed identification of experimental techniques for measuring stress relaxation in these ceramics and started creep measurements on selected high-alumina ceramics over a range of temperatures. Results in the Conservation-supported Alternate Fuels program included identification of zinc and iron as critical impurities in heavy fuel oils as being particularly damaging to the newer high-alumina refractory fibrous insulations now being used by U.S. industries. A 1000-h combustion exposure test of several refractory insulations and structural refractories was completed in the Refractory Test Facility (RTF) by use of a No. 6 oil derived from Venezuelan crude.

Transmission electron microscopy (TEM) studies of chemically vapor deposited (CVD) SiC coatings of HTGR fuel particles demonstrated the presence of hexagonal alpha polytypes within a matrix of cubic beta plus a high stacking-fault density within the grains. Detailed characterization of the grain boundaries by TEM and scanning TEM was completed, and structure was correlated with the deposition conditions. Studies of silver and palladium reactions with CVD SiC in a thermal gradient began.

A radiological environmental assessment for thorium mining and milling and 50 GWyr(e) operation of (Th,U)-carbide-fueled FBRs and their requisite reprocessing and refabrication plants was completed and the results were published. Process requirements for sintering UO_2 fuel spheres to the high densities required for use in sphere-pac fuel rods were determined, and several kilograms of the fuel were prepared for use in fuel rod tests in an LWR. Considerable progress was made on graphite materials, including analysis of the relation between creep strain and other material properties at 600°C to high fluence in the ORR. The creep did not depend strongly upon many other graphite properties. Analysis of the first major industrial production run of the advanced graphite we originally developed was completed, and we played a key role in applying nondestructive examination and statistical analysis techniques to assist the industrial fabricator to produce this material as required for the Department of Defense.

A seed money program on studies of the stability of toxic elements in solid coal gasifier slags was completed and showed that HI-Gas slags consist primarily of crystalline Fe_2O_3 in a silicate glass matrix. Under selected cooling conditions lead, selenium, titanium, and other impurity elements preferentially concentrate in these crystals. Measurements of the leaching rates of these elements from the slag were completed.

In support of the selenide generator, intensive analyses of gadolinium selenide thermoelectric test elements were completed to identify why test modules showed erratic power output. A polymorphic phase transformation and thermal stress cracking in the selenide were very detrimental to this material.

A critical materials assessment was completed of the national MHD program for the Office of Energy Research of DOE, and we completed analysis of the program system components using ceramic refractories, electrodes, and insulators.

We developed and demonstrated an Al_2O_3-platinum cermet capable of providing electrical insulation and the very high thermal shock resistance required of the sensor insulators in the AIRS program. Techniques were developed for fabricating the required shapes of these cermets with reproducible properties. Many cermet shapes were made, tested, and inserted into test assemblies for use in the Federal Republic of Germany reflood test facility.

ENGINEERING COORDINATION AND EVALUATION

D. R. Johnson

We have continued to support the Alternative Fuel Cycle Evaluation Program (AFCEP) by analysis of about 25 reactor fuel cycles as identified by the Nonproliferation Alternative Systems Assessment Program. Our involvement is in coordinating the activities of the Fuel Cycle Characterization Working Group in AFCEP, with two direct responsibilities: characterizing fuel fabrication plants using the Gel-Sphere-Pac process and preparing consistent cost

estimates for all fuel fabrication and refabrication plants. In addition, we have supplied information such as plant effluent and waste generation quantities to others. During this period eight formal reports have been published or prepared for publication. These reports will be combined with the work of others to provide a multivolume final AFCEP report to be issued in fiscal year 1980.

The Group became involved in the Fossil Energy Materials Program (FEMP) in April 1979, in the role of coordination of the FEMP management activities. Major activities to date include participation in a review of the "H-Coal Pilot Plant Mode Operations Plan" to establish the philosophy for contingency planning for that operation, a trip to the H-Coal Pilot Plant in Catlettsburg, Kentucky, to review the materials testing and failure analysis programs for that facility, and the preparation of a draft section for an upcoming issue of *ORNL Review*. Work has begun on a revision of the ORNL Fossil Energy Materials Management Plan. Our next major activity is the preparation of a Technical Program Plan for the FEMP.

The United States and the Federal Republic of Germany (FRG) are currently funding cooperative national programs for HTGR fuel recycle. These programs address the following objectives: (1) establishing a proliferation-resistant HTGR fuel cycle, (2) developing needed technology, and (3) actively supporting the market introduction of HTGRs. The respective national efforts to realize these objectives have evolved parallel program structures with the common objectives of verifying needed processes, system concepts, designs, and performance.

These common features are the basis for collaboration and cooperation in several areas of HTGR recycle technology. Specific details of U.S.-FRG cooperation have been drafted in a series of project work statements, which loosely define a framework for overall cooperation.

ORNL manages this collaborative program for the U.S. Department of Energy, and in this capacity during FY 1979 we developed a planning base for the cooperation. The planning base includes (1) an overall program plan defining objectives and organizational features of the collaborative effort, (2) a design assessment of the U.S. Hot Engineering Test (HET) Project and the FRG JUPITER Project, and (3) a program plan for a Joint Prototype Headend Facility.

We have assumed responsibility for the technical management of the Residential Conservation Service (RCS) Program. It is a national utility program that will require large utilities to offer certain services to their residential customers—energy audits; assistance with procurement, installation, and financing of conservation measures; and other related services. ORNL is providing support in all phases of the program: rulemaking, preparation of regulatory documents, technical assistance to state governments, and research and development. This work is accomplished with staff from six ORNL divisions and several subcontractors. The program began in March 1979 and will continue for five years.

The technical lead for the conceptual design of a Hot Fuels Engineering Laboratory (HFEL) came from our group. The project provides for modifications and additions to the Thorium-Uranium Recycle Facility (TURF) to support development of processes and equipment for the fabrication of radioactively hot fuels for alternative cycles. The processes and equipment developed would be used for refabricating hot fuel test rods suitable for irradiation testing. The modifications and additions of process support services, safety features, and equipment in TURF will provide the essential requirements for accommodating and supporting the refabrication process developments and tests with highly radioactive materials in a safe environment conforming with the appropriate standards. The conceptual design was done by an architect-engineer, The Ralph M. Parsons Co., and was guided by a project team chosen from the Metals and Ceramics, Chemical Technology, and Engineering Divisions.

We manage the TURF. All building equipment and containment systems are operated and maintained in accordance with DOE specifications. Two experimental programs were operating in TURF during the reporting period: (1) processing of transuranium elements and (2) nondestructive fuel assay and advanced manipulator development for the Consolidated Fuel Recycle Program.

FUEL CYCLE TECHNOLOGY

W. J. Lackey

Studies were performed this year to better understand the sintering behavior of gel-derived UO_2, $(U,Pu)O_2$, and $(Th,U)O_2$ spheres. The linear shrinkage of individual UO_2 spheres occurred in two stages. A gradual linear shrinkage of about 20% occurred from room temperature to 950°C. As the temperature was increased from 950 to 1450°C, the rate of shrinkage increased, and the total linear

shrinkage reached values greater than 55%. The shrinkage stopped abruptly in the range 1400–1450°C as the sphere reached near-theoretical density. Effluent analysis identified temperature regions over which volatile species were liberated. These studies allow optimization of the sintering cycle.

Significant advances were made in the sphere-pac process, which offers special advantages for the remote manufacture of proliferation-resistant fuels. An important development this year has been the refinement of the rod loading process to permit sphere loading and compaction in reasonably short times. With this process, full-length LWR rods are filled to acceptable density in less than 10 min; fuel sections of interest for FBR use are similarly loaded to reference smear densities of 85%. Proper blending of the three sizes of spheres is critical in achieving uniformly high smear density. Two unique blending concepts have been successfully prototyped for this application. Inspection devices are being developed to aid the development program. A fuel rod density inspection device, which uses gamma ray attenuation to automatically determine axial density profiles, has been constructed. Design of a combined density and assay determining device for use with spiked fuel is in progress.

Development work this year has shown that the sphere-cal process is a promising alternative to conventional fuel pellet fabrication methods. In this process, gel-derived spheres are cold-pressed into pellets, which are subsequently sintered. Pellets with excellent microstructures and densities exceeding 95% T.D. have been produced from urania spheres. Thoria-urania spheres produced by the SNAM external gelation process are also promising pellet press feed material because their gel structure is softer. The best sphere-cal results were obtained with spheres having a larger crystallite size and high BET surface area since they sintered together rather than sintering individually. We found that calcination of uranium-containing spheres at 600°C is necessary for reduction of the oxygen-to-uranium ratio before pelletizing and that prolonged residence times and higher temperatures minimize sphere reoxidation during handling in air. Dilatometer studies showed that all pellet shrinkage occurs rapidly between 900 and 1450°C and that slower heating in this temperature range reduces pellet cracking.

A potential HTGR fissile kernel is a highly dense sphere of UO_2 and UC_2. A procedure was developed to sinter spheres of UO_3 and carbon produced by internal gelation to the desired composition and density at temperatures as low as 1550°C. This is 200 to 300°C lower than required for previous processes. The partial pressure of CO is controlled during the process to first produce high-density $UO_2 + UC_xO_y$ and then shift the thermodynamic equilibrium to $UO_2 + UC_2$. Many fluidized-bed coating runs were made to determine if gastight coatings could be made with carbon dioxide as diluent. Coatings produced with propylene and CO_2 proved to be more gastight than coatings produced with propylene, acetylene, and CO_2. We have not yet determined if these coatings are superior to standard coatings produced with helium or argon dilution. A full-size fuel element block loaded with fuel rods produced at ORNL was processed through General Atomic's cure-in-place furnace. The objectives were met as the expected 30% coke yield was obtained, and we identified process conditions that yielded fewer defective particles than the specification limit. Other meaningful data were obtained for fuel column expansion and both fuel rod and end-plug push-out forces.

FUELS EVALUATION

F. J. Homan

Most of the support for the Fuels Evaluation group comes from the HTGR Program; some is from the Gel-Sphere Fuel Development Program to coordinate the Sphere-Pac Performance Task. During the report period this group's significant accomplishments on fuel performance for the LWR, BR, and HTGR Programs include the following.

We completed design, fabrication, and installation and started operation of the Postirradiation Gas Analyzer (PGA) system. This apparatus measures the internal gas content in irradiated HTGR fuel particles. The system is composed of an enclosed particle crushing chamber linked to a time-of-flight mass spectrometer, which is in turn linked to a PDP-11 computer. The particles are crushed and the quantities of escaping gases measured by mass number. This equipment is used to determine the ability of the particle coatings to retain fission gas during irradiation. By coupling the PGA with post-irradiation annealing at temperatures sufficient to drive dissolved fission gas from the kernel, much can be learned about the distribution of fission gases in irradiated fuel particles. This information is essential to fuel performance models because the ability of kernels to retain fission gas directly influences the

fraction of failed coatings that can be permitted in an operating core. The PGA system became operational at the very end of the reporting period, and only fuel from capsule HT-34 has been examined to date. Analysis of the HT-34 data revealed a need to upgrade the computer code that computes the theoretical amount of gas present in irradiated particles to include the production of fission gas isotopes from direct neutron absorption.

We analyzed statistically HTGR fuel performance in irradiation capsules OF-2, HT-11 through -13, and HT-31, -33, and -34. The primary analytical tool for evaluation of HTGR fuel performance is the Irradiated Microsphere Gamma Analyzer (IMGA) system, which was also designed and built at ORNL. This unique equipment can analyze the fission product inventories of individual coated particles automatically. Decisions relative to the retention of fission products can be made by comparing the ratio of gamma activity for volatile fission products (such as Cs) to the activity for stable fission products (such as Zr). One assumes that volatile fission products will escape from particles with failed coatings. The IMGA analysis of the OF-2 fuel rods revealed some very interesting results. Three batches of fissile particles produced in production-scale equipment were irradiated in that capsule. One batch was produced by use of a conical gas distributor; the other two batches used a fritted plate distributor. Two batches contained kernels made of 75% UC_2 and 25% UO_2; the other batch was 85% UO_2 and 15% UC_2. The batch with 75% UC_2 coated with the conical gas distributor performed the worst, according to IMGA. The batch with 75% UC_2 coated with the fritted plate performed the best. This is not surprising, as other work identified the fritted plate as superior to the cone. What was surprising was that the particles containing 75% UC_2 performed better than the particles containing 15% UC_2. In fact, the 75% UC_2 batch coated by use of the fritted plate was the only batch that met the Fort St. Vrain Reactor performance specification of less than 1% failure at a 95% confidence level. Metallographic and microprobe evaluations have repeatedly caused us to believe that fuels high in UO_2 content perform best.

Postirradiation examination of fuel irradiated in capsules HRB-14 and -15b proceeded through capsule disassembly, specimen photography and metallography, and some electron microprobe work.

A detailed study on the permeability of pyrocarbon for the HTGR program was completed by a visiting German scientist. Coating properties, characterization techniques, and the capability of the coatings to retain fission gas were correlated.

An irradiation testing program began for sphere-pac fuels in a research reactor (Halden) and an LWR (Big Rock Point). This is a cooperative program between ORNL, PNL, Exxon Nuclear, and Consumers Power Company.

METALS PROCESSING

R. L. Heestand

Activities in support of Space and Terrestrial Systems continued to be centered on fabricating platinum and iridium alloys for use as isotopic heat source containment. Efforts for providing improved iridium alloys for the General Purpose Heat Source were completed in FY 1979, and production will be initiated in FY 1980 and 1981. A significant accomplishment in this area in the last year was the development of warm and cold rolling procedures for producing iridium sheet and foil to the required finish and thickness without needing surface grinding. Iridium sheet and foil had not been produced previously to finished thickness by cold rolling as a production process. This conserves manpower, reduces the amount of iridium ordinarily requiring reprocessing, and increases the number of disks produced from each casting. An overall savings of 25% is realized. Also, we developed a technique for precision punching the iridium disks that eliminates electro-discharge machining and further reduces labor costs and conserves iridium. Private industry had failed to accomplish this also. Mission changes will decrease efforts with platinum alloys. All deliveries of flight hardware were made on schedule.

The waste management program on "The Volume Reduction of Low-Level TRU-Contaminated Metals by Melting" demonstrated that uranium surface contamination on common structural metals could be concentrated in a slag, reducing contaminants in the metal. Aluminum, lead, and copper can be cleaned by preoxidizing the surface and drip melting. The melt flows from the oxidized shell leaving the contaminants behind with the dross. Previously these metals were crucible melted, allowing surface contaminants to dissolve in the melt. Engineering demonstration of these experiments will be completed in FY 1979 with intentionally contaminated mixed metal scrap. Plans for FY 1980 include similar experiments for removing plutonium surface contamination and initiation of a full-scale demonstra-

tion facility, which would be available in FY 1983 for reduction of contaminated metals generated at ORNL.

In a program with Argonne National Laboratory, we are determining fabrication parameters for High-Uranium-Content U_3O_8-Al Research Reactor Fuel Elements, which will be proliferation resistant. This is accomplished by dilution from highly enriched uranium (93%) to enrichments as low as 20%. This requires incorporation of an increased volume of uranium and thus makes the determination of optimum fabrication parameters and measuring properties necessary. Upon selection of parameters the program will progress to full-scale fuel element fabrication and irradiation test sample fabrication in FY 1980. Management and surveillance of the fabrication of HFIR and ORR fuel elements are continuing.

Efforts have also been devoted to the preparation of stainless steel heats having very closely controlled compositions and the procurement of large heats of irradiation-resistant stainless steels and refractory metals for the fusion energy program on Alloy Development for Irradiation Performance. These materials are subsequently finished to the sizes required for the experiments in the Radiation Effects and Mechanical Properties Groups.

Service work for the Metals and Ceramics Division and other DOE installations has resulted in over 400 separate requests for fabrication of alloys, including 53 extrusions, 340 melts, 318 vacuum or hydrogen heat treatments, and numerous rolling, swaging, and drawing operations. These requests ranged from the extrusion of gadolinium and subsequent fabrication of rod to the extrusion of thoriated tungsten.

3. Materials Science

J. O. Stiegler

The development of principles for the design of advanced materials through understanding of the relationships among properties, composition, and structure at the atomic level is the objective of programs in the Materials Science Section. Activities range from theoretical investigations of electronic structure of solids to applied programs directed at development of radiation-resistant alloys for fast breeder and fusion reactors. About two-thirds of the Basic Energy Sciences program is devoted to long-term support for the various energy technologies and one-third to fundamental studies in advancement of the science of materials. State-of-the-art capabilities are developed, maintained, and exploited in the various areas of microstructural characterization, including analytical, high-voltage, and high-resolution electron microscopy; x-ray scattering (especially use of synchrotron radiation and position sensitive detectors); and surface analysis and nuclear micro-analysis techniques.

During the past year new programs have begun in the areas of metastable materials and elevated-temperature deformation and fracture. A consortium has been formed with university researchers to develop a major x-ray facility at the BNL Syncrhotron. Users groups have been activated in the small-angle x-ray scattering and microstructural analysis laboratories. Major scientific achievements include:

Harry Yakel has recently used diffraction of synchrotron radiation with energies near absorption edges to determine site occupation parameters in an iron-cobalt spinel. This result would not have been possible with the fixed-wavelength radiation from conventional sources.

D. S. Easton and co-workers have developed an analytical method for predicting the residual stress state and the stress-strain curves of Nb_3Sn superconducting composites at 4.2 K. The stress behavior of existing superconducting composites as well as those currently being designed can now be determined without extensive experimental measurements.

W. H. Butler and his colleagues have developed techniques for calculating the electron-phonon interaction in metals from first principles to high precision. This makes it possible to understand quantitatively the transition temperature T_c and upper critical field H_{c2} in superconductors as well as the conductivity of normal metals. It opens the possibility of choosing or designing materials with desirable values for these properties.

C. F. Yen, C. S. Yust, and G. W. Clark have observed significant improvements in strength of TiB_2, $(Ti,Cr)B_2$, and $(Ti,V)B_2$ composites formed by addition of 15 wt % Ni to the diboride. These materials are potentially important as tool and wear-resistant materials.

R. K. Williams and co-workers have identified the phonon and electronic contributions to the thermal conductivity of pure iron from 100 to 400 K. The phonon contribution is about 20% of the total and includes parameters to describe electron-phonon and phonon-phonon scattering resistances.

R. A. Vandermeer, J. C. Ogle, and C. E. Zachary have obtained experimental information that greatly increases the understanding of phase transformations between metastable states of uranium-niobium alloys.

P. T. Carlson, M. R. Hayns, and R. A. McKee have demonstrated the existence of a sharp minimum in solute diffusion rate as a function of solute concentration in lead-base alloys. The minimum (occurring in the 10–100 ppm range) is consistent with a trapping mechanism that is intrinsic to the system and is perhaps the first direct confirmation of the strong interstitial-vacancy interactions thought to occur in these alloys.

K. Farrell, E. A. Kenik, and N. H. Packan have found from extensive dual ion bombardment experiments that void swelling induced by displacement-producing 4-MeV nickel ions is markedly affected by the relative rate and mode of helium injection. The implications are significant for fast fission and planned fusion reactor materials in which helium transmutation occurs at varying rates with respect to neutron-induced displacements, depending upon material, dose, and reactor characteristics.

CERAMIC STUDIES

C. S. Yust

The work of this group falls into three principal categories: (1) erosion and wear, (2) synthesis and preparation of high-temperature materials, and (3) the study of the structure of coal. In each of these areas, significant results have been developed in the past year.

The investigation of erosion is directed toward the detailed understanding of the material damage mechanism at the particle impact site by use of

scanning and transmission electron microscopy. The results to date confirm the role of plastic deformation as well as fracture at impact sites in alumina. However, in the immediate vicinity of the impact site we have observed dislocation network configurations that cannot be readily rationalized. Since the plastic damage at a particle impact point may be a very high-strain-rate process, other plastic deformation processes at high strain rates in ceramics are under study. For example, observations of the deformed lattice of explosively compacted alumina by transmission electron microscopy indicate that heavy dislocation damage is introduced and local melting and recrystallization occur. Other similarities in the dislocation substructure are noted in the particle impact and explosive compaction damage, and further study should lead to a more complete knowledge of both processes.

The studies of high-temperature materials undertaken by this group include the preparation of directionally solidified eutectic microstructures in a wide range of refractory materials. Hard materials, such as borides and carbides, are currently of great interest because of their potential for use as wear-resistant materials and as cutting edges. The techniques for directional solidification continue to be improved, as exemplified by a recent development that permits the adjustment of the electrical conductivity of oxide-metal compacts by the controlled addition of metal particles to the test material. This step has greatly facilitated the operation of the process for growth of directionally solidified eutectics. A mixed boride-nickel composition has also been prepared by hot-pressing in the presence of a liquid phase to give a very dense, hard, fine-grained microstructure. Samples of this material have proved to be very successful as cutting tools in preliminary machining tests. Further tests are planned to evaluate this material as a wear-resistant composition.

The structure of coal continues to be of great interest as the need to utilize coal as an alternate energy source increases. The study of coal microporosity and micromineralogy will be necessary background for any large-scale coal application. This work continues to seek new techniques for coal characterization, such as the use of infrared microscopy, which has been used in this study to examine the nature of coal macerals ordinarily opaque in the visible spectrum. Electron microscopy, both scanning and transmission, is also being used to study coal characteristics, and through the combined use of these techniques, the process of secondary mineralization in Illinois No. 6 coal has been studied in detail. The growth features, purity, and crystallographic perfection of calcite, kaolinite, and pyrite in this coal have been observed and reported.

PHYSICAL METALLURGY

R. A. Vandermeer

Solid-state phase transformations and shape memory effects in uranium-base alloys are often associated with the problems of maintaining dimensional stability and mechanical property reproducibility. We seek to unravel the mechanistic details of the complex transformation patterns in alloys of practical interest. We explore how composition, temperature, stress, and microstructure influence transformation behavior.

The transformation of the elevated-temperature bcc phase in U-14 at. % Nb during both continuous cooling and isothermal aging was investigated by dilatometry and x-ray diffraction. The alloy transforms martensitically according to the sequence $\gamma(\text{bcc}) \rightarrow \gamma^{\circ}(\text{tetragonal}) \rightarrow \alpha''(\text{monoclinic})$. The M_s temperature varies significantly with cooling rate. The reverse transformation temperatures, A_s and A_f, increase as the heating rate decreases. The M_s temperature is raised significantly by interposing a brief aging treatment at a temperature well above M_s. The γ-to-α'' transition could also be accomplished isothermally by aging at a temperature 165 K above M_s.

We are determining the effect of niobium concentration on shape memory effect (SME). A series of polycrystalline alloys spanning the composition range 13.9 to 17.8 at. % Nb has been prepared and tested. An updated metastable transition phase diagram has been constructed. The room temperature stress-strain response was measured in uniaxial tension, and parameters associated with SME have been defined. The extent of mechanically reversible strain and other SME parameters were determined as functions of composition and structural state. Heat-activated strain recovery patterns have been characterized, and the SME behavior of γ° alloys was compared with that of α'' alloys.

The thermal expansion characteristics of several Nb_3Sn superconducting wire composites have been determined between room temperature and about 950 K.

Dilatometry has been used to determine the phase transformation temperatures and other expansion

characteristics between ambient and 1100 K in a U-2.4 wt % Nb alloy. Specimens with various thermomechanical histories have been examined.

PHYSICAL PROPERTIES

D. L. McElroy

The Physical Properties Research Program, which is aimed at measuring and understanding energy transport in solids, is divided into basic and applied efforts. The Division of Materials Sciences supports basic research that complements applied efforts supported this year by the Conservation Program and by the Nuclear Fuel Development Program. Accurate physical property data contribute to improved power generating systems.

Data for iron and several alloys from 100 to 400 K have been used to identify the phonon and electronic contributions to the thermal conductivity of pure iron. In this range the phonon contribution is about 20% of the total thermal conductivity; this allows identification of parameters for electron-phonon and phonon-phonon scattering resistances. The electronic Lorenz function of iron is similar to that of copper and less than the Sommerfeld value. Similar studies show that tantalum and niobium have small phonon contributions and Lorenz functions less than the Sommerfeld value, whereas chromium has a large phonon contribution and a Lorenz function that exceeds the Sommerfeld value at about 150 K. The ratio of the differential thermal expansion coefficient to the thermal expansion coefficient of ordered $V(Fe_{0.22}Co_{0.78})_3$ is less than that of other high-temperature alloys. Experimental studies of the deviations from Mattheisson's rule in transition metal alloys showed that literature results for palladium-titanium alloys are defective.

Results obtained to 1000 K using thermal conductivity Standard Reference Material 735 are within the property limits recommended by the National Bureau of Standards. These results confirm the operational procedures used with the high-temperature longitudinal heat flow apparatus. The thermal conductivity at 300°C of a helium gas-UO_2 sphere-pac increases 50% when the gas pressure is increased from 0.1 to 0.6 MPa (1 to 6 atm). Equipment has been ordered to construct an electrical heating apparatus to determine a number of physical properties in the range 1200 to 2600 K. Apparatus is being developed to measure thermal conductivity of epoxy-containing materials in the range 4 to 300 K.

Support from Conservation is aimed at improving the data base for industrial and building thermal insulating materials. This has resulted in a National Program Plan, the Thermal Insulation Conference, and active participation in ASTM C-16. Subcontracted work has obtained thermal resistance values for commercially available R-11 and R-19 batts and for high-temperature fibrous insulations. Thermal resistance testing is often complicated by thermal guarding, but calculations and tests show that low-thermal-conductivity heaters can avoid this complication. A cooperative test program has established the behavior of commercial cellulosic insulations.

RADIATION EFFECTS AND MICROSTRUCTURAL ANALYSIS

E. E. Bloom

Our main goal is to advance basic understanding of the role that microstructure, composition, radiation, and service environment play in regard to the behavior of materials and to develop alloys with properties tailored for specific applications. Electron microscopy (transmission, analytical, high-voltage), surface analysis techniques (Auger spectroscopy), and nuclear microanalysis are used to characterize structure and composition on a micro scale. The ORR, HFIR, EBR-II, ORIC, and a 5-MV Van de Graaff accelerator are used in irradiation damage studies. This report gives a brief overview of the activities of the group.

Alloy Development for Irradiation Performance (Office of Fusion Energy)

Four basic classes of alloys are being investigated for fusion reactor first-wall applications: austenitic stainless steels, higher strength Fe-Ni-Cr alloys, reactive and refractory metal alloys, and innovative materials (long-range-ordered alloys). Reactive and refractory metal alloys being investigated are alloys of titanium, niobium, and vanadium. Alloys containing nickel are typically irradiated under conditions producing both displacement damage and, as in a fusion reactor, helium from transmutation. Techniques to introduce helium into other alloys are being studied to assess their validity in simulating fusion reactor conditions.

Type 316 stainless steel and nickel-base alloys have shown degradation of tensile properties, especially loss of ductility, resulting from irradiation and the presence of helium. The effect of helium is especially

severe at temperatures above 550°C. In type 316 stainless steel, an unusual crystallographic fracture has been observed at 450°C and this behavior appears to be related to slip bands from cold work before irradiation and to precipitation of a recently identified phase. Extensive transmission electron microscopy is being conducted to characterize microstructure and precipitation in candidate alloys.

An electrohydraulic fatigue testing system capable of high vacuum, elevated-temperature strain-control remote testing has been developed and is now operational in a radiation hot cell. Low-cycle fatigue tests on type 316 stainless steel irradiated to damage levels up to 15 dpa and 1000 at. ppm He have exhibited a reduction in fatigue life of factors of 3 to 10 at 430°C.

Irradiation experiments are now in progress in the HFIR to determine the effects of high levels of helium, and a new experiment in the ORR is being planned to simulate the He/dpa ratio of a fusion reactor for correlation.

Fast Breeder Reactor Cladding and Duct Alloy Development Program

This research is part of a national program to develop alloys with improved resistance to high-temperature irradiation damage for fast reactor core applications. The work contains two major elements: (1) the development of modified AISI type 316 stainless steels with low swelling and (2) the assessment of high-strain-rate deformation and fracture behavior of irradiated advanced alloys.

A detailed investigation and assessment of the relationship between void swelling during neutron irradiation and during ion irradiation have been completed. The objective was to determine under what conditions ion irradiation can reproduce the swelling behavior, phase stabilities, and other microstructural features that develop during neutron irradiation.

In solution-annealed AISI type 316 stainless steel preinjected with helium, phase instabilities that give rise to double-peaked swelling behavior in-reactor are not reproduced during irradiations with 4-MeV Ni^{2+} ions. Neither the Ni_3Si γ' phase nor the massive nickel- and silicon-rich carbosilicide phases develop, and there is a single swelling-temperature peak. In an attempt to circumvent this difficulty, nickel-ion irradiation experiments have been conducted on specimens that had been previously neutron irradiated to establish a quasi steady state with regard to phase distribution, matrix composition, and void and dislocation sink strengths. For each neutron irradiation temperature an equivalent ion irradiation temperature (160–180°C above the neutron irradiation temperature) exists at which the evolution of the void and dislocation structures is reasonably reproduced. In general, however, the precipitate structures are not reproduced. For example, precipitates produced during neutron irradiation are unstable and redissolve. The resultant changes in matrix composition lead to changes in swelling kinetics.

This work has shown that because of the effects of damage rate on phase stability and the interaction between precipitates and helium, it is very difficult to quantitatively relate swelling behavior during nickel ion irradiations to swelling behavior under reactor conditions. Heavy-ion irradiations can be used effectively to explore the mechanisms involved in phase stability during irradiation, the interaction between precipitates and helium, and the relation of these phenomena to swelling resistance.

Postirradiation mechanical property data are being measured on ferritic alloys, precipitation hardening nickel alloys, and 300 series stainless steels that have been irradiated in EBR-II to fluences up to 1.4×10^{27} n/m^2 at temperatures between 450 and 735°C. Testing is carried out over a range of strain rates and temperatures selected to provide information on the mechanical response of alloys subjected to various reactor transient events and to fuel handling operations. The ferritic and austenitic stainless steel alloy classes exhibit satisfactory response in terms of ductility and toughness, at least, to fluences up to 7×10^{26} n/m^2, but some of the nickel-base alloys (such as alloys 706 and 718) exhibit low ductility when tested at temperatures above the irradiation temperature. An investigation of embrittlement phenomena is in progress involving SEM fractography and Auger Electron Spectroscopy measurements of fracture surface compositions. Initial results indicate that the conventional heat treatments developed for non-nuclear applications of nickel-base alloys need to be substantially modified for fast-reactor applications.

Radiation Effects (Basic Energy Sciences)

The aim of this program is to determine the mechanisms responsible for radiation-induced changes in metals and alloys under reactor conditions. The research relies heavily on combined theoretical and experimental analysis. Recent efforts have focused in three general areas: (1) the effects of gaseous im-

purities and alloying elements on microstructural evolution and swelling, (2) irradiation creep, and (3) development of nuclear microanalysis techniques.

Nickel-ion irradiations (using 5-MeV Ni) have been used to investigate the role of helium in the development of the damage structure. The method of implantation, cold or hot preinjection or simultaneous, is critical in determining the final void parameters (concentration and size). Initial results of simultaneous triple beam experiments indicate that in austenitic alloys hydrogen (deuterium) is unimportant in the microstructural evolution relative to helium. Experiments on irradiation creep of austenitic stainless steel at 440 and 540° C using 60 MeV α-particles have been completed. The results are in good agreement with those obtained by Ullmaier et al. at KFA, Jülich. Strain rates of about 5×10^{-10} and 5×10^{-9}/s can be measured during thermal and irradiation creep, respectively. Future experiments will investigate creep in samples preirradiated in EBR-II to establish the irradiation-produced microstructure. Theory and modeling have focused on the effects of damage rate and the spatial variation of damage during ion irradiations and generalization of the theory to include the effects of impurities and alloying elements. The often-observed large reductions in void nucleation and the milder reductions in void growth and creep can be explained by a theory of point defect trapping. The development of the theory of basic processes is also continuing. The derivation and calculation of the efficiencies of sinks for the absorption of point defects and the analysis of possible mechanisms of irradiation creep are examples of ongoing work.

Analytical and High-Voltage Electron Microscopy (Basic Energy Sciences)

During the past year our research effort has focused on quantification of microchemical analysis procedures by energy-dispersive x-ray spectroscopy, design and construction of an electron energy loss spectrometer, and the experimental evaluation of an advanced analytical scanning transmission electron microscope fitted with a field emission electron gun. The side entry conversion of the HVEM to facilitate in situ gas-solid reaction research and deformation observations is complete.

Methods have been developed for determination of the chemical composition of homogeneous alloys by standardless energy-dispersive x-ray microanalysis. Analyses agree to within $\pm 1\%$ with those obtained by independent methods. This work is now being extended to heterogeneous alloys. Construction of an electron energy loss spectrometer is complete. Preliminary experimental results show resolution of core electron absorption edges for carbon, titanium, and aluminum. Research is being initiated on oxygen concentration determination in bcc metals. Experimental evaluation of the advanced analytical microscope is producing superior resolution performance (0.19 nm) and exceptional diffraction results. Diffraction patterns from single dislocations in silicon and aluminum are being obtained. High-resolution imaging and diffraction research efforts on crystals containing defects will be expanded during the next year. The high-voltage electron microscope is being used for high-temperature low-pressure oxidation research on vanadium and vanadium-titanium alloys, hydrogenation research on hydrogen storage materials, and alloy fracture mechanism research.

Fundamentals of Welding and Joining

The objective of this program is to understand the relationship between weld parameters and weld composition and the resultant microstructure, mechanical properties, and long-term phase stability.

Reactions occurring under service conditions include formation of carbides, nitrides, intermetallic phases, and, usually, mixtures of these. Identification of microphases by x-ray diffraction of separated particles is now routine. Rates of carbide formation in 16-8-2 (16 wt % Cr, 8 wt % Ni, 2 wt % Mo, ~0.08 wt % C, balance Fe) have shown two modes, and these can be simulated in homogeneous alloys. Intermetallic phases form over a much longer period of time. These reactions are controlled by seemingly minor variations (<1 wt %) of elements like silicon, titanium, and carbon. Because these variations are small, they must be studied in well characterized, homogeneous alloys rather than directly in welds.

Carbon plays a critical role in the formation of several precipitates that influence mechanical properties. Activities of this element are being measured in titanium-modified steels to control precipitation of TiC as well as other titanium-containing precipitates in both austenitic and ferritic alloys. Activities in ferritic samples aged long periods of time (>1 year) are also being determined. In both cases, precipitate compositions are being related to matrix compositions and carbon activity.

Structure and Properties of Surfaces

Surface analytical techniques are being used to study the influences of grain boundary and interfacial structure and composition on materials properties.

Current activities include basic and applied research in the areas of intergranular fracture, radiation effects in materials for Fast Breeder and Magnetic Fusion Energy (MFE) programs, and plasma-wall interaction studies for the MFE program.

Detrimental near-surface grain growth in thorium-doped iridium alloys, which are used to clad fuel elements in isotopic power plants, has been shown to involve external oxidation and thus depletion of thorium at the near-surface grain boundaries. Unpinning and exaggerated growth of near-surface grains then occurs.

A portable surface analysis station incorporating ultrahigh vacuum sample handling and Auger electron spectroscopy has been developed and is now being used constantly for plasma-wall interaction studies. This system has been used on the T12 Tokamak (Kurchatov Institute, Moscow), ISX (ORNL), and Doublet-III (General Atomic) to identify impurities and to accelerate the first-wall cleaning process. Strong evidence has been obtained that the recombination of atomic hydrogen to its molecular form is often the rate limiting step in the recycling of energetic hydrogen from the wall to the plasma. This process is very sensitive to surface conditions and, in fact, may determine the concentration of hydrogen (or tritium) in the walls of a fusion reactor, thus influencing the materials problems, the tritium fuel cycle, and the economics of fusion reactors.

Studies of unipolar arcing as a source of metallic impurities in tokamak plasmas have established a correlation of arcing with surface cleanliness and plasma disruptions, but the assessment of the importance of arcing as an impurity source is just beginning.

METASTABLE AND SUPERCONDUCTING MATERIALS

C. C. Koch

Fluxoid pinning research in type II superconductors has included the completion of a study of the peak effect, summation problem, and magnetic history in a Nb–38 at. % Hf alloy, where the pinning centers are small normal precipitate particles. Studies of grain boundary pinning by the use of niobium bicrystals have been extended along with theoretical treatment of pinning by small weak pinning centers. The stress effects work in commercial multifilamentary Nb_3Sn composites has focused on the material parameters and geometry that influence mechanical and superconducting behavior. We developed a method that can predict the mechanical behavior of the composite from the volume fraction of each component and the fraction of niobium converted to Nb_3Sn. Measurements of superconducting transition temperature, T_c; upper critical field, H_{c2}; and critical current density, J_c, as functions of stress have increased our understanding of the mechanisms responsible for stress-induced degradation in Nb_3Sn conductors. A program using measured induced waveforms to predict ac losses in type II superconductors has been completed.

We have begun to redirect the group's program into research on metastable materials. To produce amorphous alloys from the liquid state, an arc hammer apparatus has been assembled and is being analyzed in an attempt to estimate the critical quenching rate required to make an alloy amorphous. A state-of-the-art vapor deposition unit has been ordered for preparation of amorphous alloys from the vapor phase. Molybdenum-base and intra-transition-metal superconducting amorphous alloys are being studied. Differential thermal analysis is being used to determine the stability of refractory metal amorphous alloys.

SURFACE AND SOLID-STATE REACTIONS

J. V. Cathcart

Studies of oxidation and diffusion phenomena emphazise the experimental characterization of defect mobility and structure coupled with theoretical modeling and calculations designed to develop both phenomenological and atomistic representations of defect motion in solids. A summary of current research activity follows.

1. The effect of alloying elements on high-temperature oxidation mechanisms is being investigated by using zirconium and zirconium-base alloys as model systems for a class of refractory metal alloys. Precision measurements of oxidation kinetics at about 1400°C show that the parabolic rate constants for oxide and alpha layer growth on Zircaloy-4 differ from those on pure zirconium by +70 and −15%, respectively, differences that can be accounted for by the 50% greater oxygen diffusion coefficient for the oxide on Zircaloy-4 than for zirconium.

2. Useful magnetic susceptibility data are being collected for very pure FeS samples as a part of our attempt to characterize the point defect structure and electrical and magnetic properties of FeS.

3. The oxidation of iron in sulfur vapor at 13 Pa (0.1 torr) and 700°C follows parabolic kinetics at

sulfidation rates considerably in excess of those previously reported in the literature.

4. Solute diffusivity enhancement measurements are used for dilute Pb-Cd and Pb-Ni alloys to investigate impurity-defect interactions in alloys in dissociative equilibrium. Both systems show a pronounced minimum in impurity diffusivities, a phenomenon not previously observed.

5. Values ranging from 3×10^{-16} m^2/s at 800°C to 5×10^{-13} m^2/s at 1000°C are reported for tritium diffusivity in Al_2O_3 single crystals. Collaborative infrared spectroscopy studies in the Solid State Division confirm the presence of O-T bonds in the samples.

6. Theoretical studies include an analysis of site blocking and correlated defect motion in tracer and chemical diffusion. Interstitial diffusion in ionic systems is treated by the methods of kinetic theory to obtain information concerning defect jump frequencies and defect interactions. The concentration dependence of solute diffusion for an alloy in dissociative equilibrium is also considered.

THEORETICAL RESEARCH

J. S. Faulkner

Besides support of the experimental materials science effort, the five-man Theory Group actively pursues fundamental research in five broad areas: electron-phonon interactions, alloy theory, band theory, surface theory, and lattice defect theory.

Areas of primary investigation and results during the past year are summarized below.

The theory of electron-phonon interactions was developed into a quantitative predictive tool. Our calculations predicted a sharp maximum in the [110] LA phonon linewidth in palladium [Fig. 3.1(a)], which was later confirmed by neutron diffraction experiments at BNL. Similar confirmation at ORNL of our calculated linewidths for niobium is shown in Fig. 3.1(b). We successfully calculated the normal state of electrical and thermal resistivities of niobium and palladium from first principles without adjustable parameters. The results agree excellently with experiment. We performed the first microscopic

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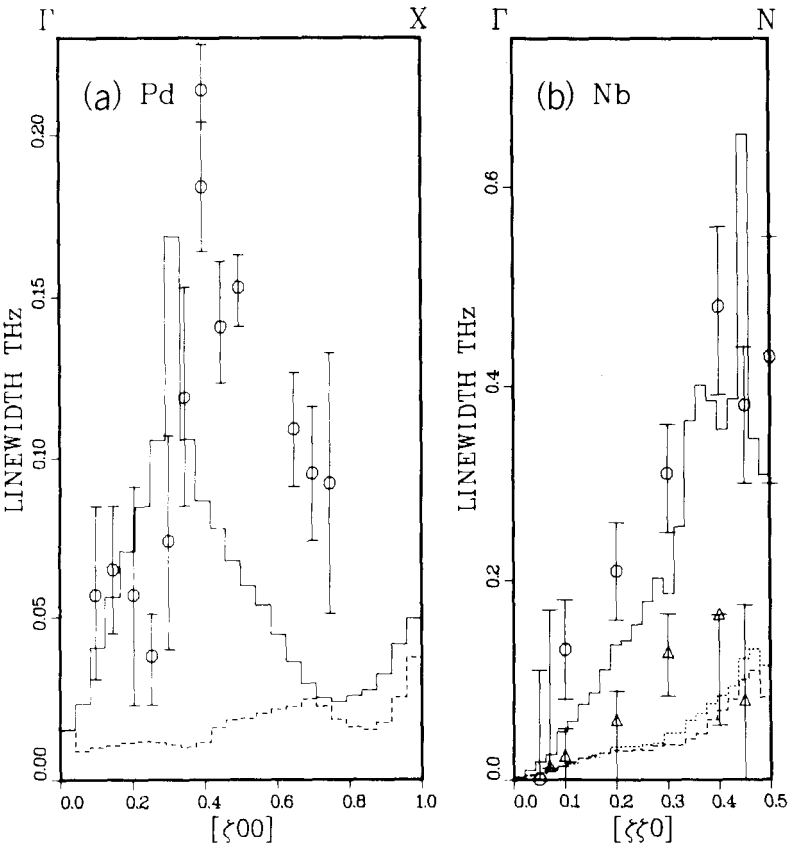

Fig. 3.1. Agreement of Theoretical and Experimental Phonon Linewidths. Histograms are calculated values—solid lines for longitudinal and dotted or dashed lines for transverse. Points with error bars are experimental—circles for longitudinal and triangles for transverse. (a) [100] phonon linewidths for palladium. (b) [110] phonon linewidths for niobium.

calculations of dependence of the upper critical field H_{c2} of a type II superconductor (niobium) on temperature and field direction. Again, results are in excellent agreement with experiment.

In alloy theory we have achieved the first solutions of the muffin-tin CPA equations. These calculations allow the electronic structure of alloys to be treated on the same footing as that of ordered materials. Calculations were performed on Cu-Ni, Cu-Pd, and Ag-Pd alloys. The results of these calculations were used to explain the results of photoemission, soft x-ray, and positron annihilation experiments on these alloys.

In band theory we have used multiple scattering theory to derive a new set of linearized band theory equations. The great computational speed that can be achieved by using these equations will allow us to study the energetics of both metals and alloys.

During the past year we developed the theoretical and computational techniques necessary to study the energetics of surface interactions. This work represents a new level of sophistication of electronic structure studies and will enable a basic understanding of the mechanisms that ultimately control reaction rates of various surface processes, such as oxidation, corrosion, passivation, activation, and heterogeneous catalysis.

Our study of lattice defect theory continues with good progress being recorded on relating theory to radiation damage and mechanical property behavior. The generalized rate theory model of loop growth and void swelling has been extended to include divacancies or helium atoms as mobile defects. A "second peak" of void swelling due to the divacancies created during neutron or ion irradiation has been predicted by the model. Also, the effect of helium created by α-particle-producing transmutations on swelling of a fusion reactor first-wall material has been predicted. The role of deformation twinning in fracture of metals and alloys was reviewed.

X-RAY RESEARCH AND APPLICATIONS

B. S. Borie

Most of the activities of the x-ray group during the reporting period are related to our efforts to accommodate to new technology: powerful new radiation sources, sophisticated new detectors, automated and computer-controlled instrumentation. C. J. Sparks heads an ORNL group charged with responsibility to provide the laboratory with experimental access to the Brookhaven synchrotron now under construction. H. L. Yakel is currently on assignment at Stanford University to test some of the new research possibilities accessable with a synchrotron radiation source. Skills developed by R. W. Hendricks in the use of position-sensitive detectors with automated and computer-controlled data collection systems in our small-angle x-ray scattering laboratory have influenced the National Science Foundation to fund the construction of a 30-m small-angle neutron scattering instrument at ORNL—a diffraction research facility unique in the United States.

At Stanford Yakel has used diffraction of synchrotron radiation with energies near absorption edges to determine site occupation parameters in compounds and alloys of first-row transition elements. He has measured the real dispersion correction for iron with a magnetite crystal and has defined the distribution of cations in an iron-cobalt spinel crystal.

Other research activities include a crystal structure refinement and an attempt to understand the small-angle scattering from the kinds of lamellae configurations that may be characteristic of polymers. Our interest in the theory of secondary extinction and the treatment of data exhibiting this effect continues.

Our group includes the primary x-ray diffraction service facility at ORNL. This laboratory, with a staff of one, examined about 500 samples during the past year. We are currently actively considering computer-controlled automated instrumentation for this laboratory, which will change its character and significantly expand its capacity.

4. Metallography and Technical Centers

This section of the report deals with metallographic work in progress and the status of two technical centers that involve materials science and technology activities and were recently assigned to ORNL. One activity is the High-Temperature Materials Laboratory (HTML), while the other is the Materials and Structures Technology Management Center (MSTMC). Both these technical management functions are multidisciplinary and national in scope.

METALLOGRAPHY

R. J. Gray

The Metallography Group of the Metals and Ceramics Division is charged with providing service in general metallography, postirradiation (hot cell) metallography, and electron beam microanalysis (scanning electron microscopy and microprobe). The services of the group are utilized by most of the scientific and technical personnel of the division as well as some other laboratory divisions and outside organizations, such as TVA, Battelle Northwest Laboratories, and DOE.

On September 21, 1978, a fire seriously disrupted operations at the United States Strategic Petroleum Reserve Site at West Hackberry, Louisiana. Members of the Division were asked to investigate portions of the damage and to serve as consultants for the investigation committee assigned to this project by DOE. This investigation found a definite leak path through welds in the wellhead and a possible leak path through a fracture in the casing. A certificate of appreciation from DOE resulted from this work.

Other failure analyses involved two large valve stems from a local power plant. Metallographic examination located the origin of failure at the root of the valve stem threads.

A continuing program of metallographic surveillance of a solvent refined coal plant at Wilsonville, Alabama, is engaged in by the Metallography Group. The most recent in-the-field metallographic examination of the fractionation column and dissolver showed both suspected and unsuspected cracks in the fractionator and no change from 1977 in the dissolver. This surveillance is performed by on-site grinding, polishing, etching, and replication of suspect areas. The replicas are examined microscopically at ORNL.

Metallographic examination was completed on a series of $^{90}SrF_2$ compatibility tests for Battelle Northwest Laboratories. These tests were to determine the compatibility of alloys TZM, Hastelloy C-276, and Haynes Alloy No. 25 in $^{90}SrF_2$ for 20,000 h at 600, 800 and 1000°C.

A summary of the group service effort is found in these numbers: 3079 specimens processed, 8245 negatives produced, and 896 slides made.

HIGH-TEMPERATURE MATERIALS LABORATORY

J. V. Cathcart

A critical need exists to address a variety of high-temperature materials problems. "Heat engines" remain the major source of energy generation in this country, and a survey of these systems shows that the *efficiency, reliability,* and, in some cases, the *feasibility* of our advanced concepts for energy production are limited by the behavior of high-temperature materials. Limitations such as those imposed by the maximum permissible operating temperature for conventional steam boilers, the erosion-corrosion problems in coal gasifiers, and the life span of electrodes in coal-fired magnetohydrodynamic (MHD) power generators immediately come to mind. The existence of such technological shortcomings underscores the complexity of high-temperature materials problems and is evidence of a need for a greater basic understanding of phenomena and properties of high-temperature materials.

As a first step in the solution of many of these problems, we have proposed that the Office of Basic Energy Sciences fund in FY 1981 the construction of an HTML. The HTML will consist of a 7000-m^2 (80,000 sq. ft.) building designed to house a professional staff of approximately 75 (total staff size: 140). The staff will be divided among six functional groups: Environmental Interactions, Physical Properties, High-Temperature Chemistry, Structural Characterization, Mechanical Behavior, and Materials Synthesis and Preparation. Current plans call for the completion of the HTML late in 1984. Operations will begin with approximately half the professional staff, with full staffing being achieved in three to four years.

We recognize the importance of close interaction between the HTML and the university and industrial research community, and we plan to emphasize the user facility aspects of the HTML. We hope to be able to accommodate users at a rate of 10 to 15 full-time equivalent persons.

Research in the HTML will encompass both applied and basic studies of high-temperature materials. We consider close interaction between these two activities to be essential, the major distinction between the two being that the basic investigations will be oriented toward the achievement of an understanding of high-temperature materials phenomena, while systems development work will be more characteristic of the applied research. Fundamental research on the complex materials used in energy systems is considered vital in this research philosophy; consequently, the HTML will contain a spectrum of research ranging from the most basic to studies contributing directly to current or advanced energy technologies. We believe that this approach to the development of a research program together with the unique, state-of-the-art collection of equipment contained in the HTML will best serve the needs of DOE and will also promote interactions with industrial research interests and be attractive to members of the university community as well.

MATERIALS AND STRUCTURES TECHNOLOGY MANAGEMENT CENTER

J. R. DiStefano

In line with its policy to decentralize the technical management of research, development, and demonstration programs, DOE has established a number of national technology management centers (TMCs). Because of its prominent role and demonstrated expertise in the LMFBR program for high-temperature structural design and structural materials, ORNL has been selected as the site for the national MSTMC. The large-component development program and the fast reactor safety program will be technically managed by ANL, and the programs on reactor fuels and core materials will be managed by HEDL. Materials programs have been delineated between core-related materials and noncore structural materials.

The objectives of the materials and structures program are to develop high-temperature design technology and to determine metallurgical behavior and properties for specific LMFBR applications. The MSTMC will technically manage materials and structural design programs at Agbabian Associates, ANL, GE, HEDL, INEL, NRL, ORNL, AI, and WARD. The MSTMC will administratively report to W. O. Harms, Director, Nuclear Reactor Technology Programs at ORNL. The materials technology tasks will be managed by J. R. DiStefano of the Metals and Ceramics Division and the structural design tasks by C. E. Pugh of the Engineering Technology Division. Major program work elements are High-Temperature Structural Design Technology, Seismic Design Technology, Mechanical Properties Design Data, Fabrication Technology, Corrosion and Tribology Technology, NDT Technology, Advanced Alloy Technology, and Documentation, Liason, and Application. Both the Engineering Technology and Metals and Ceramics Divisions will provide staff to implement technical management in these areas.

To carry out its mission, the MSTMC must interface with DOE headquarters, ORO, and the individual participants in the program. It is intended that DOE headquarters provide broad policy guidance and overall direction for program planning and implementation. The MSTMC will prepare the national program plan with the understanding and agreement of DOE and the managers of the participating organizations. DOE will approve the program and provide resources for implementation. Coordination will be maintained with the other TMCs to avoid duplication of effort, develop consistent milestone schedules, and prevent technological gaps.

Appendix A

Budget and Allocation of Funds

The Division continues to be fully supported and enjoys a reasonably healthy financial status. Total funding for operations grew at a sufficient rate in 1978 and 1979 to cope with inflation and to subcontract an increasingly larger share of the research and development effort to outside firms. The financial outlook for the tight budget year 1980 appears rather promising in terms of operating support at this time.

Table A1 presents the operating budget and allocation of funds by major program activity for the three-year period 1978 through 1980. The incremental increase of the FY 1979 financial plan over 1978 is expected to reach about $1.5 million by year-end, while the gain for 1980 is projected to run about $3.5 million. However, subcontracted work has increased from $481,000 in 1978 to an estimated $1,645,000 in 1979 and is projected to reach $2,885,000 in 1980. Consequently, the amount of support remaining for in-house work, after adjustments are made for inflation and farm-out work, indicates a slight decrease for 1979 and a rise of uncertain magnitude for 1980.

While the budget for in-house activity is tending toward stability, major changes are occurring in the distribution of support for various project activities. The Conservation Program continues to grow at an accelerated rate, while support for the Fossil Energy Program is rising at a more modest rate. Among the programs scheduled for less support are Space and NRC Safety. The expected decrease in nuclear fission work has not materialized and the level of support appears to be holding steady.

The requested and expected increase in funding on the Advanced Technology Program to permit initiation of mechanistic studies on the long-range-ordered alloys has not been realized, and this turn of events represents a serious setback for developing these promising alloys. Currently, efforts are being made to offset this setback by securing some direct support from the Fusion Energy Program.

Table A1. Division Support Sources

(Thousands of Dollars)

	Actual FY 1978[a]		Current FY 1979[b]		Predicted FY 1980[c]	
	($K)	(%)	($K)	(%)	($K)	(%)
Advanced Technology	80	0.4	427	1.8	400	1.5
Basic Energy Science	4,673	20.9	4,676	19.9	5,217	19.0
Conservation	799	3.6	2,395	10.2	5,035	18.0
Fission	9,106	40.7	8,272	35.3	9,386	33.9
Fossil	757	3.4	951	4.1	1,545	5.6
Fusion	1,748	7.8	1,872	8.0	2,015	7.3
NRC Safety	1,295	5.8	1,466	6.3	1,132	4.1
Solar	0	0	103	0.4	100	0.4
Space	2,325	10.4	1,323	5.6	1,230	4.4
Waste	196	0.9	147	0.6	240	0.9
Other	246	1.1	580	2.5	255	0.9
Service	1,128	5.0	1,248	5.3	1,100	4.0
Total	22,355		23,460		27,655	

[a]From final 1978 Management Report.
[b]From June Management Report.
[c]From Budget and Manpower Analysis of June 20, 1979.

Appendix B

Personnel Summary

The Division engages in a broad spectrum of materials science and engineering activities that require a multidisciplinary staff of competent people for implementation. This section of the report describes the full staff of the Division in terms of employee status and changes that have occurred during the past twelve months.

Despite significant changes in program mix and direction, the permanent staff of the Division has remained essentially constant, with only minor turnover during the past year. Table B1 presents the number of professional staff and support people on role as of July 1, 1978 and 1979, as well as a breakdown of personnel into various employee classifications, such as permanent, loanees, part-time, guests, and co-ops. The small decrease in professional people indicated has been fully offset by the administrative personnel added to assist in managing the national program activities recently assigned. The lack of growth in professional staff can be traced to three factors: (1) limited monies available for growth of in-house research and development, (2) personnel ceiling imposed by DOE and Laboratory management, and (3) low rate of acceptance on employment offers. Most of the budgeted increase reflected in FY 1979 over FY 1978 is earmarked to cover inflation and increased cost of subcontracting work. Of the eight people leaving the employ of the Division, five were transferred to other ORNL divisions, two resigned, and one was requested to seek employment elsewhere. During the past year, only three new professional people were hired and four were transferred from temporary to permanent roll. In addition, four new technicians were hired, and each holds the equivalent of a two-year degree or more from a technician training school.

The Division is currently below the established personnel ceiling of 300 people and anticipates difficulty in staffing to the full level required in FY 1980.

The Division continued the practice of supplementing the staff with visiting guests from other research institutions. During the year, 17 guests from outside institutions participated in on-going research and development activity. Conversely, nine Division staff people were on assignment to other laboratories, primarily in Europe.

Table B1. Division Staff Composition as of Mid-Calendar-Years 1978 and 1979

	Technical		Support		Total	
	1978	1979	1978	1979	1978	1979
Permanent employees	154	151	130	134	284	285
Temporary, >10 months	9	5	0	0	9	5
Div.-supported loanees	1	1	5	6	6	7
Loaned out	4	3	3	1	7	4
Part time	6	8	5	3	11	11
Assigned guests	11	13	0	0	11	13
Coops (1/2 time)	0	0	5	4	5	4

Appendix C

Organizational Structure and Chart

The Division is organized into a matrix structure to handle the dual administration of line organization by functional discipline and management of large, complex, and high-technology projects. The current organization of the Division is charted in Fig. C1.

During the past year, a number of management openings occurred in both the line and project organizational structure and personnel were shifted to fill these positions. In August, 1978, A. L. Lotts was named Director of the Nuclear Fuel and Waste Programs at ORNL, and subsequently R. L. Beatty of the Metals and Ceramics Division was appointed Manager of the Nuclear Fuel Development Program. In turn, F. J. Homan assumed responsibility for management of the Gas-Cooled Reactor Programs in the Division in addition to remaining as head of the Fuels Evaluation functional group. In October, R. A. Bradley was appointed Manager of the National Fossil Energy Materials Program; D. R. Johnson replaced him as head of the Engineering Coordination and Evaluation functional group, formerly known as the Fuel Cycle Engineering Group. In November, A. C. Schaffhauser was named Division Manager of the Conservation and Advanced Systems Programs, including the Space and Terrestrial Programs he previously managed. T. S. Lundy retained responsibility for management of the national program on Building Thermal Envelope Systems and Insulating Materials (BTESIM). In December, C. J. McHargue became full-time Manager of the Basic Energy Sciences Program in the Division, and J. O. Stiegler replaced him as head of the Materials Science Section. In turn, E. E. Bloom became head of the Radiation Effects and Microstructural Analysis Group.

The national Materials and Structures Technology Management Center (MSTMC) was established at ORNL in April, 1979. W. O. Harms currently serves as Acting Director of the Center, while J. R. DiStefano of the Metals and Ceramics Division and C. E. Pugh of the Engineering Technology Division were appointed Managers of Materials and High Temperature Structural Design, respectively.

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W. H. SMITH
L. J. TURNER

METASTABLE AND SUPERCONDUCTING MATERIALS
C. C. KOCH
D. M. KROEGER
A. DAS GUPTA
D. S. EASTON
W. SPECKING[19]
J. O. SCARBROUGH

SURFACE AND SOLID STATE REACTIONS
J. V. CATHCART*
P. T. CARLSON
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
J. F. HARRIS[5]
G. S. PAINTER
G. M. STOCKS
M. H. YOO

X-RAY RESEARCH AND APPLICATION
B. S. BORIE
O. B. CAVIN
R. W. HENDRICKS*
J. S. LIN
C. J. SPARKS, JR.*
H. L. YAKEL[20]

FUELS AND PROCESSES
R. G. DONNELLY, SECTION HEAD
M. C. CLARY
R. L. CASTLEBERRY
F. M. FOUST
B. D. KECK*
S. L. McCANELLY
M. S. WILLIS

NATIONAL BUILDING ENERGY CONSERVATION PROGRAM
T. S. LUNDY

GRAPHITE PROGRAMS
W. P. EATHERLY

ALUMINUM FUEL ELEMENT DEVELOPMENT PROGRAM
M. M. MARTIN*

CERAMIC TECHNOLOGY
V. J. TENNERY
E. S. BOMAR, JR*
G. W. BRASSELL
J. I. FEDERER
L. A. HARRIS
C. R. KENNEDY
R. J. LAUF
C. S. MORGAN
A. E. PASTO
J. E. SELLE
G. C. WEI
B. R. CHILCOAT
J. W. GEER
S. L. HALSTED
C. HAMBY
F. P. JEFFERS
W. R. JOHNSON
H. KEATING
J. F. WILLMERING

ENGINEERING COORDINATION AND EVALUATION
D. R. JOHNSON
B. J. BAXTER[16]
R. R. JUDKINS
A. R. OLSEN
T. F. SCANLAN
E. G. SHIELDS[10]
H. J. WALLACE
H. R. LIVESEY

FUEL CYCLE TECHNOLOGY
W. J. LACKEY
P. ANGELINI
A. J. CAPUTO
J. E. MACK
D. P. STINTON
R. R. SUCHOMEL
S. M. TIEGS
L. C. WILLIAMS
S. W. COOK
C. E. DeVORE
W. H. ELLIOTT, JR.
J. B. FLYNN*
G. F. GALLOWAY
M. S. HENDRICKS
J. C. McLAUGHLIN
W. B. STINES
R. L. WHITE

FUELS EVALUATION
F. J. HOMAN
H. CORDS[5]
E. L. LONG, JR.
J M ROBBINS
T. N. TIEGS
P. J. JONES
E. L. RYAN

METALS PROCESSING
R. L. HEESTAND
G. L. COPELAND
D. E. HARASYN
R. W. KNIGHT*
M. M. MARTIN*
R. E. McDONALD
T. K. ROCHE
G. E. ANGEL
K. S. BLAKELY
W. H. DAVIS
C. E. DUNN
J. N. HIX
C. W. HOLLAND
R. L. MARTIN
L. QUEENER
C. L. QUIMBY

*DUAL CAPACITY
[1]PART TIME
[2]ON LOAN TO GCR PROGRAM
[3]TEMPORARY ASSIGNMENT
[4]ON ASSIGNMENT TO LONG RANGE PLANNING
[5]ON ASSIGNMENT FROM KFA, JÜLICH
[6]ON LOAN FROM FINANCE AND MATERIALS DIVISION
[7]ON ASSIGNMENT FROM PLANT AND EQUIPMENT DIVISION
[8]ON ASSIGNMENT TO GFK, KARLSRUHE
[9]ON ASSIGNMENT TO KFA, JÜLICH
[10]ON LOAN FROM INFORMATION DIVISION
[11]ON ASSIGNMENT TO AERE HARWELL
[12]ON ASSIGNMENT FROM COMPUTER SCIENCES DIVISION
[13]ON ASSIGNMENT FROM INSTRUMENTATION AND CONTROLS DIVISION
[14]ON ASSIGNMENT FROM ENGINEERING TECHNOLOGY
[15]ON ASSIGNMENT FROM AERE, HARWELL
[16]ON ASSIGNMENT FROM GENERAL ATOMIC
[17]ON ASSIGNMENT TO CEN, FONTENAY-AUX-ROSES
[18]ON LOAN TO CMO BREEDER REACTOR PROGRAM
[19]ON ASSIGNMENT FROM KFK, KARLSRUHE
[20]ON ASSIGNMENT TO STANFORD SYNCHROTRON RADIATION LABORATORY
[21]ON ASSIGNMENT FROM CENTRAL ELECTRICITY GENERATING BOARD (CEGB), BERKLEY
[22]ON ASSIGNMENT TO CEGB, MARCHWOOD

Fig. C1. Metals and Ceramics Division Organization Chart.

Appendix D

Honors and Awards

Divisional staff members continue to be cited and rewarded for outstanding technical achievement. 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

October 1978

James H. Smith was advanced to Fellow of the American Society for Nondestructive Testing by the Board of Directors. He received the honor at the Society's Fall Meeting in Denver.

November 1978

Ralph G. Donnelly and *Jackson H. DeVan* were advanced to the grade of Fellow of the American Society for Metals and received the honor at the Annual Awards Banquet in Philadelphia.

April 1979

Gerald M. Slaughter was selected to present the Comfort A. Adams Lecture at the American Welding Society's Annual Meeting in Detroit. Slaughter spoke on "The Technology of Brazing and Soldering is Vital to the Industrial Economy."

April 1979

Carl C. Koch and *Robert W. Hendricks* were advanced to the rank of Fellow of the American Physical Society.

May 1979

Charles S. Yust was promoted to the rank of Fellow of the American Ceramic Society.

June 1979

James A. Horak was advanced to the grade of Fellow of the American Nuclear Society.

C. Ray Kennedy was selected to present a plenary lecture at the 14th Biennial Conference on Carbon at Pennsylvania State University. Kennedy's lecture was entitled "The Control of Physical Properties by Fabrication."

AWARDS

July 1978

Vinod K. Sikka, Stanislav A. David, Elmer H. Lee, C. W. (Pete) Houck, and *Barbra L.P. Booker* received the first place award in the Optical Microscopy—Ferrous Class at the 1978 International Metallographic Exhibit of the International Metallographic Society and the American Society for Metals in Montreal, Canada.

Reynold G. Berggren received the Honorary Member Award for 1978 of Committee E-10 on Nuclear Applications and Measurements of Radiation Effects, American Society for Testing and Materials.

December 1978

James F. King and *Ronald L. Klueh* received an American Nuclear Society Award for their poster presentation during the Materials Science and Technology Division's Poster Session at the ANS Winter Meeting in Washington, D.C.

April 1979

Reynold G. Berggren, Nancy C. Cole, Gene M. Goodwin, Robert J. Gray, Roy T. King, Gerald M. Slaughter, and *James O. Stiegler* received the McKay-Helm Award of the American Welding Society.

May 1979

David P. Stinton, Peter Angelini, W. J. Lackey, and *Nobel H. Rouse's* entry in the American Ceramic Society Ceramographic Exhibit in Cincinnati won first place in the Optical Microscopy (Transmitted Light) Category and Best in Show honors.

Sue M. Tiegs, Marilyn S. Hendricks, Nobel H. Rouse, David L. Fahey, and *E. Leon Smith* received the first place ribbon for their exhibit in the Optical Micrographs (Reflected) Category at the American Ceramic Society Ceramographic Exhibit in Cincinnati.

Tommy J. Henson, Larry G. Shrader, and *Terry N. Tiegs* received first place honors in the Scanning Electron Microscopy Category at the American Ceramic Society Ceramographic Exhibit in Cincinnati.

COMMENDATIONS

January 1979

Robert J. Gray and *Gerald M. Slaughter* were presented Department of Energy Certificates of Appreciation for their participation in the investigation of the September 21, 1978, explosion and fire at the West Hackberry, Louisiana, Strategic Petroleum Reserve.

June 1979

Henry Inouye and *Victor J. Tennery* received commendations from the Department of Energy MHD Review Board for their technical expertise and review assistance in scrutinizing various elements of the Magnetohydrodynamics Program.

David O. Hobson, Richard E. Pawel, and *James R. Weir, Jr.,* received ORNL Certificates of Appreciation for their contributions to analyses in support of emergency efforts following the Three-Mile Island Accident in March.

ELECTED OFFICERS AND MEMBERS

July 1978

Walter P. Eatherly was elected Vice Chairman and Membership Secretary of Committee C-5 on Manufactured Carbon and Graphite of the American Society for Testing and Materials.

October 1978

Robert W. Hendricks became an elected member of the Commission on Crystallography Apparatus of the International Union of Crystallography for the term August 1978 through August 1981.

April 1979

Gene M. Goodwin was elected Director-at-Large of the American Welding Society.

CERTIFICATION AND REGISTRATION

August 1978

Roddie R. Judkins became a Registered Professional Engineer in the State of California.

February 1979

Robert W. McClung also became a Registered Professional Engineer in the State of California.

APPOINTMENTS

July 1978

Caius V. Dodd was selected to serve on the Board of Directors' Awards Committee of the American Society for Nondestructive Testing during the 1978-1979 year.

Victor J. Tennery was selected to serve on the Ceramics Topics Area Team of the Educational Modules for Materials Science and Engineering Program of the National Science Foundation.

September 1978

Robert W. McClung was invited to serve as a member of the Advisory Board for the newly established Nondestructive Evaluation Division of the University of Tennessee.

Robert W. Hendricks was appointed to the Membership Committee of the Division of High-Polymer Physics, American Physical Society, for a term to end in March 1980.

December 1978

Carus K. DuBose was appointed Editor of *International Metallographic Exhibit,* a publication of the International Metallographic Society.

January 1979

W. J. Lackey was invited by the National Research Council Commission on Human Resources to serve on their panel to evaluate applications for the NRC Research Associateship Programs in 1979.

James R. Weir, Jr., was appointed to the Editorial Board of *Res Mechanica,* a journal of Applied Science Publishers Ltd., Essex, England.

February 1979

Randy K. Nanstad was appointed by the Executive Committee of the Pressure Vessels and Piping Division. American Society of Mechanical Engineers, to serve a two-year term as Chairman of the Subcommittee M&F-2 on Use of Materials Property Data in Design, under the Materials and Fabrication Committee.

April 1979

Joseph A. Carpenter was appointed to the American Society for Metals' Young Members Committee.

May 1979

W. J. Lackey was selected to serve as Chairman of the American Ceramic Society's Editorial Review Committee for the ACS *Journal* and/or *Bulletin* as well as to represent the Nuclear Division on the ACS Editorial Advisory Board.

June 1979

James R. Weir, Jr., was appointed Coeditor of *The Fusion Power Reactor,* a two-volume book by Applied Science Publishers Ltd., Essex, England.

John E. Cunningham was appointed to the American Nuclear Society's Honors and Awards Committee for a three-year term.

Appendix E

Seminar Program

Since technical advance usually evolves from work performed by others, the Division promotes and maintains an active seminar program to keep the staff informed and abreast of recent developments and findings in the field of materials science and engineering as well as in related areas of interest. Most of the talks deal with scientific and engineering subjects and are presented by invited speakers from organizations in the United States and abroad. The actual number of seminar talks scheduled for any given week varies but over the full year averages greater than one per week.

The seminar program is administered by a committee appointed by Division management. The Seminar Committee for calendar years 1978 and 1979 consists of J. D. Holder (Chairman), J. R. Keiser, and R. R. Suchomel.

The speakers and topics of seminars presented during the past year are listed below. It is interesting to note the international character of the program and the fact that 24 of the 64 talks scheduled were made by individuals affiliated with institutions located outside the United States. An alternate breakdown indicates 40 talks by university faculty members and graduate students, 7 by representatives from industrial concerns, and the balance from governmental and other organizations.

S. W. Lovesy (Institute Laue-Langevin, Grenoble, France), "Anomalous Scaling Properties of Models of Nonequilibrium Phenomena" (July 12, 1978).

David J. Reed (Massachusetts Institute of Technology), "Ion Probe Measurement of Oxygen Self-Diffusion in Aluminum Oxide" (July 18, 1978).

Ian P. Jones (University of Birmingham, England), "Investigation of the Detailed Structure of Stacking Faults by Electron Microscopy" (July 24, 1978).

W. Kesternich (KFA, Jülich, West Germany), "Radiation-Induced Formation and Dissolution of Precipitates in Ni-Cr-Fe Alloys and Stainless Steel" (July 25, 1978).

B. L. Gyorffy (University of Bristol, England), "Two-Level Tunneling States in Metallic Glasses" (August 2, 1978).

W. D. Wilson and M. Baskes (Sandia Laboratories), "Hydrogen Trapping to Vacancies, Dislocations, and Stress Fields Near a Crack Tip in FCC Metals: A Quantum-Chemical—Lattice Defect—Finite Element Hybrid Approach" (August 8, 1978).

Laura Roth (State University of New York, Albany), "Excitations in Amorphous Solids" (August 9, 1978).

K. Yagi (Tokyo Institute of Technology, Japan), "Techniques for Ultrahigh-Vacuum Electron Microscopy" (August 11, 1978).

V. L. K. Lou (Case Western Reserve University), "Materials and Processing Problems in Doped Si_3N_4—A Transmission Electron Microscopy and Thermodynamic Study" (August 15, 1978).

J. Sak (Rutgers University), "Critical Point Phenomena" (August 23, 1978).

Paul Butler (Imperial College, London, England), "High-Voltage Electron Microscopy at Imperial College: Gas-Solid Reaction Studies and Radiation Damage in Ordered Alloys" (August 25, 1978).

H. Gleiter (University de Saarlandes, West Germany), "Dislocations in Interfaces" (September 15, 1978).

John Harris (Institut für Festkörperforschung, Jülich, West Germany), "Application of Hohenberg-Hohn-Sham Theory to Chemical Bonding: 3d-Dimers" (October 4, 1978).

A. S. Roy (Ben Gurion University, Israel), "Solar Power Engineering—Systems and Materials" (October 12, 1978).

R. J. Fields (National Bureau of Standards, Washington, D.C.), "Some Effects of Geometry on the High-Temperature Fracture of Notched Components" (October 13, 1978).

A. H. Heuer (Case Western Reserve University), "Deformation Mechanisms in Oxide Single Crystals" (October 19, 1978).

A. D. Marwick (AERE Harwell, England), "Mechanisms of Radiation-Induced Segregation in Dilute Nickel Alloys" and "Radiation-Enhanced Diffusion and Segregation in Ni and Ni(Si) Alloy: The Effects of Point-Defect Trapping" (October 30, 1978).

Paul Soven (University of Pennsylvania), "Surface States on Metals" (November 1, 1978).

J.C.H. Spence (Arizona State University), "High-Resolution TEM of Defects in Diamond Cubic Semiconductors" (November 8, 1978).

H. I. Aaronson (Michigan Technological University), "Mechanisms of Diffusional Nucleation and Growth" (November 10, 1978).

Mark Rasolt (Solid State Division, ORNL), "Exchange and Correlation Effects in Many-Electron Systems" (November 15, 1978).

S. Perkowitz (Emory University), "Far Infrared Studies of Superconductors" (November 16, 1978).

Dimitri Papaconstantopoulos (Naval Research Laboratory, Washington, D.C.), "The Calculation of Electron-Phonon Interaction in Complex Structures (December 6, 1978).

J. S. Faulkner (Metals and Ceramics Division, ORNL), "On the Multiple Scattering Approach to Band Theory" (December 20, 1978).

W.A.T. Clark (Michigan Technological University), "Characterization of Interfacial Structure by Transmission Electron Microscopy" (January 4, 1979).

William Giessen (Northeastern University), "Recent Developments in Metal-Metal Glasses" (January 8, 1979).

Lars Hedin (Stanford University), "Correlated Crystal Potentials for Band Structure Calculations" (January 8, 1979).

John Ballance (Editor, *Journal of Metals*), "AIME-JOM: Editorial Policies and New Directions" (January 11, 1979).

D. E. Ellis (Northwestern University), "Metal Cluster Models: Applications to Chemisorption, Interstitial Hydrogen, and Magnetic Impurities" (January 24, 1979).

V. A. Kapustin (A. F. Ioffe Institute, Leningrad), "Transport Phenomena in Magnetic Semiconductors" (January 31, 1979).

Sumio Iijima (Arizona State University), "High Resolution Electron Microscopy of Crystalline Defects" (February 5, 1979).

A. J. Freeman (Northwestern University), "Local Density Approach to Bulk and Surface States" (February 7, 1979).

H. Ullmaier (Institut für Festkörperforschung, Jülich, West Germany), "Stress-Assisted Growth of Gas Bubbles in Metals" and "Radiation Effects Activities at KFA-Julich" (February 7, 1979).

C. H. Hodges (Daresbury Laboratory, England), "Why Do Metals Form Alloys?" (February 28, 1979).

V. O. Kostroum (School of Applied and Engineering Physics, Cornell University), "Synchrotron Radiation: Instrumentation and Applications to X-Ray Spectroscopy of Lα Edges in the 4 Å Region" (March 2, 1979).

W. A. Harrison (Stanford University), "Simple Theory of Transition Metals" (March 7, 1979).

H.G.F. Wilsdorf (University of Virginia), "In Situ Deformation of Ductile Metals in the HVEM Leading to Fracture" (March 12, 1979).

Arden L. Bement, Jr. (Director, Office of Materials Science, Advanced Research Projects Agency, Department of Defense, Arlington, Virginia), "ARPA Initiatives in Materials Science" (March 20, 1979).

R. D. Henshell (University of Nottingham, England), "Fracture Mechanics Analysis Using Finite Element Techniques" (March 23, 1979).

R. M. Mayer (Cavendish Laboratory, University of Cambridge, England), "A Model of Void Nucleation During Displacive Irradiation" (April 2, 1979).

A. W. Pense (Lehigh University), "An Analysis of Electroslag Welded Bridges in Pennsylvania" (April 10, 1979).

George M. Pharr (Stanford University), "A Numerical Study of Cavity Growth Controlled by Surface Diffusion" (April 11, 1979).

Bruce R. Somers (Lehigh University), "Fracture Toughness of Some Cryogenic Aluminum Alloys" (April 11, 1979).

F. J. Pinski (State University of New York, Stony Brook), "Calculation of Transport Properties of Transition Metals" (April 11, 1979).

R. M. Fleming (Bell Laboratories), "X-Ray Diffraction Study of Interdiffusion and Growth in (GaAs) (AlAs) Multilayers" (April 16, 1979).

E. G. Henneke (Virginia Polytechnic Institute and State University), "Nondestructive Evaluation of Composites" (April 18, 1979).

Bob Swendsen (Brookhaven National Laboratory), "Monte Carlo Renormalization Group" (April 25, 1979).

Peter Wilkes (University of Wisconsin, Madison), "Irradiation-Induced Phase Transformations" (May 3, 1979).

Ondrej L. Krivanek (University of California), "High-Resolution Microscopy of Semiconductors and Ceramics" (May 3, 1979).

W. Bollmann (Battelle, Geneva, Switzerland), "Structure of Grain and Phase Boundaries" (May 10, 1979).

P. Humble (CSIRO, Australia), "Diamonds—Their Microstructure and Plastic Deformation" (May 11, 1979).

Peter Marshall (Central Electricity Generating Board, England), "Progress in Understanding the Elevated Temperature Mechanical Properties of Type 316 Stainless Steel in Support of Fast Breeder Reactor Development" (May 11, 1979).

R. E. Marringer (Battelle Columbus Laboratories), "Rapid Quenching—A New Frontier in Metallurgy" (May 16, 1979).

Jules Carbotte (McMaster University), "Recent Developments in Strong-Coupling Superconductivity" (May 16, 1979).

J. E. Harbottle (Berkeley Nuclear Laboratories, CEGB, England), "Impurity Effects on Radiation-Induced Swelling and Creep" (May 17, 1979).

C. Schwaiger (Institut für Festkörperforschung, KFA, Jülich, West Germany), "Radiation Creep in Deuteron-Bombarded Stainless Steel" (May 18, 1979).

A. Lucas (IBM Watson Laboratory), "Studies of the Optical Properties of Voids and Gas Bubbles in Radiation-Damaged Metals" (May 22, 1979).

R. D. Henshell (University of Nottingham, England), "Fracture Mechanics Analysis Using Finite Element Techniques" (May 23, 1979).

S. M. Heald (University of Washington), "EXAFS Studies of Bromine-Graphite Compounds" (May 24, 1979).

Steven Rothman (Argonne National Laboratory), "Tracer Diffusion of Fe, Ni, and Cr in Austenitic Steels" (June 1, 1979).

G. D. Mahan (Indiana University), "X-Ray Spectra of Metals" (June 6, 1979).

Jean-Pierre Briand (University of Paris, France), "X-Ray Spectroscopy Within the Natural Line Width" (June 7, 1979).

Gunter Ziegler (Institute for Materials Research, Cologne, West Germany), "Correlation of Microstructure and Mechanical Properties of Silicon Nitride" (June 14, 1979).

S. M. Myers (Sandia Laboratories), "Metallurgy by Ion Implantation" (June 21, 1979).

Appendix F

Advisory Committee

The Advisory Committee to the Metals and Ceramics Division consists of six members appointed by the Laboratory Director. Members are appointed for a three-year term on a staggered basis so that two new members replace two members retiring from service each year. The main function of the Committee is to review on-going research and development activities and render an independent assessment on the general state and welfare, ability of staff, and progress being made in various operations and missions of the Division. Members are drawn from governmental, industrial, and educational institutions and are selected on the basis of demonstrated ability in management, research, and technology. Members of the 1979 Advisory Committee are listed below.

Dr. Walter R. Hibbard, Jr., (Committee Chairman)
University Distinguished Professor
College of Engineering
329 Norris Hall
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Dr. Arden L. Bement, Jr.
Director, Materials Science Office
Advanced Research Projects Agency
Department of Defense
1400 Wilson Boulevard
Arlington, Virginia 22009

Dr. Robert W. Balluffi, Professor
Department of Materials Science and Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts 02139

Dr. Edward H. Kottcamp, Jr.
Assistant to the Vice President
and Manager, Product Research
Bethlehem Steel Corporation
Bethlehem, Pennsylvania 18016

Mr. Manville J. Mayfield
Program Manager, Combustion Systems
Energy Research
Tennessee Valley Authority
440 Commerce Union Bank Building
Chattanooga, Tennessee 37401

Dr. John T. Stringer, Manager
Materials Support Group
Fossil Fuel and Advanced Systems Division
Electric Power Research Institute
P.O. Box 10412
Palo Alto, California 94303

Appendix G

Publications

Compiled by Denise Campbell and
Kathryn Witherspoon

P. R. Achenback, E. L. Bales, W. L. Carroll, E. C. Freeman, T. S. Lundy, D. L. McElroy, and F. J. Powell, *The National Program Plan for Building Thermal Envelope Systems and Insulating Materials,* DOE/CS-0059 (January 1979).

Laszlo Adler, K. Von Cook, William A. Simpson, Jr., and D. Kent Lewis, *Anisotropic Determination and Correction for Ultrasonic Flaw Detection by Spectral Analysis* (to U.S. Department of Energy). U.S. Patent 4,106,327. Aug. 15, 1978.

L. Adler, K. V. Cook, W. A. Simpson, D. K. Lewis, and D. W. Fitting, *Ultrasonic Flaw Detection and Characterization in Structural Materials by Spectral Analysis,* ORNL/TM-6456 (October 1978).

P. B. Allen and W. H. Butler, "Electrical Conduction in Metals," *Phys. Today* 31(12): 44–49 (December 1978).

E. J. Allen and S. R. McNeany, *Nondestructive Fissile Isotopic Measurement Technique for* ^{233}U-^{235}U *Fuels Using Prompt and Delayed Fission-Neutron Counting,* ORNL/TM-6686 (March 1979).

E. J. Allen, S. R. McNeany, and J. D. Jenkins, *Calorimetric Assay of HTGR Fuel Samples,* ORNL/TM-6665 (April 1979).

P. Angelini, J. L. Long, and D. E. Starnes, *Effect of Particle Blending on HTGR Fuel Rod Temperature Profiler,* ORNL/TM-6561 (January 1979).

P. Angelini and J. E. Rushton, *Uranium and Thorium Loadings Determined by Chemical and Nondestructive Methods in HTGR Fuel Rods for the Fort St. Vrain Early Validation Irradiation Experiment,* ORNL/TM-6562 (January 1979).

E. L. Bales, E. C. Freeman, T. S. Lundy, D. L. McElroy, W. L. Carroll, F. J. Powell, and P. R. Achenbach, "The National Program Plan for Building Thermal Envelope Systems and Insulating Materials," *ASHRAE J.* 21(3): 39–43 (March 1979).

V. B. Baylor, M. K. Booker, J. P. Strizak, and R. L. Klueh, "Cyclic Stress-Strain Behavior of ERNiCr-3 Weld Filler Metal," pp. 159–73 in *Properties of Steel Weldments for Elevated Temperature Pressure Containment Applications,* MPC-9, The American Society of Mechanical Engineers, New York, 1978.

V. B. Baylor, *Analysis of Level Control Valve Seat from the Recycle Condensate Separator at the Ft. Lewis, Washington, SRC Pilot Plant,* ORNL/TM-6680 (March 1979).

C. K. Bayne and S. R. McNeany, *Statistical Precision of Delayed-Neutron Nondestructive Assay Techniques,* ORNL/TM-6569 (February 1979).

R. J. Beaver, *State-of-the-Art Survey of Joinability of Materials for OTEC Heat Exchangers,* ORNL/TM-6284 (December 1978).

J. Bently, N. J. Zaluzec, E. A. Kenik, and R. W. Carpenter, "Optimization of an Analytical Electron Microscope for X-Ray Microanalysis: Instrumental Problems," pp. 581–94 in *Scanning Electron Microscopy, (Proc., Washington, D.C., April 16–20, 1979),* SEM Inc., AMF O'Hare, Illinois, 1979.

E. E. Bloom, E.N.C. Dalder, R. E. Gold, J. J. Holmes, D. L. Kummer, F. V. Nolfi, T. C. Reuther, J. O. Stiegler, and F. W. Wiffen, "Alloy Development for Irradiation Performance: Program Strategy," *The Technology of Controlled Nuclear Fusion* (Proc. 3rd Top. Meet. May 9–11, 1978, Santa Fe, New Mexico), CONF-780508, Vol. 1, pp. 554–64.

M. K. Booker and R. L. Klueh, *An Interim Analytical Description of the Creep and Creep-Rupture Behavior of ERNiCr-3 Weld Metal,* ORNL/TM-6464 (November 1978).

M. K. Booker and V. K. Sikka, "A Study of Tertiary Creep Instability in Several Elevated-Temperature Structural Materials," pp. 325–43 in *Properties of Steel Weldments for Elevated Temperature Pressure Containment Applications,* MPC-8, The American Society of Mechanical Engineers, New York, 1978.

M. K. Booker, *Evaluation of Creep and Relaxation Data for Hastelloy Alloy X Sheet,* ORNL-5479 (February 1979).

M. K. Booker, "Regression Analysis of Creep-Rupture Data—A Practical Approach," Part 5 in *Development of a Standard Methodology for the Correlation and Extrapolation of Elevated Temperature Creep and Rupture Data,* FP-1062, Vol. 2, Metal Properties Council, New York, 1979.

D. N. Braski and J. M. Leitnaker, "Homogenization of Ti-Hastelloy-N," *Metall. Trans. A* 10A(4): 427–32 (April 1979).

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R. H. Bryan, P. P. Holz, J. G. Merkle, G. C. Smith, J. E. Smith, and W. J. Stelzman, *Test of 6-in.-thick Pressure Vessels. Series 3: Intermediate Test Vessel V-7B,* NUREG/CR-0309, ORNL/NUREG-38 (October 1978).

W. H. Butler and R. K. Williams, "Electron-Phonon Interaction and Lattice Thermal Conductivity," *Phys. Rev. B* 18(12): 6483–94 (December 1978).

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N. J. Zaluzec, *An Analytical Electron Microscope Study of the Omega Phase Transformation in a Zirconium-Niobium Alloy,* ORNL/TM-6705 (June 1979). Ph.D. Thesis, University of Illinois, 1978.

Appendix H

Presentations at Technical Meetings

Compiled by Julia L. Bishop

38th National ASNT Fall Conference and Quality Testing Show, Denver, Colorado, October 2–5, 1978

J. H. Smith,* "Ultrasonic Evaluation of Dissimilar-Metal Transition Joint Welds"

International Atomic Energy Agency (IAEA) Symposium on Nuclear Materials Safeguards, Vienna, Austria, October 2–6, 1978

J. A. Carpenter, Jr., N. D. Holder, S. R. McNeany, L. Abraham, and P. Angelini, "Material Control and Accountability Aspects of Safeguards for the USA HTGR $^{233}U/Th$ Fuel Recycle Plant," (presented by D. H. Pike)

22nd ORNL Conference on Analytical Chemistry in Engineering Technology, Gatlinburg, Tennessee, October 9–12, 1978

P. Angelini,* F. L. Layton, and H. D. Ringel, "The Determination of Thorium and Uranium in Solutions by Multienergy Radiation Attenuation with Selective K-Edge Absorption"

Third Annual Conference on Materials for Coal Conversion and Utilization, Gaithersburg, Maryland, October 11–13, 1978

R. T. King,* "Materials for Coal Liquefaction and Low-Temperature Gasifiers Applications"

TMS/AIME Fall Meeting, St. Louis, Missouri, October 15–19, 1978

P. T. Carlson,* "Diffusion in Dilute Pb-Cd and Pb-Ni Alloys by the Dissociative Mechanism"

P. T. Carlson,* "Techniques for the Determination of Radiotracer Diffusion Coefficients"

R. W. Carpenter,* "Analytical Electron Microscopy Research at Oak Ridge National Laboratory"

J. D. Holder,* "Soret-Modified Eutectic Constitutional Supercooling Criterion"

J. R. Keiser* and C. L. White, "Effect of Alloying Additions on Mechanical Properties of Pt–30 Rh–8 W"

R. J. Lauf* and C. J. Altstetter, "Diffusion of Oxygen in Vanadium, Niobium, and Niobium Alloys"

C. T. Liu* and H. Inouye, "Control of Ordered Structure and Ductility of $(Ni,Co,Fe)_3V$ Alloys"

V. K. Sikka,* "Long-Term Creep-Rupture Ductility of Type 316 Stainless Steel"

V. K. Sikka,* "Role of Twin Boundary Cavitation in Flow and Fracture of FCC Metals and Alloys"

R. W. Swindeman, "Rupture Life-Creep Rate-Substructure Interdependence in Type 304 Stainless Steel" (presented by V. K. Sikka)

C. L. White* and C. T. Liu, "The Effect of Phosphorus Segregation to Grain Boundaries Ir + 0.3% W Alloys on High Temperature Impact Ductility"

C. F. Yen,* C. S. Yust, and G. W. Clark, "The Enhancement in Mechanical Strength of Hot-Pressed TiB_2 Composites with the Addition of Fe and Ni"

M. H. Yoo,* "Slip, Twinning, and Fracture in Hexagonal Close-Packed Crystals"

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*Speaker

Electrochemical Society Meeting, Pittsburgh, Pennsylvania, October 15–20, 1978

P. Angelini* and J. E. Rushton, "Assay of Uranium and Thorium Determined by Chemical and Nondestructive Methods in HTGR Fuel Rods"

A. J. Caputo,* D. R. Johnson, and C. K. Bayne, "Influence of Process Variables on Coke Yield and Defective Fraction of Biso- and Triso- Coated HTGR Fuel Particles During In-Block Carbonization"

F. J. Homan* and O. M. Stansfield, "Design and Qualification of a Proliferation Resistant Fuel for the HTGR"

C. R. Kennedy* and W. P. Eatherly, "Weibull Statistics in Nuclear Graphite"

H. E. McCoy, "Mechanical Behavior of Steam Cycle Alloys in HTGR Environments" (presented by J. R. DiStefano)

H. Nabielek, Ling Yang, and F. J. Homan,* "Performance Aspects of Low-Enriched Oxide Fuel for HTGRs"

D. P. Stinton,* W. J. Lackey, and B. A. Thiele, "Permeability and Anisotropy of Biso-Coated HTGR Fuel Particles"

R. R. Suchomel* and W. J. Lackey, "Recent Development of the Sphere-Pac Loading Process"

S. M. Tiegs* and D. P. Stinton, "Examination of the Carbothermic Conversion Process for UO_2-UC_2-C Fuel Microspheres"

Annual Information Meeting of the National Cladding/Duct Materials Development Program, Richland, Washington, October 16–19, 1978

A. F. Rowcliffe* and G. R. Gessel, "Tensile Properties of Advanced Alloys"

A. F. Rowcliffe,* G. R. Gessel, and C. L. White, "Irradiation Embrittlement of Inconel 706"

P. S. Sklad,* J. M. Leitnaker, and A. F. Rowcliffe, "Swelling and Phase Stability in Neutron Irradiated Compositional Variants of Alloy D9"

10th SAMPE Conference, Kiamesha Lake, New York, October 17–19, 1978

J. F. King,* "Austenitic Stainless Steel to Ferritic Steel Transition Joint Welding for Elevated-Temperature Service"

R. T. King,* "Failure Analysis in Coal Conversion Systems"

Mineralogical Society of America Meeting, Toronto, Canada, October 23–26, 1978

L. A. Harris,* O. B. Cavin, and C. S. Yust, "A Study of Secondary Minerals in a Bituminous Coal"

NBS/DOE Workshop of Materials at Low Temperatures, Vail, Colorado, October 24–26, 1978

C. J. Long,* "Materials Engineering in the Large Coil Test Facility"

C. J. Long,* R. H. Kernohan, and R. R. Coltman, Jr., "Irradiation Effects on Organic Insulators: 2×10^9 rads at 5 K"

American Ceramic Society 31st Pacific Coast Regional Meeting, San Diego, California, October 25–28, 1978

K. V. Cook* and W. A. Simpson, Jr., "Improved Ultrasonic Techniques for Nondestructive Testing of Graphite"

J. A. Horak,* "Irradiation Performance of Sphere-Pac Oxide Fuels"

C. R. Kennedy,* K. V. Cook, and B. E. Foster, "Nondestructive Evaluation of Nuclear Graphite"

C. R. Kennedy and R. K. Nanstad,* "Porosity Effects on Fracture Toughness of Graphite"

C. R. Kennedy* and W. P. Eatherly, "Statistical Characterization of Selected Nuclear and Aerospace Graphites"

J. E. Mack* and R. R. Suchomel, "Sampling, Subsampling, and Handling Techniques Developed for Nuclear Fuel Microspheres"

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*Speaker

T. K. Rao, J. L. Epler, and W. P. Eatherly,* "Mutagenicity Testing of Extracts from Petroleum and Coal Tar Pitches"

J. E. Selle,* P. Angelini, J. I. Federer, A. R. Olsen, and R. H. Rainey, "Consideration of the Use of Nuclear Fuel Spikants for Proliferation Deterrence"

S. M. Tiegs,* "Fabrication of UO_2 Fuel Pellets from Gel Microspheres"

American Physical Society Meeting, Colorado Springs, Colorado, October 30–November 3, 1978

P. Mioduszewski,* R. E. Clausing, and L. Heatherly, "Production of Metal Impurities by Microarcing"

Workshop on Solute Segregation and Phase Stability During Irradiation, Gatlinburg, Tennessee, November 1–3, 1978

K. Farrell* and J. T. Houston, "Suppression of Radiation Damage Microstructure in Aluminum by Trace Alloying Elements"

E. H. Lee,* A. F. Rowcliffe, and E. A. Kenik, "The Effect of Si and Ti on the Phase Stability and Swelling of AISI 316 During Irradiation"

L. K. Mansur,* "Solute Effects on Irradiation Induced Swelling and Creep Through Point Defect Trapping and Segregation"

Fifth Conference on Application of Small Accelerators, North Texas State University, Denton, Texas, November 6–8, 1978

M. B. Lewis,* "A Method for Simulating Fusion Reactor Radiation Damage Using Triple Ion Beams"

M. B. Lewis* and R. A. Perkins, "The Use of Nuclear Reactions to Trace the Source of Oxygen in Anodization"

Sixth Water Reactor Safety Research Information Meeting, National Bureau of Standards, Washington, D.C., November 6–9, 1978

C. V. Dodd,* "Computer-Designed Eddy Current Testing for Steam Generator Inservice Inspection"

ASM Materials and Processing Congress, Philadelphia, Pennsylvania, November 7–9, 1978

C. R. Brinkman,* "Fatigue Behavior of $2^1/_4$ Cr-1 Mo Steel in Support of Steam Generator Development"

R. E. Clausing,* C. L. White, and J. Bentley, "Application of Modern Microanalysis Techniques to Materials Problems in the Nuclear Industry"

J. H. DeVan,* "Materials Problems in Thermochemical Hydrogen Production"

International Meeting of Research Reactor Fuel Designers, Developers, and Fabricators, Argonne National Laboratory, Argonne, Illinois, November 9–10, 1978

M. M. Martin,* "High-Uranium-Loaded U_3O_8-Al Fuel Element Development Program"

American Nuclear Society Winter Meeting, Washington, D.C., November 12–17, 1978

G. L. Copeland,* R. L. Heestand, and R. S. Mateer, "Volume Reduction of Low-Level Contaminated Metal Waste by Melting"

D. R. Johnson,* R. A. Bradley, W. J. Lackey, and K. J. Notz, "Remote Fabrication Technology for HTGR Fuels"

R. L. Klueh* and J. F. King, "Strain-Rate Effects on the Elevated-Temperature Behavior of ERNiCr-3 Weld Metal"

J. E. Mack, A. E. Pasto,* D. P. Stinton, R. R. Suchomel, and P. Angelini, "Techniques for Assurance of Quality of Sphere-Pac Fuel Rods"

K. J. Notz,* R. L. Beatty, P. A. Haas, W. J. Lackey, A. D. Ryon, and R. R. Suchomel, "Remote Fabrication with Gel-Sphere-Pac Technology"

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*Speaker

D. Stahl,* J. E. Cunningham, and W. C. Francis, "Development of Advanced High-Uranium Density Reduced-Enrichment Plate-Type Fuels"

ASTM-ASME-MPC Committee J-1 Workshop, ASTM Meeting, Houston, Texas, November 13–16, 1978

R. W. Swindeman,* "Efforts at ORNL to Develop and Evaluate Methods to Determine Long-Time Strength of Structural Alloys"

24th Annual Magnetism and Magnetic Materials Conference, Cleveland, Ohio, November 14–17, 1978

W. C. Koehler* and R. W. Hendricks, "The United States National Small-Angle Neutron Scattering Facility"

IAEA Technical Committee on Time and Load Dependent Degradation of Pressure Boundary Materials, Innsbruck, Austria, November 20–21, 1978

C. R. Brinkman, M. K. Booker, J. P. Strizak, and T. Weerasooriya, "Fatigue Behavior of $2^1/_4$ Cr-1 Mo Steel in Support of Steam Generator Development" (presented by L. A. James)

American Vacuum Society Meeting, San Francisco, California, November 27–December 2, 1978

R. E. Clausing,* L. Heatherly, and L. C. Emerson, "A Versatile UHV Sample Transfer System"

L. C. Emerson,* R. E. Clausing, and L. Heatherly, "Surface Impurity Studies in the IXS-A Tokamak"

In-Situ Conference, Materials Research Society Annual Meeting, Boston, Massachusetts, November 29–December 1, 1978

J. D. Holder* and G. W. Clark, "New Developments in the IZG of Metal Oxide-Metal Eutectic Composites"

J. D. Holder* and G. W. Clark, "Oxygen Partial Pressure: A Key to Alloying and Discovery in Metal Oxide-Metal Eutectic Systems"

American Chemical Society Meeting, Corpus Christi, Texas, November 30–December 1, 1978

R. W. Hendricks,* "Small-Angle X-Ray and Neutron Scattering"

US/UKAEA Specialists Meeting on Mechanical Properties, ORNL, December 4–7, 1978

M. K. Booker,* "Analytical Representation of Mechanical Properties Data for $2^1/_4$ Cr-1 Mo Steel"

C. R. Brinkman,* "Overview of U.S. Efforts Directed Toward Development of Mechanical Properties Data in Support of FBR Development"

D. P. Edmonds,* "Joining Technology Development Summary"

R. L. Klueh,* "Tensile, Creep, and Creep-Rupture Studies on $2^1/_4$ Cr-1 Mo Steel"

V. K. Sikka,* "Tensile and Creep Properties of Type 316 Stainless Steel"

V. K. Sikka,* "Mechanical Properties of 9 Cr-1 Mo Steel"

International Symposium on the Corrosion of Reinforcing Steel in Concrete, Bal Harbor, Florida, December 5–7, 1978

J. C. Griess* and D. J. Naus, "Corrosion of Steel Tendons in Prestressed Concrete Pressure Vessels"

ASME Winter Annual Meeting, San Francisco, California, December 10–15, 1978

V. B. Baylor,* M. K. Booker, J. P. Strizak, and R. L. Klueh, "Cyclic Stress-Strain Behavior of ERNiCr-3 Weld Filler Metal"

D. P. Edmonds,* D. M. Vandergriff, and R. J. Gray, "Evaluation of Type 308 Shielded Metal-Arc Weld Metal with Varying Ferrite Content"

J. P. Hammond,* "Ductility Minimum Reversal with Overaging in Cobalt- and Nickel-Base Superalloys"

R. K. Nanstad,* "Discussion of 'Survey of Defects in Pressure Vessels Built to High Standards of Construction,' by T. A. Smith and W. A. Warwick"

V. K. Sikka,* R. W. Swindeman, and C. R. Brinkman, "Elevated-Temperature Ductility of Types 304 and 316 Stainless Steel"

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*Speaker

Annual Meeting of the Society of International Cellulose Insulation Manufacturers, Washington, D.C., January 18–20, 1979

T. S. Lundy,* "The National Program on Building Thermal Envelope Systems and Insulating Materials"

Erosion-Corrosion of Materials in Coal Conversion Systems, Berkeley, California, January 24–26, 1979

J. V. Cathcart* and R. E. Pawel, "Mechanical Behavior of Oxide Scales"

Meeting of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Philadelphia, Pennsylvania, January 29, 1979

T. S. Lundy,* "The National Program on Building Thermal Envelope Systems and Insulating Materials"

First Topical Meeting on Fusion Reactor Materials, Miami Beach, Florida, January 29—31, 1979

E. E. Bloom,* "Mechanical Properties of Materials in Fusion Reactor First-Wall and Blanket Systems"

R. E. Clausing,* L. Heatherly, and P. Mioduszewski, "Hydrogen-Recycle from 304 Stainless Steel Surfaces as a Function of Temperature"

B. L. Cox* and F. W. Wiffen, "The Ductility of Bending of Molybdenum Alloys Irradiated Between 425 and 1000°C"

J. H. DeVan,* "Compatibility of Structural Materials with Coolant and Breeder Fluids"

K. Farrell* and N. H. Packan, "A Shift in the Temperature Dependence of Swelling in the Presence of High Helium and Hydrogen Levels"

M. L. Grossbeck* and K. C. Liu, "Fatigue Life of Type 316 Stainless Steel Irradiated in a Simulated Fusion Reactor Environment"

M. L. Grossbeck* and P. J. Maziasz, "Tensile Properties of Type 316 Stainless Steel Irradiated in a Simulated Fusion Reactor Environment"

J. R. Keiser, J. H. DeVan,* and E. J. Lawrence, "Compatibility of Proposed Coolant Salts with 316 Stainless Steel and Lithium"

E. A. Kenik,* "The Influence of Helium on Microstructural Evolution in an Ion-Irradiated Low-Swelling Stainless Steel"

C. T. Liu,* "Development of Ductile Long-Range Ordered Alloys for Fusion Reactor Systems"

L. K. Mansur,* W. A. Coghlan, and A. D. Brailsford, "Swelling with Inhomogeneous and Discontinuous Point Defect Production"

L. K. Mansur* and M. H. Yoo, "Advances in the Theory of Irradiation Effects in Metals and Alloys"

L. K. Mansur,* M. H. Yoo, and E. H. Lee, "The Spatial Variation in Swelling During Charged Particle Bombardments"

P. J. Maziasz,* "The Precipitation Response of 20%-Cold-Worked Type 316 Stainless Steel to Simulated Fusion Irradiation"

P. J. Maziasz* and K. Farrell, "The Tensile Properties of High Oxide SAP Containing Helium and Tritium"

P. Mioduszewski,* R. E. Clausing, and L. Heatherly, "Observations of Arcing in the ISX Tokamak"

N. H. Packan* and K. Farrell, "Simulation of First Wall Damage: Effects of the Method of Gas Implantation"

P. F. Tortorelli* and J. H. DeVan, "Effects of Contaminants in Lithium on the Corrosion of Type 316 Stainless Steel"

P. F. Tortorelli* and J. H. DeVan, "Thermal-Gradient Mass Transfer in Lithium-Stainless Steel Systems"

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F. W. Wiffen,* "The Mechanical Properties of Nimonic PE-16 with High Helium Concentrations Produced During Neutron Irradiation"

F. W. Wiffen,* E. J. Allen, H. Farrar, IV, E. E. Bloom, T. A. Gabriel, H. T. Kerr, and F. G. Perey, "The Production Rate of Helium During Irradiation of Nickel in Thermal Spectrum Fission Reactors"

M. H. Yoo* and L. K. Mansur, "The Inclusion of Mobile Helium in a Rate Theory Model of Void Swelling"

Golden Gate Metals and Welding Conference, San Francisco, California, January 31–February 2, 1979

D. P. Edmonds* and G. M. Goodwin, "Development of Weld Deposited Pressure Vessel Overlays"

A. J. Moorhead,* "Development of Advanced Joining Techniques for Fabrication of Fuel Pin Simulators"

AIME Annual Meeting, New Orleans, Louisiana, February 18–20, 1979

J. Bentley* and J. M. Leitnaker, "Identification of a Phospho-Arsenide Phase in Aged Type 321 Stainless Steel by Analytical Electron Microscopy"

D. N. Braski, R. W. Carpenter,* and C. T. Liu, "Ordering and Precipitation in Fe-Co-V Alloys"

J. P. Hammond* and R. S. Crouse, "Chemical Compatibility and Mechanical Properties of Superalloys for $^{90}SrF_2$-Heated Power Converters"

L. A. Harris,* C. S. Yust, and R. S. Crouse, "Sulfur Analyses of Selected Coals by the Combined Coal Petrography and Microprobe Analysis (CPMA) Method"

J. D. Holder,* "Preparation of High-Temperature Oxide-Metal Eutectic Composites: A Review"

J. R. Keiser,* J. F. Newsome, and M. D. Allen, "Eutectic Temperature of Graphite with Platinum-Refractory Metal Alloys"

J. M. Leitnaker,* J. Bentley, and D. P. Edmonds, "Prevention of Chi and Sigma Phase Formation in Aged 16-8-2 Weld Metal"

C. T. Liu,* S. H. Anderson, and H. Inouye, "Effect of Oxidizing Environment on Mechanical Properties of Mo and TZM"

C. T. Liu and C. L. White,* "Outward Diffusion of Thorium and Enhanced Grain Growth in Thorium-Doped Iridium Alloys"

G. M. Stocks,* "KKR-CPA Calculations of the Electronic States of Random Substitutional Alloys"

M. H. Yoo,* "Growth Kinetics of Dislocation Loops and Voids—The Role of Divacancies"

American Society for Metals, Lehigh Valley Chapter, Bethlehem, Pennsylvania, March 2, 1979

D. A. Canonico,* "Material Applications in Light-Water Nuclear Reactor Pressure Vessels"

International Conference on Fast Breeder Fuel Performance, Monterey, California, March 5–8, 1979

J. H. Kittel,* D. L. Johnson, W. N. Beck, and J. A. Horak, "Metallic Fuel Systems for Alternative Breeder Fuel Cycles"

Workshop on Techniques for Radiation Damage Analysis, Oak Brook, Illinois, March 8, 1979

R. W. Hendricks,* "The Study of Voids and Other Defects by Small-Angle and Diffuse X-Ray and Neutron Scattering"

American Society for Metals, Fort Wayne Chapter, Fort Wayne, Indiana, March 12, 1979

R. J. Gray,* "New and Unusual Techniques in Metallography"

Corrosion '79, Atlanta, Georgia, March 12–16, 1979

J. R. Keiser and J. H. DeVan,* "Design and Operation of Thermal-Convection Loops for Corrosion Measurements in LiF-LiCl-LiBr"

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P. F. Tortorelli,* J. H. DeVan, and J. E. Selle, "Effects of Nitrogen and Nitrogen Getters in Lithium on the Corrosion of Type 316 Stainless Steel"

International Symposium on Quantum Theory, Palm Coast, Florida, March 12–17, 1979

J. Harris and G. S. Painter,* "New Basis Set for Molecular and Atomic Cluster Calculations Within the Local Density Formalism"

Central Ohio Metallographic Society, Columbus, Ohio, March 14, 1979

R. J. Gray,* "New and Unusual Techniques in Metallography"

American Physical Society Meeting, Chicago, Illinois, March 18–22, 1979

W. H. Butler* and S. Perkowitz, "For Infrared Studies of $\alpha^2F(\omega)$ in Nb"

W. H. Butler* and F. J. Pinski, "Evidence for Coulomb Mass-Enhancement in Pd, Nb, and V"

P. T. Carlson,* "The Diffusion of Solutes in Dilute Lead Alloys by the Dissociative Mechanism"

J. S. Faulkner,* "Linearizing the KKR Band Theory Equation"

R. W. Hendricks* and W. C. Koehler, "The U.S. National Small-Angle Neutron Scattering Facility—A Progress Report"

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G. M. Stocks,* "On the Electronic Structure of CuPd Alloys"

M. H. Yoo,* "The Role of Divacancies in Dislocation Loop Growth and Void Swelling During Charged Particle Damage"

Westec Conference, Los Angeles, California, March 19–21, 1979

C. R. Brinkman* and J. P. Strizak, "Effects of Environment on the Elevated Temperature Fatigue Behavior of $2^1/_4$ Cr-1 Mo Steel"

American Society for Metals Tampa Chapter, Tampa, Florida, March 21, 1979

C. J. McHargue,* "Materials for Advanced Energy Systems"

Sixth Annual Energy Conservation Management Conference, Seattle, Washington, March 26–28, 1979

T. S. Lundy,* "Insulation Needs Further Study"

Japanese Nuclear Society Meeting, Osaka, Japan, March 26–28, 1979

B. G. Eads,* J. E. Hardy, J. O. Hylton, M. B. Herskovitz, P. A. Jallouk, W. H. Leavell, R. N. McGill, A. J. Moorhead, C. S. Morgan, H. R. Payne, and M. J. Roberts, "Development of In-Vessel Reflood Instrumentation at ORNL"

International Materials Congress, Reston, Virginia, March 26–29, 1979

E. E. Bloom and J. L. Scott,* "The Engineering Test Facility Can Serve a Major Role in Materials Development for Fusion Reactors"

D. A. Canonico,* "Material Considerations in Assessing Safety and Reliability of Light-Water Reactor Pressure Vessels"

J. H. DeVan* and T. G. Godfrey, "Materials Problems in Fluidized Bed Coal Conversion Systems"

D. O. Hobson,* "In-Reactor Creep Deformation of Zircaloy Fuel Cladding"

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C. T. Liu,* H. Inouye, and A. C. Schaffhauser, "A New Class of Long-Range Ordered Alloys with Superior Structural Performance at Elevated Temperatures"

D. L. McElroy, W. W. Harris, and D. W. Yarbrough,* "Results of a Study of Cellulosic Insulations"

P. Patriarca* and C. R. Brinkman, "Materials Technology for Steam Generators in Liquid-Metal Fast Breeder Reactor Systems"

American Society for Metals Advisory Technical Awareness Council Meeting, Cleveland, Ohio, March 27, 1979

J. E. Cunningham,* "Selected Advances in Materials Research"

American Chemical Society Meeting, Honolulu, Hawaii, April 1–6, 1979

L. A. Harris* and C. S. Yust, "The Ultrafine Structure of Coal Determined by Electron Microscopy"

D. W. Schaefer* and R. W. Hendricks, "Static Correlations in Semidilute Polymer Solutions"

60th Annual Meeting of the American Welding Society, Detroit, Michigan, April 1–6, 1979

D. A. Canonico,* "Significance of Reheat Cracks to the Integrity of Pressure Vessels for Light Water Reactors"

S. A. David* and G. M. Goodwin, "Solidification Behavior of Austenitic Stainless Steel Filler Metals"

R. L. Klueh* and J. F. King, "Elevated-Temperature Tensile Behavior of ERNiCr-3 Weld Metal"

V. K. Sikka* and J. W. McEnerney, "Ultimate Tensile Strength can be Used to Estimate Creep Rupture Behavior of Austenitic Stainless Steel Welds"

Adams Lecture, Detroit, Michigan, April 2, 1979

G. M. Slaughter,* "The Technology of Brazing and Soldering is Vital to the Industrial Economy"

American Society for Metals Spring Seminar, Advanced Energy Concepts and their Material Needs, San Diego, California, April 4, 1979

J. L. Scott,* "Materials Needs for Fusion Power"

Fifth International Conference on Positron Annihilation, Lake Yamanaka, Japan, April 8–11, 1979

C. L. Snead, Jr.,* K. G. Lynn, and K. Farrell, "Determination of Formation and Binding Energies for Vacancies and Impurities in Ni and Dilute Ni Alloys"

Scanning Electron Microscopy Meeting, Washington, D.C., April 16–20, 1979

J. Bentley,* N. J. Zaluzec, E. A. Kenik, and R. W. Carpenter, "Optimization of an Analytical Electron Microscope for X-Ray Microanalyses: Instrumental Problems"

R. W. Carpenter* and J. Bentley, "On the Performance of Field Emission Gun TEM/STEM"

Workshop on Energy Dispersive Spectroscopy, National Bureau of Standards, Gaithersburg, Maryland, April 23–25, 1979

N. J. Zaluzec,* "Uncollimated Fluorescing Radiation in an AEM 100–1000 keV: Sources and Solutions"

American Ceramic Society Annual Meeting, Cincinnati, Ohio, April 28–May 2, 1979

P. Angelini* and E. J. Allen, "Control and Inspection Systems for Sphere-Pac Loading"

C. K. Bayne* and P. Angelini, "Volumetric and Gravimetric Dispensing of Fuel Particles"

J. I. Federer* and V. J. Tennery, "Behavior of Refractories Exposed to Residual Oil Combustion Products"

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C. S. Morgan,* "Thermal Shock Resistant Electrical Insulators"

A. E. Pasto* and D. P. Stinton, "Sintering of Gel-Derived Nuclear Fuel Microspheres"

D. P. Stinton,* S. M. Tiegs, W. J. Lackey, and T. B. Lindemer, "Rate Controlling Factors in the Carbothermic Preparation of UO_2-UC_2-C Microspheres"

R. R. Suchomel* and A. J. Caputo, "Process and Equipment for Loading Sphere-Pac Fuel Rods"

V. J. Tennery and A. E. Pasto,* "Results of BICM-2 Irradiation Test of Eu_2O_3 in EBR-II"

T. N. Tiegs* and M. J. Kania, "Fission Product Behavior in HTGR Fuels as Determined by Gamma Spectrometry"

G. W. Weber* and V. J. Tennery, "Ceramics for Glass Furnace Recuperators"

G. C. Wei,* C. D. Reynolds, and G. W. Brassell, "Processing and Thermal Transport Properties of High-Temperature Carbon Fiber Thermal Insulations"

C. F. Yen,* C. S. Yust, and G. W. Clark, "Fracture Strength and Microstructural Considerations of TiB_2 Composites"

C. S. Yust* and L. A. Harris, "Investigation of Erosion Damage in Alumina by Scanning and Transmission Electron Microscopy"

National Institute of Building Sciences, Insulation Task Force, Washington, D.C., May 1, 1979

T. S. Lundy,* "The National Program on Building Thermal Envelope Systems and Insulating Materials"

American Society for Metals, North Texas Chapter, Arlington, Texas, May 3, 1979

R. J. Gray,* "New and Unusual Techniques in Metallography"

Electrochemical Society Meeting, Boston, Massachusetts, May 6–11, 1979

R. E. Pawel,* "The Diffusion of Oxygen in Growing Oxide and Alpha Phases During High-Temperature Oxidation of Zircaloy-4"

International Conference on Fundamental Mechanisms of Radiation-Induced Creep and Growth, Chalk River Nuclear Laboratories, Ontario, Canada, May 8–10, 1979

L. K. Mansur and T. C. Reiley,* "Irradiation Creep by Dislocation Glide Enabled by Preferred Absorption—Theory and Experiment"

T. C. Reiley,* R. L. Auble, and R. H. Shannon, "Irradiation Creep Under 60 MeV Alpha Irradiation"

Materials Division Conference on Structural Integrity, Washington, D.C., May 9–11, 1979

D. A. Canonico,* "Structural Integrity for Coal Conversion Systems"

American Society for Nondestructive Testing, Technical Seminar, NDT in the Energy Fields, Idaho Falls, Idaho, May 16, 1979

R. W. McClung,* "Recent Studies in Nondestructive Testing at the Oak Ridge National Laboratory"

Nuclear Fuel Cycle Information Workshop, ORNL, May 17, 1979

R. L. Beatty,* "Fuel Fabrication"

Workshop on Expanding the Role of Materials Science in High-Temperature Data Extrapolation, ASTM-ASME-MPC J-1 Applied Subcommittee, San Francisco, California, May 21, 1979

T. C. Reiley* and R. W. Swindeman, "Evolution of Creep Cavities in Aluminum and Aluminum Alloys"

R. W. Swindeman,* "The Use of Materials Science Tools in Evaluating Creep-Rupture Predictive Capability"

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DOE Topical Meeting on Microchemical and Microstructural Analysis of Minority and Interface Phases, Germantown, Maryland, May 30–31, 1979

R. W. Carpenter,* "High Resolution Analytical Microscopy in Materials Science: Does a Complete Instrument Exist?"

N. J. Zaluzec,* "Principles of Thin-Film Analysis in an AEM Using EDS and ELS"

American Nuclear Society Meeting, Atlanta, Georgia, June 3–8, 1979

R. G. Cardwell,* "The Role of the INMM in Remote Fuel Fabrication"

R. L. Klueh,* "Stress-Rupture Properties of Sodium Decarburized and Aged $2^1/_4$ Cr-1 Mo Steel"

J. E. Selle,* "Nuclear Fuel Spikes and Their Implication on Fuel Recycle"

R. R. Suchomel,* A. J. Caputo, and W. J. Lackey, "Sphere Pac—A Practical Remote Fuel Fabrication Concept"

Energy Materials Correlation Committee Conference on Structural Materials, Knoxville, Tennessee, June 4–5, 1979

V. J. Tennery,* G. C. Wei, A. E. Pasto, and J. I. Federer, "Degradation of Refractory Ceramics and Insulations by Impurities in Fuels Alternate to Natural Gas"

IEEE International Conference on Plasma Science, Montreal, Quebec, Canada, June 4–6, 1979

P. Mioduszewski,* R. E. Clausing, and L. Heatherly, "Wall Erosion by Plasma-Induced Arcing"

Synchrotron Radiation Instrumentation, National Bureau of Standards, Gaithersburg, Maryland, June 4–6, 1979

C. J. Sparks, Jr. and J. B. Hastings,* "X-Ray Monochromator Geometry for Focusing Synchrotron Radiation above 10 keV"

Conference on Irradiation Behavior of Metallic Materials for Fast Reactor Core Components, Corsica, France, June 5–7, 1979

J. A. Horak, E. E. Bloom,* M. L. Grossbeck, P. J. Maziasz, J. O. Stiegler, and F. W. Wiffen, "Swelling, Mechanical Properties, and Microstructure of Type 316 Stainless Steel at Fusion Reactor Damage Levels"

L. K. Mansur* and M. H. Yoo, "Toward a Comprehensive Theory of Radiation-Induced Swelling and Creep"

L. K. Mansur,* N. H. Packan, and J. O. Stiegler, "Report on the Workshop on Solute Segregation and Phase Stability During Irradiation"

A. F. Rowcliffe,* E. H. Lee, and P. S. Sklad, "The Effect of Phase Instabilities on the Correlation of Nickel Ion and Neutron Irradiated Swelling Damage in Solution Annealed 316 Stainless Steel"

Fifth International Conference on Sintering and Related Phenomena, Notre Dame, South Bend, Indiana, June 18–20, 1979

C. S. Morgan* and V. J. Tennery, "Magnesium Oxide Enhancement of Sintering of Alumina"

Semiannual Review of Advanced Solar Technology, Long Beach, California, June 21, 1979

V. J. Tennery and T. N. Tiegs,* "Materials Considerations Relevant to Solar Heating of Chemical Reactions"

International Conference on Superconductivity in d- and f-Band Metals, San Diego, California, June 21–23, 1979

W. H. Butler,* "Progress in Calculations of the Superconducting Properties of Transition Metals"

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International Conference on Martensite Transformations, MIT, Cambridge, Massachusetts, June 24–29, 1979

R. A. Vandermeer,* J. C. Ogle, and W. G. Northcutt, "Phase Transformations and Associated Shape Memory Effects in Uranium Alloys"

14th Biennial Conference on Carbon, Pennsylvania State University, University Park, Pennsylvania, June 25–29, 1979

K. V. Cook* and W. A. Simpson, Jr., "Study of Sonic Properties and Their Impact on Flaw Detection Capabilities in Graphite"

C. R. Kennedy* and W. P. Eatherly, "The Results of the 600°C Compressive Creep Irradiation Experiment"

R. L. Klueh,* "Effect of Metallurgical Processes on the Creep of $2^1/_4$ Cr-1 Mo Steel"

R. A. Langley* and W. P. Eatherly, "Graphite Application in Tokamak Fusion Reactors"

T. K. Rao,* J. L. Epler, and W. P. Eatherly, "Mutagenicity Testing of Extracts from Petroleum and Coal Tar Pitches"

I. B. Rubin, W. H. Griest, and W. P. Eatherly,* "Preparation and Relative Aromatic Composition of Petroleum and Coal Tar Pitch Extracts for Mutagenicity Testing"

G. C. Wei,* "Outgassing Behavior of Carbon-Bonded-Carbon-Fiber Thermal Insulation"

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