



## AUTHORS – JUNE 1976

### FUSION REACTOR MATERIALS

#### PREFACE: FUSION REACTOR MATERIALS

Robert J. Teitel (BS, Purdue University, 1944; ScD, Massachusetts Institute of Technology, 1948) is a principal scientist at KMS Fusion, Inc., currently engaged in studies aimed at synthetic-fuel plants utilizing energy from nuclear fusion. He has been involved in fusion and fission nuclear reactor research and development for 28 years. His experience includes liquid-metal reactor development, nuclear space power system development, nuclear vulnerability and hardening of missile systems, as well as laser-fusion reactor studies.

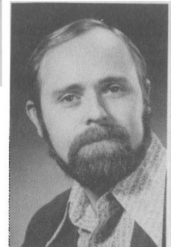
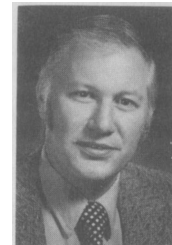
*Robert J. Teitel*



#### EFFECT OF NEUTRON IRRADIATION ON THE CRITICAL CURRENT OF Nb<sub>3</sub>Sn AT HIGH MAGNETIC FIELDS

C. Lewis Snead, Jr. (top) (PhD, physics, University of North Carolina, 1965) has been at Brookhaven National Laboratory and *The Physical Review* since 1967. Irradiation effects in materials, especially type-II superconductors, are his main interests. He is also involved in defect studies using positron annihilation and internal friction. He is currently a consulting editor to *The Physical Review*. Don M. Parkin (PhD, physics, University of Utah, 1970) is a staff member of the Los Alamos Scientific Laboratory. His current research interests include developing models for correlating radiation effects produced by different types of irradiation and developing new materials irradiation sources.

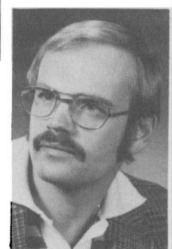
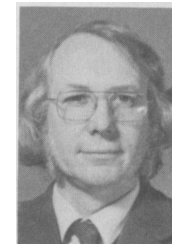
*C. L. Snead, Jr.  
Don M. Parkin*



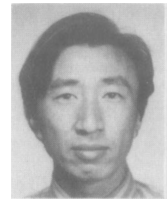
#### THE EFFECT OF ALUMINUM ADDITIONS ON Nb<sub>3</sub>Sn PRODUCED IN THE SOLID STATE

David Dew-Hughes (top) (BSc, physical and theoretical metallurgy, University of Birmingham, UK, 1954; D. Eng., metallurgical engineering, Yale University, 1959) is a metallurgist at Brookhaven National Laboratory (BNL). He has worked on various aspects of superconducting materials. His current technical interests are superconducting materials and their applications and materials problems relevant to the energy-production and conservation programs at BNL. Thomas Luhman (BSc, physical metallurgy, Washington State University, 1965; PhD, metallurgical engineering, University of Washington, 1969; Postdoctoral Fellow, physics department, Simon Fraser University) is a metallurgist at BNL. He has been involved in research

*David Dew-Hughes  
Thomas S. Luhman  
Masaki Suenaga*



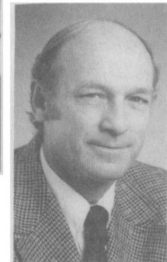
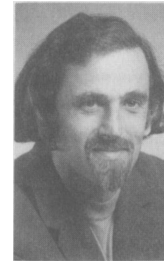
dealing with the metallurgy of superconducting material since 1972. His current technical interests center around phase stability and critical properties of practical superconducting materials. Masaki Suenaga (PhD, metallurgy, University of California, Berkeley, 1968; Postdoctoral Fellowship, 1969, Lawrence Livermore Laboratory, Berkeley) is a metallurgist at BNL. He has been involved with investigations in mechanical properties of metals at low temperatures, processing of superconducting compounds, and superconducting properties related to metallurgical variables.



### CERAMIC MATERIALS FOR FUSION

L. H. Rovner (top) (PhD, applied physics, Cornell University, 1966) is manager of the Fusion Materials Research Program at General Atomic Company. His current interests are materials-related technological problems of fusion reactors with emphasis on first wall materials. G. R. Hopkins (PhD, Iowa State University, 1954) is currently technical manager, Fusion Engineering and Technology, General Atomic Company. He has conducted research and development on helium cooling and ceramic materials for fusion applications and has a current interest in many aspects of development of fusion as an energy source.

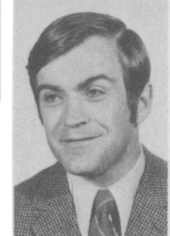
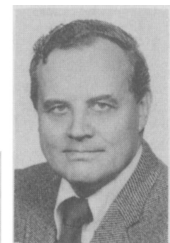
*L. H. Rovner  
G. R. Hopkins*



### HELIUM BLISTERING OF CERAMIC COATINGS ON HASTELLOY X AND Nb-1% Zr

Manfred Kaminsky (top) (PhD, physics, University of Marburg, Germany, 1957) is a senior scientist at Argonne National Laboratory (ANL). His current research interests are particle and photon impact phenomena on solids and surface science in connection with controlled thermonuclear fusion research. S. K. Das (center) (PhD, materials science, University of California, Berkeley, 1971) is a scientist at ANL. His current research interest is surface phenomena in connection with controlled thermonuclear fusion research. Ronald Ekern (bottom) (PhD, physics, Clarkson College of Technology, Potsdam, New York, 1975) has a postdoctoral appointment at ANL. His current research interest is in surface science related to controlled thermonuclear fusion research.

*M. Kaminsky  
S. K. Das  
R. Ekern*



### VAPORIZATION THERMODYNAMICS AND MOLECULAR SPUTTERING OF BINARY TARGETS

Dieter M. Gruen (top) (PhD, University of Chicago, 1951) is senior scientist and group leader, Physical and Surface Chemistry of Energy Systems, Argonne National Laboratory (ANL). His early interests included transition metal ion chemistry in fused salt solutions, matrix isolation spectroscopy of high-temperature molecules, and more recently, chemical effects of energetic particle interactions with surfaces. His current interests include chemical trapping and sputtering in relation to impurity control in thermonuclear fusion devices. Patricia A. Finn (PhD,

*Dieter M. Gruen  
Patricia A. Finn  
Dennis L. Page*



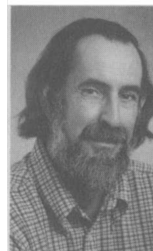
University of California, Berkeley, 1971) is an assistant chemist in the Chemical Engineering Division at ANL. She has done spectroscopic studies on transition metal complexes. Her present technical interests are in the areas of high-temperature and high-pressure chemistry. Dennis L. Page (BS, Virginia Wesleyan College, 1975) was working as a CSUI Argonne Semester Participant in performing this work.



### SPUTTERING MEASUREMENTS ON CONTROLLED THERMONUCLEAR REACTOR MATERIALS USING AUGER ELECTRON SPECTROSCOPY

*Joe N. Smith, Jr.  
C. H. Meyer, Jr.  
J. K. Layton*

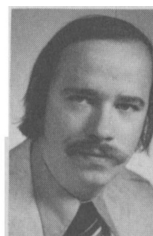
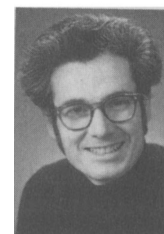
Joe N. Smith, Jr. (top) (PhD, physics, University of Leiden, The Netherlands, 1970) has extensive previous experience in research in gas-surface interactions, including reactive and nonreactive scattering of molecules from surfaces, surface chemistry, heterogeneous catalysis, and surface ionization. Charles H. Meyer, Jr. (center) (MS, physics, San Diego State University, 1957) has performed research programs concerned with various thin film deposition techniques to produce intermetallic superconducting compounds and biocompatible surfaces for medical prosthesis devices. This work has also included low-temperature testing of thin film superconductors including ac power losses. James K. Layton (bottom) (MS, physics, University of North Carolina, 1960) has past experience in atomic collision physics including cross-section measurements related to upper atmospheric processes and also fundamental studies of secondary electron emission from metal surfaces due to fast ion and neutral atom bombardment. The authors are currently engaged in sputtering and surface damage studies on materials of interest in fusion research and controlled thermonuclear reactor development within the Fusion Division of General Atomic Company.



### LOW-ENERGY PROTON IMPLANTATION OF STAINLESS STEEL

*K. L. Wilson  
G. J. Thomas  
W. Bauer*

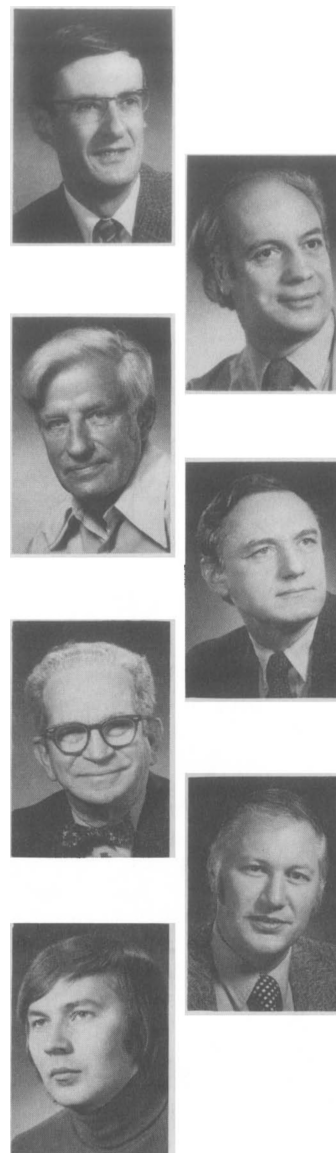
Kenneth L. Wilson (top) (PhD, materials science, Cornell University, 1975) is with Sandia Laboratories in Livermore, California. His current interests are radiation damage phenomena in metals and effects of helium and hydrogen ion irradiation in materials. George J. Thomas (center) (PhD, physics, University of Sussex, England, 1969) is with Sandia Laboratories. His current interests are radiation damage phenomena in metals and effects of helium and hydrogen ion irradiation in materials. Walter Bauer (bottom) (PhD, physics, University of Illinois, 1962) is with Sandia Laboratories. His current interests are radiation damage phenomena in metals and effects of helium and hydrogen ion irradiation in materials.



## AN INTENSE Li(d,n) NEUTRON RADIATION TEST FACILITY FOR CONTROLLED THERMONUCLEAR REACTOR MATERIALS TESTING

Pierre Grand (top left) (Dpl. Eng., Federal Technical Institute, Switzerland, 1954) joined Brookhaven National Laboratory (BNL) in 1964 to design and construct a 200-MeV linear accelerator. From 1972 to 1974, as visiting engineer in CERN (Switzerland), he helped design accelerating cavities for the 300-GeV Synchrotron and a new 50-MeV Linac. Since his return to BNL in 1974, he has been fully devoted to the design of the D-Li neutron generator. Kenneth Batchelor (top right) (BSc, special physics, London, 1953) joined BNL in 1967 to become group leader in charge of design of the new 200-MeV proton injector for the Alternating Gradient Synchrotron. He is currently working on the design of a Deuteron Linac Accelerator. John P. Blewett (second from top left) (MA, physics, University of Toronto, 1933; PhD, physics, Princeton University, 1936) joined BNL in 1947 where he worked on the development of multi-GeV superconducting accelerator technology and other projects. For the past few years he has been interested in applying accelerator technology to relevant energy-related and medical uses. Allen N. Goland (center right) (PhD, physics, Northwestern University, 1956) has been on the staff of the Physics Department at BNL since 1963. At present, he is a senior physicist and group leader in that department. His interests are generally in the field of particle-solid interactions. David H. Gurinsky (second from bottom left) (PhD, New York University, 1942) has been at BNL since 1947 with the exception of a year's leave of absence in 1958 at General Atomic. His interests are in graphite, high-temperature graphite reactors, liquid-metal-cooled reactors, liquid-metal corrosion, superconductivity, and radiation effects in solids. J. Kukkonen (bottom left) (PhD, physics, Tyvaskyla, Finland, 1973) joined BNL in 1975 to work on the neutron production and target problems of a D-Li neutron generator. C. L. Snead, Jr. (bottom right) (PhD, physics, University of North Carolina at Chapel Hill, 1965) has been associated with BNL since 1967. His main research interest is in radiation effects in metals, especially Type II superconductor of interest in high-field applications.

*P. Grand  
K. Batchelor  
J. P. Blewett  
A. Goland  
D. Gurinsky  
J. Kukkonen  
C. L. Snead, Jr.*



## CONTROLLED THERMONUCLEAR REACTOR NEUTRON SPECTRA SIMULATION AT THE LAMPF RADIATION EFFECTS FACILITY

Margaret L. Simmons (top) (BS, mathematics, University of Houston, 1959) is a staff member, Chemistry and Metallurgy Division, Los Alamos Scientific Laboratory (LASL). Her current interests include Monte Carlo methods in neutron transport, irradiation facilities, and neutron shielding. Donald J. Dudziak (PhD, mathematics; MS, radiological physics; BS, engineering) is section leader for fusion reactor nucleonic analysis, and associate group leader for transport and reactor theory, at LASL. His current interests are in fusion reactor nucleonic methods development and systems analysis, irradiation facilities, and 14-MeV neutron source shielding. Previously, he was active in several areas of nuclear engineering, including stochastic kinetics, cross-section data systems, and reactor shielding.

*M. L. Simmons  
Donald J. Dudziak*



## NEUTRON-ENERGY-DEPENDENT DEFECT PRODUCTION CROSS SECTIONS FOR FISSION AND FUSION APPLICATIONS

G. Robert Odette (top) (PhD, nuclear engineering, Massachusetts Institute of Technology, 1970) has been an assistant professor of nuclear engineering at the University of California at Santa Barbara (UCSB) since 1970. His principal fields of research and teaching are radiation damage in crystalline solids, neutron dosimetry, and energy and the environment. He has been a consultant to national laboratories and industry in the area of radiation damage in fission reactors. Daniel R. Doiron (BS, nuclear engineering, University of California at Santa Barbara, 1972) is a PhD candidate in the Department of Chemical and Nuclear Engineering at UCSB. His research interests include radiation damage and the biomedical application of nuclear instrumentation technology.

*G. R. Odette*  
*D. R. Doiron*



## HELIUM CHARGING OF METALS BY TRITIUM DECAY

J. F. Remark (top left) (PhD, chemistry, University of Kansas, 1974) is presently a research scientist with Battelle Northwest Laboratories. His interests include hydrogen and helium isotope solubilities and diffusivities in metals and corrosion and corrosion-erosion mechanisms in nonnuclear systems. A. B. Johnson, Jr. (top right) (PhD, fuel technology, University of Utah, 1958) is with Battelle Northwest Laboratories. His interests include corrosion in nuclear and nonnuclear systems, gases in metals, and tritium production in metal and ceramic systems. Harry Farrar, IV (bottom left) (PhD, nuclear physics, McMaster University, Canada, 1962) is presently project development engineer in charge of the Applied Nuclear Research Programs at the Atomic International Division of Rockwell International Corporation. He has developed a high-sensitivity mass spectrometer method of measuring very low concentrations of helium in solid materials and is applying this technique to the development of helium accumulation fluence monitors for measuring fast reactor fluence-spectra. D. G. Atteridge (bottom right) (Dr. of engineering, materials science, University of California, Berkeley, 1975) is a senior research scientist at Battelle Northwest Laboratories. His interests include mechanical property degradation due to internal helium accumulation, radiation damage, and ingress of contaminants from heat exchange coolants.

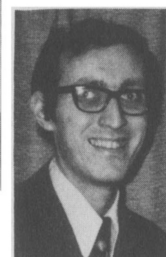
*J. F. Remark*  
*A. B. Johnson, Jr.*  
*Harry Farrar, IV*  
*D. G. Atteridge*



## EFFECTS OF HELIUM ON VOID SWELLING IN VANADIUM

J. L. Brimhall (top) (PhD, Stanford University, 1964) is currently technical leader, Radiation Effects, Battelle-Pacific Northwest Laboratory. Microstructural aspects of radiation damage have been his area of study with emphasis on void formation during radiation. E. P. Simonen (PhD, Iowa State, 1972) is senior research scientist, Battelle-Pacific Northwest Laboratory. His current interest is in the interpretation of radiation-induced microstructures from theories of diffusion, reaction kinetics, and thermodynamics.

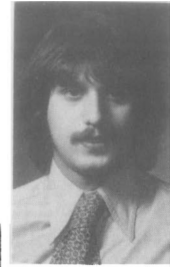
*J. L. Brimhall*  
*E. P. Simonen*



## THE CALCULATED PERFORMANCE OF VARIOUS STRUCTURAL MATERIALS IN FUSION-REACTOR BLANKETS

M. L. Williams (top) (MS, Georgia Institute of Technology, 1974) is a research engineer in the Neutron Physics Division at Oak Ridge National Laboratory (ORNL). He has worked on reactor physics and shielding analysis of the Fast Flux Test Facility and the Clinch River Breeder Reactor. His current interests are in neutronics studies of fusion and fast reactors using discrete ordinates techniques. R. T. Santoro (center) (MS, University of Tennessee, 1967) is a research staff member in the Neutron Physics Division at ORNL. His work has been in the areas of medium-energy neutron and proton spectroscopy, high-energy radiation shielding for accelerators and manned space vehicles, and cancer radiotherapy studies. His current interests focus on fusion-reactor design, particularly on neutronics problems. T. A. Gabriel (bottom) (PhD, University of Tennessee, 1969) is a research staff member in the Neutron Physics Division at ORNL. His work has been in the areas of theoretical high-energy accelerator and space shielding, developing particle-nucleus collision theories, and many basic shielding calculations with various available techniques. His current interests are in the areas of CTR neutronics and high-energy nuclear instrumentation.

*M. L. Williams  
R. T. Santoro  
T. A. Gabriel*

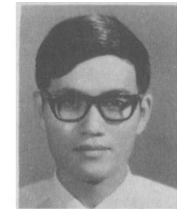


## REACTORS

### A HIGH-GAIN FUSION-FISSION REACTOR FOR PRODUCING URANIUM-233

Shang-Fon Su (top) (PhD, nuclear engineering, University of Washington, 1975) is a research associate in the Applied Physics Division of the Argonne National Laboratory. He completed his PhD dissertation in the area of fusion-fission reactor blanket studies. Gene L. Woodruff (bottom right) (PhD, nuclear engineering, Massachusetts Institute of Technology, 1966) is an associate professor of nuclear engineering and director, Nuclear Engineering Laboratories, University of Washington. His research interests are primarily in the areas of neutron spectroscopy and fusion engineering. N. J. McCormick (bottom left) (PhD, nuclear engineering, University of Michigan, 1965) is a professor of nuclear engineering at the University of Washington. He recently spent a year's leave-of-absence with the Palo Alto office of Science Applications Inc. working on reactor safety studies. Presently he is a consultant to SAI and to the Hanford Engineering Development Laboratory, where he has been engaged in the development of methods for identification of failed assemblies in fast reactors.

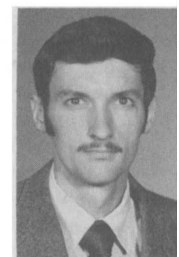
*Shang-Fon Su  
Gene L. Woodruff  
N. J. McCormick*



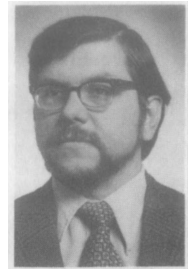
### EFFECTS OF HELIUM MIXING AND HEAT TRANSFER ON CONTAINMENT DESIGN PRESSURE IN A HIGH-TEMPERATURE GAS-COOLED REACTOR

John R. McCarty (BS, aerospace engineering; MS, nuclear engineering, University of Oklahoma) as a nuclear engineer in Gilbert/Commonwealth's Energy Conversion Systems Group is actively involved in thermal-hydraulic

*John R. McCarty  
Michael J. Kolar*



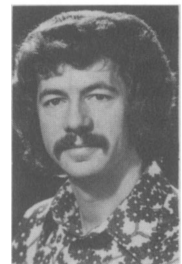
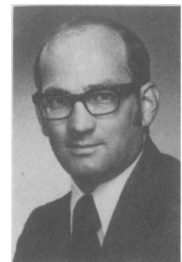
analysis applied to the design and analysis of nuclear power plants. His primary responsibility is the analysis of containment response to design basis accidents. Michael J. Kolar (MS, physics, John Carroll University; PhD, nuclear engineering, Case Western Reserve University) is a senior nuclear engineer for Gilbert/Commonwealth and is responsible for radiation analysis of nuclear power plants. He has been involved in the research and development of nuclear power through both the industrial and educational fields.



### CONSIDERATIONS IN THE DESIGN OF ELECTRON-BEAM-INDUCED FUSION REACTOR SYSTEMS

*Samuel G. Varnado  
Gary A. Carlson*

Samuel G. Varnado (top) (PhD, electrical engineering, University of Texas, Austin, 1969) is currently supervisor of the Systems Analysis Division II at Sandia Laboratories where he has been involved in the analysis of energy systems, in particular, electron-beam fusion reactor systems, since 1973. Formerly, he performed studies on electromagnetic propagation and tracking systems, and researched tumble dye lasers. Gary Carlson (BS, physical chemistry, University of Idaho, 1963; PhD, physical chemistry, University of California, Berkeley, 1966) is a staff member in the Radiation Physics Division of Sandia Laboratories. He is currently working in diagnostics development for liquid-metal fast breeder reactor safety research studies.

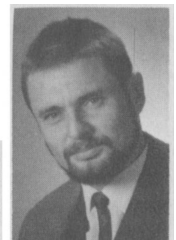


## FUELS

### DETERMINATION OF THE SPECIFIC HEAT TRANSFER BETWEEN FUEL AND CANNING FROM REACTIVITY MEASUREMENTS AT THE NUCLEAR POWER PLANT KCB

*H. Raum  
G. Bronner  
W. D. Krebs*

H. Raum (top) (MS, physics, University of Erlangen, Germany, 1963), G. Bronner (center) (MS, physics, University of Tuebingen, Germany, 1960), and W. D. Krebs (bottom) (PhD, University of Heidelberg, Germany, 1969) are physicists in the Kraftwerk Union AG in Erlangen, West Germany. They are engaged mainly in the planning, performance, and evaluation of neutron physics measurements during the startup and the power operation of nuclear power plants.



**DEVELOPMENT OF DIRECT-ELECTRICAL-HEATING APPARATUS TO STUDY THE RESPONSE OF NUCLEAR FUELS TO APPLIED TRANSIENTS***B. J. Wrona**E. Johanson*

Bernard J. Wrona (top) (BS and MS, metallurgical engineering, Illinois Institute of Technology) has been a member of the Materials Science Division of Argonne National Laboratory (ANL) since 1962. He is presently principal investigator in developing the direct-electrical-heating (DEH) apparatus, and lead experimentalist in utilizing the apparatus to study the response of nuclear oxides, carbides, and nitrides to applied power transients. Edward Johanson (BS, electrical engineering, University of Illinois, 1954) joined the Electronics Division of ANL in 1957. His present assignments include the DEH apparatus and the MARK-11C control loops for the liquid-metal fast breeder reactor program at TREAT, HFEF, and ANL-East.

