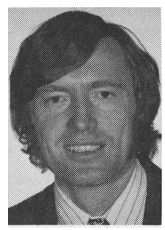
nuclear technology®

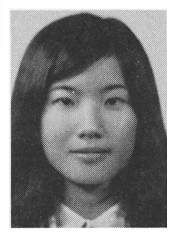
AUTHORS — FEBRUARY 1982

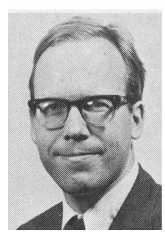
COMPARATIVE LEACHING BEHAVIOR OF RADIOACTIVE WASTE FORMS

APPLICATION OF GLASS CORROSION CONCEPTS TO NUCLEAR WASTE IMMOBILIZATION

D. E. Clark
L. Urwongse
C. Maurer



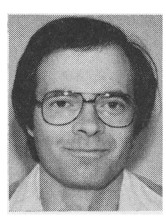




David Clark (top) (BS, metallurgical engineering, and PhD, materials science and engineering, University of Florida) is a visiting assistant professor in the Department of Materials Science and Engineering at the University of Florida. His research interests include surface characterization of glass and glass-ceramics, ceramic processing, and archaeology. **Ladawan Urwongse** (center) (BS, Chulalongkorn University Thailand, 1974; MS, 1976, and PhD, 1979, ceramic engineering, University of Missouri-Rolla) is post-doctoral research associate in the Department of Materials Science and Engineering at the University of Florida. Her current research interest is in the corrosion study of nuclear waste glasses, particularly their solution and surface chemistry. **Christopher Maurer** (bottom) (BS, physics, University of Illinois, 1971; MS, physics, University of Nebraska, 1973; PhD, ceramic engineering, University of Illinois, 1979) is a post-doctoral research associate in the Department of Materials Science and Engineering at the University of Florida. His current interests are in the corrosion of nuclear waste glasses and in the dating of archaeological ceramics.

CONTINUOUS-FLOW LEACHING STUDIES OF CRUSHED AND CORED SYNROC

David G. Coles
Fernando Bazan

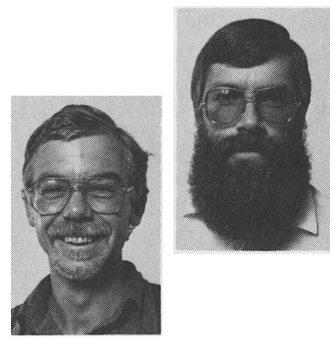


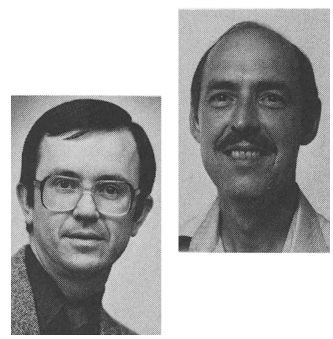
David G. Coles (top) (BS, Oregon State University, 1970; MS, nuclear chemistry and geochemistry, Oregon State University, 1972) is presently studying the geologic disposal of nuclear wastes. His particular interests are the geochemical behavior of radionuclides, both natural and artificial. He is currently a senior research scientist at the Battelle-Pacific Northwest Laboratories (PNL). **Fernando Bazan** (BA, Drew University, 1955) was from 1955 to 1958 a research chemist at Lamont Geological Observatory, Columbia University, New York, engaged in tritium studies and age determinations of geological specimens using Kr-Ar and Pb-U isotopes. From 1958 to 1965, he was a research chemist at Isotopes Incorporated, Westwood, New Jersey, engaged in nuclear fallout studies. Since 1965, he

has been a senior research chemist in the Nuclear Chemistry Division, Lawrence Livermore National Laboratory. He is currently engaged in leaching studies to assess the chemical stability of SYNROC and borosilicate glass PNL 76-68.

MECHANISMS OF LEACHING AND DISSOLUTION OF UO_2 FUEL

L. H. Johnson
D. W. Shoesmith
G. E. Lunansky
M. G. Bailey
P. R. Tremaine

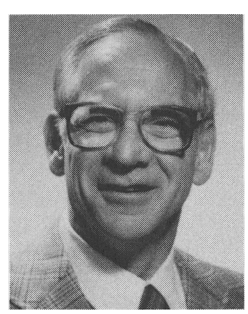




Lawrence H. Johnson (top right) (BSc, chemistry, University of Lethbridge, 1978) has been employed at the Whiteshell Nuclear Research Establishment (WNRE) since 1978, and is currently a member of the Fuel Waste Technology Branch. His research involves the characterization of irradiated fuel as a waste form, including the dissolution behavior of irradiated fuel under projected disposal conditions. **David W. Shoesmith** (top left) (BSc, chemistry, 1967, and PhD, electrochemistry, 1970, University of Newcastle-upon-Tyne) has been a member of the Research Chemistry Branch at WNRE since 1973. His research is centered around the fundamental processes involved in film formation and dissolution on metal and oxide surfaces, and their importance in nuclear reactor systems and nuclear waste management. **Gerald E. Lunansky** (not pictured) (Diploma, chemical technology, Ryerson Polytechnical Institute, 1974; BSc, chemistry, York University, 1978) at the time this work was done was a member of the Fuel Waste Technology Branch at WNRE. He has since joined the Manitoba Research Council. **M. Grant Bailey** (bottom right) (chemical technology, Ryerson Institute of Technology, 1961) has 20 years of experience in research chemistry with Atomic Energy of Canada at its two sites–Chalk River and Whiteshell. He has experience with many experimental techniques and his present research involves film formation and dissolution on metal surfaces using electrochemical techniques. **Peter R. Tremaine** (bottom left) (BSc, chemistry, University of Waterloo, 1969; PhD, physical chemistry, University of Alberta, 1974) was a member of the Research Chemistry Branch at WNRE at the time this work was done. He has since joined the Oil Sands Research Department of the Alberta Research Council. His research is centered on the fundamental chemical thermodynamics of hydrothermal systems and their application to problems in nonconventional oil recovery and nuclear power generation.

LEACH TESTING OF IDAHO CHEMICAL PROCESSING PLANT FINAL WASTE FORMS

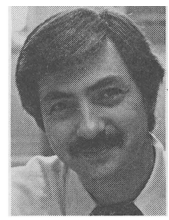
R. P. Schuman

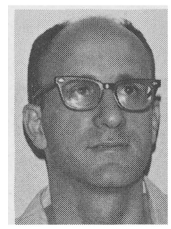


Robert P. Schuman (PhD, Ohio State University, 1946) works at the Idaho National Engineering Laboratory on the ultimate disposal of high-level defense and transuranium wastes. He worked at the Knolls Atomic Power Laboratory from 1947 to 1957 and at the National Reactor Testing Station from 1957 to 1969. He taught at Robert College at Boğaziçi Üniversitesi from 1969 to 1977 and spent 1977-1978 as a visiting professor at Iowa State University. His interests include the chemical aspects of the nuclear fuel cycle including waste management, breeder reactors, actinide and fission product cross sections and decay properties, the production and burnup of nuclides in reactors, and chemical operations with radioactive material.

MECHANISMS THAT CONTROL AQUEOUS LEACHING OF NUCLEAR WASTE GLASS

Joseph H. Simmons
Aaron Barkatt
Pedro B. Macedo

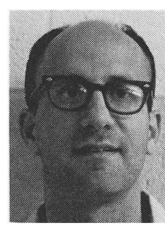


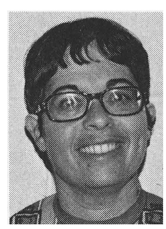


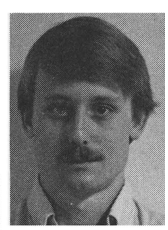
Joseph H. Simmons (top) (PhD, physics, The Catholic University of America) is a professor in the Department of Physics and a senior project manager in the Vitreous State Laboratory of The Catholic University of America. His work is in materials science and surface microstructure characterization. Prior to joining the university faculty, Simmons was a scientist of the U.S. National Aeronautics and Space Administration Lewis Research Center, where he studied current and field effects in superconducting thin films, and a senior physicist at the U.S. National Bureau of Standards, where he studied liquid-state viscoelasticity phenomena in glasses. **Aaron Barkatt** (center) (PhD, chemistry, Hebrew University, Jerusalem, Israel, 1974) is an associate research professor at the Vitreous State Laboratory, The Catholic University of America, Washington, D.C. He joined the Catholic University of America in 1976 after two years of post-doctoral work at Purdue University. His work has been in the area of the science and technology of glass, particularly chemical durability, surface properties, radiation effects, relaxation phenomena, spectroscopy, and novel glass-forming compositions. **Pedro B. Macedo** (bottom) has research interests that are focused on the investigation of liquids and amorphous solids. He has authored over 30 papers dealing with the dynamical viscoelastic aspects of the liquid state–amorphous solid (glassy) state transition. His work in combining the results of electrical, optical, and ultrasonic measurements to probe the atomic, molecular, and ionic motions associated with structural dynamics in glasses has had a major influence in the field.

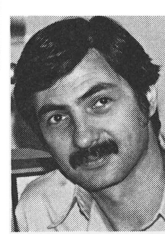
THE IMPORTANCE OF CO_2 BUFFERING AND OF THE TOTAL IONIC BALANCE IN MEASUREMENTS ON THE DURABILITY OF GLASSES

Aaron Barkatt
Alisa Barkatt
Pehr E. Pehrsson
Pedro B. Macedo
Joseph H. Simmons







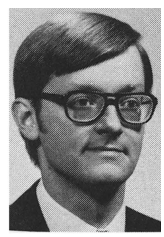
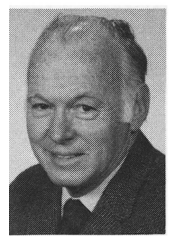
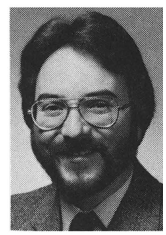
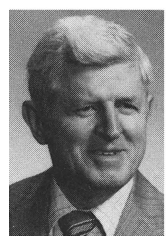


Aaron Barkatt (top right) (PhD, chemistry, Hebrew University, Jerusalem, Israel, 1974) is an associate research professor at the Vitreous State Laboratory, The Catholic University of America, Washington, D.C. He joined the Catholic University of America in 1976 after two years of post-doctoral work at Purdue University. His work has been in the area of the science and technology of glass, particularly chemical durability, surface properties, radiation effects, relaxation phenomena, spectroscopy, and novel glass-forming compositions. **Alisa Barkatt** (top left) is a research assistant at the Vitreous State Laboratory, The Catholic University of America, Washington, D.C. She joined the Catholic University of America in 1978. **Pehr E. Pehrsson** (center right) (BS, chemistry, College of William and Mary) joined the Vitreous State Laboratory in 1978, and is currently employed there while completing the PhD program in physical chemistry at The Catholic University of America. **Pedro B. Macedo** (bottom left) has research interests that are focused on the investigation of liquids and amorphous solids. He has authored over 30 papers dealing with the dynamical viscoelastic aspects of the liquid state–amorphous solid (glassy) state transition. His work in combining the results of electrical, optical, and ultrasonic measurements to probe the atomic, molecular, and ionic motions associated with structural dynamics in glasses has had a major influence in the field. **Joseph H. Simmons** (bottom right) (PhD, physics, The Catholic University of America) is a professor in the Department of Physics and a senior project manager in the Vitreous State Laboratory of The Catholic University of America. His work is in materials

science and surface microstructure characterization. Prior to joining the University faculty, Simmons was a scientist at the U.S. National Aeronautics and Space Administration Lewis Research Center, where he studied current and field effects in superconducting thin films, and a senior physicist at the U.S. National Bureau of Standards, where he studied liquid state viscoelasticity phenomena in glasses.

COMPARATIVE LEACHING BEHAVIOR OF SYNROC B AND A BOROSILICATE GLASS

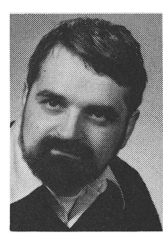
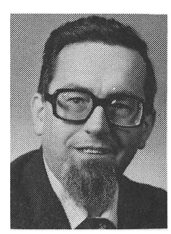
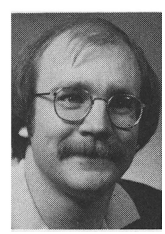
C. R. Kennedy
K. F. Flynn
R. M. Arons
J. T. Dusek

Christopher R. Kennedy (top right) (PhD, ceramic science, Pennsylvania State University, 1974) is a ceramist in the Materials Science Division of Argonne National Laboratory (ANL). Since joining ANL in 1974, he has conducted research on a wide variety of topics in the field of ceramic science, including the thermomechanical response of nuclear fuels, high-temperature corrosion of refractories by coal slags, and ceramics for nuclear waste disposal. **K. F. Flynn** (top left) (MS, chemical engineering, Illinois Institute of Technology, 1953) has been doing nuclear technology research and development work at ANL since 1951. He spent 1968 at the Swiss Institute for Reactor Research at Würenlingen, Switzerland. For the past five years he has been engaged in research on nuclear waste forms. He is currently studying the environmental effects of nuclear technology. **Richard M. Arons** (bottom right) (D. Eng. Sc., materials science, Columbia University, 1978) has been a research metallurgist in the Materials Science Division of ANL since 1977. His primary research interests have been the fabrication and performance of advanced ceramic materials. He has recently worked on the development of crystalline ceramics for nuclear waste disposal, ceramic electrodes and electrolyte structures for molten carbonate fuel cells, and solid ceramic tritium breeders for fusion reactors. **Joseph T. Dusek** (bottom left), ceramist, has spent the last 18 years at ANL fabricating nuclear fuel materials, ceramic separators for batteries, ceramic cathodes, and electrolyte structures for molten carbonate fuel cells. From 1941 to 1962, he was associated with the Illinois Institute of Technology Research Institute in ceramic research and product development.

DISSOLUTION OF ALUMINUM-, TITANIUM-, AND ZIRCONIUM-BASED CRYSTALLINE WASTE FORM COMPONENTS UNDER HYDROTHERMAL CONDITIONS

Barry E. Scheetz
William B. White
Scott D. Atkinson

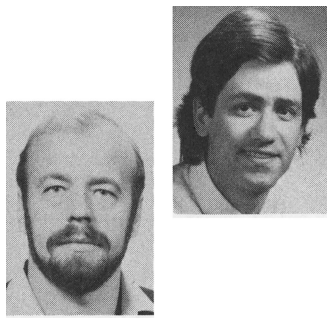




Barry E. Scheetz (top) [BS, chemistry education, Bloomsburg State College, 1967; MS, geochemistry, The Pennsylvania State University (PSU), 1972; PhD, geochemistry and mineralogy, PSU, 1976] is a research associate at the Materials Research Laboratory of PSU. His current research interests are in waste form stability, waste/rock interactions, waste package interactions, and development of cementitious materials with long-term durability for borehole and shaft sealing. **William B. White** (center) (BS, chemistry, Juniata College, 1954; PhD, geochemistry, PSU, 1962) is professor of geochemistry at the Materials Research Laboratory, the Department of Geosciences, and the Department of Materials Science and Engineering at PSU. His interests in the nuclear waste field concern waste form development, dissolution of waste forms, and near-field repository geochemistry. His other research interests are in the fields of phase equilibria, crystal chemistry, glass science, crystal growth, spectroscopy, and groundwater hydrology. **Scott D. Atkinson** (bottom) (BS, chemistry, PSU, 1978) is a senior

research technologist at the Materials Research Laboratory of PSU. His interest is in wet chemical and spectroscopic characterization of leachate derived from waste form stability experiments as well as near field repository simulation experiments.

A CRITERION FOR SELECTING LEACH TEST SPECIMEN SIZES

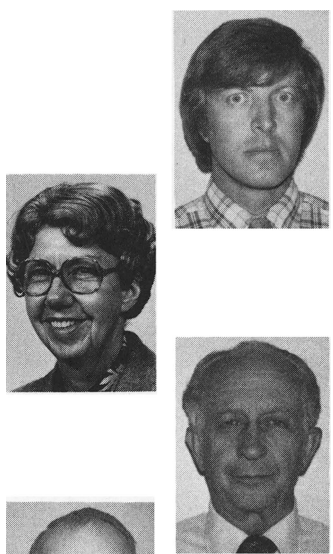
Claudio Pescatore
Albert J. Machiels



C. Pescatore (top) (Laurea in Fisica, University of Bologna, Italy, 1975) is a doctoral student in the Nuclear Engineering Program at the University of Illinois (UI), Urbana. His thesis work involves the mathematical modeling of waste form leaching. **A. J. Machiels** (PhD, nuclear engineering, University of California, Berkeley, 1976) is an assistant professor of nuclear engineering at the UI. He joined the UI faculty in 1976. His research interests are in the areas of nuclear waste management and spent fuel reprocessing.

LEACHING PROPERTIES AND CHEMICAL COMPOSITION OF CALCINES PRODUCED AT THE IDAHO CHEMICAL PROCESSING PLANT

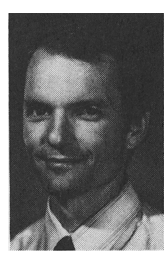
B. A. Staples
B. E. Paige
D. W. Rhodes
M. W. Wilding



B. A. Staples (top right) (MS, geochemistry, University of Arizona, 1964) has been doing nuclear development work since 1964. He has experience in the areas of radioanalytical chemistry, process off-gas cleanup, and solid waste form development and characterization. He is presently a group leader in the Technical Department of Exxon Nuclear Idaho, Inc., which operates the Idaho Chemical Processing Plant at Idaho National Engineering Laboratory for the U.S. Department of Energy. **Bernice E. Paige** (top left) (BS, chemical technology, Iowa State University, 1946) is currently on the technical staff for the Process Development Section of the Technical Department. She worked for E. I. du Pont de Nemours until 1951 in textile research, and has 30 years of experience in the nuclear field beginning with du Pont at Oak Ridge National Laboratory in 1951. Since 1952, she has worked at the Idaho Chemical Processing Plant, in development for spent fuel reprocessing and high-level waste management, as a project engineer and program manager and supervisor. **D. W. Rhodes** (bottom right) (PhD, soil chemistry, University of Wisconsin, 1950) has been involved in the management of both high- and low-level radioactive wastes resulting from the chemical reprocessing of spent reactor fuels since 1950. He is currently a group leader in the Technical Department. **M. W. Wilding** (bottom left) (MS, Iowa State College, 1949) has been doing research since 1959 in adsorption of radioisotopes on earth materials and synthetic resins. He has worked with radioactive waste disposal, water treatment, and water decontamination for the Technical Department. He was on the faculty of Brigham Young University from 1957 to 1959.

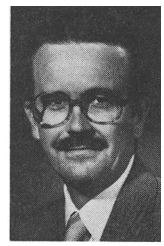
MCC-1: A STANDARD LEACH TEST FOR NUCLEAR WASTE FORMS

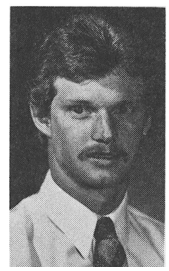
D. M. Strachan
R. P. Turcotte
B. O. Barnes



D. M. Strachan (right) (PhD, chemistry, Iowa State University, 1971) is a senior research scientist for the Battelle-Pacific Northwest Laboratories (PNL). He joined PNL in 1979 after five years with Rockwell Hanford Operations working on the

immobilization of Hanford defense waste. He is currently task leader for the development of five standard nuclear waste form leach tests for the Materials Characterization Center. **R. P. Turcotte** (top) (PhD, chemistry, Arizona State University, 1969) is manager of the Ceramics Research Section at PNL. His work has included basic studies of nonstoichiometric oxide systems and radiation damage in ceramics. During the last five years, his work has centered around development and characterization of nuclear waste forms. **B. O. Barnes** (bottom) (BS, metallurgical engineering, South Dakota School of Mines, 1978) has been a junior research scientist at PNL since 1978. His research mainly involves characterization of nuclear waste materials, particularly with respect to leaching behavior.



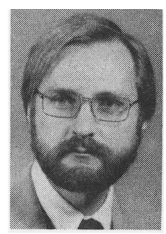


NUCLEAR SAFETY

THE EFFECT OF TIME DELAYS IN FUEL PIN FAILURE ON LOF-TOP TRANSIENT CALCULATIONS FOR A COMMERCIAL-SIZED LMFBR

P. A. Pizzica
H. H. Hummel

Philip A. Pizzica (top) (BS, mathematics, University of Illinois, 1968) has worked at Argonne National Laboratory (ANL) from 1967 to 1971 and from 1974 to the present. During the first 3 of his 11 years in the breeder reactor field at ANL, he worked in the area of fuel cycle analysis and neutronics. During the last eight years, he has worked in the fast reactor safety field, where he has developed and used mathematical computer models to describe liquid-metal fast breeder reactor accidents. **Harry H. Hummel** [PhD, chemical engineering, University of Wisconsin (UW), 1948] has been at ANL since graduating from UW. During most of that time he has worked on fast reactor physics analysis, with particular emphasis on reactivity coefficients. He currently heads a section in the Applied Physics Division engaged in modeling and assessment in the area of fast reaction safety analysis, in support of regulating and licensing activities.

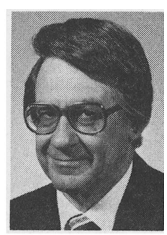


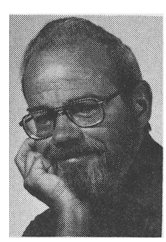
FUEL CYCLES

FISSION PRODUCT ANALYTIC IMPULSE SOURCE FUNCTIONS

R. J. LaBauve
T. R. England
D. C. George
C. W. Maynard

Raphael J. LaBauve (top) (MS, nuclear engineering, University of New Mexico, Albuquerque, 1960) has been with the Los Alamos National Laboratory (LANL) for the past 25 years. While there, he has made contributions in fields ranging from health physics and optics to reactor design calculations and cross sections. During the past 15 years his interests have centered mainly on nuclear data and, most recently, on fission product decay-energy spectra and data for activation analysis. **Talmadge R. England** (bottom) (BS, physics, 1956; MS, physics,



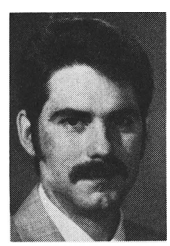


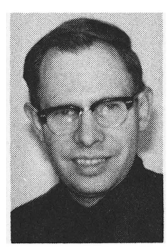
University of Pittsburgh, 1962; PhD, nuclear engineering, University of Wisconsin, 1969) is a staff member in the Theoretical Division of LANL, a recent member of the U.S. Department of Energy Advisory Panel for Reference Nuclear Data, chairman of the Fission Product Yields Subcommittee of the Cross-Section Evaluation Working Group, secretary of the American Nuclear Society (ANS) 5.1 Decay Heat Standards Committee, and chairman of the ANS 5.2 Yields Standard Committee. His current technical interests include basic nuclear, actinide, and fission product data for ENDF/B-V and -VI, and the testing and use of these data for waste management, reactor safety, and nuclear fuel cycles. **Denise C. George** (top) (AB, mathematics, University of Michigan, 1966; MS, computer sciences, University of Illinois, 1969) is a staff member in the Theoretical Division of LANL. Her current technical interests include numeric and graphic computer applications in the area of fission product data. **Charles W. Maynard** (bottom) (BS, electrical engineering, University of Maryland; PhD, applied physics, Harvard University, 1961) has worked at Bettis Atomic Power Laboratory, operated by Westinghouse Electric Company, in the Reactors Theory and Methods Section. He was appointed associate professor of nuclear engineering at the University of Wisconsin in 1961 and became a professor in 1965. His research interests are centered on design and neutronics analysis of reactors.

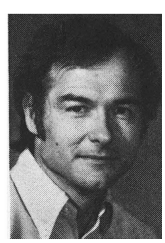
NUCLEAR FUELS

A MODEL FOR THE EFFECTIVE THERMAL AND MECHANICAL PROPERTIES OF CRACKED UO_2 PELLETS

R. E. Williford
D. D. Lanning
C. L. Mohr





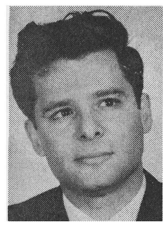
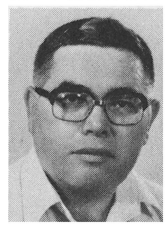


R. E. Williford (top) (BS, mechanical engineering and mathematics, Oregon State University, 1972) has held both manufacturing and research positions in the nuclear industry since 1972. Since joining Battelle-Pacific Northwest Laboratories (PNL) in 1975, his assignments have included analytical and experimental investigations into the thermal-mechanical behavior of nuclear fuel rods. A senior engineer at PNL, his current interests are in fuel rod mechanical performance and tribology. **Donald D. Lanning** (center) (BA, physics, University of Oregon, 1967; MS, nuclear engineering, University of Washington, 1979) has been at PNL since 1967. He has had various assignments related to fuel handling and test fuel production. He is currently project manager for a U.S. Nuclear Regulatory Commission-sponsored program on steady-state irradiation testing and computer modeling of fuel rods. **Charles L. Mohr** (bottom) (PhD, engineering science, Washington State University, 1973) has been at PNL since 1973 and has been involved in modeling the mechanical behavior of nuclear fuel during steady-state and transient conditions. His main interests have been evaluating and predicting the time-dependent deformation of Zircaloy fuel cladding under loss-of-coolant accident (LOCA) conditions and predicting pellet cladding interaction behavior. He is currently program manager for the NRU/LOCA simulations and is manager of the Nuclear Fuels Section at PNL.

RADIOACTIVE WASTE MANAGEMENT

PROBABILISTIC INTERPRETATION OF NUCLEAR WASTE ASSAY BY PASSIVE GAMMA TECHNIQUE

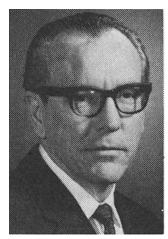
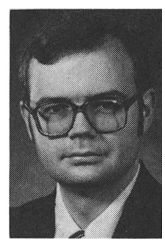
A. Knoll
A. Notea
Y. Segal

Alexander Knoll (top) (PhD, nuclear engineering, Technion, 1980) is employed at the Israel Atomic Energy Commission, Power Reactor Division, and works principally in the area of system reliability analysis. **Amos Notea** (center) (PhD, Hebrew University, Jerusalem) presently works in the area of radiation gauging techniques and interpretational models. **Yitzhak Segal** (bottom) (D.Sc., nuclear science, Technion) is currently interested in research that includes modeling of measurement systems.

NUCLEAR WASTE PARTITIONING AND TRANSMUTATION

J. O. Blomeke
A. G. Croff

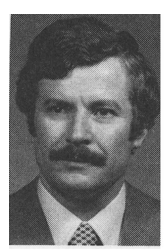
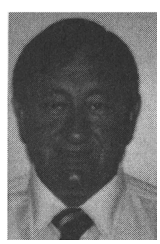



J. O. Blomeke (top) (BChE, 1943, and MSChE, 1947, University of Texas; PhD, Georgia Institute of Technology, 1950) has been a staff member since 1950 of the Chemical Technology Division at Oak Ridge National Laboratory (ORNL), where he has worked in fuel reprocessing and waste management research and development. **Allen G. Croff** (BSChE, Michigan State University, 1971; Nuclear Engineer Degree, Massachusetts Institute of Technology, 1974; MBA, University of Tennessee, 1981) has been a staff member of the ORNL Chemical Technology Division since 1974. His principal activities have involved nuclear fuel cycle studies and evaluations, with emphasis on radioactive waste management. He is currently manager of engineering analysis and planning.

ECONOMICS

THE EFFECT OF PLANT RELIABILITY IMPROVEMENT IN THE COST OF GENERATING ELECTRICITY

Seyyed Nejat
Nicholas Tsoulfanidis
Robert C. Sanders

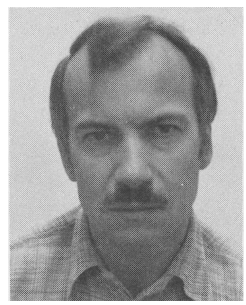
Seyyed M. Nejat (not pictured) (BS, physics, Tehran University, Iran, 1974; MS, 1976, and PhD, 1980, nuclear engineering, University of Missouri-Rolla) is currently in Iran. **Nicholas Tsoulfanidis** (top) (BS, physics, University of Athens, Greece, 1960; MS, 1965, and PhD, 1968, nuclear engineering, University of Illinois) is professor and head of the Nuclear Engineering Program at the University of Missouri-Rolla. His current research interests are in the areas of radiation transport and the nuclear fuel cycle. **R. C. Sanders** (BS, engineering physics, Oregon State University, 1966; ScD, nuclear engineering, Massachusetts Institute of Technology, 1970) is currently with MPR Associates, Incorporated. His prior experience

includes serving on the staff of the Division of Naval Reactors, U.S. Department of Energy and as assistant professor of nuclear engineering at the University of Missouri-Rolla. His current interests include improving nuclear power plant availability, power plant thermal hydraulics, and nuclear power plant safety analyses.

HEAT TRANSFER AND FLUID FLOW

ESTIMATE OF CROSS FLOW IN HIGH TEMPERATURE GAS-COOLED REACTOR FUEL BLOCKS

H. G. Groehn

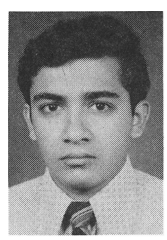


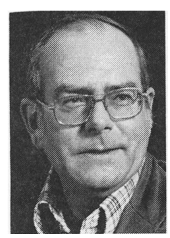
Hans-Günter Groehn (Dipl.-Ing., mechanical engineering, 1966, and Dr.-Ing., engineering science, 1979, Technische Universität Berlin) has been a research engineer in the Jülich Nuclear Research Centre, Federal Republic of Germany, since 1966. His research interests include the thermal hydraulics of reactor components of high temperature gas-cooled reactors.

MATERIALS

RADIATION-INDUCED OUTGASSING FROM SORPTION PUMP MATERIAL

Vikram N. Patel
J. N. Anno





Vikram N. Patel (top) (B. Tech., mechanical engineering, Indian Institute of Technology, 1979; MS, nuclear engineering, University of Cincinnati, 1981) performed his master's thesis research on radiation-induced outgassing at the Winkel Radiation Laboratory, University of Cincinnati. He is currently associated with Singer's Link Simulation Systems Division, where he is working on nuclear power plant simulators. **James N. Anno** (BS, 1955, MS, 1961, and PhD, 1965, physics, Ohio State University) has been active in radiation-related research since 1955, with emphasis on the effects of radiation on materials and components. Currently, he is a professor of nuclear engineering at the University of Cincinnati, having joined the faculty in 1970, and president of Research Dynamics Incorporated, an R&D corporation.