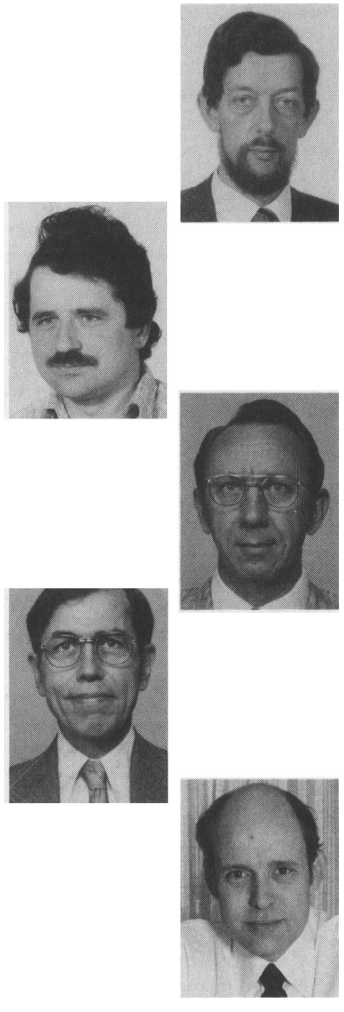
nuclear technology®

AUTHORS — MAY 1988

NUCLEAR AEROSOL SCIENCE

LARGE-SCALE EXPERIMENTS ON AEROSOL BEHAVIOR IN LIGHT WATER REACTOR CONTAINMENTS

Werner Schöck
Helmut Bunz
Robert E. Adams
Melvin L. Tobias
Frank J. Rahn



Werner Schöck (top right) [Dr. rer. nat., University of Giessen, Federal Republic of Germany (FRG)] obtained his degrees in the field of atomic spectroscopy. He has been working in aerosol research since 1971 and in reactor safety applications since 1974. He is presently leader of the Light Water Reactor (LWR) Safety Research Group at the Laboratory for Aerosol Physics and Filter Technology (LAPFT) at Kernforschungszentrum Karlsruhe. **Helmut Bunz** (top left) (Dr. Ing., University of Karlsruhe, FRG, 1985) is a scientist in the LAPFT, where he has been developing codes calculating the behavior of aerosols in containments of nuclear power plants after hypothetical accidents. He has worked mainly in the field of LWR safety recently and formerly in the field of liquid-metal fast breeder reactor safety. He is currently extending nuclear aerosol codes to applications to nonnuclear fields. **Robert E. Adams** (center right) (BS, chemistry, Memphis State University, 1954; MS, chemistry, University of Mississippi, 1956) joined Oak Ridge National Laboratory (ORNL) in 1956. His early research was in the area of fission gas adsorption and aerosol filtration. Since 1975, he has been conducting experiments studying the behavior within containment of aerosols assumed to be released during postulated liquid-metal-cooled and light-water-cooled reactor accidents. **Melvin L. Tobias** (bottom left) (BChE, City College of New York, 1944; PhD, chemical engineering, University of Minnesota, 1950) has been a staff member at ORNL since 1950. He has worked in the fields of physical properties measurements, reactor neutronics, economics, and safeguards, and since 1976 has been occupied with the analysis aspects of aerosol experiments. For several years, he was associate editor of *Nuclear Science and Engineering*. **Frank J. Rahn** (bottom right) (MS, nuclear engineering, 1965, and D. Eng. Sc., 1970, Columbia University) is a member of the technical staff at the Electric Power Research Institute. For the last 6 years, he has been active in large-scale experiments related to source term issues.

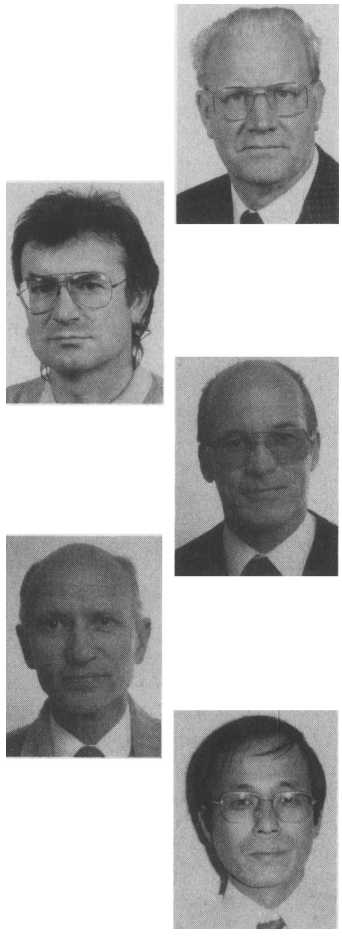
AEROSOL BEHAVIOR EXPERIMENTS ON LIGHT WATER REACTOR PRIMARY SYSTEMS

Frank J. Rahn
Jan Collén
Anthony L. Wright

Frank J. Rahn (top) (MS, nuclear engineering, 1965, and D. Eng. Sc., 1970, Columbia University) is a member of the technical staff at the Electric Power Research Institute. For the last 6 years, he has been active in large-scale experiments related to source term issues. **Jan Collén** (center) (MS, physical engineering, 1963, and DS, reactor physics, 1973, Chalmers University of Technology, Sweden) is a research engineer at Studsvik Energiteknik AB where he has been project manager of the joint reactor safety experiments at Marviken since 1981. **Anthony L. Wright** (bottom) (PhD, aeronautical engineering, University of Minnesota, 1976) is a research staff member at the Oak Ridge National Laboratory. His current interests relate to aerosol behavior in light water reactor core-melt accidents, including the performance of aerosol deposition and resuspension experiments and the validation of aerosol transport computer codes.

SODIUM AEROSOL BEHAVIOR IN LIQUID-METAL FAST BREEDER REACTOR CONTAINMENTS

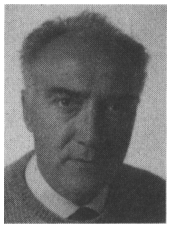
S. Jordan
W. Cherdron
Jean-Claude Malet
Roger Rzekiecki
Yoshiaki Himeno



S. Jordan (top right) [PhD, physical chemistry, University of Mainz, Federal Republic of Germany (FRG), 1967] is a senior scientist and division head at Kernforschungszentrum Karlsruhe (KfK). His current interest in the area of nuclear safety are aerosol physics and filter technology. **W. Cherdron** (top left) (Dipl., physics, University of Karlsruhe, FRG, 1973) joined the Laboratory for Aerosol Physics and Filtration Technology at KfK in 1978. His main field of interest is the experimental investigation of sodium fires on a technical scale, related to safety problems in liquid-metal fast breeder reactors (LMFBRs). He is presently working in the field of sodium/concrete interactions in a closed containment. **Jean-Claude Malet** (center right) (Docteur d'etat, Orleans University, France, 1972) worked at the Centre National de la Recherche Scientifique from 1967 to 1973, when he went to the Commissariat à l'Energie Atomique, Centre d'Etudes Nucléaires (CEA/CEN) at Cadarache, Nuclear Safety Protection Institute. He is manager of the fire studies section, in charge of experimentation and physical modeling of fire events in nuclear plants (including LMFBRs). **Roger Rzekiecki** (bottom left) (nuclear chemistry, CNAM, France, 1956) worked for CEA/CEN at Saclay, then moved to CEA/CEN Cadarache in 1965. He is now a chief researcher in the Nuclear Safety Division and is working in the field of sodium fires in LMFBR development. **Yoshiaki Himeno** (bottom right) (MS, nuclear engineering, Tohoku University, Japan, 1970; PhD, nuclear engineering, Hokkaido University, Japan, 1983) is a manager at the Power Reactor and Nuclear Fuel Development Corporation, Oarai Engineering Center. He has recently been engaged in tests and analyses of in-plant, ex-vessel accidents related to fast breeder reactor safety, including sodium fires, aerosol behavior, and source term, as well as sodium-water reactions in LMFBR steam generators.

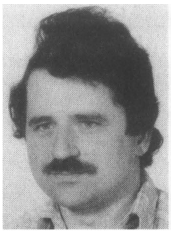
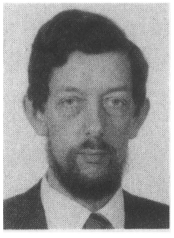
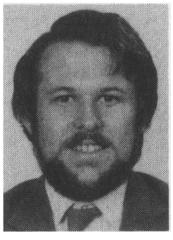
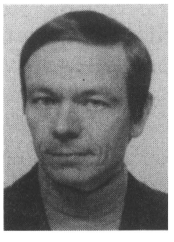
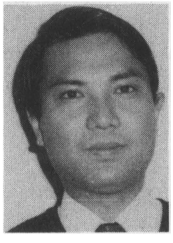
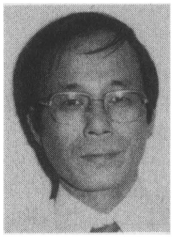
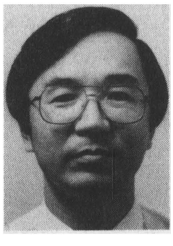
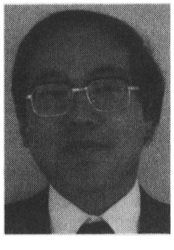
NUCLEAR AEROSOL CODES

F. Beonio-Brocchieri
Helmut Bunz
Werner Schöck
Ian H. Dunbar
Jean Gauvain
Shinya Miyahara
Yoshiaki Himeno
Kunihisa Soda
Norihiro Yamano



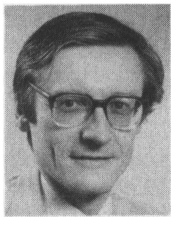
F. Beonio-Brocchieri (right) (PhD, theoretical physics, University of Milano, Italy, 1960) has worked at the University of Milano in the area of plasma physics. In 1964 he joined the Joint Research Center (JRC), Commission of the European Communities, at Ispra, Italy. He has been involved in nuclear reactor physics and in environmental activities and is currently working on source term studies in the framework of the JRC reactor

safety program. **Helmut Bunz** (top right) [Dr. Ing., University of Karlsruhe, Federal Republic of Germany (FRG), 1985] is a scientist in the Laboratory for Aerosol Physics and Filter Technology (LAPFT) at Kernforschungszentrum Karlsruhe (KfK), where he has been developing codes calculating the behavior of aerosols in containments of nuclear power plants after hypothetical accidents. He has worked mainly in the field of light water reactor (LWR) safety and also in the field of liquid-metal fast breeder reactor (LMFBR) safety. He is currently applying nuclear aerosol codes to nonnuclear fields. **Werner Schöck** (top left) (Dr. rer. nat., University of Giessen, FRG) obtained his degrees in the field of atomic spectroscopy. He has been working in aerosol research since 1971 and in reactor safety applications since 1974. He is presently leader of the LWR Safety Research Group at the LAPFT, KfK. **Ian H. Dunbar** (second from top right) (D. Phil., theoretical physics, Oxford University, United Kingdom, 1977) is a principal scientific officer at the United Kingdom Atomic Energy Authority's Safety and Reliability Directorate (SRD) in Culcheth, United Kingdom. He worked for 5 years on theoretical high-energy physics at the Universities of Bristol and Sussex. In 1981 he joined SRD and since then has worked on aerosol behavior modeling for reactor accident source term analysis. **Jean Gauvain** (second from top left) (engineer, Ecole Centrale des Arts et Manufactures, Paris, France, 1973) joined the Institute for Technological Research and Development at the Commissariat à l'Energie Atomique (CEA) in 1975. He was in charge of numerical modeling of the seismic behavior of structure and of numerical modeling of fission product aerosol behavior. He joined the Institute for Nuclear Protection and Safety of the CEA in 1986 and is currently responsible for all fission product transfer analysis in nuclear severe accident studies. **Shinya Miyahara** (third from top right) (BS, Yokohama City University, Japan, 1981) is a research engineer at Oarai Engineering Center (OEC) of Power Reactor and Nuclear Fuel Development Corporation (PNC). For the past 7 years, he has been engaged in plant safety research related to sodium fires and aerosol behavior. He is currently working on research and development of the fast breeder reactor (FBR) source term. **Yoshiaki Himeno** (third from top left) (MS, nuclear engineering, Tohoku University, Japan, 1970; PhD, engineering, Hokkaido University, Japan, 1983) is a manager at the OEC, PNC. In recent years, he has been engaged in tests and analyses of in-plant ex-vessel accidents related to FBR safety, including sodium fires, aerosol behavior, and source term, as well as sodium-water reactions in LMFBR steam generators. **Kunihisa Soda** (bottom right) (PhD, energy engineering, University of Illinois, Chicago, 1971) joined the Japan Atomic Energy Research Institute (JAERI) in 1972 and has worked on various projects on LWR safety analysis and experiments. He is presently the head of the Chemical Engineering Safety Laboratory at JAERI and is responsible for severe accident research. **Norihiro Yamano** (bottom left) (MS, nuclear engineering, University of Tokyo, Japan, 1981) joined JAERI in 1984. He has worked on development and verification of the REMOVAL code for LWR severe accident analysis. He is presently a visiting researcher at Sandia National Laboratories.

MEASUREMENT OF THE PHYSICAL PROPERTIES OF NUCLEAR AEROSOLS

Alan L. Nichols
Jolyon P. Mitchell

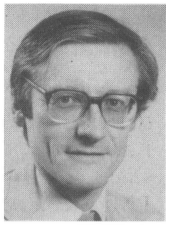


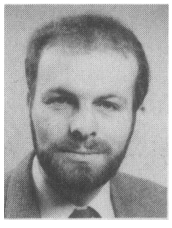
Alan L. Nichols (right) (PhD, physical chemistry, University of Leeds, United Kingdom, 1972) is a section leader at the Atomic Energy Establishment Winfrith (AEEW), U.K. Atomic Energy Authority. He has worked on Mössbauer spectroscopy, positronium chemistry, cyclotron production of radionuclides, and the

measurement and evaluation of radionuclide decay data. Currently, he is responsible for research and development studies in aerosol science and chemical aspects of hypothetical severe reactor accidents, as well as managing a wide range of analytical chemistry services within AEEW. **Jolyon P. Mitchell** (right) (PhD, physical chemistry, University of Salford, United Kingdom, 1976) is a project officer at AEEW. He gained experience in design and construction of gas and vapor detection equipment before joining AEEW to evaluate and develop a wide range of aerosol analysis equipment.

CHEMICAL CHARACTERIZATION OF NUCLEAR AEROSOLS

Alan L. Nichols
Brian R. Bowsher

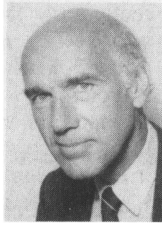




Alan L. Nichols (top) (PhD, physical chemistry, University of Leeds, United Kingdom, 1972) is a section leader at the Atomic Energy Establishment Winfrith (AEEW), U.K. Atomic Energy Authority. He has worked on Mössbauer spectroscopy, positronium chemistry, cyclotron production radionuclides, and the measurement and evaluation of radionuclide decay data. Currently, he is responsible for research and development studies into aerosol science and chemical aspects of hypothetical severe reactor accidents, as well as managing a wide range of analytical chemistry services within AEEW. **Brian R. Bowsher** (PhD, inorganic chemistry, University of Southampton, United Kingdom, 1982) is a project officer at AEEW. He has worked on crown ether chemistry and the characterization of high-temperature vapors by matrix isolation-infrared spectroscopy. Currently, he is responsible for research studies into chemical aspects of hypothetical severe accidents in pressurized water reactors.

SAFETY CONTAINMENT BUILDINGS AS BARRIERS AGAINST PARTICULATE RADIOACTIVITY RELEASE UNDER ACCIDENT CONDITIONS

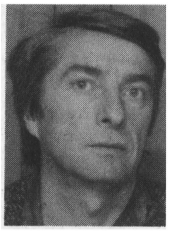
Joop F. van de Vate

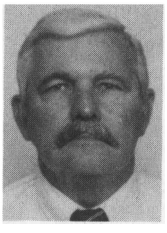


Joop F. van de Vate (PhD, chemistry, State University of Utrecht, The Netherlands; doctoral thesis, Agricultural University, The Netherlands, 1980) is scientific managing director of the Netherlands Energy Research Foundation (ECN) at Petten. He joined ECN in 1963 and has been active in aerosol research (nuclear safety and general aspects) since 1973 when he became manager of the Aerosol Research Group. He was president of the Netherlands Aerosol Study Group of the Netherlands Air Cleaning Association from 1970 to 1983.

EXPERIMENTS ON LIQUID-METAL FAST BREEDER REACTOR AEROSOL SOURCE TERMS AFTER SEVERE ACCIDENTS

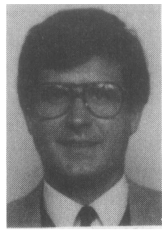
Georges Berthoud
Albert W. Longest
Anthony L. Wright
Wolfgang P. Schütz

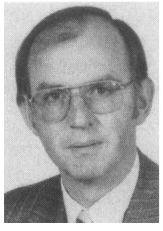




Georges Berthoud (top) (PhD, engineering, Institut National des Sciences et Techniques Nucléaires, 1973) joined the Heat Transfer Laboratory at Centre d'Etudes Nucléaires de Grenoble in 1976. He has worked in the area of multiphase multicomponent modeling, in particular fuel/coolant interaction, freezing, and instabilities. **Albert W. Longest** (bottom) (BS, chemical engineering, Virginia Polytechnic Institute and State University, 1959; graduate, Oak Ridge School of Reactor Technology, 1962) joined Oak Ridge National Laboratory (ORNL) in 1960. He has

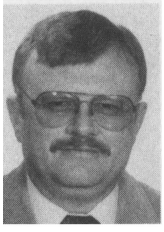
27 years' experience in irradiation testing of reactor fuels and structural materials and in performing out-of-reactor safety experiments to investigate the behavior of Zircaloy cladding and various aerosols under simulated reactor accident conditions. He was project leader responsible for the liquid-metal fast breeder reactor (LMFBR) source term experiments in the Fuel Aerosol Simulant Test facility from 1983 to 1984 and project engineer responsible for conducting single and multicomponent light water reactor (LWR) aerosol experiments in the Nuclear Safety Pilot Plant from 1984 to 1986. **Anthony L. Wright** (top) (PhD, aeronautical engineering, University of Minnesota, 1976) is a research staff member at ORNL. His current interests relate to aerosol behavior in LWR core-melt accidents, including the performance of aerosol deposition and resuspension experiments and the validation of aerosol-transport computer codes. **Wolfgang P. Schütz** (bottom) (Dr. rer. nat., nuclear physics, Technische Hochschule Darmstadt, 1974) joined the Laboratory for Aerosol Physics and Filter Technology at the Kernforschungszentrum Karlsruhe in 1976. He is leader of the LMFBR source term group since 1982. His current interests relate to nuclear aerosols in LMFBR safety, source terms, heat and mass transfer in the cover gas, and aerosol filtration.

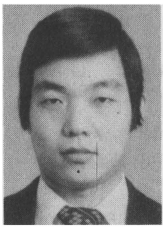


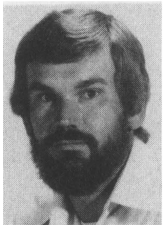


AEROSOLS RELEASED IN ACCIDENTS IN REPROCESSING PLANTS

Marcel Y. Ballinger
Peter C. Owczarski
K. Hashimoto
G. Nishio
S. Jordan
W. Lindner



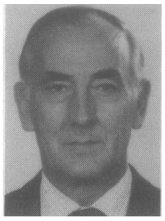




Marcel Y. Ballinger (top right) (BS, chemical engineering, Oregon State University, 1975) has been developing methods for estimating radioactive source term releases from accidents in nonreactor fuel cycle facilities for the past 7 years. She is currently a research engineer in the Atmospheric Physics and Chemistry Section at Battelle Pacific Northwest Laboratories (PNL). **Peter C. Owczarski** (top left) (BS, 1962, and PhD, 1967, chemical engineering) is a senior research engineer in the atmospheric sciences department at PNL. He has been studying the formation, transport, and deposition of aerosols within nuclear facilities. **K. Hashimoto** (center right) (BS, electrical engineering, Keio University, Japan, 1976) is a research engineer at the Japan Atomic Energy Research Institute (JAERI). He is presently engaged in severe fuel damage research for light water reactors (LWRs). He is currently interested in the pool scrubbing effect for aerosols under LWR severe accident conditions. He was previously engaged in the solvent fire test program for reprocessing plants. **G. Nishio** (center left) (chemical engineering, Professional Technology School of Tokyo Institute of Technology, Japan, 1957) is a principal engineer at JAERI. For the past 5 years, he has evaluated safety methods of postulated accidents in a spent-fuel reprocessing plant in the event of solvent fires and explosions. He was previously engaged in the field of safety research for reactor containment spray tests in the event of an LWR loss-of-coolant accident, and the aerosol behavior in the containment in the event of fast breeder reactor accidents. **S. Jordan** (bottom right) [PhD, physical chemistry, University of Mainz, Federal Republic of Germany (FRG), 1967] is a senior scientist and division head at Kernforschungszentrum Karlsruhe (KfK). His current interests in the area of nuclear safety are aerosol physics and filter technology. **W. Lindner** (bottom left) (engineer, Technical University of Essen, FRG, 1968) has worked since 1968 at KfK in the area of nuclear safety. His current interest is the formation and filtration of accident aerosols.

AEROSOL BEHAVIOR AND LIGHT WATER REACTOR SOURCE TERMS

Frank Abbey
Wolfgang O. Schikarski



Frank Abbey (top) (MA, natural sciences, Cambridge University, United Kingdom, 1955) began his career with the chemical engineering research laboratories of Courtaulds Limited. In 1960 he moved to the U.K. Atomic Energy Authority and is currently a member of the Safety and Reliability Directorate (SRD). He has worked on nuclear criticality safety, radioactive source terms, off-gas and air cleaning systems, environmental consequences of accidents, and nonnuclear safety. He is currently in charge of source term and environmental consequences research for SRD.
Wolfgang O. Schikarski (Dr. rer. nat., University of Karlsruhe, Federal Republic of Germany, 1957) has been director of the Laboratory for Aerosol Physics and Filter Technology at Kernforschungszentrum Karlsruhe since 1975. He is also a professor in the Department of Energy Engineering at the University of Stuttgart. He has worked for more than 20 years in aerosol science and is presently the president of the International Aerosol Research Assembly. His current interests are radiological source terms and nuclear aerosol behavior, aerosol research in connection with off-gas cleaning of coal burners, and atmospheric aerosol physics and chemistry.