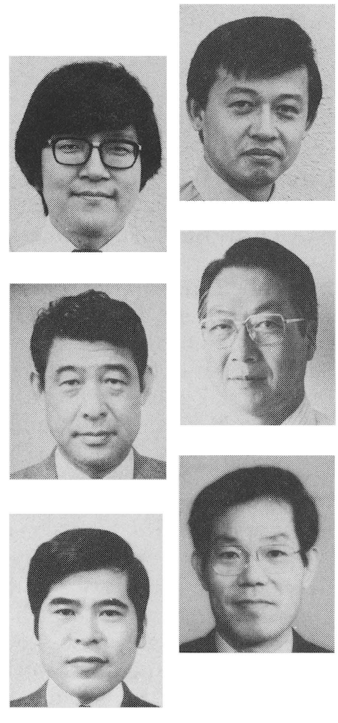
nuclear technology®

AUTHORS — SEPTEMBER 1984

STATUS OF METALLIC MATERIALS DEVELOPMENT FOR APPLICATION IN ADVANCED HIGH-TEMPERATURE GAS-COOLED REACTORS

IMPURITY GAS EFFECTS ON FRICTION AND WEAR OF HIGH-TEMPERATURE MATERIALS FOR VHTRs

Kenji Kikuchi
Hideo Kaburaki
Konomo Sanokawa
Katsuyuki Kawaguchi
Masaaki Nemoto
Shintaro Watanabe



Kenji Kikuchi (top right) (M. Eng., mechanical engineering, Tohoku University, 1977) is a research fellow of Thermal Structure Laboratory (TSL). He is involved in studying the strength and fracture of reactor core structures and high-temperature materials. **Hideo Kaburaki** (top left) (D. Sc., physics, Tokyo Institute of Technology, 1980) is also a research fellow of TSL. He is engaged in fluid-dynamic tests of very high-temperature gas-cooled reactors. **Konomo Sanokawa** (center right) (D. Eng., mechanical engineering, Tokyo University, 1968) is assigned to the Department of High Temperature Engineering, Japan Atomic EnergyResearch Institute. He has been associated with the study of heat transfer in nuclear reactors. **Katsuyuki Kawaguchi** (center left) (D. Eng., mechanical engineering, Tokyo University, 1974) is a project manager in charge of advanced energy systems at Mitsubishi Heavy Industries Ltd. (MHI). **Masaaki Nemoto** (bottom right) (M. Eng., mechanical engineering, Tokyo University, 1966) is a senior research engineer at MHI. His interest lies in the friction and wear of machine elements. **Shintaro Watanabe** (bottom left) (M. Eng., mechanical engineering, Kyushu University, 1974) is a research engineer at MHI, working in the field of the friction and wear of machine elements.

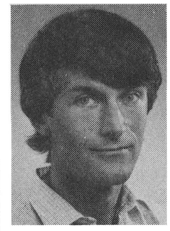
DEVELOPMENT OF PROTECTIVE COATINGS AGAINST PRIMARY COOLANT CORROSION, FRICTION, AND WEAR

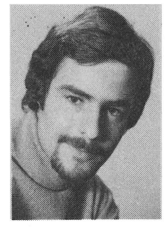
W. Thiele
Günter Lehnert

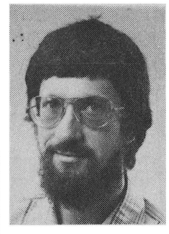
W. Thiele (top) (Dr. rer. nat., physical chemistry, Free University, Berlin, 1961) is head of the materials and reactor chemistry group at HRB Mannheim. His main interest lies in the behavior of metallic and graphitic materials under conditions found in high-temperature gas-cooled reactor circuits. **Günter Lehnert** (PhD, metallurgy and physical chemistry, Technical University of Aachen, 1961) has worked at Thyssen Specialty Steels Corporation Ltd., Krefeld, since 1961. He is presently manager of coating operations.

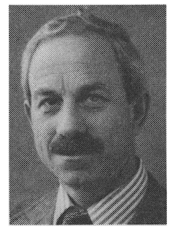
THE TRIBOLOGICAL BEHAVIOR OF TUBE SUPPORTS IN HELIUM HEAT EXCHANGERS

Marc-Olivier Borel
André Corthay
Heinz Fischli
Hans W. Fricker





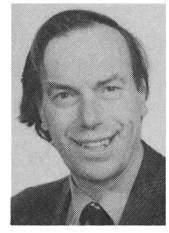


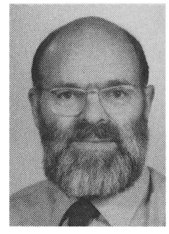


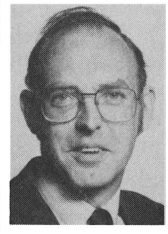
Marc-Olivier Borel (top right) (metallurgy engineer, Lausanne, Switzerland, 1977) works in the R&D department in the tribology sector at Sulzer Brothers, Ltd., Winterthur. Parallel to fundamental work on the wear of cast iron, he performs model and field tests, particularly for heat exchanger tubes and spacers. **André Corthay** (top left) (mechanical engineer, Lausanne Engineering School, 1977) works on the research and design of nuclear heat exchangers. Currently he is engaged in tests on friction wear as well as design and fabrication of heat exchanger prototypes for the Sulzer nuclear engineering department in Winterthur. **Heinz Fischli** (bottom right) (mechanical engineer, Zürich, Switzerland, 1978) has performed development work for the German-Swiss High Temperature Gas Turbine Project since 1974, parallel to his engineering studies. He is currently in charge of heat exchanger design in the nuclear engineering department at Sulzer, Winterthur. **Hans W. Fricker** (bottom left) (mechanical engineer, Burgdorf, Switzerland, 1956) did research on gas turbine components at Escher Wyss, Zürich, from 1956 to 1959, and on friction in high-temperature reactor atmospheres at the Dragon Project, Winfrith, England, from 1959 to 1964. He is currently in charge of the new technologies group in the nuclear engineering department at Sulzer, Winterthur.

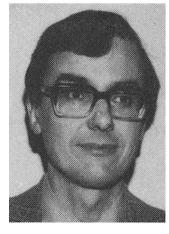
DEVELOPMENT OF A CHEMICAL VAPOR DEPOSITION SILICA COATING FOR U.K. ADVANCED GAS-COOLED NUCLEAR REACTOR FUEL PINS

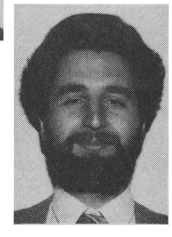
Michael J. Bennett
Michael R. Houlton
Donald A. Moore
Alan I. Foster
Michael A. M. Swidzinski







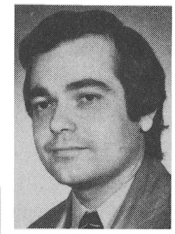




Michael J. Bennett (top right) (PhD, physical chemistry, Imperial College, London, 1957) heads the high-temperature corrosion section of the Materials Development Division at the Atomic Energy Research Establishment (AERE), Harwell. He has undertaken extensive studies of the interaction of gases and solids with metals and ceramics for use in Magnox, advanced gas-cooled reactors (AGRs), high-temperature gas-cooled reactors, and gas breeder reactors. He has authored more than 100 papers and books. **Michael R. Houlton** (top left) (BSc, London, 1949) is a scientist in the Materials Development Division at AERE. He has been involved in both isotope and ceramic development and now is concerned primarily with the high-temperature corrosion behavior of AGR materials. **Donald A. Moore** (center right) (BSc, London University, 1959) is a metallurgist at the Springfields Nuclear Power Development Laboratories of the U.K. Atomic Energy Authority. He has been engaged for many years in the development of ceramics for use in nuclear reactors at high temperatures and is currently working on protective silica coatings for gas-cooled reactor fuel cladding steels. **Alan I. Foster** (bottom right) (PhD, inorganic chemistry, City University, London, 1974) is a senior chemist in the New Technology Division of the British Petroleum (BP) Research Centre, Sunbury-on-Thames. His scientific career has involved surface science, heterogeneous catalysis, and inorganic coating development (specializing in chemical vapor deposition processes). **Michael A. M. Swidzinski** (bottom left) (PhD, materials science, Imperial College, London, 1980) is a metallurgist in the New Technology Division of the BP Research Centre, Sunbury-on-Thames. He started his scientific career in the high-temperature corrosion of gas turbine alloys and is now engaged in the development and evaluation of inorganic coating systems.

PHYSICAL BEHAVIOR OF THERMAL BARRIERS IN HIGH-TEMPERATURE GAS-COOLED REACTOR CONDITIONS

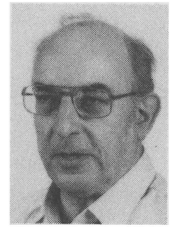
J. J. Quillico
P. J. Despresles

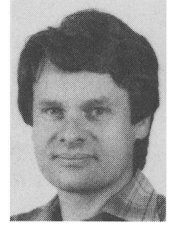


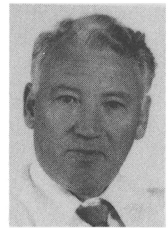
J. J. Quillico (top) (mechanical engineering, CNAM, Paris) has been with the Commissariat à l'Energie Atomique (French Atomic Energy Authority) since 1963. He has worked 14 years at Fontenay-aux-Roses Nuclear Research Center in the solid physics field. In 1977 he joined the Saclay Nuclear Research Center where he is in charge of studies on the thermal and mechanical behavior of reactor structural components. **P. J. Despresles** (CAP, mechanical studies, Paris) worked from 1940 until 1955 in the aircraft industry and then joined the Saclay Nuclear Research Center. His interests include the conceptual design and the manufacturing of test rigs devoted to reactor component thermal and mechanical studies.

TERMS AND RESULTS OF HYDROGEN PERMEATION TESTING OF OXIDE-SCALED HIGH-TEMPERATURE ALLOYS

Josef Schaefer
Detlev Stöver
Rudolf Hecker



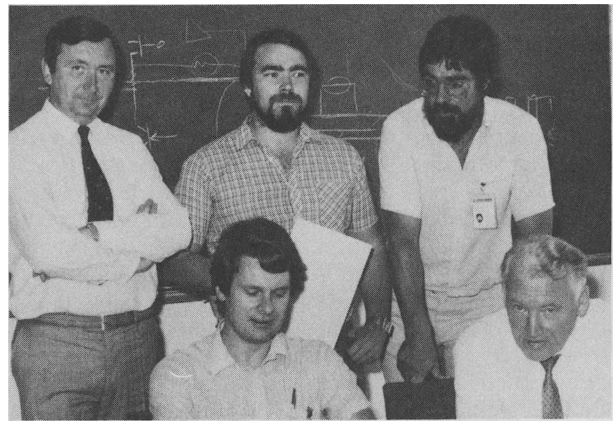




Josef Schaefer (top) (Dipl. Chem., University of Bonn, 1945) gained experience in gas-phase technology by leading the industrial production of inorganic compounds. Since 1972, he has been investigating hydrogen permeation through high-temperature alloys in contact with chemical process gas compositions at the Institut für Reaktorentwicklung (IRE) at Kernforschungsanlage (KFA)-Jülich. **Detlev Stöver** (center) (Dr. rer. nat., nuclear engineering, Technische Hochschule Aachen, 1972) leads the Reactor Technology Section in the IRE at KFA-Jülich. He has worked on fission product transport in high-temperature gas-cooled reactor (HTGR) fuel since 1972. His technical interest has changed to tritium release problems and now is focused on the investigation of tritium permeation in metallic and ceramic materials. **Rudolf Hecker** (bottom) (Prof., Technische Hochschule Aachen; Dr. rer. nat., University of Cologne) is a director at the IRE, KFA-Jülich. He is mainly concerned with reactor technology, especially HTGR, and fusion reactor technology. He is also interested in the prospects of advanced nuclear systems.

ADVANCES IN THE DEVELOPMENT AND DESCRIPTION OF TRITIUM PERMEATION BARRIERS IN HIGH-TEMPERATURE ALLOYS

Hans Peter Buchkremer
Rudolf Hecker
Heinz Jonas
Detlev Stöver
Uwe Zink

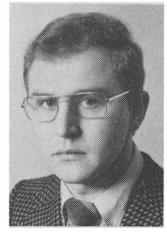


Hans Peter Buchkremer (standing, right) (Dr. Ing., mechanical engineering, Technical University of Aachen, 1975) has been employed at the Institut für Reaktorentwicklung (IRE) of Kernforschungsanlage (KFA) Jülich since 1975. He works on problems of hydrogen and tritium permeation of high-temperature gas-cooled reactors (HTGRs) for process heat applications. His interests include the development of oxide layers on high-temperature materials, which are extremely impermeable for hydrogen isotopes, and the planning and improvement of the operating test facilities. **Rudolf Hecker** (seated, right) (Prof., Technische Hochschule Aachen; Dr. rer. nat., University of Cologne) is a director at the IRE, KFA-Jülich. He is mainly concerned with reactor technology, especially HTGR, and fusion reactor technology. He is also interested in the prospects of advanced nuclear systems. **Heinz Jonas** (standing, left) (Dr. rer. nat., Technical University of Aachen, 1974) has been engaged in experiments at KFA-Jülich since 1962. Previously, he worked on reactor instrumentation and neutron spectroscopy at the IRE. He

is now working there on hydrogen permeation studies in connection with acoustic emission technics. **Detlev Stöver** (seated, left) (Dr. rer. nat., nuclear engineering, Technische Hochschule Aachen, 1972) leads the Reactor Technology Section in the IRE at KFA-Jülich. He has worked on fission product transport in HTGR fuel since 1972. His technical interest has changed to tritium release problems and now is focused on the investigation of tritium permeation in metallic and ceramic materials. **Uwe Zink** (standing, center) (Dipl.-Ing., Technical University Aachen, 1979) has worked on hydrogen permeation in HTGRs at the IRE at KFA-Jülich since finishing his studies in nuclear engineering. His main interests lie in the investigation of the correlation between permeation of hydrogen isotopes and the buildup of oxide scales on the process gas side of steam reformer tubes.

PROTECTIVE LAYERS ON HIGH-TEMPERATURE ALLOYS AGAINST HYDROGEN PERMEATION

Hans Huschka
Guenther Luthardt
Volker E. Portscher



Hans Huschka (top) (PhD, University of Vienna, 1958) is head of the R&D department at NUKEM. He has more than 20 years' experience in the nuclear industry, particularly with regard to fuel cycle requirements. His responsibilities currently are finite element development for high-temperature gas-cooled, liquid-metal fast breeder, and materials test reactors as well as high, medium, and low active waste management. **Guenther Luthardt** (center) (MS and PhD, chemistry, University of Mainz, 1967) has been engaged in nuclear fission experiments. He is currently a senior scientist at NUKEM where he is responsible for material science. His interests also involve tritium technology, which comprises handling and storage of tritium, T-box technology, and target production for medical and physical applications. **Volker E. Portscher** (bottom) (BS, chemistry, Ohm-Polytechnikum Nürnberg, 1966) has an electrochemical background through R&D activities in the battery field. At present he is an assistant scientist at NUKEM where he is concerned with corrosion studies, such as material problems with UF_6 enrichment and waste disposal, as well as developing oxide coatings.

DEVELOPMENT OF PROTECTIVE COATINGS TO REDUCE HYDROGEN AND TRITIUM PERMEATION

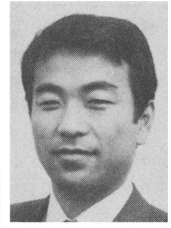
August Mühlratzer
Hans Zeilinger
Hans Günter Esser

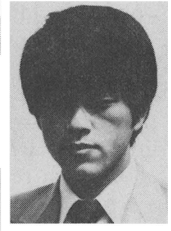
August Mühlratzer (right) (Dr. rer. nat., chemistry, University of Munich, 1977) wrote his dissertation on isothermal chemical transport dealing with the preparation of alloy and intermetallic compound coatings and superconducting phases. Now with the Maschinenfabrik Augsburg-Nürnberg (M.A.N.), R&D department, Neue Technologie in Munich, he is engaged in surface technology: special areas of chemical vapor deposition (anti-wear coatings, solar absorber coatings) and oxidation of alloys. **Hans Zeilinger** (center) (Dr.-Ing., metallurgy, Montanuniversitaet Leoben, Austria, 1960) wrote his dissertation on the heat treating of low and medium alloyed steels from forging temperatures in 1968. He was an assistant with Stahl- u. Roehrenwerke Reisholz GmbH, Duesseldorf, then engaged in the forging and foundry workshop of Krauss-Maffei, Munich, and became a chief metallurgist. Since 1970, he has been the chief metallurgist in the R&D department, Neue Technologie of M.A.N. His main areas of interest are high-strength steels, composite materials, high-temperature alloys, and surface metallurgy. Since 1980, he has also lectured at Ruhruniversität, Bochum. **Hans Günter Esser** (left) (diploma, physics, Technical University of Aachen, 1979)

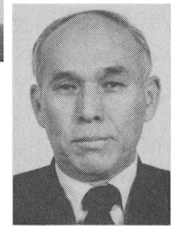
is now working on a dissertation in the field of hydrogen permeation (high-temperature reactors for process heat applications) at the Institut für Reaktorentwicklung, Kernforschungsanlage-Jülich. His main interests are designing and operating an ultrahigh vacuum test facility for the investigation of the deuterium permeation through coated high-temperature materials.

HYDROGEN PERMEATION IN METALS DURING EXPOSURE TO A PROCESS GAS ENVIRONMENT

Naoki Kishimoto
Tatsuhiko Tanabe
Hiroshi Araki
Heitaro Yoshida
Ryoji Watanabe



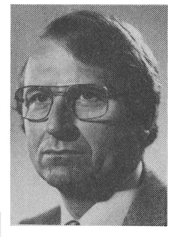
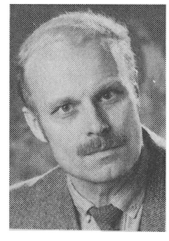




Naoki Kishimoto (top right) (PhD, physics, University of Tokyo, 1977) has worked at the National Research Institute for Metals (NRIM) as a member of a research project on direct steelmaking, using high-temperature reducing gas [high-temperature gas-cooled reactor (HTGR) program] since 1978. His special interests have been environmental effects on hydrogen permeation of reactor materials and corrosion at low-oxygen potential. He is currently involved in simulation studies of radiation damage of stainless steel. **Tatsuhiko Tanabe** (top left) (Dr. eng., metallurgy, University of Tokyo, 1963) is a senior researcher at NRIM. He has been involved in the HTGR program as a chief researcher since 1975. His interests include studies on mechanical properties and development of structural materials in reactor environments. **Hiroshi Araki** (center right) (mechanical engineering, Katsuta Technical High School, 1976) has worked at NRIM since 1976. He has been involved in the HTGR program as a researcher. He is currently in charge of electron probe microanalysis studies. His primary interest is in quantitative microanalysis of reactor materials. **Heitaro Yoshida** (bottom left) (Dr. eng., metallurgy, Kyoto University, 1952) has been in charge of implementing the HTGR program at NRIM. He is currently director of the Material Strength Division at NRIM. His main interests are mechanical properties of heat-resistant alloys for reactor environments. **Ryoji Watanabe** (bottom right) (Dr. eng., metallurgy, Hokkaido University, 1945) has been director of the Nuclear Materials Division and is responsible for the HTGR program. He is currently working in the Special Purpose Materials Division. He has been active in studying refractory metals and phase stability of nuclear materials.

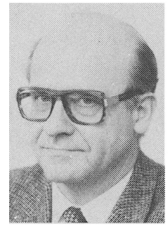
INVESTIGATIONS INTO THE IRRADIATION BEHAVIOR OF HIGH-TEMPERATURE ALLOYS FOR HIGH-TEMPERATURE GAS-COOLED REACTOR APPLICATIONS

Bernd A. Thiele
Hermann Diehl
Wilhelm Ohly
Heinz Weber

Bernd A. Thiele (top) (Dipl.-Ing., metallurgy, Technical University of Aachen, 1963) has been employed at the Nuclear Research Center Kernforschungsanlage (KFA), Jülich, since 1964. His special interest is the irradiation behavior of metals. **Hermann Diehl** (bottom) (Dr.-Ing., mechanical engineering, Technische Hochschule Darmstadt, 1977) was instructor for materials technology and testing after graduation in 1966 and worked on several research programs for creep resisting steels and on failure analysis for service loaded components at the Institute for Materials Technology of the Technische Hochschule Darmstadt. In 1977 he moved to KFA-Jülich, where he spent nearly two years at the Institute for Reactor Materials in the field of organization of the

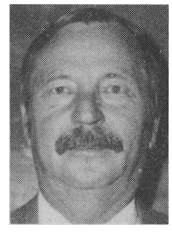
high-temperature gas-cooled reactor (HTGR) material programs and of evaluation of materials data for design. Since 1979 he has worked at Hochtemperatur Reaktorbau GmbH, Mannheim, on material problems for HTGR projects as well as for the commercial Thorium High-Temperature Reactor in construction. He is leader of the subgroup "Materials Under Irradiation" of the PNP materials program. **Wilhelm Ohly** (top) (Dipl.-Phys., Dr. rer. nat., physics, Technical University of Aachen, 1968) is employed at Interatom, Bensberg. His special interests include irradiation behavior of metals, metallurgy, and materials research. **Heinz Weber** (bottom) (Dr.-Ing., metallurgy, Technische Hochschule Aachen, 1968) is employed by the Mannesmann Forschungsinstitut (research institute) and is section leader of the working group for metallurgy. He is involved in examination and control of components in chemical plants and power stations.



IRRADIATION EFFECTS ON HIGH-TEMPERATURE GAS-COOLED REACTOR STRUCTURAL MATERIALS

James R. Lindgren

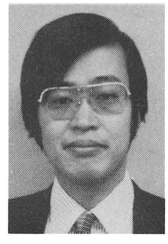
James R. Lindgren (BS, metallurgical engineering, Michigan Technical University, 1952) is on the research staff for metallurgical engineering at GA Technologies Inc. He is involved in fabrication development and testing of structural materials for the high-temperature gas-cooled reactor and previously was involved in irradiation testing of fuels and materials for the gas-cooled fast reactor.

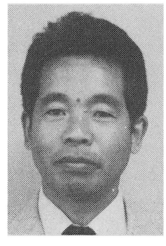


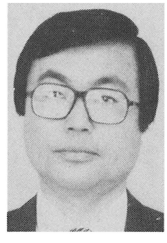
TEMPER AND NEUTRON IRRADIATION EMBRITTLEMENT IN $2\frac{1}{4}$ Cr–1 Mo STEELS FOR PRESSURE VESSELS OF HIGH-TEMPERATURE GAS-COOLED REACTORS

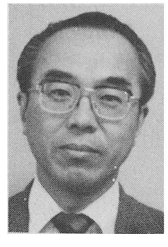
Masahide Suzuki
Kiyoshi Fukaya
Tsuneo Kodaira
Tatsuo Oku

Masahide Suzuki (top right) (M. Eng., nuclear engineering, Tokyo University, 1978) is a research engineer in the Materials Strength Laboratory (MSL), Japan Atomic Energy Research Institute (JAERI). He is involved in clarifying the metallurgical factors that affect the temper brittleness and neutron irradiation embrittlement of low alloy steels for nuclear reactor structural materials. **Kiyoshi Fukaya** (top left) (metallurgical engineering, Mito Technical High School, 1960) started his technical career in the field of electron microscopy of nuclear reactor materials and is presently engaged in the evaluation of embrittlements of structural materials for the very high-temperature reactor (VHTR) as a member of the engineering service section of JAERI. **Tsuneo Kodaira** (bottom right) (Dr. Eng., M. Eng., materials engineering, Tohoku University, 1968) is a senior engineer in the MSL, JAERI. He is engaged in the evaluation of the structural integrity of reactor components of the VHTR and is also interested in the development of surveillance techniques based on fracture mechanics for the vessels of light water reactors. **Tatsuo Oku** (bottom left) (Dr. Eng., M. Eng., applied physics, Waseda University, 1960) is a principal engineer and general manager of the MSL, JAERI, where he is studying the mechanical and physical properties of nuclear materials with particular interests in radiation effects in graphites and low alloy steels.



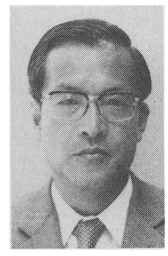


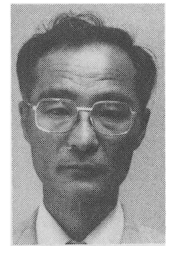




POSTIRRADIATION TENSILE AND CREEP PROPERTIES OF HEAT-RESISTANT ALLOYS

Katsutoshi Watanabe
Tatsuo Kondo
Yutaka Ogawa

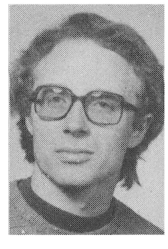
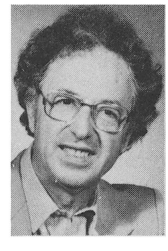
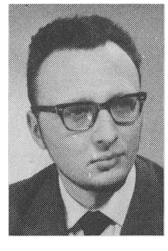




Katsutoshi Watanabe (top) (BS, metallurgical engineering, Ibaraki University, 1962) is employed at the Japan Atomic Energy Research Institute (JAERI) Materials Engineering Laboratory. He is presently engaged in the R&D of heat-resistant alloys for high-temperature gas-cooled reactor (HTGR) applications. **Tatsuo Kondo** (center) (BS, metallurgical engineering, Tohoku University; MS, 1963, and PhD, 1965, The Ohio State University) has been employed at JAERI since 1958 and is deputy director of the fuels and materials department. He has worked in the areas of corrosion-assisted fracture of metals in reactor environments and alloy development. He presently supervises the material research programs for HTGRs, light water reactors, and nuclear fusion. **Yutaka Ogawa** (bottom) (Dr. Eng., Tohoku University, 1977) works in the area of creep testing of heat-resistant alloys in simulated HTGR helium environments at JAERI. Formerly, he studied the effect of irradiation on high-temperature creep behavior of heat-resistant alloys.

INFLUENCE OF THERMAL NEUTRONS ON THE BRITTLENESS OF HIGH-TEMPERATURE GAS-COOLED REACTOR LINER STEEL

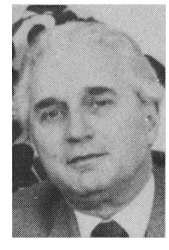
A. Alberman
G. Bley
P. Pépin
P. Soulat

A. Alberman (top right) (MSc, University of Paris, 1973; graduate, solid state physics, University of Orsay, 1974) joined the research reactor physics and dosimetry group at the Saclay Nuclear Research Center in 1975. He is now in charge of R&D in the field of radiation damage dosimetry involving in-pile experiments with damage monitors and particular applications [pressurized water reactor (PWR) pressure vessel surveillance programs]. **G. Bley** (top left) (MS, physical chemistry; D.E.A., special metallurgy, University of Paris) is a physicist and engineer and worked from 1975 to 1979 at Saclay Nuclear Research Center on irradiations of structural materials in research reactors and on the development of a hot source for the ORPHEE reactor. In 1980, he joined the Paul Langevin–Max von Laüe Institute at Grenoble where he is in charge of design and safety studies for the high flux reactor second cold source. **P. Pépin** (bottom right) (engineer; MS, mathematics, University of Montpellier) joined the Fontenay-aux-Roses Nuclear Research Center in 1957 and was assigned to reactor shielding studies. Since 1970 he has been involved in high-temperature gas-cooled reactor R&D at the Saclay Nuclear Research Center and he is currently performing PWR safety studies. **P. Soulat** (bottom left) (engineer, Industrial Electricity and Mechanical Engineering Institute, Paris; welding engineer, Welding Institute, Paris) has worked at the Nuclear Research Center in Saclay since 1962 where he has been involved in structural material research mainly on fracture mechanics and irradiation effects.

STATUS OF STRUCTURAL DESIGN CODE FOR METALLIC HIGH-TEMPERATURE GAS-COOLED REACTOR COMPONENTS

Hubertus Nickel
Florian Schubert

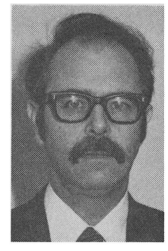


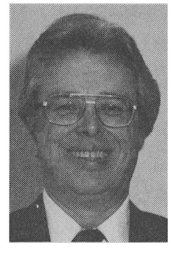
Hubertus Nickel (right) (Dr. rer. nat., chemistry, Technical University of Aachen, 1959) is head of the Institute for Reactor Materials (IRM) at Kernforschungsanlage Jülich (KFA-Jülich). He is also a full professor of reactor materials and nuclear fuel elements at the Technical University of Aachen and is a member

of the German Reactor Safety Commission. **Florian Schubert** (right) (Dipl.-Physicist, University of Saarland, 1968; Dr. rer. nat., Technical University of Aachen, 1974) is head of the materials evaluation office of IRM, KFA-Jülich. He is chairman of the materials working group of the German R&D company of high-temperature reactors, Entwicklungsgemeinschaft HTR. Before joining KFA-Jülich, he was involved in the R&D of high-temperature superalloys at Thyssen Special Steel Works and Thyssen Investment Casting Works, both in the field of metallurgy and processing. He is currently working on developing a design code for high temperatures, such as multiaxial creep, creep ratcheting, creep buckling, and lifetime prediction.

HIGH-TEMPERATURE STRUCTURAL ENGINEERING DATA NEEDS

Peter Thomas Hughes
Donald C. Allen

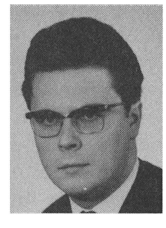


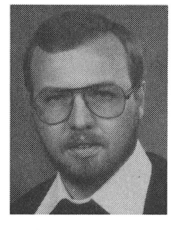


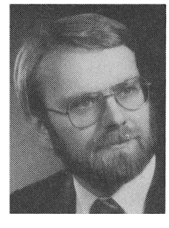
Peter Thomas Hughes (top) (BSc, aeronautical engineering, London, 1961; MSc, aeronautical engineering, Cranfield, U.K., 1964) is employed by the General Electric Company, Advanced Nuclear Technology Operation. He is responsible for U.S. Department of Energy funded work to develop the methods, procedures, and data for the structural design of gas reactor components operating at temperatures to 950°C. His principal interests include structures and the structural systems of advanced reactor types. **Donald C. Allen** (BSc, mechanical engineering, University of Maryland, 1962; MBA, University of Santa Clara, 1975) is a principal project engineer on the Gas Reactor Program, General Electric Company. He has worked in the nuclear field developing components and materials for thermionic, liquid-metal-cooled, and gas-cooled reactors. His current technical interests are in developing reformer and methanator components and systems for use in advanced applications of the high-temperature gas-cooled reactor to fulfill the future energy demands of the industrial process heat user.

MATERIAL BEHAVIOR UNDER COMPLEX LOADING

Erik Bodmann
Hans-Jürgen Breuer
Gerhard Raule
Manfred Rödig



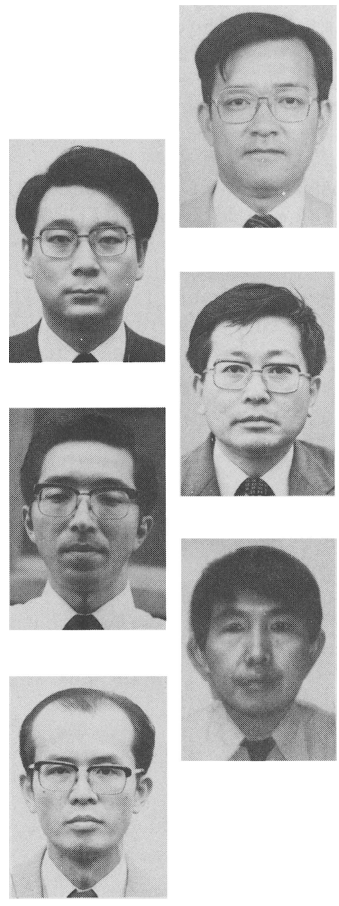




Erik Bodmann (top right) (Dipl.-Ing., Technical University of Hanover, 1966) was involved in the development of flight-gas turbines at Klöckner-Humboldt-Deutz AG until 1974, responsible for the stress calculations; thereafter he was responsible for the structural mechanics of high-temperature gas-cooled reactors (HTGRs) at Hochtemperatur-Reaktorbau GmbH and, since 1980, also for the field of materials. **Hans-Jürgen Breuer** (top left) (Dipl.-Phys., Technical University of Aachen, 1978) has been involved in the field of low-cycle fatigue testing and determination of creep/fatigue interaction of ferritic steam generator materials in the Department of Structural Materials at Interatom, Bergisch Gladbach, since 1979. In the future he plans to examine multiaxial behavior of structural materials. **Gerhard Raule** (bottom right) (Dipl.-Phys., University of Heidelberg) is investigating the annealing behavior of neutron-induced voids in austenitic reactor materials by electron microscopy at the Nuclear Research Centre of Karlsruhe. Since 1978 he has been employed at Brown, Boveri & Cie, Ltd., Mannheim, and works on the mechanical behavior of HTGR materials. His interests lie in fatigue processes at high temperatures. **Manfred Rödig** (bottom left) (Dr. rer. nat., physics, Technical University of Aachen, 1979) works at Kernforschungsanlage Jülich in the field of fracture mechanics of graphite and ceramic materials. He deals with the mechanical behavior of high-temperature alloys, with special interest on fracture mechanics and multiaxial behavior.

LIFETIME TEST OF A PARTIAL MODEL OF A HIGH-TEMPERATURE GAS-COOLED REACTOR HELIUM-HELIUM HEAT EXCHANGER

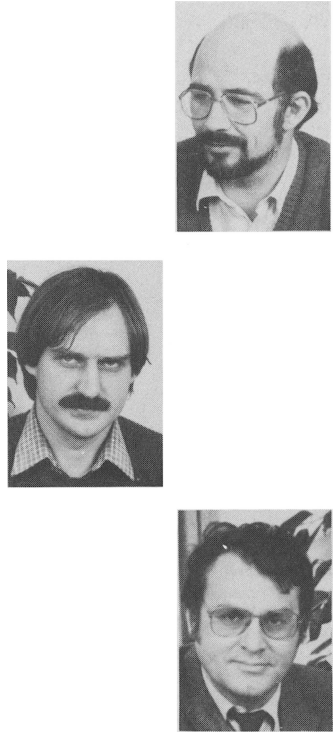
Masaki Kitagawa
Hiroshi Hattori
Akira Ohtomo
Tetsuo Teramae
Junichi Hamanaka
Hiroshi Ukikusa



Masaki Kitagawa (top right) (PhD, theoretical and applied mechanics, University of Illinois, 1967) is a chief research engineer in the metallurgy department of the Research Institute, Ishikawajima-Harima Heavy Industries Company, Ltd. (IHI). His field of interest is the creep-fatigue/environmental interaction studies and their applications to high-temperature components. He has recently been involved in the material strength research on nuclear components [fast breeder reactor and high-temperature gas-cooled reactor (HTGR)]. **Hiroshi Hattori** (top left) (MS, metallurgical engineering, Yokohama National University, Japan, 1975) is a member of the Research Institute of the IHI. He is engaged in the material strength studies for high-temperature components. His interest is creep-fatigue/environmental interaction at HTGR temperatures. **Akira Ohtomo** (center right) (metallurgical engineering, Tohoku University, Japan, 1958) is a manager of the Research Institute of the IHI. He has been involved in the study of corrosion and mechanical properties of the heat-resistant alloys. **Tetsuo Teramae** (center left) (PhD, engineering, Tokyo University, 1981) is a research staffer in the structure and strength department of the IHI. He is involved in numerical methods in structural analysis. **Junichi Hamanaka** (bottom right) (PhD, aeronautical engineering, Tokyo University, 1979) is a chief research engineer in the structure and strength department of the IHI. He is involved in the development of structural analysis methods. **Hiroshi Ukikusa** (bottom left) (MS, mechanical engineering, Tokyo University, 1967) is a chief design engineer with the energy development division of the IHI. He has been engaged in the development of the heat exchanging systems for HTGR and fusion reactors.

CONSTITUTIVE EQUATIONS FOR THE DESCRIPTION OF CREEP AND CREEP RUPTURE BEHAVIOR OF METALLIC MATERIALS AT TEMPERATURES ABOVE 800°C

Heinz-Josef Penkalla
Hans-Helmut Over
Florian Schubert

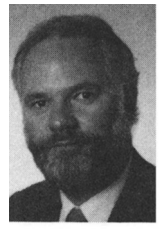


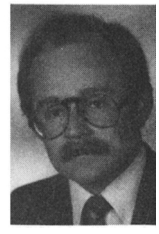
Heinz-Josef Penkalla (top) (Dipl.-Physicist, Dr. rer. nat., Technical University of Aachen, 1976) works on the development of design codes for high-temperature gas-cooled reactor (HTGR) components. Prior to joining Kernforschungsanlage (KFA)-Jülich in 1979, he was with the Joint Research Center of the European Communities in Petten, The Netherlands, for one year, where he studied the interaction of creep and carburization in process gases. **Hans-Helmut Over** (center) (Dipl.-Physicist, Dr. rer. nat., Technical University of Aachen, 1977) has been employed at the Nuclear Research Center, KFA-Jülich since 1980. Before joining KFA, he was involved in the development and testing of materials at Babcock Brown Boveri Reactor GmbH. He presently works on material problems concerning HTGR structural design codes. **Florian Schubert** (bottom) (Dipl.-Physicist, University of Saarland, 1968; Dr. rer. nat., Technical University of Aachen, 1974) is head of the materials evaluation office of the Institute for Reactor Materials at KFA-Jülich. He is chairman of the materials working group of the German Research and Development Company of HTR, Entwicklungsgemeinschaft HTR. Before joining KFA he was involved in R&D of high-temperature superalloys at Thyssen Special Steel Work and Thyssen Investment Casting Work, both in the fields of metallurgy and processing. He is currently

developing a design code for high temperatures, such as multiaxial creep, creep ratcheting, creep buckling, and lifetime prediction.

METHODS FOR NONDESTRUCTIVE TESTING OF AUSTENITIC HIGH-TEMPERATURE GAS-COOLED REACTOR COMPONENTS

Klaus Goebbels
Harald Kapitza





Klaus Goebbels (top) (Priv. Doz., Dr. rer. nat., metal physics, University of Saarbrücken, 1972) is currently head of the ultrasonics 2 division at the Fraunhofer Institute for Nondestructive Testing Techniques (IzfP), Saarbrücken. He is involved with the ultrasonic characterization of materials structure and stress as well as with the nondestructive testing (NDT) of coarse-grained materials. Additional activities are devoted to the development of NDT methods for high-temperature, high-strength ceramics. He has been a staff member since 1972 and vice-director of the institute since 1979. **Harald Kapitza** (Dipl.-Phys., Technical University Darmstadt, Hamburg University, 1975) has been a staff member of IzfP since 1979. He has been involved with the ultrasonic detection of hydrogen embrittlement and the ultrasonic structure characterization of materials. At present he is working (group leader) on the ultrasonic inspection of coarse-grained materials.