

AUTHORS — OCTOBER 1981

MATERIALS PERFORMANCE IN NUCLEAR STEAM GENERATORS

MATERIALS PERFORMANCE IN NUCLEAR PRESSURIZED WATER REACTOR STEAM GENERATORS

Stanley J. Green

J. Peter N. Paine

Stanley J. Green (top) (BS, chemical engineering, College of the City of New York, 1940; MS, chemical engineering, Drexel Institute of Technology, 1953; PhD, chemical engineering, University of Pittsburgh, 1968) is currently director of the Steam Generator Project Office of the Nuclear Power Division of Electric Power Research Institute (EPRI). This group is working on the thermal, hydraulic, chemistry, and materials aspects of pressurized water reactor (PWR) steam generators. From 1954 until joining EPRI in 1977, he worked at the Bettis Atomic Power Division of Westinghouse Electric Corporation. His last assignment there was manager of the reactor development and analysis activities. **J. Peter N. Paine** (BS, chemistry, Brigham Young University, 1959; MS, chemistry, University of Washington, 1964) is program manager for the Chemistry and Materials Program of the Steam Generator Project Office of EPRI. His previous experience was in chemistry, materials, and corrosion related to steam generators and advanced PWR systems at Westinghouse Electric Corporation.



MATERIALS PERFORMANCE IN CANDU NUCLEAR STEAM GENERATORS

G. F. Taylor

D. P. Dautovich

George F. Taylor (top) (PhD, surface radiochemistry, University of Glasgow, Scotland, 1967) is head of the System Materials Branch at Chalk River Nuclear Laboratories (CRNL). He came to CRNL in 1969 and conducted corrosion research in support of Canadian deuterium uranium reactors and heavy water production plants from then until 1978. He currently supervises research in reactor chemistry and waste processing as well as corrosion. **D. P. (Don) Dautovich** (PhD, metallurgy, University of New South Wales, Sydney, Australia) has been working in the field of corrosion since 1969. He was a research scientist at International Nickel until 1973 and since then has worked at the Ontario Hydro Research Division. He is currently the supervisor of the Corrosion and Thermal Plant Section.



STEAM GENERATOR MATERIALS PERFORMANCE IN HIGH TEMPERATURE GAS-COOLED REACTORS

J. E. Chafey

D. I. Roberts

J. E. Chafey (right) (BS, metallurgical engineering, Lehigh University; MS, metallurgical engineering, Columbia University) is a registered professional engineer with the state of California.



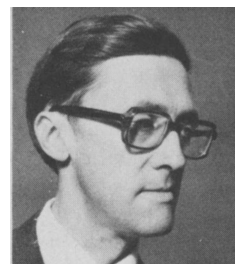
in metallurgical engineering and quality engineering. His career has included research, mill fabrication of ferrous and nonferrous metals, and the development and application of materials for nuclear power and for missiles and aerospace vehicles. He has held responsible positions with Chase Brass & Copper Co., General Dynamics, Fairchild Industries, and, currently, is project manager, Materials, General Atomic Company, San Diego, California. **D. I. Roberts** is manager of the Materials Engineering & Testing Department at General Atomic Company. In this position, he supervises a group responsible for the selection and qualification of materials for high temperature gas-cooled reactors, fusion reactors, and other advanced energy systems. His career has included involvement with materials for aerospace and water reactor applications during employment at General Electric Company, Philadelphia, Pennsylvania, and Rolls Royce & Associates, Derby, U.K. Educated at London University (U.K.), Roberts is a member of the Institution of Metallurgists (U.K.), a Chartered Engineer (U.K.) and registered as a professional engineer in California in the fields of metallurgical engineering and corrosion engineering.



EXPERIENCE IN OPERATING GAS-COOLED REACTOR STEAM GENERATORS OF U.K. DESIGN

D. W. James

D. W. James (BSc, MSc, PhD, metallurgy, University of Manchester) was elected to a fellowship of the Institution of Metallurgists (U.K.) in 1975 and is a chartered engineer. He has worked in the U.S. for Westinghouse Electric Corporation from 1963 to 1968. Since then, he has been employed by the Central Electricity Generating Board, U.K., currently at South Western Region Headquarters, Bristol. He leads a team of approximately 70 engineers and scientists covering the application of chemistry, physics, material science, tribology, and environmental science to power station problems. Approximately half of this effort is devoted to the advanced gas-cooled reactors at Hinkley Point.



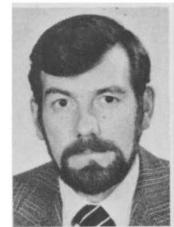
EXPERIENCE WITH LIQUID-METAL FAST BREEDER REACTOR STEAM GENERATORS—U.S. DESIGN

*C. C. Stone
J. A. Ford
F. E. Tippetts
J. S. McDonald
G. Grant
J. L. Epstein*

Cecil C. Stone (top) (BS, mechanical engineering, University of Washington, 1952) is a senior mechanical engineer at Argonne National Laboratory (ANL), Argonne, Illinois. He came to ANL in 1953 and has since had a continuing involvement in the development of steam generators for liquid-metal fast breeder reactors (LMFBRs). Among his early accomplishments were major contributions to the development of double-wall tube steam generators. More recently, he was responsible for technical management of two U.S. Department of Energy (DOE) contracts for the development of large-scale steam generators for future LMFBR plants. He is presently section manager for thermal/mechanical design in the Safety Research Experiment Facilities Project at ANL. **John A. Ford** (bottom) (BS, mechanical engineering, Lehigh University, 1959; MS, mechanical engineering, Rensselaer Polytechnic Institute, 1962) has been involved in nuclear systems and components research and development work since 1959. He was a section head at Atomic Power Development Associates in charge of systems and components for the Fermi reactor from 1964 to 1972, and



is currently director of the DOE Engineered Components Division. His activity at both organizations involved the development of components and systems for LMFBRs. **F. E. Tippetts** (top right) (PhD, mechanical engineering, Stanford University, 1962) has over 25 years of professional experience with the General Electric Company (GE) in engineering and development for nuclear power, including plutonium production reactors, the boiling water reactor, potassium Rankine cycle heat exchangers for space power systems, and, for the past 14 years, LMFBR. He is presently manager of component and systems design in the GE Advanced Reactor Systems Department, Sunnyvale, California, where he is responsible for engineering of components and systems for DOE-sponsored LMFBR and high temperature gas reactor programs at GE. He is a registered professional engineer in the state of California. **J. S. McDonald** (top left) (BS, University of Texas; MS, engineering, University of California at Los Angeles) is director of LMFBR programs at Atomics International Division, Energy Systems Group, Rockwell International. During his 23 years with the company, he has had several technical specialist and management positions including project management responsibilities for the design, manufacture, testing, and examination of the modular steam generator and the overall responsibility for the conceptual design studies and related hockey-stick steam generator scaleup studies. Prior to joining Atomics International, McDonald worked for Shell Oil Company and the U.S. Navy. **George Grant** (bottom right) (BS, mechanical engineering, Strathclyde University, Scotland, 1958; MS, thermodynamics, Birmingham University, England, 1962) has spent 13 years with Babcock & Wilcox Company (B&W) on the design of reactor vessels, heat exchangers, and steam generators for LMFBRs. He is currently manager of new product engineering with B&W's Nuclear Equipment Division. **Joseph L. Epstein** (bottom left) (BS, engineering, U.S. Naval Academy, 1962, MBA, University of Pittsburgh, 1974) is project manager for the Breeder Reactor Component Project of Westinghouse Electric Corporation, responsible for the double-wall tube LMFBR steam generator contract for DOE. He joined the Westinghouse Commercial Reactor Design Division in 1970 and worked in the areas of operating plant reliability engineering and commercial nuclear systems projects prior to his present post. Beginning in 1962, he spent eight years in the Navy nuclear program, operating and testing reactor systems.



MATERIALS REQUIREMENTS FOR PRESSURIZED WATER REACTOR STEAM GENERATOR TUBING

J.-Ph. Berge (top) (Ingénieur de l'Ecole de Physique et Chimie de Paris, 1957; Docteur-es-Sciences, 1968) has worked in the research and development (R&D) of materials and corrosion for nuclear reactors since 1958. He first worked with the French Navy, then, from 1961 to 1968, he was with the European Community for Nuclear Energy, Euratom, in the framework of the R&D agreement on water reactors with the U.S. Atomic Energy Commission. Since 1968, he has been with Electricité de France (EdF). He was head of the Materials Research Department from 1972 to 1980 and is now under special assignment for materials problems at EdF. **J. R. Donati** (Ingénieur de l'Ecole Centrale de Paris, 1963; Docteur-es-Sciences, 1967) joined EdF in 1963. He was head of the Corrosion and Chemistry Research Division from 1969 to 1972, head of the Metallurgy Research Division from 1972 to 1980, and is presently head of the Materials Research Department.

*Ph. Berge
J. R. Donati*



CHEMICAL THERMOHYDRAULICS OF STEAM GENERATING SYSTEMS

Paul Cohen



Paul Cohen (MS, chemistry, Carnegie-Mellon University, 1941) has been involved with the water technology of nuclear systems since 1949 with the Westinghouse Electric Corporation and more recently as a consultant to the Electric Power Research Institute. He is a fellow of the American Nuclear Society (ANS) and the American Society of Mechanical Engineers and author of the ANS Monograph, *Water Coolant Technology of Power Reactors*. His current interest is the effect of thermohydraulic conditions on chemical behavior and corrosion in steam generating systems.

SYSTEM CHEMISTRY CONSIDERATIONS FOR NUCLEAR STEAM GENERATORS

Frederick J. Pocock



Frederick J. Pocock (BS, chemistry, Mount Union College, 1949; attended Akron University, 1953) is senior scientist on The Babcock & Wilcox Company Alliance Research Center staff. He has been in the water technology business for 30 years and is well experienced in both utility fossil and nuclear steam generation systems. He was a technical leader in the development of water conditioning systems for sub- and supercritical fossil plants and for light water reactor systems. His experience includes startup and operation of the first commercial nuclear ship, the NSS *Savannah*. He also is involved in the development of Naval nuclear steam generation systems.

THE IMPLICATIONS FOR CONDENSATE PURIFICATION OF OPERATION AT pH 9.6

R. Garnsey

D. J. Parry

Richard Garnsey (top) (PhD, University of Reading, 1966; post-doctoral fellow, University of Maryland, 1966-1968) joined the Central Electricity Generating Board (CEGB) in 1968 at the Central Electricity Research Laboratories. He is presently the head of the Steam Water Chemistry Section, carrying out research into solution chemistry and aqueous corrosion relevant to electric power generation systems. **David J. Parry** (PhD, chemistry, University of Manchester, Institute of Science and Technology, 1968) joined the CEGB in 1960. He has spent five years studying corrosion and deposition processes in a model once-through boiler, and for the past seven years has been involved in studies of condensate purification and oxide dissolution processes.

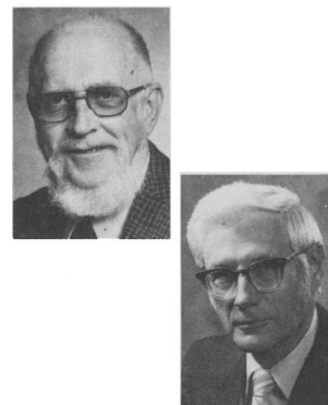


EFFECTS OF COPPER AND NICKEL COMPOUNDS ON THE CORROSION OF PRESSURIZED WATER REACTOR STEAM GENERATOR MATERIALS

Earl L. White

Warren E. Berry

Earl L. White (top) (MS, chemical engineering, The Ohio State University, 1948) is a research chemist in the Corrosion Section at the Columbus Laboratories of Battelle Memorial Institute (BMI). His experience with light water reactors (LWRs) covers a broad spectrum, and includes corrosion of structural materials, water treatment chemicals solubility, chemical hideout phenomena, and heat transfer studies. **Warren E. Berry** (BS, chemistry, Ohio University, 1947) is manager of the Corrosion Section at the Columbus Laboratories of BMI. He has been conducting and supervising corrosion studies on LWR fuel, cladding, and structural materials at BMI since 1948.



THE DESIGN AND CONSTRUCTION OF BOILERS FOR ADVANCED GAS-COOLED REACTORS IN THE UNITED KINGDOM

*P. J. Cameron
J. Walters*

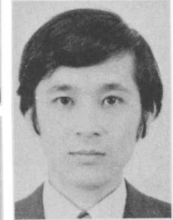
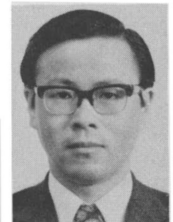
P. J. Cameron (top) (BSc, mechanical engineering, University of Manchester Institute of Science and Technology) served as a captain in the Royal Electrical and Mechanical Engineers before becoming a steam turbine designer. He has held a number of positions in the nuclear industry in the United Kingdom and is now the head of the General Engineering Division of the National Nuclear Corporation. **J. Walters** (BSc, metallurgy, University of Leeds, England, 1963) has been engaged in materials selection and assessment of manufacturing/construction methods for nuclear power plant components since 1965. His experience covers gas-, sodium-, and water-cooled reactor technology with particular interest in the corrosion field. He is presently a section head (Chemistry and Corrosion) in the Research and Development Division of the National Nuclear Corporation, working in the Risley offices.



STUDY ON HYDROGEN-INDUCED CRACKING IN THE HEAT-AFFECTED ZONE OF HEAVY FORGINGS OVERLAID BY STAINLESS STEEL

*K. Ohnishi
H. Tsukada
M. Kusuhashi
Y. Tanaka*

K. Ohnishi (top right) (Dr. Eng., material engineering, Hokkaido University, 1960) is associate general manager of the Material Research Laboratory, The Japan Steel Works, Ltd. (JSW). His primary research interests are in the area of materials development for the fusion reactor and the fast breeder reactor. **H. Tsukada** (top left) (Dr. Eng., material engineering, University of Tokyo, 1979) is manager of the Atomic Energy Department of JSW. His research interests include development of materials and manufacturing technology for nuclear pressure vessels and circuits. **M. Kusuhashi** (bottom right) is a senior engineer at the JSW Research Laboratory. His work has been in the area of materials development for nuclear pressure vessels and the primary loop piping, in particular intergranular stress corrosion cracking. **Y. Tanaka** (bottom left) is a senior engineer at the JSW Research Laboratory. His major interest has been in the area of fracture mechanics and materials development based on it.



EVALUATION OF SODIUM PHOSPHATE AS A DENTING INHIBITOR

*R. S. Pathania
E. G. McVey*

R. S. Pathania (top) (PhD, metallurgical engineering, University of British Columbia, 1970) is the leader of the Corrosion Section of the System Materials Branch, Chalk River Nuclear Laboratories (CRNL), Chalk River, Ontario, Canada. He joined Atomic Energy of Canada Limited in 1972, where he has conducted research on corrosion and stress corrosion cracking of steam generator materials and corrosion of heavy water plant materials. He has also coauthored surveys of performance of steam generator tubes in water-cooled reactors. **E. G. McVey** was educated in Scotland. He is a senior research and development technician with 25 years of experience in corrosion research and development in the nuclear and aircraft industries. He is currently working on corrosion of materials used in nuclear steam generators at CRNL.



CORROSION OF ALLOY 600 BY CATIONIC RESIN BEADS

Martin W. Kendig (top) (PhD, physical chemistry, Brown University, 1974), after conducting post-doctoral research at Lehigh University, joined the Corrosion Science Group at Brookhaven National Laboratory (BNL) in 1976 and pursued research in the area of corrosion monitoring and high temperature aqueous electrochemistry. Kendig is currently a member of the technical staff of the Rockwell International Science Center, Thousand Oaks, California. **Hugh S. Isaacs** (PhD, corrosion science, Imperial College, London University, 1972) has carried out research in the corrosion of metals in aqueous liquid-metal and gaseous environments. His current research at BNL focuses on localized corrosion, stress corrosion cracking, and solid electrolyte fuel cell electrochemistry.

*Martin W. Kendig
Hugh S. Isaacs*



PITTING CORROSION OF NUCLEAR STEAM GENERATOR MATERIALS

Peter J. King (top) (MAsc, metallurgy, University of Toronto, 1978) joined the Corrosion and Thermal Plant Section of Ontario Hydro Research in 1979. Since then he has been working on research into the corrosion performance of nuclear steam generator materials. He is also involved currently in corrosion testing of metals to be used for the containment of spent nuclear fuel in deep geologic disposal. **D. P. (Don) Dautovich** (PhD, metallurgy, University of New South Wales, Sydney, Australia) has been working in the field of corrosion since 1969. He was a research scientist at International Nickel until 1973 and since then has worked at the Ontario Hydro Research Division. He currently is the supervisor of the Corrosion and Thermal Plant Section.

*P. J. King
D. P. Dautovich*



CHEMICAL CLEANING OF THE NUCLEAR POWER DEMONSTRATION UNIT BOILER

Colin Frost (top right) (PhD, nuclear technology, Imperial College, London, 1968) has worked for ten years at Ontario Hydro on the chemical control of nuclear power plants. He joined Ontario Hydro after working on a World Health Organization water supply project for two years. Previous work includes research and development on radioactive waste management for five years with the Australian Atomic Energy Commission. **Peter Walmsley** (top left) (B Tech, mechanical engineering, University of Bradford, England, 1966) was a research officer with the U.K. Central Electricity Generating Board before joining Ontario Hydro in 1969. He was leader of the project to specify a process and clean the nuclear power demonstration (NPD) boiler in 1979. He is currently a shift supervisor at Ontario Hydro's NPD Nuclear Generating Station. **P. V. Balakrishnan** (bottom right) (MA, chemistry, University of Madras, India, 1961; PhD, chemistry, McMaster University, Canada, 1971) was a scientific officer at Bhabha Atomic Research Centre, Trombay, India, and has been with Atomic Energy of Canada Limited Research Company, Chalk River Nuclear Laboratories, since 1971. He has been involved with studies on water chemistry in power reactor coolant systems, his current interests being steam generator water chemistry and chemical cleaning of steam generators. **P. McSweeney** (bottom left) (BSc, chemistry, University College, Cork, Ireland, 1961) was a station chemist at the Electricity Supply

*C. R. Frost
P. Walmsley
P. V. Balakrishnan
P. McSweeney*



Board of Ireland. He joined Ontario Hydro's Research Division in 1974. There he has studied steam generator corrosion and chemical cleaning. He is at present working on the development of solvents to clean the secondary sides of Ontario Hydro's nuclear steam generators.

SNR 300 EXPERIENCE IN STEAM GENERATOR MATERIALS

M. H. Knaap (top right) (MSc, nuclear engineering, Delft University of Technology, 1970) is project manager for liquid-metal fast breeder reactor (LMFBR) steam generators at Neratoom, The Hague, The Netherlands. He joined Neratoom in 1971 as a heat transfer specialist and became an engineer for steam generator development in 1973. Since 1974, he has been the project manager responsible for steam generators for the SNR-300 plant in Kalkar. **H. C. D. Nieuwland** (top left) (MSc, metallurgy, Delft University of Technology, 1972) is a materials expert. He joined Neratoom in 1978. His research interests are manufacturing of nuclear components, physical metallurgy, and fracture mechanics. **J. Vrijen** (second from top right) (MSc, physics, Groningen University, 1973; PhD, materials science, Utrecht University, 1977) spent four years at The Netherlands Energy Research Foundation ECN at Petten. He investigated decomposition phenomena in alloys by means of diffuse neutron scattering. He joined Neratoom in 1978, worked on several materials research subjects and, since 1980, has been manager of the department responsible for research and development of materials, fabrication technology, and NDT techniques. **J. K. van Westenbrugge** (center left) (MSc, mechanical engineering, Technical University of Eindhoven, 1969) is coordinator of LMFBR steam generator development at Neratoom. He joined Neratoom in 1971 and has held his present position since 1976. **W. Huslage** (second from bottom right) (MSc, physical metallurgy, Delft University of Technology) joined the Metal Research Institute TNO in 1971. He has been active since 1971 in materials research for the SNR project, especially on the mechanical behavior of structural steels. **C. P. Scheepens** (bottom left) (engineer, metallurgy, Utrecht University) is an expert in the field of alloy steels, has worked in the laboratory of a special steel manufacturing company, and joined the Metal Research Institute TNO in 1967. He has been involved in materials research projects for energy installations, including the SNR project. **J. W. Schinkel** (bottom right) (MSc, metallurgy, Delft University of Technology) joined the Metal Research Institute TNO in 1966. He has been involved in applied research on metallurgy and mechanical properties of structural steels. Since 1972, he has acted as program coordinator for the materials research at TNO for the SNR project. He is currently deputy director of the Metal Research Institute.

*M. H. Knaap
H. C. D. Nieuwland
J. Vrijen
J. K. van Westenbrugge
W. Huslage
C. P. Scheepens
J. W. Schinkel*

