

AUTHORS — JANUARY 1991

REVIEW ARTICLE

THE NASA-LEWIS PROGRAM ON FUSION ENERGY FOR SPACE POWER AND PROPULSION, 1958-1978

Norman R. Schulze (top) (BS, physics, University of Chicago, 1958) works for the National Aeronautics and Space Administration (NASA). He was one of the early staff members at the Manned Spacecraft Center in Houston, where he was responsible for the management of the Gemini spacecraft's propulsion system. He has performed systems analysis on many of NASA's advanced spacecraft programs, including the space shuttle. A current interest is the development of fusion energy for space missions. **J. Reece Roth** (SB, physics, Massachusetts Institute of Technology, 1959; PhD, engineering physics, Cornell University, 1963) is a faculty member of the electrical engineering department of the University of Tennessee-Knoxville. He previously worked at NASA Lewis Research Center, where he was the principal investigator of the Lewis Electric Field Bumpy Torus Project until 1978.

*Norman R. Schulze
J. Reece Roth*



FUSION FUEL CYCLES

IGNITION AND BURN CRITERIA FOR D-³He TOKAMAK AND SPHERICAL TORUS REACTORS

J. D. Galambos (top) (PhD, nuclear engineering, University of Illinois, 1983) is a member of the Computing and Telecommunications Division at Oak Ridge National Laboratory (ORNL) and works at the Fusion Engineering Design Center (FEDC). His interests include systems analysis of tokamaks, plasma edge modeling, and advanced fuel fusion. **Y.-K. Martin Peng** (BS, electrical engineering, National Taiwan University, 1967; MS, 1971, and PhD, 1974, applied physics, Stanford University) is a member of the Fusion Energy Division at ORNL and is the plasma

*J. D. Galambos
Y.-K. Martin Peng*



engineering manager of the FEDC. His research efforts include plasma engineering studies of the Compact Ignition Tokamak and advanced tokamak reactor concepts and promotion of high-beta spherical tori studies.

ADVANCED FUELS

AN ADVANCED FUEL LASER FUSION AND VOLUME COMPRESSION OF $p\text{-}^{11}\text{B}$ LASER-DRIVEN TARGETS

George H. Miley (top right) (PhD, University of Michigan, 1958) is a professor in the Department of Nuclear Engineering at the University of Illinois. In addition to research on fusion, he is well known for his research on energy conversion and nuclear-pumped lasers. **Heinrich Hora** (top left) [Diplom-Physiker, Martin Luther University, Federal Republic of Germany (FRG), 1956; Dr. Rer. Nat., Friedrich Schiller University, FRG; DSc, University of New South Wales, Australia, 1981] has been professor and head of the Department of Theoretical Physics at the University of New South Wales since 1975. His current research interests include laser/plasma interaction theory (nonlinear forces, absorption, particle acceleration, first self-focusing theories), photodetectors, semiconductor lasers, FEL, and extreme states of matter. **Lorenzo Cicchitelli** (center right) (BSc, theoretical physics, 1983, and PhD, 1988, University of New South Wales, Australia) is a research scientist at the Centre of Safety Science, University of New South Wales. His research interests include laser/plasma interaction on classical as well as quantum electrodynamics. **Gregorios V. Kasotakis** (bottom left) (Graduate, physics, National and Capodistrian University of Athens, Greece, 1982) has been working on a postgraduate project at the University of New South Wales since 1987. His research has led to publications on the problems of inertial fusion confinement, numerically evaluating optimized fusion gains, and fuel depletion for deuterium-tritium and for clean fusion fuel. **Robert J. Stening** (bottom right) (BSc, 1962, and MSc, 1963, University of Australia-Sydney; PhD, University of Queensland, Australia, 1969; Dip. Tert. Ed, University of New England, Australia, 1977) has been at the main University of New South Wales campus at Kensington in Sydney since 1980. His research interests include ionospheric physics, tides in the upper atmosphere, and laser/plasma interactions.

*George H. Miley
Heinrich Hora
Lorenzo Cicchitelli
Gregorios V. Kasotakis
Robert J. Stening*



INSTRUMENTATION AND DATA HANDLING

CONTROL SYSTEM ARCHITECTURE FOR THE NEXT EUROPEAN TORUS

Michael L. Browne (right) (PhD, control, University of Manchester Institute of Science and Technology, United Kingdom, 1974) worked on the Joint European Torus (JET) from 1978 to 1980, where he was responsible for implementation of various aspects of machine control. In 1987, he joined the Next European Torus Team, where he has been responsible for the design of the

*Michael L. Browne
Francesco Bombi*



architecture for the central control system and for the development of plasma feedback controls. **Francesco Bombi** (right) (MS, electronics engineering, 1966, and PhD, automatic control, 1970, Padua University, Italy) led the JET Control and Data Acquisition System Division until 1984. He is now a full professor at Padua University. His current research interests include computer control system architecture and software engineering.



PLASMA ENGINEERING

EVALUATION OF DIFFERENT CONTROL METHODS FOR THE THERMAL STABILITY OF THE INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR

*John Mandrekas
W. M. Stacey, Jr.*



John Mandrekas (top) (Dipl., mechanical and electrical engineering, National Technical University of Athens, Greece, 1979; MS, 1984, and PhD, 1987, nuclear engineering, University of Illinois) is a research scientist at the Fusion Research Center, Georgia Institute of Technology (GIT). His current research interests include neutral beam current drive and impurity transport in tokamaks, stability and burn control of fusion reactors, and theoretical plasma physics. **W. M. Stacey, Jr.** (BS, physics, 1959, and MS, nuclear science, 1963, GIT; PhD, nuclear engineering, Massachusetts Institute of Technology, 1966) is Callaway Professor of Nuclear Engineering at GIT and serves as senior U.S. participant to the International Atomic Energy Agency International Tokamak Reactor Workshop.



SENSITIVITY STUDIES ON IGNITION IN IGNITOR

*Augusta Airoidi
Giovanna Cenacchi*



Augusta Airoidi (top) (Laurea in Fisica, Universita' di Milano, Italy, 1962) is a computational plasma physicist at the Istituto di Fisica del Plasma of National Research Council (IFP-CNR). Her research interests are mainly in plasma/wave interaction in the electron cyclotron range both in heating modeling and in emission phenomena. She is currently involved in Ignitor simulations. **Giovanna Cenacchi** (Laurea in Fisica, Universita' di Bologna, Italy, 1963) is a computational plasma physicist at ENEA, the Italian Atomic Energy Agency. She has worked primarily in the computational modeling of magnetohydrodynamic equilibria and transport processes in toroidal plasmas. She has also been involved in computational problems related to the toroidal magnet and the poloidal system for the Ignitor project.



A METHOD FOR MAPPING PLASMA OPERATIONAL SPACE WITHIN THE ENGINEERING CONSTRAINTS OF THE POLOIDAL FIELD COIL SYSTEM IN A TOKAMAK REACTOR

*Satoshi Nishio
Kichiro Shinya*



Satoshi Nishio (right) (BS, mechanical engineering, Keio University, Japan, 1976) is a research scientist at the Fusion Experimental Reactor Team of the Japan Atomic Energy Research Institute (JAERI). He is engaged in code development for transient electromagnetic analysis of the tokamak machine. From 1976 to 1981, he worked in the design analysis of the JT-60 toroidal field

coil system. Since 1981, he has been engaged in design activities for the International Tokamak Reactor (INTOR), the Fusion Experimental Reactor, and the International Thermonuclear Experimental Reactor (ITER). **Kichiro Shinya** (right) (BS, 1968; MS, 1970; and PhD, 1973, plasma science, Tokyo Institute of Technology, Japan) is a chief research scientist at the Energy Science and Technology Laboratory, Toshiba Research and Development Center. He is responsible for code development for magneto-hydrodynamic analysis and noninductive current drive of tokamak plasmas. From 1978 to 1980 and from 1988 to 1990, he was a visiting researcher at JAERI and he worked on INTOR and ITER design. His career includes the experiment and analysis at Doublet-III from 1980 through 1982.



A COMPARISON OF HYDROGENIC PELLET ABLATION MODELS WITH EXPERIMENT

Michael J. Gouge (top) (BS, physics, U.S. Naval Academy, 1973; PhD, physics, University of Tennessee, 1984) is a research staff member in the Fusion Energy Division at Oak Ridge National Laboratory (ORNL). His primary research interest is the development of plasma fueling systems for present and future magnetic fusion confinement experiments. **Wayne A. Houlberg** (center) (PhD, nuclear engineering, University of Wisconsin, 1977) is a staff member in the Fusion Energy Division at ORNL. His primary research interest is in the development of physics and computational models for toroidal plasmas and the extension of these models to reactor conditions. **Stanley L. Milora** (bottom) (BS, aerospace engineering, Pennsylvania State University, 1965; PhD, aeronautics and astronautics, Massachusetts Institute of Technology, 1972) is a research staff member in the Fusion Energy Division at ORNL. He is group leader of the plasma fueling program and program manager for fusion plasma technologies. His primary research interest is the development of innovative plasma fueling systems for magnetic fusion, especially pneumatic pellet injectors, and the transport physics of pellet-fueled plasmas.

*Michael J. Gouge
Wayne A. Houlberg
Stanley L. Milora*



BLANKET ENGINEERING

MAGNETOHYDRODYNAMIC FLOW IN A MANIFOLD AND MULTIPLE RECTANGULAR COOLANT DUCTS OF SELF-COOLED BLANKETS

Thanh Q. Hua (top) (BS, 1982; MS, 1984; and PhD, 1986, nuclear engineering, University of Washington) is a staff member of the Fusion Power Program and Engineering Division at Argonne National Laboratory (ANL). His current research interests include liquid-metal magnetohydrodynamic (MHD) and heat transfer analysis for fusion reactor blankets. **Basil F. Picologlou** (PhD, Purdue University, 1972) is a staff member of the Engineering Division at ANL and a co-principal investigator (with C. B. Reed) of ANL's Liquid-Metal MHD Program. His current research interests include fluid mechanics, thermal sciences, and MHD, and their application toward improved designs of liquid-metal-cooled blankets.

*Thanh Q. Hua
Basil F. Picologlou*



ACTIVE SHIELDING SYSTEM FOR REMOVAL OF STRAY TOKAMAK MAGNETIC FIELDS IN JT-60 NEUTRAL BEAM INJECTORS

Mamoru Matsuoka (top right) (M. Eng., electronic engineering, Nagoya University, Japan, 1979) is a research scientist in the Department of JT-60 Facility (DJF) at the Japan Atomic Energy Research Institute (JAERI). He was involved in developing the power supply and the magnetic system (reflecting magnet, magnetic shields, etc.) for the JT-60 neutral beam injectors (NBIs). He was also engaged in the neutral beam current drive experiments in the DIII-D tokamak under U.S.-Japan cooperation. He is currently engaged in developing the JT-60 NBI as well as neutral beam heating experiments in the JT-60. **Hiroshi Horiike** (top left) (Dr. Eng., nuclear engineering, Osaka University, Japan, 1982) is a senior scientist in the DJF at JAERI. He has worked mainly in developing the ion source and the JT-60 NBI and is currently engaged in the upgrading of the JT-60 torus system. **Takao Itoh** (second from top right) (Dr., physics, Tokai University, Japan, 1975) is a research scientist in the Department of Large Tokamak Research (DLTR) at JAERI. He has worked in developing the magnetic system for the JT-60 NBI and is currently engaged in developing a helium beam injector for the active beam diagnostic system for the JT-60. **Mikito Kawai** (second from top left) (B. Eng., electrical engineering, Kiriu Technical College, Gunma University, Japan, 1973) is an engineer in the DTF at JAERI. He is engaged in developing the control system for the JT-60 NBI. **Mitsuru Kikuchi** (third from top right) (Dr., nuclear engineering, University of Tokyo, Japan, 1981) is a senior scientist in the DLTR at JAERI. He is engaged in the JT-60 experiments with a special interest in bootstrap current. **Masaaki Kuriyama** (third from top left) (Dr. Eng., mechanical engineering, Tokyo Institute of Technology, Japan, 1976) is a principal engineer in the DTF at JAERI. He works in developing the JT-60 NBI system. **Makoto Mizuno** (bottom right) (M. Eng., electronics engineering, Nagoya University, Japan, 1981) is a research scientist in the DTF at JAERI. He worked on developing the motor generator system delivering ac power to the JT-60 heating systems and is currently engaged in developing a power supply system for neutral beam systems. **Shigeru Tanaka** (bottom left) (Dr. Eng., instrumentation engineering, Keio University, Japan, 1983) is a senior scientist in the Department of Thermonuclear Fusion Research at JAERI. He worked on developing the ion source and the JT-60 NBI and is currently engaged in research for the International Thermonuclear Experimental Reactor and Fusion Experimental Reactor.

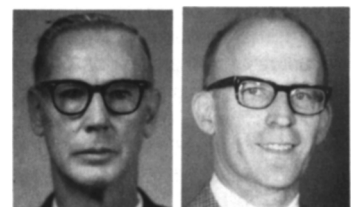
*Mamoru Matsuoka
Hiroshi Horiike
Takao Itoh
Mikito Kawai
Mitsuru Kikuchi
Masaaki Kuriyama
Makoto Mizuno
Shigeru Tanaka*



THE MADISON SYMMETRIC TORUS

R. N. Dexter (right) (PhD, University of Wisconsin, 1955) was project manager of the Madison Symmetric Torus (MST) construction. He is a solid-state physicist with research interests in plasma turbulence and confinement and in the diagnosis of high-temperature plasmas. **D. W. Kerst** (left) (PhD, University of Wisconsin, 1937) is an emeritus professor of physics who was active

*R. N. Dexter
D. W. Kerst
T. W. Lovell
S. C. Prager
J. C. Sprott*



in accelerator research before turning to plasma physics in 1957. He was the inventor of the betatron and coinventor of the toroidal multipole. **T. W. Lovell** (top) is engineering manager for the MST project. He is a long-time member of the Wisconsin Plasma Physics staff and has contributed to the Tokapole II, Levitated Octupole, and numerous other projects. **S. C. Prager** (center) (PhD, Columbia University, 1975) is a professor of physics at the University of Wisconsin-Madison. He previously worked at General Atomics and has performed research on reversed-field pinch (RFP), tokamak, octupole, and linear plasmas. **J. C. Sprott** (bottom) (PhD, University of Wisconsin, 1969) is professor of physics at the University of Wisconsin-Madison. He previously worked at Oak Ridge National Laboratory and has been involved with multipole, mirror, tokamak, and RFP research.



SAFETY/ENVIRONMENTAL ASPECTS

DIFFUSION OF TRITIATED WATER VAPOR INTO CONCRETE

Shigeo Numata (top) (M. Eng., nuclear engineering, Kyoto University, Japan, 1984) is a researcher at the Shimizu Corporation Institute of Technology. He has worked in the areas of neutron spectroscopy and radiation shielding. His current interests are material interaction and decontamination of tritium in buildings. **Yasuhiko Fujii** (center) (Dr. Eng., nuclear engineering, Tokyo Institute of Technology, Japan, 1973) is an associate professor at the Tokyo Institute of Technology. His current interest is in the area of fusion chemistry. **Makoto Okamoto** (bottom) (Dr. Eng., nuclear engineering, Tokyo Institute of Technology, Japan, 1966) is a professor in the nuclear reactor research laboratory at Tokyo Institute of Technology.

*Shigeo Numata
Yasuhiko Fujii
Makoto Okamoto*



INITIAL INTEGRATION OF ACCIDENT SAFETY, WASTE MANAGEMENT, RECYCLING, EFFLUENT, AND MAINTENANCE CONSIDERATIONS FOR LOW-ACTIVATION MATERIALS

Steven J. Piet (top) [BS and MS, 1979, and ScD, 1982, nuclear engineering, Massachusetts Institute of Technology (MIT)] is a member of the fusion safety program of EG&G Idaho at the Idaho National Engineering Laboratory. His major interests and responsibilities include International Thermonuclear Experimental Reactor (ITER), activation product behavior, and risk assessments. He is currently part of the permanent ITER team, focusing on enhancing and optimizing safety in the ITER conceptual design. **Edward T. Cheng** (bottom) (PhD, nuclear engineering, University of Wisconsin, 1976) has been a member of the development and technology group in the Fusion Division of General Atomics since 1978. His interests are in neutronics, radioactivity, and blanket engineering. He is currently coordinating the

*Steven J. Piet
Edward T. Cheng
Steve Fetter
J. Stephen Herring*



nuclear data needs activities for the development of magnetically confined fusion energy. **Steve Fetter** (top) (SB, physics, MIT; PhD, energy and resources, University of California-Berkeley) is an assistant professor in the School of Public Affairs and an affiliated faculty member in the Laboratory for Plasma Research at the University of Maryland. His research interests include national security policy, space policy, and environmental policy. **J. Stephen Herring** (bottom) (BS, mechanical engineering and electrical engineering, 1971, and PhD, nuclear engineering, 1979, MIT) is a senior engineering specialist in the Fusion Safety Program at the Idaho National Engineering Laboratory. His research interests include safety-related transients in superconducting magnet sets and fusion waste management.



THE NUCLEAR DYNAMO—CAN A NUCLEAR TORNADO ANNIHILATE NATIONS?

J. Rand McNally, Jr.

J. Rand McNally, Jr. (PhD, physics, Massachusetts Institute of Technology, 1943) is retired from the senior research staff in the Fusion Energy Division of Oak Ridge National Laboratory. His research interests include atomic physics, plasma physics, and nuclear fusion in which fields he has published well over 100 technical articles. He is now a fusion energy consultant.



COLD FUSION

POSSIBLE RESONANT MECHANISM OF COLD FUSION

Wladyslaw Zakowicz

Wladyslaw Zakowicz (MS, Warsaw University, Poland, 1966; PhD, Institute of Nuclear Research, Poland, 1973) has been at the Institute of Physics of the Polish Academy of Sciences since 1975. He has also worked at Pittsburgh University, Stanford University, Brookhaven National Laboratory, and the University of Arizona. His interests include quantum and classical optics and laser accelerators.



THE ROLE OF THE LOW-ENERGY PROTON-DEUTERON FUSION CROSS SECTION IN PHYSICAL PROCESSES

*Yeong E. Kim
Robert A. Rice
Gary S. Chulick*

Yeong E. Kim (top) (BS, chemistry and mathematics, Lincoln Memorial University, 1959; PhD, physics, University of California-Berkeley, 1963) has been a professor of physics at Purdue University since 1967. His interests are in theoretical nuclear physics, gravitational theory, theoretical geophysics, and nuclear fusion. **Robert A. Rice** (bottom) (BS, physics, Case Western Reserve University, 1988; MS, physics, Purdue University, 1990) is a graduate research assistant in the Department of Physics at Purdue University. His research interests include theoretical



nuclear physics and the few-nucleon problem. **Gary S. Chulick** (right) (BS, 1977, and MS, 1979, John Carroll University; PhD, physics, Case Western Reserve University, 1988) is a postdoctoral research associate in the Department of Physics at Purdue University. His current research interests are in theoretical nuclear physics and geophysics.



ANALYSES OF PALLADIUM CATHODES USED FOR HEAVY WATER ELECTROLYSIS

K. Kumar (top right) [B. Tech., Indian Institute of Technology (Kanpur), India, 1969; MS, Stevens Institute of Technology, 1971; ScD, Massachusetts Institute of Technology (MIT), 1975] is chief of the Materials Science and Technology Section at the Charles Stark Draper Laboratory (CSDL). His research has spanned many diverse areas of materials science and engineering. **I. S. Hwang** (top left) (PhD, nuclear materials engineering, MIT, 1987) is a research scientist in the Department of Materials Science and Engineering at MIT. His research areas include basic mechanisms of environment-assisted cracking phenomena in aqueous environments, high-temperature electrochemistry, and the effects of irradiation on corrosion and cracking. He has been active in the development of cryogenic structural materials for nuclear fusion applications. **R. G. Ballinger** (center right) (SB, mechanical engineering, Worcester Polytechnic Institute, 1976; SM, nuclear engineering, 1977; SM, materials science, 1978; and ScD, nuclear materials engineering, 1982, MIT) is an associate professor nuclear engineering and materials science and engineering at MIT. His areas of specialization include environmental effects on material behavior, the effect of radiation on aqueous chemistry, and materials development for cryogenic structural applications. He has been active in the cold fusion controversy and has testified before Congress on the subject. **C. R. Dauwalter** (bottom left) (BS, mechanical engineering, 1955, and MS, aeronautics and astronautics, 1971, MIT) has been with CSDL since 1957. He has been involved in the design and development of electromagnetic components for high-performance gyroscopes and accelerometers for inertial guidance systems. He has also been involved in the development of advanced gyroscopes and accelerometers. **A. Stecyk** (bottom right) has been a member of the technical staff at CSDL since 1967. His interests include design of test instrumentation, electro-optical design, and micromechanical measurements of length and subarcsecond angles. He is responsible for the design and experimental work of the CSDL Cold Fusion Laboratory.

*K. Kumar
I. S. Hwang
R. G. Ballinger
C. R. Dauwalter
A. Stecyk*



SOME CHARACTERISTICS OF TITANIUM AND PALLADIUM SAMPLES USED IN COLD FUSION EXPERIMENTS

Joaquin Sevilla (right) (physics, Universidad Autonoma de Madrid, Spain, 1986) is currently working in the applied physics department of the Universidad Autonoma of Madrid. His interests include cold fusion and related problems. **Francisco Fernandez** (left) (physics, Universidad Autonoma of Madrid, Spain, 1988) is currently working in the applied physics department of the Universidad Autonoma of Madrid. His interests include cold

*Joaquin Sevilla
Francisco Fernandez
Beatriz Escarpizo
Carlos Sánchez*



fusion and related problems. **Beatriz Escarpizo** (right) (chemistry, Universidad Autonoma of Madrid, Spain, 1987) is currently working in the applied physics department of the Universidad Autonoma of Madrid. Her interests include cold fusion and related problems. **Carlos Sánchez** (left) (PhD, 1968) has been a full professor in the applied physics department of the Universidad Autonoma of Madrid since 1986. His interests include defects in solids, optical and electrical properties of semiconductors, solar energy conversion and storage, photoelectrochemical devices, hydrogen production, and metal hydrides.



A SEARCH FOR TRITIUM PRODUCTION IN ELECTROLYTICALLY DEUTERIDED PALLADIUM

Kenneth A. Ritley (top right) is a member of the positron-solids interaction group in the physics department at Brookhaven National Laboratory (BNL). In addition to his recent interest in palladium-deuterium electrochemical systems, his professional interests have included models of the cohesive energy in high-temperature superconductors. He is currently investigating the application of a monoenergetic positron beam to the study of liquid metals. **Kelvin G. Lynn** (top left) is a physics group leader and head of the Applied Physics Division at BNL. His interests have included surface physics and the use of positrons in studying surface and near-surface defects. He has been actively involved with cold fusion research since the first reports of this phenomenon in March 1989. **Peter Dull** (center right) has spent a year visiting at BNL from Valparaiso University in Indiana. In addition to his recent research on cold fusion phenomena, he has recently completed a comparative study of positron moderator designs. **Marc H. Weber** (no photograph available) is currently on the faculty of the University of Bielefeld in the Federal Republic of Germany. In addition to work in the specular reflection of positronium, he has recently designed a system for low-level neutron emission studies and is currently interested in utilizing the high-intensity positron source for e^+ -H studies at BNL. **Michael Carroll** (bottom left) is a member of the positron-solids interaction group at BNL. His professional interests include designing and evaluating electronics for use in experimental physics, and he maintains a strong interest in the detection of gravitational radiation. **James J. Hurst** (bottom right) is a senior materials science associate in the Department of Applied Science at BNL. In addition to his recent interest in the metallurgical properties of palladium, his research interests have included studies of crystal growth.

*Kenneth A. Ritley
Kelvin G. Lynn
Peter Dull
Marc H. Weber
Michael Carroll
James J. Hurst*

