

AUTHORS — JULY 1992

SPECIAL ISSUE ON D-³He FUSION

FUSION POWER FROM LUNAR RESOURCES

G. L. Kulcinski (top) [PhD, nuclear engineering, University of Wisconsin (UW), 1965] is the Grainger Professor of Nuclear Engineering and the director of the Fusion Technology Institute at UW. He has worked at Los Alamos National Laboratory in the Nuclear Rocket Program, Battelle Northwest Laboratory in the Radiation Effects Program, and Kernforschungszentrum Karlsruhe as a visiting scientist in fusion materials research. His current research areas include radiation damage to materials, surface modification of metals, fusion reactor design, and unique applications of nuclear energy. **Harrison H. (Jack) Schmitt** (geology, California Institute of Technology; PhD, Harvard University, 1964) entered the Apollo astronaut program in 1965, serving as the lunar module pilot for Apollo 17, the last Apollo mission to the moon. From 1977 to 1983, he served as Senator from New Mexico. He is now a director on several corporate boards and consults, speaks, and writes on a wide range of space, energy, and public policy topics.

*G. L. Kulcinski
Harrison H. (Jack) Schmitt*



A REVIEW OF ³He RESOURCES AND ACQUISITION FOR USE AS FUSION FUEL

L. J. Wittenberg (top) [PhD, chemistry, University of Wisconsin (UW), 1953] is a senior scientist in the Fusion Technology Institute and the Wisconsin Center for Space Automation and Robotics and was instrumental in developing the concept for the acquisition of lunar ³He and its use in earth-based D-³He fusion power plants. He has made extensive studies of terrestrial and extraterrestrial resources of ³He. Additionally, he has contributed to the design of fuel cycles, breeders, and their containment systems for the conceptual design of deuterium-tritium fusion reactors. **E. N. Cameron** (center) (PhD, Columbia University, 1939) is Emeritus Professor of Geology at UW-Madison and is an economic geologist working with the Fusion Technology Institute since 1986 in order to better quantify the lunar ³He resource based on remote-sensing data and samples delivered to earth by the U.S. and USSR lunar missions. His previous studies dealt with mineral deposits in various parts of the world and with mineral resource assessments. **G. L. Kulcinski** (bottom) (PhD, nuclear engineering, UW, 1965) is the Grainger Professor

*L. J. Wittenberg
E. N. Cameron
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S. H. Ott
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of Nuclear Engineering and the director of the Fusion Technology Institute at UW. He has worked at Los Alamos National Laboratory in the Nuclear Rocket Program, Battelle Northwest Laboratory in the Radiation Effects Program, and Kernforschungszentrum Karlsruhe as a visiting scientist in fusion materials research. His current research areas include radiation damage to materials, surface modification of metals, fusion reactor design, and unique applications of nuclear energy. **S. H. Ott** (top right) (PhD, finance, UW, 1992) is a member of the Fusion Technology Institute. His current research studies involve the valuation of research and development (R&D) projects and the optimal timing of R&D investment using option pricing techniques. This research is then applied to the financial analysis of R&D investments in lunar ^3He and fusion power development. **J. F. Santarius** (top left) (BS, physics, California Institute of Technology, 1973; PhD, physics, University of Texas, 1979) is plasma engineering group leader in the UW Fusion Technology Institute and is an associate scientist in the Department of Nuclear Engineering. His current research centers on plasma physics and engineering for commercial fusion reactor and test facility design. Other research areas include fusion reactors for space applications and plasmas for industrial processing and technological applications. **G. I. Sviatoslavsky** (center right) (MS, mechanical engineering, UW, 1991) was a research assistant at the Wisconsin Center for Space Automation and Robotics. His areas of research involved the lunar miner and fusion reactor designs, including computer modeling and animation. He is currently employed at Bechtel Corporation. **I. N. Sviatoslavsky** (bottom left) (BS, physics, Davidson College, 1955; BS and MS, mechanical engineering, UW, 1961) has worked as a project engineer at Midwestern Universities Research Association and joined the UW Fusion Program in 1972. He has worked extensively on conceptual fusion reactor designs in both magnetic and inertial confinement. Currently, he is a senior scientist and group leader (blanket and design) in the UW Fusion Technology Institute. **H. E. Thompson** (bottom right) (PhD, business, UW, 1964) is Kuechenmeister-Bascom Professor of Business at UW. His research areas include regulatory economics and finance, cost of capital, and corporation finance. He is currently studying the role of risks and incentives in the valuation of public activities in alternative regulatory schemes.



D- ^3He FUSION IN THE JOINT EUROPEAN TORUS TOKAMAK – RECENT EXPERIMENTAL RESULTS

Jean Jacquinot (top) (Dr. de Troisième Cycle, 1963, and Dr. d'Etat, 1972, Université de Paris Sud, Orsay, France) has been head of the Radio Frequency Division of the Joint European Torus (JET) since its creation in 1982. He is also in charge of various aspects of the experimental physics program (in particular, the Physics Task Force). Before joining JET, he was a member of the physics team of the Tokamak Fontenay-aux-Roses with responsibility for the antennas of the ion cyclotron resonance heating system. He identified the physics of the ion-ion hybrid resonance and developed it as a heating method in tokamaks, a method now widely known as the "cyclotron minority heating" scheme. **Guy J. Sadler** (Ing. Civil Phys., University of Liege, Belgium, 1970; Dr. rer. nat., University of Cologne, Federal Republic of Germany, 1976) is a member of the experimental department of JET. He was previously involved in the specification, design, and commissioning of the JET fusion products (neutrons, gamma rays, and charged particles) and X-ray diagnostics.

*Jean Jacquinot
Guy J. Sadler
The JET Team*



His current main responsibility is the detailed interpretation of data measured by these systems with active involvement in the JET experimental program.

SPIN POLARIZATION EFFECT ON IGNITION ACCESS CONDITION FOR D-T AND D-³He TOKAMAK FUSION REACTORS

Osamu Mitarai (top) (MS, mechanical engineering, 1977, and PhD, nuclear engineering, 1979, Kyushu University, Japan) is an associate professor of electrical engineering at Kumamoto Institute of Technology. His current interests are in the areas of alternating current tokamaks, current drive, ignition studies for deuterium-tritium and D-³He tokamak reactors, spin-polarized fusion, transport studies, and plasma cosmology. **Hiroki Hasuyama** (bottom) (BS, physics; ME and PhD, nuclear engineering, Kyushu University, Japan) has worked in the Department of Nuclear Engineering at Kyushu University since 1967 and has developed sources of polarized ions and studied spin-polarized fusion. He is currently a professor of physics at Kurume Institute of Technology. A biography and photograph of **Yoshihisa Wakuta** were unavailable at publication time.

*Osamu Mitarai
Hiroki Hasuyama
Yoshihisa Wakuta*



POTENTIAL FOR D-³He EXPERIMENTS IN NEXT-GENERATION TOKAMAKS

Gilbert A. Emmert (top) (PhD, Stevens Institute of Technology, 1968) is a professor of nuclear engineering and engineering physics at the University of Wisconsin-Madison. His research interests include plasma physics, plasma engineering for fusion reactor design, and plasma/surface interactions and sheaths. **Ronald Parker** [BS, electrical engineering, Tufts University, 1960; ScD, electrical engineering, Massachusetts Institute of Technology (MIT), 1967] has been on the MIT staff since 1963 and currently serves as director of the Plasma Fusion Center. He has also headed the design team for the Compact Ignition Tokamak. His research interests are in the areas of development of fusion energy and the Alcator program at MIT.

*Gilbert A. Emmert
Ronald Parker*



SUMMARY OF APOLLO, A D-³He TOKAMAK REACTOR DESIGN

G. L. Kulcinski (top) [PhD, nuclear engineering, University of Wisconsin (UW), 1965] is the Grainger Professor of Nuclear Engineering and the director of the Fusion Technology Institute at UW. He has worked at Los Alamos National Laboratory in the Nuclear Rocket Program, Battelle Northwest Laboratory in the Radiation Effects Program, and Kernforschungszentrum Karlsruhe as a visiting scientist in fusion materials research. His current research areas include radiation damage to materials, surface modification of metals, fusion reactor design, and unique applications of nuclear energy. **James P. Blanchard** (bottom) (BS, mechanical engineering, 1983; MS, 1984, and PhD, 1988, nuclear engineering, University of California-Los Angeles) is an assistant professor in the Department of Nuclear Engineering and Engineering Physics at UW. His current work is primarily in the area

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John F. Santarius
Mohamed E. Sawan
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L. J. Wittenberg*



of the effects of disruptions, erosion, and radiation damage on stresses in blankets and plasma-facing components. **Laila A. El-Guebaly** (top right) (PhD, nuclear engineering, University of Alexandria, Egypt, 1979) is an associate scientist at the UW Fusion Technology Institute. She specializes in the area of neutronics and shielding of fusion reactors. For the last several years, she has been involved in the shield optimization analysis of deuterium-tritium and D-³He reactors for both terrestrial and space applications. Her interests include the evaluation of the effect on the superconducting magnets and personnel of radiation streaming through large penetrations and assembly gaps in fusion reactor designs. She is currently in charge of the U.S. shielding design analysis for the International Thermonuclear Experimental Reactor (ITER). **Gilbert A. Emmert** (top left) (PhD, Stevens Institute of Technology, 1968) is a professor of nuclear engineering and engineering physics at UW. His research interests include plasma physics, plasma engineering for fusion reactor design, and plasma/surface interactions and sheaths. **Hesham Y. Khater** (second from top right) (PhD, nuclear engineering, UW, 1990) is a research associate at the UW Fusion Technology Institute. He has been involved with several magnetic and inertial confinement fusion reactor design studies. He has a special interest in charged-particle activation. His research interests are in neutronics, radioactivity, and safety analysis of fusion reactors. **Charles W. Maynard** (second from top left) (BS, electrical engineering, University of Maryland; PhD, applied physics, Harvard University, 1957) has worked at Bettis Atomic Power Laboratory, operated by Westinghouse Electric Company, in the Reactor Theory and Methods Section. He was appointed associate professor of nuclear engineering at UW in 1961 and became a professor in 1965. His research interests include neutronics analysis and design of fission and fusion reactors. A biography and photograph of **E. A. Mogahed** were unavailable at publication time. **John F. Santarius** (third from top right) (BS, physics, California Institute of Technology, 1973; PhD, physics, University of Texas, 1979) is plasma engineering group leader in the UW Fusion Technology Institute and is an associate scientist in the Department of Nuclear Engineering. His current research centers on plasma physics and engineering for commercial fusion reactor and test facility design. Other research areas include fusion reactors for space applications and plasmas for industrial processing and technological applications. **Mohamed E. Sawan** (third from top left) (BS, nuclear engineering, University of Alexandria, Egypt, 1967; MS, 1971, and PhD, 1973, nuclear engineering, UW) is senior scientist and neutronics group leader at the UW Fusion Technology Institute. He worked as assistant and associate professor of nuclear engineering at the University of Alexandria for 7 years. His current interests include neutronics, shielding, activation, and safety analyses for both inertial confinement fusion and magnetic fusion reactors. **I. N. Sviatoslavsky** (bottom right) (BS, physics, Davidson College, 1955; BS and MS, mechanical engineering, UW, 1961) has worked as a project engineer at Midwestern Universities Research Association and joined the UW fusion program in 1972. He has worked extensively on conceptual fusion reactor designs in both magnetic and inertial confinement. Currently, he is a senior scientist and group leader (blanket and design) in the UW Fusion Technology Institute. **L. J. Wittenberg** (bottom left) (PhD, chemistry, UW, 1953) is a senior scientist in the UW Fusion Technology Institute and the Department of Nuclear Engineering. He is currently involved in the design and evaluation of fuel cycles, breeders, and their containment systems required in the conceptual designs of fusion power reactors. Previous industrial experience includes initiation of experimental projects and design studies related to tritium handling and containment needed in fusion-related research facilities.



OPERATIONAL PARAMETERS FOR D-³He IN FIELD-REVERSED CONFIGURATIONS

Winfried Kernbichler

Winfried Kernbichler (no photograph available) (MS, 1983, and PhD, 1987, physics, Graz University of Technology, Austria) is an assistant professor at the Institute for Theoretical Physics of Graz University of Technology. His current research interests include field-reversed configurations, fusion reactor studies, and synchrotron radiation.

CONCEPTUAL DESIGN OF THE D-³He REACTOR ARTEMIS

Hiromu Momota (PhD, nuclear energy, Kyoto University, Japan, 1965) has been a professor at the Institute of Plasma Physics at Nagoya University since 1978. His primary research interests are the origins of stochasticity in dynamic systems and the development of fusion using advanced fuels. **Akio Ishida** (BS and MS, physics, Niigata University, Japan; PhD, physics, Hiroshima University, Japan, 1976) is an associate professor in the Department of Physics at Niigata University, where he has developed a stability theory of plasma confined in the field-reversed configuration (FRC). **Yasuji Kohzaki** (MS, electrical engineering, Waseda University, Japan, 1974) is a senior researcher at the Institute for Future Technology. He has worked on systems analysis for a fusion research and development program and fusion design studies. He also organized the lunar base and lunar resources study project in Japan, which includes design studies for FRC and laser fusion reactors. **George H. Miley** (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. **Shoichi Ohi** (Dr. Eng., welding engineering, Osaka University, Japan, 1972) is an associate professor at the Plasma Physics Laboratory at Osaka University. He has researched the formation, translation, and transport of the FRC. **Masami Ohnishi** (Dr. Eng., electrical engineering, Kyoto University, Japan, 1979) is a researcher at the Kyoto University Institute of Atomic Energy. His interests have included alpha-particle transport in magnetic fusion, the dynamics and control of fusion reactors, and reactor design studies. **Kunihiro Sato** (MS, electronics, Kyoto University, Japan, 1978) is an assistant professor of electrical engineering at Himeji Institute of Technology. He has been working on microinstabilities, plasma confinement, and potential formation in open field systems. He is currently involved in research on direct energy conversion for fusion products. **Loren C. Steinhauer** (PhD, aeronautics and astronautics, University of Washington, 1970) is a principal research scientist at STI Optronics, where he has directed an FRC theory program. **Yukihiro Tomita** (ME, electrical engineering, Kyoto University, Japan, 1975) is an assistant professor at the National Institute for Fusion Science. He has been working on the stochasticity of magnetic field lines and experiments with REB rings. He is now interested in the equilibrium and stability of FRCs with external sources. **Michel Tuszewski** (PhD, nuclear engineering, University of California-Berkeley, 1976) is a member of the staff of Los Alamos National Laboratory. He is involved in both experimental and theoretical work, and his recent interests are the formation and stability of FRCs. No photographs for this group of authors were available at publication time.

Hiromu Momota

Akio Ishida

Yasuji Kohzaki

George H. Miley

Shoichi Ohi

Masami Ohnishi

Kunihiro Sato

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Yukihiro Tomita

Michel Tuszewski

D-³He-FUELED FUSION POWER PLANT BASED ON THE PULSATORY FIELD-REVERSED CONFIGURATION

V. A. Burtsev (top right) [DSc, physics, Efremov Scientific Research Institute of Electrophysical Apparatus (ESRIEA), USSR, 1958; Professor Degree, physics, 1988] is head of the Pulsed Thermonuclear Installations Division at the ESRIEA. His research interests include high-power excimer laser design, pulsed plasma systems, and conceptual design of fusion reactors. **I. M. Artyugina** (top left) [DSc, economics, Leningrad State Technical University (LSTU), USSR] is an associate professor in the Economics Department at LSTU. She is studying the economic efficiency of different energy technologies. A biography and photograph of **A. V. Izotova** were unavailable at publication time. **V. V. Kantan** (second from top right) (DSc, technology, LSTU, USSR) is an associate professor in the electrical engineering department of LSTU. His research includes systems analysis of thermal energy units with reactors of different types. **V. M. Kozhevin** (center left) (DSc, physics, ESRIEA, USSR, 1972) is a senior scientist in the Theoretical Laboratory of the Pulsed Thermonuclear Installations Division of ESRIEA. His research interests include plasma dynamics and transport processes in field-reversed configurations (FRCs). **M. V. Krivosheev** (third from top right) (DSc, physics, ESRIEA, USSR, 1971) is a senior scientist in the Systems Analysis Laboratory at ESRIEA. His research interests include systems analysis of fusion power plants and thermonuclear devices. **V. N. Litunovsky** (bottom left) (DSc, physics, ESRIEA, USSR, 1966) is head of the Pulsed Plasma Systems Laboratory in the Pulsed Thermonuclear Installations Division of ESRIEA. His research interests include experimental investigations of high-beta plasma systems, plasma accelerators, and FRC-based reactors. **V. A. Slabikov** (bottom right) (DSc, technology, LSTU, USSR) is an associate professor in the electrical engineering department at LSTU. His research interests include energy conversion, electromechanical systems, and control.

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THE PULSATOR CONCEPT AS A POSSIBLE TECHNIQUE FOR FORMATION OF A FIELD-REVERSED CONFIGURATION

V. A. Burtsev (top right) [DSc, physics, Efremov Scientific Research Institute of Electrophysical Apparatus (ESRIEA), USSR, 1958; Professor Degree, physics, 1988] is head of the Pulsed Thermonuclear Installations Division at ESRIEA. His research interests include high-power excimer laser design, pulsed plasma systems, and conceptual design of fusion reactors. **V. M. Kozhevin** (top left) (DSc, physics, ESRIEA, USSR, 1972) is a senior scientist in the Theoretical Laboratory of the Pulsed Thermonuclear Installations Division of ESRIEA. His research interests include plasma dynamics and transport processes in field-reversed configurations (FRCs). **V. N. Litunovsky** (center right) (DSc, physics, ESRIEA, USSR, 1966) is head of the Pulsed Plasma Systems Laboratory in the Pulsed Thermonuclear Installations Division of ESRIEA. His research interests include experimental investigations of high-beta plasma systems, plasma accelerators, and FRC-based reactors. **A. A. Drozdov** (center left) (engineering, ESRIEA, USSR, 1974) is interested in the engineering problems of high-power supply systems, pinch systems, and plasma accelerators. **N. A. Viknyanshchuk** (bottom right) (physics, ESRIEA, USSR, 1984) is a member of the Pulsed Plasma Systems Laboratory staff at ESRIEA. His research interests include plasma diagnostics. **I. B. Ovchinnikov** (bottom left) (physics, ESRIEA, USSR, 1977) is a senior scientist at the Pulsed Plasma Systems

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Laboratory at ESRIEA. His research interests include experimental investigations of plasma accelerators. **A. E. Soldatov** (right) (physics, ESRIEA, USSR, 1987) is a junior scientist in the Theoretical Laboratory of the Pulsed Thermonuclear Installations Division of ESRIEA. His current research interests include numerical simulations of Compact Torus equilibrium and plasma dynamics.

