Fusion Energy Division
American Nuclear Society
December 1999 Newsletter

The December 99 newsletter of the American Nuclear Society (ANS) Fusion Energy Division (FED) has been archived on the ANS-FED Web site: http://fed.ans.org/. Please share this newsletter with your colleagues. Feedback on issues related to the newsletter is welcome. If you would like to subscribe to the ANS-FED newsletter or provide a change in E-mail address, simply reply to this message and include your contact information. A text version of the newsletter is appended below for those who cannot access the Internet. If you have a choice, please use the Web version as it contains formatting that is lost upon conversion to the text version. The topics for this issue are:

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Message from the Chair, Clement Wong, General Atomics, San Diego, California

Since becoming the Chairman of FED, I find that I have embarked on a significant learning experience. Not only have I learned about the workings of ANS, but also as an ex-officio member of FESAC, I have become much more familiar with the US and world fusion programs.

I would like to acknowledge that during the last quarter, past FED Chairs Drs. W. Hogan and W. Houlberg have volunteered their time to update our FED policy statement for the ANS. Our policy statement was submitted for approval by the ANS board at the ANS winter meeting in November, 1999.

Nearly one third of our fusion scientists participated in the two week long Snowmass summer workshop (see http://www.ap.columbia.edu/SMproceedings/) which not only brought the fusion community together but also provided important inputs to the other three high level reviews requested by the Department of Energy (DOE). Presently, reports have been completed for the DOE Secretary of Energy Advisory Board (SEAB) Fusion Task Force (see http://www.hr.doe.gov/seab), and the DOE Fusion Energy Sciences Advisory Committee (FESAC) Panel on Priorities and Balance of our fusion program (see http://fire.pppl.gov). A third review, the assessment of the scientific quality of the DOE's fusion program, is being conducted by the National Academy of Sciences and has issued an interim report (see http://www.nas.edu/ and search for " Current Projects"). I will not repeat the findings here: please visit the respective web site for details. The bottom line is that these reports contributed to the increase of fusion funding to $260M for FY2000 applicable to magnetic fusion energy (MFE) and inertial fusion energy (IFE) programs. ($250M from the Fusion Energy Science budget and $10M from the DOE defense Program budget.) Under the guidance of FESAC, a more integrated national program for MFE and IFE has been defined.

I feel very fortunate to be in the midst of this period of fusion energy development. The lack of a worldwide energy crisis, especially in the US, allows us to continue our scientific search for the best embodiment of environmentally acceptable MFE and IFE options. The international concern about the greenhouse effect from the burning of fossil fuels requires that economically strong countries including the US to take the leadership in preparing a more environmental friendly long-term solution to the energy supply of the world by preparing fusion to contribute to the energy mix of the future.

As a scientific program we should be very proud of the recent achievements from our operating machines like DIII-D at General Atomics, C-MOD at MIT and NSTX at PPPL. Among other important contributions, these experiments are pointing the way to advanced tokamak operation, the necessary operation with a metallic plasma-facing plasma wall, and the possibility of much higher physics performance of a low aspect ratio configuration. Alternate MFE concepts such as the reversed field pinch and compact stellarator will be further evaluated to allow healthy competition and further optimization of the future power reactor concept. With the Next Step Option study, we are evaluating the optimum experiment for the study of long burn and ignition physics. The National Ignition Facility (NIF) at LLNL will use glass lasers to obtain target ignition and modest gain under the Inertial Confinement Fusion program. IFE program elements have been prepared to investigate the driver options and to address the chamber design issues for energy production. For both the MFE and IFE programs, strengthened theory and computation research will continue to support the fusion program and encourage research on near-term applications of plasma science and technology. Internationally, we are maintaining productive collaborations with the leading facilities in Europe, Japan, Korea and China.

For the technology aspect of our fusion science program, the Technology Program is organized into the Fusion Virtual Laboratory for Technology, (see http://vlt.ucsd.edu/).

We have initiated the fundamental research on the interaction of the plasma with the vacuum chamber wall, and new and exciting results are being generated from topical and integrated experiments. For the MFE option, it is a very significant intellectual challenge to prepare the transition from a disruption-tolerant carbon wall machine to a higher performance steady state metallic wall machine. Technology issues of high local surface heat flux and disruptive impacts can only be resolved with close collaboration between the physicists, technologists and engineers. For example, with careful selection of radiating material and operating regime, the peak surface heat flux could possibly be reduced by radiating the charged particle power to the first wall area with minimum degradation in the plasma performance. Impact from disruptions could be reduced by selecting to operate at a less disruptive plasma regime and by various means of mitigating the disruption effects. It is clear that these approaches can only be successful with additional innovations from enabling technologies like heating, profile control and diagnostics. Bold and innovative concepts are being investigated. We are evaluating the possible use of liquid walls to handle the surface heat flux, erosion effects, and to reduce the impact of radiation damage on solid structural material from the 14 MeV neutrons of the D-T fuel cycle. This is being investigated in close concert with modeling and liquid wall experiments in tokamak and linear machines. The IFE program has also been evaluating the thick liquid layer option to protect the vacuum chamber solid wall for neutrons as well as x-rays. An accelerator neutron source will be needed to establish fundamental material evaluation.

The low aspect ratio (A from 1.2 to 1.6) normal conducting coils design as is being investigated by NSTX, has the potential to become a concept to study D-T burning plasma and then evolve to an integrated component testing facility. However, in addition to addressing the physics and plasma interface issues, it is clear that once a high performance, long burn or steady state D-T plasma is envisioned, the intrinsic generation of copious neutrons will require the complete spectrum of nuclear engineering technologies to become involved in the next stage of fusion energy development.

The area of magnet design may turn out to be the most crucial area in the determination of the commercial embodiment of the toroidal fusion power system. Higher field and less expensive magnets have an important potential to reduce the projected cost of electricity. At this time we have also learned that normal conducting coils allow a thinner inboard shield (<0.3 m) and can lead to low aspect ratio designs, and superconducting coil designs with thicker inboard shields (>1 m) point towards higher aspect ratio designs. Providing innovation in the TF coil central column design, different inboard shield thickness in the range of 0.3 to 1 m could be envisioned. This could impact the selection and optimization of the aspect ratio for the toroidal system. This again shows the interactive nature of the technology and physics disciplines.

In short, I find that we are in a very exciting period of fusion energy development. The focus on science allows us to work on the fundamentals of physics and on technology. We are beginning to understand how the advanced physics and technology issues are inter-related and innovative solutions will be needed to optimize our product. As we are making further progress, the distinction between physics and technology issues will become more and more fuzzy. I am confident that our physicists and technologists will be able to meet the challenges of developing both MFE and IFE fusion energy options as we are preparing for the next millennium.

FED Slate of Candidates, Wayne Houlberg, Oak Ridge National Laboratory, Oak Ridge, Tennessee

We are offering an excellent slate of candidates for election to FED offices. It is gratifying that these interested and qualified people are willing to devote time from their busy schedules to work on behalf of our members to see that the FED succeeds as a professional society. We are now asking you to be equally committed to the success of FED by examining the qualifications of each candidate and voting. The increasing Fusion budget has been encouraging this year, but the program has been facing many changes than we can more effectively respond to as a society. We encourage you all to vote!

Vice Chair/Chair Elect:
James Stubbins - University of Illinois, Urbana-Champaign

Secretary/Treasurer:
Rene Raffray - University of California, San Diego

Executive Committee Candidates:
Chris Hamilton - General Atomics, San Diego, California

Jeff Latkowski - Lawrence Livermore National Laboratory, California

Dennis Youchison - Sandia National Laboratory, Albuquerque

FED Awards: Call for Nominations, Gerald Kulcinski, Fusion Technology Institute, University of Wisconsin-Madison

Enclosed you will find announcements for 3 awards to be given at the 14th Fusion Topical Meeting in Park City, Utah, October 15-19, 2000. These awards are:

* 2000 Outstanding Technical Accomplishments Award
* 2000 Outstanding Achievement Award
* 2000 FED Student Award for Fusion Science and Engineering

Descriptions of the selection criteria and deadlines for the nominations are included and also posted on the ANS-FED Web site: http://fed.ans.org/.

Nomination deadline is July 30, 2000.

Please make this announcement known to your colleagues and students. Thank you for your cooperation and I am looking forward to your submissions

Mail nominations to: Professor Gerald L. Kulcinski
Chair FED Honors and Awards Committee
University of Wisconsin-Madison
Department of Engineering Physics
1500 Engineering Drive, #443
Madison WI 53706-1687

2000 Outstanding Technical Accomplishment Award
and 2000 Outstanding Achievement Award

The Honors and Awards Committee of the Fusion Energy Division (FED) of the American Nuclear Society (ANS) is currently considering nominations for two awards to be presented at the 14th Topical Meeting on the Technology of Fusion Energy from October 15-19, 2000 in Park City, Utah.

THE OUTSTANDING TECHNICAL ACCOMPLISHMENT AWARD is presented to an ANS member for recognition of exemplary individual technical accomplishment (however, there could be a partnership) requiring professional excellence of a high caliber in the fusion science and engineering area.

THE OUTSTANDING ACHIEVEMENT AWARD is presented to an ANS member for recognition of exemplary individual achievement (however, there could be a partnership) requiring professional excellence and leadership of high caliber in the fusion science and engineering area.

General statement (purpose, criteria, procedure, and award) concerning both awards is enclosed. You can obtain further information about these awards from the Chair. Nominations are to include a brief statement why the candidate should receive the award.

2000 Outstanding Technical Accomplishment Award
Fusion Science and Engineering

Purpose

* For recognition of a specific exemplary individual technical accomplishment requiring professional excellence and leadership of a high caliber in the fusion science and engineering area.

* So others will understand that the Fusion Energy Division of the American Nuclear Society encourages such technical accomplishment and recognizes its importance to fusion.
* Award to recognize technical accomplishment and professional excellence by a member of the American Nuclear Society.

Criteria

* Emphasis is on individual accomplishment through a specific technical accomplishment. Therefore, the award is usually given to an individual, however, there could be a partnership.
* Emphasis is on a single technical contribution to fusion science and engineering however that contribution is made.
* Contribution to be measured as recognized by others in the field.

Procedure

* Nominations can be made by anyone at anytime to the Honors and Awards Committee Chair of the Fusion Energy Division of the American Nuclear Society.
* On an annual basis, a call will be made for candidates and the Committee will evaluate the information, gather additional information if necessary, and may actively search for additional nominations.
* A decision is made whether an award will be given to any nominee in a specific year.
* The recommended accomplishment is presented to Fusion Energy Division Executive Committee for approval and to the ANS Honors and Awards Committee for concurrence.

Award

* An object of ornamental or useful type with intrinsic value.
* A certificate designating the presentation of the award.
* Presented at any American Nuclear Society Annual Meeting or Division Topical Meeting.

2000 Outstanding Achievement Award
Fusion Science and Engineering

Purpose

* For recognition of a continued history of exemplary individual achievement requiring professional excellence and leadership of a high caliber in the fusion science and engineering area.
* So others will understand that the Fusion Energy Division of the American Nuclear Society encourages such achievement and recognizes its importance to fusion.
* Award to recognize achievement, leadership, and professional excellence by a member of the American Nuclear Society.

Criteria

* Emphasis is on a history of achievements in advancing the technological development of fusion.
* Emphasis is on a continued series of contributions to fusion science and engineering however those contributions are made.
* Contributions to be measured as recognized by others in the field.

Procedure

* Nominations can be made by anyone at anytime to the Honors and Awards Committee Chair of the Fusion Energy Division of the American Nuclear Society.
* On an annual basis, a call will be made for candidates and the Committee will evaluate the information, gather additional information if necessary, and may actively search for additional nominations.
* A decision is made whether an award will be given to any nominee in a specific year.
* Nominees' achievements not receiving an award will be re-evaluated for the next three years.

Award

* An object of ornamental or useful type with intrinsic value.
* A certificate designating the presentation of the award.
* Presented at any American Nuclear Society Annual Meeting or Division Topical Meeting.

ANNOUNCEMENT AND CALL FOR PAPERS
2000 Fusion Energy Division Student Award
Fusion Science and Engineering

The Honors and Awards Committee of the Fusion Energy Division (FED) of the American Nuclear Society (ANS) is soliciting student papers for the 2000 FED Student Award for Fusion Science and Engineering. This student award will be presented at the 14th Topical Meeting on Technology of Fusion Energy from October 15-20, 2000 in Park City, Utah. The award consists of a Certificate of Accomplishment and a cash award. Travel support is also provided if the student attends the meeting to present the paper and receive the award. In addition, the student will be given the opportunity to publish his(her) full length paper in Fusion Technology without a page charge. Eligibility and nomination requirements are summarized below.

Eligibility:

* Nominee must be a student sometime between September 1999 and June 2000.
* Nomination is made by a faculty member familiar with the accomplishment.
* Submit seven (7) copies of a complete research paper of journal publication caliber, plus nomination requirements listed below.

Requirements:

* Name and address of nominee
* Education (degrees with institutions, dates and field; present status, etc.)
* Nomination letter by a faculty member that includes comments on student's contributions to fusion science and engineering that would be recognized as significant by educators, scientists, and engineers; the creativity, novelty, and current and future importance of the accomplishment.

The award's purpose is to recognize a significant research accomplishment, of journal publication caliber, by a student in the fusion science and engineering area, and to encourage student involvement in future fusion energy programs.

Park City: Site of 14th ANS Fusion Technology Topical, Glen Longhurst, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho

The 14th ANS Topical Meeting on the Technology of Fusion Energy will be held October 15-19, 2000 at the famous resort community of Park City, Utah. The meeting is sponsored by the ANS Fusion Energy Division, by the Idaho and NORCAL sections of the ANS and by the Fusion Engineering Division of the Atomic Energy Society of Japan.

Park city is one of the premier vacation spots of the world. Located about 30 miles east of Salt Lake City, Utah, it is most famous for its skiing in wintertime. It is also a haven for golfers, hikers, shoppers, artists, and entertainers in the summer months. The town began its existence in the mid to late 1800s as a small mining community, nestled in the mountains east of the Great Salt Lake. It became one of the richest silver mining districts in the country, producing more than $500 million in silver and making 23 millionaires. Now, after almost 50 years of restoration, it has become a Mecca for the arts with galleries, music, dance, theater, and the nearby Sundance Film Festival. Many major manufacturers have discount outlets there featuring everything from hardware to sportswear, handcrafted furniture to designer boutiques. Learn more about this fascinating community at http://www.parkcityinfo.com. Transportation to Park City from the Salt Lake City airport can be arranged through "All Resort Express", www.allresort.com.

The meeting site is the spacious Park City Marriott Hotel (http://www.parkcityutah.com), the area’s largest and most complete meeting facility. It will run from Sunday October 15 through Thursday October 19, 2000. The conference has reserved 175 rooms at the special meeting rate of 84 US$ plus applicable taxes, single or double occupancy. These rooms are available at the meeting rate until September 15, 2000 (ask for the “Idaho Section for ANS” conference rate). After this date, rates are not guaranteed. Registration for these rooms is available by telephone (800-234-9003) and by fax (435-649-4852). The fax forms are available electronically at the conference web site, http://ev2.inel.gov/ParkCity/. Other hotels are available in Park City and in the surrounding area (http://www.parkcityinfo.com/lodging/hotelsWin.con.html)

A full schedule of activities for the week is planned. Registration opens Sunday afternoon, October 15 from 4:00 pm to 8:00 pm, and each morning thereafter at 7:30 am. The opening plenary session will be on Monday, October 16 at 8:30 am. Oral Sessions will run Monday through Thursday from 8:30 am through 12:30 pm. Opening plenary sessions each day followed by three parallel oral sessions are planned, but details will be determined by paper submissions. Poster Sessions are planned from 2:00 - 5:00 pm Monday through Wednesday.

A reception will be held Monday evening from 7:00 - 9:00 pm with a no-host bar. A conference banquet will be held Wednesday evening from 7:00 pm to 9:00 pm with a choice of dinner entree. For accompanying persons, there will be two general guest activities: a steam train tour on the "Heber Creeper" on Monday afternoon and a shopping tour in and around Park City on Tuesday afternoon. The Heber Creeper is “history in motion”, a vintage steam railway operating from nearby Heber City, Utah. The tour is 3 1/2 hours through the hinterlands of the West and includes lunch. The shopping tour to the Park City outlet district will keep Epicureans and budget-minded shoppers alike fascinated with the range and variety of items available. Those with a more venturesome flare can visit historical sites or points of technical interest in the Salt Lake City area, or simply take to the hills on “shanks ponies” or on more durable equestrian mounts. Fall colors in the mountains surrounding Park City should be brilliant at that time of year, and the weather should be mild and clear.

We anticipate an excellent technical program. Technical sessions are planned on a wide range of subjects including:

- Current and Planned Magnetic Fusion Experiments
- Divertor Design and Experiments
- Fuel Cycle and Tritium Technology
- Fusion Blanket and Shield Technology
- Fusion Magnet Systems
- Fusion Materials
- Fusion Plenary
- Fusion Power Plants and Economics
- Inertial Fusion Drivers and Targets
- Innovative Approaches to Fusion Energy
- International projects
- National Ignition Facility (NIF)
- Neutron Sources for Fusion Technology Testing
- Neutronic Experiments and Analyses
- Non-electric Applications of Fusion
- Plasma Facing Components: Analysis and Technology
- Plasma Heating, Current Drive, and Control
- Power Plant Design and Technology
- Recent Results from Inertial and Magnetic Confinement Experiments

Safety and Environmental Research
Status of Fusion Nuclear Data
Steady-State and Long-Pulse Machine Studies

KEY DATES

Call for Abstracts - January 14, 2000
Preliminary Registration Begins - April 1, 2000
Abstracts Due - May 1, 2000
Author Notification of Acceptance - June 5, 2000
Full Paper Submission (at meeting) - October 15, 2000

REGISTRATION

Registration Fee (includes reception, banquet, proceedings):
ANS Members: $450 before September 1, 2000, $500 after September 1, 2000
Nonmembers: $500 before September 1, 2000, $550 after September 1, 2000
Student Registration (meeting and reception only): members free, non-members $50
Extra Banquet Tickets $35
Guest Registration (Hospitality room and Shopping Tour) $30
Heber Creeper Tour $40
VISA/ MasterCard accepted

Register electronically at http://ev2.inel.gov/ParkCity/ or contact the conference secretary:

Marie Warnick
Bechtel BWXT Idaho, LLC
P.O. Box 1625
Idaho Falls, ID 83415-3860
Phone: 208-526-6977
Fax: 208-526-2930
E-Mail: mri@inel.gov

XIV Technology of Fusion Energy

Journal of Fusion Technology Seeks New Editor, Ken Schultz, General Atomics, San Diego, California.

The American Nuclear Society (ANS) is soliciting names of qualified members who have an interest in becoming the editor of the ANS journal of Fusion Technology. Professor George Miley of the University of Illinois is the founding Editor of this journal and has served as its editor since its inception in 1981 as "Nuclear Technology/Fusion", switching to "Fusion Technology" in 1984. He has done an outstanding job. Prof. Miley has indicated that he intends to retire from the Editorship in approximately 2 years. The ANS is thus seeking a qualified individual to take his place. The selected person will be appointed "Editor-Designate" by June 2000, will work with Prof. Miley to effect a smooth transition, taking over the full editor role by about January 2001.

It is the responsibility of the Editor of Fusion Technology to maintain the technical quality of this ANS journal. The Editor briefly reviews papers submitted to Fusion Technology for appropriateness and then selects suitable reviewers for detailed technical review of the paper. The Editor then reads the comments of the reviewers and decides whether the paper should be accepted as is, revised as suggested, revised and re-reviewed, or rejected. The Editor sets the technical directions of the journal by soliciting papers, special issues, and reviews on important and timely technical topics.

The editorial and administrative work associated with editing the journal (receiving manuscripts, mailing manuscripts to reviewers, following up to get reviews back, technical editing, typesetting and printing) will be done by the ANS Headquarters staff. The role of the Editor is thus primarily technical leadership and direction, not clerical. Past experience indicates that this requires on the average about 20% of the Editor's time (~8 hours per week), including attendance at the ANS National meetings and approximately two topical meetings per year. The ANS pays the Editor a small honorarium, provides a travel budget to attend the required meetings, and pays communications costs as needed.

Candidates for the Editorship must be knowledgeable and respected members of the fusion nuclear community, and members of the ANS. They must have experience with and appreciation for the role of research and journal publication in the nuclear area.

Individuals who are qualified and interested in this vital position are requested to send a letter expressing interest and a detailed resume of their qualifications and experience to the ANS Technical Journals Committee by February 15, 2000:

ANS Technical Journals Committee
c/o Dr. Kenneth R. Schultz
General Atomics
P.O. Box 85608
San Diego, CA 92186

Telephone: 858-455-4304
E-mail: ken.schultz@gat.com

Ongoing Fusion Research:

The MST Reversed Field Pinch Experiment, Stewart Prager, Department of Physics, University of Wisconsin-Madison

The reversed field pinch (RFP) is an axisymmetric, toroidal magnetic fusion concept. It is much like a tokamak, except the toroidal magnetic field is about ten times weaker than in a tokamak (of the same current and size). The weaker toroidal magnetic field leads to an array of potentially positive reactor attributes, including normal (non-superconducting) coils, high beta values, very high engineering beta (ratio of plasma pressure to magnetic pressure at the surface of the coil), weak force at coils, relatively small size, single piece maintenance, and free choice of aspect ratio (limited by engineering, rather than physics, constraints). These potential advantages have been demonstrated about ten years ago in the TITAN systems study. However, this study was based on several strong physics assumptions. The purpose of the present RFP experimental program is, in part, to determine whether these assumptions can be proven.

The RFP is an old concept, first studied several decades ago. The weak magnetic field renders the RFP prone to MHD tearing instabilities. These result in magnetic fluctuations which drive large transport. Recently, it has been demonstrated experimentally that the transport can be reduced significantly. Realizing that the gradient in the current density is the source of the fluctuations, the current profile was altered by time-programming the inductive electric field. The current profile control halved the magnetic fluctuations, increased the energy confinement time by a factor of five, and the triple product ($nT\tau$) by a factor of ten. Although substantial further improvement is necessary, this and other results led the Fusion Energy Sciences Advisory Committee recently to recommend that RFP research proceed to a proof-of-principle (PoP) program.

The Madison Symmetric Torus (MST) experiment, at the University of Wisconsin, would serve as the proof-of-principle facility. MST has operated for about ten years as a concept exploration experiment. However, the size, current, pulse duration, and first wall characteristics imply that MST would be suitable for the new program. The major and minor radii of MST are 1.5 m and 0.5 m, and the plasma current is 0.5 MA. The first wall/vacuum chamber is 5 cm thick boronized aluminum, with about 10% of the surface covered with graphite armor. The wall is robust and can withstand the high power deposition associated with the auxiliary heating and current drive experiments planned for the PoP program. Furthermore, the conducting vacuum vessel functions as the toroidal field winding and the poloidal field windings are wrapped around the iron core. Thus, the torus is unencumbered by coils resulting in good diagnostic access and easy machine disassembly for internal modifications; properties useful for the PoP program.

The past focus of MST activity has been understanding and improving transport, with relatively limited diagnostics and relatively crude current profile control techniques. The future MST program calls for a more aggressive approach to confinement understanding and improvement, and new physics elements. The key issues to be studied are confinement, beta limits, and plasma sustainment. The main approach to confinement improvement is current profile control through improved inductive programming, through lower hybrid current drive and, possibly, through electron cyclotron current drive using electron Bernstein wave propagation. Although existing RFP experiments operate at high beta values (5% - 15%), the experimental limit is unknown. To study the beta limit, MST will employ either lower hybrid, fast wave, or neutral beam heating (to be determined by initial low power experimental tests). The RFP requires a technique for steady state sustainment. In MST, the inductive, AC helicity injection technique known as Oscillating Field Current Drive will be tested.

Much of the MST plans rely upon the controlled deposition of auxiliary power into the RFP. All past RFP experiments have only incorporated ohmic power input. Development of efficient and controlled auxiliary current drive and heating will be a major technical challenge. The larger PoP program includes theory and computation, targeted system studies, and concept exploration experiments. Candidate topics for concept exploration experiments include the study and control of resistive wall instabilities, and the study of RFP plasmas with varied geometry (such as low aspect ratio). The concept exploration component of the RFP program is not yet formulated.

MST is part of a relatively small, but coordinated, world RFP program. In particular RFP experiments of similar size, but higher plasma current capability, are underway in Padua, Italy (the RFX experiment with a current capability of 2 MA) and in Tsukuba, Japan (TPE- RX, at 1 MA). These experiments are presently focused on the investigation of the scaling of RFP energy confinement with plasma current. In Stockholm, Sweden, the smaller T2 experiment is focused on the diagnosis of resistive wall instabilities. Hence, the US RFP program complementary to and a key part of the world RFP program.

Although not emphasized in this report, MST research is also intended to contribute strongly to basic plasma physics through study of phenomena associated with magnetic fluctuations (such as magnetic chaos, magnetic fluctuation induced transport, MHD turbulence, and dynamo effects). These physics issues are of fundamental interest, and must be understood to advance the RFP as a fusion concept. Hence, the RFP program embodies both the science focus and energy goal of the restructured fusion program.

For further information on MST contact the web site:
http://sprott.physics.wisc.edu/mst.html

SiC Composites as Structural Materials in Nuclear Systems, Lance Snead, Metals and Ceramic Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee

The benefit of silicon carbide (SiC) materials for nuclear systems has been discussed for many years. These benefits include the high temperature strength, leading to high thermodynamic efficiencies of gas (He) cycles, the lack of the need for heat exchangers, and the inherently low induced radioactivity. If such a material becomes a viable structural material for large structures, its application offers several advantages in the areas of safety, maintenance, and disposal over conventional materials, and would likely be a primary reason for considering fusion an attractive future energy source. This was, in fact, the conclusion of the 1988 Department of Energy sponsored report "Exploring the Competitive Potential of Magnetic Fusion Energy," which compared the future outlook of fossil, fission, and fusion energy. Following the reasoning of this study, the primary advantage fusion power has over its leading competitor fission power, is its ability to significantly reduce the long-term radioactive by-products.

Since the initial proposals to use monolithic ceramics as structural materials in fusion systems (1970's), relatively little materials study and development has been conducted to demonstrate their viability. This is mainly because although monolithic ceramics are relatively common and possess very high modulus and strength, they tend to fail in a brittle, erratic manner. The resultant wide distribution in failure strengths, which is commonly described using Weibull statistics, is extremely undesirable from the design point of view. There are also other serious, practical objections to their use. For example, can large components be precision manufactured, and can these parts be joined to other components?

Recently, there has been significant development of SiC/SiC composites in the US for applications such as heat exchangers, turbines, and other applications where the resistance to corrosion of SiC is beneficial. The attraction of the composite material system is that, through the incorporation of high strength whiskers, platelets, or continuous fibers into a ceramic matrix, cracks can be arrested or deflected at the matrix/dispersion interface and a degree of toughness is gained. Thus, for a properly engineered composite, the benefits of monolithic ceramics are retained while the problem of a wide distribution in failure strengths (hence the need for a Weibull failure treatment) can be avoided. The SiC/SiC development work has been sponsored primarily by the DOE-Energy Efficiency and Renewable and Fossil Energy programs which undertook the rather aggressive, long range goal of strengthening the development of the materials and domestic manufacturing capability. An example of an end product is the SiC/SiC combustor liners developed by the Allied Signal/Solar Turbines team under the CFCC program. Like the gas turbines and turbine liners developed under the Fossil program, these composites were successful in meeting their structural performance criteria, but were found to lack resistance to the application environment, specifically due to water vapor, sulfur and oxygen corrosion.

Beginning in the early 90's, the DOE Office of Fusion Energy began to explore the potential for SiC/SiC composite as a fusion structural material. This work essentially drew from the experience in the much larger ongoing SiC/SiC development programs and focussed its effort on fusion specific areas such as stability under neutron irradiation. It was quickly realized that the "off the shelf" materials suffered very large (~50%), and rather puzzling, degradation in mechanical performance under neutron irradiation. It turned out that this particular composite system was extremely sensitive to small, non-isotropic changes in its composite constituents (fiber, matrix) and the critical interfacial material between the fiber and matrix. Study revealed that the ceramic fiber itself underwent shrinkage under neutron irradiation, contrary to the typical behavior of ceramics. From this point, emphasis was put into the understanding of radiation effects in composites and the development of more radiation resistant materials. Collaborations were established to take advantage of the composite development strengths within the US (specifically at ORNL, PNNL, General Atomics, and certain small businesses such as Hypertherm and MER Inc.,) and the fiber manufacturing and research strengths residing in the Japanese industry and universities.

Recently, the benefit of the various collaborative research efforts has begun to be realized. At radiation dose levels where the original materials studied would undergo serious degradation (equivalent to a month or so of fusion power plant operation), the newest materials processed at ORNL with Japanese fibers undergo essentially no degradation. However, this dose is still well short of any design goal for SiC/SiC application. Reaching these higher doses is currently underway. An added benefit from the newer materials is the increased upper application temperature from about 1000°C to about 1600°C, promising even higher potential thermodynamic efficiencies. The thermal conductivity of some of the experimental materials has also been improved from the typical ~20 W/m-K to >60 W/m-K at room temperature, though reduction in this property under irradiation and high temperature may still be the Achilles' heel of these materials, depending on their final application.

Currently, the fusion materials SiC/SiC development program is still emphasizing its development and irradiation performance efforts, but has begun to move into other equally important issues. These include enhancement and understanding of thermal conductivity for composites under neutron irradiation, bonding of these materials to each other and to metallic structure, compatibility with breeding materials, and issues such as environmental degradation. This last point, while it appears to be the major drawback for the applications studied in the Fossil and Renewable Energy programs, should be less of an issue for fusion, though still an important consideration. The area of the large helium and hydrogen generation, which is intrinsic for these materials under fusion neutron irradiation (up to an atom percent in some applications,) is also now beginning to be studied. In common with all structural materials being considered for fusion, the effects of the gases produced by neutrons at fusion relevant neutron energies are largely unknown and will likely be an active area for future research.

International Activities:

Progress of LHD Experiment, Osamu Motojima, Head of LHD Experiment, National Institute for Fusion Science, Toki, Japan

The Large Helical Device (LHD) is a steady-state, superconducting (SC) heliotron experimental machine with continuous l=2 / m=10 helical coils and currentless plasma system. LHD started its first operation in early 1998 in Toki, Japan. Its major mission is to produce 10 keV range plasmas that possess high performance close to the breakeven condition without any hazardous disruptions. Demonstration of steady-state plasma production with a helical divertor is recognized as another important mission. The LHD's specifications are listed in Table 1. The numbers in parentheses indicate specifications for the second phase, which will start several years after finishing the present experiments.

Table 1. Specifications of LHD

Major Radius	3.9 m
Coil Minor Radius	0.975 m
Averaged Plasma Radius	0.5-0.65 m
l , m	2 , 10
Magnetic Field	3 (4) T
Helical Coil Current	5.85 (7.8) MA
LHe Temperature	4.4 (1.8) K
Poloidal Coil Current:	
Inner Vertical Coil	5.0 MA
Inner Shaping Coil	-4.5 MA
Outer Vertical Coil	-4.5 MA
LHe Temperature	4.5 K
Plasma Volume	20-30 m^3
Heating Power	40 MW
Coil Energy	0.9 (1.6) GJ
Refrigeration Power	9 (15) kW
Total Weight	1,500 ton
LHe Cooled mass	900 ton

During the last two years, LHD successfully executed three experimental campaigns. The present day achieved plasma parameters are summarized in Table 2.

Table 2. Achieved Parameters

	High Temp ECH	High Temp NBI	High Confinement NBI
T_e (keV)	3.5	3.3	1.1

T_i (keV)		2.4	1.1
τ_E (s)	0.08	0.16	0.3
P_{abs} (MW)	0.9	2.6	2
n_e (m^{-3})	0.45e19	1.5e19	6.5e19

The magnetic field has gradually increased to reach 2.85 T at the 3.6 m magnetic axis, with careful monitoring of the stability of the SC conductor, heat input rate, mechanical deformation and stress level of the supporting system, etc. We have experienced a single quench phenomena in one of the two helical coils during a coil excitation test at a magnetic field of 2.74 T. Nevertheless, we were able to demonstrate the correct function of the coil power circuit for the quench protection. Furthermore, we successfully withdrew the coil magnetic energy with no damage detected to the SC coil systems. The quench phenomena analysis for such large SC coil system offered valuable experience. In addition, a useful database was compiled to investigate the real capability of the SC coils. The experience gained and the database are applicable to the design of SC coil systems for future engineering fusion reactors.

The heating power has also gradually increased up to 4.2 MW for NBI with two beam lines, up to 1.3 MW for ICRF with one antenna system, and up to 0.9 MW for ECRH with 6 gyrotrons. As indicated in Table 2, the results of the three campaigns show good progress. The $n_i\tau_E T_i$ value amounts to 2e19 keV.s/m^3, the plasma energy reached 0.8 MJoule at a temperature of 3.5 keV, the average beta is 1.3% at 0.75 T, and the maximum electron density is 8.8e19 m^{-3}. These values are reasonable considering the present heating power level. The observation of a good energy confinement time of 0.2-0.3 s is encouraging. In previous helical system and stellarator experiments, the energy confinement time was expressed by the International Stellarator Scaling, which has similar characteristics to the ITER Elmy-H mode scaling governed by the Gyro Bohm type scaling. Our new data is > 1.5 times higher than existing scaling laws. Utilizing the strong density dependence with the high density limit of heliotrons and stellarators, it is now possible to make an experimental program to reach the high $n\tau_E T$ regime of the LHD experiment, increasing both the heating power and the density at the same time. Energy confinement time is evaluated by diamagnetic measurements and by kinetic temperature and density profiles.

The diagnostic systems are also showing rapid progress. For example, with 50 Hz and 130 channels, the Thomson scattering system demonstrates the precise electron temperature profiles. It indicates that the presence of a temperature pedestal plays an important role in confinement improvement. The ion temperature is measured by the Charge Exchanged Recombination Spectroscopy (CXRS) and the Neutral Particle Analyzer (NPA). The CXRS measurement indicates the presence of a plasma poloidal rotation and a resultant radial electric field around 10 kV/m. A Heavy Ion Beam Probe (HIBP) with 6 MeV will be installed soon to demonstrate the real role and structure of the radial electric field in the neoclassical transport mechanism and micro-turbulence. Based on the bolometric measurements, the radiation levels are usually low.

During the beginning of this year's third campaign, graphite tiles were installed along the helical divertor traces on the surface of the vacuum chamber. The metallic impurity lines were dramatically reduced after this process. Of interest is that the area covered by the graphite tiles is 35 m^2, which represents only 5% of the total surface area of the vacuum chamber. This means that the major function of the divertor recycling takes place on the graphite tiles. In addition, the screening effect of the divertor area around the confined plasma prevents the incoming flux of metals from reaching the vacuum chamber wall; which means a screening effect was observed.

The present results are quite promising and important to the future of the LHD experiment. It is anticipated that the heating power of the LHD device will gradually increase up to 15 MW in the near future. The rapid progress of the LHD experiment is due to the fact that a disruption never occured in the LHD's currentless plasma. De-conditioning due to disruption is not needed. The researchers never have to worry about disruption when proceeding with a new operational regime, assuring active operation of the LHD experiments.

The majority of the LHD experiments are supported by close collaborations with scientists from the Japanese universities. The research is also open for international collaboration. For further information on the LHD experiment, visit the LHD web site: www.nifs.ac.jp

International Cooperation in Fusion Research, Tom Dolan, Head Physics Section, IAEA, Vienna, Austria

During 1999, the IAEA held or co-sponsored the following meetings relating to international cooperation in fusion research.
(TCM = Technical Committee Meeting).

28 Jan	Paris	Status of Fusion Report (IFRC)
8-12 March	Washington	Current Trends in International Fusion Research (co-sponsor)
9-10 June	Vienna	International Fusion Research Council (IFRC)
21-23 June	Kloster Seeon, Germany	TCM--First Principle Based Transport Theory
19-21 July	Lisbon	TCM--Control, Data Acquisition, and Remote Participation for Fusion Research (jointly with the IEA, Paris)

12-17 Sep	Bordeaux	Inertial Fusion Sciences & Applications (co-sponsor)
27-29 Sep	Culham, UK	TCM--H-mode Physics & Transport Barriers
4-8 Oct	Oh-arai, Japan	TCM--ECRH Physics & Technology for Fusion Devices
12-14 Oct	Naka, Japan	TCM--Energetic Particles in Magnetic Confinement Systems
18-20 Oct	Chengdu, China	TCM--Research Using Small Fusion Devices
25-29 Oct	Kyushu, Japan	TCM--Steady State Operation of Magnetic Fusion Devices
29 Nov-3 Dec	Vienna	Research Coordination Meeting--Applications of Plasma Physics and Fusion Technologies

If you would like further information about the outcome of a particular IAEA meeting, please contact t.dolan@iaea.org for the IFRC, "Current Trends", TCMs on ECRH, and transport theory meetings and u.schneider@iaea.org for all other meetings.

In 2000, the following IAEA meetings are planned:

- Programme Committee Meeting for 18th Fusion Energy Conference (May, Vienna)
- Research Coordination Meeting--Comparison of Compact Toroid Configurations (10-13 July, Vienna)
- TCM--Fusion Reactor Safety (probably in Sep. in UK or France)
- International Fusion Research Council (3 Oct., Sorrento, Italy)
- 18th IAEA Fusion Energy Conference (4-10 Oct., Sorrento, Italy)
- TCM--High average power drivers
- Advisory Group Meeting-- International Cooperation in Fusion Research
- TCM--Applications of fusion energy research and ignition facilities to science & technology
- Research Coordination Meeting--Power plant design for inertial fusion energy.

The details of these meetings will be listed on the PlasmaNet:
plasmant@sakura.cc.tsukuba.ac.jp , http://list.ias.unu.edu/plasmanet/