American Nuclear Society
Fusion Energy Division
June 2005 Newsletter

Letter from the Chair, Jake Blanchard, University of Wisconsin-Madison, Madison, WI.

I had hoped that there would be a decision on the ITER site by now, but it appears there won't be one until at least July (http://fire.pppl.gov/iter_tocqueville_041205.pdf). In addition to the important research results it will produce, ITER is of interest to the US fusion program because of its potential effect on our budgets. The current plan, as seen in a talk by Mike Roberts (http://fire.pppl.gov/iter_bpm_roberts_031505.pdf), is for the US ITER contribution over the next few years to be as follows:

	$M
2006	49.5
2007	146.0
2008	200.8
2009	207.5
2010	199.3

It is quite possible that these numbers will be reduced, as a result of delays in the siting process, but nonetheless they are significant in the context of the total US fusion budget. If these are to be met with no new funding, they will require significant changes in our current program mix. This has already been felt, to some extent, in the context of the proposed elimination of the materials program in the 2006 budget request. The relevant quote from the request, which can be found at http://www.sc.doe.gov/orm/Budget_Finance/FY_06_Budget/FES.pdf, is:

> *In addition, the Materials Research program will be eliminated in favor of reliance upon the general BES materials effort for scientific advances in areas of fusion interest.*

As I write this article, it appears that this proposal will not remain in the final budget and the materials program will be retained, but this may be an indicator of what the next few years will bring, potentially impacting a wide range of fusion research activities. I would encourage all of you who feel strongly about this to contact your representatives in the House and Senate and make your feelings known.

Finally, I'd like to thank everyone who helped with the Fusion Energy Division activities over the past year. Many people volunteer their time to help make the Division have as broad an impact as possible and they've made it a pleasure to serve as the FED Chair for the past year. Said Abdel-Khalik, Southern Nuclear Distinguished Professor at Georgia Tech, will take over for me after the National Meeting in June and I'm sure he'll do a wonderful job. Feel free to let either Said or myself know if you have comments or questions regarding any aspect of the FED.

Officers and Executive Committee List, René Raffray, University of California, San Diego.

We are pleased to announce and welcome the new Officers and Executive Committee members of the Fusion Energy Division. Vice-Chair Said Abdel-Khalik (Georgia Institute of Technology) becomes our new Chair. Jeff Latkowski (LLNL), the present Secretary/Treasurer, has been elected as the new Vice-Chair/Chair-Elect. Lee Cadwallader (INL) has been elected as Secretary/Treasurer. The newly elected Executive Committee members are Neil Morley (UCLA), Paul Wilson (UW) and Minami Yoda (GIT). These new members join an excellent group of individuals who have already been serving the FED as Executive Committee members. Congratulations to all!

We would also like to include a special mention for the unlucky candidates who contributed to a strong slate of candidates. We would like to thank the EC members whose term has just ended, namely Susana Reyes (LLNL) and Lance Snead (ORNL). Above all, we would like to express our appreciation to Jake Blanchard (UW) for his service this past year as FED Chair. He will now become the Nominating Committee Chair. Also, we would like to thank the FED members who are serving on the many standing committees that help maintain a responsive and well-functioning Division (see the list below).

FED Officers:

Chair:	Said Abdel-Khalik (GIT)	(05-06)	said.abdelkhalik@me.gatech.edu
VC/Chair-Elect:	Jeff Latkowski (LLNL)	(05-06)	latkowski@llnl.gov
Secy./Treas.:	Lee Cadwallader (INL)	(05-07)	lcc@inel.gov

Executive Committee Members:

	Gianfranco Federici (IPP)	(04-07)	federig@ipp.mpg.de
	Neil Morley (UCLA)	(05-08)	morley@fusion.ucla.edu
	Farrokh Najmabadi (UCSD)	(04-07)	najmabadi@fusion.ucsd.edu
	Akio Sagara (Japan)	(04-06)	sagara@LHD.nifs.ac.jp
	Ken Schultz (GA)	(03-06)	ken.schultz@gat.com
	Phil Sharpe (INL)	(03-06)	SHARJP@inel.gov
	Roger Stoller (ORNL)	(04-07)	stollerre@ornl.gov
	Paul Wilson (UW)	(05-08)	wilsonp@engr.wisc.edu
	Minami Yoda (GIT)	(05-08)	minami.yoda@me.gatech.edu

Past Chair: Jake Blanchard (UW) blanchard@engr.wisc.edu

FED Standing Committee Chairs:

	Nominating	Jake Blanchard (UW) - Chair
	Honors and Awards	Farrokh Najmabadi (UCSD) - Chair

FED Representatives on National Committees:

	ANS Publications	Ken Schultz (GA)
	ANS Public Policy	Bill Hogan (LLNL)

Editors:	Newsletter	Laila El-Guebaly (UW) Dennis Bruggink (UW)
	Fusion Science & Technology Journal	Nermin Uckan (ORNL)

Liaisons to other ANS divisions and organizations:

	ANS Board	Gary Gates (Omaha Public Power District)
	MS&T	Ken Schultz (GA)
	IEEE	George Miley (UIUC)
	RPS	Ham Hunter (ORNL)

FED webmasters:	Mark Tillack (UCSD) Dennis Bruggink (UW)

Treasurer's Report, Jeff Latkowski, Lawrence Livermore National Laboratory, Livermore, CA

As of December 2004, our division had a balance of $10,958. Income in 2004 included $749 from membership dues (division membership increased from 691 to 749). Expenses in 2004 included $1500 for student travel support for the 16th TOFE meeting, $300 for the ANS Student Conference, and $1500 for achievement and technical awards. The division made a $1500 contribution to the Edward Teller Endowment Fund. Finally, the division incurred an $83 expense for a conference phone at the June meeting.

Our income for 2005 is projected to be $700 from membership dues and approximately $9,000 in profits from the 16th TOFE meeting.

Projected 2005 expenses total $1500. They include $500 for conducting business meetings during the ANS National Meetings, a $500 contribution to the NEED Scholarship, and $500 for miscellaneous expenses.

We project a balance of $19,158 at the end of 2005. Given that the 17th TOFE meeting will occur in 2006, it will be a more expensive year. Additional expenses will include student travel support and awards.

At the June 5, 2005 Executive Committee meeting, discussions were held regarding the possible implementation of a new, 4-year rolling budget cycle. Division funds vary widely from one year to the next due to the biennial TOFE meetings, which are responsible for most of the division income. Additional uncertainty arises from the fact that one never knows if a particular TOFE meeting will generate a profit. By switching to a 4-year rolling budget cycle, the division would be able to better balance the sporadic income against expenses. It is expected that the division would use the additional flexibility to increase funding for student activities.

Fusion Energy Division Support for the John Landis Challenge, Steve Dean, Fusion Power Associates, Gaithersburg, MD and Ken Schultz, General Atomics, San Diego, CA.

We'd like to draw your attention to the December 2004 issue of ANS News and the information presented there about the Landis Challenge.

John Landis has always been a strong supporter of fusion energy within the ANS. The Fusion Energy Division (then called the Controlled Thermonuclear Fusion Division) was formed under his ANS Presidency in 1971-72. John is also a great advocate of support for student education and founded the NEED (Nuclear Engineering Education for the Disadvantaged) Scholarship fund to help needy students get an education in nuclear engineering. John has established a "challenge grant" to raise funds for special projects to further the mission and goals of the Society.

The December 2004 ANS News can be retrieved at http://www.ans.org/members/ansnews/ and the Landis Challenge article is repeated below. The article noted that there is growing momentum to meet John's challenge and it also thanked, and listed, those who have contributed so far. Further information about the Landis Challenge is at http://www.ans.org/about/landis .

The Fusion Energy Division urges all of our members to rise to John's challenge and make a contribution to the Landis Challenge fund. When you do so, please note that you are a member of the Fusion Energy Division, as we want to show our support for John and his long record of support for the ANS and for fusion energy.

December 2004 ANS News Article: The Landis Challenge Gains Momentum

The Landis Challenge was established through a contribution of $50,000 from John W. Landis, an ANS Fellow, founding member, and past president (1971–72). Landis challenges other ANS members to donate at least $100 each to collectively match his initial contribution. Landis has pledged to contribute another $50,000 to the Society once the challenge is met. The funds will be used to further the mission and goals of the American Nuclear Society. As John Landis said, "The peaceful uses of nuclear energy have already saved countless lives around the world. For 50 years, ANS has been a strong leader of the 'peaceful atom' movement. With additional resources, we can help lead the movement to unforeseen accomplishments."

To make a contribution to the Landis Challenge, send a check payable to the American Nuclear Society to ANS headquarters at 555 N. Kensington Ave., La Grange Park, IL 60526; please write "Landis Challenge" on the memo line of your check. Contributions, which are tax deductible, can also be made online at http://www.ans.org/about/landis .

Fusion Award Recipients, Laila El-Guebaly, University of Wisconsin-Madison, Madison, WI.

Fusion awards have been established to formally recognize the outstanding contributions to fusion developments made by members of the fusion community. Congratulations to the honored recipients of the 2004/2005 fusion awards and our kudos to all of them.

These awards were available to the newsletter editor at the time of publishing this newsletter. We encourage all members of the fusion community to submit information on future honorees to the editor (elguebaly@engr.wisc.edu) to be included in future issues.

Plasma Science and Technology Division of American Vacuum Society Award

Prof. **Noah Hershkowitz**, Department of Engineering Physics at the University of Wisconsin-Madison, has received the 2004 Plasma Prize for his outstanding contributions to the fundamental understanding of plasma transport in materials-processing devices. In addition, it recognizes his many technical advances in plasma physics, his research on the fundamental properties of magnetized plasmas for fusion applications, his mentoring activities, and exemplary service to the plasma community.

ANS Radiation Science and Technology Division Award

The 2004 Award was presented to Prof. **George H. Miley**, Department of Nuclear, Plasma and Radiological Engineering at the University of Illinois. Prof. Miley was cited for "his creative contributions to radiation science and technology in furthering the development of nuclear batteries, nuclear pumped lasers, and small fusion-based neutron sources for industrial neutron activation analysis."

IEEE Nuclear and Plasma Sciences Society Award

The 2005 lifetime achievement Award for Particle Accelerator Science and Technology was presented to Prof. **Ronald C. Davidson**, of the Princeton Plasma Physics Laboratory of Princeton University in recognition of his pioneering contributions to the theory of charged particle beams with intense self-fields, including fundamental studies of nonlinear dynamics and collective processes. This is the highest award in the field of particle accelerator science and technology in the nation and is conferred biennially.

Plasma Physics Division of European Physical Society (EPS) Award

The Board of the Plasma Physics Division of EPS has awarded the 2005 Hannes Alfvén prize to:

Prof. **Malcolm G. Haines**, of Imperial College, London
Dr. **Thomas W.L. Sanford**, of Sandia Laboratories, US
Prof. **Valentin P. Smirnov** of the Kurchatov RRC, Moscow

"For their combined development of an ultra-bright radiation source using multi-wire array Z-pinch pulsed power configurations from initial experiments on the Angara facility in Russia, through to the Z project in Sandia, resulting in electrical to radiation energy conversion efficiency over 15%, radiated energy of 2 MJ and pulsed power levels of 200 TW, representing one of the fastest developments in this field over the recent decades." The prize will be presented at the Annual Conference of the Division, to be held in Tarragona, Spain from June 27 to July 1, 2005.

ISFNT Awards

The Miya-Abdou award was presented at the 7th International Symposium on Fusion Nuclear Technology, held May 22-27, 2005 in Tokyo, Japan. The award aims at acknowledging outstanding technical contributions to the field of Fusion Nuclear Technology at a young age, 40 y or younger.

The 2005 award was given to Dr. **Pietro Barabaschi** (ITER, Garching) for his technical accomplishments and outstanding contributions to the engineering and management of the ITER project, Dr. **Takeshi Hirai** (FZJ, Germany) for his outstanding contributions in the field of plasma facing materials, and Dr. **Yves Poitvin** (EFDA, Garching) for his outstanding contributions in the field of high heat flux components and breeding blanket technology.

News from Fusion Science and Technology (FS&T) Journal, Nermin A. Uckan, FS&T Editor, Oak Ridge National Laboratory, Oak Ridge, TN.

During the past six months, since the last newsletter issued in December 2004, FS&T has been busy with publication and scheduling of several special issues and an excellent selection of contributed papers. The 2004 (second half)/2005 (first half) issues included the following special issues:

July & Sept. 2004	Selected papers from 14th IEA Int. Stellarator Workshop [Guest Editor: Fritz Wagner]
November 2004	ARIES-IFE [Guest Editor: Farrokh Najmabadi]
January 2005	Transactions - 5th Int. Conference on Open Magnetic Systems for Plasma Confinement
February 2005	TEXTOR Tokamak (Jülich, Germany) [Guest Editor: Philippe Mertens]
April & May 2005	Proceedings of the 16th Topical Meeting on the Technology of Fusion Energy (16th TOFE, Parts I & II)

The following special issues are already scheduled for the remainder of 2005:

July/Aug. 2005	Proceedings of the 7th International Conference on Tritium Science and Technology (Baden-Baden, Germany)
October 2005	DIII-D Tokamak (San Diego, CA)

Future (2006-2007) special issues will include: Fast Ignition (US, JA, EU), Alcator C-Mod Tokamak (MIT), JFT-2M Tokamak (JA), JET Tokamak (EU), 7th Carolus Magnus

(EU), MFE Diagnostics (EU, JA, RF, US), 15th IEA Stellarator Workshop (Madrid, Spain), 16th Target Fab. Specialist's Meeting (Scottsdale, AZ), 17th TOFE (Albuquerque, NM), and more.

Don't miss any of these issues by signing-up for an individual ANS member subscription or through your library.

Electronic access to FS&T is available from 1997-to-present. Additional journal back issues will continue to be added (depending on demand). Recent (2002 and later) camera-ready special issues are also available online. Tables of contents and abstracts of papers can be accessed at http://www.ans.org/pubs/journals/fst/. Individual and library subscribers can access the full text articles at http://epubs.ans.org/.

I'm looking forward to receiving your comments and suggestions on FS&T content and coverage, and potential future topical areas that are timely and of interest. Contact e-mail: fst@ans.org.

ONGOING FUSION RESEARCH:

Alcator C-Mod: Program, Recent Results and Plans, Earl Marmar, MIT Plasma Science and Fusion Center, Cambridge, MA.

Alcator C-Mod[1] is the high-field, high-density divertor tokamak in the world fusion program. The main parameters of the experiment are summarized in Table 1. Organization of the research program is realized through a combination of topical science areas and programmatic thrusts. The topics relate to the generic plasma science, covering turbulence and transport, plasma boundary science, macroscopic stability, and wave-plasma interactions. The thrusts focus this science on integrated fusion objectives crucial to the international program. The two thrusts are **Advanced Tokamak** and **Burning Plasma Support**. The Burning Plasma Support thrust takes advantage of the unique high-field, high-pressure capability of the facility and includes critical research aimed at resolving questions related to high performance H-mode regimes for next-step fusion experiments, particularly ITER. The Advanced Tokamak thrust takes advantage of the unique long-pulse capability of the facility (relative to skin and current decay times), at 5 Tesla, combined with new current drive tools, to investigate the approach to steady-state in fully non-inductive regimes at the no-wall beta limit; this is particularly relevant to the prospects for quasi-steady operation on ITER.

Unique aspects of the Alcator C-Mod facility provide the logical foundations for the scientific areas of emphasis in our research endeavors to answer key outstanding questions in the development of practical fusion energy:

Table 1. Alcator C-Mod Parameters

Toroidal Field	2.5 to 8.1 Tesla
Plasma Current	0.2 to 2.0 MA
Plasma Density	0.2 to 7.0 x 10^{20} m^{-3}
Compact Size	R = .67 m, a =.22 m, plasma volume = 1 m^3
High Power Density	Up to 0.5 GW/m^2 parallel flow in SOL
Flexible Topology	SNL, SNU, DN, limited
Plasma Facing Components	All metal (molybdenum, tungsten)
Triangularity	0 < d < .85
Elongation	0.9 < e < 1.85
Ion Cyclotron RF	4 MW tunable 50 to 80 MHz 4 MW fixed 80 MHz 2 dipole antennas 1 4-strap phaseable antenna
Lower Hybrid RF	3 MW, 4.6 GHz 1 launcher, 96 window array, real-time phase control

- **Long pulse capability** — C-Mod has the unique ability among highly-shaped, diverted tokamaks, to run high pressure plasmas with pulse length equal to the L/R relaxation time, at $B_T > 4$ Tesla. This provides an outstanding opportunity to investigate the extent to which enhanced confinement and stability of Advanced Tokamak configurations can be maintained in steady-state, using active profile control.
- **High magnetic field** — With capability to operate at very high absolute plasma densities (to 10^{21} m^{-3}) and pressures (approaching 10 atmospheres), and with magnetic field spanning the ITER field (5.3 Tesla) and beyond (to 8 Tesla), C-Mod offers a unique test-bed for exploring the physics and engineering which is prototypical of ITER and proposed compact ignition experiments. C-Mod currently holds the world record for volume average plasma pressure in a toroidal device (1.8 atmospheres), achieved at the toroidal field and normalized b planned for ITER (see Figure 1). Because of the short ion-electron thermal equilibration time, relative to energy transport times, at the high densities, C-Mod studies are routinely accomplished in the reactor relevant regimes with $T_e = T_i$.
- **Exclusively RF driven** — C-Mod does not use beams for heating, fueling or momentum drive. As a result, the heating is decoupled from particle sources and there are no external momentum sources to drive plasma rotation. It is likely that the same constraints will exist in a fusion power plant; the studies of transport, macro-stability and AT physics in C-Mod are thus highly relevant to reactor regimes.
- **Unique dimensional parameters** — C-Mod is dimensionlessly comparable to larger tokamaks, but dimensionally unique, which allows us to provide key points on scaling curves for confinement, H-Mode threshold, pressure limits, etc. At the same time, coordinated experiments with other facilities allow for important tests

of the influence of non-similar processes, including radiation and neutral dynamics. Many of these experiments are coordinated through the International Tokamak Physics Activity (ITPA).

- **Very high power density scrape-off layer plasma** — With parallel power flows approaching 1 GW/m^2 (as expected in ITER), C-Mod accesses unique divertor regimes that are prototypical of burning plasma conditions. The issues of edge transport and power handling which are explored beyond those specific to the tokamak, being relevant to essentially all magnetic confinement configurations.
- **High Z metal plasma facing components** — The molybdenum plasma facing components on C-Mod are unique among the world's major facilities. The use of high Z PFC's is also reactor prototypical, and leads to unique recycling properties, and wall conditioning, density, and impurity control challenges. Because of tritium retention issues, ITER must consider high Z plasma facing components as one option, and studies of hydrogenic retention in C-Mod, both with molybdenum and tungsten, will contribute significantly to this decision.

Education is an integral part of the Alcator project mission, and the project has a large contingent of graduate students working toward their PhD degrees. They are drawn from four departments at MIT, as well as from collaborating universities. Currently 29 graduate students are doing their research on Alcator C-Mod.

Recent Research Highlights

A small sample of recent research highlights are summarized here:

– Studies of edge and scrape-off layer rotation, combined with the surprising results of very strong spontaneous plasma flows seen in the absence of direct momentum input[2,3], are leading to the first understanding of a long-standing puzzle in tokamak physics, the sensitivity of the H-Mode threshold to details of the magnetic topology with respect to the direction of the ion grad-B drift.

– Studies of mode conversion processes in the ion cyclotron frequency range include direct measurements of the mode-converted waves in the plasma[4] and detailed agreement with state of the art computational models[5].

– Suppression of core turbulence has been realized through the application of radially localized off-axis radio-frequency heating, leading to strong reductions in core energy and particle transport, and active control of the subsequent evolution with a combination of on- and off-axis heating. These Internal Transport Barrier discharges[6,7] are unique, with positive shear magnetic field, and do not rely on strong external torques or core fueling, making them of particular interest for next steps with potential for application in reactors. The mechanisms responsible for these dynamics are being revealed by gyrokinetic computer models.[8]

– Measurements and modeling of the effects of very small non-axisymmetric magnetic field components[9] ($\delta B/B \sim 1 \times 10^{-4}$) on MHD modes, and scalings through coordinated experiments with DIII-D and JET, have led to improved extrapolation to ITER. The understanding gained from these studies has allowed us to implement error-field correction coils, which have been very successful in expanding the C-Mod operating space to regimes with higher plasma current (up to 2 MA), and lower density (and thus collisionality).

– Probe measurements have revealed the intermittent nature of the edge and scrape-off layer transport, and advanced ultra-high-speed imaging has revealed the detailed nature of the turbulence. This has lead to a revolutionary understanding of the importance of cross-field particle transport on the open field lines at the plasma boundary, and possible relationship to the empirical density limit[10].

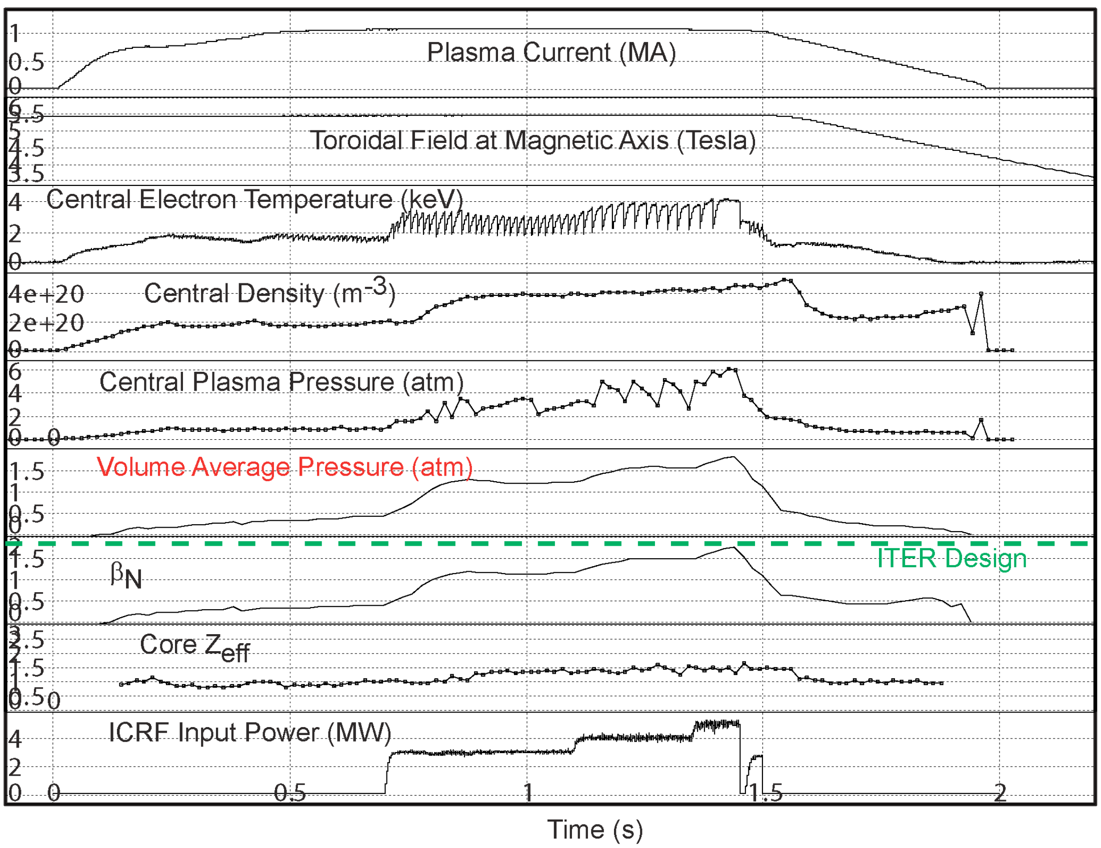


Figure 1. World record volume average pressure plasma has been achieved in Alcator C-Mod. In this case, the toroidal magnetic field is 5.3 Tesla (the same as the ITER design).

Near Term Plans

Planned research on Alcator C-Mod for the next five years will concentrate on exploiting recent facility upgrades, as well as installation of several new capabilities. The full complement of tunable ICRF power will be used for studies of flow drive and localized current profile modification. The most significant new tool installed on C-Mod is a high-power microwave system (4.6 GHz, 3 MHz), aimed at very efficient far off-axis current drive through coupling of lower hybrid waves to the electron population, for advanced tokamak studies. Real-time phase control should allow for dynamic studies of the effects of varying the locations of the current drive. The ultimate goals of this research include the realization of fully non-inductive quasi-steady-state high confinement configurations, and possible extrapolation to ITER. A high-pressure gas puff system has been installed to investigate disruption mitigation techniques at high absolute plasma pressure. Recently commissioned diagnostics, including motional stark effect for current profile measurements, and Charge Exchange Recombination Spectroscopy for ion temperature and rotation profiles, will be applied across the entire research spectrum. New facility upgrades planned for the coming two years include the addition of a divertor cryopump for active density control, complete conversion of high heat-flux divertor components to ITER prototypical tungsten, and the installation of a second Lower Hybrid current drive launcher for increased power and compound phasing.

References:
1) More details on the C-Mod Program can be found at http://www.psfc.mit.edu/research/alcator/index.html
2) J. Rice, et al., Nuclear Fusion, **45**(2005)251.
3) B. Labombard, et al., Nuclear Fusion, **44**(2004)1047.
4) Y. Lin, et al., Physics of Plasmas, **11**(2004)2466.
5) J.C. Wright, et al., Physics of Plasmas, **11**(2004)2473.
6) S.J. Wukitch, et al., Physics of Plasmas, **9**(2002)2149.
7) C.L. Fiore, et al., Physics of Plasmas, **11**(2004)2480.
8) D.R. Ernst, et al., Physics of Plasmas, **11**(2004)2637.
9) S.M. Wolfe, et al., Physics of Plasmas **12**(2005)056110.
10) J.L. Terry, et al., Physics of Plasmas, **10**(2003)1739.

High-Temperature Electrolysis For Hydrogen Production, Steve Herring, Idaho National Laboratory, Idaho Falls, ID.

Currently there is strong interest in the large-scale production of hydrogen as a secondary energy carrier for the non-electrical market. Hydrogen is of particular interest as a secondary energy carrier because it has the potential to be storable, transportable, and environmentally benign. Hydrogen is now produced primarily via steam reforming of methane. From a long-term perspective, methane reforming is not a viable process for large-scale production of hydrogen as a major energy carrier since such fossil fuel conversion processes consume non-renewable resources and emit greenhouse gases to the environment. Consequently, there is a high level of interest in production of hydrogen from water splitting via either thermochemical or electrolytic processes.

High-temperature nuclear reactors have the potential for substantially increasing the efficiency of hydrogen production from water splitting, with no consumption of fossil fuels, no production of greenhouse gases, and no other forms of air pollution. Thermal water-splitting for hydrogen production can be accomplished via high-temperature electrolysis or thermochemical processes, using high-temperature nuclear process heat. In order to achieve competitive efficiencies, both processes require high-temperature operation (~850°C). Thus these hydrogen-production technologies are tied to the development of advanced high-temperature nuclear reactors. High-temperature electrolytic water splitting supported by nuclear process heat and electricity has the potential to produce hydrogen with overall system efficiencies near those of the thermochemical processes, but without the corrosive conditions of thermochemical processes and without the fossil fuel consumption and greenhouse gas emissions associated with hydrocarbon processes. Specifically, a high-temperature advanced nuclear reactor coupled with a high-efficiency high-temperature electrolyzer could achieve a competitive thermal-to-hydrogen conversion efficiency of 40 to 50%.

A research program is under way at the Idaho National Laboratory to assess the performance of solid-oxide cells operating in the steam electrolysis mode for hydrogen production over a temperature range of 800 to 900ºC. The research program includes both experimental and modeling activities. Selected results from both activities are presented in this article. Experimental results were obtained from a ten-cell planar electrolysis stack, fabricated by Ceramatec, Inc. The electrolysis cells are electrolyte-supported, with scandia-stabilized zirconia electrolytes (~140 μm thick), nickel-cermet steam/hydrogen electrodes, and manganite air-side electrodes. The metallic interconnect plates are fabricated from ferritic stainless steel. The experiments were performed over a range of steam inlet mole fractions (0.1 – 0.6), gas flow rates (1000 – 4000 standard [0º C, 1 atm] cubic cm /min [sccm]), and current densities (0 to 0.38 A/cm^2). Hydrogen production rates up to 90 normal liters per hour were demonstrated. Stack performance is shown to be dependent on inlet steam flow rate.

A three-dimensional computational fluid dynamics (CFD) model was also created to model high-temperature steam electrolysis in a planar solid oxide electrolysis cell (SOEC). The model represents a single cell as it would exist in the experimental electrolysis stack. Mass, momentum, energy, and species conservation and transport are provided via the core features of the commercial CFD code FLUENT. A solid-oxide fuel cell (SOFC) model adds the electrochemical reactions and loss mechanisms and computation of the electric field throughout the cell. The FLUENT SOFC user-defined subroutine was modified for this work to allow for operation in the SOEC mode. Model results provide detailed profiles of temperature, Nernst potential, operating potential, anode-side gas composition, cathode-side gas composition, current density and hydrogen production over a range of stack operating conditions. Mean model results are shown to compare favorably with the experimental results obtained from the ten-cell stack tested at INL.

A close-up photograph of the test article, a 10-cell solid-oxide electrolysis stack, is shown in Fig. 1. The stack was fabricated by Ceramatec, Inc. of Salt Lake City, UT. The active area is 64 cm^2 per-cell. It is designed to operate in cross flow, with the steam/hydrogen gas mixture entering the inlet manifold on the right in the photograph, and exiting through the outlet manifold, visible on the left in the photograph. Air flow enters at the rear though an air inlet manifold (not visible in Fig. 1) and exits at the front directly into the furnace. The power lead attachment tabs, integral with the upper and lower interconnect separator plates are also visible in the photograph. Stack operating voltages were measured using wires that were directly spot-welded onto these tabs. Since the stack air outlet plane is not enclosed, the small air flow channels are accessible for instrumentation. Four intermediate cell voltages were monitored using small-diameter wires inserted into these air flow channels. In addition, four miniature thermocouples (inconel-sheathed, 0.010-inch (250 μm) OD, mineral-insulated, ungrounded, type-K) were inserted into the air flow channels to monitor internal stack temperatures.

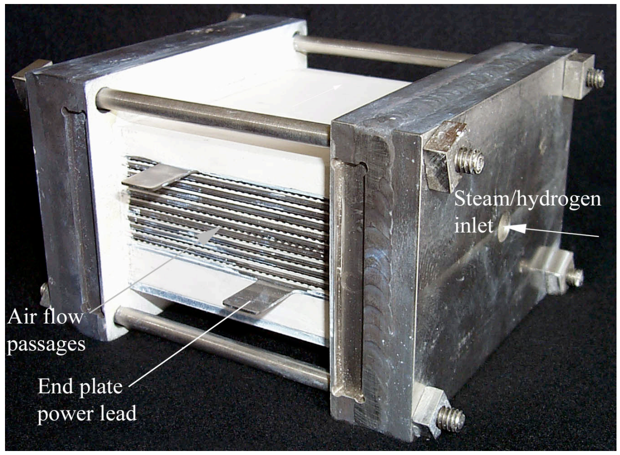


Figure 1. Detail of stack.

The internal components of the stack are shown in Fig. 2. The interconnect plate, shown on the left in Fig. 2, is fabricated primarily from low-chromium ferritic stainless steel. It includes an impermeable separator plate (~0.46 mm thick) with edge rails and two corrugated / perforated "flow fields," one on the air side and one on the steam/hydrogen side. The height of the flow channel formed by the edge rails and flow fields is 1.0 mm. Each flow field includes 32 perforated flow channels across its width to provide uniform gas-flow distribution. The steam/hydrogen flow field (shown in Fig. 2) is fabricated from nickel foil. The air-side flow field is ferritic stainless steel. The interconnect plates and flow fields also serve as electrical conductors and current distributors. To improve performance, the air-side separator plates and flow fields are pre-surface-treated to form a rare-earth conductive oxide scale. A perovskite rare-earth coating is also applied to the separator-plate oxide scale by either screen printing or plasma spraying. On the steam/hydrogen side of the separator plate, a thin (~10 μm) nickel metal coating is applied.

The electrolyte/electrode assembly is shown on the right of Fig. 2. The electrolyte is scandia-stabilized zirconia, about 140 μm thick. The air-side electrode (anode in the electrolysis mode), visible in the figure, is a strontium-doped manganite. The electrode is graded, with an inner layer of manganite/zirconia (~13 μm) immediately adjacent to the electrolyte, a middle layer of pure manganite (~18 μm), and an outer cobaltite bond layer. The steam/hydrogen electrode (cathode in the electrolysis mode) is also graded, with a nickel-zirconia cermet layer (~13 μm) immediately adjacent to the electrolyte and a pure nickel outer layer (~10 μm).

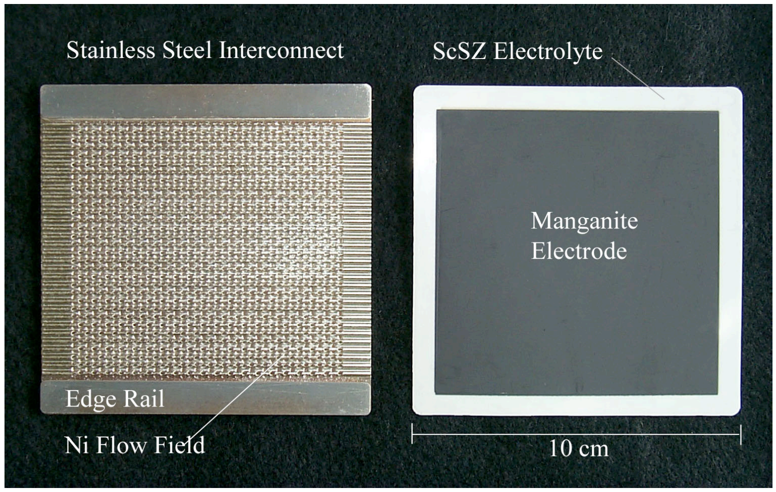


Figure 2. Interconnect plate and single electrolysis cell.

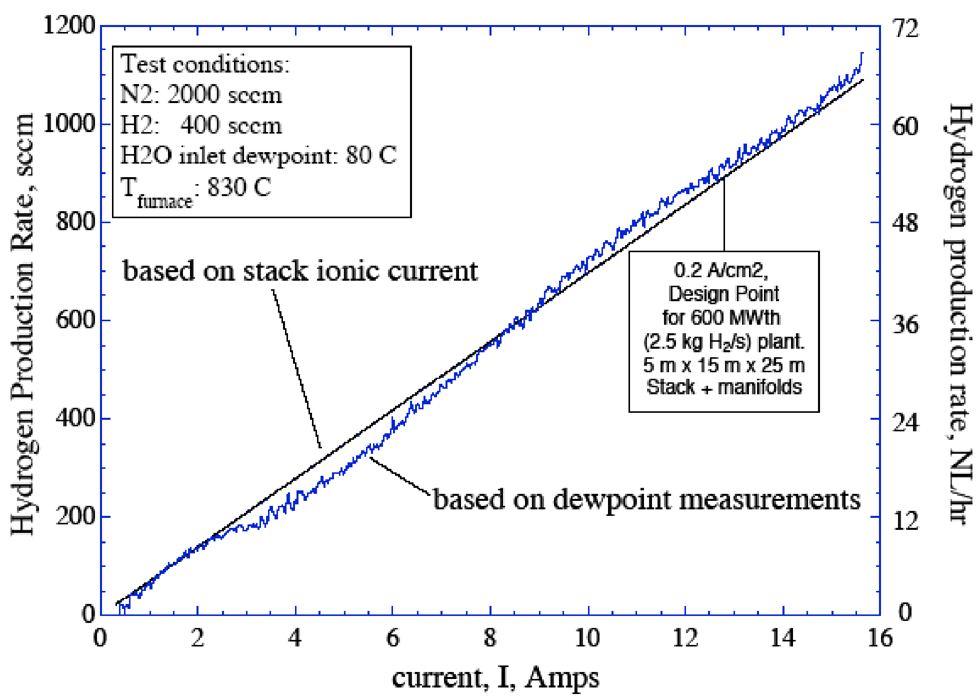
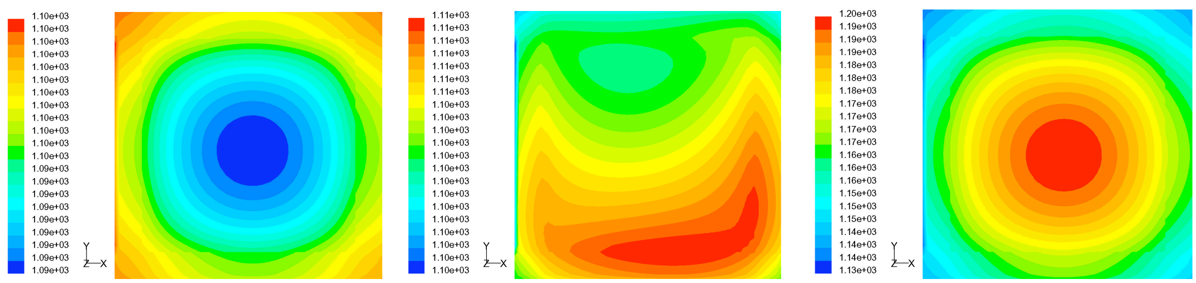


Figure 3. Hydrogen production rates during DC potential sweep.

Hydrogen production rates can be calculated directly from the stack electric current and independently from the measured inlet and outlet dewpoint measurements. A representative plot of hydrogen production during DC potential sweep #2 is shown in Fig. 3. The left-hand vertical scale is in sccm and the right-hand vertical axis is in normal liters per hour (NL/hr). The current-based hydrogen production rate is simply a straight line since hydrogen production is directly proportional to the current. The dewpoint-based measurement shows some scatter associated with the instantaneous measured inlet and outlet dewpoint values. Agreement between the two measurements is generally very good. Hydrogen production rates as high as 90 NL/hr were achieved with this stack.



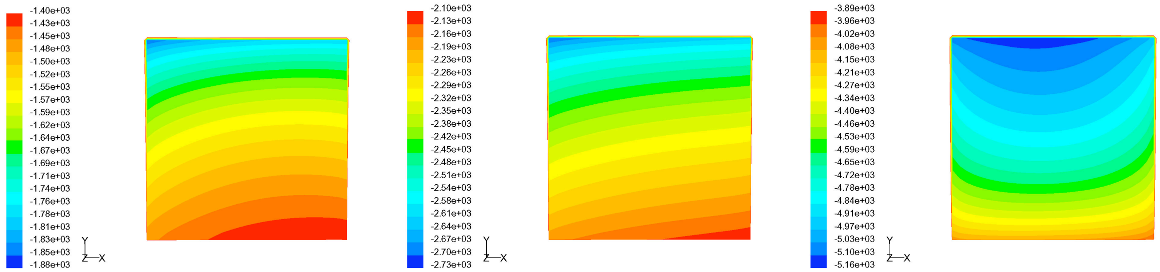
(a) (b) (c)

Figure 4. Temperature (K) contours on the electrolyte and insulator for currents of 10, 15, and 30 amps.

Contour plots representing local FLUENT results for electrolyte temperature and current density are presented in Figs. 4 and 5. In these figures, the steam/hydrogen flow is from top to bottom and the air flow is from left to right. Figure 4 shows electrolyte temperature contour plots for amperages of 10, 15, and 30 amps. These current values correspond to operating voltages near the minimum electrolyte temperature (10 amps), near thermal neutral voltage (15 amps), and in the region dominated by ohmic heating (30 amps). The radiant boundary condition at 1103 K tends to hold the outside of the model at a higher temperature for the 10-amp case (Fig. 4 (a)), while the endothermic heat requirement maintains the center of the electrolyte at a lower temperature. Minimum and maximum temperatures for this case are 1091 K and 1100 K respectively.

The center Fig. 4 (b) shows a temperature difference across the electrolyte of only one degree K, with values very near 1103 K; this current density is very near the thermal neutral voltage. Fig. 4 (c) shows that ohmic heating in the electrolyte is dominating and the thermal boundary condition is keeping the edges cooler than the inside. Minimum and maximum temperatures are 1139 K and 1197 K, respectively, for this case.

Contour plots of local current density on the electrolyte are shown in Figure 5 for 10, 15, and 30 amps. Mean current densities for these three cases are: 0.156, 0.234, and 0.469 A/cm^2. These plots correlate directly with local hydrogen production rates. Since FLUENT is being run in electrolysis mode, the current density values are all negative and hence the blue values have the largest magnitudes. Highest current density magnitudes occur near the steam hydrogen inlet (the top of the figures). This corresponds to the location of the greatest steam concentration. The orange areas show where the current density is lowest because the available steam concentration is lower.



(a) (b) (c)

Figure 5 Current density (A/m^2) contours on the electrolyte for currents of 10, 15, and 30 amps.

Figure 6 shows the overall hydrogen production efficiency, defined as the lower heating value of the hydrogen produced divided by the total thermal energy used for both steam and electricity production. The family of curves shown represent a range of assumed electrical generating efficiencies from 30% to 50%. The output and cell characteristics were those measured in our tests at the INL during January 2005. The cell operating voltage varies from approximately the open circuit voltage to the thermal neutral voltage.

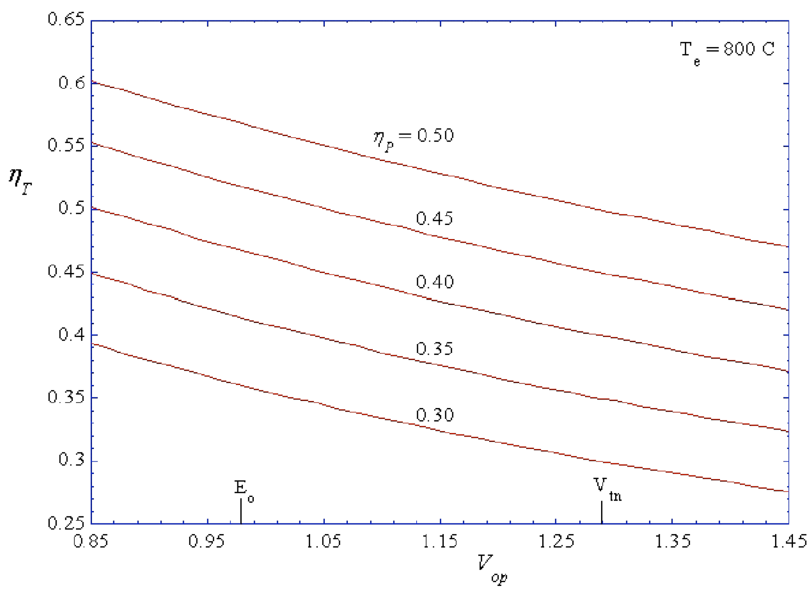


Figure 6. Cell hydrogen production efficiency.

Further modeling of the hydrogen production plant, including the pumps, compressors and the heat exchangers necessary for recuperation as well as the cell performance, has shown that the overall efficiency would be approximately 41.6% to 44.5% for an electrical generating efficiency of 45%.

Acknowledgement: This work was supported by the US Department of Energy, Office of Nuclear Energy Science and Technology, Nuclear Hydrogen Initiative Program.

INTERNATIONAL ACTIVITIES:

Fusion's Contribution to Sustainable Development, Ian Cook,

Euratom/UKAEA Fusion Association, Culham, Oxfordshire, UK.

'Fusion's contribution to sustainable development' sums up well the theme of an international Workshop on the socio-economic aspects of fusion power, held at Culham, UK in April 2005. The results of the extensive studies presented at the Workshop showed the general maturity of work in this area and provide clear and compelling evidence that fusion is an attractive option to contribute to sustainable energy generation.

The Workshop was held under the auspices of the International Energy Agency's Task for collaborative activities in this field. About twenty contributors attended, from Europe, US, Japan and China, together with observers. The US was well represented with contributions from Gerald Kulcinski (UW), Farrokh Najmabadi (UCSD), John Schmidt (PPPL), and Les Waganer (Boeing). Most of the presentations made at the workshop are available online at http://www.fusion.org.uk/socioecon.

The presentations and discussions fell broadly into the following categories.

Energy Issues and Policies

These presentations covered: worldwide and regional energy demand issues; the contributions that may be possible from coal, oil, gas, nuclear fission and various renewables; the cost of electricity from these; and the probable or possible constraints on their deployment arising from a wide variety of factors. Of particular interest are the huge projected increases in energy demand from very necessary and welcome economic development in China and India, and the possibility that nuclear fission and carbon capture and storage may serve as bridges to fusion.

Internal Costs

Internal costs of electricity are the conventional costs arising from constructing, operating, maintaining and decommissioning power plants. The methodologies for calculating fusion internal costs are now well understood and validated apart from details. There is broad agreement across continents that the range of calculated fusion internal costs of electricity – depending upon the assessed levels of technological maturity and materials and plasma performance – is similar to the published ranges of such costs for other sources of electricity.

Spillover Costs

Spillover costs (technically known as 'external costs' or 'externalities') are the costs associated with environmental damage and adverse impacts upon health. For many current sources of electricity the spillover costs are substantial. Very comprehensive studies have shown that fusion, because of its good safety and environmental characteristics, belongs to the class of very low spillover cost sources of electricity.

Social Acceptance

A succession of studies have established that fusion will have well-attested and attractive inherent safety and environmental features, in particular: low limits to the consequences of worst possible accidents, and no need for long term repository disposal of the activated material produced by the operation and dismantling of the plant. These advantages should be very helpful in securing social acceptance, but this is not the same thing as actually securing such acceptance! Promising studies on the factors influencing acceptance were reported, though this field is in its early stages.

Non–Electric Applications of Fusion

Non–electricity products of fusion were discussed. Many fusion-produced applications are possible, several of which could be attractive in the near term in fields such as medicine and security. On the longer time scale, hydrogen production may be a very attractive application, possibly better than electricity generation.

Fusion in Energy Scenarios

With the information from the foregoing presentations in place, attention turned to the incorporation of fusion power into consistent energy/environment/economic scenarios for the future. By now, there have been quite a number of scenario modelling studies incorporating fusion, for a variety of regions and for the world. Scenario model development is continuing. All the energy sources are potentially constrained, for example by: costs; their limited or intermittent nature; fuel availability; environmental imperatives; social acceptance; or – as in the case of fusion – assessed limits to the speed with which they can be deployed. The outcome of the modeling is critically dependent on the assumed constraints. Typically, fusion captures about twenty percent of the electricity market by the end of the century if there are significant emission constraints and nuclear fission is either constrained by acceptability problems or by declining fuel availability.

Development Pathways

The scenario modeling indicates that if fusion were developed faster it would capture a larger share of the market. The potential financial gains are very large. Accelerated (fast track) development plans have been produced in the fusion programs in Europe, US and Japan. These are broadly in agreement, though there are significant differences in detail. Probabilistic analyses indicate that the expected discounted value of developing fusion power greatly exceeds the cost, and is greater if fusion is developed faster. Indeed, one simple fact is very striking: the total cost of developing fusion is equal to only a few days spending in the international energy markets!

7th International Symposium on Fusion Nuclear Technology, Masahiro Seki, Japan Atomic Energy Research Institute, Naka, Ibaraki, Japan.

The 7th International Symposium on Fusion Nuclear Technology (ISFNT-7) was held May 22-27, 2005 at the National Museum of Emerging Science and Innovation, in Tokyo, Japan. The General Chair was Dr. Masahiro Seki of the Japanese Atomic Energy Research Institute (JAERI). Drs. Hideaki Takatsu and Masato Akiba from JAERI were the symposium secretaries. The symposium was organized by JAERI. The co-organizers included the Atomic Energy Society of Japan, the Japanese Society of Plasma Science and Nuclear Fusion Research, and the National Institute of Fusion Science (NIFS). This symposium was supported by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) of Japan.

The number of registered participants was about 300. A total of 266 presentations were given during the four and a half day symposium: two keynote lectures, two plenary sessions, 16 oral sessions, and 5 poster sessions. These sessions included 2 keynote lectures, 9 plenary presentations, 28 invited oral talks, 42 contributed oral presentations, and 185 poster presentations. Most of the peer-reviewed papers will be published in the Fusion Engineering and Design journal.

Registered participants	~300
Sessions:	
Keynote	2
Plenary	2
Oral	16
Poster	5
Presentations:	
Invited Plenary and Oral	39
Contributed Oral	42
Posters	185
Total	266
Topics:	
Blanket Technology	51
First Wall Technology and HHF Components	48
Material Engineering for FNT	40
Models and Experiments for FNT	25
Nuclear System Design	25
Fuel Cycle and Tritium Processing	20
Safety Issues and Waste Management	18
Burning Plasma Control and Operation	9
FNT Contributions to Other Fields	9
IFE Studies and Technologies	7
Repair and Maintenance	2
Vacuum Vessel	1

Keynote/Plenary	11
Total	266

Countries:

Japan	137
United States	35
Germany	24
China	14
Italy	9
Russian Federation	8
Korea	8
EFDA	7
UK	6
France	6
Others	12
Total	266

Prof. Hiroyuki Abe, an executive member of the Council of the Science and Technology Policy, gave the keynote lecture (keynote 1) on the Science and Technology Policy in Japan. Following the lecture, Dr. Yasuo Shimomura, the Director of the ITER International Team (ITER) summarized the recent status of the ITER project. In the Plenary session 1, Prof. Satoru Tanaka from the University of Tokyo, Dr. Roberto Andreani from EFDA-Garching, Prof. Neil Morley from UCLA, and Dr. Yury Strebkov from the Dollezhal Research and Development Institute, Russia gave overview talks on the recent activities of the fusion nuclear technologies in Japan, EU, US, and Russia, respectively.

On the third day, Prof. Mohamed Abdou from UCLA gave the keynote lecture (keynote 2) titled "Progress and Future Perspective in FNT", where he reviewed the history of Fusion Nuclear Technology (FNT) and presented the future perspective toward fusion power plants. After that, a lecture was held for the public and high school students.

In the Plenary session 2 of the last day, Dr. Enrico di Pietro from EFDA-Garching, Dr. Masahiro Mori from JAERI, Prof. Valery Belyakov from the Efremov Institute and Dr. Ned Sauthoff from PPPL, reviewed the ITER activities of EU, Japan, Russia, and the United States, respectively. After the plenary session, the Miya-Abdou Awards were bestowed to the following scientists/engineers: Dr. P. Barabaschi (ITER, Garching), Dr. T. Hirai (FZJ, Germany), and Dr. Y. Poitvin (EFDA, Garching).

The next symposium (ISFNT-8) will be held at Heidelberg, Germany in October 2007.

Major Topics of FNT Fields:

First Wall Technology and High Heat Flux Components

S. Suzuki presented R&D for plasma facing components made of reduced activation ferritic-martensitic steel (F82H) for the DEMO plant. M. Merola gave a presentation on the preparation of the procurement of the ITER divertor in EU. Advanced concepts, such as liquid surface for PFCs and helium-cooled PFCs, were present by M. Ulrickson, S. Mirnov, and T. Ihli. In addition, the R&D for the plasma facing materials was reported by T. Hino, K. Tokunaga, and T. Tanabe. The plasma facing components for ITER and DEMO were presented. In addition, the development of plasma facing materials, such as tungsten and boron-titanium, was reported.

Blanket Technology

There were two sessions on blanket technology. In the first special session on ITER Test Blanket Modules, representatives of the Test Blanket Working Group (TBWG) presented the activity of each party and the development status of the TBMs. Coherent designs and test plans for the TBMs are almost completed. It has been recognized that technology development toward test blanket modules is now stepping up into Engineering Development with scalable mock-ups in some parties. In the other blanket session, presentations were given on detailed stress analysis of the ITER shield blanket module by K. Ioki, a very unique investigation of Be multiplier thermo-mechanical characteristics by J. Reimann, innovative breeder material development by S. Sharafat, liquid LiPb blanket module designs by C. Wong and A. Puma, and the tritium control of molten salt Flibe by S. Fukada. Presentations were made for the main liquid breeder blankets: liquid LiPb, liquid Li, and molten salt Flibe. The major topics for the liquid breeder blankets were the MHD effect and hydrodynamics, tritium behavior, and interactions with hydrogen or Be.

Fuel Cycle and Tritium Processing

M. Glugla presented the recent R&D progress for the ITER fuel cycle to meet the ITER objectives of high flexibility, reliability, and low tritium inventory. T. Hayashi presented the tritium accountancy in a fusion demo plant. W. Farabolini and I. Cristescu presented the tritium control modeling for the helium-cooled blanket and the ITER fuel cycle, respectively. The tritium behavior in systems, water, and materials has been studied at Toyama University, Kyoto University, JAERI, ITER, NIFS, FZK, EURATOM, and China Academy. Active discussions on these subjects transpired in this session.

Material Engineering for FNT

Hasegawa indicated that the materials issues are the crosscutting issues over various blanket systems. Fabritsiev introduced Russian accomplishments of materials development over the last ten years. As for the reduced activation ferritic/martensitic steels, Dan Der Schaaf made a comprehensive introduction about the materials development focusing on EUROFER. Kimura, Lucon, Tsuzuki and Pint gave presentations on the application to blanket systems, irradiation performance of EUROFER steel, PWI at TEXTOR, and compatibility with liquid metals, respectively. For 316 stainless steel, results on SCC and unique experimental results of in-beam fatigue tests were shown by Sueishi and Murase, respectively. A concept of SiC/SiC composite processing to fabricate components with a property tailoring capability was described by Kato. SiC/SiC composite processing methodologies were introduced by Kim and Lee, respectively. Tsuchiya and Jung reported a mechanical property and processing method of breeding materials in addition to a unique 2-D T distribution measuring method with imaging plate technique by Tanabe. For neutron multipliers, Uchida and Munakata discussed the strength and the compatibility of the $Be_{12}Ti$ intermetallic compounds.

Vacuum Vessel, Repair and Maintenance

Y. Song presented the mechanical analyses on the vacuum vessel of EAST, a Chinese tokamak device, under electromagnetic force and thermal load. He also presented some key R&D including supporting system, bellows and the assembly of the whole vacuum vessel. G. Micciche presented the back plate replacement including rescue procedures and evaluation of a prototype maintainability of IFMIF. Y. Ohtsuka presented the fundamental experiment for inspection of the cooling pipe using EMAT.

Nuclear System Design

For tokamak reactors, DEMO and commercial fusion plat designs were reviewed by D. Maisonnier. M. Sawan addressed the physics and technology conditions and the R&D required for attaining tritium self-sufficiency. A systems code analysis on PPCS was presented by P. Karditsas. Compact low-aspect-ratio DEMO reactor design at JAERI was reported, focusing on concept (K. Tobita), core and divertor design (M. Sato), structural aspects (S. Nishio), magnet (T. Isono), NBI (T. Inoue) and ECRF (K. Sakamoto). For helical reactors, R. Raffray gave an overview talk on ARIES-CS. Japanese designs on helical reactors were reported on systems code analyses (K. Yamazaki and T. Goto) and magnet (S. Imagawa). Neutronics calculations were presented on VECTOR (T. Nishitani) and CREST (Q. Huang) and on advanced shield materials with metal hydrides and borohydrides (T. Hayashi).

Safety Issue and Waste Management

Dust mobilization and filtering were discussed by W. Han, S. Suzuki, M. Porfiri, and P. Sharpe. Presentations on tritium matters (inventory, behavior, processing, monitoring, etc.) in ITER and future fusion reactors were carried out by M. Kubota, H. Nakamura, T. Hayashi, M. Tanaka, K. Kobayashi, T. Uda and V. Kapyshev. L. El-Guebaly, N. Taylor, G. Cambi, and L. Petrizzi gave presentations related to tritium breeding, shielding, and material activation by neutrons, including benchmark studies. Some safety analysis studies including that of component failure rate database were presented by T. Pinna, Y. Bai, S. Zheng, and L. Hu. L. El-Guebaly presented a study for burning the long-lived nuclides in a fusion device.

Models and Experiments

H. Hashizume presented the models and experiment of the MHD issues for the liquid metal blanket system. D. Petti presented an updated program for JUPITER-II on the molten salt Flibe tritium chemistry and safety experiment. S. Pinaev presented the development of the technology of MHD-resistance reduction in the ducts of heavy liquid metal coolants and increasing the stability of the structural materials by formation of oxide coatings. X-Y. Luo presented a numerical study of the characteristic behavior of liquid metal free surface jets under the effect of transverse fields and field gradients. K. Ochiai presented the measurements of the deuteron-induced activation cross sections for IFMIF accelerator structural materials in the energy range of 22-40 MeV. 2-D and 3-D models of tritium permeation in helium-cooled solid breeder blanket units were presented by M-J. Ni. The design of a new planned experimental facility, Helium Loop Karlsruhe (HELOKA) for the testing of various components for nuclear fusion facilities was presented by M. Ionescu-Bujor. Y. Verzilov presented the development of a new fusion power monitor based on the activation of flowing water via the $^{16}O(n,p)^{16}N$ reaction.

Burning Plasma Control and Operation

As a test bed towards the high power density steady-state power plant with advanced tokamak operation, design studies of FIRE (D. Meade) and National Centralized Tokamak (K. Tsuchiya) were presented. Studies on divertor modeling (H. Kawashima), plasma equilibrium modeling and control (K. Kurihara), L-H transition (R. Hiwatari), and magnetic sensorless control (K. Nakamura) were reported.

Inertial Confinement Fusion Studies and Technologies

R. Raffray presented the recent progress in the solid wall chamber technology for the laser IFE. M. Andersen proposed a micro-engineered tungsten foam for the armor material of the laser IFE chamber. H. Azechi showed the recent results of the direct heating experiment for the fast ignition and related R&Ds.

FNT Contribution to Other Fields of Science and Technology

Synergies between FNT developments and advanced fission technologies, especially structural materials, were discussed by E. Bogusch. A. Nishimura presented the neutron irradiation effects on superconducting magnets of fusion devices and particle accelerator system. Progress in inertial electrostatic confinement fusion and application to landmine detection and medical examination were presented by Y. Yamamoto.

IFMIF

A. Möslang reviewed the IFMIF test facility design. H. Matsui presented the role of IFMIF in fusion technology. W. Han presented lithium loop activation. G. Miccich presented the remote handling of the replaceable back-plate. S. Ebara presented a cast-like IFMIF high flux test module. H. Kondo presented surface shape measurements on high speed liquid Li flow.

Neutronics

P. Batistoni presented an overview of the nuclear design activities conducted in the EU on the development of ITER TBMs and the layout of Material Test Modules for IFMIF. U. Fischer also presented recent progress in IFMIF neutronics. S. Sato presented recent experimental studies on the blanket nuclear property integral experiments in FNS. K. Seidel stressed the need for an improvement to the tungsten database in preparation for wide use of tungsten in plasma facing components of future fusion reactors. T. Muroga presented neutronics assessment for Li/V and Flibe/V systems.

Calendar of Upcoming Conferences on Fusion Technology

2005:

ANS Annual Meeting
June 5-9, 2005, San Diego, California, US
http://www.ans.org/

35th Annual Anomalous Absorption Conference
June 26 - July 1, 2005, Fajardo, Puerto Rico
AAC2005@this.nrl.navy.mil
http://www.sainc.com/AAC2005

12th International Conference on Emerging Nuclear Energy Systems (ICENES-2005)
August 21-26, Brussels, Belgium
http://www.sckcen.be/sckcen_en/activities/conf/conferences/icenes2005/index.shtml

4th International Conference on Inertial Fusion Sciences and Applications – IFSA-2005
September 5-9, 2005, Biarritz, France
ifsa05@celia.u-bordeaux1.fr
http://ifsa05.celia.u-bordeaux1.fr/

EUROMAT 2005, Materials for Fusion Applications
September 5-8, 2005, Prague, Czech Republic
http://www.euromat2005.fems.org

21st Symposium on Fusion Engineering – SOFE-2005
September 26-29, 2005, Knoxville, Tennessee, US
http://www.ornl.gov/fed/sofe05

47th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
October 24-28, 2005, Denver, Colorado, US

ANS Winter Meeting
November 13-17, 2005, Washington, D.C., US
http://www.ans.org/

12th International Conference on Fusion Reactor Materials - ICFRM-12
December 4-9, 2005, Santa Barbara, California, US
http://icfrm-12.pnl.gov

15th International Toki Conference on Fusion & Advanced Technology (ITC-15)
December 6-9, 2005, Toki, Japan
http://www.nifs.ac.jp/index.html

2006:

ANS Annual Meeting
June 4-8, 2006, Reno, Nevada, US
http://www.ans.org/

24th Symposium on Fusion Technology - SOFT
September 11-15, 2006, Warsaw, Poland

48th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
October 30 - November 3, 2006, Philadelphia, PA, US

ANS Winter Meeting
November 12-16, 2006, Albuquerque, New Mexico, US
http://www.ans.org/

ANS 17th Topical Meeting on the Technology of Fusion Energy – TOFE-2006
November 13-16, 2006, Albuquerque, New Mexico, US
http://www.ans.org/

2007:

ANS Annual Meeting
June 2007
http://www.ans.org/

22nd Symposium on Fusion Engineering – SOFE-2007

8th International Symposium on Fusion Nuclear Technology - ISFNT-8
Oct 1-7, 2007, Heidelberg, Germany

ANS Winter Meeting
November 2007
http://www.ans.org/

49th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 12-16, 2007, Orlando, Florida, US

13th International Conference on Emerging Nuclear Energy Systems (ICENES-2007)

13th International Conference on Fusion Reactor Materials - ICFRM-13

2008:

ANS Annual Meeting
June 2008
http://www.ans.org/

ANS Winter Meeting
November 2008
http://www.ans.org/

ANS 18th Topical Meeting on the Technology of Fusion Energy – TOFE-2008

50th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 17-21, 2008, Dallas, Texas, US

25th Symposium on Fusion Technology - SOFT