American Nuclear Society
Fusion Energy Division
December 2004 Newsletter

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

First of all, I'd like to express my thanks to René Raffray, the outgoing chair of the Fusion Energy Division, for his leadership over the past year.

It's been an interesting year for the fusion community. The siting of ITER has dragged on far longer than we all would have liked and it isn't at all clear how it will be resolved. I have to believe that it will get worked out somehow, as the stakeholders will ultimately realize that it is critical that they find some way to get the device built. Meanwhile we all sit back and wait (and speculate!).

In more concrete news, the US has chosen a partnership of PPPL and ORNL to host the US ITER Project Office; further members of the multi-institutional team will be selected competitively. The US ITER Project Office will be at PPPL and the effort will be led by Dr. Ned Sauthoff. The Office will be responsible for project management of the US activities supporting the construction of ITER. See Sauthoff's article for more information on the US contributions to ITER.

With regard to the Fusion Energy Division, things are going pretty well. We have had a relatively steady bank balance for years and that should continue as we expect a generous income from the recent Topical Meeting. These funds are typically used for awards and for helping students travel to meetings, including ANS National meetings, our Topicals, and the ANS student conferences. We have a slowly increasing membership in the Division and have done well in the recent ANS Division assessment efforts. In an attempt to increase our involvement in ANS National Meetings, we have begun to pursue joint sessions with other Divisions. We are planning on two joint sessions with the Radiation Protection and Shielding Division for the upcoming National Meeting in San Diego in June and will pursue others in the future. In addition, we are planning to revive our FED Program Committee in order to assist with the planning for future meetings. If you have any interest in assisting us with this effort, please let me know.

Finally, let me congratulate Jerry Kulcinski and Laila El-Guebaly for putting on an outstanding Topical Meeting in September. As you may know, Craig Olson and Gary Rochau at Sandia have agreed to host the next Topical, which will be embedded in the ANS National Meeting in Albuquerque in November 12-16, 2006. The Division appreciates their willingness to host the meeting and looks forward to a fruitful meeting.

FED Slate of Candidates, René Raffray, University of California-San Diego, San Diego, CA.

All FED members will receive a ballot early next year for the election of FED Officers and Executive Committee members. We encourage each member to vote in this election, so please take the time to fill out and return your ballot per the instructions supplied with the ballot. The outcome of the election will be announced before the June 2005 ANS annual meeting in San Diego. The FED is always looking for members who would like to become active in the operation of the Division. If you are interested, please contact Jake Blanchard (who will be chairing the nominating committee for next year's candidates) or any other member of the Executive Committee.

We have an excellent slate of candidates for the upcoming FED election and their willingness to contribute their time and effort to FED is much appreciated. The current Vice Chair/Chair-Elect, Said Abdel-Khalik from the Georgia Institute of Technology will become FED Chair at the end of the FED Executive Committee meeting in June 2005. The list of candidates (in alphabetic order) for the 2005 election consists of:

Vice Chair:	Jeff Latkowski (LLNL)
Secretary/Treasurer.	Lee Cadwallader (INEEL)
Executive Committee (3 members to be elected):	Neil Morley (UCLA) Tim Renk (SNL) Shahram Sharafat (UCLA) Paul Wilson (UW) Minami Yoda (Georgia Tech.).

16th ANS Topical Meeting on the Technology of Fusion Energy, Gerald Kulcinski, Fusion Technology Institute, University of Wisconsin-Madison, Madison, WI.

The 16th Topical Meeting on the Technology of Fusion Energy (TOFE) was held September 14-16, 2004 at the Monona Terrace Community & Convention Center, Madison, Wisconsin. The General Chairman was Professor Gerald Kulcinski from the University of Wisconsin (UW) and the Vice Chairman was Dr. Masahiro Seki from the Japanese Atomic Energy Research Institute (JAERI). Dr. Laila El-Guebaly from the UW was the Technical Program Chair and she was assisted by Dr. Ichiro Yamamoto from Nagoya University and Dr. René Raffray from the University of California-San Diego (UCSD). Meeting sponsors included the Fusion Engineering Division (FED) of the American Nuclear Society (ANS), the Atomic Energy Society of Japan, the Fusion Technology Institute (FTI) of the University of Wisconsin, the Department of Energy, and the Wisconsin Local Section of the ANS. The Department of Energy (DOE), Naval Research Laboratory (NRL), General Atomics (GA), Sandia National Laboratory (SNL), Oak Ridge National Laboratory (ORNL), the Atomic Energy Society of Japan, AREVA, and the Fusion Technology Institute of the University of Wisconsin contributed additional financial support.

The number of registered participants was 209 distributed as follows: Austria (1), Belgium (2), Canada (1), Germany (7), France (1), Italy (1), Japan (44), Kazakhstan (2), Korea (1), Russia (2), United Kingdom (4), and the United States (143). There were 54 students registered and many more participated by helping with the organization and operation of the meeting. A total of 204 papers were given in three plenary sessions, 15 oral sessions and 2 poster sessions. The number of plenary presentations was 11, the number of oral presentations was 83 and there were 110 poster presentations. Most of the peer-reviewed papers will appear in the ANS publication, Fusion Science and Technology journal.

Dr. Harrison Schmitt from New Mexico, former Apollo 17 Astronaut and Senator, gave the keynote speech. His theme was “Large Energy Development Projects: Lessons Learned from Space and Politics”. He discussed the keys to success in the successful Apollo program to land a man on the Moon and he compared them to what is needed for a successful energy development program. Following the keynote speech, Dr. Anne Davies (DOE) summarized the US National Magnetic Fusion Energy (MFE) program. Dr. Chris Keane (DOE) then summarized the US Inertial Confinement Program and Dr. Seki (JAERI) gave an overview of the recent activities in the Japanese fusion technology program.

After the plenary session there were three parallel session on: 1) Engineering of Experimental Devices, 2) High Average Power Laser Program, and 3) Socioeconomics, Safety, Radwaste, and Licensing. The afternoon of the first day started with 56 poster papers presented on six different topics. This session was followed by 3 more parallel oral sessions on: 1) Power Plant Studies, 2) ITER Test Blanket Modules, and 3) Non-Electric Applications.

There was a reception on the first night and one of the highlights was the presentation of the first “Senior Statesman of the Fusion Program” to Dr. Steve Dean of Fusion Power Associates.

The second day started with a plenary session on the Development of Fusion and Near Term Facilities. Dr. Steve Dean gave a comprehensive Historical Perspective on the US Fusion Program and Iotti's presentation on the Role of Industry in Fusion Development. These talks were followed by an extensive summary of the National Ignition Facility (NIF) by Craig Wuest (LLNL) and a summary of the European Technology Program by Dr. Roberto Andreani (EFDA-Garching). The plenary session was followed by three parallel oral sessions: 1) ARIES Power Plant Studies, 2) Target Development and IFE Technology, and 3) Latest Fusion Technology and Tritium Systems. There were 54 more poster papers in the afternoon followed by another three parallel oral sessions: 1) US Contributions to ITER, 2) Breeding Blanket Developments, and 3) IFE Designs and Technology.

At the banquet on the second day, several awards were given. First, the award for the best student work presented at the 16th TOFE went to Devesh Ranjan and John Niederhaus (UW) for their joint paper “Investigation of Hydrodynamic Instabilities in Shock-Accelerated Flows for ICF”. This honor also included a $500 check. Dr. Najmabadi of UCSD, the Chairman of the FED Honors and Awards committee, also awarded three honors (see the Awards article in this newsletter). The Technical Program chairperson for the 16th TOFE meeting, Dr. Laila El-Guebaly was also honored for her extraordinary effort in making this meeting a success.

The final day of the meeting began with three parallel oral session: 1) Materials Development, 2) High Heat Flux Components, and 3) Nuclear Technology Experiments and Testing. An especially lively plenary session was held at the close of the meeting. The ITER project was described by three experts; Dr. Pietro Barabaschi of the International ITER team, Dr. Ned Sauthoff, the US Project Manager, and Dr. Charles Baker, the Director of the US Virtual Technology Laboratory. The "top to bottom" review of the ITER project elicited many comments from the audience and ended the meeting on a high technical note.

The plenary and oral presentations have been posted at the TOFE website: http://fti.neep.wisc.edu/tofe. Click on the title to download the presentation in PDF format. Hundreds of photos taken for the meeting attendees have also been posted on the TOFE website to download and print.

Dr. Davies (DOE) giving a plenary talk on the US MFE program

Finally, the organizing committee for the meeting was:

General Chair	Gerald Kulcinski (UW)
Vice Chair	Masahiro Seki (JAERI)
Technical Program Chair	Laila El-Guebaly (UW)
Assistant Tech. Prg. Chairs	Ichiro Yamaoto (NagoyaU)
	René Raffray (UCSD)
Finance Chair	James Blanchard (UW)
Publications Chair	Mohamed Sawan (UW)
Registration Chair	Mark Anderson (UW)
Student Awards	Paul Wilson (UW)
Technical and Spouse Tours	John Santarius (UW)
	Joan LePain (UW)
Publicity and Webpage	Dennis Bruggink (UW)

Fusion Award Recipients, Farrokh Najmabadi, University of California-San Diego, San Diego, CA and Paul Wilson and 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 fusion awards. 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.

ANS-FED Awards

The Honors and Awards Committee of the Fusion Energy Division (FED) of the American Nuclear Society (ANS) announced the recipients of the FED Awards for 2004. The *Outstanding Achievement Award* was presented to Dr. **Roger E. Stoller** at the Oak Ridge National Laboratory. The *Outstanding Technical Achievement Award* was presented to Dr. **A. René Raffray** of the University California San Diego and Dr. **Lance L. Snead** of Oak Ridge National Laboratory (individual awards).

The *Outstanding Achievement Award* is the most prestigious award of the FED and is presented to an ANS member in recognition of exemplary individual achievement requiring professional excellence and leadership of high caliber in Fusion Science and Engineering. The award to Dr. **Stoller** was made in recognition of outstanding achievement in multi-scale modeling of fusion structural material.

The *Outstanding Technical Accomplishment Award* is presented in recognition of an exemplary technical accomplishment requiring professional excellence of a high caliber in Fusion Science and Engineering. The award to Dr**. Raffray** was made in recognition of his outstanding accomplishments in MFE and IFE fusion core design and analysis. The award to Dr. **Snead** is made in recognition of his outstanding technical research in the development of radiation-resistant reduced activation SiC/SiC composites.

Award for Best Student Work Presented at 16th TOFE Meeting

Devesh Ranjan and **John Niederhaus** (University of Wisconsin-Madison) were awarded the *Best Student Presentation* at the recent 16th Topical Meeting on the Technology of Fusion Energy (see article above) for their poster "Investigation of Hydrodynamic Instabilities in Shock-Accelerated Flows for ICF". Nearly 30 students presented over 30 posters on their work ranging from fundamental studies of superconductors to near-term applications of inertial electrostatic devices to the development of hydrodynamic codes for modeling inertial fusion energy chambers. About 40 judges assisted in comparing the posters which included points for the technical merit of the work, the quality of the abstract and poster, and the ability of the student to present their material and answer questions. The judges were generally impressed by the quality of the posters and enjoyed their interactions with the students. **Ranjan** and **Niederhaus** will share a cash prize, receive an engraved plaque, and be invited to publish a full paper related to this work in the Fusion Science and Technology journal.

FPA Awards

The Fusion Power Associates Board of Directors announced the recipients of its 2004 awards. The awards will be presented at the FPA 2004 annual meeting and symposium, December 13 in Gaithersburg, MD.

The *Leadership Awards* will be presented to Prof. **Raymond Fonck** (University of Wisconsin) and to Prof. **Farrokh Najmabadi** (University of California, San Diego). The award recognizes Prof. **Raymond Fonck**'s many scientific contributions to the study of fusion plasmas in both tokamak and alternate confinement concepts, as well as his leadership role in securing national funding priority for research of burning plasmas. In selecting Prof. **Farrokh Najmabadi**, the Board recognizes his many contributions to a variety of fusion concepts and especially commends him for his recognition of the importance of the inter-related physics/technology systems aspects of these concepts. The Board also notes the important role he has played as leader of the national fusion power plant studies, which have provided perspective and guidance for the near-term fusion research effort.

The *Distinguished Career Award* will be presented to Prof. **Bruno Coppi** (MIT). In selecting Prof. **Coppi**, the Board recognizes his seminal contributions to plasma and fusion science over many decades. The Board notes that the world fusion effort is especially in his debt for his early and continuing recognition of the importance of high magnetic field in the design and operation of tokamak fusion devices and for his tireless efforts to urge the construction of a fusion ignition experiment.

The *Excellence in Fusion Engineering Award* will be presented to Dr. **Camille Bibeau** (Lawrence Livermore National Laboratory). In selecting Dr. **Bibeau**, the FPA Board recognizes her many technical contributions to the design, construction and operation of laser systems, as evidenced by her exemplary publications record and her role as Project Leader of the Mercury diode-pumped solid state laser program at LLNL. The Board especially recognizes her outstanding communications skills in providing clear and understandable presentations on highly complex topics to a variety of audiences.

Other Awards

Dr. **Everett Bloom (**Oak Ridge National Laboratory) has been awarded the 2004 *Outstanding Achievement Award* by the Materials Science and Technology Division of the American Nuclear Society, in recognition of his significant and sustained contributions to the development of materials for advanced nuclear fission and fusion systems.

Fusion Power Associates president Dr. **Steve Dean** was presented the *Senior Statesman of the Fusion Program Award* at the ANS 16th Topical Meeting on the Technology of Fusion Energy, September 14-16, 2004 in Madison, Wisconsin. The award was presented by the TOFE General Chair, Prof. G. Kulcinski (UW) on behalf of the Fusion Community in recognition of **Dean's** many contributions to the development of fusion energy.

Prof. **Nathaniel Fisch**, a Princeton University professor and a scientist at the Princeton Plasma Physics Laboratory, is among seven winners of *the US Department of Energy's 2004 Lawrence Award*. The award is given in categories for outstanding contributions in the field of atomic energy. **Fisch** received the award in the nuclear technology category for his discovery of ways to use radio waves to drive electric currents in the plasma. These wave-induced currents prove to be an essential ingredient in the steady-state operation of fusion power systems.

Dr. **Philip B. Snyder**, a theoretical plasma physicist at General Atomics, is the recipient of the 2004 *General Atomics Marshall Rosenbluth Fusion Theory Award.* The newly created 2003 award recognizes outstanding young theorists in the field of plasma physics. The award to Dr. **Snyder** was made in recognition of his important contributions to understanding the behavior of the tokamak edge plasma that is critical for enhancing the confidence of the performance of next step burning plasmas, including ITER.

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

During this past year, FS&T has been busy with publication and scheduling of several special issues and excellent selection of contributed papers. The 2004 issues included the following special issues:

March 2004	Selected papers from 15th Target Fabrication Specialists' Meeting [Guest Editor: Robert C. Cook] & 6th Carolus Magnus Summer School Proceedings
May 2004	FTU Tokamak (Frascati, Italy) [Guest Editor: Claude Gormezano] & IFSA-2003 Proceedings
July & September 2004	Selected papers from 14th IEA International Stellarator Workshop [Guest Editor: Fritz Wagner]
November 2004	ARIES-IFE Study [Guest Editor: Farrokh Najmabadi]

The following special issues are already scheduled for 2005: TEXTOR Tokamak (EU), DIII-D Tokamak (GA), 16th TOFE 2004, and 7th Tritium 2004. Future (2005-2007) 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), NIF program and beyond (LLNL), magnetic fusion reactor studies (EU, JA, US).

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

Electronic access to FS&T is available from 1997-to-current. Additional journal back issues will continue to be added (depending on demand). Recent (2002 and beyond) 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/

Looking forward to receiving your comments and suggestions on FS&T contents and coverage, and potential future topical areas that are timely and of interest. Contact e-mail: fst@ans.org.

US ITER Activities, Ned Sauthoff, US ITER Project Office, DOE Princeton Plasma Physics Laboratory, Princeton, NJ.

Since the previous report (which was written in May, 2004), site-focused negotiations involving high-level government officials have continued while the US fusion community has engaged in the two major areas of activity of the ITER Transitional Arrangements: "Joint technical preparations directed at maintaining the coherence and integrity of the ITER design and at preparing for an efficient start of ITER construction," and "Organizational preparations directed at enabling the ITER Legal Entity to enter into effective operation with least possible delay following the entry into force of the ITER Joint Implementation Agreement."

The US is both providing staff (in the form of secondees/visiting researchers) to the International Team and performing agreed tasks aimed at refining and documenting the design and addressing areas of risk. The 2001 Final Design Report is being updated by the International Team in key areas, with the goal of providing a coherent document that describes the current design that has matured since the 2001 design. The US focus has been mostly in areas of its provisionally allocated in-kind contributions: modules of the central solenoid magnet, a portion of the blanket, segments of the ion cyclotron and electron cyclotron systems, parts of the vacuum and fueling systems, the tokamak exhaust processing system, cooling water and steady-state power systems, and diagnostic systems. In these areas, the US is performing tasks that have been coordinated with the international ITER team in order to maximize effectiveness of the joint activity. As of Summer 2004, the US was providing the equivalent of 3 full-time members of the ITER international team and performing 12 tasks.

In the magnet area, the US activity addresses completion of the design as well as management of risks in the areas of strand-performance (e.g., amperes per square millimeter), jacket material characteristics, and joints. In Plasma-Facing Components, the activity addresses design, as well as fabrication and non-destructive testing methods. In the other areas, US participants on the International Team and on the US participant team are serving on task forces and performing agreed R&D and design tasks. Specifically, the US participates on multi-party task forces in the areas of Magnets, Diagnostics and Port Engineering, Tritium Processing Integration, Materials, and Test Blanket studies among others.

In December 2003, the Department of Energy called for proposals for laboratories to host the US ITER Project Office, which would serve as the US Domestic Agency. In July 2004, the Department announced that a team consisting of the Princeton Plasmas Physics Laboratory and the Oak Ridge National Laboratory had been selected. Since then, the Project Office has worked on the establishment of the US ITER Project, which focuses on the provision of US contributions to ITER from both the technical and project management perspectives. In compliance with the DOE Order on Project Management, the Office is working with the Department of Energy in the planning of work aimed at achieving the Critical Decisions. The Department of Energy has drafted the Mission Need Statement, which is under active discussion and review within the government. The Project Office is focusing on the preparations for the next Critical Decision that entails a preliminary Project Execution Plan, the Acquisition Strategy, Conceptual Design, and the Cost/Schedule Range. Meanwhile, the Department of Energy is developing within the government its portion of the President's 2006 Budget Proposal.

Progress on Z-Pinch IFE, Craig L. Olson, Sandia National Laboratories, Albuquerque, NM.

The goal of Z-pinch IFE is to extend the recent single-shot Z-pinch ICF results on Z to a repetitive-shot Z-pinch power plant concept for the economical production of electricity. Z-pinch IFE is relatively new, and has become part of the IFE community over the past five years. Z-pinch IFE has been part of the 1999 Snowmass Fusion Summer Study, the IAEA Cooperative Research Project on IFE Power Plants (2001), the 2002 Snowmass Fusion Summer Study, the FESAC 35-year Plan Panel Report (2003), and the FESAC IFE Panel Report (2004).

Over the last few years, several outstanding results have been achieved with Z-pinch ICF targets on the Z accelerator at Sandia National Laboratories. On Z, the high magnetic field pressures associated with 20-MA load currents implode a Z-pinch wire array, generating up to 1.8 MJ of x-rays at powers as high as 230 TW. Using a double-pinch hohlraum target, capsule implosions in the ~70 eV hohlraum have been radiographed by 6.7 keV x-rays produced by the Z-Beamlet Laser (ZBL). These experiments demonstrated capsule implosion convergence ratios between 14 and 21 from a radiation drive symmetry that is within 1.6 to 4 times the symmetry required for scaling to high yield. Using a dynamic hohlraum target, a 2.1-mm-diameter deuterium-filled CH capsule absorbs up to 35 kJ of x-ray energy from the □ 220 eV dynamic hohlraum. The capsule convergence ratio is 5-10 and the thermonuclear DD neutron yield measured with activation detectors is up to 8 $x10^{10}$. These yields approach being a factor of 10 higher than that achieved by any other indirect-drive target experiments. Computer simulations of the symmetry, electron temperature, electron density, and convergence agree reasonably well with the measurements in both target configurations. Hemispherical capsule implosions have also been radiographed on Z in preparation for future experiments with fast ignition targets.

Based on (1) these demonstrated Z-pinch driven target results, (2) the high demonstrated electrical conversion efficiency (□ 15%) on Z from wall-plug to x-rays, and (3) the lowest cost in $/joule for all IFE drivers, it appears that Z-pinches are particularly attractive for IFE provided a suitable method for rep-rated standoff (separation of driver and target) can be devised. Although several concepts for repetitively replacing the final magnetically insulated transmission line that connects the driver to the target have been proposed, the simplest and most robust is the Recyclable Transmission Line (RTL) concept as shown in Fig. 1. In this concept, an RTL is made from a solid coolant (e.g., Flibe or LiPb), or a material that is easily separable from the coolant (e.g., low activation carbon steel). The latter is the present preferred choice for Z-pinch IFE. The RTL would enter the chamber through a single hole at the top of the chamber (□1 meter radius), and extend into the chamber a distance of two or more meters. Note that the RTL would bend at the top of the chamber, and upper shielding would be placed above it. Note that this bend alleviates the usual problem of a final optic. For a spherical chamber of radius 5 meters, and an RTL entrance hole at the top of the chamber of radius 1 meter, the entrance hole represents only 1% of the chamber surface area. Therefore, in principle, 99% of the chamber can be shielded by the thick liquid walls. For power plant operation, the RTL/target assembly is inserted through the single opening at the top of the thick liquid wall chamber, the shot is fired, portions of the RTL are vaporized and end up mixed with the coolant to be recycled, the upper remnant of the RTL is removed, and the cycle is repeated. The present strategy for Z-pinch IFE is to use high-yield targets (□3 GJ/shot) and low repetition rate per chamber (□0.1 Hz).

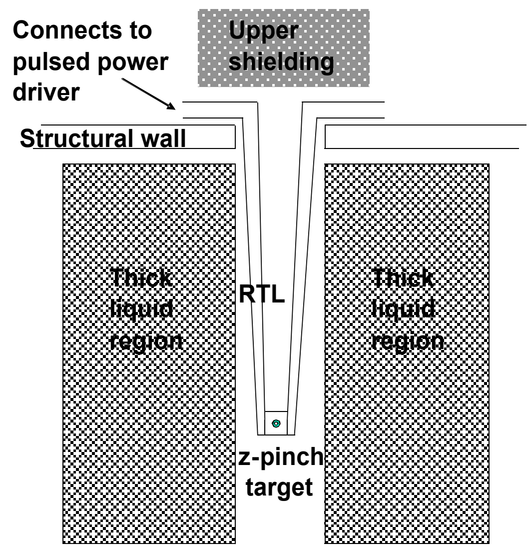

Fig. 1. The RTL concept.

Issues associated with the RTL include movement to insert it into the chamber (but the required accelerations are very low, since there is 10 seconds between shots); RTL electrical current initiation; RTL low-mass limit and electrical conductivity; structural properties; mass handling; shrapnel; vacuum/electrical connections; activation; waste stream analysis; shock disruption to liquid walls; manufacturing/cost; optimum configuration (inductance, shape, etc.); power flow limits for magnetic insulation; effects of post-shot electro-magnetic pulse, debris, and shrapnel up the RTL; and shielding of sensitive accelerator parts. Initial experiments over the last four years at the 10 MA level on Saturn have been successfully used to study the electrical current initiation in the RTL, the RTL low-mass limit, and the RTL electrical conductivity.

Recent funding by a US Congressional initiative of $4M for FY04 is supporting research on Z-pinch IFE through DOE NNSA DP. A Z-pinch IFE research team has been created that includes SNL, LLNL, LANL, NRL, UCB, U. Wisconsin, UCD, UCLA, Georgia

Tech., U. Missouri-Columbus, U. Alabama, UNM, GA, MRC, EG&G, Omicron, FPA, IHCE-Tomsk (Russia), and Kurchatov Institute-Moscow (Russia). Research has been initiated on (1) RTLs, (2) repetitive pulsed power drivers, (3) shock mitigation [because of the high-yield targets], (4) planning for a proof-of-principle full RTL cycle demonstration [with a 1 MA, 1 MV, 100 ns, 0.1 Hz driver], (5) IFE target studies for multi-GJ yield targets, and (6) Z-pinch IFE power plant engineering and technology development. Some recent research results in each of these areas are as follows:

1. RTL: The present approach is to use a carbon steel RTL, with a total mass of about 50 kg, in a chamber with a pressure of 10-20 torr. The structural properties of the RTL set the pressure limit. Power flow properties of the RTL are being investigated. The major concerns involve electrode heating, the formation of surface plasmas, accurate determination of the electrical conductivity, magnetic field diffusion into the electrode material, and motion of the electrode material during the power pulse. 2D and 3D codes are being used to evaluate these effects. Initial results using the Alegra and LSP codes suggest that these effects will be tolerable for the currents required to drive 3 GJ targets.
2. Repetitive Pulsed Power Drivers: Although other potential repetitive pulsed power technologies are being assessed, the present approach is to use a Linear Transformer Driver (LTD) voltage adder accelerator. In the LTD concept, a series of compact, low inductance capacitors are charged directly in parallel, in cylindrical formation. A series of switches next to the capacitors, and in the same cylindrical formation, switches the charged capacitors to directly apply voltage to a single, inductively-isolated gap. Several such cells are combined in a voltage-adder formation to reach high voltage. Progress is being made on an LTD PoP (Proof-of-Principle) accelerator at 1 MA, 1 MV, 100 ns, 0.1 Hz. One cell (100 kV, 1 MA, 100 ns) has been designed, constructed, and successfully tested. Two more cells are being constructed.
3. Shock Mitigation: The envisioned fusion yields for Z-pinch IFE are large (□3 GJ) compared to the other IFE approaches that typically use yields □ 0.4 GJ. Therefore, shock mitigation (in the thick liquid walls) to protect the structural chamber walls is an issue that must be addressed. This is being modeled in scaled experiments with a shock tube and water layers, and with explosives and water jets. Foamed liquid water jets have also been demonstrated. Code calculations are being performed with the goal of validating the codes with the experiments, and then using the codes to predict effects for a full-scale Z-pinch IFE power plant.
4. PoP Experiment Planning: The Z-PoP experiment is in the planning stages. It is based on a 1 MA, 1 MV, 100 ns, 0.1 Hz LTD accelerator, as mentioned above, that is under development. Z-PoP would use this driver, together with an RTL, and a z-pinch load (□5 kJ), and would be automated to run at 0.1 Hz. The procedure would be to insert an RTL and a Z-pinch load, fire, remove the remnant, reload, and repeat the process. Robotic systems are being investigated to perform these functions for Z-PoP.
5. Targets for Z-pinch IFE: The dynamic hohlraum target is the preferred target for Z-pinch IFE, although other targets (double pinch, fast igniter, etc.) are also being

considered. Based on Lasnex simulations, and analytic scaling studies, fusion yields of 3 GJ may be obtained with this target with gains G □100. This gain, coupled with a driver efficiency (□) that is already 15% (and should be optimized to 25% or more in the future), gives a favorable □G □ 15 or more. This high value of □G ensures a favorable power plant operating scenario.

6. Z-pinch Power Plant Technologies: An initial multi-chamber Z-pinch power plant study named ZP3 was completed to establish one complete (but non-optimized) 1000 MW_e power plant scenario. This concept assumed Marx generator/water line technology for the pulsed power driver, a carbon steel RTL to connect the driver to the target, a dynamic hohlraum target, and a thick-liquid wall chamber (with pressure 10-20 torr of an inert gas such as Ar). Activation studies indicate that a one-day supply of RTLs should permit a sufficient cool-down time for the RTL material. If each RTL is □50 kg, then a one-day supply is 5,000 tons. This is the inventory needed for the power plant, and it would be recycled constantly. (For comparison, the one-day waste from a coal-fired power plant is about 5,000 tons.) Studies regarding other activation concerns and waste stream analysis are in progress.

A Road Map for Z-pinch IFE has been created that would lead to electricity on the grid in about 25 years. The plan includes an Engineering Test Facility (ETF) in two phases. ETF Phase I would be a single-shot Z-Pinch High Yield Facility built using RTLs, LTD accelerator technology, and the single-shot equivalent of a thick-liquid wall chamber. After high-yield targets have been demonstrated, the facility would be converted to ETF Phase II, which would be repetitive at 0.1 Hz and produce electricity for short periods of time. The combined ETF Phase I and Phase II would span about 14 years.

Perspectives of the International Atomic Energy Agency's Controlled Nuclear Fusion Activities

G. Mank, A. Malaquias, and T.J. Dolan, International Atomic Energy Agency (IAEA), Vienna, Austria.

The IAEA's Programme on Plasma Physics and Controlled Nuclear Fusion

The current IAEA activities in plasma physics and fusion research address issues of magnetic and inertial confinement as well as the study of dense plasmas. Subjects on fusion technology may be included in the future. The Agency could enhance worldwide commitment to fusion by creating awareness of the benefits of magnetic and inertial confinement. Since 1970 [1], the International Fusion Research Council (IFRC), comprised of leading experts from both developed and developing Member States, gives guidance to the plasma physics and nuclear fusion activities of the Agency.

Programs to harness the potential of nuclear fusion for electrical power production are being pursued in about 46 countries including 292 fusion research institutions, laboratories, university institutes and departments, and official institutions, as reported in the 2001 IAEA World Nuclear Fusion Survey. The numbers have changed in the last three years, and a new World Survey will be published in 2005.

Progress so far has clearly established the feasibility of controlled thermonuclear fusion on the basis of underlying physics. The remaining scientific, technological and economic issues are now being addressed to make fusion power a viable energy option. The IAEA program in 2005 should play a catalytic role by fostering information exchange, promoting research and development, organizing consultancies and technical meetings, monitoring the global activities and supporting technical cooperation projects.

In response to IFRC recommendations and good progress with the ITER project [2] and other research, the IAEA has upgraded its fusion activities from "Project" status in 2002/2003 to a separate "Sub-Program" in Nuclear Fusion Research since the beginning of 2004.

The Plasma Physics and Fusion activities of the IAEA in 2005 will promote the exchange of ideas on basic topics that need further and enhanced understanding for utilizing fusion as an energy source option for the benefit of mankind. The Agency continues to support the most advanced alternatives, i.e. magnetic and inertial confinement, in a relative proportion to the status of development, on the road to fusion, and scientific and technological spin-offs for social benefit. The ITER project is expected to become the most visible realization of progress in magnetic confinement. The IAEA supports fusion activities worldwide, provides the auspices for ITER activities, and offers common ground for high-level ITER meetings.

The IAEA's aim to foster the exchange of scientific and technical information on peaceful uses of atomic energy worldwide is exemplified by the biennial Fusion Energy Conference. The first conference of this series was convened by the IAEA in Salzburg in September 1961 [1]. Since 1998 the conference proceedings are available on the web pages of the IAEA: http://www-naweb.iaea.org/napc/physics/fec.htm. Many other current conferences on fusion, plasma physics and nuclear data are supported by the IAEA.

The Agency maintains the FENDL-2 nuclear cross section data library (http://www-nds.iaea.org/), which has been adopted as the reference library for neutronics design calculations for ITER. The upgraded Version FENDL-2.1 is scheduled for release in 2005.

IAEA Technical Meetings

Through the guidance and support of the IFRC, the IAEA organizes many international Technical Meetings (TM) on key issues of plasma physics and fusion research. The Member States generously provide sites for many of the meetings. For 2005, the Agency plans to hold several technical meetings related to magnetic fusion, seven of which would be strongly ITER-related. An overview of the five IAEA meetings for the first 6 months of 2005 is given below:

– The 4th IAEA TM on "Steady State Operation of Magnetic Fusion Devices and MHD of Advanced Scenarios" will be held in Gandhinagar, India on 1 – 5 February. The meeting will provide an opportunity for developed and developing countries to share their achievements on physics and technology to support continuous operation of a fusion reactor.

- From 2 – 4 March 2005, Italy will host the 2nd IAEA TM on "Theory of Plasma Instabilities: Transport, Stability and their Interaction." The seminar is co-organized by the IAEA and the Abdus Salam International Centre of Theoretical Physics (ICTP) and will take place in Trieste.
- The 3rd IAEA TM on "ECRH Physics and Technology for ITER" will take place in Como, Italy from 2 – 4 May 2005. The meeting will be followed by the ITER ITPA Topical Group on Steady State Operation and Enhanced Performance meeting.
- The IAEA TM on "Negative Ion Based Neutral Beam Injectors", which will be held from 9 – 11 May in Padova, Italy, will restart a series of meetings, the last of which had been held in 1991.
- The 5th IAEA TM on "Control, Data Acquisition, and Remote Participation for Fusion Research" will take place from 12 - 15 July 2005 and will be hosted by the Research Institute for Particle and Nuclear Physics, Budapest, Hungary.

IAEA Research Coordination Meetings

The IAEA encourages the exchange and training of scientists and experts in the field of peaceful uses of atomic energy. Besides fellowship programs, the IAEA organizes Coordinated Research Projects (CRP), related to major topics of research. Within the time schedule of about 4 – 5 years, several Research Coordination Meetings (RCM) are supported by the IAEA. Further information can be found on http://www-crp.iaea.org/.

The CRP on "Tritium Inventory in Fusion Reactors" will be finished in 2004. The objective of this CRP is to gather and generate new data relevant to the overall inventory of tritium in fusion reactors.

Another CRP on "Data for Molecular Processes in Edge Plasmas" will also be finalized in 2004. It focuses on the assessment and collection of new data for molecular processes in edge plasmas that are available from both experimental and theoretical studies, and the identification and fulfillment of new data requirements.

The recently initiated CRP "Joint Research Using Small Tokamaks" is aimed to give a visible contribution in understanding plasma turbulence, transport and edge physics, dimensionless scaling of turbulence properties, modeling, by utilizing a network of smaller tokamaks gathering contributions from developed and developing countries.

The work on "Dense Magnetized Plasmas" will continue in 2005. This CRP provides studies on plasma facing materials under irradiation by X-rays, particles, and neutrons. It also supports the development of plasma focus devices technology for applications making use of neutron and X-ray beams (material science, medicine, etc.). A new high density plasma negative ion source is also being developed for intense negative ion beam production.

Plasma Physics Program in Cooperation with ICTP

Founded in 1964 by Abdus Salam, the International Centre for Theoretical Physics (ICTP, http://www.ictp.it) operates under the aegis of two United Nations agencies - the

United Nations Educational, Scientific and Cultural Organization (UNESCO) and the IAEA. The ICTP was formally inaugurated in October 1964 with programs in Plasma, High Energy, and Nuclear Physics. In 2005, two workshops related to Plasma Physics and Fusion will take place at the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy. The workshop on "Plasma Physics Capacity Building in Plasma Applications and Diagnostic Techniques", and the workshop on "Nuclear Structure and Decay Data: Theory and Evaluation" constitute a unique opportunity for scientists to exchange knowledge on fusion research topics.

IAEA fusion activities are periodically updated on the Agency's web page http://www.iaea.org/ and the web pages of the Physics and Nuclear Data Section accessible through http://www-naweb.iaea.org/napc.

References:

[1] D. Fischer, History of the International Atomic Energy Agency: The First Forty Years, Vienna (1997), "A Fortieth Anniversary Publication", ISBN 92–0–102397–9.
[2] ITER Technical Basis, IAEA, Vienna (2002), IAEA/ITER EDA/DS/24.