Fusion Energy Division
American Nuclear Society
June 1999 Newsletter

Letter from the Chair, Wayne Houlberg, Fusion Energy Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee

As I near the end of my term as Chair of the FED, I believe we have made progress in facing the challenges posed by the Society and the fusion program. But, there are many more hurdles ahead. As the old saying goes: there is nothing constant but change.

The ANS has been addressing change through a series of 'Infrastructure' assessments. The ANS Infrastructure III meeting I attended in March addressed the relationship between the Society and the Divisions. One of the biggest issues was the format and frequency of national meetings. There was widespread support for moving toward a single national meeting, but there was also discussion of co-located topical meetings replacing one or both of the national meetings. One proposal was to arrange these around 'tracks,' which would partition the Divisions into four groups responsible for organizing the technical part of the meeting in a two-year cycle. It maintains the two meeting per year format, but releases Divisions from the responsibility of organizing sessions twice a year. No matter how the tracks are set up, however, there would be many members who would be in more than one track because of membership in multiple Divisions. The track concept also would pose a more direct challenge to stand-alone topicals, which everyone considers to be a very important aspect of the Society. A weakness of the national meetings, which stand-alone topicals address, is publication of papers in a form that can be referenced. Another is the variety of presentation formats. Poster sessions, for example, are not included in national meetings but are an important element of topicals. They provide the means for one-on-one dialog with those most interested in the subject, are appropriate for work in progress, give students (among others) that are uncomfortable with oral presentations an opportunity to present their work in a more relaxed setting, allow grouping several smaller subjects into more of a critical mass, and are a means of fostering the important hallway discussions that are crucial for successful technical meetings. The excessive number of governance meetings held concurrently with technical sessions at national meetings has also been a sore point with many people because it draws people away from the technical sessions -- and the hotels because it takes up so much meeting space. The 1999 June meeting in Boston will be a breakthrough in this area because governance meetings will not be able to convene until late in the afternoon. The Infrastructure III meeting was successful in bringing issues to the table for discussion and increasing the dialog between the Divisions and ANS staff. However, there were no votes taken on how to resolve any issue so it will be interesting to see how the summary report characterizes the conclusions to be drawn from the discussion.

ANS headquarters is making progress in moving into electronic communication. They are bringing new staff to support Web pages and newsletters. We can take pride that the FED has been one of the leaders in this area and have Laila El-Guebaly and Mark Tillack to thank for their efforts. There was considerable vocal support for electronic review of summaries submitted to the national meetings as a means of reducing the costs associated with the present review meetings. Several other divisions have been moving to electronic reviews for their topical meetings. We need to support the efforts of the FED Technical Program Committee to implement an electronic review for our 14th Topical on Technology of Fusion Energy scheduled for October 2000 in Park City, Utah. You can read more about the 14th Topical in the report from W. Carmack later in this newsletter.

Fusion funding seems to have stabilized, but we will continue to address the balances between physics and technology, between magnetic and inertial confinement, and between the domestic program and foreign collaboration. There are several reviews of the fusion program underway that will likely have a strong influence on future directions. I believe our strongest influence on the program will come through the Fusion Energy Sciences Advisory Committee (FESAC) and participation in the Snowmass meeting this summer. The FED Board of Directors has endorsed the Snowmass meeting, which will provide a forum for us to make technical evaluations of the various opportunities in the fusion program. The record of meetings similar to Snowmass by other programs indicates that we can expect emphases in our program to evolve over a period of years following the meeting. This happens through recommendations by various advisory committees that rely on such broad community input for technical guidance. For instance, FESAC plans to rely heavily on input from Snowmass in making recommendations to the DOE on program choices and funding. Mike Mauel, one of the Snowmass organizers, reports later in this newsletter on the plans for the Snowmass meeting. On behalf of the FED Board of Directors I encourage you to get involved. Younger members of our program are especially welcome because the future of the fusion energy program is theirs. Our ANS interests lie heavily on the technology aspects of fusion. It is regrettable that there are deep cuts in fusion technology funding in the preset FY2000 budget. We need to ensure that the opportunities to advance fusion technology are adequately supported by the community, and that these opportunities receive adequate funding. The most visible spin-offs from the fusion program have come through the technology program.

I wish Clement Wong well in taking up the challenge to lead the FED through the next year. He has been attending the FESAC meetings (held about every two months) as an observer, to come up to speed during this information gathering period that will culminate in a major report to Martha Krebs this fall on fusion program recommendations. Sometime in the near future, George Miley will be retiring and we will have to find a new Editor for Fusion Technology. Although the ANS Technical

Publications Committee takes primary responsibility for this task, we will need to provide input. Planning for the 14th Topical will be a major focus of energy during the next year. We need to continue to pursue opportunities to strengthen this series of topical meetings through joint sponsorship with other organizations. I expect the dialog on national meetings to continue, but recognize that change will be slow -- the rumblings for a single national meeting have already existed for many years.

Officers and Executive Committee List, Bill Hogan, Lawrence Livermore National Laboratory, Livermore, California

I appreciate the interest and effort shown not only by the winners in this election but all those who ran for office. Those who actively participate in FED are the ones who will make it a success. I encourage those who did not win this time to run again in the future.

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Nominating Committee	Wayne Houlberg
Honors/Awards Committee	Gerald Kulcinski
Membership Committee	Ken Schultz
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Representative on ANS Publications Committees	Ken Schultz
Representative on ANS National Program Committees	Steve Herring
Representative on ANS Public Policy Committee	Bill Hogan
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Newsletter Editor	Laila El-Guebaly
Editor Fusion Technology Journal	George Miley
Web site maintenance	Mark Tillack
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Liaisons to other Organizations	John Davis - MS&T
	George Miley - IEEE

Treasurer's Report, Sandra Brereton, Lawrence Livermore National Laboratory, Livermore, California

As of April 1999, our division has a balance of $6,233. Income in 1998 included:

- $612 from membership
- $1800 from Topical meeting profits
- $6925 carry forward from 1997.

Expenses in 1998 included:

- $500 for awards
- $1950 for student support
- $654 for national meeting expenses (conference calls).

For 1999, our income will include approximately $600 from membership dues. Anticipated expenses in 1999 include:

- $1000 for awards outstanding
- $250 for national meeting expenses (conference calls).

The projected balance at the end of 1999 is approximately $5,600.

In the past, a complicated method was used to determine the amount of funds the technical divisions within ANS would be allowed to carry forward from one year to the next. On occasion, this calculation required year-end balances to be "adjusted", based on spending. At the November ANS National Meeting in Washington D.C., the ANS Board of Directors elected to eliminate the carry forward calculation. From this point on, the ending statement balance for the previous year will always be the beginning balance for the current year.

***Fusion Technology* Journal Needs Your Help!**, Ken Schultz, General Atomics, San Diego, California.

The ANS Fusion Energy Division is extremely fortunate to have a high quality journal, *Fusion Technology*, devoted almost entirely to topics of interest to the Division. It is *our* journal. However, *Fusion Technology* is in serious trouble. We are close to going subcritical! If we cannot reverse this trend, *Fusion Technology*will be canceled. It is imperative that all members of the Fusion Energy Division support our journal. In particular, we request that each member please take the following steps to keep *Fusion Technology* healthy:

1. Library subscriptions. Make sure the library at your organization receives a subscription. Contact them today!

2. Personal subscriptions. A good deal at $100/year! Buy one! Just call ANS at 708- 579-8210. Do it now!

3. Page charges. Make sure that you and others in your organization pay the page charges for your papers.

4. Contribute articles. For *Fusion Technology* to remain the leading journal for fusion engineering and technology, we must keep a steady flow of high-quality papers. We particularly encourage you to consider special issues and review articles.

Page charges are a particular concern. All ANS journals use page charges in order to offer subscriptions to members at significantly lower cost than that of commercial journals. Although ANS policy is to publish papers even if page charges cannot be paid, Fusion Technology counts on these page charges to balance its budget. Since page charges are levied after the paper is accepted, and the paper is written after the work is finished, frequently difficulty arises in paying these page charges since the grant or contract that sponsored the work is actually over. To help with this situation, ANS is willing to arrange with the authors to prepay estimated page charges while the contract is in place, for a paper they expect to write at the conclusion of the work. To take advantage of this arrangement, contact Mary Beth Gardner at ANS Headquarters, 708-352-6611.

If you have further suggestions, please contact Ken Schultz, our Division's representative to the ANS Publications Steering Committee or George Miley, Fusion Technology Editor.

Meeting Announcement: ANS 14th Topical Meeting on the Technology of Fusion Energy, William Carmack, Fusion Safety Program, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho

The 2000 American Nuclear Society 14th Topical Meeting on the Technology of Fusion Energy will be held at the Olympia Park Hotel in Park City, Utah from October 15th to the 19th, 2000. This will be the first ANS Fusion Topical Meeting of the new millennium. Please plan to join us in Park City for an international exchange and meeting on the latest developments in fusion technology. It will be an international forum for presentation and discussion of scientific and technical information covering all aspects of fusion technology, including the most recent developments in both inertial and magnetic confinement fusion energy. The meeting will offer an excellent opportunity for people involved or interested in fusion activities to learn of the latest developments in the field of fusion nuclear energy.

The meeting web site provides detailed information on abstract submittal, meeting registration, lodging, and activities. Abstracts will be accepted beginning in July 1999. The web site can be found at: http://ev2.inel.gov/ParkCity/. Please plan to join us in Park City in October of 2000.

1999 Fusion Summer Study: Opportunities and Directions in Fusion Energy Science for the Next Decade, Michael Mauel, Department of Applied Physics, Columbia University, New York.

Individuals involved with fusion research are invited to come together at Snowmass, Colorado for two weeks of discussion, technical debate, and spectacular scenery during July 11-23,

1999. The Fusion Summer Study is entitled "Opportunities and Directions in Fusion Energy Science for the Next Decade." The goal of the workshop is to interact with each other and to develop a scientific and technical basis for consensus on (1) the key issues for plasma science, technology, and energy and environment for fusion energy development, and (2) the opportunities and potential contributions of existing and possible future facilities and programs to reduce fusion development costs and achieve attractive economic and environmental features.

The 1999 Fusion Summer Study is a workshop endorsed by the American Physical Society (APS) and the ANS Division of Fusion Energy. The workshop will be open to all members of the international fusion science and technology community including experts in all approaches to magnetic and inertial fusion energy, and it is co-sponsored by DOE and all of the major US fusion research centers, laboratories, and organizations.

The level of interest expressed in Snowmass has been gratifying. The meeting will be attended by well over 250 scientists and engineers, and the fusion community should be looking forward to a highly productive workshop.

The 1999 Fusion Summer Study has been modeled, in part, after the series of workshops held at the same location by the APS Division of Particles and Fields. The meeting begins with a day of plenary talks by US and international leaders of the fusion program. After that, participants will divide into six working groups with several subtopical discussion groups lead by convenors and session chairs. At the end of the workshop, the working group convenors will summarize the scientific and technical findings of each group. Proceedings of the Fusion Summer Study will be published on a CD-ROM. The proceedings will include summary reports from each working group and from each subgroup. Page-limited contributions from individuals are also welcome.

The web-page of the Summer Study is located at http://www.pppl.gov/snowmass. The web site presents the general schedule, lists the working group convenors, and suggests key questions to stimulate discussion within the subgroups. Three working groups meet in the mornings to discuss fusion research from the point-of-view of the various fusion concepts: Emerging Fusion Concepts, Inertial Fusion Concepts, and Magnetic Fusion Concepts. In the afternoons, three "cross-cutting" working groups will meet to discuss fusion research from the point-of-view of Plasma Science, Energy Issues, and Technology. Working days end with an outdoor social hour surrounded by mountain views.

The working group convenors are representatives knowledgeable of the broad, interdisciplinary character of fusion research. Over the past few months, they have constructed a framework for discussing the key scientific and technical issues associated with fusion's next decade. The working group meetings will not be a series of seminars. Instead, subtopical discussion groups will leadoff with one or two short but provocative talks followed by discussions and/or smaller break-out groups. Key issues are treated as scientific problems to be addressed on honest technical grounds, and results from the break-out groups are reported back to the larger working and subtopical groups for further discussion. All Snowmass participants are strongly encouraged to contact the convenors of those working groups in which they are most interested and become involved with ongoing preparations.

The 1999 Fusion Summer Study will be a wonderful opportunity for participants to develop a greater appreciation of the goals and objectives of fusion's many subdisciplines. The meeting will also be located away from the distractions of daily business at a spectacular and well-equipped meeting site. Participants will be able to share ideas with the entire fusion community, socialize with scientific and technical colleagues, and contribute directly to the future direction of fusion energy science.

Ongoing Fusion Research:

Advanced Design Program, Farrokh Najmabadi, Department of Electrical and Computer Engineering, Fusion Energy Research Program, University of California San Diego

The Advanced Design Program (also known as the "Power-Plant Studies Program" or "System Studies Program") encompasses research efforts on identifying the role of fusion in a global energy strategy and power plant studies. During the past ten years, these research activities have been at the forefront in identifying the optimal plasma-physics regimes of operation for different confinement concepts as well as identifying the critical issues and direction of high-leverage research in physics and technology for the U.S. and worldwide fusion programs. This role has become even more critical with the expanded focus on innovation and new initiatives in the U.S. fusion program.

Development of fusion as a commercial product is a great challenge, in part for technical reasons, in part due to limited resources, and in part due to competition from other options. Strategic planning and forecasting studies help develop criteria describing what fusion must do to be successful in the market place. Socioeconomic studies of fusion's role in a sustainable global energy strategy address the potential of fusion to resolve global energy issues such as greenhouse gases and sustainable economic development, as highlighted in the Rio and Kyoto Agreements. In 1999, several new initiatives were launched in this area. Because the cost of energy from fusion sources is dramatically reduced as the fusion power is increased, a study by ORNL and partners from industry and utilities is aimed at identifying options to deploy large fusion power plants including hydrogen production and co-generation (of hydrogen and electricity). A study by PPPL is aimed at establishing the merits and addressing the issues associated with the introduction of the fusion electricity. The focus of this study is the environmental impact of reduced CO_2 emission, waste disposal, and waste recycling; resource needs of special materials and tritium; and the potential role of fusion/fission combinations. A study by the University of Wisconsin-Madison will calculate and compare energy payback ratio and CO_2 emission rate from fusion as well as fossil fuels, fission, and wind power plants.

Most of the research in the power plant studies area is performed by the national power plant studies program, the ARIES Team. Two projects are underway: (1) Advanced ARIES-RS, and (2) Non-Electric Applications. ARIES-RS is the current vision of the advanced tokamak program and is used to determine R&D directions in both physics and technology. Considerable progress in the understanding of advanced tokamaks has been made in the last two years since the conclusion of the ARIES-RS research study. This progress has shown that plasmas with higher performance can be achieved. New efforts on next-step options are expected to concentrate on developing lower cost development options for fusion. The cornerstone of this strategy is to use advanced tokamak modes to achieve high performance. As a result, the tokamak program will focus even more on advanced tokamak modes.

Questions have been raised by many program leaders on how good ARIES-RS can become if both higher performance physics and higher performance technologies (e.g., higher-field magnets) can be assumed. The advanced ARIES-RS research is launched to address this issue. We expect that new insights in the optimization of advanced tokamak modes will lead to higher performance plasmas with a higher beta and lower current-drive power as compared to ARIES-RS. In the technology area, improvements to the overall system may be possible using high-temperature superconductors (HTS) because of their capabilities for higher critical current density at higher field and operation at or close to liquid nitrogen temperature. The development of HTS in recent years has been dramatic and is expected to continue rapidly in the coming decade. Since SiC/SiC composites were first proposed in ARIES-I, R&D results have become available and new design ideas developed. For example, it appears that combination of SiC/SiC composites, as a structural material, with PbLi coolant/breeder can lead to a high performance blanket. Because of the high coolant- outlet temperature of such blanket, Brayton power conversion systems with high efficiency, approaching 60%, can be used.

During the last few years, the progression of the ARIES designs (pulsed-tokamak, steady- state operation, and reversed shear) have shown that improved physics and technology lead to a factor of almost two reduction in size and cost of electricity. Advanced ARIES-RS research will follow this trends toward more attractive fusion power plants.

The ARIES Team also has launched a study on the non-electric applications of fusion. Non-electric applications have been considered since the earliest days of the fusion program. Early considerations of fusion included: (1) hybrids for breeding of fossile fuel (*i.e.,* in an energy-suppressed mode of operation) and also hybrids for energy production (*i.e.,* in a mode in which the fusion neutrons drive a subcritical blanket); (2) the use of fusion neutrons for the transmutation of radioactive waste from fission reactors; and (3) the application of a fusion-based neutron source for fusion materials and engineering testing. More recent studies have added to the repertoire applications such as tritium production, burning of plutonium from dismantled weapons, radioisotope production, medical radiotherapy, hydrogen production, and detection of explosives. A unique characteristic of the more recent studies is the consideration of applications allowing a range of neutron source strengths from $\sim 10^{11}$ - 10^{13} n/s, on the low-end, up to $\sim 10^{19}$ - 10^{21} n/s on the high-end. The high-end studies have considered plasmas based on ITER physics, advanced mode tokamak operation, and the spherical torus. The low-end studies have focused on the inertial electrostatic confinement concept.

Based on the previous discussion, the ARIES team has initiated the study of a fusion neutron source focused at the high-end neutron strength, $\sim 10^{19}$ - 10^{21} n/s. The purpose of this study is to assess the potential and competitiveness of a fusion neutron source as a near-term application of fusion energy research. This study will begin with a concept definition phase that will last about six months and consist of five activities: (1) Assessment to identify the most useful application and product, (2) Interactions with the fission and accelerator communities to understand the potential of reactors and accelerators for neutron source applications, (3) System studies to assess the performance/metrics of ITER-based and advanced mode tokamaks and the spherical torus for neutron source applications (this would include assessments of both D-T and D-D-T fuel cycles), (4) A compilation and assessment of the engineering and nuclear performance of the various concepts proposed for neutron-source applications including fusion, fission and accelerator systems, and (5) An assessment of the environmental, safety, and licensing implications of fusion neutron source applications such as plutonium disposition and radioactive waste transmutation. Depending on the results of the concept definition phase, a design phase may be launched to further examine one of the embodiments and to evolve a development plan.

For further information on the ARIES project, visit the ARIES web site: http://aries.ucsd.edu/PUBLIC

Inertial Fusion Energy Technology - R&D on Chambers and Targets, Wayne Meier and Grant Logan, Lawrence Livermore National Laboratory, Livermore, California, and Ken Schultz, General Atomics, San Diego, California.

In FY99, the Office of Fusion Energy Sciences (OFES) established the Virtual Laboratory for Technology (VLT) as part of the restructuring of its Technology Program and named Dr. Charles Baker from the University of California-San Diego (UCSD) as director. The VLT includes five elements: Plasma Technologies, Fusion Technologies, Advanced Design, Advanced Materials, and Inertial Fusion Energy (IFE) Technology.

The IFE Technology element is coordinated by Dr. B. Grant Logan from Lawrence Livermore National Laboratory (LLNL). The scope of IFE Technology R&D encompasses

- IFE chamber design and development, including protection of final optics
- IFE target development, low cost fabrication, injection and tracking technology
- Safety and environmental research for driver, chamber and target systems

The major challenges in developing IFE chambers and target systems for inertial fusion power plants arise from the basic system requirements of these subsystems, which include the need to:

1. Maintain chamber conditions suitable for target injection, driver beam propagation, and target ignition with high energy gain at rates of 5-10 pulses per second.
2. Protect the fusion chamber walls and driver beam interfaces so that the chamber can last for several years, or be easily replaceable in sections, if needed.
3. Extract fusion energy with high-temperature coolants for efficient conversion to electricity, while regenerating the tritium fusion fuel for targets with small just-in-time inventory.
4. Manufacture precision targets at economically low cost and accurately inject them into the center of the fusion chamber at rates of ~5-10 pulses per second.

5. Reduce radioactive waste generation, inventory, and possible release fractions to levels low enough that no public evacuation is needed in worst-case accidents.

Conceptual design studies have identified research and development needs for several driver/chamber /target options, the most promising of which are dry-wall chambers with direct-drive targets for laser drivers (KrF and DPSSL drivers), and renewable liquid-wall chambers with indirect-drive targets for heavy ion drivers. Over the next four years, the Phase I research objectives in power plant systems for both approaches is to show (through assessment studies, small scale experiments and simulations) that technical solutions are plausible for the most critical issues to meet the power plant requirements. This work must provide a firm basis for request for larger amounts of money required after Phase I to demonstrate integrated solutions at full fusion chamber conditions. Preliminary plans for a ~$7M/y R&D program are being proposed to DOE with activities in the following areas:

Liquid Chamber R&D. Liquid wall chamber concepts use either a thin liquid layer (e.g., Prometheus, Osiris, and HIBALL concepts) to protect chamber structures from short-ranged target emissions (x rays and debris) or a thick liquid layer to also protect structures from neutron damage and reduce activation (e.g., HYLIFE-II). The major Phase I research objectives for liquid chamber R&D are to determine the feasibility with scaled liquid experiments of 1) establishing the liquid protection schemes and 2) clearing the chamber of droplets, condensing the vapor, and recovering liquid flows in less than 1/5 second. Current work on liquid chamber fluid dynamics is underway at UC-Berkeley, UCLA and Georgia Tech. Argonne National Lab and Idaho National Engineering and Environmental Lab have also recently proposed activities using their facilities and expertise to address issues related to liquid chamber R&D.

Dry Wall Chamber R&D. Dry-wall chamber concepts (e.g., Sombrero) rely on a low-density (< 1 torr), high-z gas to prevent x-ray and debris damage to the first wall, which is a carbon/carbon composite in the case of Sombrero. The major Phase I research objective for dry wall chambers is to determine the plausibility of achieving dry-wall chamber lifetimes > 1 year minimum between replacements, taking into account damage due to neutrons, x-rays, and target debris. Modeling and experiments on gas-protected chamber dynamics are continuing and future work is planned at the University of Wisconsin (UW), UCSD, Sandia National Lab and UCLA. Oak Ridge National Lab (ORNL) and Pacific Northwest National Lab (PNL) are also interested in working with the IFE element of the VLT on assessments of materials issues.

Driver Chamber Interface. The interface of the driver beam with the fusion chamber is an important area of R&D for the IFE/VLT. For heavy ion drivers, near term efforts will be to produce a self-consistent design for final-focus/chamber interface consistent with heavy-ion target requirements and protection of the focus magnets from radiation damage and excess nuclear heating. Recent driver designs require 40 or more beams from each of two sides for indirect drive targets, so the physical packing of these magnets presents a design challenge. For lasers, the key issues are the design and survivability of the final optics. Options include grazing incidence metal or liquid metal mirrors, and hot fused silica diffractive optics or transmission gratings. Experiments to establish laser fluence limits and analysis and experiments of radiation damage effects are being proposed. LLNL, UCSD, UW, ORNL and others will be involved in this work with assistance from the driver design groups at LBNL, LLNL and NRL.

Target Fabrication and Injection. At the heart of an inertial fusion explosion is a target that has been compressed and heated to fusion conditions by the driver beams. For direct drive, the target is a spherical capsule containing DT fuel. For indirect drive, the capsule is contained within a metal container or hohlraum, which converts the driver energy into x-rays to drive the capsule. The target factory at an inertial fusion power plant must produce about 1-2 x 10^8 targets each year with extreme precision of manufacture, fill them with deuterium-tritium fuel, and layer the fuel into a symmetric and very smooth shell inside the capsule. These fragile targets must be precisely injected at a rate of 5-10 Hz to the center of the high temperature target chamber without damage. An integrated effort on target technologies has also begun and plans for an expanded effort have been completed. General Atomics and Los Alamos National Lab are taking the lead in this area. For both heavy ion and laser drivers, the near term objectives are to identify methods for low cost manufacture and rapid injection of direct- and indirect-drive targets.

Environmental and Safety. Attractive environmental and safety characteristics are essential to the eventual acceptance of fusion as a future energy source. An integrated effort on E&S is planned to develop the tools and carry out analyses for both laser and heavy ion IFE. Issues specific to each chamber approach will be addressed, for example, activation, recovery and recycle of hohlraum materials in indirect drive targets and dust transport in dry-wall chambers. Experiments are needed to quantify release fraction for key in-chamber materials, which will allow more detailed accident consequence assessments. A key goal is to develop power plant designs that can avoid the need for a public evacuation plan. Meeting low-level waste criteria and recycling radioactive materials to minimize waste streams are also goals of this work. LLNL, INEEL and UW are the primary groups involved in this R&D.

International Activites:

Fusion Technology Activities at Karlsruhe Research Center, Dieter Roehrig, Fusion Project Manager, Research Center Karlsruhe, Germany

The Research Center Karlsruhe (FZK) is one of the major government-funded research units in Germany that were founded in the late fifties in order to catch up with the activities of the nuclear power states for a peaceful, safe, and economic use of the atom. Mainly two advanced power reactor lines (the Helium-cooled High Temperature Pebble Bed Reactor and the Na-cooled Fast Breeder Reactor) were being pursued at that time, where Karlsruhe had been focused on the Fast Breeder development. Besides the traditional nuclear activities, a diversification of topics was slowly introduced to cover novel, mainly non- nuclear, areas of research that could not be done elsewhere either because of their specific infrastructure needs or because of their more generic objectives that would not provide immediate return. Among those areas, fusion technology was recognized as a genuine topic for the Research Center Karlsruhe and, therefore, formally introduced in 1983 as a project within its R&D programme.

Despite the lack of its own plasma physics programme and dedicated facilities, the project was seen necessary to complement the ongoing activities mainly in the Garching Institute for Plasma Physics, with the understanding that the time had come to address the technological issues for the next step fusion devices.

Besides this national collaboration and from the very beginning, the Karlsruhe activities were embedded in the European Fusion Technology Programme and thus harmonized with the contributions of the other European Associations. Meanwhile, the 5^{th} European Framework Programme has been adopted with a fusion-related volume of roughly 800 Mio Euro (850 US M$) for 4 years of which FZK holds an adequate share. Within the FZK R&D program, fusion technology amounts to about 17% which translates into an annual budget of almost 60 Mio DM (32.5 US M$). This comprises a staff of nearly 200 people who are working for fusion in about 10 different organisation units. Major contributors are the Materials Research Institutes, the Institute for Technical Physics, the Institute for Neutron Physics, the Institute for Reactor Safety, the Institute for Applied Thermohydraulics, and the Main Departments for Engineering and for Testing Technology. Different from the common approach adopted by other Research Centers of dedicating all activities to a specific fusion concept (e.g., tokamak, stellarator, mirror, Éetc), the FZK programme is broken down according to topics or components that are considered essential elements for almost all fusion concepts. The major activities are related to the development and testing of large superconducting magnets for plasma confinement and of plasma heating by microwaves with the near-term goal of providing the technology for the next- step fusion devices like the ITER tokamak and the Wendelstein-7X stellarator. The second large complex of work is devoted to the blanket technology and structural materials development. Those activities have a distinct long-term aspect. A third area of work, again directed to the next-step devices like ITER, complies with the requirements of an ignited, or driven, plasma for exhaust gas pumping and tritium processing. Besides these large R&D blocks some more generic or safety-related studies attributed to the above topics are performed. Inertial confinement-related activities are almost negligible.

In the field of magnet technology, FZK plays a leading role in the qualification of large superconducting magnets for fusion. Already under the IEA collaboration for the Large Coil Task (LCT), FZK had been involved in the development and pre-testing of the Euratom coil that had afterwards been integrated in the 6 coils assembly and successfully operated at the U.S. Oak Ridge National Laboratory. The Institute for Technical Physics has continued since then working in the magnet technology and safety areas and is presently engaged in the preparation of the ITER Toroidal Field Model Coil testing. To provide a proper background field, the old LCT coil will again be used, but at a 1.8 K cooling level. Meanwhile the existing TOSKA test bed is committed to the testing of the prototype modular coil for the Wendelstein-7X stellarator project.

Microwave technology plays an important role not only for plasma heating, but also for non-inductive current drive and plasma shaping for both tokamaks and stellarators. The goal is to develop gyrotrons that operate between 140 and 170 GHz with outputs of 1 MW or more in the continuous wave (cw) mode. In close collaboration with industry, the development focuses on a novel high power gyrotron with a coaxial resonator and the potential for frequency tuning. For Wendelstein-7X, FZK has the duty to provide the complete plasma heating system based on 10 gyrotrons with 1 MW output each at a fixed frequency of 140 GHz. An important component besides power generation is the transmission of waves to the plasma chamber. Quasioptical transmission lines are developed at the University of Stuttgart, whereas the covers at both ends (which have to be windows with minimal electrical losses and at the same time reliable barriers against vacuum and tritium leakage) have evolved from a comprehensive research at FZK and collaboration with industry and JAERI. Synthetic diamond has proven to be the best solution because of its extremely favorable dielectric and thermal properties. Moreover, windows with an aperture of 80 mm that are suited for 1 MW cw transmission have been realized. Present investigations will determine the maximum tolerable neutron load. This is an important issue especially for ignited fusion devices.

Nuclear technology in a broader sense is pursued for fusion in the areas of tritium technology and blanket development, comprising the long-term need for low-activation structural materials. For any system aiming at a measurable fraction of fusion reactions, tritium processing plays a decisive role. FZK has undertaken to develop a suitable method for tritium recovery from the plasma exhaust gas that, at the same time, complies with the requirements for reliability, ecology and safety. This method is based on permeation, catalytic conversion, and isotope exchange steps. It fulfils the specification of a decontamination factor in the 108 range and has been adopted for ITER. It is now being demonstrated on a technical scale in our Tritium Laboratory (the only one that will be available in Europe in the future for this purpose) with an inventory of 25 g tritium that can be increased to up to 40 g if necessary. As a side point, a number of novel instrumentation, process control, and accountancy issues are being realized and tested. The powerful infrastructure of the tritium lab is now also being used to address specific issues for JET operation wherever tritium comes into play.

In the context of exhaust gas handling, torus pumping is also a subject of R&D work at FZK. It could be shown that cryopumping can comply with all boundary conditions of an ignited fusion device, e.g. tritium issues, helium and impurity removal, high magnetic fields, and high neutron load and radiation heating. Based on extensive experimental work, a cryosorption pump was specified for ITER and a model pump at a 1:2 scale has been built by industry. Preparations for performance testing of this device at FZK are almost complete, and the test programme is expected to start in the first half of this year.

The blanket technology programme aims at the provision of two different European blanket concepts, a water-cooled Pb-17Li blanket and a helium-cooled ceramic blanket. Blanket modules shall be built and preferably be tested in ITER in order to validate the design, identify critical issues, and evolve decision criteria for a fusion power reactor. In the harmonized European Blanket Project, FZK maintains the role of the leading laboratory for the solid pebble bed blanket concept and works on the majority of related tasks. Key problems are the optimization of the concept, fabricability of the blanket box with integrated cooling channels, behaviour of breeding material and beryllium (an indispensable neutron multiplier), thermomechanic and thermohydraulic issues, and investigations into safety and reliability. Neutronics is an important issue both for tritium economy and radioactivity- related issues. Both experimental and theoretical work are going on in order to reliably predict the attainable tritium breeding rates and to determine the shielding factors, radioactivity levels, and heat production. Concerning the closure of the fuel cycle, tritium release from the ceramic breeder material has been investigated out-of-pile with a large variety of irradiated specimens. Studies have also been performed on the most effective method of tritium extraction from the purge gas. An experimental validation is now planned with a gas loop that is being installed in the tritium laboratory.

While ITER, or any other next step fusion device, has to rely on the available, technically proven, nuclear-grade structural materials, a fusion power reactor can only be realized with materials having a sufficiently long lifetime under harsh thermal and neutronic conditions and a sufficiently low radioactivity burden that does not need deep waste repositories. Recognizing that the development of such materials requires very long lead time, the fusion project management has initiated from the very beginning of its activities R&D work on ferritic steels as the most promising candidate material. The development started from a steel that had already been qualified for high doses in a fast breeder neutron environment. The alloy composition was gradually enhanced, especially with a view to those elements that are responsible for the long-term activation in a fusion neutron spectrum. Besides characterization and optimization, the behaviour of irradiated materials continues to play a key role. In particular, radiation-induced embrittlement, as measured by impact testing, has proven to be a sensitive method to determine neutron effects. In parallel, tools for translating the mechanical properties into fracture-mechanical quantities and design codes are being developed. It has also been realized that materials testing in fission reactors are not very adequate to account for the much higher neutron energies and dose levels in the first wall of fusion power reactors. Specifically, the helium generated by the 14 MeV neutrons to a much higher extent cannot easily be simulated by any other means. Therefore, FZK has been actively involved for a number of years in a study of an intense fusion-related neutron source under the umbrella of an IEA Implementing Agreement. The study has focused on the IFMIF conceptual design and ought to come to a decision on the construction of such fusion neutron source soon.

You can find a wealth of further information on the FZK web site: http://www.fzk.de/pkf. (A link to the English version is marked by the British flag).

International Fusion Research Activities of IAEA, Tom Dolan, Head Physics Section, IAEA, Vienna, Austria

The IAEA has begun a new Coordinated Research Project on "Comparison of Compact Toroid Configurations," including spherical tokamaks, spheromaks, and field reversed configurations (FRCs). The objective of this CRP is to compare various compact toroid configurations with regard to:

- plasma stability
- plasma formation and sustainment techniques
- advantages and disadvantages

including both experiments and theoretical models. The first Research Coordination Meeting, held in December 1998, specified 10 tasks for cooperative research. The report of that meeting is available from the IAEA. The countries participating are Argentina, Brazil, China, India, Israel, Italy, Japan, Russia, UK, Ukraine, and USA

The IAEA meetings planned for the rest of 1999 are shown below.

9-10 June	Vienna, Austria	International Fusion Research Council
21-23 June	Kloster Seeon, Germany	First Principle Based Transport Theory
19-21 July	Lisbon, Portugal	Control, Data Acquisition, and Remote Participation for Fusion Research (co-sponsored by the IEA)
12-17 September	Bordeaux, France	Inertial Fusion Sciences & Applications (co- sponsor)
27-29 September	Culham, UK	H-mode Physics & Transport Barriers
4-8 October	Ooarai, Japan	ECRH Physics & Technology for Fusion Devices
12-14 October	Naka, Japan	Energetic Particles in Magnetic Confinement Systems (formerly called Alpha Particle Physics)
18-20 October	Chengdu, China	Research Using Small Fusion Devices
25-29 October	Kyushu, Japan	Steady State Operation of Magnetic Fusion Devices
December	Vienna, Austria	Applications of Plasma Physics and Fusion Technologies

Production of the CD-ROM of the proceedings of the 17th IAEA Fusion Energy Conference (Yokohama, Japan, October 1998) has been delayed, because most of the electronic files submitted were not in the required form. Planning is underway for the 18th IAEA Fusion Energy Conference in Sorrento, Italy, 4-10 October 2000.

We would welcome suggestions for future IAEA activities from ANS members. The International Fusion Research Council will meet in Vienna 9-10 June to advise the IAEA about its 2001-2002 programme plan.

Calendar of Upcoming Conferences on Fusion Technology

ANS Annual Meeting
June 6-10, 1999, Boston, Massachusetts, USA
http://www.ans.org/

1999 Fusion Summer Study

July 11-23, 1999, Snowmass, Colorado, USA
http://www.pppl.gov/snowmass/

First International Conference on Inertial Fusion Sciences and Applications - IFSA (formerly LIRPP)

September 12-17, 1999, Bordeaux, France
http://lasers.llnl.gov/lasers/ifsa/

5th International Symposium on Fusion Nuclear Technology - ISFNT-5

September 19-24, 1999, Roma, Italy

http://www.isfnt5.enea.it/

9th International Conference on Fusion Reactor Materials - ICFRM-9

October 10-15 , 1999, Colorado Springs, Colorado, USA
http://www.pnl.gov/icfrm9/

18th IEEE/NPSS Symposium on Fusion Energy

October 25-29, 1999, Albuquerque, New Mexico, USA
http://www.sandia.gov/sofe99

18th IAEA Fusion Energy Conference

October 4-10, 2000, Sorrento, Italy

14th ANS Topical Meeting on Technology of Fusion Energy

October 16-20, 2000, Park City, Utah, USA
http://ev2.inel.gov/ParkCity/

ANS Winter Meeting

November 14-18, 1999, Long Beach, California, USA
http://www.ans.org/
