THERMAL HYDRAULICS DIVISION NEWSLETTER

Spring 2003

Message from the Chair

I am pleased to report that ANS Thermal Hydraulics Division continues to grow strong, thanks to its robust activities, solid technical programs, and many dedicated members.

Our Division accomplished much in the past year. Our sessions at the 2002 Summer Annual Meeting in Hollywood, Florida were well received, with the usual high-quality technical papers presented in topical areas that were deemed timely. Traditionally strong in its technical content, our Division has maintained the core activities while developing a broader scope and experimenting new ideas. New members have been added to our membership roster and some highly energetic and active members were recruited to our Division's Program Committee and Executive Committee. The composition of our Division membership is more diverse than has been for long. We helped the Student Conference by providing a financial support, and also fully complied with the ANS initiative on Professional Division Vitality Measures.

On the international front, our Division's primary topical meeting, NURETH-10, appears bound to be a highly successful conference. The meeting will be held in Seoul, Korea, October 5-10, 2003. I hope many of you will attend the meeting. For more details, refer to the report on NURETH-10 included in this newsletter, or visit the conference site at http://www.nureth10.org/

Another equally important international conference, NUTHOS-6, is at a planning stage. This conference, which attracted a large number of participants in the past, will be held in Nara, Japan, October 4-8, 2004. See the report on NUTHOS-6 included in this newsletter. The conference home page has been created at http://www.nuthos6.org/

Looking ahead, the future of our Division looks as bright as ever with our strong membership and our Division members' active participation in some innovative new research programs that are emerging around the world, such as Generation IV Program, see the articles on this program in this newsletter. The level of enthusiasm and participation in thermal hydraulic sessions and topical meetings is rising. Many dedicated members of our Division worked hard to infuse a fresh breath into our existing programs and create new ones.

We face some uncertainties, however, concerning our traditional affiliation with National Heat Transfer Conference, which for many years served as a great venue and primary vehicle for our Division members to exchange ideas, meet, interact, and network with colleagues from other professional societies for the common good of nuclear technical community. See the report on this issue in this newsletter. We will keep trying to find ways to maximize the value for our Division members.

I have benefited greatly from the ungrudging help and support from my immediate predecessors, Cetin Unal and F. Bill Cheung, and thank them for sharing their experience and wisdom with me that helped me serve you better. My appreciation is further extended to the incoming Chair, Whee G. Choe, who interacted with ANS on my behalf on matters related to the Professional Division Vitality Measures.

It's been a great honor and privilege for me to serve you.

Jong H. Kim
Chairperson (2002-2003)
Thermal Hydraulics Division

2002 ANS THD AWARDS

2002 ANS THD Technical Achievement Award was given to Professor Jean-Marc Delhaye at the ANS Annual Winter Meeting in Washington, D.C. The award carries a plaque and a check of $1,000. Professor Delhaye is an international authority on multiphase flow fundamentals, including analytical formulation, modeling, and measurement techniques. He is currently Research Professor of Mechanical Engineering at Clemson University. Before joining Clemson, he held positions as Director of Research at CEA/Grenoble, France and Professor at Ecole Centrale Paris and French National Institute for Nuclear Science and Technology. He is a Co-Founder and Co-Editor of Multiphase Science and Technology Quarterly.

THD and National Heat Transfer Conference

THD had been a co-sponsor of National Heat Transfer Conference (NHTC) for many years. NHTC is where experts in thermal hydraulics and heat transfer meet annually to discuss the latest developments in science, technology, and practice of heat transfer and thermal hydraulics. Our Division members were highly active and played key roles in NHTC and, through the process, energized our Division's technical activities. Nuclear issues being global in nature, such exchanges had been beneficial to all parties involved. This long-standing formal partnership ended when the dates of NHTC sometimes fell within one month of ANS Summer Annual Meeting in recent years, as ANS policy prohibits co-sponsoring of any other meeting that is held within one month of the ANS Annual Meetings. Thus, there are no longer sessions formally designated as ANS sessions at NHTC, so our Division members may only participate on individual basis. It may be desirable to revive the formal ties with NHTC on a continuing basis if possible. This will further vitalize our Division and broaden the scope of our activities. If you have any suggestions on this issue, please contact one of the TH Division Officers.

THD Membership

Our Division membership increased to 805 in 2002. The trend has been upward over the past few years.

Year	Number
1997	808
1998	771
1999	753
2000	770
2001	782
2002	805

THD welcomes anyone who is interested in thermal hydraulics and related areas to join the Division and participate in the Division activities. The Division activities include paper review, paper presentations, organizing and chairing technical sessions, sponsoring topical meetings, recognizing worthy candidates for honors and awards, overseeing and participating in all aspects of meetings sponsored by the Division, and supporting student conferences. If you are interested in becoming a new member of our Division or if you are currently a member and would like to participate in any of our activities, please contact any of the Division Officers.

Report on NURETH-10

Won-Pil Baek, Korea Atomic Energy Research Institute
Phone: +82 2 868-8913 E-mail: wpbaek@kaeri.re.kr

The Tenth International Topical Meeting on Nuclear Thermal Hydraulics (NURETH-10) will be held in Seoul, Korea, October 5-9, 2003. NURETH is the premier international conference of ANS Thermal Hydraulics Division. NURETH series of conferences dates back to the inauguration conference held in Saratoga Springs in 1980. Preparation for NURETH-10 is progressing very well both in terms of technical contents and local arrangements. Plenary speakers will set the tone for the conference and invited keynote speakers in technical sessions will deliver lectures on the latest developments in nuclear thermal hydraulics. Selected papers will be recommended for publication in an archival journal. Technical tours complemented with sightseeing will be arranged.

Korea is a country of very active nuclear power programs, with 18 operating nuclear units and several more units currently under construction. This aggressive national nuclear strategy spurs R&D activities including thermal hydraulics. As for the conference, Seoul in October 2003 will be an exciting place and time for nuclear engineers to meet international experts and exchange ideas as well as enjoy the city of modern and ancient under a most pleasant autumnal climate.

A total of 352 contributed summaries from 32 countries have been accepted and their full-length manuscripts will be reviewed. The countries that contributed more than 10 summaries are Korea, Japan, USA, France, Germany, Russia, and China. In addition, the Technical Program Committee is also inviting approximately 20 plenary and keynote speakers.

An exhibition on nuclear technology and R&D will be held in parallel with the conference.

The Technical Program Committee and the Organizing Committee of NURETH-10 warmly extend invitation to all ANS Thermal Hydraulics Division members to attend the conference.

For details about the conference, visit the conference website: www.nureth10.org

Report on NUTHOS-6 Planning

Hisashi Ninokata, Tokyo Institute of Technology
Phone: +81 3 5734-3056 E-mail: hninokat@nr.titech.ac.jp

NUTHOS-6, the 6th International Topical Meeting on Nuclear Reactor Thermal Hydraulics, Operation and Safety

October 4 - 8, 2004
Nara-Ken New Public Hall, Nara, JAPAN

Sponsors
Atomic Energy Society of Japan (AESJ)
American Nuclear Society (ANS) Thermal Hydraulics Division
Co-sponsors (partly to be decided)
Japan Atomic Industrial Forum (JAIF)
AESJ-THD, Nuclear Power Div, Human-Machine System Div.
International sponsors Nuclear Societies of the Pacific Rim countries, ENS, …

NUTHOS Home Page: http://www.nuthos6.org/

Invitation to ANS Thermal Hydraulics Division Members

The Organizing Committee of the Sixth International Topical Meeting on Nuclear Reactor Thermal Hydraulics, Operation and Safety (NUTHOS-6) warmly extends invitation to all ANS Thermal Hydraulics Division members to participate in this important series of international topical meeting in the fields of thermal hydraulics, operation, safety, and related areas. The NUTHOS series is rooted in its long history since 1982 primarily with support and participation from the Pacific Rim countries that have been active in designing and building new nuclear power plants such as ALWRs (ABWR, APWR, APR1400) and Liquid Metal Cooled FBR. In particular, the North-East Asia consisting of Korea, Japan and China is the region that has been pursuing nuclear option aggressively and constitutes perhaps the greatest potential market for nuclear technology and business for the foreseeable future.

In view of the global nature of nuclear issues, it is imperative that forums such as NUTHOS provide a global communication channel to enhance exchange of ideas and information and encourage cross-fertilization of research and development efforts among all nuclear countries around the world. NUTHOS-6 truly welcomes and encourages participation and support from every nuclear nation.

The NUTHOS series was given a birth in 1982 by young volunteers from the Pacific Rim countries including USA, the Republic of China (ROC), Korea and Japan. Since then it has been supported by overwhelming and enthusiastic participants from all over the world including Europe and South America. The first meeting was held in Taipei, ROC in 1982, followed by four meetings, Tokyo (Japan, 1984), Seoul (Korea, 1988), Taipei (ROC, 1994) and Beijing (People's Republic of China, 1997). Every NUTHOS conference was highly successful, with a large number of nuclear professionals participating from around the world. All the meetings have been sponsored by the nuclear society of each country. In particular, the members of ANS Thermal Hydraulics Division have played key roles in each conference.

With the new century upon us, the nuclear energy is faced with major challenges such as radioactive waste, economics, proliferation and, last but not least, safety. Buoyed by a sign of cautious optimism for the return of nuclear option in countries such as the U.S., we recognize the heightened importance of plant operation, safety, and thermal hydraulics that must support safe operation of nuclear plants. With the introduction of evolutionary and revolutionary concepts of reactor designs around the globe, including the so-called Generation IV Nuclear Energy Systems, multilateral R&D opportunities are being explored in the areas of thermal-hydraulics, operation, and safety.

This will be the second NUTHOS meeting in Japan. The major sponsor of the conference is the Atomic Energy Society of Japan, supported by thermal hydraulics division of nuclear society of each Pacific Rim country. This time the conference city is Nara, an ancient capital of Japan before Kyoto took its position, from 710 to 784. It is one of the cities in Japan that can provide a perfect academic environment for international conferences as well as offer an ideal setting for tourists. It is abundant of well-preserved historical sites, shrines and temples containing national treasures, surrounded by beautiful nature. The city is easily accessible from every corner of the world by international flights.

The NUTHOS has been a very successful and popular series of conferences, a forum that originally aimed at closer contacts for the Pacific Rim countries but eventually brought experts from all over the world to the exciting destinations. It has a long history dating back to Taipei, ROC Taiwan, 1982, and since then has been held in Japan, Korea, Taipei and Beijing in sequence.

NUTHOS has served for international nuclear society as an open forum where high-quality and up-to-date information is actively discussed and exchanged among world-class experts. Now NUTHOS-6 will bring together all the experts, together with new information and research results from all over the world. It is our utmost pleasure to welcome you to this significant international conference.

Call for Abstracts

Prospective authors are invited to submit abstracts of not more than 500 words to the technical program committee for review.

Preliminary Topics

- Fundamentals of Thermal Hydraulics, Single- and Two Phase Flow and Heat Transfer
- Mathematical and Computational Method, Theory and Validation
- CFD Applications
- Subchannel Analysis
- Thermal Hydraulics and Safety of Advanced Reactor
- Plant Transients and Accidents Analysis and Testing
- Severe Accidents and Degraded Core Thermal Hydraulics
- Accident Management
- Steam Generator Thermal-Hydraulics
- Thermal Hydraulic Loads and Flow-Induced Vibration
- Containment Analysis and Experiment
- Advances in Measurements and Instrumentations
- Load Follow Strategies
- Thermal Hydraulics of Plant Power Uprating
- Thermal Hydraulics of Waste Management
- Design and Behavior of Spent Fuel Repository
- Plant Operation, Retrofitting, and Maintenance Experiences
- Plant Diagnostics and Monitoring
- Application of Innovative Technology: AI, Expert Systems, Robotics, and Others
- Plant Licensing Renewal and Life Extension
- In-Core Fuel Management
- Steam Generator Operation and Maintenance
- Plant Simulators, Analyzers, Operator Training
- Design Code and Standard
- PRA Applications to Design, Operation and Maintenance
- Risk-Informed and Performance Based Regulation
- Current Topics

Important Schedule and Deadlines

Sep. 1 - Oct. 15, 2003	Submission of Summaries
Nov. 30, 2003	Notification to Authors of Abstracts Acceptai
Jan. 31, 2004	Full Manuscripts for Review Deadline
Aug. 31, 2004	Early Bird Registration

Organizers

General Chairs	Dr. M. Akiyama (IAE) Prof. N.E. Todreas (MIT)
Organizing Committee Chairs	Prof. H. Ninokata (TITECH) Prof. J.H. Kim (EPRIww/KAIST)
Technical Program Committee Chairs	Prof. H. Yoshikawa (Kyoto U) Prof. S. H. Chang (KAIST)

More information is available, which will be updated, at the following conference web site: http://www.nuthos6.org/

Generation IV Nuclear Energy Systems Initiative

Implementation of the Generation IV Nuclear Energy Systems Program is underway. It is based on (1) the long-term outlook for nuclear energy in the United States, (2) the advice of the Nuclear Energy Research Advisory Committee during the two-year development of the Generation IV Technology Roadmap, and (3) the need for the Generation IV Program to be integrated with other nuclear energy programs of the Department. Considerable emphasis is given to developing the priorities and necessary timelines for the U.S. Generation IV Program, as well as developing international R&D cooperation that will benefit the program and strengthen U.S. leadership in commercial nuclear technology.
Historical Context: From the early beginnings of nuclear energy in the 1940s to the present, the United States has led the development of three generations of nuclear energy. The first three generations of nuclear energy have been successful in the following ways: (a) Nuclear energy supplies a significant share of electricity for today's needs—over 20% of U.S. and 16% of world demand. (b) Nuclear energy plays a large role in the U.S. economy. In 2002, the 103 operating U.S. nuclear power plants generated 790 billion kilowatt-hours of electricity, valued at $50 billion. (c) Through the use of nuclear energy, the United States has avoided over three billion tons of air emissions since 1970. (d) U.S. nuclear plants are highly reliable and in 2001 produced electricity for 1.68 cents per kilowatt-hour on average. This low cost is second only to hydroelectric power among baseload generation options. (e) In return for access to peaceful nuclear technology, over 180 countries have signed the Non-Proliferation Treaty to help ensure that peaceful nuclear activities will not be diverted to making nuclear weapons.

Although nearly all U.S. light water reactors are expected to file for 20-year license extensions, it is clear that new nuclear energy systems need to address issues of safety, economics, waste, and proliferation resistance with a robust research and development (R&D) program. Advances in all of these areas can contribute to increasing the sustainability of nuclear energy.

Energy Demand Outlook: The outlook for energy demand in the United States underscores the need to increase the share of nuclear energy production. The *2003 Annual Energy Outlook* projects an annual growth rate of 1.5% in total energy consumption to the year 2025. At the same time, domestic energy production will grow only 0.9% per year, creating a widening gap to be filled by energy imports. Further, most of the projected domestic energy production increase is to be provided by coal and natural gas. Thus, the outlook implies an increasing burden from carbon emissions with the potential for long-term consequences from global climate change, as well as an increasing dependence on foreign energy sources. These create a strong motivation for seeking to increase the share of nuclear-generated electricity above its current 20% level.

The outlook for energy demand within the major sectors of energy use other than electricity also points out an emerging role for nuclear energy in hydrogen production. *Energy Outlook* projects an annual growth of 2.0% per year for the transportation sector, while the electricity and heating sectors will grow at 1.4% and 1.2%, respectively. Transportation is almost exclusively dependent on petroleum. This dependence has caused fluctuations in fuel prices of 30% and several 'energy shocks' since the 1970s. This volatility creates a significant need for seeking to diversify with new fuels, such as hydrogen for use in emissions-free fuel cells that power electric vehicles. President Bush has recently announced the FreedomCAR and Hydrogen Fuel Initiatives to make a fundamental difference in this situation through the development of hydrogen-powered cars and clean fuel sources. Large-scale production of hydrogen by nuclear energy would be free of greenhouse gas emissions. To achieve these benefits, new nuclear energy systems that are specialized for hydrogen production at competitive prices need to be developed.

Thus, in addition to short-term nuclear deployment, two long-term technology development objectives for nuclear energy in the U.S. are derived from the needs identified above: (1) Develop advanced nuclear energy systems that can address the barriers to growth and significantly increase the share of nuclear electric generation while increasing their sustainability in the long term, and (2) Develop systems for nuclear-assisted hydrogen that can diversify the energy supply for the transportation sector and reduce the dependence on petroleum.

***Generation IV International Forum**:* Beginning in January 2000, ten countries joined together to form the Generation IV International Forum (GIF[1]) to develop future-generation nuclear energy systems that can be licensed, constructed, and operated to provide competitively priced and reliable energy products while satisfactorily addressing nuclear safety, waste, proliferation, and public perception concerns. The overarching objective for these new nuclear energy systems—known as Generation IV—is to have them available for international deployment before the year 2030.

***The Roadmap**:* From its beginning, the GIF discussed the R&D necessary to support next-generation nuclear energy systems. From those discussions a technology roadmap to guide the Generation IV effort began and was completed in two years with the participation of over 100 experts from the GIF countries. The effort ended in December 2002 with issue of the final Generation IV Technology Roadmap.[2] Especially noteworthy was the recognition gained by the U.S. by leading the formation of the GIF and the development of the technology roadmap. This has helped to strengthen U.S. leadership in the peaceful uses of nuclear energy and to underscore the importance of collaborative R&D on future nuclear energy systems.

The roadmap evaluated over 100 future systems proposed by researchers around the world. The scope of the R&D described in the roadmap covers the six most promising Generation IV systems. It is important to note that each GIF country will focus on those systems and the subset of R&D activities that are of greatest interest to them. Thus, the roadmap provides a foundation for formulating national and international program plans on which the GIF countries will collaborate to advance Generation IV systems.

***Most Promising Systems**:* The roadmap identified six most promising systems. Two employ a thermal neutron spectrum with coolants and temperatures that enable hydrogen or electricity production with high efficiency (the Supercritical Water Reactor—SCWR and the Very High Temperature Reactor—VHTR). Three employ a fast neutron spectrum to enable more effective management of actinides through recycling of most components in the discharged fuel (the Gas-cooled Fast Reactor—GFR, the Lead-cooled Fast Reactor—LFR, and the Sodium-cooled Fast Reactor—SFR). The Molten Salt Reactor (MSR) employs a circulating liquid fuel mixture that offers considerable flexibility for recycling actinides, and may provide an alternative to accelerator-driven systems.

Priorities for the Generation IV Program: For each of the six systems above, the roadmap develops the R&D needs in considerable detail and highlights the major R&D issues, benefits, and risks. The specific R&D issues and risks, identified in the roadmap and also identified by the NERAC Subcommittee on Generation IV Technology R&D Planning, had a strong bearing on the prioritization of the systems versus the U.S. needs and technology objectives discussed above. From these studies and interactions, the following two principal priorities emerged:

Priority 1: Develop a VHTR to achieve economically competitive hydrogen production in the midterm. The highest priority on developing a capability for nuclear-assisted hydrogen with the VHTR reflects the excellent potential for this system to provide a major competitive advance toward the long-standing need to diversify the energy supply of the U.S. transportation sector. Successful development of an economically competitive nuclear-assisted hydrogen supply will be the focus of an initiative by the Office of Nuclear Energy, Science and Technology to deploy a VHTR by 2017 that is dedicated to hydrogen production research and demonstration. To begin the effort, a nuclear hydrogen roadmap will be completed in FY 2003.

The initiative is projected to be able to complete its key R&D by about 2012. This is partially enabled by many prior developments in high-temperature gas-cooled reactors internationally. As a result, completion and startup of a demonstration VHTR may be possible by 2017. This would be the earliest Generation IV system in the United States.

The development of a VHTR would have a number of associated benefits including the establishment of a basis for development of a fast-spectrum gas reactor discussed in the next priority.

Priority 2: Develop a fast reactor to achieve significant advances in sustainability for the long term. The high priority on fast reactors reflects their good potential to make significant gains in reducing the volume and radiotoxicity and increasing the manageability of spent nuclear fuel wastes. The advances may be able to avoid a second geological repository. Fast reactors also hold the potential for extending the useful energy yield of the world's finite uranium supply many-fold in the very long term. The chief issues in the development of a next-generation fast-spectrum reactor for use in the United States are its economic competitiveness and management of the overall risks to workers and the public from the deployment of a closed fuel cycle.

Three of the most promising Generation IV systems are fast-spectrum (the GFR, LFR, SFR) for enhanced sustainability, and one (the MSR) employs a reactor specialized for actinide destruction. Among these four, the initial sense of priority is that the GFR should be given the most emphasis in order to resolve its issues and uncertainties, since fast gas reactors have not been fully demonstrated. The SFR is already at a fairly advanced state of development, and some technologies for the LFR have been demonstrated internationally. All of these systems should be brought to a state where a downselection on economics, safety and reliability, sustainability, and proliferation resistance and physical protection can be undertaken. Finally, the MSR should be studied with a lower priority, given the system's uncertainties and development needs.

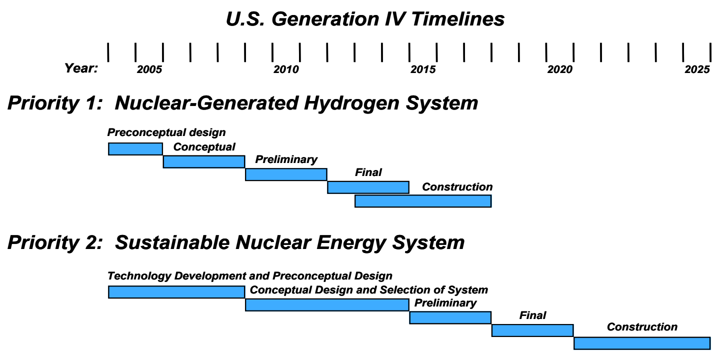
[1] Argentina, Brazil, Canada, France, Japan, the Republic of Korea, the Republic of South Africa, Switzerland, the United Kingdom, and the United States currently constitute the GIF. New members can be added by a process outlined in the GIF charter.

[2] "A Technology Roadmap for Generation IV Nuclear Energy Systems," Generation IV International Forum, GIF-002-00, December 2002, available at http://www.inel.gov/initiatives/generation.shtml, accessed February 2003.

The ultimate selection of the most promising system will likely be driven by fuel cycle decisions that will follow from the Advanced Fuel Cycle Initiative as well as the development of an effective fast transmutation system

The most direct influence of these priorities for the U.S. Generation IV Program is in the allocation of R&D resources between the systems in the program plan. An additional area of R&D is the crosscutting research needed by these systems. Arising from the common need for advances against challenging requirements on fuels and materials, fuel cycle technology, and system design to achieve highly safe and reliable systems, these crosscut areas are given the most emphasis. Energy conversion technology is another important need also highlighted in the program plan. Specific yet limited activities are found in other crosscutting areas that are not as directly involved in the feasibility of the priority systems.

Timeframes for the Generation IV Systems: Proposed timelines for the two priorities are shown in the figure below. For the development of a VHTR in Priority 1, a 15-year timeline is to be implemented. This balances the benefit of demonstrating a large-scale economically competitive nuclear hydrogen system with the technical issues and risks establishing an aggressive schedule for its development. Note that key R&D will require about 5 years, followed by a 10-year demonstration phase.



For the development of a fast-spectrum reactor in Priority 2, a 20–25-year timeline is to be implemented. This fits with the expected future need for radiotoxicity reduction and closure of the U.S. nuclear fuel cycle, and allows the progression of several most promising candidates to a downselection in about a decade, followed by a demonstration of all elements of a closed fuel cycle within about a decade thereafter.

The above article was contributed by INEEL.

Generation IV Activities at the INEEL

Chang H. Oh, INEEL, Idaho Falls
Phone: (208) 526-7716 E-mail: CHH@inel.gov

As the Earth's population grows from about 6 billion people to 10 billion people by the year 2050, we will face more challenges from increasing demand for energy. For the Earth to support its population, we must increase the use of energy supplies that are clean, safe, and cost-effective. Population and industrial growth both nationally and internationally are taxing the available energy resources. Climate change and air quality are putting pressure on fossil fuel-based energy generation. Almost overlooked but sitting in our own backyard, nuclear power has the potential to help solve some of this century's energy problems.

The ten Generation IV International Forum (GIF) countries have recently selected six concepts to develop in order to meet the technology goals for new nuclear systems. As the US Department of Energy's designated nuclear energy laboratory, scientists at the Idaho National Engineering and Environmental Laboratory (INEEL) started working on the next generation reactors called Very High Temperature Gas-Cooled Reactors (VHTR), which are primarily envisioned for missions in hydrogen production and other process-heat application with a possibility of electricity generation as well. The VHTR is a graphite-moderated, helium-cooled reactor with a once-through uranium fuel cycle based on a 600 MWth core connected to an intermediate heat exchanger to deliver process heat. The VHTR offers a broad range of process heat applications and an option for high-efficiency electricity production, while retaining the desirable safety characteristics offered by modular high-temperature gas-cooled reactors (HTGR). Fig. 1 illustrates the conceptual design of the VHTR.

The technical challenges of the VHTR are design, safety, analysis tools, fuel development, material and components, hydrogen production, and high performance helium turbines. To address some of the technical issues, INEEL team has joined researchers at the University of Michigan, Korea Advanced Institute of Science & Technology, and Seoul National University, to analyze design safety, to develop improvements to an existing system code for analyzing hypothesized accident scenarios, and to perform code verification and validation using data in literature and/or data to be collected as part of US-Korea International Nuclear Engineering Research Initiative.

Another INEEL team works on an HTGR project. This project involves development of a supercritical carbon dioxide Brayton cycle for the HTGR, improvement of the plant efficiency, and testing of material compatibility at high temperatures and pressures. Still other INEEL teams work on the Gas-Cooled Fast Reactor, Supercritical Water Reactor, and Very High Temperature Gas-Cooled Reactor, respectively.

Recent news announced by Idaho Senator Larry Craig and the Chair of the Senate Energy Committee, Senator Peter Domenici, indicated that they would authorize $1 billion to build a gas-cooled type Gen-IV reactor at the INEEL site by the year 2010. They said that the INEEL would be the lead DOE laboratory along with Argonne National Laboratory for all stages of the project.

Generation IV nuclear energy systems follow three other distinct periods of reactor development. Generation I experimental reactors were developed in the 1950s and 1960s. Generation II large, central-station nuclear power reactors, such as the 103 plants still operating in the United States, were built in the 1970s and 1980s. Generation III advanced light-water reactors were built in the 1990s primarily in East Asia to meet that region's expanding electricity needs. More detailed information can be found at http://gif.inel.gov/roadmap/.

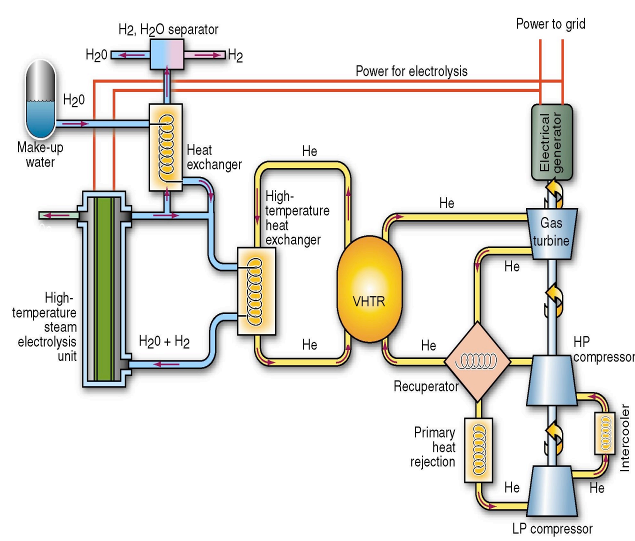


Figure 1. The conceptual design of the VHTR

In-Vessel Retention Strategy for Advanced Reactors

F. B. Cheung, Pennsylvania State University
Phone: (814) 863-4261 E-mail: fxc4@psu.edu

Nuclear reactors are designed to produce clean energy and operate safely throughout the lifetime of the reactor. Nevertheless, under certain adverse circumstances, severe accidents could occur in nuclear reactors although the probability for such occurrence is extremely low. To assure public safety, the issue of severe accident management (SAM) needs to be addressed seriously. One key SAM strategy that has been adopted by some operating nuclear power plants and advanced light water reactors (ALWRs) is the so-called in-vessel retention (IVR). If there were inadequate cooling during a severe accident, a significant amount of core material (i.e., corium) could become molten and relocate to the bottom head of the reactor pressure vessel (RPV), as happened in the Three Mile Island Unit 2 (TMI-2) accident. The concept of IVR is to provide adequate cooling of the lower head (by use of in-vessel core catcher and/or flooding of the reactor cavity) to maintain the vessel integrity such that relocated corium could be retained within the vessel. If IVR is demonstrated to be feasible in ALWRs, then the enhanced safety associated with these plants can reduce concerns about containment failure and associated risk. For example, the enhanced safety of the Westinghouse Advanced 600 MWe PWR (AP600), which relied upon external reactor vessel cooling (ERVC) for IVR, has resulted in the NRC's approval of the design without requiring certain conventional features common to existing LWRs.

One viable means for IVR is the use of core catcher for internal cooling of RPV under severe accident conditions. This can be done by installing an in-vessel core catcher on the interior side of the reactor lower head that forms an engineered gap between the core catcher and the inner surface of the lower head. One major function of the in-vessel core catcher is to retain relocated corium and to assure rapid quenching of corium within the lower head. Another major function of the in-vessel core catcher is to remove (as well as dilute) the decay heat from the corium by heat transfer through the lower surface of the core catcher via narrow gap cooling. To assure the viability of the core catcher, however, its configuration, size and materials need to be carefully selected to meet certain design and performance criteria. For example, the core catcher should be mechanically and thermally strong enough to withstand and contain the relocating corium. It should provide long-term coolability via narrow gap cooling and be relatively inexpensive, easily installed, maintained and structurally stable for the reactor's lifetime. It should not adversely affect reactor performance or coolant circulation nor should it result in recriticality of relocated corium, promote steam explosion, or present a seismic hazard. To meet all these criteria, detailed studies on the flow, thermal, and structural behavior of the system as well as the material interactions need to be done in designing such an in-vessel core catcher for enhancing IVR.

Another viable means for IVR is the method of ERVC by flooding of the reactor cavity during a severe accident. Design features of most ALWRs include provision for substantial water accumulation within the containment during postulated accident sequences. With water covering the lower external surfaces of the RPV, decay heat could be removed from relocated corium through the vessel wall by downward facing boiling on the vessel outer surface. As long as the wall heat flux from corium does not exceed the critical heat flux on the vessel outer surface, nucleate boiling would be the prevailing regime. In that case, the vessel outer surface temperature could be maintained near the saturation temperature of water such that the reactor vessel could be sufficiently cooled to maintain the integrity of the RPV. For many operating reactors and ALWRs, however, the reactor vessel is surrounded by a thermal insulation structure that forms an annular flow channel with the reactor vessel. Because of the geometrical difference between the insulation structure and the reactor lower head, there is a bottleneck present at the minimum gap location. At high heat flux levels, a large amount of vapor masses would be generated at very high rates on the vessel outer surface that could choke the steam venting process through the bottleneck. Once choking occurs, steam would no longer be able to vent through the annular channel and the channel below the minimum gap position would be completely occupied by vapor masses. The water ingression process would cease and there would be no supply of liquid water from the flooded cavity. Premature dryout would occur on the vessel outer surface and the wall temperature would rise that could severely jeopardize the integrity of the reactor vessel.

The heat flux level beyond which choking would occur at the bottleneck near the minimum gap location as a result of excessive steam generation on the vessel outer surface, is defined as the choking limit for steam venting (CLSV). During ERVC in a flood cavity under severe accident conditions, dryout of the vessel outer surface would occur if either the CLSV or the CHF limit were exceeded. It follows that the viability of ERVC as a means of IVR is limited by the lower value of these two factors. If the CLSV is smaller than the CHF limit, then the limiting factor for ERVC is the choking limit for steam venting. On the other hand, if the CLSV is higher than the CHF limit, then the limiting factor for ERVC is the critical heat flux. Only in the latter case that it is meaningful to assess the feasibility of IVR by use of the concept of thermal margin defined in terms of the CHF limit and the wall heat flux from the corium. It should be noted that the CLSV and the CHF are two distinctly different limiting factors. Whereas the CHF depends primarily on the hydrodynamic stability of the downward facing boiling process on the vessel outer surface, the CLSV depends largely on the steam venting rate and the bottleneck configuration of the annular channel. To enhance ERVC, therefore, it is necessary to increase not only the CHF limit but also the CLSV. A higher CHF limit could possibly be achieved either by applying an appropriate surface coating on the vessel outer surface to promote downward facing boiling or by use of an enhanced vessel/insulation design to promote steam venting. On the other hand, the CLSV could be increased only by use of an enhanced vessel/insulation configuration that facilitates the steam venting process. Figure 1 shows the proposed methods to improve margins for ERVC whereas Fig. 2 shows the proposed method for selecting suitable vessel coatings. An illustration of how the vessel coating works is depicted in Fig. 3 using metallic porous layer coatings as an example.

Although ERVC appears to be a viable means for IVR, it is not clear that ERVC without additional enhancements could provide sufficient cooling for high-power reactors (up to 1500 MWe). If the local CHF limits are not sufficiently high to provide adequate margin for ERVC or if the vessel/insulation configuration is such that the CLSV would be exceeded, the integrity of RPV could be challenged under severe accident conditions. To enhance public acceptance for the peaceful use of nuclear energy, it is important to demonstrate the viability of IVR should the unlikely event of core meltdown occur in a nuclear power plant. Evidently, research activities in the IVR area should be strongly encouraged, particularly those aimed at developing innovative heat transfer enhancement techniques for long-term in-vessel cooling and retention of corium in high-power reactors.

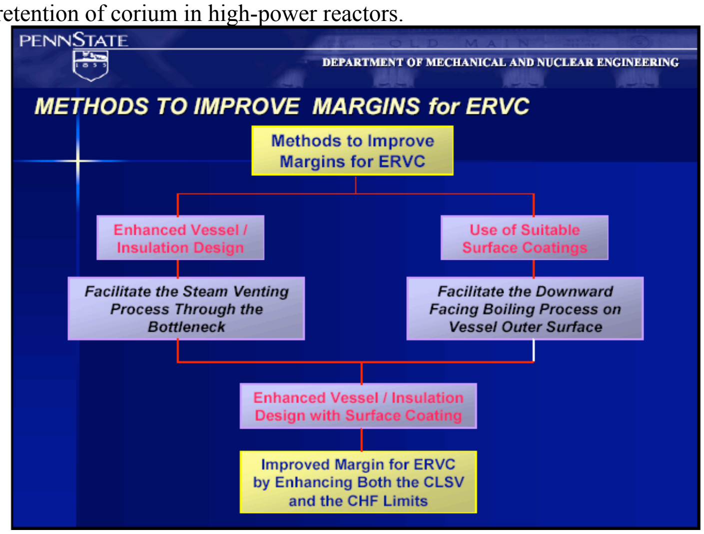


Figure 1. Methods to Improve Margins for ERVC

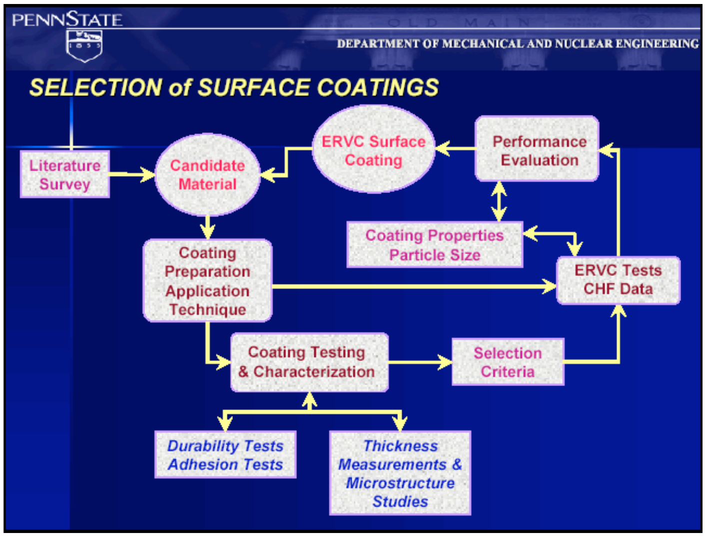


Figure 2. Method for Selecting Suitable Vessel Coatings

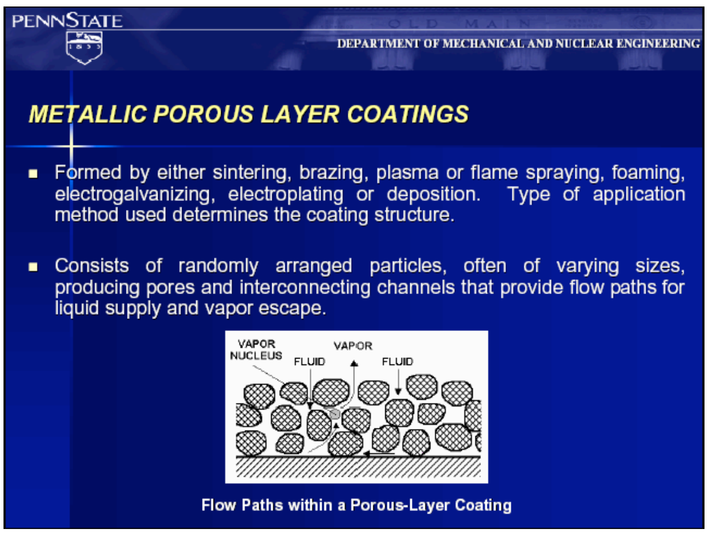


Figure 3. Metallic Porous Layer Coatings

Results of ANS Thermal Hydraulics Division Elections

The results of the recent ANS elections are in. We have the following new Division Officers and Executive Committee members.

Division Chair: Whee G. Choe, whee.choe@txu.com

Vice Chair/Chair Elect: Yassin Hassan, hassan@cedar.ne.tamu.edu

Treasurer: Joy Rempe, YOJ@inel.gov

Secretary: Robert Martin, robert_martin@nfuel.com

Executive Committee (3 year term):
David Bessette, deb@nrc.gov
Martin Bertodano, bertodan@ecn.purdue.edu
Cetin Unal, cu@lanl.gov

2002-2003 TH Division Officers

Chair: Jong H. Kim

Vice Chair: Whee G. Choe

Secretary: Shripad Revankar

Treasurer: Jovica Riznic

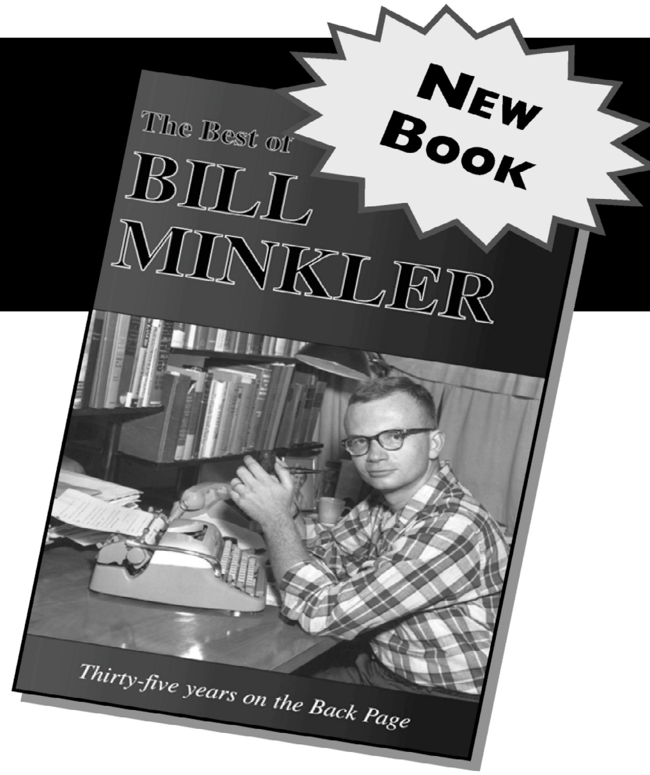
Executive Committee Members:

Jong H. Kim (2003)	Jovica Riznic (2003)
Shripad Revankar (2003)	Mamoru Ishii (2004)
Larry Hochreiter (2004)	Yassin Hassan (2004)
Joy Rempe (2005)	Whee G. Choe (2005)
Per Peterson (2005)	

Committee Chairs:
Program Committee - Martin Bertodano
Honors and Awards Committee – Jose Reyes
Nominating Committee – Fan-Bill Cheung
Membership Committee – Tom Larson

The Best of Bill Minkler

Thirty-five years on the Back Page



Bill Minkler's columns at the back of *Nuclear News* are always a treat. Now a new book collects the best of the columns that have appeared over the past 35 years.

This American Nuclear Society publication gives you the choice columns about the humorous happenings in the fictional town of Blightsburg, from the Beta Bar to Nuke University.

The humor—the fun—in Minkler's columns can be appreciated without your being a nuclear engineer. In fact, you don't need to be into science at all to enjoy these columns.

So, the book makes a great gift for yourself—or for someone else.

Each copy costs just $20; ANS members receive a 10% discount. (Add $5 for shipping to U.S. addresses; $10 for elsewhere.)

276 pages, soft cover. ANS order number: 690057
American Nuclear Society, 555 N. Kensington Ave., La Grange Park, IL 60526
Phone: 708/579-8210; Fax: 708/579-8314; e-mail: orders@ans.org

A publication of the
American Nuclear Society

American Nuclear Society
555 N. Kensington Avenue
La Grange Park, IL 60526

Address Service Requested

Nonprofit
U.S. Postage
PAID
Hinsdale, IL 60521
Permit No. 139