POLICY ISSUE
(Notation Vote)

January 8, 2009 SECY-09-0006

FOR: The Commissioners

FROM: R. W. Borchardt
Executive Director for Operations

SUBJECT: CRITICAL RESEARCH FACILITIES FOR SEVERE ACCIDENT RESEARCH AT LIGHT WATER AND ADVANCED REACTORS

PURPOSE:

The purpose of this paper is to provide recommendations to the Commission about critical research facilities, both domestic and international, that will be needed for future research on severe accidents at light water and advanced reactors and the appropriate level of U.S. Nuclear Regulatory Commission (NRC) involvement in those facilities as specified in Staff Requirements Memorandum (M080317B). This paper does not address any new commitments or resource implications.

SUMMARY:

NRC has a large number of bilateral and multilateral agreements for the exchange of nuclear safety information within the international community. NRC also participates in the Organisation for Economic Cooperation and Development's (OECD's) Nuclear Energy Agency (NEA) and several of its subgroups in planning for the worldwide availability of experimental facilities. The NRC has cooperated with the domestic organizations in gathering experimental data important to nuclear safety. The staff's review of severe accident research facilities to identify those that are critical to maintain revealed that very few are necessary to maintain for the long term. The NRC may need to continue participation with a few of those research facilities beyond the present program. The staff recommends that the Office of Nuclear Regulatory Research (RES) continue to negotiate bilateral and multilateral agreements for light water reactor experimental programs as discussed below.

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The staff is currently working to identify high-temperature gas reactor (HTGR) severe accident programs through the OECD Task on Advanced Reactor Experimental Facilities (TAREF) program. Finally, the staff notes that the industry is responsible for providing the experimental data necessary to support the safe design, maintenance, and operation of nuclear power plants. Were any data to be identified as important to a safety evaluation for an existing or future plant, the industry would be required to provide that information, and the staff would determine the need to perform confirmatory research, potentially through a collaborative program.

BACKGROUND:

The potential risk to the public from nuclear power generation arises from low-frequency accidents that are predicted to progress to the point where fuel degradation occurs and large quantities of radioactive material are released to the environment. It is important to NRC's mission that it possess expertise in severe accident phenomenology and a predictive capability for simulating the response of nuclear power systems to postulated severe accidents. Maintaining expertise in severe accident phenomena to help meet the needs of the agency supports continuing some level of severe accident research, even absent specific, immediate, regulatory questions.

NRC has been conducting research on severe accidents for the existing light-water reactors for decades and has used the results to inform and improve nuclear power plant risk assessments and to improve regulations that in part stem from consideration of severe accidents. In the specific area of severe accident risk, research results have been used to refine estimates of power plant risk, such as from previously postulated early containment failure mechanisms (large-scale steam explosions that fail containment, direct containment heating, and, for large-dry containments, hydrogen combustion), showing that these phenomena pose no significant contribution to early containment failure and risk. Moreover, research results are being used to estimate the offsite consequences of selected severe reactor accidents (State-of-the-Art Reactor Consequence Assessment project). Severe accident research has also been used in the regulatory framework of design basis events, such as in the development of the alternate source term (NUREG-1465, "Accident Source Terms for Light-Water Nuclear Power Plants," February 1995), and to support development of risk-informed regulations, Part 50.44 of Title 10 of the Code of Federal Regulations, "Combustible gas control for nuclear power reactors." Currently, severe accident analysis methods are being applied to spent fuel pool heat removal and to analyses of the dose contribution from boiling-water reactor (BWR) Main Steam Isolation Valve leakage. Severe accident information also is regularly used in risk-informed decisions that use Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis"; cost-benefit analyses; evaluation of new generic issues; and risk-informed prioritizations. Moreover, the information has been used in license renewal applications and in new reactor licensing in evaluation of design features to prevent and mitigate severe accidents.

The regulatory framework has benefitted from the agency's severe accident research program, and the staff continuously evaluates the availability of severe accident research facilities to ensure that the agency's research needs are met. Participation in international cooperative programs is an effective means of maintaining access to such facilities. NRC uses seven criteria to guide the decisions about participation in international cooperative programs. Those criteria were provided to the Commission on December 7, 2007 ("Criteria for Selecting International Projects for Cooperation and Participation," Agencywide Documents Access

and Management System ML073300235). The staff has used these criteria to evaluate participation in the programs discussed below. In addition, the staff has considered the results of international reviews of the issue of world-wide availability of experimental facilities for research in areas of importance to the nuclear power industry and concluded that the international views are not materially different from its own. In 2002, OECD's Committee on the Safety of Nuclear Installations (CSNI) established a senior group of experts on nuclear safety research (SESAR) to assess the need for and strategy of maintaining key research facilities. In 2007, OECD published the outcome of the SESAR review in "Nuclear Safety Research in OECD Countries: Supporting Facilities for Existing and Advanced Reactors" (SFEAR). The staff participated in these activities and considered their findings in the staff's evaluation of critical facilities.

In addition to its relationship with OECD, NRC has bilateral agreements with many countries. One group of bilateral agreements is organized into the Cooperative Severe Accident Research Program (CSARP). The participating countries receive NRC's severe accident code, MELCOR, and offsite consequence code, MELCOR Accident Consequence Code System (MACCS2) and, in exchange, NRC receives in-kind research in addition to support for code modifications. Through some of the CSARP agreements, the NRC receives access to experimental facilities and data.

NRC also cooperates with domestic organizations and has signed a Memorandum of Understanding (MOU) with the Electric Power Research Institute (EPRI), which has in the past enabled EPRI and NRC to share planning and execution of experimental programs. Recently, EPRI and NRC have cooperated on experimental programs such as fuel performance, fire, and nondestructive examination. The MOU recognizes the need for NRC to maintain its regulatory independence; this has been and will be accomplished by separate interpretation of the results or implications of the data derived from the cooperative research programs. Although the present program with EPRI does not include severe accident research, the program may be a model for industry-regulatory authority cooperation. Lastly, NRC has recently signed an MOU with the U.S. Department of Energy (DOE) covering NRC's participation in the Next Generation Nuclear Plant project. The MOU provides for the NRC's review of DOE's plans in numerous technical areas and for "observation of tests, experiments, simulations, and demonstrations" related to those areas.

DISCUSSION:

RES continuously evaluates its research programs to ensure they are meeting the needs of the agency. These evaluations include consultation with the regulatory offices to help determine the need for confirmatory research on current issues under review as well as consultation with the domestic and international community to identify opportunities for collaboration. RES also considers facility availability in its evaluations.

RES has found the CSNI SFEAR report to be of use when considering severe accident facility availability. The report recommends that the CSNI and the Committee on Nuclear Regulatory Activities (CNRA) encourage nuclear industry support of infrastructure preservation by emphasizing: 1) the responsibility of industry to develop sufficient data to support their applications, 2) the benefits of cooperative research, and 3) the value of preserving critical research infrastructure. The factors the SESAR group cites as being important to the ability to maintain critical infrastructure include the facility operating and replacement cost, the ability to

define a useful experimental program, the long-term resource implications and priorities, the industry participation, and the host country's long-term plans and commitments. NRC maintains membership in numerous CSNI and CNRA committees and groups and could be influential in the efforts to maintain nuclear industry-unique facilities worldwide, if those facilities were to be important to NRC activities. The NRC staff uses the seven criteria discussed previously when evaluating participation in such cooperative programs.

The SFEAR report provides light- and heavy-water-related facility evaluations. At the time the document was written, no CSNI recommendations for HTGR facilities were deemed warranted because of the early stage of design development. The SFEAR report contains a discussion of HTGR issues, based in part on a 1999 OECD conference on "Survey on Basic Studies in the Field of High Temperature Engineering," and in part on a 2002 workshop documented in "Advanced Nuclear Reactor Safety Issues and Research Needs." The scope of the workshop included advanced light water reactors and liquid metal reactors, in addition to HTGRs. A new CSNI working group, called TAREF, was formed recently to address HTGR facility issues. RES is a participant in this effort.

The SFEAR report identifies the PHEBUS experimental facility in France as a facility of high importance to severe accident research. Recently, because of its high cost, the Institut de Radioprotection et de Sûreté Nucléaire decided to shut down PHEBUS. Some of its activities could be conducted elsewhere in test reactors in the United States, Japan, or Norway, or in the future, in France. As the results from the PHEBUS program are analyzed, NRC expects to receive additional information on ruthenium behavior that will be of use in the phase behavior that will be of importance for reactor accident source term estimation as well as for spent fuel pool accident source terms.

RES evaluated its present programs in severe accident research and has identified nine facilities that today substantially contribute to severe accident programs for light-water reactor technology (the staff is in the process of reviewing facilities important to advanced reactor technologies). Each program is briefly described below. Some are important to retain for the NRC's long-term program and others will be reevaluated for long-term support at the end of the current program.

The following provides the programs likely to require long-term support, the host country, and the program through which NRC participates:

- VERDON, France, is a bilateral agreement through the International Source Term Program (ISTP), and studies the fission product behavior in containment. This experimental facility will provide data to validate fission product release models under steam/hydrogen mixture or air-ingress conditions.

- Two facilities, KROTOS, France, and Test for Real cOrium Interaction (TROI), Korea, are part of the OECD's Steam Explosion Resolution for Nuclear Applications (SERENA) program. SERENA is quantifying the effects of voiding on ex-vessel steam explosion potential and energetics to bound the calculated pressure-time history and loads on structures. These facilities can also support experimental programs on fuel-coolant interaction. The need to maintain two facilities will be reevaluated at the end of SERENA, but it is likely that support for at least one will continue.

The facilities for which the long-term support will be evaluated at the completion of the present program are:

- AeRosol Trapping In a STeam Generator (ARTIST), Switzerland, is a bilateral agreement, involving studies of aerosol behavior in the secondary side of a steam generator and separate effects in piping. Results from the current research will allow NRC to improve source term bypass models and evaluate fission product resuspension.

- QUENCH, Germany, is a bilateral agreement through CSARP, which studies the effectiveness of core melt prevention scenarios. This research will provide data to evaluate success criteria in severe accident analyses under over-heated fuel conditions.

- Experimental Programme of Iodine Chemistry Under Radiation (EPICUR), France, is a bilateral agreement through ISTP, which studies iodine behavior in containment. This research will address uncertainties related to iodine interactions with paints and the need for pH control in the containment sump.

- CHemistry of Iodine Project (CHIP), France, is a bilateral agreement through ISTP, which studies iodine chemistry in the reactor coolant system. This program is evaluating the potential for release of gaseous iodine into the containment, for instance from revaporization from surfaces.

- Behavior of Iodine Project (BIP), Canada, is a bilateral agreement through OECD, which studies iodine behavior. This research will quantify various processes on surfaces leading to gaseous iodine formation; measure adsorption/desorption rate constants on containment surfaces as a function of temperature, relative humidity, and carrier-gas composition in humid environments; and measure absorption of iodine on sump materials.

- Melt Coolability and Concrete Interaction (MCCI), United States, is an OECD program hosted by the NRC, which studies ex-vessel core-concrete interactions using prototypic materials in a large scale facility. The program is acquiring data to improve our understanding of certain phenomena and to support model development for special mitigation features intended to protect the bottom-cooled basemats of the European Pressurized Reactor and the Economic Simplified Boiling Water Reactor.

The NRC does not have active programs at any of the three following facilities, but they may become more important in the future to support licensing review activities.

- Thermal Hydraulics, Aerosols and Iodine (THAI), Germany, presently evaluates thermal-hydraulic and aerosol behavior in containment. The facility may be of use in the future to study graphite dust in HTGRs.

- Molten Fuel Moderator Interaction (MFMI), Canada, studies core disassembly and fuel channel safety for Canadian-designed reactors. This facility could be important to NRC if design certification is sought for an Advanced Canadian Reactor (ACR).

- The Natural Convection Shutdown Heat Removal Test Facility (NSTF), United States, is a large-scale facility designed to investigate HTGR reactor cavity cooling system performance under severe accident conditions.

Severe accident experimental research, as typified by the work in the facilities discussed above, is expensive because the facilities must operate under challenging conditions. In addition, facilities that use radioactive materials are especially expensive because of material control requirements. The expense has fostered the international cooperation discussed above because each country with interests in the area has recognized that it cannot afford to provide the necessary funding solely from its own budget.

For the nine facilities with active programs, RES has budgeted a total of $1.2M in fiscal year (FY) 2009 and $1.1M in FY 2010. Each of the cooperative programs is covered by a detailed bilateral or multilateral agreement and has been evaluated to ensure that the program complies with the seven criteria and is cost-beneficial to the agency. Nonetheless, NRC does not know in all cases how much money or in-kind research is provided to the program by third parties so the total cost is not known for every program. However, for those programs where NRC does know the cost, NRC's share is about 10 percent where the United States is not the host country, or could be as high as 50 percent where the United States is the host country. Because of their high costs, experimental programs are highly leveraged in the international community and have been for many years. However, because of their long lead times for planning, procurement, and analysis, experimental programs require multiyear funding support from the participants.

RECOMMENDATION:

The staff recommends that the Commission agree that the staff continue to negotiate bilateral and multilateral agreements for light-water reactor and high-temperature gas reactor experimental programs to meet the needs of the agency.

COORDINATION:

The Office of the General Counsel reviewed this paper and has no legal objection.

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