POLICY ISSUE
(INFORMATION)

October 21, 2011 SECY-11-0148

FOR: The Commissioners

FROM: Brian W. Sheron, Director
Office of Nuclear Regulatory Research

SUBJECT: NRC PARTICIPATION IN THE OECD HALDEN REACTOR PROJECT DURING 2012–2014

PURPOSE:

The purposes of this memorandum are (1) to inform the Commission of the results of the agency's past participation in the Halden Reactor Project (HRP), sponsored by the Organisation for Economic Co-operation and Development (OECD), and (2) to inform the Commission of the staff's plans to continue participating in the project during 2012–2014.

SUMMARY:

The OECD HRP is a cooperatively funded international research and development project that operates under the auspices of OECD's Nuclear Energy Agency with the sponsorship of 18 countries, including the United States (Enclosure 1). The HRP is located in Halden, Norway, and the Norwegian Institute for Energy Technology (Institutt for Energiteknikk (IFE)) manages it.

The international organizations actively participating in the HRP represent a cross-section of the nuclear community: licensing and regulatory interests, national research organizations, reactor and fuel vendors, and utilities. HRP membership is divided between signatory members (e.g., the U.S. Nuclear Regulatory Commission (NRC)) and associated parties (e.g., General Electric/Global Nuclear Fuel, Westinghouse Electric Company, Electric Power Research Institute, and the U.S. Department of Energy). The research programs at the HRP address five areas of interest to the NRC: (1) nuclear fuels, (2) nuclear reactor materials performance, (3) the testing, development, and analysis of digital instrumentation and control (I&C) systems, (4) human factors, and (5) human reliability analysis (HRA). In addition to direct research benefits, participation in the HRP facilitates cooperation and information exchange with the

CONTACT: Alysia G. Bone, RES/DRA
301-251-7602

participating countries. Additionally, participation provides an opportunity to effectively and efficiently use NRC research funds by combining these funds with those of the other signatories and associated parties.

BACKGROUND:

The NRC and its predecessor, the U.S. Atomic Energy Commission, have participated in the HRP since its inception in 1958. During this period, the NRC has received the benefit of many research products from this internationally funded cooperative effort. Enclosure 2 provides a listing of HRP reports for the 2009-2010 time period (those from 2011 have not yet been added to the HRP document library). The Office of Nuclear Regulatory Research (RES) has copies of these reports, and they can also be accessed through the HRP's online document sharing repository. The staff plans to continue to participate in the project for the 2012–2014 agreement period because of the benefits received from HRP's unique collection of research capabilities and the ability to effectively and efficiently utilize agency resources due to the multinational financial contributions to the program.

The HRP includes the Halden Boiling-Water Reactor, which currently operates at 18 to 20 megawatts and is contained within a mountain in Halden, Norway. The HRP has recently been subject to both national (Norwegian) and international (International Atomic Energy Agency) safety reviews and has approval from both to continue operating. The reactor supports instrumented in-reactor testing of fuel and reactor materials. It also delivers steam to a nearby paper factory. Since its initial startup, the reactor facility has been progressively updated and can mimic both boiling-water reactor (BWR) and pressurized-water reactor (PWR) phenomena, and hundreds of in-reactor experiments have been performed. The HRP focuses on fuel performance and materials safety considerations using the large number of experimental channels in the core that are capable of handling many test rigs simultaneously. Of particular interest to the NRC is the series of loss-of-coolant accident tests and the stress relaxation material tests that the HRP has conducted and plans to continue in the next program cycle. These loss-of-coolant accident tests study high burnup fuel phenomena that supports 10 CFR 50.46 rulemaking, and the materials tests study reactor vessel material behavior that supports plant life extension.

The HRP also includes the Man-Technology-Organization (MTO) Laboratory. The Halden Man-Machine Laboratory (HAMMLAB) is one of the principal experimental facilities in this laboratory. The HAMMLAB includes a reconfigurable simulator control room that facilitates human factors, HRA, and I&C research. Currently, HAMMLAB has hardware and software enabling it to simulate the Fessenheim PWR plant in France, the Forsmark-3 BWR plant in Sweden, and the Ringhals-3 PWR plant in Sweden. Due to the similarity between these plants and their US counterparts, the broad insights derived from the Halden simulator exercises have general applicability to US research for the purposes of human performance measurement. Many of the HAMMLAB experiments are performed with the control room configured as a prototype advanced control room with an integrated surveillance and control system. This setup is used to explore the impacts of automation and advanced human system interfaces on operator performance. HAMMLAB has extensive data collection capabilities and typically uses qualified nuclear power plant operators (who are familiar with the plants being simulated) as test subjects. The MTO Laboratory also includes a virtual environment center and an integrated operations laboratory. The HRP has applied virtual environments in the nuclear arena in the areas of training, work planning, and control room design, as well as the use of virtual

environments for research purposes. This technology has been used to design control rooms for nuclear and other process control applications. An extensive and experienced human factors research staff augments these facilities. Their insights are useful for NRC in both ongoing human factor reviews and new reactor applications.

The HRP plans its program in 3-year agreement periods. The current period expires at the end of the calendar year 2011, and the upcoming cycle covers the period 2012–2014. As the signatory member from the United States, the NRC has a voting representative on the Halden Board of Management (HBM), which approves the HRP's plans and provides project oversight. Currently, Dr. Brian Sheron, Director of RES, is serving a 1-year assignment as the Chair of the HBM. NRC hosted one of the HBM's biannual meetings in Rockville, MD, in June 2011, during which the HBM members discussed high-level programming decisions and all meeting objectives were met. The NRC also has representatives on the Halden Program Group, which provides technical input to the project.

The NRC benefits from participation in the HRP as the associated products have supported many regulatory applications, leveraged limited nuclear safety resources, supported knowledge transfer to the NRC staff, and supported the NRC's international communication, coordination, and collaboration efforts. HRP data have supported preparation of the NRC's generic communications, including an information notice on fuel thermal conductivity. In addition, HRP provided data to inform the development of staff review guidance on computerized procedures and control room staffing criteria, answering a user-need request from the Office of New Reactors. The NRC also applied HRP data in a 2005 Catawba mixed-oxide (MOX) licensing hearing; the staff entered an exhibit that showed hundreds of MOX data points from the HRP, thus providing material evidence supportive of the staff's licensing decision. The staff has used information from the materials testing program to assess irradiation effects on materials. The staff recently approved industry's plans to inspect PWR reactor vessel internals based, in part, on materials performance data generated by the HRP.

By taking part in this multinational research agreement, the NRC leverages its resources to collect a large amount of data to support regulatory applications, such as those mentioned above, in a manner that is much more efficient and effective than if the NRC was forced to develop the same data alone. Involvement in the HRP also supports knowledge transfer to the NRC staff through visits to the HRP facilities and rotational opportunities. For example, during the summer of 2010, a member of the RES staff participated in a 4-month rotation to the HRP facilities to become familiar with the HRP and take part in its ongoing HRA research. The experience greatly contributed to the staff member's professional development and provided essential knowledge to support her role as the HRP project manager. The HRP is well equipped to support such rotations, since it has an internship program that allows guest researchers from all of the member countries to partake in short-term assignments at the HRP.

DISCUSSION:

The HRP is organized into two parallel research programs: the fuels and materials (F&M) program and the MTO program. The F&M program focuses on nuclear fuels and nuclear reactor materials performance. The MTO program focuses on human factors, HRA, and the testing, development, and analysis of digital I&C systems. These programs are structured to respond to the needs of the HRP member organizations (including the NRC). The following subsections briefly describe the benefits derived by the NRC from past and continued

participation in the HRP for each area of work. Enclosure 3 provides a more detailed discussion of these areas along with examples of regulatory products.

Nuclear Fuels

Fuel damage criteria and computer codes that describe fuel rod behavior are used in reactor safety analyses. These criteria and codes are used to ensure fuel integrity during normal operation (including anticipated transients) and to ensure that postulated accidents do not exceed established safety limits. These criteria and computer codes were originally developed from a database largely related to low-burnup fuel with Zircaloy cladding. The HRP fuel program is enhancing this database by addressing the effects of longer fuel burnup times, new fuel and cladding materials that are being used to achieve high burnups, and MOX fuel that will be used for plutonium disposition in the United States. Data from the HRP fuel program have been employed directly in recent reviews of industry fuel behavior codes. These data, which take several years to gather, are also essential for updating the NRC's fuel codes and materials properties library in order to support audits of industry safety analyses. The fuel properties and codes are also used to assess spent fuel storage and transportation. Of particular interest to the NRC for the enhancement of its own fuel code calculations is the HRP's extensive loss-of-coolant accident test series.

Nuclear Reactor Materials Performance

The HRP has provided fundamental technical information to aid in understanding the performance of irradiated reactor pressure vessel materials and to supplement the results generated under NRC research programs. The HRP has been an essential partner in evaluating the irradiation-assisted stress-corrosion cracking (IASCC) of light-water reactor (LWR) materials. The staff utilized HRP facilities to irradiate materials that were later tested under the NRC's research program at Argonne National Laboratory to measure crack initiation, fracture toughness, and crack growth rate under representative LWR conditions. The HRP is also participating jointly with the NRC in the Cooperative IASCC Research Program (CIR), which is based in Halden. The CIR is an international collaboration among utilities, vendors, regulators, and research organizations to develop IASCC data. Experiments conducted under the CIR program are unique because no other facilities exist that can conduct in-situ testing to capture prototypical conditions. Thus, irradiation assisted degradation data generated under the HRP complement other NRC-sponsored research. The NRC staff uses such data to inform its reviews of licensee aging management programs for reactor pressure vessel internals during license renewal. Recently, the NRC also used the information from the HRP materials testing program to provide part of the technical basis for the approval of industry's plans to inspect PWR reactor vessel internals. Over the next 3-year period, the HRP plans to continue irradiated material testing, which will augment the technical basis for assessing the structural integrity of reactor vessel internals during long-term operation.

Human Factors

The HRP's MTO program conducts experiments related to human error, human performance, teamwork, and the effects of computer-driven interfaces using IFE's HAMMLAB and virtual environment capabilities. The results of HRP research have served as a part of the technical bases for NRC regulatory guidance to aid staff reviews of issues such as the potential impacts on operator performance of control room modernization projects (including the challenges to

operator performance associated with navigating through computerized displays) and potential staffing configurations in computer-based control rooms or remote locations that may differ from the required configurations in current plants. The NRC has also integrated the results of HRP human factors research into Chapter 18, "Human Factors Engineering," of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition"; NUREG-0700, Revision 2., "Human-System Interface Design Review Guidelines," issued May 2002; NUREG-0711, Revision 2, "Human Factors Engineering Program Review Model," issued February 2004; and NUREG-1791, "Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)," issued July 2005. The NRC staff uses these guidance documents in reviewing changes to control stations for current reactors and for new reactor applications, license amendment requests, and plant inspections. Future HRP human factors research will continue to contribute to the development of the technical basis for human factors guidance, especially for new reactor designs. Specifically, the staff will use HRP research to revise NUREG-0700 and NUREG-0711. Of particular interest to the NRC staff is the HRP's integrated-systems validation work that is planned for the upcoming program cycle.

Human Reliability Analysis

During the current 3-year agreement period, the HRP has focused on significant research projects that uniquely address the uncertainties in and the need for empirical data to support HRA. The HRP offers a strong capability in terms of the facilities, experience, and expertise to conduct simulator experiments. This capability supports HRA model development and testing through the collection of human failure event data. In particular, this program has provided critical support to the International HRA Empirical Study, a multinational study aimed at developing an empirically based understanding of the performance, strengths, and weaknesses of HRA methods used in risk-informed regulatory applications. The NRC is using the conclusions from this study as input in responding to Staff Requirements Memorandum M061020, dated November 8, 2006 (ML063120582), which directs staff to evaluate different human reliability models in an effort to propose either a single model for the agency to use or guidance on which model(s) should be used in specific circumstances. In addition, the NRC is replicating the methodology from this study in the U.S. HRA Empirical Study, which aims at further validating the results of the international study for U.S. crews. Furthermore, through collaborations with the NRC and U.S. utilities, the HRP recruited six U.S. crews to participate in the 2011 HAMMLAB study. This is the first time in the HRP's history that U.S. crews have participated in an experiment at the HRP facilities. HRA studies continue to be an integral part of the HRP's research plan for 2012–2014 and include such experimental goals as improving scenario analysis for HRA and modeling operator behavior in emergency response.

Instrumentation and Controls

HRP has been conducting I&C research for a number of years, both in the areas of computerized operation and maintenance support as well as in software systems dependability. Past efforts include information surveillance and monitoring techniques based on advanced decision algorithms. These techniques include those for core monitoring, condition monitoring of electrical cables, and early fault detection in process systems. In recent years, the HRP has expanded its research efforts in digital systems safety. For the next 3-year cycle, the HRP has organized its digital systems research into three aspects: the dependability of software

systems, condition monitoring and maintenance support, and operation support. Within this research portfolio, the NRC is particularly interested in HRP research regarding digital systems safety.

RESOURCES:

The cost of the NRC's participation in the HRP during the 2012–2014 agreement period is 33 million Norwegian kroner. This amounts to a total obligation of approximately $2.04 million per year given an exchange rate of 5.4 kroner[1] to the dollar. This obligation is higher than that for the previous 3-year period. According to the HRP, the roughly 10-percent increase covers higher materials costs because of inflation and cost of living increases in salaries and benefits. The staff continues to engage with the HRP regarding strategies for containing future cost increases; such strategies include increasing HRP membership, identifying other sources of funding, and addressing salary and benefit increases.

The staff has budgeted the following resources for the 2012-2014 agreement period:

- $2.1 million has been budgeted, each year, in the FY 2012 and FY 2013 budget requests. Funding for FY 2014 will be addressed through the agency's Planning, Budgeting, and Performance Management (PBPM) process.

- The FY 2012 and FY 2013 funds are located in the following products:

FY 12	FY13	Business Line	Product Line	Product
$1.4M	$1.4M	Operating Reactors	Research	International Research
$ .7M	$ .7M	Operating Reactors	Rulemaking	Rulemaking Support

- Resources for FY 2014 will be addressed through the PBPM process.

[1] The exchange rate of 5.4 kroner to the dollar was calculated on September 2, 2011. Within the last year, the exchange rate has ranged from 5.23 to 6.21 kroner to the dollar.

COORDINATION:

The Office of the Chief Financial Officer has reviewed this paper for resource implications and has no objections. The Office of the General Counsel has no legal objection to this paper. The Office of International Programs has no objections to this paper.

/RA/

Brian W. Sheron, Director
Office of Nuclear Regulatory Research

Enclosures:
1. Members of the Halden Reactor Project
2. Listing of Halden Reports for 2009-2010
3. Extended Summary of NRC Involvement in the Halden Reactor Project

COORDINATION:

The Office of the Chief Financial Officer has reviewed this paper for resource implications and has no objections. The Office of the General Counsel has no legal objection to this paper. The Office of International Programs has no objections to this paper.

/RA/

Brian W. Sheron, Director
Office of Nuclear Regulatory Research

Enclosures:
1. Members of the Halden Reactor Project
2. Listing of Halden Reports for 2009-2010
3. Extended Summary of NRC Involvement in the Halden Reactor Project

ADAMS Accession No.: ML112341235

OFFICE	RES/DRA	QTE	RES/DRA	RES/DRA	RES/DSA	RES/DE
NAME	A. Bone	K. Azariah-Kribbs (via email)	K. Coyne	R. Correia	K. Gibson	M. Case
DATE	8/30/11	8/25/11	9/2/11	9/19/11	9/30/11	9/27/11
OFFICE	OCFO	OGC	OIP	RES		
NAME	G. Peterson (via email)	J. Biggins (via email)	M. Doane (via email)	B. Sheron		
DATE	9/30/11	10/3/11	9/28/11	10/21/11		

OFFICIAL RECORD COPY