

POLICY ISSUE
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FOR: The Commissioners

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SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION PARTICIPATION IN THE
HALDEN REACTOR PROJECT DURING 2018–2020

PURPOSE:

The purpose of this paper is to inform the Commission of the results of the U.S. Nuclear Regulatory Commission's (NRC's) past participation in the Halden Reactor Project (HRP) and the staff's plans to continue participating in the project during 2018–2020.

SUMMARY:

The HRP is a cooperatively funded international research and development project that operates under the auspices of the Organisation for Economic Co-operation and Development's Nuclear Energy Agency. The HRP, located in Halden, Norway, is managed by the Norwegian Institute for Energy Technology (Institutt for Energiteknikk or IFE). The organizations actively participating in the HRP represent a cross-section of the nuclear community, including licensing and regulatory authorities, national research organizations, reactor and fuel vendors, and utilities. U.S. membership in the HRP is divided between a signatory member (the NRC) and associated parties (General Electric/Global Nuclear Fuel, Westinghouse Electric Company, the Electric Power Research Institute, and the U.S. Department of Energy).

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The HRP research programs address four primary areas: (1) nuclear fuels, (2) irradiation-assisted degradation of nuclear reactor materials, (3) human factors, and (4) digital systems. The NRC has benefited directly from research in these areas. The NRC's participation has also maximized the use of the agency's research funds by leveraging the resources of other HRP participants. In addition, participation in the HRP facilitates cooperation and technical information exchange with the participating countries. The staff plans to continue to participate in the project for the 2018–2020 agreement period because of the highly leveraged (~15:1 ratio of total HRP funding to NRC funding) research benefits in key technical areas and the excellent opportunity for international cooperation and information exchange.

BACKGROUND:

The NRC and its predecessor, the U.S. Atomic Energy Commission, have participated in the HRP since its inception in 1958. The HRP membership has expanded over the years and currently includes 31 organizations from 20 countries (Enclosure 1). The HRP plans its program in 3-year agreement periods. The current agreement expires at the end of calendar year 2017, and the upcoming cycle covers 2018–2020. In advance of each 3-year program, the HRP prepares a research proposal detailing the planned areas for the upcoming period. The research proposal is provided to HRP member organizations for review. The HRP also visits each member organization to present the proposal formally and to discuss how the proposal could be improved to better meet each member's needs. NRC staff members from the Office of Nuclear Regulatory Research (RES), Office of Nuclear Reactor Regulation (NRR), Office of New Reactors (NRO), and Office of International Programs (OIP) participate in the day-long proposal discussions to ensure that the HRP receives a variety of agency perspectives. HRP members provide feedback by ranking each proposed project to communicate their preferences for the direction and approach of the specific proposed projects. RES staff members coordinate the NRC's proposed project rankings with NRR and NRO counterparts before submitting final ranking sheets to the HRP. The HRP reconciles this feedback and uses it to prioritize its activities.

The HRP is organized into two parallel research programs: (1) the Fuels and Materials (F&M) program and (2) the Man-Technology-Organization (MTO) program. The F&M program focuses on nuclear fuels and nuclear reactor materials performance through tests conducted in the Halden Boiling-Water Reactor (HBWR). The HBWR supports instrumented in-reactor testing of fuel and reactor materials using numerous experimental loops that run through the reactor core. Since its initial startup, the reactor facility has been progressively updated and currently contains multiple loops to simulate both boiling-water reactor (BWR) and pressurized-water reactor (PWR) environments. Fuels research includes loss-of-coolant accident testing, fission gas release studies, and fuel and cladding creep experiments. Materials research projects focus on irradiation-assisted stress-corrosion cracking (IASCC), stress relaxation, and creep experiments for reactor internal materials.

The MTO program focuses on human factors and digital systems. The HRP uses nuclear power plant simulators, a virtual environment, and an integrated operations laboratory to support this research. For instance, the Halden Man-Machine Laboratory (HAMMLAB) includes a reconfigurable simulator control room with hardware and software to simulate PWR and BWR plants. The HAMMLAB conducts human performance research generally using operators from Sweden. In recent years, the laboratory also has started to use operators from U.S. plants and staff from the NRC's Technical Training Center for its human performance research. The broad insights derived from the HRP simulator experiments generally apply to U.S. research for the purposes of better understanding and improving human performance.

The HRP endeavors to coordinate its research programs and the needs of member organizations through frequent interactions. The Halden Board of Management (HBM) meets semiannually to provide project oversight and review and to decide whether to approve or disapprove the HRP's plans. The HBM consists of representatives from signatory members (no more than one per country). Mr. Mark Thaggard, Deputy Director of RES's Division of Risk Analysis, is currently the NRC's voting representative on the HBM. The Halden Program Group (HPG) also meets semiannually and provides a technical advisory forum for member organizations to give technical recommendations to the HRP. The NRC's technical staff members serve as representatives on the HPG and interact with HRP to ensure that the agency's research needs are represented in HRP projects. They also collaborate with representatives from other member organizations to provide input on the scope and focus of research to the HRP.

DISCUSSION:

The NRC has benefited from participation in the HRP to conduct necessary research by providing access to unique experimental and research facilities that are not available in the United States; leveraging limited nuclear safety resources; supporting knowledge transfer to the NRC staff; and supporting the NRC's international communication, coordination, and collaboration efforts. By taking part in this multinational research agreement, the NRC leverages its resources to collect a large amount of valuable data at a reduced cost. Involvement in the HRP also supports knowledge transfer to the NRC staff through visits to the HRP facilities, summer school training courses, and rotational opportunities. The HRP is well equipped to support such rotations through its secondee program, which allows guest researchers from all member countries to partake in short-term assignments at the HRP. Finally, participation in the HRP provides an ideal venue for cooperation and information exchange with international counterparts.

During the current 2015–2017 program period, the NRC has benefited from many HRP research products. Enclosure 2 lists HRP reports for 2015–2017 (up to July 2017). 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

Reactor safety analyses use fuel damage criteria and computer codes that describe fuel rod behavior under a variety of operating conditions. These criteria and codes are used to ensure fuel integrity during normal operation (including anticipated operational occurrences) and to ensure that fuel subjected to postulated accidents does 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 accident-tolerant fuels being pursued by U.S. industry and the U.S. Department of Energy.

Recent reviews of industry fuel behavior codes have used data from the HRP fuel program. These data take several years to gather and are essential for updating the NRC's fuel codes and materials properties library to support audits of industry safety analyses. Today, over half of the assessment cases used to validate the NRC's steady-state fuel performance code, FRAPCON, were derived from HRP tests. The fuel properties and codes are also used to

assess spent fuel storage and transportation. Of particular interest to the NRC is the HRP's extensive loss-of-coolant accident test series that enhances the NRC's fuel code calculations and directly informs the draft final rulemaking for Title 10 of the *Code of Federal Regulations* (10 CFR) 50.46c, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors." Additionally, the staff plans to use test data acquired at Halden to support licensing of Accident Tolerant Fuel (ATF) designs. During the next 3 years, the HRP will continue research of high interest to the NRC in the area of fuel testing and performance.

Nuclear Reactor Materials

The HRP has provided fundamental technical information to better understand the performance of irradiated reactor internals materials. The HRP has been an essential partner in evaluating the IASCC of light-water reactor materials. The staff has worked with the Electric Power Research Institute to send ex-plant reactor internals materials to the HRP for further irradiation and IASCC testing. The NRC staff uses such data to inform its license renewal reviews of applicants' aging management programs for reactor pressure vessel internals. The NRC also has used the information from the HRP materials testing program to provide part of the technical basis for the review of industry's plans to inspect PWR reactor vessel internals in MRP-227, "Materials Reliability Program: Pressurized Water Reactor Internals Inspection and Evaluation Guidelines." 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 potential subsequent license renewal periods.

Human Factors

The HRP's human factors research program has four sections: (1) operator reliability, (2) severe accidents and human performance, (3) control room design and evaluation, and (4) advanced reactors. This program examines aspects of human performance and human factors considerations in new and existing operational concepts and the use of new and existing technologies. The results of the HRP research have served as a part of the technical basis for the NRC's regulatory guidance for reviewing changes to control rooms for operating reactors, new reactor application reviews, license amendment reviews, and plant inspections. The HRP research has supported the development and updating of key guidance documents, including NUREG-0700, "Human-System Interface Design Review Guidelines," issued May 2002, and NUREG-0711, "Human Factors Engineering Program Review Model," issued November 2012. For example, the MTO program has worked closely with the NRC and other international organizations to collect human reliability data, which provide benchmarking for the NRC's development of improved human reliability methods. In addition, the HRP's integrated systems validation project has provided useful information for the NRC's update of human factors review guidance in this area. During the next 3 years, the HRP will continue research of high interest to the NRC, particularly in the area of human reliability analysis (HRA).

Digital Instrumentation and Controls

The HRP's digital instrumentation and controls (I&C) systems research covers safety and security in digital I&C design, human aspects in the development of safe digital I&C, and digital I&C safety demonstrations. The NRC's primary interest in this area is both safety and security in digital I&C design and digital I&C safety demonstrations. The HRP research can provide important insights related to the technical basis for some of the critical design challenges, such as defense against common cause failure, in the deployment of digital I&C at U.S. reactor facilities. The HRP performed a case study in the current program period to assess the basis of safety assurance in a licensing submittal to NRO and coordinated a workshop hosted at the

NRC in March 2017 on this topic. The staff believes that future Halden work using a method similar to that of the case study can identify potential gaps in the technical basis and regulatory criteria. Both areas provide opportunities for enhancing the agency's strategic modernization of the I&C regulatory infrastructure improvements¹, and this supports further research of high value to the NRC and other HRP members.

Challenges Facing the Halden Reactor Project

Financial challenges associated with operating costs for the HBWR have created some uncertainty regarding the status and continued operation of the HBWR, both during the 2018-2020 period and beyond 2020. In October 2017, IFE indicated it may encounter funding challenges during the 2018-2020 period due to a lack of bilateral projects to help support the reactor operating costs. However, IFE is still committed to the HRP and is working to secure additional bilateral and multilateral projects to support operation from 2018-2020. The NRC staff is engaged through its participation on the HBM in discussions to address the funding issue and will continue to assess the potential impacts of this issue on NRC research priorities.

Even before the funding concerns raised by IFE in October 2017, IFE had identified a longer-term need to look at a more sustainable funding model for the HRP. In June 2017, IFE informed the HBM of the need to improve the current business model for operating the HBWR to ensure sustainability beyond 2020. IFE is having discussions with HRP members and the Norwegian Government on ways to improve the financial sustainability of operating the HBWR. In considering continued operation of Halden beyond 2020, a key consideration is the HBWR license. The HBWR's license from the Norwegian nuclear regulatory authority is valid through 2020 and will need to be renewed to continue operation beyond 2020. The staff is not aware of any anticipated technical issues that would prevent a renewed license for the HBWR beyond 2020, but the process for applying to renew the license needs to begin by June 2018. These financial challenges combined with the expiring HBWR license create uncertainty with the status and continued operation of the HBWR beyond 2020. The NRC staff is participating in an HBM working group focused on this sustainability issue.

RESOURCES:

The cost of the NRC's participation in the HRP during the 2015–2017 agreement period was 33 million Norwegian kroner (NOK) or approximately \$1.4 million (U.S. dollars) per year. The HRP has proposed, and the HBM agreed to, a 6-percent increase in contributions for 2018–2020. Based on contributions from new members and increased contributions from U.S. associated parties, the HRP notified the NRC that its contribution would decrease by 7 percent in NOK from the previous agreement. Therefore, the cost of the NRC's participation in the HRP during the 2018–2020 agreement period is 30.7 million NOK. This amounts to an estimated total obligation of about \$1.3 million (U.S. dollars) per year given an exchange rate of 7.93 NOK to the dollar.²

The staff has budgeted the following resources for 2018:

¹ See Modernization Plan 4B of the Integrated Action Plan (ML16097A182).

² The exchange rate of 7.93 NOK to the dollar was calculated on July 31, 2017. Within the last year, the exchange rate has ranged from 7.86 to 8.72 NOK to the dollar, which corresponds to an annual NRC contribution range of \$1.17 million to \$1.30 million.

- The NRC has budgeted \$1.44 million for the budget request for fiscal year (FY) 2018 to provide some margin to account for changes in currency exchange rates. Additional resources estimates for future fiscal years can be found in Enclosure 4 and are not publicly available.
- The table below lists the projected funding in FY 2018 in the research product line of the Operating Reactor Business Line budget.

FY 2018	Business Line	Product Line	Product
\$0.48 million	Operating Reactors	Research	Systems Analysis Research
\$0.48 million	Operating Reactors	Research	Risk Analysis Research
\$0.24 million	Operating Reactors	Research	Aging and Materials
\$0.24 million	Operating Reactors	Research	Engineering Research
\$1.44 million	TOTAL		

The staff is also beginning to explore the accessibility and projected costs of using experimental facilities other than Halden, if Halden were to close down or no longer be accessible to support NRC research. Under the auspices of NEA, the NRC is participating in a multi-lateral assessment of the accessibility and capability of nuclear research facilities around the world. This assessment will not only inform future decisions on whether to continue to cooperate with Halden after 2020, but also in planning and budgeting future NRC research.

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. OIP has no objections to this paper.

/RA/

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Enclosures:

1. Members of the Halden Reactor Project
2. Listing of Halden Reactor Project Reports from 2015–2017
3. Expanded Summary of U.S. Nuclear Regulatory Commission's Involvement in the Halden Reactor Project
4. Budget Planning for the Halden Reactor Project

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