POLICY ISSUE
(Information)

February 13, 2003 SECY-03-0023

FOR: The Commissioners

FROM: William D. Travers
Executive Director for Operations /RA/

SUBJECT: NRC PLANS TO PARTICIPATE IN THE OECD HALDEN REACTOR PROJECT DURING 2003–2005

PURPOSE:

To inform the Commission of the results of the agency's past participation in the Halden Reactor Project sponsored by the Organization for Economic Cooperation and Development (OECD), as well as the staff's plans to continue participating in the project during 2003–2005.

BACKGROUND

The Halden Reactor Project (HRP) is a cooperatively funded international research and development (R&D) project that operates under the auspices of the OECD's Nuclear Energy Agency (NEA) with the sponsorship of 19 countries, including the United States (Attachment 1). The international organizations actively participating in the Halden project represent a cross-section of the nuclear industry consisting of licensing and regulatory interests, national research organizations, reactor and fuel vendors, and utilities. The research programs at the HRP address five areas of specific interest to the NRC, including (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 research; and (5) human reliability analysis (HRA). Participation in the project gives the NRC a forum for international cooperation and information exchange with the participating countries. Additionally, participation provides an opportunity to leverage NRC research funds. The HRP budget is approximately $45M over the 3-year period of 2003–2005. The NRC's contribution remains at $1.0M per year, the same level as in previous years.

Contacts:
Julius J. Persensky, RES
301-415-6759

Shana R. Browde, RES
301-415-7652

The NRC and its predecessors have participated in the HRP since its inception in 1958. During this period, the NRC has received the benefit of numerous research products from this internationally funded cooperative effort. The staff plans to continue to participate in the project for the 2003–2005 agreement period because of the benefits received and the ability to leverage agency resources.

The NRC uses products and information generated by the HRP to develop and extend the applicability of analytical tools and as the technical basis for regulatory guidance. Recently, the NRC reviewed FRAMATOME's COPERNIC fuel rod code, and a variation of that code called COPERNIC-MOX is currently under review for the anticipated plutonium disposition program. Data from more than 13 different HRP reports on tests in the HRP reactor were used in performing these reviews. The HRP has provided irradiation of specimens that were subsequently tested under NRC contract at Argonne National Laboratory in support of user need requests by the NRC's Office of Nuclear Reactor Regulation (NRR). The HRP has expanded its research effort in digital systems safety and analysis, providing a technical basis for realistic safety decisions in the instrumentations and controls arena. HRP products have contributed to work addressing the staffing of advanced reactors, which serves as a basis for a user need request from NRR.

The HRP includes the Halden Boiling-Water Reactor (BWR), which currently operates at 18 to 20 Megawatts (MW) and is contained within a mountain in Halden, Norway. Norwegian authorities have licensed the reactor for operation until 2010. The reactor is fully dedicated to 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 has now become one of the most versatile test reactors in the world. In the course of this development, more than 300 in-reactor experiments have been performed. The joint program 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.

The HRP includes a reconfigurable simulator that is easily available to the NRC for human factors and human reliability research. These facilities include the Halden Man-Machine Laboratory (HAMMLAB), which contains a pressurized water reactor (PWR) simulator based on the Fessenheim Plant in France, a BWR simulator based on the 1160-MW Forsmark-3 Plant in Sweden, and a VVER-440 simulator based on the Loviisa Power Plant in Finland. The HRP has access to qualified operators who are familiar with these plant designs and can serve as test subjects. The HAMMLAB has a prototype advanced control room with an integrated surveillance and control system, which is used as a test bed for exploring human-machine issues regarding the role of the operator and interactions with advanced automated controls. The HAMMLAB also has extensive data collection capabilities. In addition, the project has developed a capability in the area of virtual environments, which has been used as a cost-efficient way to design control rooms for nuclear and other process control applications. These facilities are augmented by the largest human factors research staff in the international nuclear community.

DISCUSSION

The research programs at the HRP address five areas of specific interest to the NRC, including (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 research; and (5) human reliability analysis (HRA). These programs are structured to respond to the needs of all member organizations within the international nuclear community. The following subsections briefly describe the benefits derived by the NRC from past and continued participation in the HRP for each area of work. Attachment 2 provides a more detailed discussion of these areas.

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 evolve into core melt scenarios. These criteria and computer codes were originally developed from a database of mostly low-burnup fuel with Zircaloy cladding. The HRP fuel program is addressing the effects on this database of longer fuel burnup times, new materials that are being used to achieve high burnups, and mixed-oxide (MOX) fuel that will be used for plutonium disposition in the United States. The behavior of new fuel designs that may be used in Generation IV reactors is also being investigated. Data from the HRP fuel program have been employed directly in recent reviews of industry fuel behavior codes. These data are also essential for updating the NRC's fuel codes and materials properties library, which are used to audit industry analyses.

Nuclear Reactor Materials Performance

The HRP has provided neutron irradiation of test specimens for NRC research programs, most notably the Environmentally Assisted Cracking of Light-Water Reactors (LWRs) program that is ongoing at Argonne National Laboratory. The crack initiation, fracture toughness, and crack growth rate data from this program are being generated specifically in response to user need requests by NRR. Results are applied, for example, in evaluating control rod drive mechanism cracking events and aging management of reactor internals. In addition, the test results and analyses reported by the HRP continue to be of great use in validating the NRC’s program results and extending the agency’s overall understanding of irradiation-assisted stress corrosion cracking (IASCC) mechanisms and mitigation. For example, HRP tests will attempt to verify the stress corrosion cracking mitigation effectiveness of BWR hydrogen water chemistry. Participation in the Halden Programme Group has enabled the NRC to leverage the high cost of irradiation and testing.

Instrumentation and Controls

Historically, HRP’s I&C research has focused on the front end of the software development cycle, primarily in the areas of formal methods for review of requirements, and integration of diagnostics into plant control systems. As a result of activities to develop operational support systems for the Halden reactor, commercial reactor applications, and the HAMMLAB, HRP has acquired the skills and knowledge to develop and test digital systems. Over the past 3 years, HRP has expanded its research efforts in the area of digital system safety. In formulating the new 3-year research program, HRP is modeling its program on the NRC’s “Research Plan for Digital Instrumentation and Control,” SECY-01-0155, dated August 15, 2001. Specifically, the HRP will expand its research into areas of current NRC interest, including digital system reliability and application of emerging technologies to support both plant control room upgrades and future plant designs. The staff believes that the research products generated during the next few years will aid the agency in establishing the technical bases for realistic safety decisions regarding current and new digital system designs and technologies for safety-related applications. Of particular note, some U.S. nuclear utilities have also expressed interest in the application of some of the HRP- developed operator support systems and their virtual environments technology for the design and evaluation of hybrid control stations. The agency's continued cooperation with HRP will allow access to technical information on these systems, as well as access to operational experience from European reactors, thereby leveraging the agency's digital I&C resources as it establishes a technical basis for reviewing these advanced systems.

Human Factors

Experiments related to human error, human performance, and the effects of computer-driven interfaces are conducted in the HAMMLAB. The HAMMLAB facilities, which are unlike anything found in the United States, include a reconfigurable simulator, a prototype advanced control room with an integrated surveillance and control system, data collection facilities, and capabilities in virtual and augmented environments. The results of HRP research have served as a part of the technical basis for regulatory guidance in areas such as alarm systems, hybrid control rooms, display navigation, control room staffing, and measures of human performance, which were developed in response to user needs from NRR. The results of HRP human factors research have been integrated into the basis of a current revision to Chapter 18, "Human Factors Engineering," of the Standard Review Plan (NUREG-0800). In addition, guidance documents for use in reviewing changes to control stations at current reactors and for licensing reviews of new reactors include results from HRP research. Future Halden human factors research will continue to contribute to the technical basis for human factors guidance, as well as the NRC's HRA efforts, as described below.

Human Reliability Analysis

HRA is a new area for the HRP, which 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 collection of human failure event data. In particular, the staff expects that HRP experimental studies will be designed to develop objective measures of performance-shaping factors used in HRAs to account for factors that influence human performance under accident conditions. Furthermore, the HRP experiments will address issues related to specific accident sequences that are of regulatory importance, such as steam generator tube rupture. The NRC staff is working closely with the HRP staff to ensure that research conducted in the HAMMLAB will be risk-informed and will result in data and information that the NRC can use to improve HRA development.

NRC PARTICIPATION IN THE HALDEN REACTOR PROJECT DURING 2003–2005

The cost of the NRC's participation in the HRP during the 2003–2005 agreement period will be limited to $1.0M per year. Funds are available in the approved RES budget for FY 2003 and are included in the proposed FY 2004 budget. Funding for FY 2005 will be addressed during the upcoming FY 2005 PBPM process.

Approximately 2 FTE per year are allocated to work on HRP related efforts. This ensures that experimental results obtained from the HRP experiments are appropriately incorporated into regulatory activities. Additionally, this enhances interaction among HRP, NRC, and other contractors' staff.

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 and the Office of International Programs have no legal objection to this paper.

CONCLUSION

The work performed at the HRP contributes to meeting the NRC's goals of maintaining safety and regulatory effectiveness by conducting experiments and analyses that are used to develop technical bases for realistic safety decisions and that prepare the agency for the future by evaluating safety issues involving current and new designs and technologies. In addition, sharing the costs of the program with other signatories provides an opportunity to leverage NRC research resources.

/RA by William F. Kane Acting For/

William D. Travers
Executive Director
for Operations

Attachments
1. Members of the Halden Reactor Project
2. Extended Summary of NRC involvement in the Halden Reactor Project

MEMBERS OF THE HALDEN REACTOR PROJECT

The members of the Halden Reactor Project include both signatory members and associated party members, as listed below. Representatives from signatory members may vote on issues brought before the Halden Board of Management and the Halden Program Group. Representatives from associated party members may attend meetings of the Halden Board of Management and the Halden Program Group, but have no vote on issues addressed by those bodies.

SIGNATORY MEMBERS

1. The Norwegian Institutt for Energiteknikk
2. Belgian Nuclear Research Center
3. RISO National Laboratory, Denmark
4. Finnish Ministry of Trade and Industry (VTT)
5. Electricite de France
6. Gesellschaft fur Anlagen-und Reaktorsicherheit, Germany
7. Italian Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (ENEA)
8. Japan Atomic Energy Research Institute (JAERI)
9. Korean Atomic Energy Research Institute (KAERI)
10. Spanish Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
11. Swedish Nuclear Power Inspectorate (SKI)
12. Swiss Federal Nuclear Safety Inspectorate
13. British Energy, United Kingdom
14. U. S. Nuclear Regulatory Commission

ASSOCIATED PARTY MEMBERS

15. Argentinian National Nuclear Commission
16. Nuclear Research Institute, Czech Republic
17. Institute for Protection and Nuclear Safety (IPSN), France
18. Hungarian Atomic Energy Research Institute
19. Russian National Research Center, Kurchatov Institute
20. Slovakian Nuclear Power Plant Research Institute, Slovak Republic
21. CE Nuclear Power LLC, USA
22. Electric Power Research Institute, USA
23. Global Nuclear Fuel - Americas

MEMBER & ASSOCIATE COUNTRIES

1. Argentina
2. Belgium
3. Czech Republic
4. Denmark
5. Finland
6. France
7. Germany
8. Hungary
9. Italy
10. Japan
11. Korea
12. Norway
13. Russia
14. Slovak Republic
15. Spain
16. Sweden
17. Switzerland
18. United Kingdom
19. United States

EXTENDED SUMMARY OF NRC INVOLVEMENT IN THE HALDEN REACTOR PROJECT

This attachment discusses in detail ongoing and planned work at the Halden Reactor Project (HRP) in the areas of nuclear fuel, nuclear reactor materials performance, instrumentation and controls (I&C), human factors, and human reliability analysis (HRA) and how the work has been used at the NRC.

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 that significant fuel damage does not occur during normal operation, including anticipated transients, and that postulated accidents do not evolve into core melt scenarios. These criteria and computer codes were originally developed from a database of mostly low-burnup fuel with Zircaloy cladding. Effects of high burnup (i.e., above 40 GWd/t) were noticed about a decade ago and research was initiated to investigate the burnup effects. As burnups in commercial reactors continue to increase and new fuel rod cladding alloys (like ZIRLO and M5) are introduced to reduce normally occurring corrosion, the adequacy of regulatory criteria and evaluation models must be assessed to confirm their continued appropriateness. If the criteria and models are found to be inadequate or nonconservative, they must be modified in a way that the NRC finds acceptable.

NRC licensees use computer codes to calculate detailed fuel rod behavior for several important aspects of their safety analyses. The NRC reviews and approves those codes before they are actually used in the safety analyses, and the NRC's Office of Nuclear Regulatory Research (RES) maintains a similar but independent code, known as FRAPCON-3, for use in studies and in auditing licensees' results. RES also maintains a related materials properties library, called MATPRO, which is referenced by the NRC's codes and many computer codes around the world. Recently, the NRC reviewed FRAMATOME's COPERNIC fuel rod code, and a variation of that code called COPERNIC-MOX is currently under review for the anticipated plutonium disposition program. Data from more than 13 different HRP reports on tests in the HRP reactor were used in performing these reviews. Those and more than a half dozen other HRP reports are also being used to make corrections and improvements in the NRC's fuel codes and materials properties library, which are used for audit calculations.

During the next 3 years, the HRP will work on the following fuel-related activities:

1 **Fuel High-Burnup Capabilities in Normal Operating Conditions**
1.01 Performance of gadolinia fuel
1.02 VVER fuel behavior
1.03 Thermal and fission gas release behavior of mixed-oxide (MOX) fuel
1.04 Tests on inert matrix fuel (IMF)
1.05 Thermal, fission gas release, and pellet-cladding-mechanical-interaction (PCMI) behavior of LWR fuel at high burnup
1.06 Power cycling behavior of high-burnup fuel
1.07 Fission gas release from fuel with high initial rating
1.08 Iodine release and gap inventory

1.09 Tolerable internal pressure in pressurized- and boiling - water reactor (PWR and BWR) rods in normal operation
1.10 Cladding creep under variable loading conditions
1.11 Proposed post-irradiation examination

2 **Fuel Response to Transients**
2.01 Rim fuel investigations during reactivity transients
2.02 Loss of coolant
2.03 BWR power oscillations without scram (ATWS)
2.04 Axial gas transport in high burnup fuel

3 **Fuel Reliability Issues**
3.01 Cladding corrosion and hydriding
3.02 CRUD deposition and axial offset effects
3.03 Localized corrosion

Each of the above activities involves one or more individual test rigs (assemblies or loops) in separate locations in the HRP reactor. Thus, it can be seen that very large amounts of data are emerging from the fuel program at the HRP. The HRP provides basic fuel performance data for regulators, manufacturers, and utilities around the world. The NRC's codes rely on results from HRP, and it would be difficult to make any progress in assessing fuel design and safety without participating in this project. Requests for burnup extensions from the current 62- GWd/t limit to 75-GWd/t are expected in the next few years based on statements from industry spokespersons and generic industry submittals. Fuel rod behavior codes have not been validated for burnups in this extended range. Testing of a wide range of features to support development and validation at these higher burnups is covered in the above list of activities for the next agreement period of the HRP.

NUCLEAR REACTOR MATERIALS

The HRP has provided neutron irradiation of test specimens for NRC research programs, most notably the Environmentally Assisted Cracking of Light-Water Reactors (LWRs) program that is ongoing at Argonne National Laboratory (ANL). The crack initiation, fracture toughness, and crack growth rate data from this program are being generated in response to user need requests. Results are applied, for example, in evaluating control rod drive mechanism cracking events and aging management of reactor internals. Because the HRP reactor is operated continuously for periods of about 100 days, the specimens are of good quality, with a minimum of thermal cycling and with relatively high neutron fluences if placed in central core locations. In addition, the test results and analyses reported by the HRP continue to be of great use in validating the NRC's program results and extending the agency's overall understanding of irradiation-assisted stress corrosion cracking (IASCC) mechanisms and mitigation. Participation in the HRP program has enabled the NRC to leverage the high cost of irradiation and testing.

Irradiation of test specimens at the HRP for the ANL program is expected to continue into 2003. The HRP reactor may also be a viable source of irradiations for ongoing and future research programs, including as a possible replacement for the Ford reactor, which is likely to be decommissioned. The test data generated by the HRP will also continue to be of use in understanding irradiation-assisted degradation mechanisms such as IASCC. In-core crack initiation testing at the HRP is expected to continue through 2004. The HRP is also planning follow-on IASCC testing to be done between 2003 and 2005, to incorporate materials of interest to members and high-fluence reactor material samples. For example, HRP tests will attempt to verify the stress corrosion cracking (SCC) mitigation effectiveness of BWR hydrogen water chemistry. In addition, the HRP is participating in a round robin, sponsored by the International Atomic Energy Agency (IAEA), to explore the use of small punch tests to verify reactor pressure vessel integrity.

The primary product that the HRP has provided is irradiation of specimens that were subsequently tested under NRC contract at Argonne National Laboratory in support of NRR user need requests. This work is intended to increase understanding of the effects of irradiation on core internal structural materials. Of particular interest is the susceptibility of these materials to primary water stress corrosion cracking (PWSCC) or IASCC. The crack morphology, initiation time, and crack growth rates associated with these degradation modes are being studied. More than 50 specimens have been irradiated to a total of three fluence levels in sealed capsules, in what is referred to as the HRP Phase I Dry Irradiations. The specimens, including stainless steel base materials and samples from heat-affected zones of welds, were exposed to fluences up to a level simulating end-of-life fluence for BWR core internals. The test specimens include tensile specimens, for slow strain rate tensile tests indicating cracking susceptibility, and specimens for determining fracture toughness and crack growth rate. Testing of these specimens is being carried out at ANL in simulated LWR environments. Testing and post-test evaluation is expected to continue through 2005.

In addition to specimen irradiations for NRC testing at ANL, the HRP is performing in-core IASCC crack initiation and crack growth rate tests. These tests involve pre-irradiated specimens under constant loading, in environments simulating reactor coolant chemistries, such as PWR water, BWR normal water chemistry, and BWR hydrogen water chemistry. The test matrix includes three materials (304, 304L, 347) and a range of fluences (7.0×10^{19} to 2.5×10^{22} n/cm^2). The HRP is the only known laboratory performing such crack growth rate studies in-core, so that irradiation of the samples is continuing during the tests, rather than testing irradiated specimens in a laboratory autoclave. In this way, any potential synergism between the reactor coolant environment and radiation exposure is replicated.

As a member of the Halden Programme Group, the NRC receives copies of Halden Project reports, summarizing results of work funded in aggregate by Halden Programme Group members. The reports provide essential information for comparison with ANL test data and for extension of the NRC's understanding of radiation-induced material degradation. Reports have included summaries of IASCC crack initiation and crack growth rate data, as well as microstructural characterization of irradiated materials and oxide films.

In addition, the NRC's membership in the HRP program complements the agency's membership in the Cooperative IASCC Research (CIR) program, an international cooperative group administered by the Electric Power Research Institute (EPRI). The HRP will share test results with CIR from a proposed series of in-core tests, as an in-kind contribution for membership in CIR. These reports can be shared freely with CIR members because all seven full members of the CIR program are also Halden Programme Group members. Also, the NRC presents findings from its contractors' work on IASCC, including tests on HRP-irradiated specimens, as a part of the NRC's commitment to participation in CIR.

Approximately 40 specimens will be irradiated in the Phase II Dry Irradiations, scheduled to be completed in mid-2003. Laboratory tests on these specimens are expected to continue through 2006. The HRP is expected to continue its in-core tests to characterize IASCC crack initiation and crack growth rate. In addition, the HRP is participating in an IAEA-sponsored round robin exploring the use of small punch tests to verify reactor pressure vessel integrity. Specimens machined from RPV base metal, weld metal, and heat-affected zones are being irradiated at different elevations within the core. Subsequent tests of the small disk samples will measure embrittlement by recording load as a function of the constant-rate punch displacement. The technique shows promise as a replacement for use of large Charpy specimens, particularly where such specimens become scarce as service time increases.

The HRP reactor is being considered as a possible source for neutron irradiation of test specimens for other ongoing programs. For example, the HRP may serve as a substitute provider of neutrons for the Heavy Section Steel Irradiation (HSSI) program after the University of Michigan's planned shutdown of their Ford research reactor in or about July 2003.

Neutron irradiation of test specimens for ongoing research programs will continue to be the primary use of HRP products, in the near term. The next set of specimens are expected to be transferred from the HRP to ANL in mid-2003, to support testing schedules for the existing program on environmentally assisted cracking of LWRs. In the future, it may be desirable to irradiate specimens for other programs at the HRP. As noted earlier, the test results and analyses reported by the HRP continue to be of great use in extending the NRC's overall understanding of IASCC mechanisms and mitigation.

INSTRUMENTATION & CONTROLS

The NRC has used HRP operational support systems since the early 1990s to provide a platform for development of new training support systems and simulator upgrades at the NRC's Technical Training Center in Chattanooga, Tennessee. These HRP developed tools have supported the upgrading of several full-scope reactor simulators. In addition, several surveillance and monitoring techniques that have been developed at the HRP are now of considerable interest to U.S plants. In 2000, the NRC issued a safety evaluation report (SER 93653) approving a predictive approach proposed by EPRI for online monitoring for calibration reduction. The HRP PEANO system has been evaluated by several U.S. plants for application of this methodology.

The HRP also has ongoing research in the areas of core monitoring, condition monitoring of electrical cables, early fault detection, optimization of plant performance and maintenance, and computerized procedures. Many of these systems have been evaluated for use by U.S. plants. As control room upgrades become a reality in the next few years, the research on these systems will support NRC needs to establish a technical basis for evaluating the technology.

Until recently, the HRP's I & C research has, for the most part, focused on the development of operational support systems, as discussed above. In the last 3 years, the HRP has expanded its research efforts in digital systems safety. The HRP's research in the area of digital system safety and analysis has focused on the front end of the software development cycle, primarily in the areas of formal methods for review of requirements, and integration of diagnostics into plant control systems, including systems based on artificial intelligence (neural networks, fuzzy logic, etc). This research, although not directly supporting NRC objectives in this area, has been of value to the NRC by providing the needed research and operational data to support development of a technical basis for these types of systems should they be proposed for use by U.S. licensees.

In developing the new 3-year research program, the HRP has modeled its program on the NRC's "Research Plan for Digital Instrumentation and Control," SECY-01-0155, dated August 15, 2001. Specifically, the HRP will expand its research into areas of current NRC interest, including systems aspects of digital systems, software quality assurance, digital system reliability, and emerging technologies needed to support both plant control room upgrades and future plant designs. In the system aspects area, the HRP will continue its work on requirements assessment and start a new program on evaluation of software life cycle models, a topic of current interest to U.S. vendors. In the area of software quality assurance, the HRP will evaluate the effectiveness of software testing methods and current software engineering practices, both of which are the subject of current interest to the NRC. In the area of risk assessment of digital systems, the HRP will begin work on developing and testing risk assessment of human-system interfaces and commercial-off-the-shelf (COTS) systems, both of which hold significant interest for the NRC and are areas in which the HRP is particularly well qualified. In the area of emerging technologies, Halden will look at both security aspects of digital systems and verification and validation of advanced technologies.

The products and tools created during the next few years will be useful for establishing the technical bases for realistic safety decisions, thereby preparing the NRC for future safety issues involving current and new digital system designs and technologies for safety-related applications. Some U.S. nuclear utilities have also expressed particular interest in the application of some of the Halden-developed operator support systems and their virtual-environments technology for the development and evaluation of hybrid control stations.

Since the HRP has included an extensive effort in risk assessment of digital I&C systems, the NRC and signatory countries supporting the HRP have initiated communications and interactions with the HRP on the topic of performing focused research on assessment methods, including pilot projects. The HRP provided the opportunity for interested parties to give feedback on how its current efforts can support digital systems risk assessment. Further, the NRC participated in an HRP sponsored workshop (on November 7–8, 2002) on methods and R&D needs in this area, as part of its work planning for 2004 and beyond.

Through these communications and interactions, the NRC staff has developed confidence that the HRP project can provide valuable support in the I&C area. Additionally, participation in the HRP allows the NRC to develop a collaborative research program with other countries.

Although the NRC has made significant improvements its ability to interact with the HRP and positively influence the direction of research in this area, extensive interaction with the HRP staff is needed to ensure that products will be of regulatory use. Many other participants have assigned full-time staff, referred to as secondees, to the project. The NRC has never had a "secondee" at the HRP in this field.

HUMAN FACTORS

The goal of the RES Human Performance program is to provide the regulatory staff with tools, developed from the best available technical bases, necessary to accomplish their licensing and monitoring tasks. The ultimate goal is to minimize the human error contribution to the risk associated with the design, construction, operation, testing, and maintenance of nuclear facilities. The human performance research efforts at the HRP contribute to maintaining reactor safety. The research efforts develop an improved technical basis for realistic safety decisions that will prepare the agency for the future by evaluating safety issues involving the introduction of new technology into existing control rooms and issues related to new reactor designs and technologies.

The NRC uses HRP-generated products and information to develop and extend the applicability of analytical tools for use in assessing those aspects of nuclear facility design, construction, operation, testing, and maintenance that effect human performance, as well as to develop the technical basis for regulatory guidance. The results of human factors research and experiments performed in the HRP Man-Machine Laboratory (HAMMLAB) have provided the technical basis for regulatory guidance or confirmatory research in areas such as alarm systems, computerized procedures, hybrid control rooms, display navigation, control room staffing, and measures of human performance. Additionally, the research results contribute to NRC's risk-informed regulatory activities by providing data and information for human reliability analysis (HRA).

Participation in the HRP gives the NRC access to facilities that are otherwise unavailable in the United States and to extensive amounts of experimental human factors data. It also allows the NRC to interact with human factors professionals from the nuclear community around the world. The HRP is the only cooperative international program of this magnitude in the human factors arena. With the resources available at the HRP, it is possible to collect experimental simulator data that will serve as the technical bases for human factors guidelines used in the review of changes to current control stations and for the review of advanced reactor applications.

The NRC used HRP products as a basis for review guidance on alarm processing, filtering, integration, and prioritization. HRP research has also developed technical bases for guidance on function allocation, human-centered automation, computer-based procedure functionality and approaches to procedure step tracking, use of large screen displays, display navigation, and hybrid control room reviews. Additionally, the HRP conducted a study on staffing for advanced reactors. The results of this study serve as a basis for developing guidance in response to an NRR User Need on the evaluation of exemption requests to the staffing requirements of 10 CFR 50.54(m).

A primary benefit of the HRP is the availability of one of only two Western reconfigurable simulators that are available to the NRC for human factors research. (The other simulator is a 1000-MW CE-PWR simulator in South Korea.) The HAMMLAB contains a PWR simulator based on the French Fessenheim 900-MW plant, a BWR simulator based on the 1160-MW Swedish

Forsmark-3 plant, and a VVER-440 simulator based on the Loviisa Power Plant in Finland. The HRP has easy access to qualified operators who are familiar with these plant designs and can serve as test subjects for human factors experiments, which also provide data and information for human reliability studies. These facilities are augmented by the largest human factors research staff in the international nuclear arena.

Because the HAMMLAB control room is reconfigurable and highly automated, it is one of the most comprehensive facilities in the world for performing experimental research on issues regarding the human-system interfaces for advanced technology in nuclear power plant control rooms. Research performed in the HAMMLAB will be of continuing interest as the NRC increases its focus on advanced reactors. The HRP staff have developed an extensive capability in the development and operation of simulators. This capability can be employed in developing simulation facilities for new reactor designs and concepts of operations for modular reactors. HAMMLAB includes a prototype advanced control room with an integrated surveillance and control system, which is used as a test bed for exploring human factors issues regarding the role of the operator and interactions with advanced automated controls. Further, the data collected for human factors research can provide input to HRA and I&C work. Synergy can be achieved among the areas of human factors, I&C, and HRA through the data collection and interpretation activities of this project.

The HRP has also developed a capability in the area of virtual and augmented environments, which are useful, cost-efficient tools for applications such as control room design, outage planning, and decommissioning. If the U.S. industry begins to use the virtual reality and augmented reality tools, the NRC may have a future interest in these areas.

As a member of the Halden Programme Group, the NRC receives copies of HRP reports, summarizing results of work funded in aggregate by Halden Programme Group members. Upcoming reports will provide essential information in the areas of technical basis for human system interface (HSI) review guidance, design guidelines for hybrid control rooms, and advanced control room design and development process. This information will be used as a technical basis for developing future guidance and also to support confirmatory research for existing guidance. Also, this research will support a joint effort by the U.S. Department of Energy (DOE) and EPRI Nuclear Energy Plant Optimization (NEPO) to develop design guidelines for control room upgrades. The NRC may need to review those guidelines as they are applied in the U.S. nuclear industry.

HUMAN RELIABILITY ANALYSIS

Although the HRP has been performing human factors research for many years, the concept of using the archival data from those experiments for the planning of future experiments to specifically address HRA needs has only recently been incorporated into their long-range planning. Through the efforts of its signatories and the OECD NEA Committee on the Safety of Nuclear Installations (CSNI), the HRP has recognized that one of the most important needs in the HRA community is improved data and information. A high-priority task within the NRC's HRA Program is data collection and analysis. Further, the CSNI Working Group, WG Risk, which both the NRC and Halden support, has a task that focuses on HRA data needs.

Because of its long history in performing studies on topics related to human factors, Halden has the capability, facilities, and expertise to conduct simulator experiments and collect data to address HRA modeling and quantification issues. In briefing the Advisory Committee on Reactor Safeguards (ACRS) on the HRA and Human Factors programs on September 10, 2002, the NRC staff included a discussion on the HRP “Study of Control Room Staffing Levels for Advanced Reactors" (NUREG/IA-0137), with the objective of demonstrating how HRP expertise and facilities can support the NRC’s HRA research needs.

The HRP’s next 3-year program includes specific tasks focused on supporting HRA data needs. The NRC and other signatories are communicating and interacting with Halden on the topic of performing HRA-focused research. Informal meetings were held between the HRP and interested signatories at recent conferences. In addition, the HRP held an HRA-related workshop in Norway on November 5–6, 2002, which was chaired by a member of the NRC staff. Through these interactions, the NRC staff has developed confidence that the HRP can provide valuable support to the agency’s HRA research program. Specifically, the HRP can interface with and support the NRC’s “HRA Data Collection and Analysis” project, carried out at the Idaho National Engineering and Environmental Laboratory (INEEL).

During the next 3 years, the NRC staff expects that the HRP will design and execute studies focusing on testing HRA models and developing data for estimating human error probabilities. In particular, the staff expects that Halden experimental studies will be designed to develop objective measures of performance-shaping factors used in HRAs to account for factors that influence human performance under accident conditions. Furthermore, the HRP experiments will address issues related to specific accident sequences that are of regulatory importance, such as steam generator tube rupture. The HRP experiments will also be designed to generate information needed to test the underlying theories (e.g., cognitive information processes) and hypotheses used by HRA methods. Finally the HRP will collect human failure data generated during simulator studies. In fact, the HRP is in the process of reviewing past work with the objective of extracting information to support the estimation of human error probabilities.

The products of these studies will be HRP reports documenting why the studies were performed, how they were executed (including psychological protocols and measurements used, limitations of the studies, underlying hypotheses, etc.), what results were obtained, and how the results should be used for HRA purposes. The NRC will use the results of these studies to improve the quantification processes and data used by the various HRA methods (e.g., ATHEANA) as well as to perform HRAs as part of PRAs performed by the NRC (e.g., steam generator tube rupture PRA). The results will also be used to derive insights and lessons learned in order to improve the HRA review guidance, which is currently under development.