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.

One series of HRP fuel tests is of high interest to the NRC's current effort to revise the cladding embrittlement criteria in 10 CFR 50.46. The in-pile loss of coolant accident (LOCA) test series was designed in such a way that the results will be complementary to related investigations elsewhere, particularly NRC sponsored tests in a hot cell at Argonne National Laboratory (ANL). The Halden tests will focus on in-reactor effects that are different from those obtained in out-of-reactor tests.

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. Recently, the NRC issued NUREG/CR-6534 Vol4 "FRAPCON-3 Updates, Including Mixed-Oxide Fuel Properties" that made extensive use of experimental data from the HRP. These data demonstrate that the code used by NRC staff is adequate for a wide variety of fuel designs and reactor conditions.

By February 2004 memorandum, RES responded to the Office of Nuclear Reactor Regulation (NRR) User Need regarding a Duke Energy proposal to use mixed-oxide (MOX) lead test assemblies (LTA) at the Catawba reactor. The response made use of fission gas release data from Halden tests to confirm computer analyses of the LTA behavior. During the MOX Hearing in July, the NRC staff responded to Blue Ridge Environmental Defense League claims that data were limited. Extensive use of Halden fuel centerline thermocouple data were presented.

In FY-06, a RES contractor (Pacific Northwest National Laboratory) will review Halden data for enhanced helium production from mixed-oxide and integral burnable poison fuel rods (e.g., MOX Fuel Behavior Test IFA-597, HWR-729; Thermal and Gas Release Data, HWR-712). This will include not only production, but also helium adsorption (from initial fill gas) and release at high burnup due to helium concentration buildup in the fuel.

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 Post-irradiation examination

2 **Fuel Response to Transients**
2.01 Rim fuel investigations during reactivity transients
2.02 Loss of coolant
2.03 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. Fuel rod behavior codes have not been validated for extended burnups. 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 NRC's relationship with the materials testing aspects of the Halden reactor program is at a crossroads. For almost ten years, our principal contractor in the irradiation-assisted stress corrosion cracking (IASCC) area, ANL, has been providing Halden with ready-to-test specimens, which are irradiated to specific levels [up to about 3 displacements per atom (dpa)], and return shipped to Argonne for subsequent testing and examination. These test specimen irradiations supported research associated with environmentally-assisted cracking of light water reactor (LWR) materials. 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 and post-test evaluation of these specimens is being carried out at ANL in simulated LWR environments, and is expected to continue through 2005. Planned research addresses issues relating to BWR materials degradation, which is characterized by radiation damage in the range of 0 - 10 dpa. In the last five years, the Argonne program has produced NUREG/CR-6687, "Irradiation-Assisted Stress Corrosion Cracking of Model Austenitic Stainless Steel Alloys," and NUREG/CR-6826, "Fracture Toughness and Crack Growth Rates of Irradiated Austenitic Stainless Steels," describing the results of testing of these Halden-irradiated specimens. Two additional NUREG/CRs (Refs. 1, 2) are in the final stages of publication. Three additional NUREG/CRs are scheduled for receipt during the remaining fiscal year.

The last shipment of specimens from Halden to Argonne was completed in January 2005. At this point and including the January 2005 shipment, Argonne has all of the irradiated test specimens needed for the duration of the current scope and milestones. No additional irradiations are planned at the Halden reactor for supplying specimens to RES-funded programs. From this point forward, NRC's benefits from participation in the Halden program in this area will derive primarily from our continuing receipt of IASCC data generated from the Halden IASCC program itself, which is increasing in size and scope. The HRP is performing in-core IASCC crack initiation and crack growth rate tests. These tests involve the use of 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. In this way, any potential synergism between the reactor coolant environment and radiation exposure is replicated. The test matrix includes three materials (304, 304L, 347) and a range of fluences (7.0x1019 to 2.5x1022 n/cm2). Secondly, Halden engineers are in the leading stages of an aggressive program for the development and validation of in-reactor instrumentation for assessment of water quality and corrosion potential at, or near the in-core region. The instrumentation studies are very helpful adjuncts to the IASCC program, since they provide valuable information on the corrosion potential of the simulated coolant in the test loop. Results of both programs are transmitted to NRC by the Halden Work Report (HWR)-series of Halden reports, as well as by presentations at meetings attended by NRC staff.

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. The stress corrosion cracking data that we have, and will continue to receive will provide valuable input to deliverables for user need requests about environmentally assisted degradation of PWR (NRR-2003-001) and BWR (NRR-2002-026) internals, components and piping.

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.

INSTRUMENTATION & CONTROLS

The HRP has a recognized presence in the U.S. nuclear community. For example, the NRC has in the past used HRP operational support systems for development of new training support systems and simulator upgrades at the NRC's Technical Training Center (TTC) in Chattanooga, Tennessee. These HRP-developed tools have supported the upgrading of several full-scope reactor simulators. Another example is HRP's work in the area of instrumentation surveillance and monitoring techniques based on advanced decision algorithms(e.g., fuzzy logic, neural networks), which are now of 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 Process Evaluation and Analysis by Neural Operators (PEANO) system (a neuro-fuzzy expert system) has also been evaluated by several U.S. plants for application of this methodology. Other areas of research which HRP is involved include 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. HRP work on cable condition monitoring was recently the subject of an international workshop at Zurzach, Switzerland, in September 2004.

The Halden Reactor Project is currently developing a complementary, in situ condition monitoring technique for electrical cables which is based upon the NRC/FAA-Boeing initiative for a diagnostic and condition monitoring method for installed cable systems in operating nuclear power plants. This technique, when proven effective, can be used to determine the current condition of the wire system and detect incipient defects before failures can occur. Another objective is the prediction of remaining useful life, including the establishment of acceptance criteria. The completed phase 1 of the project included collection of aged cable samples from the HBWR reactor and the development of the Line Resonance Analysis (LIRA) method. Phase 2 (2005/2006) will continue the development of LIRA methodology, conduct tests with naturally and artificially aged cables, and setup collaborative work with other organizations. Phase 3 (2006-2008) of the project will test cable samples with different insulation material, and investigate the effectiveness of the method to detect and locate thermal hot spots, localized defects, discontinuities in electric properties, and on-line tests during plant operation.

Over time the HRP has expanded its research efforts in digital systems safety. The HRP's early research in the area of digital system safety and analysis 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). In the current 3-year research program (i.e., the 2003 - 2005 research cycle), the HRP modeled its program on the NRC's "Research Plan for Digital Instrumentation and Control," SECY-01-0155, dated August 15, 2001. Specifically, the HRP structured its research similar to the NRC to ensure complementary effort on systems aspects of digital systems, software quality assurance, digital system reliability, and risk assessment of digital systems. HRP has demonstrated expertise in risk assessment of human-system interfaces and commercial-off-the-shelf (COTS) systems, both of which hold significant interest for the NRC. HRP's research to date has been of value to the NRC by providing the needed research and operational data to support development of a technical basis for advanced, software-based systems should they be proposed for use by U.S. licensees.

The products and tools created during the next few years will be useful for establishing the technical bases for realistic safety decisions pertaining to software-based digital systems, thereby preparing the NRC for future safety issues involving current and new digital system designs and technologies for safety-related applications. The Project's next three-year research program focuses on software systems dependability issues related to the engineering and architecture of digital safety systems. Some of the metrics of dependability are reliability, safety, and security, and the HRP plan will investigate the importance of these parameters at various points in a system's life cycle. Specific areas of research are Requirements Engineering, Fault Tolerance, Pre-Developed Software, and Integrated Tool Environments. Also, HRP will establish a software engineering laboratory - the SElab - which will be an organizational unit that provides the systems and resources needed to support research, development, assessment, consultancy and training related to safety-oriented software engineering. Some examples of the SElab's utility are: to maintain and continually improve a baseline software process; to apply the baseline process in empirical research on relevant software engineering issues; serve as a training facility on issues researched on, e.g., software quality management, software process improvement, auditing; to facilitate collaboration with other laboratories, internally at the Halden Project and externally; to support development of tools useful to software engineering; and to facilitate controlled experiments with methods, techniques, and tools to evaluate their potentials and risks. Given the NRC's focus on software quality in the Digital System Research Plan, FY2005 - FY2009, the HRP's 2006 - 2008 research program will again focus on research issues complementary to NRC's efforts.

The NRC staff has provided feedback to the HRP on its 2006 - 2008 research program, resulting in HRP aligning its work with the recently revised NRC Digital System Research Plan, FY2005 - FY2009, particularly with regard to outputs and outcomes. The NRC has placed emphasis on obtaining measurable products for all of the research projects it undertakes, such as software tools, practical and useful review guidance, and objective acceptance criteria. Because the HRP has responded favorably to NRC's feedback by incorporating many of NRC's suggestions into its own research program, the NRC staff believes that the research products generated from the HRP research over the next few years will aid the NRC in establishing the technical bases for realistic safety decisions regarding current and new digital system designs and technologies for safety-related applications. 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 reactor operators and vendors, thereby leveraging the agency's digital I&C resources as it establishes a technical basis for reviewing these advanced systems.

Through various 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 continues to improve 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 can be effectively integrated into the NRC's regulatory programs. 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

A primary goal of the RES human factors 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 this goal and ultimately to 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 HRA.

The NRC used HRP products as a basis for review guidance on alarm processing, filtering, integration, and prioritization (NUREG/CR-6684, "Advanced Alarm Systems: Revision of Guidance and It's Technical Basis"). 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, which were all incorporated into NUREG-0700, Rev.2., "Human-System Interface Design Review Guidelines." Additionally, the HRP conducted a study on staffing for advanced reactors. The results of this study serve as a basis for developing guidance (NUREG-1791, "Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements of 10CFR 50.54(m).") in response to an NRR User Need on the evaluation of exemption requests to the staffing requirements of 10 CFR 50.54(m). Other recent guidance documents that have been based in part on HRP research include: Chapter 18, "Human Factors Engineering," of the Standard Review Plan (NUREG-0800); and NUREG-0711, Rev.2., Human Engineering Program Review Model. These guidance documents were developed in response to NRR user needs and are for use in reviewing changes to control stations at current reactors and for licensing reviews of new reactors, for license amendment reviews, and for inspections. Recently, some of these guidance documents have been used: to review NEI-04-01, "Draft Industry Guideline for Combined License Applicants Under 10 CFR Part 52, Rev. D."; in an inspection related to a deviation from plant's fire protection plan; to support proposed rulemaking and an associated Regulatory Guide related to crediting manual actions in place of certain physical barriers; and to support licensing of a fuel fabrication facility for the Office of Nuclear Materials Safety and Safeguards (NMSS).

An important aspect of participation in the HRP is that it gives the NRC access to facilities that are otherwise unavailable in the United States, as well as, 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 in the nuclear industry. 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.

A primary benefit of the HRP is the availability of one of only two Western style light water reactor 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 and a BWR simulator based on the 1160-MW Swedish Forsmark-3 plant. 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. This facility has also allowed the performance of other NRC work to evaluate the use of human performance simulation against human performance in the simulator environment. This resulted in a peer reviewed article in the international journal Cognition, Technology, and Work on “Predicting nuclear power plant operator performance using discrete event simulation” (Yow, et.al., 2005). 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. The capability is also being applied to enhancement of the BWR/4 simulator at the NRC’s TTC using Halden’s Picasso program to improve the graphical user interface. HAMMLAB includes a modifiable 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 world class capability in the area of virtual and augmented environments, which are useful, cost-efficient tools for applications such as control room design, outage planning, training, and decommissioning, as well as for research. As the U.S. industry begins to use the virtual reality (VR) and augmented reality tools, the NRC will have to determine how to assess the application of VR to licensing issues, such as, control room design and operator licensing. For instance, Halden is working with EPRI, the Callaway Plant, and the Nuclear Engineering Department at the University of Illinois on a case study involving the application of CREATE to develop a Callaway Plant virtual control room model as part of the modernization of the Callaway main control room.

In the 2006-2008 program in human factors and human reliability, the HRP proposes to investigate the context concept, task complexity factors, sustained workload as a performance shaping factor, with an aim to provide data for the estimation of probabilities of human failure events for post accident operation. Furthermore, HRP plans to investigate work practices in computer-based control rooms and team co-operation in new operational settings.

They will also address issues of importance both to current nuclear power plant (NPP) control rooms and future advanced reactor control centers, by developing and evaluating Human System Interfaces (HSIs) that deliver relevant data and information in comprehensible and understandable formats and present the data and information in a manner that does not cause mental overload or confusion. Their overall goal is to work towards a unified HSI design concept including advanced HSIs. The HRP proposes to continue its work providing practical and efficient methods supporting the control center design and evaluation process. They also propose to establish a simulator-based test-bed in the Halden Man-Technology-Organization (MTO)-lab, building on and complementing the simulation capabilities already present in the laboratory. The purpose is to investigate design characteristics for new advanced reactor control rooms/centers.

HRP research in the virtual environments area will address virtual reality techniques which can support early human factors design input in control room design projects. Another proposal is to improve the Project's radiation visualization methods to visualize the distribution of the radiation levels in 3D space. The VR-based training element will concentrate on computer-supported cooperative work and multi-user systems to support training of teams.

The HRP will follow technology advances carefully, explore candidate technologies for best utilization, and identify potential weaknesses and safety concerns associated with different solutions. The prioritized areas are sensor validation, condition monitoring, early fault detection, diagnostics, prognostics, and new regimes for integrated advanced control. The proposed work will include assessment of various technological proposals and development of prototypes for evaluation. Experience will be collected in the framework of the MTO-lab with demonstration of integrated systems solutions.

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 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, the HRP has supported a joint effort by the U.S. Department of Energy (DOE) and EPRI Nuclear Energy Plant Optimization (NEPO) project to develop design guidelines for control room upgrades. The NRC will need to review those guidelines as they are applied in the U.S. nuclear industry.

HUMAN RELIABILITY ANALYSIS

Human reliability analysis is performed as part of probabilistic risk analysis (PRA) to support risk-informed regulatory decision making. Given the increasing importance of the role of PRA in regulatory decision making, it is necessary to use HRA methods, tools, and data that can, for a given risk-informed decision, adequately account for the human contribution to risk. However, HRA is viewed by experts as the one area that contributes significantly to the uncertainties of PRA results. The quality of available HRA data is a major concern for the practitioners and decision makers. Data are needed not only for estimating of human failure event probabilities but also to improve the models used by the various HRA methods. The OECD Nuclear Energy Agency (NEA) Committee on the Safety of Nuclear Installations (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 that can be applied to HRA modeling and quantification issues. During the last 3 years, HRP devoted considerable efforts on designing and executing experiments related to human actions modeled in PRA accident sequences. Initial results demonstrated the usefulness of the HRP experiments for HRA from many perspectives:

- From the HRA perspective, the initial results indicate that experimental work can generate information needed to improve HRA methods in terms of underlying theories as well as actual quantitative models employed to focus the analysis on the most risk-significant issues. For example, initial results demonstrated the experimenter’s ability to make interesting manipulations of performance shaping factors (PSFs) (e.g., time pressure and information load) to see their effects on performance and determine which PSFs (and combination of) can be more pervasive than others. Also, these results demonstrated that analysts can use simulator studies to perform comparisons of predicted and observed behaviors and explain the difference.

- From a safety perspective, the results indicate a high degree of confidence in performing human actions under conditions typically modeled in PRA. The results also provide evidence of a high degree of success as well as evidence of less optimal behavior in challenging scenarios. Further, they provide indications for their relative likelihood and help explain contributing factors to both types of behaviors. Therefore, the results could be used to improve safety in NPPs by identifying potential “vulnerabilities,” e.g., crew communications, work allocation, decision making, procedures, and training.

- These studies can also have an impact on the overall PRA quality. For example the BWR results indicate that scenario-specific insights (e.g., challenges in dealing with loss of offsite power) and situation-specific insights (e.g., complications associated with establishing low pressure injection system during medium loss-of-coolant-accident) can be derived for use in PRAs. Also, the BWR study indicates that simulators can be used to better understand the contribution of human performance to the initiating event frequency, typically not practiced today. (Currently, when estimating initiating event frequencies, the human-introduced initiating events are treated as random events and are directly combined with equipment-induced initiating events)

During the next three years, Halden intends to continue the current line of research, further investigating “complexity,’ and related PSFs, and exploring different “crew characteristics.” HRP also intends to collect error data generated during simulator studies and analyze them to identify how crews are led to make mistakes. Another major task for next 3 years is for HRP to improve its methodology for performing HRA work, document it and distribute it to signatory countries for comment. The methodology will address issues related to validation and generalization of the experimental results and approaches for resolving them, possibly by repeating the experiments in different settings. It appears that Halden is committed to fully support experiments in various settings.

Furthermore, Halden intends to load new and archival data into the NRC's Human Repository and Analysis (HERA) database, so that HERA can be used as a gateway for Halden's HRA studies to other signatory counties. It appears that Halden has committed the resources needed to accomplish this; Halden has temporarily assigned staff to the Idaho National Laboratory to work on this objective.

While simulators provide an ideal environment for conducting studies of crew performance under conditions similar to those modeled in a PRA/HRA, thus far, they have been underutilized for this purpose. Halden facilities and expertise are unique for these types of NPP studies. However, Halden has only recently incorporated into their long-term planning, work addressing HRA needs and therefore it needs the continued support of signatory countries to succeed in this area. Since the Halden workshop on HRA (November 2002), the NRC has had strong interactions with HRP staff to ensure that the results of this work will indeed address HRA issues. Interactions included working with Halden to identify scenarios of interest for HRA, review and comment on proposed experiments, and PRA/HRA technology transfer through staff visits (both at Halden and at the NRC) and staff exchanges. It is noted that Halden has been very forthcoming in committing resources and attention needed to these activities. These efforts appear to produce the desired results. This work will be used to provide insights into future revisions of NUREG-1792, "Good Practices for Implementing Human Reliability Analysis (HRA)" and it's companion document (in development) on HRA methods evaluation. These documents will be used by regulatory reviewers to assess HRAs that are submitted in support of risk-informed licensing actions.

References

1. “Crack Growth Rates of Irradiated Austenitic Stainless Steel Weld Heat Affected Zone in BWR Environments,” ANL 04/20, O.K. Chopra, B. Alexandreanu, E.E. Gruber, R.S. Daum, and W.J. Shack, to be published August 2005

2. “Irradiation-Assisted Stress Corrosion Cracking Behavior of Austenitic Stainless Steels Applicable to LWR Core Internals,” ANL 04/10, H.M. Chung and W.J. Shack, to be published in August 2005.