SECY-99-0290

December 27, 1999

FOR: The Commissioners

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

SUBJECT: NRC PLANS TO PARTICIPATE IN THE OECD HALDEN REACTOR PROJECT DURING 2000 - 2002

PURPOSE:

To inform the Commission of the results of the Agency's past participation in the Organization for Economic Cooperation and Development (OECD) Halden Reactor Project and staff plans to continue participation during 2000 - 2002.

BACKGROUND:

The Halden Reactor Project is a cooperatively funded international research and development project that operates under the auspices of the OECD - Nuclear Energy Agency with the sponsorship of 21 different countries. The research encompasses (1) nuclear fuels and materials performance and (2) process control development and qualification, which includes both human factors research and the test and development of advanced computerized operator support systems.

The Nuclear Regulatory Commission (NRC) has participated in the OECD Halden Reactor Project 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 NRC uses Halden-generated products and information to develop and extend the applicability of analytical tools and as the technical basis for regulatory guidance. The staff plans to continue its participation in the 2000 - 2002 agreement period because of the benefits received and the leverage of resources by participation with 14 signature and 11 associate members representing 21 countries.

The benefits derived from the past and continued participation in the OECD Halden Reactor Project include:

1. Testing of UO_2 fuel that has achieved very high burnup in the Halden reactor was done prior to increasing commercial burnup limits. This testing has also resulted in the quantification of important changes in thermal properties. Degradation in thermal conductivity, increases in fission gas release, and changes in gap conductance have all been measured and have been used to upgrade the NRC's fuel rod codes, FRAPCON and FRAPTRAN, for applications up to 65 GWd/t burnup. These codes are used for audit purposes during licensing reviews and for other special analyses.

2. Testing that has been initiated recently on properties of new fuel cladding alloys that are being introduced in U.S. plants to reach higher burnups with more reliability. Corrosion rates and creep rates for low-tin Zircaloy, Zirlo, and M5 cladding will be measured. These results will be used to update the NRC's fuel rod codes for application to the new cladding alloys.

3. Materials that have been irradiated at this facility have subsequently been provided for use by the NRC staff for performing tests to evaluate the effects of irradiation-assisted stress-corrosion cracking on reactor internals. Results from this work have been used by NRR for more accurate assessments of crack growth rates in irradiated components. This has resulted in licensee reduction in inspections and outage times.

4. Products from Halden formed part of the technical bases for the development of new regulatory guides on software quality and life-cycle, as well as review guidance such as revisions of the Standard Review Plan (Chapters 7 and 18) on Advanced Instrumentation and Controls, Man-Machine Interfaces, Software Quality Assurance, and Advanced Control Room Design Reviews.

5. The results of human factors research and experiments performed in the Halden Man-Machine Laboratory (HAMMLAB), which is operated by a highly qualified staff that plans and conducts experiments related to human error, human performance, and the effects of computer-driven interfaces. The results of this research serve 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. Halden's program on human error analysis is being developed to contribute to improved human reliability information. This will contribute to NRC's risk-informed regulatory activities.

6. Data and information from test and evaluation, led to the development of new review guidance for instrumentation and control (I&C) technology. This information has been and can be used to develop technical bases for realistic safety decisions that will prepare the Agency for the future by evaluating safety issues involving current and new designs and technologies. 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.

7. A forum for international cooperation and information exchange with 21 different countries.

8. International cooperative funding that provides leverage for the NRC research funds. The NRC gets the benefits of a $40M three-year research program for a contribution of $2.85M.

Attachment 1 is the Proposed Program Plan for the next three-year Joint Program Agreement. Attachments 2 is the Executive Summary of the "Achievements of the Halden Project Programme in the 1997 - 1999 Period," and Attachment 3 is the Executive Summary for the Man-Machine Systems and Fuel Performance and Materials Testing program.

DISCUSSION:

The OECD Halden Reactor Project (HRP) is an internationally funded and staffed nuclear research and development organization located in Halden, Norway. Currently there are 21 countries that cooperate in the HRP. A primary facility of the Halden Reactor Project is the Halden Boiling Water Reactor that currently operates at 18 to 20 Megawatts (MW) and is contained within a mountain. Norwegian authorities have re-licensed the reactor for an additional 10 years, to 2010. The reactor is fully dedicated to instrumented in-reactor testing of fuel and core materials behavior. It also delivers steam to a nearby paper factory.

The research programs at the Halden Project address two broad areas of interest to the NRC: 1) nuclear fuels and materials performance and 2) process control development and qualification, which includes both human factors research and the test and development of advanced computerized operator support systems. The programs are structured to respond to the needs of all member organizations within the international nuclear community. Since the 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, over 300 in-reactor experiments have been performed.

Following the early development of in-core instruments on fuel rods, in-reactor testing of basic fuel rod reliability parameters was conducted with the objectives of defining performance data and exploring mechanisms. This in-core measurement capability has been expanded through the development of experimental rig and loop systems in which reactor fuel and materials can be tested under simulated water reactor conditions. Increasingly, fuel reliability and safety considerations are emphasized under the jointly financed program while development and optimization issues are addressed in bi-lateral programs with specific users. The Halden reactor has a large number of experimental channels in the core that are capable of handling many test rigs simultaneously. In the coming 3-year period, approximately 14 different investigations will be conducted on fuel high-burnup capabilities during normal operation, about six efforts will be initiated related to fuel response to transients, and another six studies will be undertaken on fuel reliability issues.

The Halden reactor is now one of the leading research facilities in the world for the study of irradiation assisted stress corrosion cracking (IASCC). The NRC directly benefits from the irradiations they have performed to support the IASCC work being done at Argonne National Laboratory (ANL) for the NRC. Specimens have been irradiated for slow strain rate testing, crack growth rate testing, and fracture toughness tests at ANL. Halden is unique in its capability to perform the testing under prototypical conditions in a radiation environment. They have also developed unique approaches to fabricating specimens that make it easier to use materials irradiated in power reactors as well as test specimens irradiated in Halden.

As part of the Joint Program, Halden is also participating in a program of research on IASCC developed by the Cooperative International Research Program on IASCC (of which the NRC is a member). They are doing IASCC tests under uniaxial loading and biaxial loading and tests using fracture mechanics specimens.

The OECD Halden Reactor Project also maintains and is expanding 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. For nearly 20 years, the HAMMLAB has included a full scope VVER-440 simulator, based on the Loviisa Power Plant in Finland. Over the last 3 year-period, the project has acquired a Pressurized Water Reactor (PWR) simulator based on the Fessenheim Plant, a French 900 MW PWR, and is building a Boiling Water Reactor (BWR) simulator based on the 1160 MW Swedish Forsmark-3 Plant, as well as upgrading the VVER simulator. In addition, Halden has developed a set of advanced computerized operator support systems for control rooms, which it tests and upgrades continually. 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 program has also 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 arena.

As part of the Joint Program, Halden also conducts research to assure and enhance the quality of computer-based systems. The research addresses topics covering various types of instrumentation and control systems as well as all the life-cycle phases of these systems. The development and application of both formal and conventional methods to verify and validate high integrity software are also subjects of research at the project.

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. Attachment 4 contains a list of the current members of the OECD Halden Reactor Project and a description of the Steering Bodies.

The results from the research conducted at Halden are distributed to the signatory and associate members in the form of technical reports. Halden publishes approximately 50 reports per year. There are also 3 to 4 workshop meetings per year on specific topics. About every 18 months, Halden conducts an Enlarged Halden Program Group Meeting. At these meetings, research results are presented from programs at Halden as well as from member countries. This provides the attendees with a window to international activities on fuel performance and materials testing, digital instrumentation and control system safety and reliability issues, and human factors issues associated with computer-driven interfaces.

The Halden experimental program is conducted in two ways. The first is the Joint Program, which is a program of work jointly agreed to by members of the project that is planned over 3-year periods and reviewed annually. This part of the program leverages the NRC's funds since all data and information generated from the Joint Program are available to the members for their use. The members can also establish bi-lateral agreements to conduct specific

experimental programs. These bi-laterals are funded entirely by the sponsor and the data are only disclosed to other project members at the sponsor's discretion. The bi-lateral efforts and the Joint Program benefit from the synergy of the knowledge that the researchers gain from performing the research.

The Halden project, through its long operation, has proven to be highly versatile and responsive to the changes of research and development needs. It is a relatively small and non-bureaucratic operation where recommendations and priorities by members are accommodated in a flexible manner.

PLANS FOR WORK AT HRP DURING 2000 - 2002:

The NRC staff met with members of the Halden staff on October 20, 1998, and again on October 29, 1999, to discuss the next 3-year program as proposed in the draft report, "Halden Reactor Project Program, Proposal for the 3-Year Period, 2000 - 2002." This report contains proposals for research and development programs on Fuels and Materials and Man-Machine Systems.

The Fuel and Materials Program encompasses four major topics:

- Fuel High Burn-Up Capabilities, Normal Operating Conditions
- Fuel Response to Transients
- Fuel Reliability Issues
- Plant Lifetime Assessments, including IASCC

Experimental and analytical activities will be performed to assess fuel performance capabilities and property changes at high burn-up. The extensive use of refabricated and instrumented commercial fuels is anticipated. The proposed work on safety transients is intended to complement investigations carried out elsewhere on the loss-of-coolant and reactivity-initiated transients. Tests on short-term dry-out associated with anticipated transients without scram (BWR oscillations) are also contemplated. Investigations on fuel performance anomalies arising from current operational experience will be conducted in close collaboration with participants with the purpose of identifying realistic design or operational remedies. Tests are being planned in a sweep-gas rig on release rates of short-lived fission products, particularly iodine and cesium, to provide the basis for an overhaul of the industry standard, ANS-5.4, which describes a standard fission product release model. The NRC participates in this standards activity and uses the standard model for setting source terms for several design-basis accidents. The activities on plant lifetime assessments focus on stress corrosion cracking of structural reactor materials under the combined effect of water chemistry and radiation environment. The proposed program relies on the Halden in-reactor measurement capabilities, on rigs designed to produce a variety of test conditions, and on in-reactor water loops able to create flexible coolant environments.

The Man-Machine Program focuses on four areas:

- Experimental Program and Operation of HAMMLAB
- Human Factors and Control Room Engineering
- Plant Operational Support
- System Safety and Reliability

Computerized operator support systems are to be introduced in the upgraded HAMMLAB for testing to demonstrate the merits of such systems in an integrated control room environment. The activities on human factors and control room engineering area will extend the knowledge of human performance in process control environments and of how this can be incorporated in control room design review guidance. The research conducted in this area will address issues of human error and human reliability. The proposed work on plant-performance monitoring and optimization is intended to develop system solutions that have the potential to improve plant performance as well as operational safety. The aim of the activities on system safety and reliability is to provide methods to enhance the reliability of automated systems and, in particular, safety-critical software for digital I&C. The technical basis for the Man-Machine Program consists of the upgraded test facility HAMMLAB, together with the test methodology, the software, simulation, and control room expertise developed around it.

NRC PARTICIPATION IN 2000 - 2002 HALDEN PROGRAM:

The cost of participation during the 1997 - 1999 agreement period was 23M NoK (Norwegian Kroner) or $3.1M. The NRC's share according to an OECD formula is 23.5 NoK, for the 2000 - 2002 period. During the RES self-assessment and budgeting process $850K was allocated for this effort in FY-2000. It is expected that $1.0 M will be available in FY 2001 and 2002. Halden project management has agreed, that based on the current exchange rate and with payment early in the year, $2.85M would meet our obligation. As always, it is understood and the agreement will be signed with a statement that funding will be subject to the availability of appropriated funds.

Based on our latest contacts, we understand that all of the other member countries have either already signed the agreement or expressed their intent to extend their participation in the Halden Reactor Project for the 2000 - 2002 program period.

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.

CONCLUSION:

The NRC plans to continue participation by signing an agreement with the OECD Halden Reactor Project for the period January 1, 2000, to December 31,

2002. The work performed at Halden contributes to meeting the agency 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, the leverage achieved by sharing the costs with other sponsors makes resource utilization efficient and effective, by getting the benefits of a $40M three-year research effort for $2.85M.

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Attachments: As stated

ATTACHMENT 4

MEMBERS OF THE HALDEN REACTOR PROJECT

The members of the OECD Halden Reactor Project consist of signatory members and associated party members. Representatives from signatory members of the Halden Reactor Project may vote on issues brought before the Halden Board of Management and the Halden Program Group. Representatives from associated members of the Halden Reactor Project may attend meetings of the Halden Board of Management and the Halden Program Group, but have no vote on issues addressed by these bodies. The signatory members and associates are:

- The Norwegian Institutt for Energiteknikk
- The Belgium Nuclear Research Center
- RISO National Laboratory, Denmark
- The Finnish Ministry of Trade and Industry (VTT)
- Electricite de France
- Gesellschaft fur Anlagen-und Reaktorsicherheit, Germany
- The Italian Ente per le Nouve Tecnologie, l'Energia e l'Ambiente (ENEA)
- The Japan Atomic Energy Research Institute (JAERI)
- Korean Atomic Energy Research Institute (KAERI)
- The Spanish Centro de Investigaciones Energeticas, Medioambientales y Tecnologias
- The Swedish Nuclear Power Inspectorate (SKI)
- The Swiss Federal Nuclear Safety Inspectorate
- British Energy, United Kingdom
- United States Nuclear Regulatory Commission

The associated party members of the Halden Project are:

- Comissao Nacional de Energia Nuclear, Brazil
- Nuclear Research Institute, Czech Republic
- Atomic Energy Research Institute, Hungary
- N.V. Tot Keuring van Elektrotechnische Materialen (KEMA), the Netherlands
- Russian National Research Center, Kurchatov Institute
- Slovakian Nuclear Power Plant Research Institute, Slovak Republic
- Institute for Protection and Nuclear Safety (IPSN), France
- Argentinian National Nuclear Commission , Argentina

Associated Parties In The USA:

- ABB Combustion Engineering N.P
- Electric Power Research Institute (EPRI)
- General Electric Company (GE)

Steering Bodies:

Under the Halden Agreement, an international committee, known as the Halden Board of Management, reviews and approves the research and experimental program and budgets on a yearly basis. The Halden Board of Management meets twice a year to conduct its business. Each signatory member of the Project has a representative on the Halden Board of Management. The U.S. Nuclear Regulatory Commission's representative to the Halden Board of Management is Dr. Margaret Federline, Deputy Director, Office of Nuclear Regulatory Research.

An international technical group, known as the Halden Program Group, provides input to the research program and reviews and evaluates the products from the research. The Halden Program group meets two to three times a year to conduct its business. Each signatory member and associate member of the Project has a representative on the Halden Program Group. The U.S. Nuclear Regulatory Commission's representative to the Halden Program Group is Dr. J. J. Persensky, Senior Human Factors Analyst and Team Leader, Regulatory Effectiveness Assessment and Human Factors Branch, Division of Systems Analysis and Regulatory Effectiveness, Office of Nuclear Regulatory Research.