NRC STAFF RESPONSES TO RECOMMENDATIONS
ON SPECIFIC RESEARCH ACTIVITIES CONTAINED IN
NUREG-1635, VOL. 9, "REVIEW AND EVALUATION OF THE NUCLEAR
REGULATORY COMMISSION SAFETY RESEARCH PROGRAM"

On April 7, 2010, the Advisory Committee on Reactor Safeguards (ACRS) submitted a letter to the Honorable Gregory B. Jaczko enclosing Volume 9 of NUREG-1635, "Review and Evaluation of the Nuclear Regulatory Commission Safety Research Program." That report contains a number of observations and recommendations about the U.S. Nuclear Regulatory Commission's (NRC's) safety research program. The NRC staff responses follow below.

Life Beyond 60

The staff agrees with the ACRS observation that the critical research required for license renewal beyond 60 years generally relates to aging management of passive systems, structures, and components (SSCs), including the reactor coolant system, the reactor internals, concrete, cables, and support system components such as buried piping. The staff also agrees with the ACRS observation that efforts should be made to identify degradation processes that are not now manifest or anticipated, and that NRC research should be coordinated with the work being done by the Department of Energy (DOE) and the industry. In support of these goals, the staff has several initiatives underway. The Office of Nuclear Regulatory Research (RES) has been working with the Division of License Renewal in the Office of Nuclear Reactor Regulation (NRR) to:

- Develop an Expanded Materials Degradation Assessment (EMDA) to verify current assumptions regarding materials degradation during a subsequent license renewal period.

- Hold recurrent NRC/industry workshops on the status of operating experience from the initial renewal term and industry research activities to address aging management technical issues for a subsequent license renewal.

- Assess results from implementation of license renewal aging management programs and recommend improvements for a subsequent license renewal period.

- Continue to develop domestic and international partnerships to share expertise, capabilities, and resources related to aging management research for long-term operations.

The staff is also cooperating with the DOE Light-Water Reactor Sustainability Program (LWRSP) to expand on the proactive materials degradation assessment NUREG/CR-6923, "Expert Panel Report on Proactive Materials Degradation Assessment," published in February 2007. The EMDA will update existing information and also add information on safety-related secondary systems, concrete structures, safety-related instrumentation, and low-power cable insulation. Moreover, according to a recent Memorandum of Understanding (MOU), the staff and DOE will also share information as the Electric Power Research Institute (EPRI) is updating its Materials Degradation Matrix.

RES is also working to leverage international expertise and experience in this area. For example, the staff is working through the Organization for Economic Cooperation and Development (OECD), Nuclear Energy Agency's Committee on the Safety of Nuclear Installations on cooperative research efforts related to long-term operations. The staff is also working with the International Atomic Energy Agency (IAEA) on a 3-year Coordinated Research Program on "Continued Operations Beyond 60 Years in Nuclear Power Plants," and has agreed to co-host (with DOE) in 2012 the next IAEA Plant Life Management meeting.

RES is strengthening the connection between the activities mentioned above and existing programs that can inform Life Beyond 60 research. For example, staff will review licensees' aging management programs to verify their effectiveness to adequately manage aging effects. Also, RES staff is actively conducting research into the effects of irradiation-assisted stress corrosion cracking (IASCC) on core internals. The staff agrees that one of the critical issues for extended operating periods is whether the current correlations for reactor pressure vessel neutron irradiation embrittlement can be extrapolated to 80 years (or more) of operation. The staff will collaborate with domestic and international partners in the "Development of Predictive Models of Neutron Irradiation Embrittlement in Reactor Pressure Vessel Steels to Support Worldwide Efforts on Nuclear Power Plant Life Extension" program that will begin with a meeting in Rockville, MD, on September 14–15, 2010.

The staff is also following other research efforts being undertaken by the DOE's LWRSP that includes research into the long-term aspects of nuclear materials aging and degradation; advanced light-water reactor nuclear fuel development; advanced instrumentation, information, and control (II&C) system technologies; risk-informed safety margin characterization; advanced modeling and simulation tools; and efficiency improvement. As appropriate, RES is coordinating research efforts with the LWRSP, including the EMDA collaborative work. RES staff is also following the work the LWRSP is performing on advanced II&C replacement systems and on other economic improvements (e.g., extended power uprates).

Digital Instrumentation and Control Systems

The ACRS noted that RES has developed a Digital Instrumentation and Control (DI&C) System Research Plan to address the critical issues involved in the application of digital technology to safety systems. RES recently completed an update to the DI&C Research Plan after extensive input from and reviews by the Office of Nuclear Material Safety and Safeguards (NMSS), the Office of New Reactors (NRO), NRR, and the ACRS. The ACRS report also noted the formation of the DI&C Steering Committee that has provided oversight of working groups formed to address specific regulatory issues identified by the industry as needing additional guidance. The ACRS noted that the subsequently issued Interim Staff Guidance has provided much needed and valuable guidance to industry and for staff reviews. The staff agrees with the ACRS recommendation that the DI&C Steering Committee could assist in keeping research focused on products that will be of use to NMSS, NRO, and NRR.

Fire Safety

We appreciate the Committee's feedback on our Fire Safety research program and agree that ongoing and future research should address such issues as the effects of fire and heat on fiber

optic cables, the effects of heat on digital equipment, and smoke damage to digital signal processing and computation modules. To date, limited knowledge has been acquired on the effects of fire on fiber optic cable through observation of testing done by the Naval Research Laboratory that has shown the limiting components in the digital system are the end devices that process the optical signal and control electrical equipment. To address further research needs, a literature search will be conducted to identify known vulnerabilities of digital equipment and systems, and a project has been initiated with the National Institute of Standards and Technology (NIST) to evaluate the effects of smoke on digital components.

The staff agrees that research priorities and programs should anticipate emerging applications and intermediate- to long-term requirements that are not fully dictated by current user needs and, therefore, the staff will take every opportunity to do so within budget and schedule constraints. Two examples at NIST include the Cable Response to Live Fire NUREG/CR-6931 testing to develop a thermally-induced electrical failure model and the electrical cable heat release rate and flame-spread testing for future fire model applications. This work has been useful to address questions raised as part of the National Fire Protection Association (NFPA) 805 Frequently Asked Questions program.

We agree that additional testing and fire experiments through collaborative efforts with the U.S. industry and international organizations should be encouraged and supported. We are updating the Fire Research Addendum to the EPRI MOU and are continuing or planning joint programs on direct current circuits, incipient detection equipment, and Phenomena Identification and Ranking Table generation and expert elicitations for electrical circuit failure. In addition to EPRI, RES is also cooperating with the University of Maryland on selected fire research projects. On the international front, RES participates in the OECD International Fire Event data collection program.

We further agree that additional information is needed to evaluate such issues as fire initiation frequencies, human-caused fires, effectiveness of detection and suppression, and propagation of heat and smoke through compromised fire barriers that are uniquely associated with personnel activities and SSC configurations during plant shutdown. The fire risk guidance for low power and shutdown (LP&SD) operation is being developed primarily by NRC staff with input from EPRI. A draft of the fire LP&SD method has recently been circulated internally and to EPRI for their preliminary comments in preparation for issuance of the document for formal public comment. The LP&SD document will be published for use as interim guidance while we continue to work with EPRI to update it in a future effort. The present draft of the interim guidance document includes consideration of fire initiation frequencies, human-caused fires, effectiveness of detection and suppression, and propagation of heat and smoke through compromised fire barriers.

Reactor Fuel

The ACRS noted that "NRC does not have empirical or analytical capability to quantitatively assess the risks of Pellet Cladding Interaction (PCI) fuel failures during anticipated operational occurrences (AOOs) on current or future fuel designs."

The staff believes that the assessment of risk is addressed qualitatively by NRO and NRR by reviewing fuel-operating limits established by each plant. These limits are based on test reactor data and are considered by NRC in reviews of licensee safety analyses, thereby ensuring safety. The NRC staff continues to participate in international programs, to communicate with the international research community, and to monitor new developments concerning PCI and will take appropriate action as necessary.

This issue was discussed at an ACRS Materials, Metallurgy, and Reactor Fuels Subcommittee meeting on March 3, 2009, which included presentations by NRR and RES staff, as well as the industry. The RES presentation included information describing our participation in the Studsvik Cladding Integrity Project (SCIP), which is a multilateral international program attempting to develop a mechanistic understanding of the phenomenon affecting PCI. In addition to a broad experimental program investigating not only PCI but other fuel and cladding phenomena, the SCIP program is attempting to use the results to improve fuel code modeling capabilities.

The issue was also raised to the ACRS Full Committee in June 2009. NRC staff stated that PCI failures are of low safety significance. Industry representatives from AREVA, Global Nuclear Fuel, and EPRI presented various views opposing new regulatory criteria on PCI failures. The Committee decided that this is not an immediate safety concern. NRC staff is willing to discuss this issue in more detail with the Committee upon its request to the staff.

Human Factors and Human Reliability

We appreciate the Committee's assessment that NRC's Human Factors and Human Reliability Assessment (HRA) research programs and activities are based on sound rationale, focused on both the near- and long-term needs of the agency, and yield products of use to the regulatory process.

In alignment with the Committee's recommendation and the Commission's direction as part of its Benchmarking and Model Differences projects, the staff is investigating and evaluating the validity of the assumptions behind the HRA models. The staff plans to continue to keep the ACRS informed of progress in this area.

Materials and Metallurgy

RES agrees with the ACRS observation that the Proactive Management of Materials Degradation (PMMD) program needs to maintain its momentum and to improve its focus. In consultation with NRO and NRR, RES has undertaken activities to ensure this. Specifically, RES, NRO, and NRR staff members have developed a revised user need that will:

- Evaluate degradation management of existing in-service inspection and mitigation efforts.
- Evaluate the effectiveness of licensees's aging management programs.

- Expand upon the initial NUREG/CR-6923 findings by evaluating aging in other important components (e.g., containment, low-voltage power cable, and secondary-side piping) and considering operating periods beyond 60 years.

- Develop domestic and international partnerships to share expertise, capabilities and resources related to “high susceptibility/low knowledge” materials research as identified in NUREG/CR-6923 and the planned expansion of these predictions.

These activities support both the continued evaluation of the NUREG/CR-6923 predictions and the Life Beyond 60 program. In particular, the EMDA work discussed above is part of these efforts, and the Life Beyond 60 program is explicitly coupled to the PMMD research so that much of the activities described for that program is applicable here.

In addition, RES has a variety of ongoing activities that will validate or refute several of the predictions found in NUREG/CR-6923, including research to address:

- Primary water stress corrosion cracking in dissimilar metal welds and control rod drive mechanism tubes and welds.

- Steam generator tubing integrity.

- Irradiated-assisted degradation and stress corrosion cracking in reactor vessel internal materials.

These efforts include international cooperative research, RES confirmatory research, and work being accomplished collaboratively with industry. In addition, RES is monitoring work that the industry has underway to address other NUREG/CR-6923 concerns such as boric acid corrosion of bottom head penetrations.

The ACRS recommended that mitigation efforts to address Environmentally Assisted Cracking (EAC) should be confirmed by long-term and aggressive confirmatory testing. RES agrees that actions implemented by licensees have been effective in reducing the frequency of EAC events; however, EAC does continue to occur as plants age. RES is working with the Division of Component Integrity in NRR to evaluate factors that affect EAC susceptibility including crack growth rates in high-chromium nickel alloys and the effects of alloy processing, welding and component fabrication. In the area of IASCC, the staff is addressing the measurement of IASCC growth rates, radiation embrittlement, and the mechanisms of void swelling in austenitic stainless steel materials.

Moreover, the staff is working with EPRI and international partners on collaborative primary water stress corrosion cracking (PWSCC) and IASCC research. The collaboration has been beneficial in the evaluation of potential mitigation methods for IASCC and PWSCC such as evaluation of recently developed weld metal chemistries engineered to improve weldability, reduce the probability of weld defects, and provide resistance to PWSCC; and developments of stainless steel chemistries to reduce the probability of crack nucleation and growth on the

reactor core internals under continued neutron irradiation. The new Zorita reactor internals research program initiative is expected to augment the existing database on the effects of total neutron dose, internal core material microstructures, water chemistry, and fabrication effects on IASCC susceptibility.

Operational Experience

We appreciate the Committee's assessment that the Operational Experience research program is being managed and executed in a manner consistent with the needs of NRC, and that it provides data and tools necessary for both regulatory decision making and the assessment of regulatory effectiveness.

Probabilistic Risk Assessment

We appreciate the Committee's feedback on our probabilistic risk assessment (PRA) research activities and agree that the agency needs to continue research activities to advance the development of tools in support of risk-informed regulatory processes. We also agree regarding the importance of developing a strategic vision for organizing ongoing research projects and identifying longer term PRA research needs. We have found that a strategic-planning process improves the identification of future resource needs and the communication of the overall goals and objectives of our PRA research programs with stakeholders. We will continue to strategically plan our research projects to ensure our activities are consistent with the user need process and the agency's long-term research plans. For example, as we plan the new Level 3 PRA project, we will consider the need to improve the agency's PRA infrastructure to take advantage of more accurate and faster computational techniques and improved means to archive and retrieve PRA models. As another example, in our long-term research project investigating advanced Level 2 and Level 3 methods, we will be exploring the integration of plant system and operator behavior in a dynamic framework. In the digital instrumentation and control area, the FY2010-2014 DI&C Research Plan includes several tasks related to the treatment of digital systems in nuclear plant PRAs to support risk-informed regulatory approaches in this emerging area.

RES is also working with the Office of Nuclear Security and Incident Response to develop a research plan and associated user need to investigate risk-informed improvements in the security area.

We agree that more research is needed in support of expert elicitation processes and the treatment of uncertainty. However, we are still considering whether development of common, agencywide approaches for these areas would result in the most efficient and effective use of resources. As we gain experience from case-by-case applications such as seismic risk assessments, we will evaluate the need to develop more generic agencywide methods and approaches for elicitation processes and uncertainty evaluations.

Nuclear Materials and Waste

We appreciate the Committee's assessment that NRC has been successful in leveraging its nuclear materials and waste research efforts with those of other Federal agencies and other

organizations and that these collaborations are productive, provide significant synergy with NRC research activities, and produce results that support a range of topics important to regulatory decision making.

Seismic and Structural Engineering

The staff appreciates the support of the ACRS for the seismic and structural engineering program. The staff will continue its efforts involving seismic hazard characterization and earthquake engineering.

Thermal Hydraulics

The ACRS noted that NRC currently has only a modest effort in the area of computational fluid dynamics (CFD) and it is limited to some use of commercial CFD codes. The ACRS also noted that although commercial CFD codes are used in the process industry for qualitative indications of phenomena, they are validated to a much less rigorous standard than codes for nuclear use, and the source codes are not available. In addition, the ACRS believes that they include a number of *ad hoc* fixes to improve stability and robustness that may affect their predictive capability for situations that cannot be studied experimentally.

The commercial CFD codes in use by the staff have a large worldwide user base and a significant history of verification and validation (V&V). NRC benefits from the worldwide efforts to improve the codes' user interfaces, provide support for the codes, find and eliminate code errors, and validate the codes for a variety of flow problems. Worldwide efforts in these areas dwarf the advancements that could be practically achieved through NRC efforts alone. The vendors of the codes in use by RES have received ISO-9001 certification, and the ANSYS/FLUENT code development is now conducted under the American Society of Mechanical Engineers NQA-1 quality standards. The staff sees no benefit in starting over with a less mature code to meet the CFD simulation needs of the agency. The staff believes that V&V efforts for these commercial codes are more efficient than V&V efforts applied to less mature CFD codes due to the refined coding, ease of use, and existing history of V&V associated with the commercial codes. The staff has made arrangements with the vendors to study the source code, if necessary, for both of the commercial codes in use by RES. NRC staff is willing to discuss this issue in more detail with the Committee upon its request to staff.