July 5, 2005

MEMORANDUM TO: Chairman Diaz
Commissioner Merrifield
Commissioner Jaczko
Commissioner Lyons

FROM: Luis A. Reyes ***/RA Martin J. Virgilio for/***
Executive Director for Operations

SUBJECT: DRAFT REPORT ON PROACTIVE MATERIALS DEGRADATION ASSESSMENT FOR PRESSURIZED WATER REACTORS (REFER TO SRM M041108AB)

In response to Staff Requirements Memorandum (SRM) M0401108AB dated November 17, 2004, we are providing you information copies of the attached draft report on a study to identify components that may reasonably be expected to experience degradation. The study used an approach similar to the Phenomena Identification and Ranking Table (PIRT) process. Identifying the components susceptible to degradation is a necessary first step for any proactive materials degradation management (PMDM) program. This report addresses PWR plant components. Similar work is continuing for BWR components. The Office of Nuclear Regulatory Research (RES) has recently provided copies of the draft report to the Office of Nuclear Reactor Regulation (NRR) for information and review.

Both NRC and industry have an interest in being proactive with respect to materials degradation management. Proactive management would allow age-related materials degradation to be corrected before significant challenges to structural integrity and safety arise. In addition, proactive management of materials degradation will enhance safety, reliability, and regulatory effectiveness and reduce radiation exposure. Implementation of PMDM programs requires the involvement and commitment of the nuclear reactor community, including regulators and the industry (licensees, nuclear steam supply system vendors, and research organizations).

PMDM programs would identify locations where degradation could realistically be expected in the future so that mitigation or prevention of the potential degradation could be considered. If these actions are not feasible due to lack of knowledge or resources, proactive programs would still identify the components of interest for inspection and monitoring to detect degradation, follow its growth, and repair or replace the components before the degradation impairs

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structural integrity or safety. Therefore, identifying components of interest is a critical aspect of any proactive materials degradation management approach. In addition, a proactive approach requires a technology base for preventing potential degradation; or detecting degradation, monitoring its growth, and repairing the component in a timely manner.

NRC and industry have taken the important first step of identifying components of interest through complementary efforts. Several coordination meetings have been held between the industry and NRC, and with industry participation on the NRC's expert panel, as discussed below, the industry has continuing access to NRC's results and assessments. The industry developed a materials degradation matrix that addressed materials degradation in a top down fashion to identify, on a global level, potential degradation that may affect materials in primary power reactor systems. In NRC's work, using a bottom up approach, approximately 2200 PWR components were addressed, additional assessments were carried out, and new insights were gained. The additional assessments included a semi-quantitative assessment of the potential for cracking and an assessment of the existing level of knowledge for developing potential mitigation actions. Insights were gained into time-dependent phenomena that could lead to new degradation mechanisms. Issues were also identified related to plant operations (e.g. the potential for cracking due to aggressive environments that may develop from plant coastdown at the end of fuel cycles, and the removal of fibrous insulation from pipes to address sump clogging but could render the pipes susceptible to stress corrosion cracking from the outside surface).

The NRC staff realized that a comprehensive analytical prediction of future degradation would require extensive time, funding, data, and a mechanistic understanding of degradation processes that is not available for all components. The staff concluded that identification of components susceptible to future degradation is best accomplished by expert opinion. Therefore, the staff used a structured PIRT-like approach which embodies, as the central feature, the work of an expert panel to identify and rank potential degradation of components based on a component's material, environment, operating history, and considerations of time-dependent phenomena and changes in future operations. These considerations include degradation phenomena that have not yet occurred due to long incubation periods, new or different degradation mechanisms, concentration of aggressive chemical species, fatigue, thermal aging, power uprates, and changes in water chemistry. The panel consists of eight international scientists and engineers with knowledge and experience in materials engineering, corrosion science, and plant materials behavior. The experts evaluated systems and components whose failure could lead to release of radioactivity or compromise safety. They identified several degradation mechanisms that apply, with varying degrees of susceptibility, to many components. A subset of these components that were rated highly susceptible could be candidates for PMDM programs. Although experts were used in this exercise and many components were evaluated, some future degradation could be experienced that was not identified at this time. Even though the panel considered several cascading degradation scenarios (e.g. boric acid corrosion of manway retaining bolts caused by flange leakage), the panel concentrated on degradation of a given component without evaluating the potential degradation of adjacent components since this would require detailed spatial plant drawings which were not available to the panel.

In this study a component was defined as a continuous section of a system that is of the same material and product form and experiences similar stressors (temperature, pressure, irradiation, residual stresses, water chemistry, etc.). Available information on the associated stressors for each component was provided in tabular form to the expert panel. Operational experience and incidences of failure were also provided. To manage the number of assessments to be performed, the expert panel agglomerated the many components of a subsystem into fewer subgroups. The subgroup consists of components of the same or similar material type and product form (cast stainless steel, wrought stainless steel, carbon steel, etc.) that are exposed to similar operating environments and other stressors and would therefore be equally susceptible to the same degradation mechanisms. The degradation mechanisms were then identified for each subgroup. Once the subgroups and associated degradation phenomena were identified, the expert panel members individually assigned numerical values to each of three parameters for each degradation phenomenon identified. These three parameters are susceptibility factor, confidence level, and knowledge level. The numerical scores can be used to identify components with high susceptibility for possible inclusion in PMDM programs and to identify research needs for international cooperation.

The attached report provides the results of the proactive materials degradation assessment (PMDA) PIRT study for PWR components. The report contains an executive summary, a description of the process used, presentation and discussion of the results, conclusions, and various appendices. The expert panel examined approximately 2200 components. The results apply to many more than 2200 components since only one loop and single trains were analyzed for a typical four-loop plant. On the average, three potential degradation mechanisms per component were identified and rated by the expert panel; although the susceptibility level for most components was rated low. Using expert panel ratings for each degradation mechanism allows prioritization of components (based on the likelihood of occurrence) for proactive management programs. These programs would involve preventing or mitigating degradation, and/or inspecting, monitoring, and repairing or replacing components in a timely manner. Interpretation of the scores is reflected in a color scheme implemented by the expert panel and presented in tables in Chapter 3 of the attached report. From the thousands of combinations of components and potential degradation mechanisms that were considered, only about 200 components were rated highly susceptible and could be considered for inclusion in PMDM programs. The individual expert scores and their reasoning are provided in Appendix E.4 of the report. As discussed later, the highly susceptible components will be further prioritized using probabilistic risk assessment (PRA) to assess the safety significance to support potential proactive regulatory actions.

Appendix A of the report discusses corrosion fundamentals as a tutorial for various users of the report. Appendix B provides more detailed information on technical issues, degradation mechanisms, and the state of knowledge (dependencies, laboratory and field experience, etc.). This information will be useful for developing future research needs for international cooperation.

The evaluation of BWR components is still ongoing. The results will be combined with the PWR results into a single draft report scheduled for December 2005. The final report for the PWR and BWR plant types, which will address comments from an international peer review, is expected to be published by June 2006.

In addition to the PMDA PIRT effort to identify components of interest, the staff is conducting several other PMDM activities. One such activity is a study to evaluate the effectiveness of inspection techniques and requirements for passive components that have experienced, or are expected to experience, degradation according to the Generic Aging Lessons Learned (GALL)

Report. The purpose of this evaluation is to assess the effectiveness of current inservice inspection techniques and requirements for timely detection of degradation before component integrity is compromised. A draft report with the results of this evaluation and recommendations for improvements, where necessary, is expected to be available in November 2005.

To gain further insights from the PIRT PMDA study and to guide regulatory actions, the staff has conducted a preliminary risk importance evaluation using conditional core damage probability (CCDP) for reactor system components. The staff is planning further analysis to identify the risk importance of the components with the highest potential for future degradation. Other methods for evaluating risk importance will be considered that are consistent with the current standards and risk-informed applications (e.g. 10CFR 50.69, "Risk-informed categorization and treatment of structures, systems and components for nuclear power reactors"). These analyses will be performed using the Standardized Plant Analysis Risk (SPAR) models, or other appropriate models, and may identify a number of components as risk important. The risk importance results will be provided to NRR for use in developing improved inspection and monitoring requirements and other PMDM regulatory actions as required. The staff is initiating a research activity using probabilistic fracture mechanics to determine probabilities of failure for important components. The probabilities of failure for these components are expected to be used in future robust PRA studies to evaluate the risk and safety significance in support of additional future proactive regulatory actions.

Finally, the staff is working to develop an international cooperative group and an international program plan to address the research needed for implementation of regulatory and industry programs for proactive materials degradation management. The first meeting to identify potential participants and to start the development of a detailed program plan is scheduled for August 2005.

The above research programs and activities may be useful to the industry in implementing PMDM programs (NEI 03-08, "Guideline for the Management of Materials Issues," May 2003) and will allow the NRC to determine what changes, if any, are needed in the regulatory framework to further ensure plant operators continue to manage degradation so as to maintain safety and limit the potential for materials degradation surprises in the future.

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