NRC Responses to Comments from
Dr. Barbara Pellegrini to Dr. Gregory Jaczko in Letter dated May 30, 2012

Comment 1: The field of materials science offers insight and techniques that would be useful to the management of the aging phenomena that are occurring in nuclear power plants.

NRC Response: Both the nuclear power industry the NRC have expertise in the field of material science and are diligent in addressing how the properties of materials and their suitability for continued safe service are affected by their use in the challenging environments of a nuclear power plant. Insights from materials science are therefore crucial to ensure the current and continued safe service in the challenging environments of a nuclear power plant. A significant amount of information on this topic exists not only in textbooks and technical papers, but also in various NRC reports, regulatory guides, and rules. The NRC has developed a comprehensive summary of this body of work in NUREG-1801, "Generic Aging Lessons Learned (GALL)," (see http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1801/r2/index.html). The GALL Report contains the staff's generic considerations for the aging management programs that are currently in use at operating nuclear power plants in the United States. These programs are needed to monitor, control, and limit the effects of aging on materials performance in nuclear power plants. The GALL Report also documents the staff's technical basis for determining where existing programs are adequate without modification versus where existing programs need to be augmented for operation beyond the initial 40-year plant operating license. The GALL Report addresses the aging management of a large number of structures and components in the major plant systems of a nuclear power plant (i.e., containment structures, support structures, the reactor pressure vessel, reactor vessel internals, the engineered safety features, electrical components, auxiliary systems, and the steam and power conversion system). Each section of the GALL Report contains information on the materials that comprise each system, the environment(s) to which these materials are subjected, the aging mechanism (or mechanisms) that result from each material/environment combination, and a reference to the aging management program that the NRC considers acceptable to provide reasonable assurance of safety for each aging mechanism.

Comment 2: The NRC is missing hard objective evidence of aging.

NRC Response: The GALL Report requires licensees to inspect for and collect hard evidence of aging as part of an effective aging management program. This evidence is crucial to making safety decisions. For example, licensees are required to manage the effects of reactor vessel embrittlement which is caused by exposure to neutrons over time. The NRC requires the following key measurements and calculations to provide a reasonable assurance of reactor vessel safety:

1. Measure the relevant material quantities, and how they change with time. In the case of reactor vessel embrittlement, key measurements required of the licensees include the following:

    a. Monitoring of embrittlement by testing samples of the reactor pressure vessel steel stored in surveillance capsules. Because these capsules are located between the core and the inner diameter of the reactor vessel they accumulate neutron exposure, and thereby embrittlement, sooner than does the reactor vessel. In this way the

surveillance program provides the NRC with advance information on the amount of embrittlement in the vessel. For example, the capsule removed after 20 years of operation could have the amount of neutron exposure, and thereby embrittlement, that the reactor vessel would not experience until 60 years of operation.

b. The location and size of the flaws that may be present in the reactor vessel are measured through a nondestructive in-service inspection following the procedures outlined in Section XI, of the American Society for Mechanical Engineers (ASME) Boiler and Pressure Vessel Code.

2. Calculations using these measurements, along with information about the operational loads are performed to establish limits on the maximum allowable pressure and temperature as well as the maximum allowed embrittlement. These calculations are then used by the NRC to establish regulations that ensure these limits are enforced.

This approach has proven sufficient in monitoring and safely limiting the effects of embrittlement on reactor vessel integrity. The approach of (a) measuring/monitoring material degradation, (b) calculating safety margin, and (c) providing limits on degradation and/or operating conditions to maintain safety is followed, in general, for all safety-significant systems that make up a nuclear power plant.

Comment 3: Recommends that the NRC seek the advice of a small group of leaders in material science.

NRC Response: In addition to using proven technologies of the type just described for regulatory purposes, the NRC staff is cognizant of and, in some cases, participates in the development of advanced materials science and non-destructive evaluation techniques. As these techniques reach technical maturity, it is expected that they will be applied in commercial nuclear power plants. The Department of Energy (DOE) recently completed a relevant study in 2012 entitled "Roadmap for Nondestructive Evaluation of Reactor Pressure Vessel Research and Development by the Light Water Reactor Sustainability Program" (http://energy.gov/sites/prod/files/LWRS%20NDE%20RD%20Roadmap_9-12-2012.pdf). In this effort, the DOE brought together, similar to Dr. Pellegrini's suggestion, experts from universities, the DOE laboratory system, the NRC, and the commercial nuclear power industry to provide advice on what advanced measurement techniques from the fields of material science and non-destructive evaluation might be feasible for use, now and in the future. With regard to reactor pressure vessel embrittlement, this report made the following statements:

> *Attempts to use non-destructive evaluation (NDE) techniques to detect reactor pressure vessel (RPV) embrittlement have been ongoing since the 1960s without significant success. Major obstacles to the use of NDE for embrittlement quantification have been (1) the length scales of the features of interest (several nano-meters) relative to the gauge length of typical NDE methods (100s of micro-meters and up), and (2) the sensitivity of NDE techniques to multiple factors. The result is the inability (with high confidence), with a single measurement, to distinguish between multiple factors and correlate the measurement to the fracture toughness.*

The NRC staff is closely following this project as part of its effort to stay abreast of the latest information on materials degradation. In addition to this information, the NRC obtains information on materials degradation from NRC funded research, NRC participation in codes

and standards activities, and operational experience from reactors operating both within and outside of the United States. The NRC uses all of this information as part of our existing regulatory framework to ensure the continued reasonable assurance of safe nuclear power generation in the United States.