April 18, 1997

The Honorable Shirley Ann Jackson
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Dear Chairman Jackson:

SUBJECT: ESTABLISHING A BENCHMARK ON RISK DURING LOW-POWER AND SHUTDOWN OPERATIONS

This report is to draw attention to the critical need for developing an understanding of risk posed by low-power and shutdown operations at nuclear power plants. This need is apparent as a result of: (1) repeated events during these modes of power plant operations, (2) changes being made in plant operations in response to economic forces, and (3) the ongoing NRC initiative to develop risk-informed, performance-based regulation. We believe it is essential that the NRC staff undertake a quantitative examination of risk during low-power and shutdown operations at representative nuclear power plants. That is, the NRC staff needs to establish a high-quality benchmark on risk during low-power and shutdown operations comparable to that which it has derived for risk during power operations from the NUREG-1150 study [Ref. 1] and other sources. The benchmark for risk during low-power and shutdown operations should address the following:

- a representative range of plant types,
- all phases of low-power and shutdown operations,
- accidents initiated by internal fires and other external events,
- human performance, the unusual source term, radionuclide dispersal, and on-site populations that will affect the predictions of accident consequences, and
- uncertainties to a depth similar to that done for the risk benchmark for power operations.

A substantial effort will be required to develop the technical capabilities to conduct this benchmark risk analysis. Results of the benchmark risk analysis may suggest the need for refinements to the Commission's Safety Goals. In particular, the Commission may find from the results that it wants to specify limits on the tolerable durations of plant configurations that pose very high risks.

Our recommendation for a detailed benchmark analysis is based on the results of scoping risk studies done by the staff contractors [Refs. 2,3], the continuing string of worrisome events at plants

during low-power and shutdown operations, and assessments of the risk significance of plant events by the Office for Analysis and Evaluation of Operational Data. The staff's contractors have done limited analyses of risk during one phase of shutdown operations at a pressurized water reactor with a subatmospheric containment [Ref. 2] and one phase of shutdown operations at a Mark III boiling water reactor [Ref. 3]. Results of these studies show that even when the risk for a short period of shutdown operations is normalized over a full calendar year, the risk is a significant fraction of the risk calculated for the same plant during power operations:

Boiling Water Reactor

	Power Operations	Shutdown Operations*
Mean Core Damage Frequency	4.1x10-6	2.1x10-6
Mean Early Fatality Risk	8.2x10-9	1.4x10-8
Mean Latent Cancer Fatality Risk	9.5x10-4	3.8x10-3

* Plant Operating Mode 5 (cold shutdown) only.

Pressurized Water Reactor

	Power Operations	Shutdown Operations*
Mean Core Damage Frequency	4.1x10-5	4.2x10-6
Mean Early Fatality Risk	2.0x10-6	4.9x10-8
Mean Latent Cancer Fatality Risk	5.2x10-3	1.6x10-2

* Mid-loop operation only.

These partial results, however, may not adequately reflect current operating practices. The industry has instituted new guidelines [Ref. 4] for low-power and shutdown operations that are intended to reduce risk. Several licensees are using software such as the Electric Power Research Instituteþs ORAM (Outage Risk Assessment and Management) to plan activities during low-power and shutdown operations. These software tools are based on risk insights derived from simplified probabilistic risk assessments. If the NRC staff is to provide effective safety oversight of low-power and shutdown operations, the staff will have to understand the technical bases of the software tools and the approximations in risk assessments that have been used to develop these tools. The availability of benchmark risk assessments for low-power and shutdown operations for representative plants akin to the benchmark

risk assessments for power operations appears to be essential for the development of this understanding.

Despite the new guidelines and software tools developed by the nuclear power industry for low-power and shutdown operations, events that reveal safety vulnerabilities of the plants continue to occur. Among the more recent of these events are:

The Wolf Creek plant was in a "hot shutdown" condition when activities involving the residual heat removal system created a flow path that allowed approximately 9,200 gallons of reactor coolant to transfer to the refueling water storage tank. Had this draining not been promptly terminated, the operability of the emergency core cooling system would have been compromised. The Accident Sequence Precursor Analysis indicated that this event had a high conditional core damage probability [Ref. 5]. The scoping studies of shutdown risk, however, suggested that a "hot shutdown" condition was of such a low risk significance that it did not merit quantification.

Loss of core cooling was threatened by the formation of a nitrogen bubble in the reactor coolant system at the Haddam Neck plant as a result of an improper valve lineup. Injection of high-pressure nitrogen into the reactor vessel continued for over three days while the plant was in a "cold shutdown" condition. The water level in the reactor vessel was believed to have been displaced three feet below the vessel flange [Ref. 6].

At the Cooper plant, about 10,000 gallons of water was inadvertently lost from the refueling cavity because a submerged valve was opened to the main steam line drains. It took over an hour for operators to identify the source of the loss of coolant inventory [Ref. 7].

Events during low-power and shutdown operations are consuming significant staff resources. At our meeting on December 5, 1996, we were told that more than 50 percent of recent events requiring Augmented Inspection Teams have occurred when plants were in low-power or shutdown conditions. Human errors during these conditions appear to be especially probable. A number of incidents that have occurred during low-power and shutdown conditions are reviewed in the report NUREG/CR-6093 [Ref. 8]. This report concluded that factors influencing operator actions are different from those typically regarded as important during full-power operations and states that: "Unlike full-power operations, large numbers of multiple concurrent tasks are possible during LP&S (low-power and shutdown) conditions. This has implications for both the PRA (probabilistic risk assessment) modeling process and the HRA (human reliability assessment) quantification process."

We are concerned that this situation will be exacerbated as the industry moves to longer cycle times with less frequent opportunities to exercise its low-power and shutdown operating procedures. The situation may also be exacerbated by industry efforts to shorten the duration of low-power and shutdown operations by increasing the intensity of activities during these

periods. The industry will want to relieve burdens during outages by doing some maintenance while the plant is operating. For the staff to approve a trade-off between maintenance "on-line" and maintenance during outages, it will have to consider risk. To do this, the staff will have to gain an understanding of risk during low-power and shutdown operations commensurate with its understanding of risk during power operations.

The staff is now embarked on an effort to develop risk-acceptance criteria for providing regulatory relief to licensees. Staff judgments on these matters are based on a firm foundation concerning event probabilities during power operations derived both from the Individual Plant Examinations done by licensees and from its own benchmarking risk studies reported in NUREG-1150. There is no comparable basis for making judgments concerning the accident probabilities and risk during low-power and shutdown operations. At present, there is no defensible regulatory basis to determine the extent to which results obtained for power operations ought to be augmented to account for risk of low-power and shutdown operations. A more complete understanding of risks during all phases of nuclear plant operations is essential to ensure that regulations address real, significant risks and do not impose ad hoc measures to correct discovered deficiencies in the hope that these measures will also address risk-significant issues.

We believe it is essential for the success of the Commission's effort to adopt risk-informed, performance-based regulation that a more complete understanding of the full spectrum of risk be established on a defensible technical basis. This more complete understanding is needed now as pivotal decisions are being made on the implementation of risk-informed, performance-based regulation. We do not believe that existing scoping analyses or further scoping efforts will establish adequate benchmarks concerning risk during low-power and shutdown operations. This is especially so in light of evidence that time-dependent human performance is important. Significant efforts may be needed to establish new risk assessment methods and to understand phenomena associated with core damage events and the dispersal of radioactivity during these phases of plant operations. We are confident that areas of substantial uncertainty will arise in the assessment of risk during low-power and shutdown operations. Defensible quantification of these uncertainties will require the same type of effort that was needed to quantify uncertainties in risk during power operations.

It will take time to develop a usefully complete understanding of risk during low-power and shutdown operations. We recommend that a well-planned, deliberate effort with realistic time schedules and extensive peer review be undertaken first to develop methods and technologies that may be needed and then to benchmark risk during low-power and shutdown operations.

Sincerely yours,

/s/

R. L. Seale

Chairman

References:

1. U.S. Nuclear Regulatory Commission, NUREG-1150, Vol. 1, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," December 1990.
2. U.S. Nuclear Regulatory Commission, NUREG/CR-6144, BNL-NUREG-52399, Vol. 1, Brookhaven National Laboratory, "Evaluation of Potential Severe Accidents During Low Power and Shutdown Operations at Surry, Unit 1," Summary of Results, October 1995.
3. U.S. Nuclear Regulatory Commission, NUREG/CR-6143, SAND93-2440, Vol.1, Sandia National Laboratories, "Evaluation of Potential Severe Accidents During Low Power and Shutdown Operations at Grand Gulf, Unit 1," Summary of Results, July 1995.
4. NUMARC 91-06, Nuclear Management and Resources Council, Inc., "Guidelines for Industry Actions to Assess Shutdown Management," December 1991.
5. U.S. Nuclear Regulatory Commission, Information Notice 95-03, Supplement 1, "Loss of Reactor Coolant Inventory and Potential Loss of Emergency Mitigation Functions While in a Shutdown Condition," dated March 25, 1996.
6. U.S. Nuclear Regulatory Commission, Information Notice 94-36, Supplement 1, "Undetected Accumulation of Gas in Reactor Coolant System," November 1996.
7. U.S. Nuclear Regulatory Commission, AEOD/S96-02, "Assessment of Spent Fuel Pool Cooling," September 1996.
8. U.S. Nuclear Regulatory Commission, NUREG/CR-6093, "An Analysis of Operational Experience During Low Power and Shutdown and a Plan for Addressing Human Reliability Assessment Issues," June 1994.