UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

November 26, 1999

MEMORANDUM TO: David B. Matthews, Director, DRIP:NRR
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Gary Holahan, Director, DSSA:NRR
Bruce Boger, Director, DIPM:NRR

FROM: Thomas L. King, Director
Division of Risk Analysis and Applications
Office of Nuclear Regulatory Research

SUBJECT: REQUEST FOR REVIEW OF THREE REPORTS ON THE RELIABILITY OF HIGH PRESSURE INJECTION SYSTEMS IN BOILING-WATER REACTORS

Attached for your information and review are draft reports on the reliability of three high-pressure injection systems at U.S. commercial boiling-water reactors (BWR): Reliability Study Update: High-Pressure Coolant Injection (HPCI) System, 1987-1998; Reliability Study Update: High-Pressure Core Spray (HPCS) System, 1987-1998; and Reliability Study Update:: Reactor Core Isolation Cooling (RCIC) System, 1987-1998.

These reports are the first update of the original reliability studies of risk-important safety systems that covered the time period from 1987 to 1993. The updated studies provide estimates of the system unreliabilities based on unplanned system demands, and quarterly and cyclic surveillance tests during the years 1987 through 1998. In addition, the reports identify dominant contributors to system unreliability, evaluate significant trends, and provide insights on failure detection methods and significant contributors to system failures.

These studies support the strategic goals of maintaining safety, improving regulatory effectiveness and efficiency, reducing unnecessary burden, and ensuring public confidence as noted below. The major findings that support each of the strategic goals are presented with specific cognizant organizations indicated in parentheses.

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- **Maintaining Safety** - These studies provide an evaluation of the failure probabilities and the trends in time. The analysis of system performance trends in time is useful for determining whether safety is improving, deteriorating, or remaining constant in light of both NRC and licensee safety initiatives. (NRR:DSSA:SPSB, NRR:DIPM:IIPB, RES: DSARE: REAHFB)

  - *Overall system unreliabilities.* The industry-wide unreliabilities of the HPCI, HPCS and RCIC systems calculated from the 1987-1998 operating experience are nearly identical for all three systems--about 6E-2 failures per demand. Recovery actions by the operator to restore the failures resulted in little improvement in these system unreliabilities. The unreliability estimates are based on failures that occurred during both unplanned demands and cyclic and quarterly surveillance tests.

  - *Unreliability trends.* Estimates of system unreliability when modeled as a function of calendar year identified no statistically significant trend for any of the three systems.

  - *Unplanned demand frequency trends.* Statistically significant decreasing trends were identified in the frequency of unplanned demands for all three systems when modeled as a function of calendar year. The frequency of unplanned demands decreased by about a factor of six for the HPCS system and a factor of nine for both the HPCI and RCIC systems. This is consistent with the findings presented in NUREG/CR-5750, *Rates of Initiating Events at U.S. Nuclear Power Plants, 1987-1995.*

  - *Failure frequency trends.* Statistically significant decreasing trends were identified in the frequency of failures of the HPCI and RCIC systems when modeled as a function of calendar year. The frequency of system failures decreased by about a factor of four to five for the HPCI and RCIC systems. These trending analyses included failures that were observed by all detection methods, such as all types of tests, inspections, and unplanned demands. Analysis of the HPCS system failure frequency found no statistically significant trend, mainly due to few failures of the HPCS system during the 1987-1998 time period (18 system failures from 8 plants).

  - *Trends by low-power license date.* No statistically significant decreasing trends in system unreliability, unplanned demand frequency, and system failure frequency were identified for any of the three systems when modeled as a function of low-power license date. The age of the plants did not affect the unreliability or performance of any of the three systems.

- **Improving Regulatory Effectiveness and Efficiency** - The results, findings, conclusions, and information contained in these and similar system reliability studies conducted by RES are intended to support several risk-informed regulatory activities. These regulatory activities include plant inspections, technical review of proposed license amendments, regulatory effectiveness analyses, and development of risk-based performance indicators.

Plant inspections. The studies provide information which can be used for risk-informing inspection activities to enhance the use of inspection resources. The reports indicate the leading contributors to system unreliability which should be the focus of risk-informed inspections of these systems. In addition, they indicate the trends in reliability, demands, and failures to assist in determining whether more, less, or the same level of inspection is warranted. (NRR:DIPM:IIPB)

Technical reviews of proposed license amendments. The results of these studies can be used to compare licensees' risk-informed applications under Regulatory Guides 1.174, 1.175, and 1.177 with operating experience. These comparisons should allow reviews to be completed more efficiently by focusing on areas where there may be substantial differences rather than focusing on all of the risk calculations in the submittal. (NRR:DSSA:SPSB)

Regulatory effectiveness analyses. The information in these reports can be used to determine whether the impact of the regulatory activities have achieved the intended risk result by comparing the goals with the observed experience. The trending information on reliabilities, demands, and failures also provides information for determining the degree of change these activities may have accomplished. (RES:DSARE:REAHFB)

Risk-based performance indicators. This work is also being used in the development of risk-based performance indicators that will be based to a large extent on plant-specific system and equipment performance. (RES:DRAA:OERAB)

The significant insights that can be used to support this strategic goal include the following:

- *Leading contributors to system unreliabilities.* The leading contributors to system unreliability vary for each of the three systems. The leading contributors (with recovery actions) included are:

  HPCI system--failure of the injection valve to reopen, i.e., cycling the injection valve for subsequent reactor pressure vessel water level control (33%), failure to start of the system other than injection valve (26%), and maintenance out of service of the HPCI system (24%).

  HPCS system--maintenance out of service of the injection train (71%) and failure to start due to the injection valve failing to initially open (22%).

  RCIC system--failure to start of the system other than injection valve (46%) and failure to run (18%).

- *Leading component failures.* Generally, the major contribution to the unreliability of the HPCS and RCIC systems were not the result of failure of any specific component type. However, the failure of the injection valve to reopen was the major contributor to HPCI system unreliability, which contributed to 33% of the system unreliability. This contributor was due to events where the HPCI system failed as a result of thermal overload of the motor operator from repeated cycling of the injection valve during recovery from reactor trips.

- *Effectiveness of various detection methods.* Generally, testing of various types and frequencies was the most effective method in detecting failures in all three systems. Inspections (e.g., walkdowns, casual observations, plant tours) identified less than 15% of the failures of the HPCI and RCIC systems, whereas 30% of the failures of the HPCS system were identified by inspections. About one-third of the failures of the HPCI and RCIC systems were immediately identified, meaning that the failures were of the nature where plant personnel were able to respond to the failures immediately after they occurred.

  The HPCI and RCIC system injection valves are tested quarterly; however, the quarterly surveillance tests of these valves are done in an environment that does not produce the same stresses on the valve that the valve would encounter in an accident environment. In addition, the injection valve is not cycled repeatedly during the quarterly test (as was the case in many unplanned demands).

- *Between-plant variations.* Statistical analysis showed plant-to-plant variations in the data of system unreliability for all three systems. However, in each case, plant-specific results of system unreliability vary little about the industry-wide average mean. The differences between plants were small and not risk-significant.

- *Comparison with PRA/IPEs.* The industry-wide average of the HPCI and RCIC system unreliabilities calculated using data (e.g., component failure probabilities, maintenance unavailability) extracted from the (PRA/IPEs) are about a factor three lower than the industry-wide estimate based on the 1987-1998 experience.

  The industry-wide average of the HPCS system unreliability based on PRA/IPE data is consistent with industry-wide estimate based on the 1987-1998 experience. The leading contributors to these unreliabilities are consistent between the PRA/IPEs and the operating experience.

- *Generic Safety Issues and Generic Communication.* The studies investigated whether there are any generic safety issues which are specific to the RCIC, HPCI, or HPCS systems and found none. The studies did identify generic communications (e.g., information notices) which are applicable to these systems. Three specific topic areas were identified: turbine overspeed trip failures (RCIC and HPCI), debris plugging of ECCS suction strainers (all three systems), and pressure locking and thermal binding of valves (RCIC and HPCI). Only one operational event, which was associated with an HPCI turbine

overspeed trip failure, was identified and used in the associated study computations.

- **Reducing Unnecessary Burden** - The reports include engineering insights that provide information that may be used to focus inspection activities on failure mechanisms consistent with their risk significance and, consequently, reduce unnecessary inspection burden. (Regional offices, NRR:DIPM:IIPB)

  The engineering insights summarized for the previous strategic goal can also be used to reduce unnecessary burden to licensees. These include insights associated with the leading contributors to system unreliabilities, leading component failures, effectiveness of various detection methods, and between-plant variations.

- **Ensuring Public Confidence** - The final analyses provide rigorous and peer reviewed evaluations of operating experience to enhance the technical credibility of the agency with respect to quantitative risk assessment. Specifically, they demonstrate the agency's ability to analyze operating experience independently of licensee sponsored risk assessments (i.e., IPEs, IPEEEs). These independent assessments allow the NRC to determine whether licensee assessments of risk are appropriate in risk-informed activities.

To help better identify and relate this detailed information to various risk-important regulatory applications, we have provided a Forward section in each of the reports. The Forward section provides directions to the relevant quantitative and qualitative information contained in the report. The Forward also indicates the appropriate type of engineering review of this information needed for application on a plant-specific basis.

RES plans to update these and other related studies on a regular basis. These updates will continue our support of the NRC commitment to use operating experience in risk-informed regulatory activities.

We are specifically interested in your review of:

- The technical adequacy of data, specifically during the 1994-1998 update period,
- The appropriateness of the risk-important findings, and
- How the information contained in the report can be presented in order to better help you in your risk-informed regulatory activities.

We intend to have a review meeting on Wednesday, December 22, 1999 at 1:30 pm in room T9C1 to discuss any comments or recommendations you might have before we issue the final report. In addition, we welcome questions, and written and verbal comments at anytime before the meeting.

Attachment: As stated

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Memorandum Dated: 11 / 26 /99

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