MEMORANDUM TO: John A. Zwolinski, Director, DLPM:NRR
Farouk Eltawila, Acting Director, DSARE:RES
Michael E. Mayfield, Director, DET:RES

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

SUBJECT: REQUEST FOR REVIEW OF DRAFT STUDY: NUREG-1715, VOL. X, COMPONENT PERFORMANCE STUDY - AIR-OPERATED VALVES, 1987-1998

Attached for your information and review is the draft study, NUREG-1715 Vol. X, on the air-operated valve (AOV) reliability at U.S. commercial pressurized water reactors (PWRs) and boiling-water reactors (BWRs). This study documents an analysis of the performance of safety-related AOVs in the PWR and BWR risk-important (RI) systems.

This study is part of an on-going program of risk-based analysis of reactor operating experience. This effort was undertaken to systematically identify risk significant insights and provide feedback to the regulatory process. This study 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.

This study provides an estimate of the air-operated valve unreliability based on Engineered Safety Features (ESF) actuations and surveillance test demands between 1987 and 1998. It identifies dominant contributors to component unreliability and provides an evaluation of significant trends. In addition, the study includes a comparison with air-operated valve unreliability estimates published in probabilistic risk assessments (PRAs) and individual plant examinations (IPEs).

This study supports the strategic goals of maintaining safety, improving staff regulatory effectiveness, efficiency and realism, reducing unnecessary burden, and increasing public confidence. This study supports these goals as noted below. The major findings that support each of these strategic goals are presented with specific cognizant organizations indicated in parentheses

- **Maintaining Safety -** This study provides an evaluation of the AOV failure probabilities and the trends in time. The analysis of component performance trends in time could be useful for determining whether safety is improving, deteriorating, or remaining constant in light of NRC and licensee safety initiatives. (NRR:DSSA:SPSB, NRR:DIPM:IIPB, RES: DSARE: REAHFB)

CONTACT: James R. Houghton (JRH2) OERAB:DRAA:RES (301) 415-6353

– *Probability of failure on demand*. The AOV probability of failure on demand estimates developed in this study for the PWR and BWR RI systems are consistent with the generic values from NUREG/CR-4550 (which provided the input to the NUREG-1150 analyses), except the PWR RHR system mean value (5.2E-4) is significantly lower than the NUREG/CR-4550 mean and lower boundary values. The generic and calculated probability values are as follows:

	LOWER BOUND	MEAN	UPPER BOUND
NUREG/CR-4550	5.4E-3	2E-3	4.8E-3
PWR RI SYSTEMS:			
Auxiliary Feedwater (AFW)	4.6E-6	1.8E-3	6.9E-3
High Pressure Injection (HPI)	4.8E-6	1.2E-3	4.7E-3
Residual Heat Removal (RHR)	6.1E-5	5.2E-4	1.3E-2
Chemical and Volume Control (CVCS)	3.5E-7	3.4E-3	1.5E-2
Component Cooling Water (CCW)	6.7E-5	5.8E-3	2.1E-2
BWR RI SYSTEMS:			
Reactor Core Isolation Cooling (RCIC)	3.5E-4	3.0E-3	7.7E-3
High Pressure Coolant Injection (HPCI)	4.3E-4	3.6E-3	9.5E-3
Low Pressure Core Spray (LPCS)	2.9E-15	2.1E-3	1.2E-2

– *Failure rate trends*. Failure rates, as a function of component-years, were compared among the PWR plant age groups (3 groups of approximately equal size from older to newer plants by commercial operation date). For PWRs, the review of plant age groups did not show evidence of increasingly higher failure rates for any plant age group due to aging mechanisms. For BWRs, failure data was too sparse for trending failure rates.

• **Improving Regulatory Effectiveness, Efficiency and Realism -**The results, findings, conclusions, and information contained in this and similar component performance 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 study provides information for risk-informed inspection activities to enhance the use of inspection resources. The report indicates the leading contributors to component unreliability and their failure causes which should be useful in the inspection program. In addition, it indicates the trends in failure rates (see above) 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 this study can also be used to compare licensees' risk-informed applications under Regulatory Guides 1.174, 1.175, and 1.177 with operating experience (see failure probability above). These comparisons could be used to focus 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 this study 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 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 technical insights that support this goal include:

- *Leading contributors to failure.* The evaluation of PWR AOV subcomponent (e.g., valve body and pneumatic operator) failure patterns demonstrated that failures of pneumatic-operator subcomponents were the biggest contributors (greater than three-fourths) to AOV failures. BWR AOVs also showed that valve operators were the biggest contributor, although the number of failures (6) was sparse.

- *Failure trends.* For the PWR RI systems during the 1987-1995 period, there was no discernible failure trend. For BWR RI systems, no trending was determined due to sparsity of failure data.

- *Failure causes.* Failure of AOVs in PWR RI systems was mainly due to age/wear causes (47%).

- *Probability of failure on demand*. The AOV mean probabilities of failure on demand used in plant-specific IPE studies were compared with the results of this study. The PWR IPE mean values were generally consistent with the results of this study and the NUREG/CR-4550 generic values. No comparison was made with BWR IPE mean values as few BWR plants IPEs provided AOV failure probabilities on demand.

- **Reducing Unnecessary Burden -** This report includes engineering insights that provide information that may be used to focus inspection program activities consistent with industry performance 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 by limiting activities in areas that are not important contributors to reliability or by adjusting intervals for inspection consistent with observed trends in performance. These include insights associated with the leading contributors to failures and failure causes noted above.

- **Increasing 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 risk assessments (i.e., IPEs, IPEEEs). These independent assessments allow the NRC to determine whether licensee assessments of risk are reasonable.

We have recently begun a cooperative activity between Operating Experience Risk Analysis Branch (OERAB) and Inspection Program Branch (IPB) to make more effective use of pertinent insights from this and similar work in risk-informed inspection activities. OERAB will work with IPB to develop and test a process to better capture risk-based operating experience and update risk-informed inspection activities using this and other near term or recently completed studies. In this regard, OERAB is ready to assist other users of this report or other operating experience reports as well. RES plans to update these and other related studies periodically.

In February 2000, NUREG-1275, Vol. 13, "Evaluation of Air-Operated Valves at U.S. Light-Water Reactors" was issued. That report raised concerns about the potential occurrence of AOV common cause failures that could disable redundant trains of a safety system. In particular, the possibility of AOV failures from accident or transient conditions (pressure, temperature, flow), air system contamination, or from fabrication and maintenance activities was identified.

Using a more risk-based approach, and considering actual AOV failures resulting from surveillance testing and engineered safety features (ESF) actuation, this study found consistency with generic values for probability of failure on demand and with plant IPE mean values for AOVs. No indications of increased failure rates due to "aging" concerns were found. No evidence of increased CCF susceptibility was found. An earlier report, NUREG/CR-6644, "Generic Issue 158: Performance of Safety-Related Power-Operated Valves Under Operating Conditions" (September 1999), identified that the total number of AOV failure events (with failure modes: failure-to-open, failure-to-close, and failure-to-operate as required) was decreasing with time. A review of the 5 AOV events from the NUREG-1275, Vol.13 report that identified differential pressure design inadequacies found that they did not meet the criteria for being Accident Sequence Precursors.

There are differences in the evaluation methods between this study and the previously published NUREG-1275, Vol. 13. These differences are in scope, data sources, AOV boundaries, single failure and common cause failure (CCF) definitions, and results from feedback of operating experience. The AOV boundaries in this study exclude main steam isolation valves (MSIVs), pressurizer power-operated relief valves (PORVs), and the instrument air system and its components (such as air regulators, valves, airlines, and backup accumulators). The failures counted are actual and complete (i.e., not potential or degraded). The CCF definition used in this study is based on the four criteria in NUREG/CR-6268, Vol. 3, "Common-Cause Failure Database and Analysis System: Data Collection and Event Coding" (June 1998), while NUREG-1275, Vol. 13 used a broader definition of CCF "conditions" that included postulated, potential, and partial failures that have not resulted in actual safety system failures. NUREG-1275, Vol. 13 did not assess the risk significance of events identified as CCF "conditions."

We are specifically interested in your review of:

- The technical adequacy of data.
- The appropriateness of the risk-important findings, and
- How the information contained in the study can be presented in order to better help you in your risk-informed regulatory activities.

We intend to have a review meeting on November 7, 2000 at 1:30 PM in room T4B3 @ 1:30 P.M. 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

cc w/attch:
A. Thadani, RES
M. Federline, RES
S. Collins, NRR
R. Zimmerman, NRR
B. Sheron, NRR
J. R. Johnson, NRR
C. Paperiello, DEDMRS

MEMORANDUM DATED: / /00

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5. Nancy - Please Distribute and send 15 copies of the reports to Mike Markley of the ACRS		
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