50-528

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

March 21, 1997

Mr. James M. Levine
Executive Vice President, Nuclear
Arizona Public Service Company
Post Office Box 53999
Phoenix, Arizona 85072-3999

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION REGARDING RISK-INFORMED INSERVICE TESTING FOR PALO VERDE NUCLEAR GENERATING STATION (TAC NOS. M94139, M94140, AND M94141)

Dear Mr. Levine:

References:

1. Arizona Public Service letter 102-03554-WLS/AKK/GAM, from W. L. Stewart to the NRC, dated November 27, 1995
2. Arizona Public Service letter 102-03573-WLS/SAB/GAM, from W. L. Stewart to the NRC, dated December 20, 1995
3. NRC letter from Charles R. Thomas to W. L. Stewart, APS, dated March 15, 1996
4. Arizona Public Service letter 102-03714-JAB/AKK/GAM, from Jack A. Bailey to the NRC, dated June 7, 1996
5. Arizona Public Service letter 102-03752-WLS/AKK/GAM, from W. L. Stewart to the NRC, dated August 7, 1996
6. Arizona Public Service letter 102-03763-AKK/GAM, from A. K. Krainik to the NRC, dated August 23, 1996

Arizona Public Service (APS) submitted a request to the NRC (references 1 and 2) to utilize a risk-informed inservice testing (RI-IST) program to determine inservice test frequencies for certain valves that were categorized as low safety significant. The request was part of a pilot plant effort with TU Electric. The NRC staff provided an initial request for additional information (RAI) to APS related to the proposed RI-IST program via reference 3. The NRC staff met with APS at the Palo Verde Nuclear Generating Station (PVNGS) site on April 23 and 24, 1996, to discuss the RAI. APS provided a partial response to the NRC staff's initial RAI via reference 4. In Reference 5, APS committed to provide a revised schedule for fully responding to the staff's initial RAI to the NRC staff by September 15, 1996. APS submitted some additional information to the NRC in support of their proposed RI-IST program via reference 6.

The NRC Staff used the information provided by both pilot plant licensees to help develop a draft RI-IST Regulatory Guide (DG-1062) and Standard Review Plan section (SRP Section 3.9.7). Enclosed is an additional RAI aimed at determining the extent to which the RI-IST program proposed by APS is consistent with the guidance being considered by the staff in the draft RI-IST

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Regulatory Guide and Standard Review Plan section (which will soon be made available for public comment). Several of the questions in the RAI were based on information provided to the NRC by Oak Ridge National Laboratory (ORNL) in letter reports. These letter reports (Attachments to the Enclosure) document ORNL's review of Nuclear Plant Reliability Data System (NPRDS) failure records associated with Palo Verde.

Because of ongoing work on the draft risk-informed Regulatory Guides and Standard Review Plan sections, the staff may need to ask the pilot plant licensees questions in addition to those contained in the attachment to this letter. These additional questions may relate to the policy issues discussed in the January 22, 1997, Staff Requirements Memorandum. It is anticipated that the final RAI will be sent to the RI-IST pilot plant licensees shortly after the draft RI-IST regulatory guide (RG) and standard review plan (SRP) are sent out for public comment. While we regret that a comprehensive set of RAIs cannot be provided to the pilot plant licensees at this time, we are confident that significant progress will continue to be made towards implementing RI-IST programs at Palo Verde.

Sincerely,

Original Signed By

Charles Thomas for
James W. Clifford, Senior Project Manager
Project Directorate IV-2
Division of Reactor Projects - III/IV
Office of Nuclear Reactor Regulation

Docket Nos. STN 50-528, STN 50-529
STN 50-530

Enclosure: Request for Additional Information

cc w/encl: See next page

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Because of ongoing work on the draft risk-informed Regulatory Guides and Standard Review Plan sections, the staff may need to ask the pilot plant licensees questions in addition to those contained in the attachment to this letter. These additional questions may relate to the policy issues discussed in the January 22, 1997, Staff Requirements Memorandum. It is anticipated that the final RAI will be sent to the RI-IST pilot plant licensees shortly after the draft RI-IST regulatory guide (RG) and standard review plan (SRP) are sent out for public comment. While we regret that a comprehensive set of RAIs cannot be provided to the pilot plant licensees at this time, we are confident that significant progress will continue to be made towards implementing RI-IST programs at Palo Verde.

Sincerely,

James W. Clifford, Senior Project Manager
Project Directorate IV-2
Division of Reactor Projects - III/IV
Office of Nuclear Reactor Regulation

Docket Nos. STN 50-528, STN 50-529
and STN 50-530

Enclosure: Request for Additional Information

cc w/encl: See next page

cc w/encl:
Mr. Steve Olea
Arizona Corporation Commission
1200 W. Washington Street
Phoenix, Arizona 85007

Douglas Kent Porter
Senior Counsel
Southern California Edison Company
Law Department, Generation Resources
P.O. Box 800
Rosemead, California 91770

Senior Resident Inspector
USNRC
P. O. Box 40
Buckeye, Arizona 85326

Regional Administrator, Region IV
U. S. Nuclear Regulatory Commission
Harris Tower & Pavillion
611 Ryan Plaza Drive, Suite 400
Arlington, Texas 76011-8064

Chairman, Board of Supervisors
ATTN: Chairman
301 W. Jefferson, 10th Floor
Phoenix, Arizona 85003

Mr. Aubrey V. Godwin, Director
Arizona Radiation Regulatory Agency
4814 South 40 Street
Phoenix, Arizona 85040

Ms. Angela K. Krainik, Manager
Nuclear Licensing
Arizona Public Service Company
P.O. Box 52034
Phoenix, Arizona 85072-2034

Mr. John C. Horne, Vice President
Power Supply
Palo Verde Services
2025 N. Third Street, Suite 220
Phoenix, Arizona 85004

Mr. Robert Burt
Los Angeles Department of Water & Power
Southern California Public Power Authority
111 North Hope Street, Room 1255-B
Los Angeles, California 90051

Mr. David Summers
Public Service Company of New Mexico
414 Silver SW, #0604
Albuquerque, New Mexico 87102

Mr. Bob Bledsoe
Southern California Edison Company
14300 Mesa Road, Drop D41-SONGS
San Clemente, California 92672

Mr. Robert Henry
Salt River Project
6504 East Thomas Road
Scottsdale, Arizona 85251

Terry Bassham, Esq.
General Counsel
El Paso Electric Company
123 W. Mills
El Paso, Texas 79901

COMMENTS AND REQUEST FOR ADDITIONAL INFORMATION

PALO VERDE PILOT PROPOSAL FOR RISK-INFORMED INSERVICE TESTING

DOCKET NOS. STN 50-528, STN 50-529, STN 50-530

The following are the supplemental questions and comments that have been developed by NRC staff reviewers who have been evaluating the proposed risk-informed inservice testing (RI-IST) program for Palo Verde.

These questions and comments are comprised of two parts: (1) additional questions that remain from our review of the responses received for the first set of RAIs, and (2) relatively new issues that have been identified during the ongoing development of the NRC's guidance documents on risk-informed regulations. We recognize that for some of these questions, the licensee's response to the first RAIs provided part of the answer that is being sought, and we encourage the licensee to refer to the previous RAI responses where appropriate.

1. What components are the major contributors to the change in core damage frequency (ΔCDF) associated with the proposed RI-IST program at Palo Verde? What testing or other measures (including possibly taking credit for activities that would tend to reduce risk) can the licensee take to reduce the negative impact on ΔCDF? Can the licensee make a more realistic estimate of the aggregate effect on CDF of the proposed RI-IST program (i.e., as opposed to a "conservative" estimate where component failure rate (λ) is linearly extrapolated)? This reassessment should include an identification of potential areas in which there was an overly conservative treatment in the quantification of both the baseline PRA risk levels and the change in risk associated with the proposed RI-IST program. Qualitative information should be provided for those areas that cannot be quantified.

2. Does the licensee's PRA assume that the current Code-required testing is 100 percent effective in assessing a component's operational readiness? Does the current Code-required testing provide adequate information relative to the failure modes modeled in the licensee's PRA (e.g., failure of a valve to remain open for a 24-hour period)? What consideration has been given to test effectiveness in establishing the proposed risk-informed IST program? Are any PRA model or test strategy adjustments warranted?

3. On a component-specific basis, the licensee should identify each instance where the proposed IST program change will affect the licensing basis of the plant (e.g., commitments made in response to NRC generic letters such as GL 89-10, TMI action plan items, components relied on by the staff in concluding that the system and plant designs were acceptable). These commitments, which may be incorporated into plant procedures, may not be modeled in the licensee's PRA. The licensee should identify the source and nature of the commitment (or requirement), and document the basis for the acceptability of the proposed change. The licensee should consider the original acceptance

conditions, criteria, and limits as well as the risk significance of the component. Consideration should also be given to diversity, redundancy, defense in-depth, and other aspects of the General Design Criteria. If the licensing basis is not affected by the proposed IST program changes, the licensee should so indicate in its risk-informed IST Program description.

4. Provide any component-specific exemption requests, technical specification amendment requests, and relief requests necessary to implement the proposed RI-IST program. Has the licensee submitted revised relief requests for high safety significant components (HSSCs) that were the subject of previously approved relief requests? These relief requests should be reevaluated in light of the components risk significance. Has the licensee submitted relief requests for high and low safety significant components not tested in accordance with the Code test method requirements or methods described in an NRC endorsed Code Case? Has the licensee submitted relief requests for HSSCs that will not be tested in accordance with the Code test frequency requirements?

5. Please provide a detailed risk-informed IST Program implementation plan (i.e., for both HSSCs and LSSCs). This implementation plan should contain details on how each component, or group of components, categorized as being LSSC, will have its test interval extended. For example, the staff needs to see a detailed description, or draft procedure, documenting how component test intervals will be extended in a step-wise manner (i.e., not just the "speed limit" test interval). The implementation plan should describe how various component groupings were selected (e.g., using the guidance contained in NRC Generic Letter 89-04, Position 2 for check valves; Supplement 6 to NRC Generic Letter 89-10 and Section 3.5 of ASME Code Case OMN-1 for motor-operated valves). The implementation plan should document how the licensee proposes to use past performance, service condition, etc., in establishing the test strategy for specific components (see question 10 below). If the licensee wants to take credit for other operations and maintenance activities to justify less frequent inservice testing, then the details of these other activities and how they relate to the IST strategy needs to be described explicitly.

6. Provide a detailed description of how the licensee's integrated decision making process addressed each of the following issues:

   shutdown and low power modes of operation
   seismic risk
   fires
   flooding
   other external events

   It is not sufficient to say that a "deliberative [undefined]" process was used to account for these PRA scope issues. If a well-defined process was not used, offer suggestions on how each issue might be addressed to produce well-defined, systematic, and scrutable results.

7. Please identify (if any) human actions that were used to compensate for a basic event probability increasing as a result of a test interval extension, specify the human failure probability used and describe how the licensee will ensure performance at this functional level.

8. How specifically will each of the following factors be considered by the licensee's integrated decision making process to establish an appropriate test strategy (i.e., test frequency and test method) for components:

   - past performance history,
   - service condition,
   - design, and
   - safety significance?

   Either describe in detail the process that was used by APS to factor these variables into the test strategy determination or propose a process. The staff recognizes that, to some extent, these factors are embedded in the models and data supporting the licensee's PRA. However, the staff expects licensee's to augment its PRA with a component-specific evaluation of performance, conditions, and design to arrive at an appropriate test strategy (including test interval).

9. A November 11, 1996 (Attachment 2), letter report from A. B. Poole (ORNL) to J. E. Jackson (NRC) indicates that ORNL did a brief review of the available NPRDS failure records and performance data for approximately 228 "low risk significant" check valves (i.e., data from 1986 to 1995) at Palo Verde. Of the 106 NPRDS failure records on check valves at Palo Verde during this period, 55 were associated with check valves categorized as LSSC. Seventeen percent of the LSSC check valves listed in the licensee's RI-IST program submittal have experienced repeated failures. Some valves had as many as seven repeat failures (all three units considered). At least 16 of the check valves had failed or degraded internals caused at least in part by some age-related failure mechanism such as "wear" or "cyclic fatigue." How were these types of failure causes considered when evaluating whether, and the extent to which, the testing interval could be extended?

   At least 75 percent of the check valves categorized as LSSC come from either AFW, diesel starting air, containment isolation, CCW, main steam, or RHR systems, "which in previous ORNL studies have been shown to have some of the highest relative failure rates by system for significant failures (in terms of component degradation)." The number of repeat failures and the type of failures listed in NPRDS seems to indicate that age-related failure mechanisms are present in the CVCS, diesel starting air, main steam, and RHR systems. Unmitigated component aging can significantly increase component unavailability and the risk of undetected failure due to decreased testing. Unavailabilities of all check valves in applications susceptible to aging should be simultaneously increased by the appropriate factor to cover the simultaneous effects of aging. This should be completed to show that the impact on risk remains low even for unmitigated aging.

10. A November 6, 1996 (Attachment 1), letter report from A. B. Poole (ORNL) to J. E. Jackson (NRC) indicates that ORNL reviewed NPRDS failure records for low risk significant motor-operated valves (MOVs) (i.e., data from 1987 to 1995) at Palo Verde. This letter report states that "ample evidence exists to question the technical validity of extending the inspection interval for the requested valves" particularly those in certain systems (e.g., auxiliary feedwater and safety injection systems). While a failure rate for MOVs derived from NPRDS data since 1987 may be overly conservative (i.e., because it does not adequately reflect improvements to MOVs made as a result of GL 89-10), it may also be non-conservative (i.e., because MOV testing has not typically evaluated MOV performance under dynamic conditions). Describe the basis for the selection of failure rates used in licensee's PRA. How were these failure rates adjusted based on plant-specific experience and operating environment?

11. The licensee should describe in detail its performance monitoring plan and explain how sufficient data will be developed to facilitate PRA and risk-informed IST Program updates. Will there be sufficient monitoring of both HSSC and LSSC to support the periodic updates? As noted in RAI #1, have the components that contribute most to risk increase been identified and a monitoring program specifically planned that could be used to modify assumed failure rate data that is currently either under or overly conservative?

    Does the proposed performance monitoring process ensure:

    - enough tests are included, over gradually extending time periods, to provide meaningful data;

    - incipient degradation is likely to be detected and corrective action taken; and

    - appropriate parameters, as required by the ASME Code or ASME Code case, are trended as necessary to provide validation of the PRA?

    Does the proposed performance monitoring process ensure that degradation is not significant for components that are placed on an extended test interval, and that failure rate assumptions for these components are not compromised by test data?

12. Does the licensee's corrective action program:

    a. Comply with 10 CFR 50, Appendix B, Criterion XVI, Corrective Action?

b. Evaluate IST components that fail to meet the test acceptance criteria as well as IST components that are otherwise determined to be in a nonconforming condition.

c. For each component failure:

   (i) comply with 10 CFR 50, Appendix B, Criterion XVI, Corrective Action

   (ii) determine the impact of the failure or nonconforming condition on system/train operability since the previous test,

   (iii) determine and correct the root cause of the failure or nonconforming condition (e.g., improve testing practices, repair or replace the component),

   (iv) assess the applicability of the failure or nonconforming condition to other components in the IST program (including any test sample expansion that may be required for grouped components such as relief valves),

   (v) correct other susceptible similar IST components as necessary,

   (vi) assess the validity of the PRA failure rate and unavailability assumptions in light of the failure(s), and

   (vii) consider the effectiveness of the component's test strategy in detecting the failure or nonconforming condition. Adjust the test frequency and/or methods, as appropriate, where the component (or group of components) experiences repeated failures or nonconforming conditions.

d. Provide the licensee's PRA group with the corrective action evaluations so that any necessary model changes and re-grouping are done as might be appropriate. Is any credit taken for the corrective action program in the PRA? If not, do you think that it is feasible and justified to do so?

13. Are there any RI-IST program changes that the licensee proposes to make without prior NRC approval other than changes explicitly described by the licensee in RI-IST program submittals and approved by the staff (e.g., component categorization/re-categorization in accordance with an NRC approved methodology, gradual extension of a component's test interval in a step-wise fashion as approved by the staff in its safety evaluation)? Does the licensee have an adequate process or procedures in place to ensure that RI-IST program changes of the following two types get reviewed and approved by the NRC prior to implementation:

(1) test method changes that involve deviation from the NRC-endorsed Code requirements.

(2) changes to the risk-informed IST program that involve process changes (e.g., changes to the plant probabilistic model assumptions, changes to the grouping criteria or figures of merit used to group components, changes in the Acceptance Guidelines used by the licensee's integrated decision-making process [e.g., expert panel]).

14. Does the licensee's RI-IST program test components in the HSSC category that are not in the licensee's current IST program commensurate with their safety significance? These components should be tested in accordance with the ASME Code where practical, including compliance with all administrative requirements. Where ASME Section XI or O&M testing is not practical, has the licensee proposed alternative test methods to ensure operational readiness and to detect component degradation (i.e., degradation associated with failure modes identified as being important in the licensee's PRA)?

15. Are IST components in the RI-IST program (with the exception of check valves) exercised or operated at least once every refueling cycle? Are components in the following categories exercised more frequently than once per operating cycle, if practical:

(a) components with high risk significance,

(b) components in adverse or harsh environmental conditions, or

(c) components with any abnormal characteristics (operational, design, or maintenance conditions)?

16. How does the licensee plan to address, or deal with, the synergistic effects of implementing its risk-informed IST program and other risk-informed initiatives? How does the licensee plan to maintain the level of commitment of plant resources (e.g., QA or maintenance) that was assumed in justifying extended IST intervals?

17. Does the licensee have procedures for conducting the periodic risk-informed IST program review to ensure that it

- prompts the licensee to conduct overall program assessments periodically (i.e., at least once every two refueling outages) to reflect changes in plant configuration, component performance, test results, industry experience, and to reevaluate the effectiveness of the IST program,

- prompts the licensee to compare actual component performance to predicted levels to determine if component performance and conditions are acceptable (i.e., as compared to predicted levels). If performance or conditions are not acceptable then the cause(s) should be determined and corrective action implemented,

- prompts the licensee to review and revise as necessary the assumptions, reliability data, and failure rates used to group components to determine if component groupings have changed, and

- prompts the licensee to reevaluate equipment performance (based on both plant-specific and generic information) and test effectiveness to determine if the inservice test program should be adjusted (Plant-specific data should be incorporated into the generic data using appropriate updating techniques)?

Does the licensee have procedures to ensure that the results of its corrective action program for IST program components get fed back into its periodic IST program reassessment?

Does the licensee have procedures in place to identify the need for more emergent RI-IST program updates (e.g., following a major plant modification, or significant equipment performance problem).

18. To avoid being overly prescriptive in its guidance, yet still ensure that certain topics having major safety importance for all risk-informed programs are addressed in licensee's proposals, the staff has identified a set of five key safety principles in the draft risk-informed guidance documents. It is currently intended that the 5 key principles given below must be explicitly addressed in all licensee applications for risk-informed programs. The regulatory guides that are under development are to provide an example of acceptable means for satisfying these key principles. Because that guidance has not been finalized, it would be useful to have the pilot plant licensees describe how their proposed RI-IST program satisfies each of the following key safety principles:

    (a) The proposed change meets the current regulations. [This principle applies unless the proposed change is explicitly related to a requested exemption or rule change.]

    (b) The defense in depth philosophy is maintained.

    (c) Sufficient safety margins are maintained.

    (d) Proposed increases in risk, and their cumulative effect, are small and do not cause the NRC Safety Goals to be exceeded.

    (e) Performance-based implementation and monitoring strategies are proposed that address uncertainties in analysis models and data and provide for timely feedback and corrective action.

In addressing these principles, the licensee should describe how:

- All safety impacts of the proposed changes were evaluated on a component-specific basis as well as in an integrated manner as part of an overall risk management approach in which the licensee uses risk analysis to improve operational and engineering decisions broadly and not just to eliminate requirements that the licensee sees as undesirable. The approach used to identify changes in requirements should be used to identify areas where requirements should be increased as well as where they could be reduced.

- The acceptability of proposed changes should be evaluated by the licensee in an integrated fashion that ensures that all principles are met.[1]

- Core damage frequency (CDF) and large early release frequency (LERF) can be used as suitable metrics for making risk-informed regulatory decisions.

- Increases in estimated CDF and LERF resulting from proposed CLB changes will be limited to small increments.

- The scope and quality of the engineering analyses (including traditional and probabilistic analyses) conducted to justify the proposed CLB change should be appropriate for the nature and scope of the changes proposed and should be based on the as-built and as-operated and maintained plant.

- Appropriate consideration of uncertainty is given in analyses and interpretation of findings.

- The plant-specific PRA supporting decisions has been subjected to quality controls such as an independent peer review.

- Data, methods, and assessment criteria used to support the proposed IST program changes (e.g., those used by the licensee's expert panel) must be available for public review.

19. Please summarize any reviews (e.g., peer review, industry-wide comparison, etc.) that was performed on the PRA used to support the licensee's proposed RI-IST program.

Attachments: 1. ORNL Letter Report dtd. 11/6/96
2. ORNL Letter Report dtd. 11/11/96

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[1] One important element of integrated decision making can be the use of an "expert panel." Such a panel is not a necessary component of risk-informed decision making; but when it is used, the key principles and associated decision criteria still apply and must be shown to have been met or to be irrelevant to the issue at hand.

OAK RIDGE NATIONAL LABORATORY
MANAGED BY LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE U.S. DEPARTMENT OF ENERGY

PHONE: (423) 574-0734
FAX: (423) 576-0493

INTERNET: AOP@ornl.gov

POST OFFICE BOX 2009
OAK RIDGE, TN 37831-6038

November 6, 1996

Jerry E. Jackson
U. S. Nuclear Regulatory Commission
MS T10 E10
Washington, D.C. 20555

Dear Mr. Jackson:

As was discussed in the October 8, 1996 meeting with NRC personnel, Palo Verde motor-operated valves (MOVs) listed in Appendix D to 13-NS-CO5, Rev. 0 were reviewed relative to failures. The time period covered was from 1987 through 1995.

NPRDS was searched for failures of the above components at Palo Verde. A total of 28 MOVs from the Appendix D population were identified with failures during the time period. This represents about 4% of the total MOV population at all of the Palo Verde units and about 17% of all the MOV failures. These components and the tabulation of all failures by year are shown in the attached summary report. If packing leaks and external leakage are excluded the results are provided in Table 1. If the 21 valves listed in Table 1 are evaluated for mean time between failures (MTBF), then this value is determined to be 3.81 years.

This value of MTBF is considerably smaller than the 6 year test interval being requested.

The distribution of leakage related and degraded normal operation failures as identified in NPRDS was 40 due to leakage and 51 due to degraded operation. Table 2 identifies the distribution of failures between the actuator, electrical supply, and valve. This shows that one failure was due to the electrical supply and that the other failures were distributed with 45 in the actuator and 9 in the valve.

Table 3 provides a listing of the NPRDS symptom of failure for each year studied. Table 4 provides a listing of the NPRDS cause of failure for each year studied. Table 5 provides a listing of symptom of failure relative to actual cause of failure. The NPRDS evaluation shows that 51% of the failures were detected during some form of testing.

If the 28 valves are reviewed for system of service and type of failure the following evaluation is found:

System	Degraded Operation	Leakage
AFW	18	2
Charging System	2	10
Containment Purge	1	0
Essential Cooling Water	5	0
Reactor Vent & Drains	1	0
Rad. Waste Drain	1	0
Steam Generator Bypass	1	0
Safety Injection	26	24
Total:	**55**	**36**

This evaluation shows that AFW accounts for 22% of the MOV failures in this population and the Safety Injection System accounts for 55% of the MOV failures.

Although this examination was rather cursory in nature, ample evidence exists to question the technical validity of extending the inspection interval for the requested valves. These failure rates would suggest an over all total MOV failure rate at Palo Verde of approximately 1×10^{-5} failures per hour.

We hope that this information will be useful to you and should you need additional information we would be glad to provide further assistance. More failure data information on MOVs will be provided later by special Letter Report.

Sincerely,

A. B. Poole

A. B. Poole

ABP:jkc

Attachments

cc/enc: P. L. Campbell, NRC
J. Colaccino, NRC
D. F. Cox
D. C. Fischer, NRC
W. C. Gleaves, NRC
T. G. Scarbrough, NRC
W. E. Vesely, SAIC
J. P. Vora, NRC
G. H. Weidenhamer, NRC
R. H. Wessman, NRC

An Examination of Motor-Operated Valve Failures With Application to Increasing the Surveillance Testing Period at Arizona Public Service Company

Palo Verde, Units 1, 2, and 3

Prepared by

D. F. Cox

Oak Ridge National Laboratory

Prepared for
U.S. Nuclear Regulatory Commission

In a response to a request by Arizona Public Service, Palo Verde Nuclear Generating Stations 1, 2 and 3 to extend the inspection interval for low safety-significant motor-operated valves, data were collected from the Institute of Nuclear Power Operations (INPO) Nuclear Plant Reliability Data System (NPRDS). The data were collected using the following search methodology and search parameters.

- Selected Components are VALVE and VALVOP
- Selected VALVE Types are Butterfly, Gate, and Globe
- Selected VALVE Operator is Electric Motor/Servo
- Selected VALVOP Types are Electric Motor-AC and Electric Motor-DC
- Selected VALVOP Subtype is Geared
- Selected Unit IDs are PALO VERDE 1, PALO VERDE 2, and PALO VERDE 3

This search yielded a total of 523 failures noted as motor-operated valve failures. It is important to note here that the term failure refers to component degradation that affects valve or actuator function. In common terms, if the motor-operated valve does not function as designed then that degradation is considered a failure.

The 523 failures are distributed among 159 MOVs and 11 years, from 1986 to 1996. The distribution of failures by year of occurrence is shown in Figure 1. This list of valves was compared to the list of valves for which an extension of the inspection period is requested. This resulted in a total of 91 failures among 28 valves. The failure narratives for these failures were analyzed and data grouped by the following categories.

Component	The area of failure was limited to actuator, valve, or electrical. Actuator failures involve failures of the MOV that include the housing, motor, switches, etc. Basically this includes anything between the valve and actuator mounting flange to the conduit containing power and control cables. Valve failures involve the valve body, bonnet, stem, and trim. Electrical failures include components in the motor control center, including breakers and thermal overloads
Problem	Three categories were used here to further segregate failures. The event was either leakage related, a problem that *did not* cause a loss of operability/functionality, or a problem that did cause a loss of operability/functionality.
Symptom	This category lists the unusual circumstance that alerted utility personnel that a degraded condition existed.
Cause	What was the actual cause of the observed symptom.
Detection	What activity led to the discovery of the failure. The method of detection was listed as either a failure on demand, discovered during maintenance, observation (usually limited to leaks), testing, or walkdowns.

After categorizing, packing leaks and external leakage records were removed from further analysis since they were not considered critical to MOV operation. This resulted in a total of 55 failures among 21 valves from 1987 to 1995, with no failures noted for 1994. For the readers convenience these failures are listed below by component identifier and year of failure in Table 1.

Table 1 - Tabulation of failures by component identifier

Component ID	1987	1988	1989	1990	1991	1992	1993	1995	Total by component id
AFAHV0032	0	0	1	0	1	1	0	0	3
AFBHV0030	0	0	4	0	0	0	1	0	5
AFBHV0031	0	0	1	0	1	1	0	0	3
AFBUV0035	0	0	0	0	1	0	0	0	1
AFCHV0033	1	0	1	0	0	1	0	0	3
AFCUV0036	1	0	1	0	0	1	0	0	3
CHAHV0531	0	2	0	0	0	0	0	0	2
CPAUV0002A	0	0	0	0	0	0	0	1	1
EWAUV0065	1	0	0	0	0	0	0	1	2
EWAUV0145	1	1	0	1	0	0	0	0	3
GRAUV0001	0	0	0	0	0	1	0	0	1
RDAUV0023	0	0	0	0	0	0	0	1	1
SGEUV0169	0	0	1	0	0	0	0	0	1
SIAHV0657	1	0	0	5	0	1	0	0	7
SIAHV0698	0	0	0	0	1	0	0	0	1
SIAUV0634	0	0	0	1	0	0	1	0	2
SIAUV0644	0	0	0	0	1	0	0	0	1
SIBHV0658	0	0	1	0	0	0	1	0	2
SIBHV0699	0	0	1	0	0	0	1	0	2
SIBUV0665	0	1	5	0	0	0	0	1	7
SIBUV0667	0	0	3	0	0	1	0	0	4
Total by year	5	4	19	7	5	7	4	4	55

The reader may wish to observe that 14 of the 21 components identified have multiple failures, and only two of these have a time period of six years between failures. The distribution of these failures is shown in Figure 1.

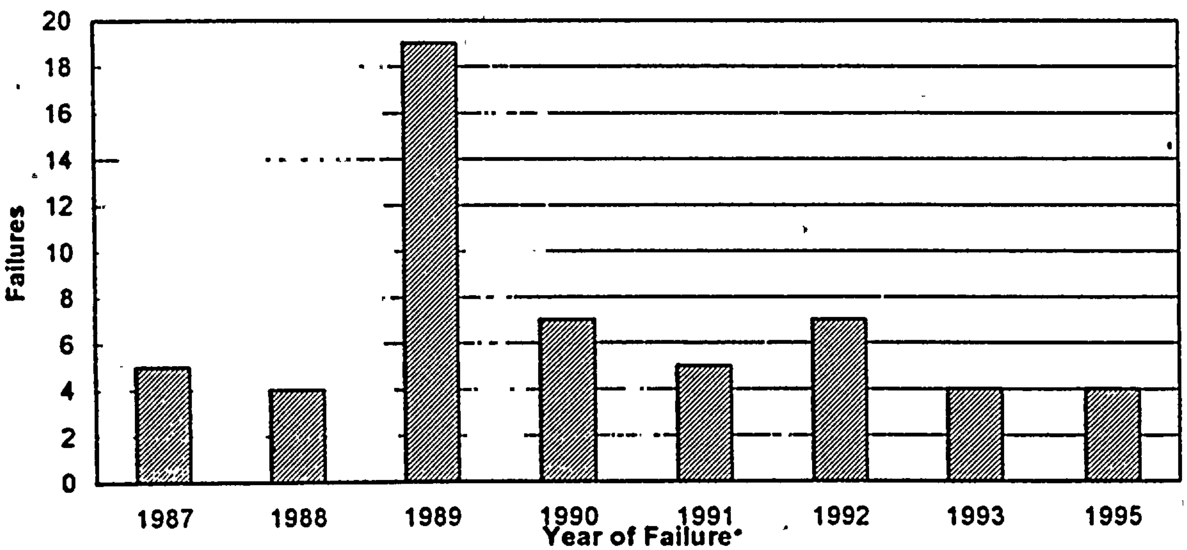

Figure 1 - Distribution of Failures by Year

Examination of these failures identifies the actuator as the component area with the largest percentage of failures (82%). This is shown below in Table 2. It should be noted that units 1 and 2 at Palo Verde started commercial operation in 1986, and unit 3 started commercial operation in 1988. Aging of valve components in contact with the fluid may not see aging related failures without additional service wear.

Table 2 - Failure tabulation by major component and year of failure

Major component area	1987	1988	1989	1990	1991	1992	1993	1995	Total by component area
Actuator	5	3	15	6	5	4	3	4	45
Valve	0	1	4	1	0	2	1	0	9
Electrical	0	0	0	0	0	1	0	0	1
Total by year	5	4	19	7	5	7	4	4	55

As can be seen in Figure 2, if data for 1989 is not averaged then actuator failures are relatively constant in number.

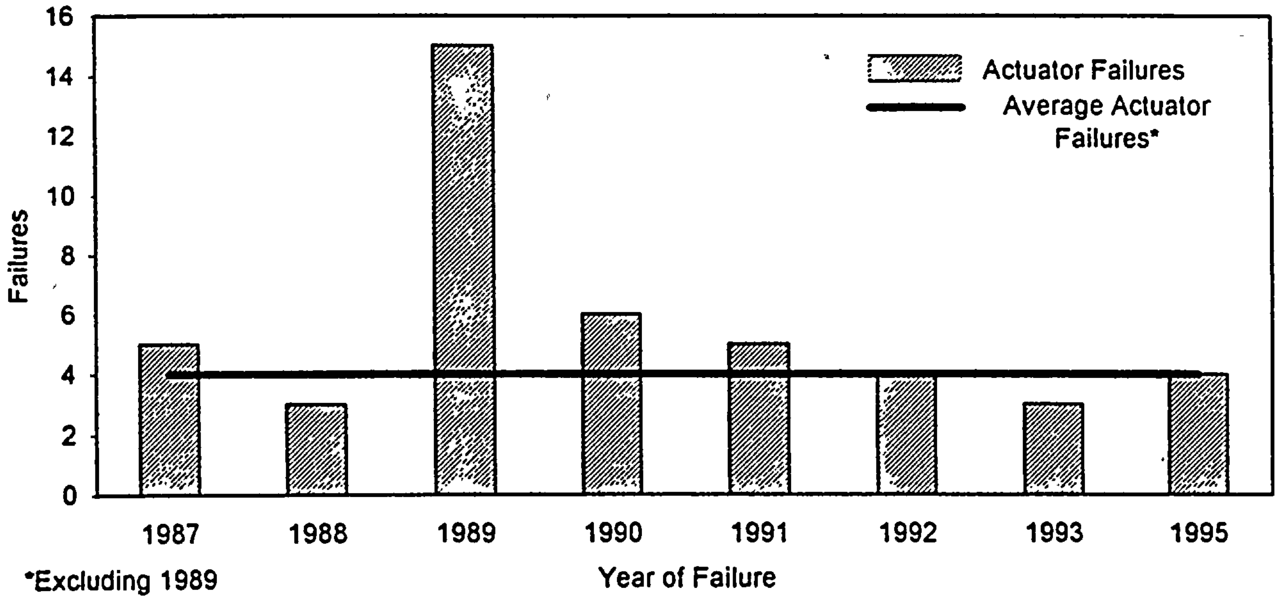

Figure 2 - Distribution of actuator failures by year

In examining the symptom that led to discovery of the failure it can be seen that failure to move to either the fully open or closed position or change positions with adequate thrust margin accounts for approximately 51% of the failures. These categories have been highlighted in Table 3 below. The term "Failure to Close" means that the actuator would not move in the closed direction. "Failure to Close Completely" means that actuator moved the valve in the desired direction but was incapable of accomplishing a full stroke. The same applies to failures in the open direction. If the failure narrative did not specify the desired direction of travel the term "Failure to Operate" was used.

Table 3 - Tabulation of failures by symptom and year of failure

Symptom of failure	1987	1988	1989	1990	1991	1992	1993	1995	Total by symptom
Breaker Trip	0	0	3	0	0	0	0	0	3
Broken Ls Rotor	0	0	1	0	0	0	0	0	1
Cycling	0	0	0	0	1	1	0	0	2
Declutch Not Disengaging	0	0	1	0	0	0	0	0	1
Degraded Stroke Time	0	0	0	1	0	0	0	2	3
Failure To Declutch	0	0	1	0	0	0	0	0	1
Failure To Close	0	0	0	0	0	1	1	0	2
Failure To Close Completely	3	2	1	2	0	1	0	1	10
Failure To Open	0	1	4	1	0	0	1	1	8
Failure To Open Completely	0	1	0	0	0	1	0	0	2
Failure To Operate	1	0	1	0	0	1	0	0	3
High Run Current	0	0	2	0	0	0	0	0	2
Improper Ls Setup	0	0	0	0	0	0	1	0	1
Inadequate Voltage	0	0	0	0	1	0	0	0	1
Internal Leakage	0	0	1	2	0	0	0	0	3
Locked Rotor	1	0	0	0	0	0	0	0	1
None	0	0	0	0	1	0	1	0	2
Over Thrusting	0	0	0	1	1	1	0	0	3
Partial Rotor Rotation	0	0	1	0	0	0	0	0	1
Power Imbalance	0	0	1	0	0	0	0	0	1
Smoke	0	0	1	0	0	0	0	0	1
Under Thrusting	0	0	1	0	1	1	0	0	3
Total By Year Of Failure	5	4	19	7	5	7	4	4	55

If we examine the cause of the failure that generated the symptoms noted above we see that setpoint shift accounted for 29% of the failures. The reader may note that the limit switches for this particular type of actuator are adjusted with gears, not a sliding stop Therefore a change in limit switch setting requires wear of the limit switch adjusting gears, which are located in a sealed gear box packed with grease. The reason for this amount of wear is not explained in the failure narratives.

Table 4 - Tabulation of failures by cause and year of failure

Cause	1987	1988	1989	1990	1991	1992	1993	1995	Total by Cause
Bent Stem	0	0	2	0	0	0	0	0	2
Blown Fuse	0	0	0	0	0	1	0	0	1
Degraded Packing	0	0	2	0	0	0	0	0	2
Design Error	0	1	0	0	2	1	0	1	5
Grease Migration	2	0	1	0	0	0	0	0	3
Improper Assembly/Operation	0	1	1	0	0	1	0	0	3
Loose Valve to Actuator Mount	0	0	0	1	0	0	0	0	1
LS Setpoint Shift	3	1	1	4	0	0	0	1	10
Motor Short	0	0	2	0	0	0	1	1	4
Normal Wear/Aging	0	0	2	1	0	0	0	0	3
Travel Stop Drift	0	0	0	0	0	1	0	1	2
TS Roll Pin Shear	0	0	0	1	0	0	1	0	2
TS Setpoint Shift	0	1	3	0	1	1	0	0	6
Under Thrusting	0	0	0	0	0	1	1	0	2
Unknown	0	0	5	0	2	1	1	0	9
Total by Year	5	4	19	7	5	7	4	4	55

The information in Table 5 allows the reader to examine the coded symptom of failure relative to the coded cause of failure.

Table 5 - Tabulation of Failures bySymptom and Cause of Failure

Symptom of Failure	Bent Stem	Blown Fuse	Degraded Packing	Design Error	Grease Migration	Improper Assembly/Operation	Loose Actuator Mount	LS Setpoint Shift	Motor Short	Normal Wear/Aging	Travel Stop Shift	TS Roll Pin Shear	TS Setpoint Shift	Under Thrusting	Unknown	Total by Symptom
Breaker Trip	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3
Broken LS Rotor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Flow Oscillations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Declutch Not Disengaging	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Degraded Stroke Time	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	3
Failure to Declutch	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Failure to Close	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	2
Failure to Close Completely	0	0	0	0	0	0	0	7	0	0	0	0	2	1	0	10
Failure to Open	1	0	0	1	0	1	1	0	2	0	0	0	0	0	2	8
Failure to Open Completely	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2
Failure to Operate	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	3
High Run Current	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
Improper LS Setup	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Inadequate Voltage	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Internal Leakage	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	3
Locked Rotor	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
None	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2
Over Thrusting	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	3
Partial Rotor Rotation	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Power Imbalance	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Smoke	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Under Thrusting	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3
Total by Cause of Failure	2	1	2	5	3	3	1	10	4	3	2	2	6	2	9	55

Although the above examination was rather cursory in nature, ample evidence exists to question the technical validity of extending the inspection interval for the requested valves. The degree of wear displayed at these units does not support extending the inspection interval without further analysis of the failures, their causes, and actions implemented to prevent recurrence.

OAK RIDGE NATIONAL LABORATORY
MANAGED BY LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE U.S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2009
OAK RIDGE, TN 37831-8038

PHONE: (423) 574-0734
FAX: (423) 576-0493

INTERNET: AOP@ornl.gov

November 11, 1996

Jerry E. Jackson
U. S. Nuclear Regulatory Commission
MS T10 E10
Washington, D.C. 20555

Dear Mr. Jackson:

As we discussed in the October 8, 1996 meeting with NRC personnel, selected Palo Verde check valves listed in Appendix D to 13-NS-CO5, Rev. 0, have been reviewed relative to failure history. The time period covered was from 1986 through 1995.

Palo Verde has requested IST extension from their current Code requirements (usually quarterly) to an interval of 6 years on approximately 228 "low risk significant" check valves (76 valve applications were listed in the submittal; it is assumed that all three units affected). In an effort to provide information needed to evaluate potential candidate risk based inservice test (RBIST) check valves at Palo Verde for extended IST intervals, Oak Ridge National Laboratory (ORNL) has done a brief review of the available NPRDS failure records and performance data for the valves in question. The results of this review are provided in the attached summary report.

The most significant findings of this study resulted from a brief review of the 106 raw NPRDS failure records listed for check valves at Palo Verde Units 1, 2, 3 during the time period 1986-1995. Of the 106 raw NPRDS failure records, 55 were associated with the candidate valves. Seventeen percent of the valve applications listed in the relief request submittal have experienced repeat failures. Some valves had as many as seven repeat failures (all three units considered). It is important to note that at least 16 of the failed valves listed in Table 10 of the attachment had failed or degraded internals caused at least in part by some age-related failure mechanism such as "wear" or "cyclic fatigue." These types of failure causes need to be considered when evaluating whether to extend inservice testing intervals. Of the 55 failure records associated with the deferral candidate valves, 11 involved external leakage, while a characterization of the remainder according to extent of degradation resulted in 29 (66%) moderate and 15 (34%) significant failures. These results are comparable to those found industry-wide during previous ORNL studies for check valve failures occurring during 1991 and 1992.

The system of service for candidate IST deferral should also be considered. At least 75 percent of the candidate "low safety significance" valves for deferral come from either AFW, Diesel Starting Air, Containment Isolation, CCW, Main Steam, or RHR systems, which in previous ORNL studies have been shown to have some of the highest relative failure rates by system for significant failures (in terms of component degradation).

The number of repeat failures and type of failures listed in NPRDS (see page 7, 8, and 9 of the attachment) certainly seems to indicate that age-related failure mechanisms are present in the following systems:

- CVCS
- Diesel Starting Air
- Main Steam
- RHR

The recently provided Draft NUREG/CR-6508 "Component Unavailability Versus Inservice Test (IST) Interval: Evaluations of Component Aging Effects With Applications to Check Valves," has shown that unmitigated component aging can significantly increase the unavailability and risk due to decreased testing. The Palo Verde submittal has not addressed aging-related effects on the risk analysis completed.

Although this examination was rather cursory in nature, ample evidence exists to question the technical validity of extending the inspection interval for the requested check valves. Unavailabilities of all check valves in applications susceptible to aging should be simultaneously increased by the appropriate factor to cover the simultaneous effects of aging. This should be completed to show that the impact on risk remains low even for unmitigated aging.

We hope that this information will be useful to you. Should you need additional information we would be glad to provide further assistance. More failure data information on check valves will be provided later by special Letter Report.

Sincerely,

A. B. Poole

A. B. Poole

ABP: jkc

Attachments

cc:enc:	P. L. Campbell, NRC	F. Grubelich, NRC
	J. Colaccino, NRC	W. E. Vesely, SAIC
	K. L. McElhaney	J. P. Vora, NRC
	D. C. Fischer, NRC	R. H. Wessman, NRC
	W. C. Gleaves, NRC	

Evaluation of Candidate LSSC Check Valves for Risk Based IST Extension at Palo Verde Units 1,2,3

K.L. McElhaney

Oak Ridge National Laboratory
Oak Ridge, Tennessee

November 12, 1996

NRC Job Code W6324

Evaluation of Candidate LSSC Check Valves for Risk Based [illegible] Extension at Palo Verde Units 1,2,3

Background

Palo Verde Nuclear Generating Station has recently submitted to the NRC a request for relief from the Inservice Test (IST) intervals currently required by the ASME Code for certain check valves based on a probabilistic analysis of the valves' importance to safety. In theory, this analysis methodology results in the ranking of components into two basic categories, those of high safety significance and those with low safety significance. The goal is to ensure that the components more important to plant safety are to be tested in a manner that provides a high level of assurance of their operability. Another goal of the Risk Based approach (RBIST) is to show that IST intervals may be extended beyond the current requirements without resulting in significantly increased safety risks. One consideration in this type of analysis is supposed to be component performance history, both from the specific plant as well as from an industry perspective.

Palo Verde has requested IST extension from their current Code requirements (usually quarterly) to an interval of 6 years on approximately 228 (assuming 76 valve application groups/unit x 3 units) "low risk significant" check valves. In an effort to provide information needed to evaluate potential candidate check valves at Palo Verde for extended IST intervals, Oak Ridge National Laboratory (ORNL) has done a brief review of the available performance data for the valves in question. The following is a summary report on that analysis.

Analysis Results

An analysis was done on available component performance data using both the characterized data from the ORNL check valve performance database and raw NPRDS data. The ORNL database is composed of over 2000 check valve failure records derived from NPRDS from 1984-1992, and manually reviewed, filtered to remove non-failures, non-check valves, and external leakage type failures, and characterized according to consistent criteria for a number of parameters, such as failure mode, failure area, failure cause, specific valve type (where possible; e.g., swing check, lift check), etc. Raw (uncharacterized) NPRDS data is not generally preferred for analysis purposes due to the lack of some data and inconsistency in data input practices between plants, but for some portions of this analysis, raw failure data for all Palo Verde check valve failures recorded in NPRDS from 1986-1995 was also used.

<u>CEOG Generic Valve Groups</u>

Where possible, it is particularly beneficial to compare check valve performance based on specific application. Unfortunately, specific valve application information is rarely available, due to differences in plant designs and terminology and a lack of information available from NPRDS. When this type of comparison is desired, it is generally necessary to review plant-specific FSARs and attempt to develop some type of generic valve application groups. This task is usually both time-consuming and frustrating, since comparisons can usually only be made among plants with the same NSSS and very similar system configurations.

A recent report issued by the Combustion Engineering Owners Group (CEOG), CE NPSD-1048, "Demonstration Project to Apply Risk Based Inservice Testing (IST) to ECCS Check Valves,"[1] attempted to develop certain generic application categories for ECCS check valves in a number of CE plants. Six utilities with a total of ten plants participated in the CEOG study. In order to gather data on check valves within the scope of the study, CEOG sought to facilitate cross-plant comparisons by developing a set of generic check valve configuration diagrams with a corresponding set of generic check valve groups based on location and function. Since Palo Verde was one of the ten plants participating in the CEOG study, ORNL was able to cross-reference the valves that appeared in both the CEOG report <u>and</u> the IST relief request in order to review both plant-specific and industry valve performance based on the generic

groupings. Table 1 lists the CEOG generic group descriptions for those groups of "low risk significant" Palo Verde valves which also included candidate relief request valves.

Table 1
CEOG Report CE NPSD-1048 Generic Valve Group Descriptions

CEOG Report Group	Description	Palo Verde Valve Application Groups
Group B	SIT Outlet Check Valves	SIEV215, SIEV225, SIEV235, SIEV245
Group D	LPSI Pump Discharge Check Valves	SIAV434, SIBV446
Group E	LPSI Pump Suction Check Valves	SIAV201, SIBV200
Group H	LPSI Pump Miniflow Check Valves	SIAV451, SIBV448
Group J	Hot Leg Injection Line Check Valves	SIAV523, SIBV533
Group K	Hot Leg Injection Line to RCS Loop Check Valves	SIAV522, SIBV532
Group M	HPSI Pump Discharge Check Valves	SIAV404, SIBV405
Group O	HPSI Pump Miniflow Check Valves	SIAV424, SIBV426
Group P	Containment Spray Header Check Valves	SIAV164, SIBV165
Group R	Containment Spray Pump Discharge Check Valves	SIAV485, SIBV484
Group S	Containment Spray Pump Suction Check Valves	SIAV157, SIBV158
Group T	Containment Spray Pump Miniflow Check Valves	SIAV486, SIBV487

The 1984-1992 ORNL-characterized failure and 1991 population databases were used to review the performance history of the 13 groups of valves listed from the ten plants included in the CEOG report. A summary of the initial findings is as follows:

Industry Failures Based on CEOG Report Generic Application Groups:

No Failures: Groups E, H, O, P, R, S, T.

Group B:

1 failure; St. Lucie 2. Borg-Warner 12" DWG 73060 check valve. Valve was stuck open. Significant.

Group D:

1 failure; San Onofre 2. Anchor/Darling 10" DWG 3454-3 check valve. Broken tack welds and binding between disc skirt and valve stem. Significant.

Group J:

1 failure; Palo Verde 2. Borg-Warner 3" DWG 77700 check valve. LLRT failure. Moderate.

Group K:

3 failures- St. Lucie 2. All 3" Westinghouse Model 03000CS8800007 swing check valves. Excessive seat leakage due to steam erosion of the discs. Moderate.

Group M:

6 failures-(1) Palo Verde 2, Borg-Warner 4" DWG 79120-1 check valve. Seat leakage. Moderate.
(5) St. Lucie 2, Anchor/Darling 4" DWG 3527-3 check valve: (1) stuck open-cause unknown-significant; (1) damaged internal parts resulted in restricted motion due to wear-significant; (1) stuck open due to packing binding-significant; (1) internal damage (galling) caused restricted motion - combination design problem and operating error-significant; (1) internals galling resulted in restricted motion - material incompatibility and excess tightening of the valve to the closed position - significant.

Conclusion: St. Lucie has had operational problems with this valve due to a combination of causal factors. Failures were related to galling and binding of internal parts.

Industry Parameters Reviewed Using the 1984-1992 ORNL Database

Two additional industry-wide performance parameters were also investigated using the ORNL database. This review focused on the specific candidate valves by manufacturer and design.

Industry Failures By Manufacturer/Model Number:

- All Palo Verde valves reviewed were manufactured by Borg-Warner (now BW/IP).

- All Borg-Warner check valves in the "low safety significant" groups identified at Palo Verde are swing check valves, except those valves in CEOG Group O (SIAV424, SIBV426), which are Borg-Warner lift check valves.

- No other plants have Borg-Warner valves with model/drawing numbers corresponding to those at Palo Verde, since Borg-Warner apparently uses unique drawing numbers instead of model numbers for each plant, so results of a failure history search by model number were inconclusive. Additional design information is necessary to evaluate failures of specific Borg-Warner valves.

Industry Failures- Borg-Warner Valve Failures at All Plants:

Borg-Warner (including Borg-Warner Corp., Byron-Jackson Pumps Div./Borg-Warner, Nuclear Valve Division/Borg-Warner, and Weston Hydraulics Div/Borg-Warner) totals 749 valves installed as recorded in the 1991 NPRDS database. This makes Borg-Warner 13th of over 150 valve manufacturers in terms of actual number of valves installed. (Note: some model numbers listed in the database for Borg-Warner may actually be Kerotest valves, which may differ in design from the other Borg-Warner valves.) Tables 2-8 show the failure distributions of all Borg-Warner check valves in all plants by various parameters, from 1984-1992. It should be noted, however, that in order to establish any relative failure rates, the population distribution based on each parameter must also be determined. Any conclusions drawn without considering population effects would almost certainly be misleading.

Table 2
Industry Borg-Warner Failure Distribution by Component Age Group

Component Age Group (at time of failure)	No. Failures	Percent of Total Borg-Warner Failures
<5	19	63
>=5 and <10	10	33
>=10 and <15	1	3

Table 3
Industry Borg-Warner Failure Distribution by Plant Age Group

Plant Age Group (at time of failure)	No. Failures	Percent of Total Borg-Warner Failures
<5	15	50
>=10 and <15	4	13
>=5 and <10	11	37

Table 4
Industry Borg-Warner Failure Distribution By Extent of Degradation

Extent of Degradation	No. Failures	Percent of Total Borg-Warner Failures
Moderate	20	67
Significant	10	33

Table 5
Industry Borg-Warner Failure Distribution by Valve Size Group

Component Size Group	No. Failures	Percent of Total Borg-Warner Failures
<=2	15	50
>2 and <=4	13	43
>10	2	7

Table 6
Industry Borg-Warner Failure Distribution by System

ORNL Standard System Name	No. Failures
AFW	5
Containment Isolation	10
Control Rod Drive	3
CVCS	2
Feedwater	3
HPSI	3
Reactor Recirculation	1
RHR	1
Standby Liquid Control	2

Table 7
Industry Borg-Warner Failure Distribution by Manufacturer Model/Drawing Number and Extent of Degradation

Manufacturer Model (Drawing) Number	No. Moderate Failures	No. Significant Failures
None listed	0	1
116CCB1-004	3	0
116FCB1-005	1	0
3-75500	1	0
316DCBL-005	0	1
465QBB1-002	0	1
74730	0	1
74750	0	1
75560	0	1
76790-1	1	0
77680-1	0	1
77700	1	0
79120-1	1	0
80200	0	1
82530	3	0
CN-0900-1206H-203	0	1
CN-1500-1009J-255	5	0
CN-1500-1206J-230	2	0
DWG 73060	0	1
MC-0900-1206H-101	2	0

Table 8
Industry Borg-Warner Failure Distribution by Unit

Unit Name	No. failures	Ext. of Degradation
CATAWBA 2	7	Moderate 6; Significant 1
BYRON 2	3	Moderate 2; Significant 1
PALO VERDE 2	3	Moderate 2; Significant 1
PERRY 1	3	Moderate 3; Significant 0
COMANCHE PEAK 1	2	Moderate 1; Significant 1
MCGUIRE 1	2	Moderate 1; Significant 1
MCGUIRE 2	2	Moderate 2; Significant 0
ARKANSAS NUCLEAR ONE 2	1	Moderate 0; Significant 1
BRAIDWOOD 2	1	Moderate 1; Significant 0
BYRON 1	1	Moderate 1; Significant 0
ST. LUCIE 2	1	Moderate 0; Significant 1
SUSQUEHANNA 1	1	Moderate 0; Significant 1
SUSQUEHANNA 2	1	Moderate 0; Significant 1
WNP-2 2	1	Moderate 1; Significant 0
WOLF CREEK 1	1	Moderate 0; Significant 1

<u>Palo Verde Check Valve Failure History Using Raw NPRDS Data (1986-1995)</u>

All failures of Palo Verde check valves occurring during the time frame 1986-1995 (inclusive) were downloaded from NPRDS. (This was done for completeness, since the current ORNL check valve performance database contains failures only through 1992, and many of the Palo Verde failures were assumed to have occurred after 1992. Palo Verde Units 1 and 2 began commercial service in 1986, while unit 3 began commercial service in 1988.) Failures were manually reviewed (and characterized only according to extent of degradation to the component), and external leakage type failures were included for most of the following analysis. The following are the results of a cursory evaluation of the 106 NPRDS check valve failures from Palo Verde for this time period:

- Fifty-five of the 106 NPRDS failure records involved the deferral candidate check valves. Of the 76 valve application groups represented, 13 groups experienced repeat failures. There were nine individual valves that experienced repeat failures and three valves that had repeat significant* failures. Table 9 shows the number of failures by valve application group, unit, and extent of degradation.

- Of the 55 failure records associated with the deferral candidate valves, 11 involved external leakage. The remaining 44 failures were reviewed and characterized in terms of extent of degradation in accordance with the criteria used in previous ORNL analyses.[2,3] There were 29 (66%) failures deemed moderate in nature and 15 (34%) termed significant. This ratio is very close to that exhibited industry-wide for 1991 and 1992.[2,3]

- The set of 228 deferral candidate valves (76 valve application groups/unit x 3 units) accumulated approximately 2100 valve-years of service during the period 1986-1995. If the number of significant failures only is considered, this represents a failure rate of approximately 7×10^{-3}/yr. for the set.

* "Significant" in terms of the degradation to the valve's ability to function. These failures include those with broken and/or detached internals, restricted motion, stuck open, and stuck closed cases.

Table 9
Distribution of Palo Verde Check Valve Failures (1986-1995) by Unit and Extent of Degradation

Valve Application Group	System	Unit 1 Failures	Unit 2 Failures	Unit 3 Failures	Total by Group
AFAV137	AFW	1S			1
AFBV138	AFW	1E			1
CHAV177	CVCS	1E			1
CHAV190	CVCS		1S		1
CHBV331	CVCS		2M	1M	3
CHEV334	CVCS		1S	2M	3
CHNV154	CVCS		2S		2
CHNV494	CVCS		1M		1
DGAV066	Diesel Starting Air	3M	3S	1M	7
DGAV067	Diesel Starting Air	1M	1S		2
DGAV397	Diesel Starting Air		1S		1
DGBV068	Diesel Starting Air	1M		1M	2
DGBV069	Diesel Starting Air	1M			1
GAEV015	Containment Isolation		1M	1M	2
HPAV002	Combustible Gas Control			1M	1
NCEV118	CCW		1M		1
NPBV004	Combustible Gas Control			1M	1
SGAV043	Main Steam			1E	1
SGAV044	Main Steam	1E	2S		3
SGEV005	Main Steam			1S	1
SGEV642	Main Steam	1M			1
SGEV693	Main Steam			1S,1E	2
SIAV404	RHR	1S			1
SIAV434	RHR	2E	1E		3
SIAV485	RHR	1E			1
SIAV523	RHR	1M	1M	1M	3
SIBV405	RHR	1M	1M		2
SIBV446	RHR		1E		1
SIBV484	RHR	1E			1
SIBV533	RHR	1M	2M	1M	4

M-Moderate failure S-Significant failure E-External leakage (no internals degradation)

- Table 10 shows a list of all candidate Palo Verde "low safety significant" check valves application groups for IST interval deferral. It also lists the number of failures recorded in NPRDS from 1986-1995, and the number of repeat failures. Where applicable, the corresponding CEOG report generic valve application group is also listed.

Table 10
Palo Verde RBIST Relief Request Check Valves

Palo Verde RBIST Deferral Candidate Check Valve Application Group	Sytem	Failures in NPRDS (1986-1995)	Repeat Failures per Application Group ?	Notes	Valve Listed in CEOG Report?
AFAV007	AFW				
AFAV015	AFW				
AFAV137	AFW	1 (Unit 1)		1	
AFBV022	AFW				
AFBV024	AFW				
AFBV138	AFW	1 (Unit 1)			
CHAV177	CVCS	1 (Unit 1)			
CHAV190	CVCS	1 (Unit 2)			
CHAV328	CVCS				
CHBV331	CVCS	2 (Unit 2), 1 (Unit 3)	Yes	4	
CHEV334	CVCS	1 (Unit 2), 2 (Unit 3)	Yes	4,9	
CHEV433	CVCS				
CHEV440	CVCS				
CHNV118	CVCS				
CHNV154	CVCS	2 (Unit 2)	Yes	5	
CHNV155	CVCS				
CHNV494	CVCS	1 (Unit 2)		4	
CHNV835	CVCS				
CTAV016					
CTAV037					
CTBV020					
CTBV038					
DGAV066	Diesel Starting Air	3 (Unit 1), 3 (Unit 2), 1 (Unit 3)	Yes	2,6	
DGAV067	Diesel Starting Air	1 (Unit 1), 1 (Unit 2)	Yes	3	
DGBV068	Diesel Starting Air	1 (Unit 1), 1 (Unit 3)	Yes	3	
DGBV069	Diesel Starting Air	1 (Unit 1)			
GAEV011	Containment Isolation				
GAEV015	Containment Isolation	1 (Unit 2), 1 (Unit 3)	Yes	4	
HPAV002	Combustible Gas Control	1 (Unit 3)			
HPBV004	Combustible Gas Control	1 (Unit 3)			
NCEV118	CCW	1 (Unit 2)		4	
SGAV043	Main Steam	1 (Unit 3)			
SGAV044	Main Steam	1 (Unit 1), 2 (Unit 2)	Yes	8	
SGEV003	Main Steam				
SGEV005	Main Steam	1 (Unit 3)		10	
SGEV006	Main Steam				
SGEV007	Main Steam				
SGEV642	Main Steam	1 (Unit 1)			
SGEV652	Main Steam				
SGEV653	Main Steam				
SGEV693	Main Steam	2 (Unit 3)	Yes	11	
SGEV887	Main Steam				

Table 10
Palo Verde RBIST Relief Request Check Valves

Palo Verde RBIST Deferral Candidate Check Valve Application Group	Sytem	Failures in NPRDS (1986-1995)	Repeat Failures per Application Group ?	Notes	Valve Listed in CEOG Report?
SGEV888	Main Steam				
SIAV157	RHR				Group S
SIAV164	RHR				Group P
SIAV201	RHR				Group E
SIAV404	RHR	1 (Unit 1)			Group M
SIAV424	RHR				Group O
SIAV434	RHR	2 (Unit 1), 1 (Unit 2)	Yes		Group D
SIAV451	RHR				Group H
SIAV485	RHR	1 (Unit 1)			Group R
SIAV486	RHR				Group T
SIAV522	RHR				Group K
SIAV523	RHR	1 (Unit 1), 1 (Unit 2), 1 (Unit 3)	Yes	4	Group J
SIBV158	RHR				Group S
SIBV165	RHR				
SIBV200	RHR				Group E
SIBV405	RHR	1 (Unit 1), 1 (Unit 2)	Yes	4	Group M
SIBV426	RHR				Group O
SIBV446	RHR	1 (Unit 2)			Group D
SIBV448	RHR				Group H
SIBV484	RHR	1 (Unit 1)			Group R
SIBV487	RHR				Group T
SIBV532	RHR				Group K
SIBV533	RHR	1 (Unit 1), 2 (Unit 2), 1 (Unit 3)	Yes	2	Group J
SIEV215	RHR				Group B
SIEV225	RHR				Group B
SIEV235	RHR				Group B
SIEV245	RHR				Group B
SPAV041	ESW				
SPBV012	ESW				
WCEV039					
DGAV396	Diesel Starting Air				
DGBV496	Diesel Starting Air				
DGBV497	Diesel Starting Air				
DGAV397	Diesel Starting Air	1 (Unit 2)		7	

Table 10 Notes:

1 Stuck open failure due to corrosion and normal wear.

2 Repeat failures due to pitting and corrosion caused by debris and moisture buildup in system. Repeat "failed to seat" failures.

3 Repeat leakage and binding failures attributed to corrosion buildup in system and normal operational and environmental wear/aging.

4 Internal leakage due to normal wear or aging/cyclic fatigue.

5 2/17/95: Leakage past seat attributed to wear. Disc stud broken due to cyclic fatigue.
3/27/95: Pieces of valve internals found to be missing, including a 2-inch length of the disc stud with the welded nut, stud sleeve, and washer. Valve would not have functioned properly. Failure attributed to inadequate design and cyclic fatigue.

6 Repeat stuck closed failures.

7 Broken hinge arm and loose internal parts attributed to possible cyclic fatigue.

8 Repeat hinge pin failure due to wear.

9 Internal leakage caused by abnormal wear/cyclic fatigue.

10 Stuck open condition due to cyclic conditions.

11 Valve binding (restricted motion) due to inadequate assembly.

Conclusions

Thirteen of the generic valve application groups listed in the CEOG RBIST report contained valves for which Palo Verde has requested IST relief. Of these, seven groups had no recorded failures for any of the ten plants in the CEOG study, while six groups did have failures recorded in the ORNL failure database during the time period 1984-1992. The most failures occurred in generic Group M, HPSI pump discharge check valves.

Failure histories based on valve manufacturer (Borg-Warner) and manufacturer/model number were also reviewed with generally inconclusive results. Since this particular manufacturer uses unique drawing numbers rather than model numbers for its valves, making direct comparison based on design is difficult without additional information. Some other industry analyses based on various parameters related to Borg-Warner check valves were also presented.

Potentially the most significant findings resulted from a brief review of the 106 raw NPRDS failure records for Palo Verde Units 1,2,3 during the time period 1986-1995. Fifty-five of the 106 NPRDS failures involved deferral candidate valves. Thirteen valve application groups experienced repeat failures across all three units. Nine individual valves experienced repeat failures, and three valves had repeat significant failures. It is important to note that at least 35 of the 44 failures involving internals degradation were attributed by Palo Verde (in the NPRDS narratives) at least in part to some age-related failure mechanism such as "wear," "cyclic fatigue," or "debris buildup." These types of failure causes must be considered when evaluating whether to extend inservice testing intervals.

The system of service for candidate IST deferral should also be considered. At least 75 percent of the deferral candidate "low safety significance" valves are located in either AFW, Diesel Starting Air, Containment Isolation, CCW, Main Steam, or RHR systems, which have been shown to have some of the highest relative failure rates by system for significant failures (in terms of component degradation).[2,3]

It is not clear from the performance data reviewed so far that IST interval extension is justified for all the components listed in the Palo Verde relief request. Although both the Palo Verde relief request itself and the CEOG report identify specific component performance as a critical consideration in the determination of both level of safety significance and length of interval extension, how this criteria was applied is not straightforward. Neither document cites either plant-specific or industry data as their source for check valve failure rates used as input for the probabilistic analyses. Instead, it appears that "generic" data was used as input for all the probabilistic analyses, which would fail to take into account any of the performance history parameters reviewed herein.

In order to fully justify IST interval extension for any of the components listed as candidates for deferral in the Palo Verde relief request submittal, a further review of both operational performance data and other plant practices should be undertaken. For example, it might be prudent to ask, " What measures have been taken to ensure that the Diesel Starting Air system is free of corrosion and debris caused by moisture inside the system?" This is especially important, since from previous industry-wide studies[2,3] it has been shown that Diesel Starting Air check valves have been especially prone to failure (*significant* failure: both stuck open and stuck closed) from this problem. The current ORNL review has also shown that several of the candidate Palo Verde valves in the Diesel Starting Air system have failed repeatedly for the same reason. Other supporting programs such as plant maintenance and preventive maintenance should be reviewed also when considering IST deferral, since component performance and longevity are highly dependent upon these practices.

References

1 Combustion Engineering Owners Group (CEOG), CE NPSD-1048, "Demonstration Project to Apply Risk Based Inservice Testing (IST) to ECCS Check Valves," June 1996.

2 Oak Ridge National Laboratory, NUREG/CR-5944, Vol. 2, "A Characterization of Check Valve Degradation and Failure Experience in the Nuclear Power Industry - 1991 Failures," July 1995.

3 Oak Ridge National Laboratory, ORNL/NRC/LTR-96/11, "A Characterization of Check Valve Degradation and Failure Experience in the Nuclear Power Industry - 1992 Failures," June 1996.