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U.S. Nuclear Industry Approaches to Address Gate Valve Pressure Locking, Thermal Binding and Related Issues

U.S. Nuclear Industry Approaches to Address Gate Valve Pressure Locking, Thermal Binding and Related Issues

TR-114051

Topical Report, December 1999

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This report describes research sponsored by EPRI.

The report is a corporate document that should be cited in the literature in the following manner:

U.S. Nuclear Industry Approaches to Address Gate Valve Pressure Locking, Thermal Binding, and Related Issues, EPRI, Palo Alto, CA, 1999. TR-114051.

REPORT SUMMARY

In recent years, U.S. nuclear utilities have taken a variety of approaches to address important generic valve and piping issues. This report discusses gate valve pressure locking and thermal binding, potential effects of high ambient temperature on electric motor actuator output in motor-operated valves (MOVs), and the need for guard piping surrounding containment sump piping and valves. The report provides a valuable resource for comparing the relative merits of each approach to these issues.

Background

Over the years, the U.S. NRC has identified corrective actions for a number safety-related valve and piping issues. In 1995, the NRC issued Generic Letter 95-07, "Pressure Locking and Thermal Binding of Safety-Related Gate Valves." This Generic Letter required U.S. nuclear utilities to 1) perform evaluations in order to identify safety-related gate valves that may be susceptible to pressure locking or thermal binding and 2) implement corrective action to ensure proper operation under design basis conditions. In addition, tests conducted in the 1990s under NRC sponsorship demonstrated that the electric motor actuator output in MOVs can decrease significantly at elevated ambient temperatures due to increased winding resistance. Finally, the NRC Standard Review Plan (SRP) requires the use of guard piping surrounding containment sump piping and valves that extend beyond the primary containment boundary. U.S. utilities have taken a variety of approaches to address these issues and requirements. Electricite de France requested that EPRI conduct a survey to summarize U.S. approaches for comparison with French approaches.

Objective

To document the various approaches taken by U.S. nuclear utilities in addressing the following generic technical issues: 1) Gate valve pressure locking and thermal binding; 2) Potential effects of elevated ambient temperature on electric motor actuator output in MOVs; and 3) Design requirements for isolation valves in piping that penetrates the primary containment boundary.

Approach

The project team first developed a detailed questionnaire to obtain information on the generic technical issues under consideration. The team next sent questionnaires to all U.S. and some Canadian nuclear utilities. They received detailed responses from approximately 25% of the units surveyed. Responses were biased more heavily in favor of PWR units than BWR units. Respondents included 29% of all U.S. PWR units (21 of 72) and 14% of all BWR units (5 out of 37). All four nuclear steam supply system (NSSS) suppliersóWestinghouse, Combustion Engineering, Babcock and Wilcox, and General Electricówere represented in the survey. The largest number (54%) of responses received were from Westinghouse plants. Finally, team members compiled, tabulated, and evaluated information received to extract meaningful data.

Results

This report provides detailed survey responses as well as summary tables documenting utility approaches to important generic valve and piping issues. Following are key conclusions:

\Utilities address the majority of valve pressure locking problems through physical modifications, for example, drilling a hole in the upstream side of the disk, installing a bypass line between the upstream pipe and the valve bonnet, or installing a pressure relief device in the bonnet. Conversely, utility changes in operating procedures generally resolve valve thermal binding issues.

Limitorque Technical Update 93-03, "Starting Torque at Elevated Temperature," provides guidance to address ambient temperature effects on electric motor actuator output in MOVs.

To address heat-up of fluid in containment sump isolation valves, approximately half of U.S. plants surveyed feature double-walled containment sump piping. The other half meet regulatory requirements by demonstrating a high level of margin in the structural capability of piping leading to the in-board isolation valve. None of the plants surveyed have converted from double- to single-wall containment sump piping, although technical justifications for such modifications are feasible.

EPRI Perspective

In recent years, U.S. nuclear power plants have focused considerable attention on gate valve pressure locking and thermal binding as well as MOV actuator capability under design basis conditions. This report provides a valuable resource for U.S. and international nuclear utilities to compare and contrast approaches for addressing the performance of safety-related valves.

TR-114051

Keywords

Valves
Motor-operated valves

ABSTRACT

The objective of this project is to document U.S. approaches to address the following issues: (1) Demonstration of the capability of power-operated gate valves to operate under potential pressure locking conditions; (2) demonstration of the capability of power-operated gate valves to operate under potential thermal binding conditions; (3) potential for fluid heat up and/or air entrainment in water upstream of valves required to open to allow pumping of water in the containment sump to supply containment sprays or other safety-related systems and functions; (4) the purpose and need for guard piping surrounding containment sump piping, and defining any modifications implemented to remove such guard piping; and (5) potential reductions in electric motor actuator output torque under elevated temperature conditions.

All U.S. nuclear power plants were surveyed to obtain data to fulfill each of these objectives. Survey responses were obtained from 17 of the 42 U.S. nuclear power utilities. This represents 24 percent of the total nuclear power generation capacity in the U.S. Accordingly, the survey responses are considered a representative sampling of the U.S. nuclear power industry.

Detailed responses from each utility were compiled in summary tables to extract meaningful conclusions to meet each of the project objectives. This report can provide valuable insights to U.S. as well as to foreign utilities by comparing their programs to those summarized herein.

ACKNOWLEDGEMENTS

The following individuals are recognized for taking time from their busy schedules to provide the valuable information presented herein.

Bruce Huhmann	Ameren Union Electric
James F. Szivos	Baltimore Gas & Electric
Mark McClellan	Boston Edison Company
Stephen D. Hart	Duke Power Company
Steve Loehlein	Duquesne Light Company
Matt McGinley	Niagara Mohawk Power Corp.
Roger Eisner	Northeast Utilities Company
Marvin Engen	Northern States Power Company
Jim Geschwender	Omaha Public Power District
Arthur S. Mortorff	Pacific Gas & Electric Company
Robert Justice	South Carolina Electric & Gas Company
Charles Rowland	Houston Light & Power Company
Chris Hansen	Vermont Yankee Nuclear Power Company
Sam Gates	Southern Nuclear Operating Company
John Hosler	Electric Power Research Institute
Jean-Pierre Renaudier	Electricite de France
Bob Elfstrom	L.R.E. Associates

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1 INTRODUCTION

1.1 BACKGROUND

The U.S. Nuclear Regulatory Commission issued Generic Letter 95-07 [1*], "Pressure Locking and Thermal Binding of Safety-Related Power-Operated Gate Valves," in 1995. The Generic Letter requested U.S. licensees to perform evaluations to identify gate valves that are susceptible to pressure locking or thermal binding, and to perform analyses and/or implement corrective actions to ensure that these valves are capable of performing their safety functions under design basis conditions. At the same time, France has been reviewing the design bases capability of power-operated gate valves in their plants.

France has been interested in obtaining a comprehensive comparison of the approaches used in the United States to address pressure locking and thermal binding issues, including their relative benefits and drawbacks. Electricite de France (EdF) requested EPRI to conduct a survey of the U.S. industry to fulfill the objectives stated below.

Objective

The objective of this project is to document U.S. approaches to address the following issues:

1. Demonstration of the capability of power-operated gate valves to operate under potential pressure locking conditions.

2. Demonstration of the capability of power-operated gate valves to operate under potential thermal binding conditions.

3. Potential for fluid heat up and/or air entrainment in water upstream of valves required to open to allow pumping of water in the containment sump to supply containment sprays or other safety-related systems and functions.

4. The purpose and need for guard piping surrounding containment sump piping, and documentation of any modifications implemented by U.S. utilities to remove such guard piping.

5. Potential reductions in electric motor actuator output under elevated temperature conditions.

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* Numbers in brackets denote references given in Section 7.

1.2 APPROACH

In recent years, there has been a considerable technical focus on the gate valve pressure locking and thermal binding as well as the actuator capability under design basis condition in U.S. industry [1-7, 12-21] as well as in France [8-10, 22]. The technical publications cited above were reviewed to develop an overview of the current industry understanding of the issues and alternative hardware, operational, testing, and analytical approaches to address pressure locking and thermal binding problems. Based on this overview and the stated objectives of this project, a survey questionnaire was prepared to obtain detailed feedback from individual U.S. and Canadian nuclear utilities. The appropriate individual at each utility was contacted before and after sending the questionnaire in order to encourage them to respond and to provide any clarification. The questionnaire is included in Appendix A.

Survey responses were obtained from 17 out of the 42 nuclear power utilities. The number of operating plant units covered by this response is 26 out of a total of 109 units in operation in the U.S. This represents 24 percent of the total nuclear power generation capacity (23,524 MWe out of 99,673 MWe total) in the U.S. Accordingly, the survey responses are considered a reasonable, representative sampling of the U.S. nuclear power industry.

The response was biased more heavily in favor of PWR units than BWR units. The response included 29 percent of all the PWR units (21 of 72) and 14 percent of all BWR units (5 out of 37) in the U.S. All four Nuclear Steam Supply System (NSSS) suppliers, i.e., Westinghouse, Combustion Engineering, Babcock and Wilcox, and General Electric, are represented in the survey. The largest number (54 percent) of the responses received were from the Westinghouse plants.

Detailed responses from each utility were compiled in summary tables (Appendix B) to extract meaningful conclusions for each of the project objectives. Some of the utilities sent additional attachments to support their responses. Relevant information from these attachments has also been included in this report.

Although all U.S. nuclear utilities have submitted responses to NRC GL 95-07, most utilities have received requests for additional information from USNRC and many have not achieved closure at this time.

2
APPROACHES TO ADDRESS PRESSURE LOCKING ISSUES

2.1 INTRODUCTION

The USNRC has issued several generic communications related to pressure locking of gate valves. A comprehensive discussion of the U.S. experience related to pressure locking issues is included in Generic Letter 95-07 [1]; NUREG 1275, Vol. 9, "Operating Experience Feedback Report – Pressure Locking and Thermal Binding of Gate Valves" [17]; and NUREG/CP-0146, "Proceedings of Workshop on Gate Valve Pressure Locking and Thermal Binding" [18]. The pressure locking phenomenon described in these references is referred to as "traditional pressure locking phenomenon" in this report. This phenomenon along with another related phenomenon, referred to as "pressure-related disc pinching effect", which can be equally significant in the operation of gate valves, are described below.

Traditional Pressure Locking Phenomenon

The traditional pressure locking phenomenon is defined as "the condition in which the fluid trapped in the bonnet area of gate valves is at a higher pressure than both the upstream and the downstream pressures." This phenomenon is applicable to most gate valve designs (e.g., flexible wedge, split wedge, parallel slide, and double disc expanding gate valves) in which the higher bonnet pressure can act on both the upstream and the downstream disc faces and force them against their respective seats. This higher bonnet pressure introduces disc sliding friction at both disc/seat interfaces rather than just one, as in the case of a normal valve operation under differential pressure. This results in an increase in the unwedging/unseating thrust above the normal conditions. This phenomenon is not applicable to solid wedge gate valve designs.

The conditions/mechanisms that can cause the fluid in the bonnet to acquire a higher pressure than both the upstream and downstream piping systems are:

- A pressure transient that causes the upstream line to depressurize, and
- A temperature increase of the fluid trapped in the bonnet area. This causes thermal expansion of the fluid in the confined bonnet volume with a corresponding increase in pressure. The temperature increase may result from heat-up during plant operations, a rise in ambient air temperature, or thermal conduction and convection through the process fluid in the connecting piping during plant operation.

Pressure-Related Disc Pinching Phenomenon

Based on the traditional understanding and definition of pressure locking phenomenon, no increase in unwedging thrust is expected to occur in (1) a flexible wedge disc with a drilled hole (or other means for flow path) to equalize bonnet pressure to the upstream side, or (2) a solid wedge gate valve when subjected to conditions that are conducive to pressure locking. However, recent industry experience shows that in both of these designs an increase in unwedging thrust can occur in some cases after these valve design/configurations are subjected to pressure changes between the time of closure to reopening [3, 16]. For example, in pressure locking tests performed by Commonwealth Edison on flexible wedge gate valves, an increase in unwedging thrust was consistently measured in one of the flexible wedge gate valves in which bonnet pressure was equalized to the upstream side [3]. Additionally, at a U.S. plant, an increase in unwedging thrust was observed in two *solid wedge* gate valves after being subjected to a specific sequence of pressure changes [16]. The increase in unwedging thrust in both of these cases was determined to be caused by "pressure change-related disc pinching phenomenon," which is described in detail in References 4 and 5. The phenomenon is potentially applicable to all types of wedge gate valves (flexible, split, solid, double disc), and is briefly described below.

Due to the fact that the valve bodies are flexible (not rigid, as commonly assumed), they respond elastically to changes in pressures, seat loads, and valve end loads. After the valve is closed, an increase in line pressure tends to move the seat faces further apart and, conversely, a reduction in line pressure tends to move the seat faces closer together. Changes in such pressures after the disc is wedged between the seat faces can cause an increase or decrease in the seat reaction forces. Furthermore, the valve stem/yoke assembly and the operator in a valve assembly are also flexible and capable of storing strain energy that can drive the wedge further if the disc/seat friction can be overcome after being subjected to pressure changes.

For a wedge gate valve that is subjected to a certain sequence of pressure changes between the time the valve is closed and opened, the body flexibility and the release of stored strain energy in the valve topworks can cause disc pinching and an increase in the unwedging thrust. An example of the conditions that can cause disc pinching is as follows. The valve is closed and wedged without system pressure. The system is pressurized, and the valve body/seats expand. As seat contact stress decreases, friction force between the disc and seat decreases. The strain energy in the stem and valve topworks drives the wedge further into the seats. Subsequent decrease in the system pressure allows the body and seats to relax/contract, causing disc pinching. This in turn increases the seat contact stress and friction, which increases the unwedging thrust. The increase in thrust due to the disc pinching phenomenon can be negligible or quite significant as compared to the normal unwedging thrust. The magnitude of increase depends upon valve design and the magnitude of pressure changes. The increase in unwedging thrust due to disc pinching phenomenon is in addition to the increase that can be seen by the traditional pressure locking phenomenon.

2.2 APPROACHES TO ADDRESS TRADITIONAL PRESSURE LOCKING ISSUES

Traditional pressure locking issues in gate valves can be addressed by approaches that involve (a) hardware modifications, (b) changes in operating procedures, and (c) analysis to demonstrate capability to operate the valve.

(a) Hardware Modifications

- Drill a hole in the upstream disc
- Use an external pipe between bonnet and upstream piping
- Use an external pipe between bonnet and nearby drain
- Use a relief valve to limit bonnet pressure
- Use an external pipe between bonnet and upstream/downstream piping with manual or automatic switching valve
- Attach an air volume chamber to the bonnet
- Replace valve
- Upgrade/replace actuator

(b) Changes in Operating Procedures

- Periodically stroke valve (especially during large changes in temperature and/or pressure, e.g., during change of plant operating modes).
- Use limit switch in the closing direction to prevent wedging and sealing simultaneously on both the upstream and downstream seats. This solution is not suitable for valves that are required to provide a tight shut-off under low DP conditions.
- Modify the operating procedure to ensure that the subject valve is only operated under no- or small-effect from pressure locking (e.g., the bonnet pressure and temperature during opening are at or below those used during closing).

(c) Use of Analytical Procedures

Industry has developed analytical procedures to predict increase in unwedging thrust under pressure locking conditions. Two analytical procedures were available to the industry during the time the utilities were addressing their 180-day response to NRC Generic Letter 95-07. These procedures are commonly referred to as the "Entergy Method" and the "ComEd Method." Both of these analytical procedures address only the traditional pressure locking phenomenon. Neither methodology takes into account the disc pinching phenomenon since this phenomenon was recognized only recently in the industry. The effect of disc pinching phenomenon can be significant for some valves under pressure changes. Recently a validated "Generalized Pressure Locking Methodology" was developed that addresses the traditional pressure locking phenomenon as well as the disc pinching phenomenon. The generalized methodology shows good agreement against all ComEd and INEEL test data [4]. Further discussion of these methodologies is included in the next section.

2.3 DISCUSSION OF ANALYTICAL METHODS TO ADDRESS PRESSURE LOCKING

Entergy Method: In Reference 2, D. E. Smith of Entergy Corporation presents an early analytical method used to estimate the required thrust to open a flexible wedge gate valve under pressure locking conditions. This method is based on the assumption that the increase in seat reaction forces and therefore the unwedging thrust under pressure locking conditions can be calculated by considering only the disc flexibility. Classical closed-form strength-of-material equations for circular plates [28] were used to calculate the increase in seat reaction forces. The results were compared against one valve and were found to be in good agreement with the test data.

ComEd Method: In Reference 3, Bunte and Kelly introduced Commonwealth Edison's Method, which eliminates certain assumptions and provides an improvement over the Entergy method. Key differences between ComEd and Entergy methods are

- In the ComEd Method, vertical (stem axis) pressure load on the elliptical projected area of the disc is considered separately from PL load. The Entergy Method relies on use of the open disc factor for translating the increased seating contact force into an increased unseating load. This assumption in the Entergy method is non-conservative.
- Deflection of the disc (circular plate) due to transverse shear load, neglected in the Entergy Method, is included in the ComEd Method. Shear load contribution can be significant.
- Hub elongation in the axial direction is considered in the ComEd Method, but not in the Entergy Method.

Commonwealth Edison performed pressure locking tests on three flexible wedge gate valves to validate their methodology [3]. Whereas the agreement between predictions and test data were very good for two valves, the predictions were nonconservative by as much as 40 percent for the third valve under certain test conditions. The third valve also exhibited an increase in unwedging thrust even when the bonnet pressure was equalized to the upstream pressure (i.e., after eliminating pressure locking).

Generalized Pressure Locking Methodology: Under the sponsorship of eight U.S. utilities, Kalsi Engineering completed the development and validation of a generalized pressure locking methodology to calculate the opening thrust of a wedge gate valve under pressure locking conditions due to both traditional pressure locking phenomenon and the disc pinching phenomenon [4, 5]. In addition to disc flexibility, which is considered in both the earlier methodologies, this methodology takes into account the flexibility of the valve body, stem, and yoke. It accounts for the disc pinching phenomenon by considering the elastic strain energy in the valve stem/yoke and the sequence of pressures that can wedge the disc further.

This method was verified against finite element analysis results (for body flexibility) and was validated against test data for three valves from Commonwealth Edison [2] and one valve from INEEL [6]. In all cases, agreement between the predictions and test data was found to be good with uncertainties of less than 15 percent if closed-form equations for body flexibility are used and less than 10 percent if finite element analysis results for the body flexibility are used [4]. This methodology was also found to correctly predict the increase in unwedging thrust for the ComEd test valve that exhibited such increase when the bonnet pressure was equalized. This methodology, which is available only to the participating utilities, was released in March 1998.

2.4 SUMMARY OF PRESSURE LOCKING SURVEY RESULTS

The Pressure Locking Survey (see Appendix A) was submitted to all of the U.S. utilities and some Canadian Utilities. Twenty-six U.S. nuclear plants responded to the pressure locking (PL) survey and the detailed results are given in Table B.1 in Appendix B. The key results of the PL survey are summarized as follows:

Population of Gate Valves with Traditional Pressure Locking Concerns (Item 1.1)

- The total number of gate valves susceptible to PL is 427 valves with an average of 16 valves per plant. The number of PL-susceptible valves per plant ranged from a minimum of 4 valves in one plant to a maximum of 50 valves in another plant.
- The number of valves in water systems is about 83 percent of the total number of valves reported to be susceptible to PL. The remaining 17 percent of the gate valves susceptible to PL are in other systems (primarily steam).

Causes of Traditional Pressure Locking in Gate Valve (Item 1.2)

- 355 valves (an average of 14 valves per plant), which represents 83 percent of the PL-susceptible population, were reported to be susceptible to PL due to pressure transient.
- 72 valves (average of 3 valves per plant), which represents 17 percent of the PL-susceptible population, were reported to be susceptible to PL due to rise in outside environmental temperature.
- 28 valves (average of 1 valve per plant), which represents 7 percent of the PL-susceptible population, were reported to be susceptible to PL due to rise in process fluid temperature.
- There was no reported concern about pressure rise between two isolation valves as the root cause for pressure locking.

Valve Bi-directional Sealing Functions (Items 1.3)

- 93 gate valves (22 percent) of the total number of valves with PL concern were reported to have bi-directional sealing function. On average, this represents about 4 valves per plant.

Valve and Disc Designs (Items 1.4)

305 valves (74 percent of total) were reported to be of flexible wedge gate designs.

60 valves (14 percent of total) were reported to be of double disc designs.

31 valves (8 percent of total) were reported to be of split wedge disc designs.

16 valves (4 percent of total) were reported to be of parallel disc designs.

Hardware Modifications Used to Eliminate or Mitigate PL Conditions (Item 1.5)

- In 113 valves (average of 4 valves per plant), which represents 27 percent of the PL-susceptible population, a hole was drilled in the upstream side of the disc to equalize the bonnet pressure with the upstream pressure, thus to eliminate the potential for PL.
- In 48 valves (average of 2 valves per plant), which represents 11 percent of the PL-susceptible population, an external pipe between bonnet and upstream pipe was used to equalize the bonnet pressure with the upstream pressure, thus eliminating the potential for PL.
- In 9 valves, a bonnet pressure relief valve was used to relieve excess bonnet pressure, thus limiting bonnet pressure to an acceptable level.
- In 110 valves, which represents 26 percent of the PL-susceptible population, an external pipe between bonnet and upstream/downstream piping with manual or automatic switching valve was used to relieve excessive bonnet pressure. This option was used by one utility with multiple plants.
- At the same above utility, 30 valves were replaced.
- At the same above utility, 24 actuators were replaced.
- Some utilities used other approaches such as:
  - Attached air volume pipe to the bonnet,
  - Increased actuator output thrust by replacing actuator gears with higher ratio gear set.

Analytical Methods Used to Address Pressure Locking Concerns (Item 1.6)

- 17 plants (65 percent of the total) used analytical methods to demonstrate unwedging capability under PL conditions.
- 8 of the 17 plants noted that they used analytical methods for short term, and subsequently long-term solutions were implemented.
- 7 plants (27 percent of the total) used Entergy's Method to address PL concerns.
- 15 plants (58 percent of the plants responding to the survey) used ComEd's Method to address PL concerns.

- Kalsi Engineering's Generalized PL Method was not used because it was not available at the time the U.S. utilities submitted their responses to the NRC GL 95-07.
- For thermally induced pressure locking, two plants calculated the bonnet pressures using 40 psi/^{o}F per INEEL test data [8].
- One plant reported using Westinghouse Owners Group criteria of 23 psi/°F criterion.
- One utility (with several plants) used the following pressure increases vs. temperature to calculate bonnet pressures based on combination of (1) Commonwealth Edison's pressure locking test results, (2) Westinghouse Owners Group's statistical review of industry data prior to 1995, and (3) NRC's Operating Experience Feedback Report, NUREG 1275 Volume 9.

5 psi/ ^{o}F	for temperature changes	<	130^{o}F
23 psi/ ^{o}F	for temperature changes	>	130^{o}F and < 450^{o}F
100 psi/ ^{o}F	for temperature changes	>	450^{o}F

- Two utilities have reported that they are currently using the generalized pressure locking methodology in their response to U.S. NRC's Request for Additional Information (RAI).

Changes in Operating Procedures Used to Address PL Concerns (Item 1.7)

Seven U.S. plants (27 percent of the plant responses) used changes in operating procedures to address the effect of pressure locking including:

- Periodically stroke valves (three plants).
- Close on limit (to prevent wedging and simultaneous sealing of the upstream/downstream seats) for valves with no tight shut-off requirements (two plants).
- Impose limitation on plant technical specifications during short valve closures (two plants).
- Revise procedures to provide an alternate flow path if valve pressure locking occurs (one plant).
- Drain fluids from bonnet (one plant).

Scope of PL Screening (Item 1.8)

Three plants extended pressure-locking screening to include nonsafety-related valves, which are important to plant operation.

Credit for Potential Factors That May Affect PL (Item 1.9)

- On short-term basis, 8 plants (31 percent of total) took credit for the presence of air trapped in the valve bonnet.
- On short-term basis, 10 plants (38 percent of total) took credit for seat leakage.
- On short-term basis, 7 plants (27 percent of total) took credit for packing leakage.

- On short-term basis, 7 plants (27 percent of total) took credit for bonnet pressure reduction due to stem retraction through the clearance between stem-head and T-slot.
- On short-term basis, 12 plants (46 percent of total) took credit for decay of pressure locking with time before opening the valve.

Personnel Requirements to Screen for PL Susceptibility (Item 1.10)

- 12 plants (46 percent of total) used interdisciplinary team of valve experts, system engineers and operational personnel to perform screening for PL susceptibility.
- 9 plants (35 percent of total) used valve experts and system engineers (but not operations personnel) in the teams to perform screening for PL susceptibility.
- 3 plants (12 percent of total) used only their valve experts to perform screening for PL susceptibility.
- 2 plants (8 percent of total) used only their system engineers.

Discussion

The survey results show that

- There is a large variation among different U.S. utilities in the number of valves being identified as susceptible to pressure locking. The variation is rather small between plants within the same utility or operating company.
- The majority of pressure locking issues are caused by pressure transients in water systems.
- In general, the "disc pinching" phenomenon has not been addressed as part of the industry’s response to traditional pressure locking issues.
- Detailed and validated analytical methodologies can be used to predict thrust requirements under pressure locking conditions.

3 APPROACHES TO ADDRESS THERMAL BINDING ISSUES

3.1 INTRODUCTION

U.S. Nuclear Regulatory Commission Generic Letter 95-07 recommended that all of the U.S. nuclear power plants identify and address the potential for thermal binding in gate valves in safety-related systems. The thermal binding phenomenon in gate valves occurs when the required opening thrust increases due to temperature changes between the time the valve is closed and the time it is required to open. The combination of temperature changes and the difference in the coefficient of thermal expansion of the body material and the disc material may cause disc pinching or further wedging of the disc, which can cause a significant increase in the seat-to-disc contact stresses. Both solid and flexible wedge gate valves are susceptible to thermal binding, and the severity of binding depends upon the specific design of the valve and the magnitude of the change in operating temperature.

Operating experience, as documented by U.S. utilities, USNRC, NSSS owners' groups, and valve manufacturers [10, 15, 17-19, 22-26], show that wedge gate valves can thermally bind (i.e., experience a large increase in unwedging thrust) after being subjected to one of the following two scenarios:

> ***Scenario # 1:*** Valve is wedged closed while hot, and allowed to cool down before reopening.
>
> ***Scenario # 2:*** Valve is wedged closed while cold, then heated up (typically due to increase in fluid temperature on one side of the disc), then reopened.

3.2 ANALYTICAL METHODOLOGY TO ADDRESS THERMAL BINDING

Thermal binding is a significantly more complex phenomenon than pressure locking, and the options to mitigate its effects are fewer. At the present time there is no validated analytical methodology to predict the increase in unwedging thrust under thermal binding conditions. Unvalidated criteria based on operating experience and engineering judgment have been used to identify valves susceptible to thermal binding.

EPRI undertook the development of a validated thermal binding methodology in 1998. Under the first phase of this project, an analytical methodology based on first principles for predicting the increase in unwedging thrust under various thermal-binding scenarios was developed [12-14].

The EPRI thermal binding methodology is very comprehensive and takes into account all the known significant mechanisms that can contribute to an increase in unwedging thrust after being subjected to thermal binding conditions. The methodology described in detail in Reference 12. The EPRI methodology is applicable to the following sequences of operation:

- The valve is closed hot and allowed to cool down before unwedging
- The valve is closed cold and exposed to high temperature on one side before unwedging
- The valve is subjected to changes in upstream and downstream pressures (which can cause pressure-induced disc pinching) either apart from or in conjunction with the temperature changes.

The methodology has been exercised over a wide range of valve design parameters and operating conditions [14]. The results show that unwedging thrust under thermal binding conditions can increase by a relatively small amount to as much as over 100 percent over the baseline unwedging thrust. The increase depends upon the disc stiffness, body stiffness, stem/yoke stiffness, the fluid medium, the fluid temperature, and whether the valve is closed hot/opened cold or closed cold/opened hot, and whether pressure change effects are present in conjunction with the thermal effects.

Under Phase II of this project, EPRI is pursuing plans to test a 3-inch gate valve simulating PORV block valve conditions, and possibly other valves, under a variety of thermal binding scenarios, fluid conditions, and design parameters to validate the methodology.

3.3 METHODS TO ADDRESS THERMAL BINDING

Thermal binding concerns for gate valves can be mitigated by several approaches, such as:

- Closing the valve using a limit switch to prevent wedging. This option is permissible only if seat shut-off under low DP is not of concern.
- Frequently operating the valves to limit the temperature change between closure and opening. This can limit the increase in unwedging thrust to small and acceptable magnitudes.
- Some combinations of coefficients of thermal expansion (body, seat, and disc as well as stem and yoke) may reduce or eliminate thermal binding under one of the scenarios mentioned earlier. For example, some valves may not bind under Scenario #1 if the disc shrinks more than the body when the valve is cooled after closure.
- Determining unwedging thrust increase under the expected scenarios by testing. The test data can be used to ensure adequate actuator capability margins under design basis conditions.
- Replacing the wedge gate valve with a parallel slide (non-wedging) gate valve. This option should consider the differences in the shut-off capability of the parallel slide design as compared to the wedge gate valve.

3.4 SUMMARY OF THERMAL BINDING SURVEY RESULTS

The Thermal Binding Survey (see Appendix A) was submitted to all of the U.S. utilities and some Canadian utilities. Twenty-six U.S. nuclear power plants responded to the thermal binding (TB) survey, and the detailed results are given in Table B.2 in Appendix B. Key results of the TB survey are summarized as follows:

Population of Gate Valves with TB Concerns (Item 2.1)

- For the plants that responded to the survey, the total number of gate valves found to be susceptible to TB is 336 valves with an average of 13 valves per plant. The number of susceptible valves per plant ranges from a minimum of 0 valves in one plant to a maximum of 45 valves in another plant.
- The number of valves in water systems is about 91 percent of the total number of valves reported to be susceptible to TB. The remaining 9 percent of the gate valves susceptible to TB are in other systems (primarily steam).

Causes of TB in Gate Valve (Item 2.2)

- 299 valves (average of 12 valves per plant) were reported to be susceptible to TB due to temperature reduction (closed hot and opened after cooling).
- 5 valves were reported to be susceptible to TB due to temperature increase (closed cold followed by heat-up from upstream or downstream side).
- 16 valves were reported to be susceptible to TB due to transient conditions (closed hot and attempted reopening within short period of time while the system remained hot).

Valve and Disc Designs (Items 2.3)

- 71 valves (23 percent of total) were reported to be of solid wedge gate designs.
- 216 valves (68 percent of total) were reported to be of flexible wedge gate designs.
- 28 valves (9 percent of total) were reported to be of split wedge disc designs.

Hardware Modifications Used to Eliminate or Mitigate TB Conditions (Item 2.4)

- One plant replaced 2 valves with another valve design (GE Sentinel valve) which is qualified against thermal binding by analysis and flow loop testing as well as in-situ testing. Both valves were 10-inch, Class 900 valves. They were installed in the high-pressure coolant injection (HPCI) system as turbine steam admission and outboard containment isolation valves.

Scope of TB Screening (Item 2.5)

- Three plants extended thermal-binding screening to include nonsafety-related valves, which are important to plant operation.

Empirical and Analytical Methods Used to Justify Gate Valve Capability under TB Conditions (Item 2.6)

- All 26 plants used empirical methods to determine the susceptibility to TB.
- 17 plants (65 percent of total) used empirical criteria to justify gate valve opening capability under TB conditions.
- 1 plant used in-situ testing under typical operating conditions to demonstrate opening capabilities of gate valves that were thought to have a potential for thermal binding.
- The remaining 8 plants (31 percent of the total) utilized changes in operating procedures to prevent the occurrence of thermal binding (see summary for Item 2.9 below).
- 1 plant performed a prototype test at Wyle Laboratories. Empirical approach based on test data was used to address TB at that plant. The plant identified 11 valves with TB concerns.

Specific Empirical Methods Used to Screen for TB Potential (Item 2.7)

Seven plants (within one utility) used the following criteria to screen for the potential for thermal binding:

- *Solid* wedge gate valves are considered susceptible to thermal binding when the temperature change between the time the valve is closed and the time the valve is opened is greater than 50ºF.
- *Flexible* wedge gate valves are considered susceptible to thermal binding when the temperature change between the time the valve is closed and the time the valve is opened is greater than 100ºF.

One plant used the following criteria to screen for the potential for thermal binding:

- *Solid* wedge gate valves are considered susceptible to thermal binding when the temperature change between the time the valve is closed and the time the valve is opened is greater than 75ºF.
- *Flexible* wedge gate valves are considered susceptible to thermal binding when the temperature change between the time the valve is closed and the time the valve is opened is greater than 150ºF.

Six plants used the following criteria to screen for the potential for thermal binding:

- Wedge gate valves (both *solid* and *flexible* wedge gate designs) are considered susceptible to thermal binding when the temperature change between the time the valve is closed and the time the valve is opened is greater than 100ºF, and the valve is opened at temperatures greater than 200ºF.

Awareness of EPRI's Thermal Binding Method (Item 2.8)

- 17 plants (65 percent of the total) reported that they were aware of EPRI's Thermal Binding Method. These plants had about 85 percent of the total population of gate valves within this TB survey.
- 5 plants indicated that their potential use of EPRI's Thermal Binding Method is for the PORV block valves. These plants had about 43 percent of the total population of gate valves within this TB survey.
- At the time of this survey, EPRI's TB Method was not used by any of plants.

Changes in Operating Procedures Used to Address TB Concerns (Item 2.9)

Nineteen plants (73 percent of the total) used changes in operating procedures to address thermal binding concerns. The following changes in operating procedure were reported:

- Periodically stroke TB susceptible valves during significant temperature changes such as during plant heat-up and cooldown (six plants, or 23 percent of total). In general, the valve stroking frequency is set such that temperature changes are limited to less than 50ºF.
- Close on limit to prevent wedging (three plants, or 12 percent of total).
- Limit opening of the LPI valves only at temperatures below 200ºF (three plants within one utility).
- Do not declare valve operable until after a thermal equilibrium is reached (two plants within one utility).

Discussion

The survey results show that most thermal binding concerns were addressed using operating experience and limiting the temperature change to an acceptable level by unwedging the valve frequently during large temperature changes. Limit closing without wedging the disc was another commonly used option. One plant used prototype testing simulating the plant conditions in a flow loop to determine increases in unwedging thrust under different magnitudes of changes in temperature between closure and opening. Increases in thrust ranging from 10 percent to over 100 percent were measured during the testing. Actuator modifications were performed to ensure adequate unwedging thrust capability for valves found to have increased unwedging thrust requirements. Another plant used in-situ testing under thermal binding conditions to demonstrate valve unwedging under TB conditions. Unlike for pressure locking, options for hardware modifications are limited to valve and/or actuator upgrading.

Once validated, the EPRI gate valve thermal binding methodology will provide a useful tool for utilities to quantify increased thrust requirements under thermal binding conditions.

4 APPROACHES TO ADDRESS HEAT UP OF FLUID IN CONTAINMENT SUMP ISOLATION VALVES

Containment sump valves are connected to the containment spray system and/or the safety injection system. Under design basis conditions (e.g., LOCA), these valves are required to open to recirculate the sump water. In some plants these valves are classified as "containment isolation valves."

As described in Section 2, under certain conditions, the bonnet cavity in the containment sump gate valve can trap water. During LOCA, the high temperature of water in the containment sump can cause heat-up of this trapped water by thermal conduction and convection through the connecting pipe between the containment sump and the containment sump isolation valves. The purpose of conducting this survey was to determine the various approaches used by the U.S. utilities to address this issue.

The survey form for thermal heat-up of fluid in the containment sump piping and its effect on sump isolation valves (see Appendix A) was submitted to all of the U.S. utilities and some Canadian utilities. Twenty-one PWR plants responded to this survey and the detailed results are given in Table B.3 in Appendix B. The key results of the survey responses are summarized as follows:

Susceptibility of the Containment Sump Isolation Valves to PL and/or TB (Item 4.1)

- The containment sump isolation valves in 18 plants (86 percent of total) were found to be susceptible to pressure locking and thermal binding prior to implementing the necessary modifications (see results of the first two tasks in this survey).
- Two plants reported that the sump isolation valves are normally open per Normal System Alignment (NSA), and as such are not susceptible to PL/TB. (See Survey Results, Item 5.1 in Section 5.2 below, for more information about those two plants.)
- One plant reported that the containment sump isolation valves are butterfly valves, which are not subject to PL/TB.

Valve and Disc Designs (Item 4.2)

- 29 valves (58 percent of total) were reported to be of flexible wedge gate design.
- 11 valves (22 percent of total) were reported to be of solid wedge gate design.
- 6 valves (12 percent of total) were reported to be of double disc design.
- 2 valves (4 percent of total) were reported to be of parallel disc design.
- 2 valves (4 percent of total) were reported to be butterfly valves.

Water Flooding of the Sump Pipe between Sump and Sump Isolation Valves (Item 4.3)

- 13 plants (62 percent of total) reported that the piping between the sump and the sump isolation valves is flooded. Eight of these plants monitor and maintain the sump water level.
- 2 plants (24 percent of total) monitor sump water level using level switches and observation. Four plants have surveillance procedures to monitor the sump water level.

Evaluation of the Thermal Mixing Effect on the Temperature Rise at the Containment Sump Valve in the Dead Leg under Design Basis Conditions (Item 4.4)

- 5 plants (24 percent of total) evaluated the thermal mixing effect on the temperature rise at the containment sump valve in the dead leg under design basis conditions using calculations (1 plant), Westinghouse evaluation (2 plants), and engineering judgement (2 plants).

Sump Design Basis Pressure and Temperature Used to Determine Required Opening Thrust for the Sump Isolation Valves (Item 4.5)

- 15 plants (71 percent of total) use sump design basis pressure and temperature to determine the required opening thrust for the sump isolation valves. One plant assumed bonnet temperature to rise to the average temperature on both sides of the valve. Two plants have normally open valves and are not subject to PL/TB. One plant has butterfly valves, which also are not subject to PL/TB. Two plants did not provide a response to this question.

Discussion

The survey results show that all PWR plants have identified the sump isolation gate valves that are normally closed to have pressure locking and thermal binding concerns. Hardware and operating procedures were modified to address PL and TB. The survey did not reveal a generic criterion (such as water volume, horizontal and vertical pipe length/diameter ratio) to determine the effect of thermal mixing on the temperature rise at the sump valves. However, Westinghouse has provided evaluations for at least 2 Westinghouse plants.

Two plants use double tandem seal design in their sump recirculation pump to eliminate the need for sump isolation valves. These valves are kept in the fully open position per Normal System Alignment (NSA). Description and basis for this specific pump design are provided in Section 5.

The sump isolation valves in one plant are butterfly valves, which are not subject to PL and TB. The MOV engineer in this plant indicated that seat replacement and other maintenance of these butterfly valves are extremely difficult due to tight space and poor accessibility.

5 THE PURPOSE OF AND ALTERNATIVES TO DOUBLE-WALLED CONTAINMENT SUMP PIPING

5.1 INTRODUCTION

The USNRC Standard Review Plan describes the purpose and need for double-walled containment sump piping [29]. In particular, on page 6.2.4-4 of the SRC, the USNRC states "*If it is not practical to locate a valve inside containment (for example, the valve may be under water as a result of an accident), both valves may be located outside containment. For this type of isolation valve arrangement, the valve nearest the containment and the piping between the containment and the valve should be enclosed in a leak-tight or controlled-leakage housing. If, in lieu of a housing, conservative design of the piping is assumed to preclude a breach of piping integrity, the design should conform to the requirements of SRP Section 3.6.2. Design of the valve and/or piping compartment should provide the capability to detect leakage from the valve shaft and/or bonnet seals and terminate the leakage*."

Some PWR plants in the U.S. do not have this leak-tight or controlled-leakage housing (also called double-walled containment sump piping). The basis and technical justification for eliminating this leak-tight or controlled-leakage housing in these plants can be found in the plant design documents for these specific plants. A survey to determine the status of this issue in the U.S. was conducted and the results are summarized in the following section.

5.2 SUMMARY OF SURVEY RESULTS FOR THE NEED FOR DOUBLE-WALLED CONTAINMENT SUMP PIPING

The survey for the need for double-walled containment sump piping (see Appendix A) was submitted to all of the U.S. utilities and some Canadian utilities. Twenty-one PWR plants responded to this survey and the detailed results are given in Table B.4 in Appendix B. The key results of the survey responses are summarized as follows:

Population of Plants with Containment Sump Valves and Piping of Double-Wall or Encapsulated Piping Design (Item 5.1)

- The containment sump isolation valves and piping in 10 PWR plants (48 percent of total) had a double-wall, or encapsulated design. The remaining 11 plants did not have a double-wall or encapsulated design.
- One plant has their sump piping system qualified under specific General Design Criteria (GDC) references, and their pump seals have been qualified as a containment boundary. The

pump seals are a double (tandem) seal design with a pressurized, non-radioactive water supply to the gap between the seals. Performance of these seals is monitored through instrumentation so their integrity can be continuously confirmed.

- A sister plant (to the above plant) has 2 of its 4 pumps inside the containment and would not require isolation for containment integrity. The other 2 pumps have the same design as the one mentioned above.

Primary Objective of the Double Wall Containment Sump Piping (Item 5.2)

- Five plants (50 percent of total) stated that the primary purpose of the double-wall containment sump piping is to be an extension of the containment boundary.
- Five plants (50 percent of total) stated that the primary purpose of the double-wall containment sump piping is to limit an unisolable leak from containment causing a fission products release path to the auxiliary Building.
- One plant cited conservation of water inventory as another primary purpose of the double-wall containment sump piping.
- Two plants attached the following write-up to their response on Item 5.2:

> ***Containment Sump Piping Protective Barrier***
>
> *The RHR suction lines from the containment recirculation sump constitute a special case. It is not in the best interest of safety to have an inboard isolation barrier on this penetration, or to have additional isolation valves on the suction lines. Hence, there is no inboard isolation barrier, and there is only one outboard isolation valve. The closed RHR system is considered to be a second outboard barrier. As a consequence of this configuration, in an effort to compensate for the lack of an inboard barrier, a second barrier has been provided around the outboard portion of the penetration, surrounding the penetration piping and outboard valve. This barrier is in the form of a guard pipe and protective chamber. This barrier is leak-tight and serves to contain any leakage which might come through the valve shaft or bonnet seals. The chamber meets the same code standards as the containment liner plate. The design pressure of this chamber is 20 psig. The chamber is fitted with observation ports and a level detection system to allow detection of any leakage into it.*
>
> *Since the chamber functions as a second leakage (but not pressure) barrier to the valve seals, it is a Design Class I structure, and the connecting piping is Design Class I, Utility Quality Class II. Presently, no credit is taken in the off-site dose analysis for the leak-tightness of the chambers, and they are not surveillance tested for leak-tightness.*

Modification to Eliminate the Outer Envelope of the Containment Sump Piping (Item 5.3)

- There has been no implementation of any modifications to eliminate the outer envelope of the containment sump piping by any of the plants that responded to the survey.
- During construction, two plants prepared technical justification to eliminate the double-walled piping for the containment sump. However, due to construction schedule, the double-walled piping was used. These plants provided the following justification with their response to this survey:

> *The SIS and CSS are closed systems designed to seismic Category I standards, classified SC2, protected from missiles and have a design temperature and pressure rating at least equal to that for the Containment.*
>
> *The three RCB emergency sump recirculation lines, each of which supplies suction to a LHSI pump, HHSI pump, and Containment spray pump, are each provided with a single remote-manual gate valve outside the RCB In lieu of encapsulation of the recirculation lines and sump isolation valves, the piping and valves are conservatively designed to preclude a breach of piping integrity. Level instrumentation in the FHB SIS cubicle sumps will detect leakage in the recirculation loop, including the valve seals. This leakage will be terminated by manually isolating that pump train from the control room.*
>
> *The SI recirculation phase is automatically initiated by a low-low level in the RWST coincident with the SI signal. The HHSI and LHSI pump's miniflow valves are automatically closed and the sump isolation valves automatically opened.*
>
> *With this system, no single failure of either an active or passive component will prevent the recirculation of core cooling water or adversely affect the integrity of the RCB. The present arrangement meets all safety requirements.*

Discussion

The survey results show that none of the U.S. plants had converted the double-walled containment sump piping to a single-wall piping. However, alternatives and technical justifications are feasible.

In some U.S. plants, double-walled containment sump piping presented difficulty to perform modifications and maintenance on the containment sump isolation valves.

6
POTENTIAL REDUCTION IN ELECTRIC MOTOR ACTUATOR OUTPUT UNDER ELEVATED TEMPERATURE CONDITIONS

6.1 INTRODUCTION

Background

In 1989 the USNRC issued Generic Letter 89-10 ("Safety-Related Motor-Operated Valve Testing and Surveillance"), which recommended that each US nuclear utility develop a program to ensure that the switch settings on all safety-related, motor-operated valves are selected, set, and maintained in such a way as to ensure that the MOVs will operate under design basis conditions. To fulfill this requirement, utilities were required to more accurately determine valve requirements and actuator capability under design basis conditions. As valve requirements increased, the actuator was challenged to meet these higher demands while still meeting valve closure speed specifications.

Since the issuance of Generic Letter 89-10, testing and analysis by actuator manufacturers, industry, and the USNRC have shown that the output of some electric motors decreases significantly at higher temperatures, mostly because of the higher resistance in the motor windings. This is the case regardless of whether the increase in temperature is caused by ambient conditions or by motor operations.

AC Motors

Reliance 3-Phase electric motors are used extensively in Limitorque Corporation valve actuators. Evaluation of these motors shows that the locked rotor torque and locked rotor amperage will vary with motor temperature. Typically locked rotor torque and locked rotor amperage decreases as motor temperature increases. Based on analysis performed by Reliance Electric [34] and testing performed by Limitorque [32, 34], amperage loss can be as high as 29.0% and torque loss can be as high as 30.8%, depending on electric motor rated torque, frame size, and speed. Adjustments to account for the loss of torque due to temperature effects are provided by Limitorque for operation in the temperature range of 77°F (25°C) to 356°F (180°C). Within this range the current and torque loss were found to vary linearly with temperature. The motor starting torque ratings given for Reliance motors are applicable up to 104°F (40°C), and no adjustments need to be made for temperatures up to 104°F (40°C). For temperatures higher than 104°F (40°C), the torque should be adjusted as stated in References 32 and 34. Only minimal speed reduction occurs as a function of temperature until the motor approaches the reduced stall torque output.

Rotork Controls, Inc. recommends reducing the starting torque capability for their AC motor for temperatures greater than 162°F (72°C). The motor sizing factors vary from 1.1 for temperatures up to 256°F (124°C) to as high as 1.17 for temperatures up to 370°F (188°C). Specific guidelines are given in Reference 39.

DC Motors

Compound wound, RH-insulated DC motors used in Limitorque actuators produce rated torque up to a maximum ambient temperature which varies from 120°F (49°C) to 300°F (149°C) depending on the motor size and voltage rating [37]. For their maximum service rating of 340°F (171°C) ambient temperature, Limitorque [36] provides a single value of derated torque at an ambient temperature of 340°F (171°C) for each DC motor with a starting torque rating of 40 ft-lb or greater. For motors smaller than 40 ft-lb, the starting torque rating remains the same up to 340°F (171°C) ambient temperature. Limitorque provides no guidance for determining torque loss due to motor heating during operation. Limitorque is currently evaluating test data developed by INEEL [38] on the effect of temperature on DC motors.

Motor speed reduction as a function of temperature is more significant in DC motors than in AC motors, and the loss in speed for the same torque is dependent on the motor size.

The INEEL tests showed that the torque output from smaller size DC motors at ambient temperature can be significantly higher than the motor's rating. This higher torque output can lead to unconservative predictions of stroke time at elevated temperature when the predictions are based on stroke tests at room temperature ambient conditions. The reduction in speed also has a compounding effect on the gear efficiency. The added loss in gear efficiency can further reduce the stroke time based on the valve-required torque at elevated temperature.

6.2 SUMMARY OF SURVEY RESULTS FOR APPROACHES TO ADDRESS EFFECTS OF ELEVATED TEMPERATURE ON ELECTRIC MOTOR ACTUATOR OUTPUT CAPABILITY

The survey for approaches to address effects of elevated temperature on electric motor actuator output (see Appendix A) was submitted to all US utilities and some Canadian utilities. Twenty-five US plants responded to this survey and the detailed results are given in Table B.5 in Appendix B. Key results of the survey responses are summarized as follows:

Population of Electric Motors Used in MOVs (Item 3.1)

- All plants have Reliance three-phase motors. Sixteen plants (64 percent of total) have Peerless Porter DC motors. Four plants (16 percent of total) have Rotorque motors. Two plants (8 percent of total) have Limitorque motors. Three plants (12 percent of total) have Electric Apparatus motors.

Number of MOVs Susceptible to Elevated Temperature Effect on Motor Output Reduction (Item 3.2)

- 849 valves (34 MOVs per plant) were reported to be susceptible to elevated temperature effect on motor output reduction under postulated accident conditions.
- 514 valves (21 MOVs per plant) were reported to be susceptible to elevated temperature effect on motor output reduction under normal operating conditions.

Major Causes of Electric Motor Heating (Items 3.3)

- 696 valves (28 MOVs per plant) were reported to be susceptible to elevated temperature effect on motor output reduction caused by rise in ambient temperature only.
- 480 valves (19 MOVs per plant) were reported to be susceptible to elevated temperature effect on motor output reduction caused by electric-motor-generated heat in addition to rise in ambient temperature.
- There was no report that electric-motor-generated heat alone was the cause for elevated temperature effect on motor output reduction.

Primary Concern of Increase in Electric Motor Temperature (Item 3.4)

- Twenty-four plants (96 percent of total) reported that the primary concern about increased electric motor temperature is reduction in motor output torque.
- One plant (4 percent of total) indicated that an increase in stroke time in DC motors was the primary concern of increase in electric motor temperature.
- One plant (4 percent of total) reported that the primary concerns about increased electric motor temperature are reduction in motor output torque as well as increase in stroke time.

Hardware Modifications Used to Eliminate Potential Reduction of Motor Output Due to Temperature Rise (Item 3.5)

- Five plants (20 percent of total) reported that hardware modifications were used to eliminate the potential reduction of motor output due to temperature rise.
- Three plants (12 percent of total) replaced the motor to eliminate the potential reduction of motor output due to temperature rise. However, motors were replaced in conjunction with other reasons such as to increase the output thrust/torque and to increase speed.
- Two plants (8 percent of total) replaced the actuator to eliminate the potential reduction of motor output due to temperature rise. However, actuators were replaced in conjunction with other reasons such as to increase the output thrust/torque and to increase speed.
- One utility with two plants replaced gears on 50 MOVs. Another plant replaced gears on 8 MOVs.
- One plant incorporated losses into design calculations. However, other plants may have done the same but have not reported it.

Use of Transient Analysis to Take Credit for Lag in Temperature Rise between Ambient Temperature and Motor Winding (Item 3.6)

- Three plants (12 percent of total) performed transient analysis to take credit for lag in temperature rise between ambient temperature and motor windings.

Sources of Information Used to Evaluate Motor Output Degradation Due to Temperature Rise (Item 3.7)

- All plants used Limitorque Technical Update 93-03 [32].
- Three plants (12 percent of total) performed transient analysis to take credit for lag in temperature rise between ambient temperature and motor windings.

Changes in Operating Procedures to Eliminate Motor Output Degradation Due to Temperature (Item 3.8)

- None of the plants participating in this survey reported any changes in operating procedures to eliminate motor degradation due to temperature.

Discussion

Survey results show that all plants used Limitorque Technical Update 93-03 (starting torque at elevated temperature). Hardware changes included replacement of motors, actuators, and actuator gears. Some hardware changes were done in conjunction with other objectives.

7
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A
QUESTIONAIRE SENT TO U.S. AND CANADIAN UTILITIES

This appendix provides a copy of the survey material and the cover letter that was e-mailed to all U.S. utilities and some Canadian utilities. Requests for additional information and clarification were also submitted by e-mail as well as telephone and fax messages. The survey is divided into five sections; each section addresses one of the five tasks discussed in the main body of this report.

Responses were received over a period of several months. Appendix B provides the summary of responses from U.S. nuclear power plants.

Questionaire Sent to U.S. and Canadian Utilities

From: John Hosler / EPRI
M. S. Kalsi / Kalsi Engineering
B. H. Eldiwany / Kalsi Engineering

Subject: Comparison of US and French Strategies
for Pressure Locking / Thermal Binding

Generic Letter 95-07 was issued to address pressure locking and thermal binding (PL/TB) of power-operated valves at US nuclear power stations. EPRI, in collaboration with the French, has embarked on a project to exchange information and compare approaches on the matter at an international level. As most U.S. utilities are well along, if not finished with their efforts to address PL/TB, the French are interested in comparing approaches to dealing with this issue to the benefit of the industries in both countries. Additionally, the French are interested in learning more about motor torque degradation caused by elevated ambient temperatures, and the use and requirements for use of double-walled containment sump piping (encapsulation).

The first portion of this effort is to conduct a survey of both U.S. and French units to determine what approaches are being used and to provide a basis for comparison. From the standpoint of U.S. utilities, minimizing the time spent on this survey may be accomplished by the use of previously generated responses to the NRC or summary reports prepared for that purpose. Use of this type of information would allow EPRI to extract the needed information without placing undue burden on the utilities.

US utilities completing the survey will enjoy the benefit of participating in an international project to resolve a potentially significant safety concern. Participants will also receive a copy of the final report, which will include survey results from both countries.

Please provide your input in the space provided and feel free to attach any additional information you consider important to this project. Responses by e-mail are encouraged if it is more convenient for survey respondents.

Kalsi Engineering, Inc. has been retained to conduct this study. Clarifications, discussions, and questions should be forwarded to Dr. M. S. Kalsi or Dr. Bahir Eldiwany at:

Telephone: (281) 240-6500

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Note: The attached file is in MS Word 6.0/95.

EPRI Survey Questionnaire

Comparison of US and French Strategies for Pressure Locking, Thermal Binding

Name:________________________	Utility:________________________
Title:________________________	Plant/Unit:________________________
Telephone No: ________________________	NSSS:________________________
Fax No.:________________________	e-mail Address:________________________

Please note that 180-day responses and previous summary reports prepared by your plant to address NRC Generic Letter 95-07 can be used to minimize your effort to respond to this survey. Please provide answers for each plant/unit.

The objectives for the five tasks under this project are stated for your information only, followed by the list of questions that we need you to answer.

Task 1: Compare and Contrast US and French Approaches to Gate Valve Pressure Locking (PL) Issue.

The EPRI objective is to compare assumptions and analytical methods used by US utilities to demonstrate gate valve capability under pressure locking conditions to those being used by France. The relative benefits and shortcomings of each approach shall be tabulated.

To support this objective, please answer the following questions:

1.1 Approximate number of valves susceptible to PL

- a) In water systems ________________
- b) In steam systems with steam condensate ________________

1.2 Approximate number of valves susceptible to PL due to:

- a) Bonnet pressure increase caused by: pressure transient ________________
- b) Bonnet pressure increase caused by: rise in bonnet temperature ________________
  - i) Due to increase in outside environmental temperature ________________
  - ii) Due to increase in water temperature inside the piping ________________
- c) Pressure increase in piping between two isolation valves ________________

1.3 Approximate number of valves that are susceptible to PL and have bi-directional sealing function ________________

1.4 Types and manufacturers of gate valves susceptible to PL:

a) Number of flexible wedge / manufacturer ____________________

b) Number of double disk / manufacturer ____________________

c) Number of split wedge / manufacturer ____________________

d) Number of parallel disk gate valves / manufacturer ____________________

e) Other (specify and provide additional information) ____________________

1.5 Did you use hardware modifications to eliminate potential PL problems Yes/No ____________

If yes, which hardware modification was implemented
(Enter the approximate number of valves for each modification)

a) Drilled a hole in the upstream disk ____________

b) Used an external pipe between bonnet and upstream piping ____________

c) Used an external pipe between bonnet and nearby drain ____________

d) Used a safety relief valve to limit bonnet pressure ____________

e) Used an external pipe between bonnet and upstream/downstream piping with manual or automatic switching valve ____________

f) Replaced valve ____________

g) Replaced actuator ____________

h) Other modifications, ... Specify and provide additional information. ____________

1.6 Did you use analytical methods to demonstrate gate valve capability under PL conditions? Yes/No ____________

If yes, which method was used (check one)

a) Entergy Operations Method (Reference 1*) ____________

b) Com-Ed Method (Reference 2*) ____________

c) KEI Generalized PL Method (Reference 3*) ____________

d) Other Method (specify and provide references and relevant information) ____________

* **References:**

1. B. D. Bunte and J. F. Kelly. "Commonwealth Edison Company Pressure Locking Test Report," U.S. NRC NUREG/CP-0152, presented at Fourth NRC/ASME Symposium on Valve and Pump Testing, July 1996.
2. D. E. Smith. "Calculations to Predict the Required Thrust to Open a Flexible Wedge Gate Valve Subjected to Pressure Locking," *Proceedings of Workshop on Gate Valve Pressure Locking and Thermal Binding*, U.S. NRC, NUREG/CP-0146, February 1994.
3. J. K. Wang and S. S. Averitt. "Generalized Pressure Locking Methodology," Kalsi Engineering, Inc. Document No. 1968C, Rev 0, 1998.

e) Did your analytical methods apply to valves with thermally induced pressure locking (caused by bonnet pressure rise of trapped water due to temperature increase)? ________________

i) If so, what was the pressure increase (psi/°F) used in your evaluation? ________________

1.7 Did you use changes in operating procedures to eliminate potential for PL (e.g., used limit switch in closing to prevent wedging, periodically stroke valve, reduce steam condensate at or near isolation valves ...etc.) Yes/No ________________

If yes, provide a brief description.

1.8 Did the PL screening include valves with nonsafety-related functions that are important to plant operation Yes/No ________________

1.9 Did you take credit for any of the following for reduction in bonnet pressure? (check all applicable items)

a) Air in the bonnet Yes/No ________________

b) Seat leakage Yes/No ________________

c) Packing leakage Yes/No ________________

d) Bonnet pressure reduction due to stem retraction caused by stem head to T-slot clearance Yes/No ________________

e) PL condition decay with time before opening valve Yes/No ________________

1.10 Screening for PL was performed by:

a) Valve experts Yes/No ________________

b) System engineers Yes/No ________________

c) Operations personnel Yes/No ________________

d) Interdisciplinary team (all of the above) Yes/No ________________

Task 2: Compare US and French Approaches to Gate Valve Thermal Binding (TB) Issue.

The EPRI objective is to compare assumptions and analytical methods used by US utilities to demonstrate gate valve capability under thermal binding conditions to those being used by France. The relative benefits and shortcomings of each approach shall be tabulated.

To support this objective, please answer the following questions:

2.1 Approximate number of valves susceptible to TB

- a) In water systems ________________
- b) In steam systems ________________

2.2 Approximate number of valves susceptible to TB caused by: ________________

- a) Temperature reduction (closed hot and opened after cooling) ________________
- b) Temperature increase (closed cold followed by heat-up from upstream or downstream side) ________________
- c) Transient conditions due to hot closure and attempted reopening within short period of time (the system remains hot) ________________

2.3 Types and manufacturers of valves determined to be susceptible to TB:

- a) Solid wedge gate valves/manufacturer ______________________________
- b) Flex wedge gate valves/manufacturer ______________________________
- c) Other (specify and provide additional information) ______________________________

2.4 Did you use hardware modifications to eliminate potential TB problems? Yes/No ________________

If yes, which hardware modification was implemented?(Enter the approximate number of valves in each modification)

- a) Replaced valve (specify old and new types and manufacturers) ________________
- b) Replaced actuator ________________
- c) Other modifications, ... Specify and provide additional information. ________________

2.5 Did the TB screening include non safety-related valves that are important to plant operation? Yes/No ________________

2.6 Did you use analytical methods or empirical criteria to justify gate valve capability under TB conditions? (circle one) Analytical/Empirical ________________

2.7 Which method was used (check one)

- a) Empirical-based operating temperature difference criteria Yes/No ________________
  - i) ΔT for solid wedge gate $\Delta T =$ ________________
  - ii) ΔT for flexible wedge gate $\Delta T =$ ________________
- b) Other Method (specify) ________________

2.8 Are you aware of EPRI's first principles thermal binding model (Reference 1*) that has been developed and is being validated to predict unwedging thrust under thermal binding scenarios? Yes/No ________________

a) If yes, identify the type of applications for which it has the potential to resolve thermal binding problems in your plant (attach details). ________________

2.9 Did you use changes in operating procedures to justify TB conditions (e.g., used limit switch in closing, periodically stroke valve during heat-up/cool-down,...etc.) Yes/No ________________

If yes, provide a brief description.

* **Reference:** 1. *Gate Valve Thermal Binding Methodology*, Electric Power Research Institute Report EPRI GC-110301, prepared by Kalsi Engineering, Inc., March 1998.

Task 3: Compare US and French Approaches to Address Potential Effects of Elevated Temperature on Electric Motor Actuator Output Capability.

The EPRI objective is to compare Limitorque guidance regarding ambient temperature effects as well as assumptions being made by US utilities regarding potential magnitudes in ambient temperatures under accident and normal operating conditions to those being made by France and their motor actuator vendors.

To support this objective, please answer the following questions:

3.1 Name of manufacturers of electric motors used on your MOVs

a) Reliance 3-phase ____________________

b) Rotorque ____________________

c) Other (specify) ____________________

Manufacturer address ____________________

& telephone. No. ____________________

____

3.2 Number of MOVs susceptible to elevated temperature effect on motor output reduction

a) Under postulated accident conditions only ____________

b) Under normal operating conditions ____________

3.3 Number of MOVs susceptible to motor actuator output reduction due to

a) Ambient temperature rise only. ____________

b) Motor-generated heat in addition to ambient temperature rise ____________

c) Motor-generated heat only. ____________

3.4 Was the primary concern due to temperature increase limited to

a) Reduced motor output torque ____________

b) Reduced stroke time ____________

c) Both ____________

3.5 Did you use hardware modifications to eliminate potential reduction of motor output due to temperature rise? Yes/No ____________

If yes, which hardware modification was implemented (Enter the number of MOVs in each modification)

a) Replaced motor ____________

b) Replaced actuator ____________

c) Incorporated thermal barriers/insulation ____________

d) Other modifications, ... Specify and provide additional information. ____________

3.6. Did you perform transient thermal analysis to take credit for lag in temperature rise between ambient and the motor winding? Yes/No ________________

3.7 Did you evaluate motor output degradation due to temperature rise using:

a) References 1 and 2* Yes/No ________________

b) Other sources (specify and provide details) ________________

3.8 Did you use changes in operating procedures to eliminate motor output degradation due to temperature? Yes/No ________________
If yes, provide brief description or attach details

* **References:** 1. Limitorque Technical Update 93-03: Reliance 3-Phase Limitorque Corporation Actuator Motors (Starting Torque @ Elevated Temperature);
2. Potential 10CFR 21 Condition for Reliance 3-Phase, L. C. Motors (Starting Torque at Elevated Temperature); Limitorque Corporation, May 13, 1993.

Task 4: Compare US and French Approaches to Address Thermal Mixing within Containment Sump Piping and Its Effect on Sump Isolation Valves

The EPRI objective is to compare assumptions and methods used by US utilities to address the potential for fluid temperature increase at the inlet of gate valves which must open to allow suction from the containment sump, and any consequent pressure locking/thermal binding effects, to those being used by France.

To support this objective, please answer the following questions:

4.1 Are the containment sump isolation valves susceptible to PL and/or TB? Yes/No ________________

If no, what was the justification?

a) Plant experience ________________

b) Testing ________________

c) Other justification (provide explanation) ________________

4.2 Provide type/manufacturer of sump isolation valve

a) Number of flexible wedge/manufacturer ________________

b) Number of double disk/manufacturer ________________

c) Number of parallel disk gate/manufacturer ________________

d) Number of split wedge/manufacturer ________________

e) Other (specify) ________________

4.3 Is the sump pipe between sump and sump isolation valve flooded with water to provide a thermal barrier ("dead leg" effect) to delay/limit the heating of the sump isolation valves during LOCA? Yes/No ________________

If so, do you monitor and maintain the sump water level? Yes/No ________________
(Attach a description of the approach.)

4.4 Was the effect of thermal mixing on the temperature rise at the containment sump valve in the *dead leg* of the piping evaluated under design basis conditions? Yes/No ________________

If yes, specify approach used

a) Measurement/testing Yes/No ________________

b) Computational Fluid Dynamics (CFD) Analysis Yes/No ________________

c) Other, ... Specify and provide details ________________

d) Was a generic criteria developed? (e.g., horizontal and vertical pipe length/diameter ratio, water volume) Yes/No ________________

If yes, attach description/references. Yes/No ________________

4.5 Was the sump design basis pressure and temperature used to determine required opening thrust for the sump isolation valves? Yes/No ________________

Task 5: Compare U.S. and French Positions Regarding the Purpose and Need for Double Walled Containment Sump Piping

The EPRI objective is to compare U.S. and French positions on the purpose of and the need for double walled containment sump piping. The reviewer shall include a definition of any U.S. utilities who may have removed such piping. Evaluation of the specific bases for such actions is beyond the scope of this project.

To support this objective, please answer the following questions:

5.1 Are your containment sump valves and piping of double-wall or encapsulated design (i.e., surrounded by a metallic envelope)?

5.2 What is the primary objective of the double wall containment sump piping? (Attach brief description.)

a) Extension of the containment boundary Yes/No ________________

b) Damage protection from missiles ________________

c) To ensure train separation by maintaining recirculation inventory and preventing damage to the opposite train due to flooding in the Auxiliary Building. ________________

d) Limiting an unisolable leak from containment causing a fission products release path to the Auxiliary Building ________________

e) Other reason (specify) ________________

5.3 a) Have you implemented any modifications to eliminate the outer envelope of the containment sump piping? Yes/No ________________

If yes, describe the approach and basis. ________________

b) Do you know of any other plant that implemented modifications that eliminate the outer envelope of their containment sump piping? Yes/No ________________

If yes, identify the plant. ________________

B
SUMMARY OF SURVEY RESULTS

APPENDIX B

SUMMARY OF SURVEY RESULTS

As part of this project, a detailed survey was conducted (see forms in Appendix A. The survey consists of five sections, and each section addresses one of the stated tasks. The survey results for each task are summarized in separate tables as follows:

Table B.1	Summary of Pressure Locking Survey Results
Table B.2	Summary of Thermal Binding Survey Results
Table B.3	Summary of Survey Results for Thermal Mixing within Containment Sump Piping and Its Effect on Sump Isolation Valves
Table B.4	Summary of Survey Results for the Need to and Options for Double Walled Containment Sump Piping
Table B.5	Summary of Survey Results for Potential Reduction in Electric Motor Actuator Output under Elevated Temperature Conditions

These tables are provided in this appendix. Each table provides the following information:

- Column 1 provides the question number in each task
- Column 2 provides the total number of valves or plants (referred to as "units"), as applicable
- Subsequent columns include NSSS design, plant design (PWR or BWR), the number of plants (units) included in the response, and the specific responses for each question.
- Footnotes are provided as needed to document plant-specific comments.

Table B-1
Summary of Pressure Locking Survey Results (Task 1)

Item No.	Total	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6	Response 7	Response 8	Response 9	Response 10	Response 11	Response 12	Response 13	Response 14	Response 15	Response 16	Response 17
NSSS		West.	Comb. Eng.	GE	West.	B&W	West.	West.	West.	GE	Comb. Eng.	GE	Comb. Eng.	West.	West.	West.	West.	GE
		Section 5	Section 8	Section 9	Section 17a	Section 17b	Section 17c	Section 18-1	Section 18-2	Section 26	Section 27	Section 28	Section 29	Section 31	Section 36	Section 38	Section 39	Section 42
System		PWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR
No. of Units	26	1	2	1	2	3	2	1	1	2	1	1	1	2	1	2	2	1
1.1	427	4	20	12	100	43	67	6	17	10	6	17	6	38	25	9	38	9
1.1a	354	4	14	12	82	40	63	6	17	10	5	14	6	30	20	9	14	8
1.1b	73	0	6	0	18	3	4				1	3	0	8	5		24	1
1.2 (multiple sources of PL)		4	20	14	110	43	67	8	19	10	6	19	11	48	20	9	38	9
1.2a	355	0	14	6	110	28	67	6	14	10		15	6	36	18	9	8	8
1.2b	100	4	6	8	0	15	0	2	5	0	6	4	5	12	2	0	30	1
1.2b.i	72	0	6	4		15		2	5		1	2	3	10	0		24	
1.2b.ii	28	4	0	4							5	2	2	2	2		6	1
1.2c	0																	
1.3	93		10	8	10	9	10	2				0	2	0	3		38	1
1.4	412	4	20	12	110	43	67	6	14	2	6	15	6	38	25	9	26	9
1.4a	305	4	18	11	78	34	37	4	12	2	4	15	6	13	23	9	26	9
1.4b	60			1	28	8								21	2			
1.4c	31					1	26	2	2									
1.4d	16		2		4		4				2			4				
1.4e	0																N/A	
1.5 (units)	22	Yes (1)	Yes (2)	Yes (1)	Yes (2)	Yes (3)	Yes (2)	Yes (1)	Yes (1)	Yes (2)	Yes (1)	Yes (1)	Yes (1)	Yes (2)	Yes (1)	No	No	Yes (1)
1.5a	113			4	26	15	15	4	12	4	2	11	3	8	2			7
1.5b	48		4	2				2	2	6	1			30				1
1.5c	0																	
1.5d	9			2						2	2				3			
1.5e	110				60	20	30											
1.5f	30				12	6	12											
1.5g	24				12	2	10											
1.5h	Note1,3,9,10	Note 1	Note 3												Note 9			1, Note 10
1.6	9-Yes / 8 ST	Short term (1)	Yes (2)	No	Short term (2)	Short term (3)	Short term (2)	No	No	No	Yes (1)	No	No	No	Yes (1)	Yes (2)	Yes (2)	Yes (1)
1.6a (units)	(14 w/3 Initial)	1	2-Initially								1		2					1-partial
1.6b (units)	(15)		Yes (2 units)		Yes (2 units)	Yes (3 units)	Yes (2 units)								Yes (1)	Yes (2)	Yes (2)	partial (1)
1.6c	2,Note 13																	
1.6d																		
1.6e (units)	(11)	Yes,Note11(1)	Yes,Note4(2)		Yes,Note 5(2)	Yes,Note 5(3)	Yes,Note 5(2)								No	No		Yes,50 psid(1)
1.6e.i																		
1.7 (units)	(7)	Yes,Note2 (1)	No	Yes (1)	No	No	No	No	No	No	Yes,Note 6(1)	Yes,Note 7(1)	Yes,Note 8(1)	No	Yes,Note 6(1)	No	No	Tempo. (1)
1.8 (units)	(3)	No	Yes (2)	No	No	No	No	No	No	No	No	No	Yes (1)	No. Note 12	No	No	No	No
1.9 (units)																		
1.9a (units)	(1, 7 S.T.)	Yes (1)	No	No	Short term (2)	Short term (3)	Short term (2)	No	No	No	No	No	No	No	No	No	No	No
1.9b (units)	(1, 9 S.T.)	Yes (1)	Short term (2)	No	Short term (2)	Short term (3)	Short term (2)	Yes	Yes	No	No	No	No	No	No	No	No	No
1.9c (units)	(7 S.T.)	No	No	No	Short term (2)	Short term (3)	Short term (2)	No	No	No	No	No	No	No	No	No	No	No
1.9d (units)	(7 S.T.)	No	No	No	Short term (2)	Short term (3)	Short term (2)	No	No	No	No	No	No	No	No	No	No	No
1.9e (units)	(5, 7 S.T.)	Yes (1)	No	No	Short term (2)	Short term (3)	Short term (2)	Yes	Yes	No	No	No	No	Yes (2)	No (per NRC)	Yes (2)	No	No
1.10a (units)	(12)	Yes (1)			Yes (2)	Yes (3)	Yes (2)			Yes (2)	Yes (1)							Yes (1)
1.10b (units)	(11)				Yes (2)	Yes (3)	Yes (2)				Yes (1)						Yes (2)	Yes (1)
1.10c (units)	(1)																	Yes (1)
1.10d (units)	(12)		Yes (2)	Yes (1)				Yes (1)	Yes (1)			Yes (1)	Yes (1)	Yes (2)	Yes (1)	Yes (2)		

Note 1: Added air volume pipe attached to valve bonnet
Note 2: The PORV Block valves are stroked periodically. Others closed on limit.
Note 3: Installed a flow path to ensure the presence of a water slug thermal barrier.
Note 4: 40 psi/deg F based on INEEL test data.
Note 5: 5 psi/oF if < 130 oF; 23 psi/oF if >130 and <450; 100 psi/oF if >450 oF.
Note 6: Periodically stroke valve.
Note 7: Close on limit (to prevent wedging) for valves with no seat leakage requirements. Limitation of the plant technical spec. during surveillance testing of other valves.
Note 8: Revised procedures to provide an alternate flow path if valve binds.
Note 9: Regear to increase actuator output.
Note 10: Accumulator on bonnet.
Note 11: Westinghouse Owners Group uses generic value of 23 psi/deg F.
Note 12: NRC Requirements
Note 13: Two utilities used the generalized pressure locking methodology after submitting their response to the survey questionnaire.

Table B-2
Summary of Thermal Binding Survey Results (Task 2)

Item No.	Total	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6	Response 7	Response 8	Response 9	Response 10	Response 11	Response 12	Response 13	Response 14	Response 15	Response 16	Response 17
NSSS		West.	Comb. Eng.	GE	West.	B&W	West.	West.	West.	GE	Comb. Eng.	GE	Comb. Eng.	West.	West.	West.	West.	GE
		Section 5	Section 8	Section 9	Section 17a	Section 17b	Section 17c	Section 18-1	Section 18-2	Section 26	Section 27	Section 28	Section 29	Section 31	Section 36	Section 38	Section 39	Section 42
System		PWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR
No. of Units	26	1	2	1	2	3	2	1	1	2	1	1	1	2	1	2	2	1
2.1	336	**2**	**4**	**3**	**90**	**66**	**80**	**3**	**3**	**30**	**5**	**3**	**11**	**6**	**3**	**0**	**26**	**1**
2.1a	306	2	2	0	86	63	80	3	3	30	4	2	9			0	22	
2.1b	30		2	3	4	3					1	1	2	6	3	0	4	1
2.2	320	**2**	**4**	**3**	**90**	**66**	**80**	**3**	**3**	**30**	**5**	**3**	**11**	**6**	**3**	**0**	**10**	**1**
2.2a	299			3	90	60	80	3	3	30	3	3	11	6	3		4	
2.2b	5		2	0							2							1
2.2c	16	2	2	0		6											6	
2.3	315	**2**	**4**	**3**	**90**	**74**	**77**	**3**	**3**	**2**	**5**	**3**	**13**	**6**	**3**	**0**	**26**	**1**
2.3a	71		2		10	37	14			2			6				0	
			2.5" Velan		Walworth	Walworth	Walworth-Greenburg						Crane					
					Pacific	Borg Warner	Borg Warner											
						Crane												
						Powell												
2.3b	216	2	2	3	80	36	36	3	3		5	3	7	6	3		26	1
		Westinghouse	12" Velan	Velan	Borg Warner	Walworth	Walworth-Alloyc	Velan	Westinghouse		Velan	Anchor/Darling	5 Velan	Velan	Westinghouse		Westinghouse	Walworth
					Westinghouse	Borg Warner	Borg Warner						2 Crane					
					Rockwell													
2.3c	28					1	27											
						1-Split Wedge												
						Walworth-Alloyc	Walworth-Alloyco											
2.4 (units)	Yes (5)	No	No	Yes (1)	No	No	No	No	No	No	No	No	No	Yes (2)	No	No	Yes (2)	No
2.4a	1			1-Sentinel Valve														
2.4b	2			2														
2.4c																		
2.5	3	No	Yes (2)	No	No	No	No	No	No	No	No	No	Yes (1)	No	No		No	No
2.6 (units)	Empirical (17)		Empirical (2)	Empirical (1)	Empirical (2)	Empirical (3)	Empirical (2)	Empirical (1)	Empirical (1)		Empirical (1)		Empirical (1)				Analytical (2)	Yes,In process
2.6 (units)	Insitu test (1)																	
2.6 (units)	None (8)	Neither (1)								No (2)		No (1)		No (2)	No (1)	No (1)		
2.7																		
2.7a (units)	Yes (13)		Yes (2)	Yes (1)	Yes (2)	Yes (3)	Yes (2)	Yes (1)	Yes (1)	No (2)	Yes (1)	No (1)	No (1)	No (2)	No (1)	No (2)	No (2)	No (1)
i) deg F			Yes		50	50	50	To>200 F and	To>200 F and		75							
ii) deg F			yes		100	100	100	DT>100 F	DT>100 F		150							
2.7b				In-situ testing									prototype testing				System Analysis	
2.8 (units)	Yes (17)	No (1)	No (2)	Yes (1)	Yes (2)	Yes (3)	Yes (2)	Yes (1)	Yes (1)	No (2)	Yes (1)	Yes (1)	No (1)	Yes (2)	No (1)	No (1)	Yes (2)	Yes (1)
2.8a	None			Not used	N/A	PORV Block Valv	PORV Block Valv	None	None		Not evaluated	Not evaluated		Not used			None	Valve noted
2.9 (units)	Yes (19)	Yes (1)	Yes (2)	No (1)	No (2)	Yes (3)	No (2)	Yes (1)	Yes (1)	Yes (2)	Yes (1)	Yes (1)	Yes (1)	Yes (2)	Yes (1)	No (2)	Yes (2)	Yes (1)
		Close on limit	Periodic Stroke			Stroke LPI at		Valve declared inoperable until		Crackvalves	Periodic	Periodic	Periodic	Usedlimit	Periodic		Delayopening	
		1/2" before hard	during Heatup/			less than		stroked after thermal equilibrium		until cool	Stroking	Stroking	Stroking	switch	Stroking		time	
		seat	Cooldown			200 F						during						
												Cool-Down						

Table B-3
Summary of Survey Results for Thermal Mixing Within Containment Sump Piping and Its Effect on Sump Isolation Valves (Task 4)

Item No.	Total	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6	Response 7	Response 8	Response 9	Response 10	Response 11	Response 12	Response 13	Response 14	Response 15	Response 16	Response 17
NSSS		West.	Comb. Eng.	GE	West.	B&W	West.	West.	West.	GE	Comb. Eng.	GE	Comb. Eng.	West.	West.	West.	West.	GE
		Section 5	Section 8	Section 9	Section 17a	Section 17b	Section 17c	Section 18-1	Section 18-2	Section 26	Section 27	Section 28	Section 29	Section 31	Section 36	Section 38	Section 39	Section 42
System		PWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR
No. of Units	21	1	2	1	2	3	2	1	1	2	1	1	1	2	1	2	2	1
4.1 (units)	18	Yes (1)	Yes (2)	N A	Yes (2)	Yes (3)	Yes (2)	No	No	NA	Yes (1)	NA	No	Yes (2)	Yes (1)	Yes (2)	No	NA
4.1a																		
4.1b																		
4.1c								Note 5	Note 5							ComEd	Drilled Disc	
4.2a	29	2-West	4-24" Velan		4-West		4-Walworth-..		2-A/D	2					2-West	1-West	6-West	
		2-A/D					Greensburg											
4.2b	6													4-A/D	2-A/D			
4.2c	2										2-A/D							
4.2d																		
4.2e	11-solid Wedge					6-Solid wedge		2-Solid Wedge					2-B'fly valves			3-Solid wedge		
	2-B'fly					Powell		Pacific					Allis Chalmers			Copes-Vulcan		
4.3 (units)	Yes (13)	No	Yes (2)		Yes (2)	Yes (3)	Yes (2)	N/A	N/A		Yes (1)		No	No	Yes (1) Note 8	Yes (2)	No	
4.3a (units)	Yes (8)		Yes (2), Note 2		No	No	No				Yes (1) Note6				Yes (1) Note 6	Yes (2) Note 6	No	
4.4 (units)	Yes (5)	No	Yes (2)		No	No	No	N/A	N/A		Yes (1) Note7		No	No		Yes (2)	No	
4.4a																		
4.4b																		
4.4c			Note 3															
4.4d			No													Yes		
																Westinghouse		
																Evaluation		
4.5 (units)	Yes (16)	Yes (1)	Yes (2)		Yes (2)	Yes (3)	Yes (2)	N/A	N/A		No		N/A	Yes (2)		No	Yes (2)	
		Note 1	Note 4															

Note 1: Bonnet temperature assumed to rise to average water temperature on both sides of the valve

Note 2: Level switches and observation

Note 3: Engineering judgement

Note 4: Pressure only

Note 5: Normal System Alignment (NSA)-Open

Note 6: Surveillance procedure

Note 7: Calculations

Note 8: Prior to drilling holes in the discs

Table B-4
Summary of Survey Results for the Need to and Options for Double Walled Containment Sump Piping (Task 5)

Item No.	Total	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6	Response 7	Response 8	Response 9	Response 10	Response 11	Response 12	Response 13	Response 14	Response 15	Response 16	Response 17
NSSS		West.	Comb. Eng.	GE	West.	B&W	West.	West.	West.	GE	Comb. Eng.	GE	Comb. Eng.	West.	West.	West.	West.	GE
		Section 5	Section 8	Section 9	Section 17a	Section 17b	Section 17c	Section 18-1	Section 18-2	Section 26	Section 27	Section 28	Section 29	Section 31	Section 36	Section 38	Section 39	Section 42
System		PWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR
No. of Units	21	1	2	1	2	3	2	1	1	2	1	1	1	2	1	2	2	1
5.1 (units)	Yes (10)	Yes (1)	Yes (2)	NA	No	No	No	No	No	NA	Yes (1)	NA	Yes (1)	Yes (2)	Yes (1)	Yes (2)	Double wall	NA
			Encapsulated								Encapsulated							
5.2a (units)	Yes (5)	No									Yes (1)		Yes (1)	No	Yes (1)	Yes (2)		
5.2b (units)													No	No				
5.2c (units)													No	No				
5.2d (units)		Yes (1)	Yes (2)										No	Yes (2)				
5.2e (units)			Water invetory										No					
5.3a (units)		No	No								No		No	No	No	No	No	
5.3b (units)		No	No								No			No	No	No	No	

Table B-5
Summary of Survey Results for Potential Reductions in Electric Motor Actuator Output Under Elevated Temperature Conditions (Task 3)

Item No.	Total	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6	Response 7	Response 8	Response 9	Response 10	Response 11	Response 12	Response 13	Response 14	Response 15	Response 16	Response 17
NSSS		West.	Comb. Eng.	GE	West.	B&W	West.	West.	West.	GE	Comb. Eng.	GE	Comb. Eng.	West.	West.	West.	West.	GE
		Section 5	Section 8	Section 9	Section 17a	Section 17b	Section 17c	Section 18-1	Section 18-2	Section 26	Section 27	Section 28	Section 29	Section 31	Section 36	Section 38	Section 39	Section 42
System		PWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR	PWR	BWR	PWR	PWR	PWR	PWR	PWR	BWR
No. of Units	25	1	2	1	2	3	2	1	1	2	1	1	1	2	1	2	2	1
3.1a (units)	Reliance (25)	No response	Reliance (2)	Reliance (1)	Reliance (2)	Reliance (3)	Reliance (2)	Reliance (1)	Reliance (1)	Reliance (2)	Reliance (1)	Reliance (1)	Reliance (1)	Reliance (2)	Reliance (1)	Reliance (2)	Reliance (2)	Reliance (1)
3.1b (units)	Rotorque (4)										0	Rotorque (1)		Rotorque (2)	Rotorque (1)			
3.1c (units)	Peerless (16)			Peerless (1)	Peerless (2)	Peerless (3)	Peerless (2)	Peerless (1)			0	Peerless (1)	Peerless (1)	Peerless (2)		Peerless (2)		Peerless (1)
	Limitorque (2)													Limitorque (2)				
	Elect. App (3)												Elect. App (1)	Elect. App (2)				
3.2a	(849)			85	50	111	50	67	128	80%		49	35	56	60	0	148	10
3.2b	(514)			0	30		10	102, Note 5	128			44	0	0	20	6	154	20
3.3a (MOVs)	(696)			4	80	42	60			All	52	49	35	46	20	6	302	
3.3b (MOVs)	(480)			81		69		102	128			0		10	60	0		30
3.3c (MOVs)				0								0		0	0			
3.4a (units)	(24)		Yes (2)	Yes (1) Note2	Yes (2)	Yes (3)	Yes (2)	Yes (1)	Yes (1)	Yes (2)	Yes (1)	Yes (1)	Yes (1)	Yes (2)	Yes (1)	Yes (2)	Yes (2)	
3.4b (units)								No	No	No		No	No	No				
3.4c (units)										No			No	No				Yes (1)
3.5 (units)	(5)		No	Yes (1)	No, Note 4	No, Note 4	No, Note 4	No	No	No	Yes (1)	No	No	No	No	No	Yes (2)	Yes (1)
3.5a (units)	(3)			Yes (1) Note3							Yes (1), 3							Yes (1)
3.5b (units)	(2)			Yes (1) Note3														Yes (1)
3.5c (units)				No														
3.5d (units)								Note 6			Note 7						Gear changes	
																	on 50 MOVs	
3.6 (units)	(3)		No	Yes (1)	No	No	No	Yes (1)	Yes (1)	No	No	No	No	No	No	No	No	No
3.7a (units)	(25)		Yes (2)	Yes (1)	Yes (2)	Yes (3)	Yes (2)	Yes (1)	Yes (1)	Yes (2)	Yes (1)	Yes (1)	Yes (1)	Yes (2)	Yes (1)	Yes (2)	Yes (2)	Yes (1)
3.7b (units)			Note1					No	No	No			No					
3.8 (units)			No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No

Note 1: Limitorque guidance

Note 2: Increase stroke time for DC motors only

Note 3: Motors were replaced in conjunction with other reasons including increase in output thrust/torque and increase speed

Note 4: Not Solelly due to temperature effects

Note 5: Due to mispositioning event assumed for all 89-10 MOVs

Note 6: Incorporated losses into design calculations

Note 7: Changed gears on 8 MOVs

Note 8: Changed gears on 50 MOVs