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

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SUBJECT: SUMMARY OF PUBLIC WORKSHOP ON GATE VALVE PRESSURE LOCKING AND THERMAL BINDING

On February 4, 1994, AEOD and NRR, together with Research and Regional staff, hosted a public workshop with representatives of the nuclear industry, including licensees, vendors and consultants. The purpose of the workshop was to discuss potential pressure locking and thermal binding of gate valves at nuclear power reactors. Enclosure 1 is the agenda and Enclosure 2 is a list of the workshop participants. Each presentation is summarized below, in the order shown on the agenda. AEOD is also preparing a detailed NUREG which will provide broader discussions of each of the issues raised at the meeting.

Enclosure 3 provides a copy of questions received by the staff in response to the Federal Register Notice, published on November 29, 1993, announcing the workshop. Only one member of the public responded, and the questions posed were addressed during the course of the workshop.

WELCOME AND INTRODUCTION (Jack Rosenthal, AEOD, and John Hannon, NRR)

The purpose and format of the workshop were discussed, together with the history of the issues to be addressed. Attendees were referred to NUREG-1275 (Volume 9) for more historical details and discussions of potential remedial actions to address pressure locking and thermal binding issues. The staff has published many information notices and other generic communications regarding pressure locking and thermal binding, and this workshop was designed to help industry focus on these issues. Concern was expressed that plant operations may not be getting adequate attention by those addressing pressure locking and thermal binding. Recent PRA analyses indicated that the conditional core

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damage frequency could significantly increase due to common mode failures caused by pressure locking and/or thermal binding.

NRC STAFF SUMMARY OF PRESSURE LOCKING AND THERMAL BINDING ISSUES (Earl Brown and Chuck Hsu, AEOD, see Enclosure 4)

NUREG-1275 (Volume 9) was referenced regarding an historical perspective. The presenters stated that flexible wedge, double disc and parallel slide gate valves were most susceptible to pressure locking while solid wedge valves were most susceptible to thermal binding. For pressure locking to occur, there must be a source of water to fill the bonnet, and a mechanism to increase the bonnet pressure, such as heating the enclosed water or pressure from a connected system. Bonnets can become pressurized due to ambient temperature effects. Thermal binding (due to differential contraction of dissimilar metals in the valve body and disc) can be caused by temperature gradients.

For proper analysis, the precursors to pressure locking must be understood, particularly with regard to normal plant operations, inservice testing, and post-accident situations. With regard to operations, re-alignment of valves after tests can lead to problems. Normal valve alignments must be studied. The Vogtle pressure locking case was referenced as an example. Several improper assumptions such as lack of operational maintenance history, no leakage past inline check valves, and consideration of normal operations only can prevent the identification of susceptible valves. Because of the broad, complex nature of the contributing factors to pressure locking, a team approach utilizing people with expertise in component operation, system operation, and plant operations should be employed.

There are several stages to lockup. Partial lockup can cause damage to a valve that is not immediately obvious. For example, locked rotor current in 10 to 15 seconds can degrade the torque capability and possibly burn up the windings.

Possible scenarios for pressure locking in various systems were discussed for both BWR and PWR plants, and included sump suction, RHR, low pressure safety injection, and core spray valves, and PORV block valves. Flex wedge, split wedge, parallel slide and double disc gate valves have the potential for pressure locking.

The conclusion was that no generalizations regarding valve susceptibility to pressure locking and/or thermal binding can be made. Rather, all valves must be looked at individually as related to their environments during all modes of plant operations, including the full accident sequence.

LICENSEE EXPERIENCE - ENTERGY/GRAND GULF (Dana Smith, Entergy Operations, Incorporated, see Enclosure 5)

Grand Gulf re-evaluated their flex wedge gate valves, and determined that a method to predict pressure locking problems was needed. They developed an analysis technique to predict total required stem thrust and initially utilized it as a justification for continued operation. One valve, a 14 inch Powell gate valve, has been laboratory tested as part of the validation process. Modifications have already been made on many valves, and other

problem valves are to be modified during the next outage. They have chosen external modifications because they preferred not to deal with problems associated with disassembly/re-assembly.

INTERNATIONAL EXPERIENCE - SIEMENS (N. Schauki, Siemens, see Enclosure 6)

Pressure locking of gate valves was discovered at fossil plants in Germany almost 30 years ago. Tests were conducted to determine the pressure increase versus the temperature in the bonnets. The tests began at 63 °F and showed that bonnet pressure increased rapidly after the temperature exceeded 70 °F. The bonnet pressure was 1000 psi when the temperature reached 100 °F. Techniques were developed to solve the problems, and included disc drilling and valve bonnet internal venting. Recently, relief valves have been used, and a new valve design, utilizing a disc holder, has been developed. The disc holder concept allows the disc to float, seating downstream of the high pressure side of the valve. If the downstream pressure increases, then the disc can float to the upstream seating surface. This provides a relief path from the bonnet to the high pressure side of the disc, regardless of the direction of the pressure gradient across the valve.

The presenter also mentioned a problem which can occur when two globe valves are installed in opposite orientations in a piping system, and both are closed. The fluid between the two valves can achieve very high pressures due to temperature increases, possibly challenging the pressure boundary.

LICENSEE EXPERIENCE - COMMONWEALTH EDISON/LASALLE (Mark Dowd, LaSalle Station, see Enclosure 7)

The presenter, who has many years experience in operations (up through the supervisor level), stated that regardless of the precautions, operator error is possible. Therefore, the operators should not be needlessly challenged.

An event at LaSalle regarding pressure locking of an RCIC valve was described in great detail. The valve was changed from a flex wedge to a double disc valve due to high pull out forces and leakage. In cycling the new valve, pressure locking occurred, and internal retaining pins on the valve sheared. A multi-discipline team (engineering, operations and maintenance) was formed to evaluate the problem, and developed a list of questions used to determine susceptibility to pressure locking. They reviewed 750 valves (of which 301 are included in the Generic Letter [GL] 89-10 program), and found 40 different categories of valves which were susceptible. This review took approximately three months. PRA was used for prioritization, and all ECCS valves were included in the high priority group. To date, one valve disc has been drilled, with modifications to other valves planned in upcoming outages.

Thermal binding was also discussed. A temperature gradient was established across a valve because of plant conditions, and the valve subsequently failed to open due to thermal binding. Also, ambient temperature effects can cause pressure locking, as demonstrated by the event at LaSalle. The presenter emphasized that both pressure locking and thermal binding are real and need to be properly analyzed using a team approach. As a result of their research, they presented information that illustrated a valve initially at 84 °F

subjected to an external 64 °F temperature rise (148 °F air temperature) resulted in a bonnet pressure of 2000 psi within 15 to 20 minutes depending upon the heat transfer coefficient. They also described an event in which the presence of condensate in a steam system valve caused pressure locking.

In response to a question from the audience, organic intrusion into systems due to valve modifications was discussed. The presenter was emphatic in stating that these concerns are real and must be analyzed, but that they are much less important than pressure locking.

LICENSEE EXPERIENCE - AMERICAN ELECTRIC POWER/D.C. COOK (Dick Kadlec, D.C. Cook, see Enclosure 8)

The presenter stated that pressure locking and thermal binding were considered as part of the original plant design. When thermal binding was suspected, parallel slide valves were utilized. Some containment sump recirculation valves had equalizing lines installed to protect against pressure locking, but were later removed following a study conducted in response to an INPO generic communication.

After discussing valve problem history at Cook, the presenter mentioned that equalizing lines, instead of disc drilling, had been employed. Double disc valves were modified first, then flex wedge valves. They chose not to drill the discs because they did not want the valves to become unidirectional. The licensee conducted a study of valves, which operations reviewed. Out of 200 valves, 80 were considered for modification.

LICENSEE EXPERIENCE - ENTERGY/ANO (Bill Rowlett, ANO and Jim Warren, Gilbert Commonwealth, see Enclosure 9)

ANO has a proactive program to address all possible valve locking problems. The presenters stated that they believed it was more cost effective to modify valves than to perform a detailed analysis to justify no modifications. The licensee has identified 181 gate valves under the GL 89-10 program for the two units at the site. Valve data were analyzed to determine which valves needed particular attention regarding potential locking. A total of 74 valves were identified that required further review, and were placed into four categories: thermal binding, pressure locking, proximity effect locking, and environmental effect locking. Of these valves, 28 have the potential for pressure locking and 18 have the potential for thermal binding.

The potential susceptibility of containment sump recirculation valves to pressure locking was discussed. One issue of concern is whether there is a mechanism to fill the bonnet with water, such as during plant startup. Both the B&W and CE units at ANO have intervening valves that are closed during plant startup. This appears to be an option to reduce or alleviate subsequent pressure locking of these valves.

VENDOR ACTIONS - WESTINGHOUSE (Ike Ezekoye, Westinghouse Electric Corporation, see Enclosure 10)

Westinghouse has conducted laboratory tests on valves, and has proposed corrective actions for field use. They expect the licensees to provide them

with the valve conditions which must be accounted for in the design. The advantages and disadvantages of four corrective measures were discussed. When a valve is modified by drilling a hole in the disc, the hole size should be limited (about 1/8 inch or less). The use of manual isolation valves for relief lines is difficult to implement on small valves. When relief valves are used which vent back into the system, sizing and lift point are critical issues. When venting to other areas, these concerns are not as critical. When providing a vent by installing an internal hole in the valve body, the hole may be more susceptible to blockage than a hole in the disc, which can be flushed by system flow.

VENDOR ACTIONS - ANCHOR DARLING (Drew Wright, Anchor Darling, see Enclosure 11)

The presenter discussed some of Anchor Darling's findings and potential solutions to pressure locking and thermal binding problems. They found that valve bodies and discs have different coefficients of thermal expansion. This can lead to the disc contracting less than the body during cooldown (after closure), causing thermal binding.

Regarding pressure locking, the bonnet of the valve can be pressurized without flexing the disc. In addition, increasing pressure in the bonnet could lift the disc off the seat slightly, causing leakage. Recommended solutions for pressure locking included disc drilling, bonnet pressure vents, and external bypass lines from bonnet to body.

The vendor suggested that the licensees identify susceptible valves and provide more operational data so that additional engineering effort can be focused on these problems.

VENDOR ACTIONS - VELAN (John Farrell, Velan, see Enclosure 12)

One remedial solution proposed for thermal binding was to periodically cycle the valve as it cooled down, preventing the build up of stresses. Also, insulated valves may experience less temperature change, resulting in lower binding forces. Velan believes thermal binding can be caused by disc expansion, not just differential contraction of the body/disc. Therefore, they re-analyzed the wedge design, leading to design changes. They reduced the amount of material in the wedge (while still meeting ASME Code requirements), which significantly reduced the forces caused by thermal binding.

NRC DRAFT GENERIC COMMUNICATION ON PRESSURE LOCKING AND THERMAL BINDING (Tom Scarbrough, NRR, see Enclosure 13)

The proposed generic communication on pressure locking and thermal binding was discussed. The current proposal is not restricted to motor-operated valves, but also includes power operated valves. Manual valves could also be a concern, though there are few safety related manual valves.

Concerns were expressed regarding the reliability of the Grand Gulf methodology in justifying valve operability because the licensee's validation

only included tests on one valve. Any licensee utilizing this analytical approach will need to consider validation testing.

QUESTION AND ANSWER SESSION

The panel session to address questions, scheduled for the end of the day, was not necessary, as the participants had asked questions of each speaker during the presentations.

CLOSING REMARKS

Jack Rosenthal thanked the over 300 industry representatives attending the workshop for their enthusiastic partic ation. He stated that a NUREG will be prepared by AEOD to discuss the workshop, and should be issued this spring.

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Enclosure 1

Meeting Agenda

OAM-12-6

PUBLIC WORKSHOP MEETING AGENDA — FEBRUARY 4, 1994

GATE VALVE PRESSURE LOCKING AND THERMAL BINDING

WELCOME AND INTRODUCTION	8:00 a.m.
Jack Rosenthal, AEOD, and John Hannon, NRR	
PRESSURE LOCKING AND THERMAL BINDING ISSUES	8:15 a.m.
Earl Brown and Chuck Hsu, AEOD	
LICENSEE EXPERIENCE AND EFFORTS	
Dana Smith – Entergy, Grand Gulf	9:30 a.m.
Identifying susceptible valves, tests to confirm thrust levels during pressure locking, corrective actions	
BREAK	10:00–10:15 a.m.
Mark Dowd – Commonwealth Edison, LaSalle	10:15 a.m.
Identifying susceptible valves, steam system pressure locking, combined pressure locking/thermal binding	
Dick Kadlec – American Electric Power, D. C. Cook	11:15 a.m.
Efforts to alleviate pressure locking at D. C. Cook	
Bill Rowlett – Entergy, Arkansas Nuclear One Jim Warren – Gilbert Commonwealth	11:45 a.m.
RHR valve sequencing to lessen pressure locking; pressure locking/thermal binding review at ANO	
LUNCH	12:15–1:15 p.m.
VALVE VENDOR CORRECTIVE ACTIONS	
Ike Ezekoye – Westinghouse Electric Corp.	1:15 p.m.
Design modifications to alleviate pressure locking	
Drew Wright – Anchor Darling	1:45 p.m.
Corrective actions to address pressure locking	
John Farrell – Velan	2:15 p.m.
Thermal binding test and analysis	
NRC DRAFT GENERIC COMMUNICATION	2:45 p.m.
Tom Scarbrough, NRR	
BREAK	3:15–3:30 p.m.
QUESTION AND ANSWER SESSION	3:30 p.m.
All presenters as panel	
CLOSING REMARKS	4:45 p.m.
Jack Rosenthal, AEOD, and John Hannon, NRR	

Enclosure 2

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Earl J. Brown
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Office for AEOD
Washington, DC 20555

Enclosure 3

Questions Received From Public in
Response to Federal Register Notice

BAL-TECH
205 RHINEFORTE DRIVE, CHURCHVILLE, MARYLAND 21028-1517

December 31, 1993

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Dear Allen G. Hansen,

This letter is in response to the Notice of Meeting published in the Federal Register on November 29, 1993. To assist NRC in preparing for the meeting interested parties were requested to mail questions to NRC concerning potential pressure locking and thermal binding of gate valves installed in safety related systems at both boiling water and pressurized water reactors. Attached is a list of 34 questions.

We appreciate the opportunity to raise these questions, and look forward to your response to each at the public meeting.

Sincerely,

Michael M. Martin
Senior Engineer

BAL-TECH
205 RHINEFORTE DRIVE, CHURCHVILLE, MARYLAND 21028-1517

ATTACHMENT
QUESTIONS

Pressure Locking and Thermal Binding

1. Are only valves mounted with stems horizontal or oriented so that the valve bonnet is below the valve body susceptible to pressure locking?

2. Are valves mounted with the stem vertical not susceptible to pressure locking?

3. Was pressure locking caused by an increase in ambient temperature in any of the cases studied by the AEOD? If so, which case?

4. Has pressure locking been caused by an increase in ambient temperature in any case of which NRC is aware? If so, when and where?

5. Was pressure locking caused by an increase in system fluid temperature in any system that is not used to remove core decay heat in any of the cases in the AEOD study? If so, which case?

6. Was pressure locking caused by an increase in system fluid temperature in any system that is not used to remove core decay heat in any cases of which NRC is aware? If so, when and where?

7. Was the pressure locking event caused by an increase in fluid temperature in the Residual Heat Removal System at a BWR, and documented in the AEOD study, a safety concern? Was the valve that pressure locked required to be operable in the plant mode of operation in which the valve was found to be pressure locked?

8. Were the pressure locking events caused by an increase in fluid temperature in the Residual Heat Removal System at PWRs, and documented in the AEOD study, a safety concern? Were the valves that pressure locked required to be operable in the plant mode of operation in which the valve was found to be pressure locked?

9. Did all the AEOD study documented cases of differential pressure locking occur post hydrostatic testing? If not, which case?

   Note: Differential pressure locking is descibed in SOER 84-07, Page 6.

10. Are the AEOD documented cases, which are due to hydrostatic testing, at a significantly higher pressure than the pressure available from the process fluid system? If not, which case?

11. Did any differential pressure locking cases occur, of which NRC is aware, which did not occur post hydrostatic testing? If so, when and where?

12. NRC recommends valve modifications and appropriate procedures to prevent binding from occuring in the AEOD study. Are actuator modifications also a reasonable means to prevent binding? If not, why not?

13. Is there any available NRC accepted calculational methodology in use to determine the amount of thrust required to unseat a pressure locked valve? If so, please provide a reference. If not, why not?

14. Is the calculational method provided in Sections 2.1 through 2.4 and Section 5.2 of NUREG/CR-5807, a valid methodology to find the amount of thrust required to unseat a pressure locked valve? If not, why not?

15. For a flex wedge gate valve, may the double disk drag forces in Section 5.2 of NUREG/CR-5807 be reduced to account for the decreased surface area of the valve inside disk due to the disk hub, and remain a valid calculation? If not, why not?

16. For cold water systems (less than 200 degrees F), may a flex- wedge gate valve disk to seat coefficient of friction of 0.4 be used for each valve disk if a significant amount of preconditioning has not been performed? If not, why not?

17. May a significant amount of preconditioning be defined as more than 100 full strokes within a one year period? If not, why not?

18. Is pressure locking a concern only when steam is introduced into a previously hydrostatically tested steam system before proper draining?

19. For valves that are potentially susceptible to pressure locking, if an actuator is used that can provide ten times the amount of thrust as the actuator that would normally be used, is the valve no longer a pressure locking concern? If not, why not?

20. How much greater actuator capability is required to assure a valve susceptable to pressure locking will not pressure lock? Why was this value picked?

21. Did any case of the AEOD study occur due to thermal binding of a gate valve where the component was required to be operational and a Technical Specification Action Statement not entered? If so, which case?

22. Is there any case of which NRC is aware where thermal binding of a gate valve occurred where the component was required to be operational and a Technical Specification Action Statement not entered? If so, where and when?

23. Is operating within the Action Statements of Technical Specifications operating within the safety design bases of the plant?

24. Is there any proposed physical modification of Containment Isolation Valves that does not jeopardize Containment Integrity (especially under low differential pressure, long term LOCA, conditions)? Do these modifications involve increased flowpaths or reduce the integrity of the present barriers that prevent radioactive materials from escaping to the environment?

25. Do proposed modifications comprise additional safety related equipment (ie. solenoid or relief valves) governed by Containment Isolation Criteria?

26. If valve bonnet relief or solenoid operated valves are used to physically modify susceptable valves, what setpoints should be considered for such equipment (See question 13)?

27. Do all the proposed modifications increase the probability of contaminates being introduced into the reactor coolant system from the service water systems, condensate transfer systems, torus or containment sump? Note: Increased contaminates should be compared to normal makeup. For BWRs normal make up is from the condenser (deaerated), and the condensate and feedwater systems via the condensate demineralizers.

28. Have the analyses for recent events involving shroud cracking, reactor jet pump support degradation, or steam generator tube leaks, shown that contaminant intrusion by way of valve disk modifications for pressure locking, was not a significant contributor nor the root cause?

29. Is Intergranular Stress Corrosion Cracking a major safety concern at light water reactors?

30. Is Intergranular Stress Corrosion Cracking promoted by oxygen and contaminants, notably chlorides?

31. Is intrusion of organic contaminants more of a safety concern than pressure locking?

32. Is making modifications to valves deemed potentially susceptible to pressure locking more of a safety concern than not making modifications? If not, why not?

33. Has AEOD/NRC considered other potential adverse affects of proposed gate valve pressure locking modifications? What, if any, are there?

34. Is NRC Information Notice 92-26 the only present regulatory document that requests that modifications be evaluated? If not, what others?

Enclosure 4

Slides

Pressure Locking and Thermal Binding Issues

Earl Brown and Chuck Hsu, AEOD

PRESSURE LOCKING AND THERMAL BINDING OF GATE VALVES

NEW ORLEANS, LOUISIANA
FEBRUARY 4, 1994

EARL J. BROWN, AEOD

OBJECTIVES

- Pressure Locking and Thermal Binding History
  - NUREG-1275, Vol. 9
  - Flexible Wedge, Split Wedge, Double Disc
  - Solid Wedge
- Phenomena
- Components, Systems, Operations, NSSS
- Operating Experience and Preventive Methods

NUREG-1275, Vol. 9

- Pressure Locking and Thermal Binding History
- Technical Aspects of Phenomena
- Preventive Measures
- Consequences

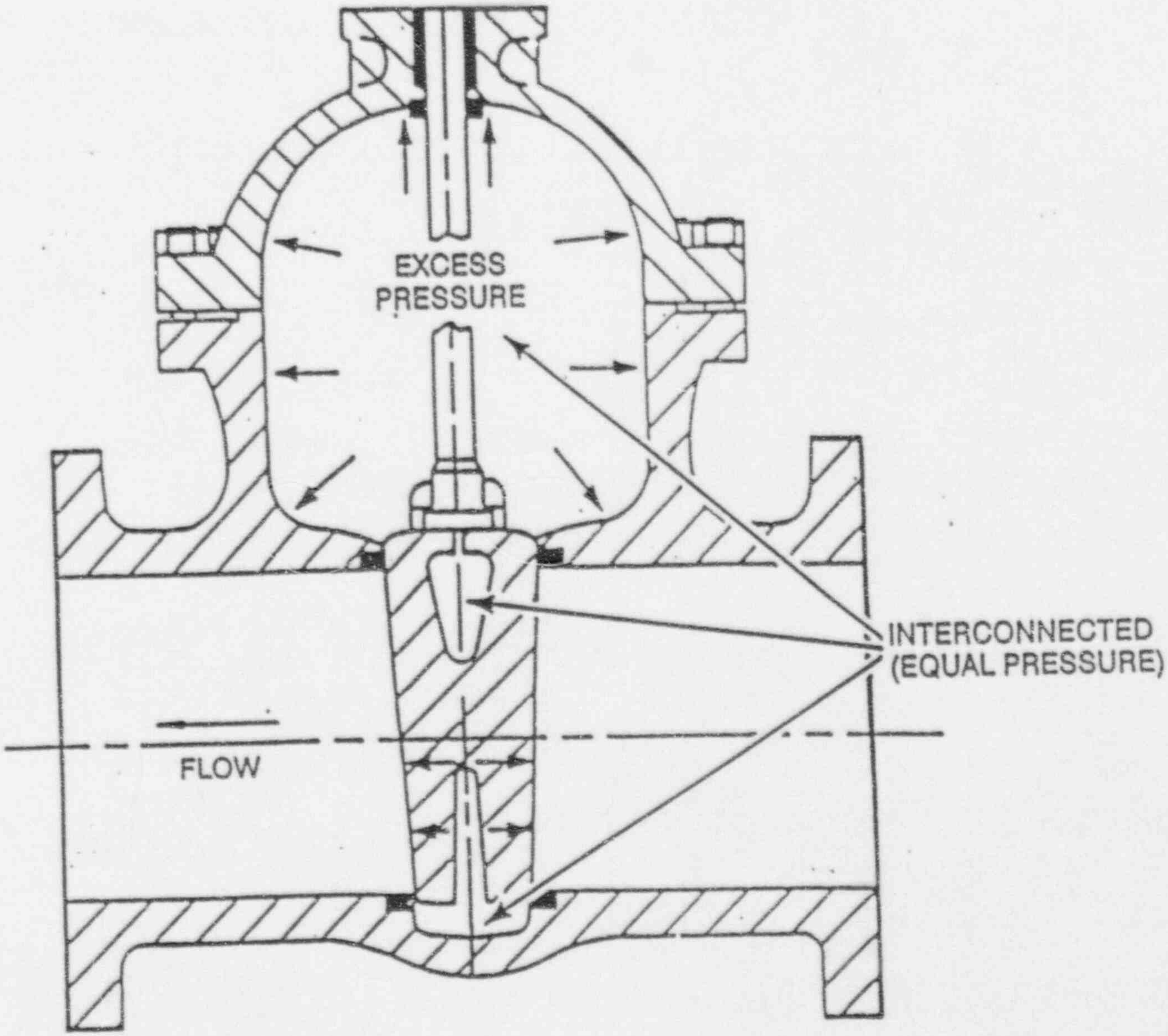
PRESSURE LOCKING AND THERMAL BINDING PHENOMENA

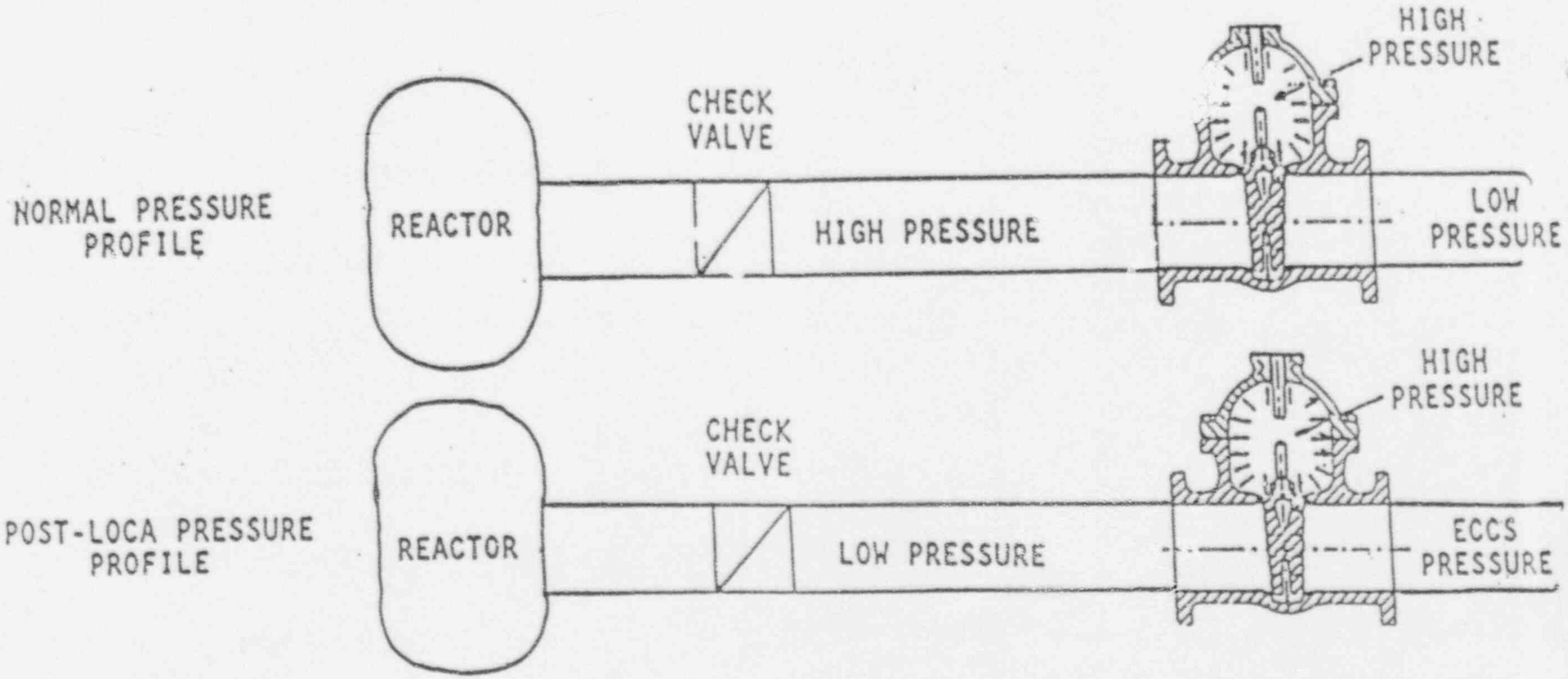
- PRESSURE LOCKING (FLEXIBLE WEDGE, DOUBLE DISC)
  - FLUID SOURCE TO FILL BONNET
    - OPEN/CLOSE
    - DIFFERENTIAL PRESSURE ACROSS DISC
    - CONDENSATE
  - PRESSURE SOURCE
    - CONNECTION TO HIGH PRESSURE SOURCE
    - BONNET VOLUME TEMPERATURE INCREASE

- THERMAL BINDING (SOLID WEDGE, OTHERS)
  - CLOSE HOT/OPEN COLD
  - TEMPERATURE GRADIENT ACROSS DISC

- CONTRIBUTORS TO STEM THRUST

Pressure Locking
Flexible-Wedge Gate Valve





BWR LOW PRESSURE SAFETY INJECTION

FACTORS INFLUENCING OCCURRENCE

- Component
  - Design Characteristics
  - Tolerance
- System
  - Pressure, Temperature
  - Connecting System
  - Operating Conditions and When

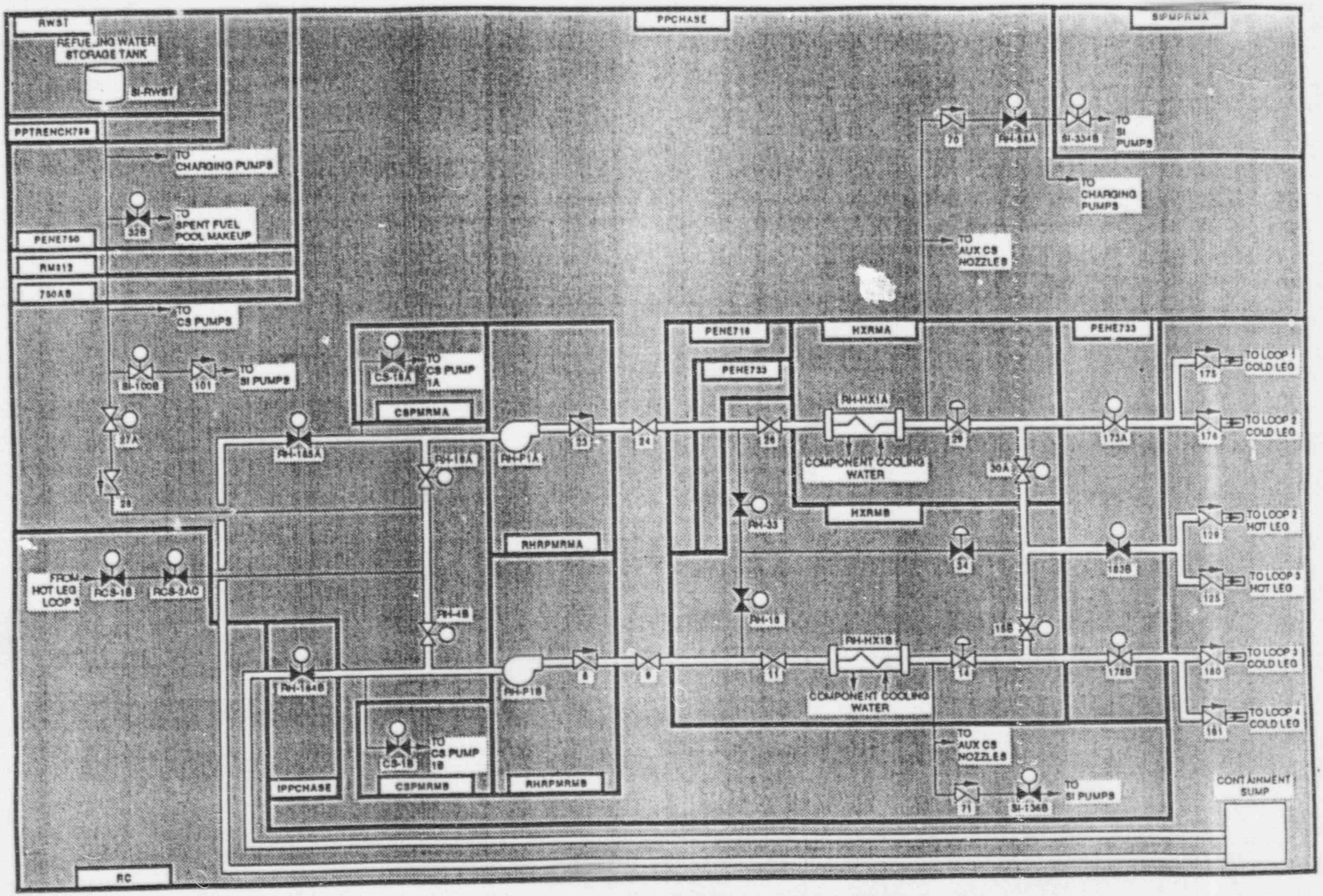
FACTORS INFLUENCING OCCURRENCE (CONT.)

- PLANT OPERATIONS
  - PRESSURE, TEMPERATURE
  - VALVE OPEN/CLOSE, WHEN, HOW LONG
- NSSS
  - PLANT TYPE (BWR, PWR, ETC.)
  - CONSTRUCTION YEAR
  - CONTAINMENT TYPE

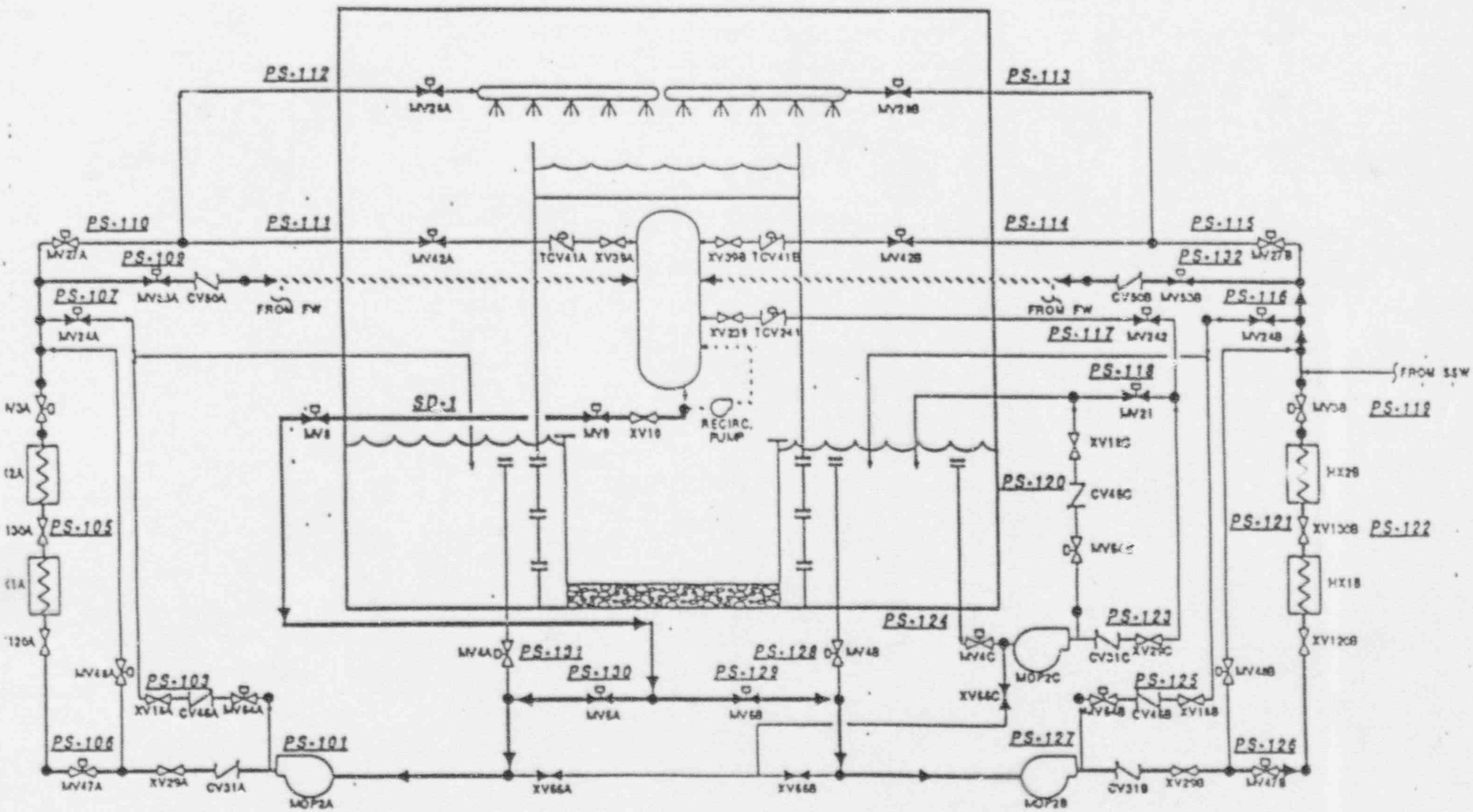
PLANT VISITS

ASSUMPTIONS PREVENTING IDENTIFICATION OF SUSCEPTIBLE VALVES

- NO MAINTENANCE/OPERATIONAL HISTORY OF PROBLEM
- LEAKAGE PAST IN-LINE CHECK VALVE ASSUMED TO BE ZERO
- REVIEW NORMAL SYSTEM OPERATION ONLY

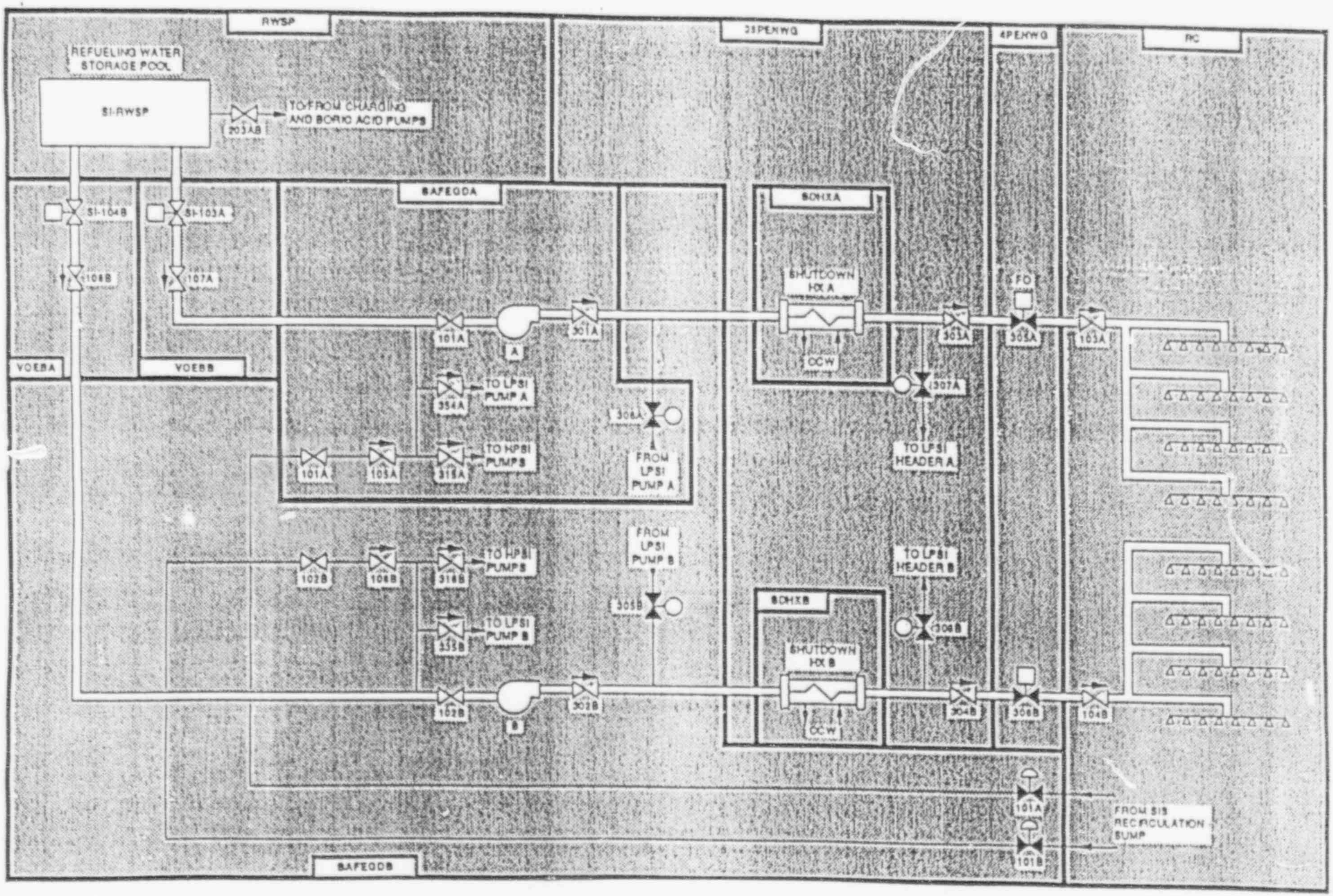


RESIDUAL HEAT REMOVAL SYSTEM



VALVE POSITIONS ARE SHOWN IN THEIR STANDBY MODE

BWR SHUTDOWN COOLING



PWR CONTAINMENT SPRAY

SAFETY SIGNIFICANT SUSCEPTIBLE VALVES

- BWRs
  - Low Pressure
    - LPCI, LPCS (injection) – leaking check valves
    - RHR Modes – reposition valves
  - High Pressure
    - HPCI, HPCS (injection) – leaking check valves
    - HPCS (suction) – conduction heatup
    - HPCI, RCIC (steam admission) – orientation, condensate

SAFETY SIGNIFICANT SUSCEPTIBLE VALVES

- PWR – Westinghouse
  - Low Pressure
    - Containment Sump (suction) – bonnet filled, heatup during LOCA
    - Hot Leg Injection – leaking check valve
    - Decay Heat Removal (cold shutdown plant) – RCS pressure
    - ECCS Cross-connect/Recirculation – RCS pressure
  - High Pressure
    - PORV Block Valve – closed during operation, feed and bleed

SAFETY SIGNIFICANT SUSCEPTIBLE VALVES

- PWR – Babcock & Wilcox Co.
  - Low Pressure
    - Containment Sump (suction) – bonnet filled, heatup during LOCA
    - Valves for Boron Precipitation – leaking check valves
    - Decay Heat Removal (cold shutdown plant) – RCS pressure
    - LPCI (injection) – leaking check valves
    - ECCS Cross-connect – leaking check valves
  - High Pressure
    - PORV Block Valve – closed during operation, feed and bleed
    - AFW (injection) – leaking check valves
    - AFW (Admission) – orientation, condensate

SAFETY SIGNIFICANT SUSCEPTIBLE VALVES

- PWR – Combustion Engineering (Most closed valves are globe)
  - Low Pressure
    - Containment Sump (suction) – bonnet filled, heatup during LOCA
    - Decay Heat Removal (cold shutdown plant) – RCS pressure
    - ECCS Cross-connect – leaking check valves (not all plants)
  - High Pressure
    - PORV Block Valve – closed during operation, feed and bleed
    - AFW (injection) – leaking check valves
    - AFW (steam admission) – orientation, condensate
    - Containment Spray – bonnet filled during startup

Enclosure 5

Slides

Licensee Experience
Entergy/Grand Gulf

Dana Smith, Entergy Operations

Calculation tc Predict the Required Thrust to Open a Flexible Wedge Gate Valve Subjected to Pressure Locking

Prepared by
Dana E. Smith

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P.O. Box 756
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Prepared for
NRC Public Meeting
February 4, 1994
New Orleans, LA

1.0 PURPOSE

The purpose of this calculation is to determine the normal force on the seat ring of a valve for the potential pressure locking conditions so as to determine the total required stem thrust to open the valve.

2.0 REFERENCES

2.1 Formulas for Stress and Strain, Roark and Young, 6th Edition.

2.2 NUREG/CR-5807, Improvements in Motor Operated Gate Valve Design and Prediction Models for Nuclear Power Plant Systems, Wang and Kalsi, May 1992.

3.0 ASSUMPTIONS

3.1 The flexible discs act like two uniform thick, flat circular plates with a fixed hub connection at the center.

3.2 The analysis will be broken down into four load cases and then numerically added together.

3.3 The high side pressure loads on the hub area will be transferred directly to the low side disc.

3.4 As stated in the body of the calculation.

4.0 CALCULATIONS

The internal pressure will be analyzed using Ref. 2.1 Table 24 Case 2d. This will provide the force exerted on the seat ring by the disc with the internal pressure. This analysis will use the following equations and values and is performed in an Excel spreadsheet.

4.1 Force on the perimeter of the disc hub (Q_b) (Case 2d)

$$Q_b = qa \frac{C_2 L_{17} - C_8 L}{C_2 C_9 - C_3 C_8}$$

where

$$C_2 = \frac{1}{4}\left[1 - \left(\frac{b}{a}\right)^2 \left(1 + 2\ln\frac{a}{b}\right)\right]$$

$$C_7 = \frac{b}{4a}\left\{\left[\left(\frac{b}{a}\right)^2 + 1\right]\ln\frac{a}{b} + \left(\frac{b}{a}\right)^2 - 1\right\}$$

$$C_8 = \frac{1}{2}\left[1 + \nu + (1 - \nu)\left(\frac{b}{a}\right)^2\right]$$

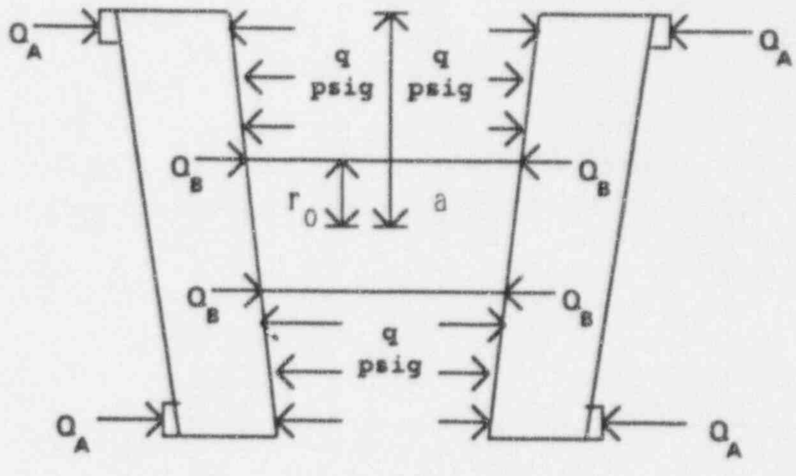
$$C_9 = \frac{b}{a}\left\{\frac{1+\nu}{2}\ln\frac{a}{b} + \frac{1-\nu}{4}\left[1 - \left(\frac{b}{a}\right)^2\right]\right\}$$

$$L_{11} = \frac{1}{64}\left\{1 + 4\left(\frac{r_o}{a}\right)^2 - 5\left(\frac{r_o}{a}\right)^4 - 4\left(\frac{r_o}{a}\right)^2\left[2 + \left(\frac{r_o}{a}\right)^2\right]\ln\frac{a}{r_o}\right\}$$

$$L_{17} = \frac{1}{4}\left\{1 - \frac{1-\nu}{4}\left[1 - \left(\frac{r_o}{a}\right)^4\right] - \left(\frac{r_o}{a}\right)^2\left[1 + (1+\nu)\ln\frac{a}{r_o}\right]\right\}$$

Force on the perimeter of the disc (Q_a) at the seat ring (Case 2d)

$$Q_a = Q_b\frac{b}{a} - \frac{q}{2a}\left(a^2 - r_o^2\right)$$



4.2 The external pressures, on the high pressure side and on the low pressure side, will be analyzed using Ref. 2.1 Table 24 Case 2d and Case 1b in combination. Case 2d will be used to determine the force exerted on the disc hub perimeter and on the disc perimeter at the seat ring. Based on the configuration of the pressures, the force on the seat ring will be in the opposite direction as the force obtained for the internal pressure load. Since the pressure on the high pressure side of the disc is higher than the pressure on the low pressure side of the disc, the differential force Q_b at the perimeter of the disc hub will be used in the Case 1b analysis to determine the additional force on the seat ring on the low pressure side disc. Case 1b is considered to be appropriate since the disc hub will provide a rigid "guided" type of configuration in the center of the disc.

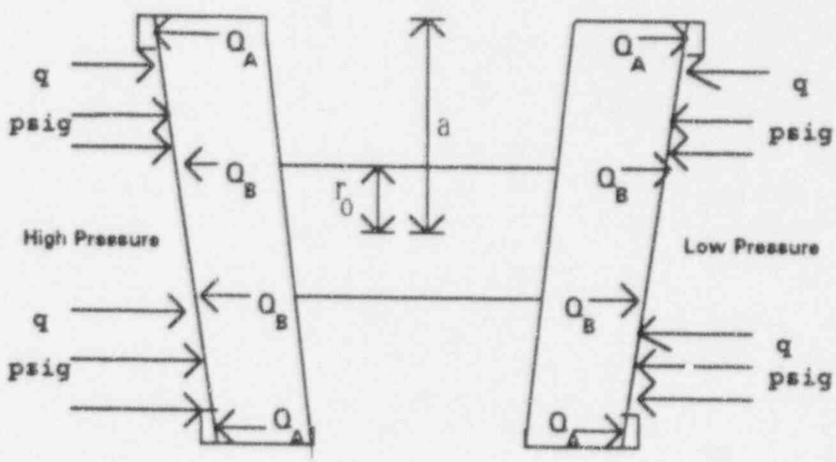
Force on the perimeter of the disc hub (Q_b) (Case 2d)

$$Q_b = qa\frac{C_2L_{17} - C_8L_{11}}{C_2C_9 - C_3C_8}$$

where the equations for the C and L variables are given on the prior page.

Force on the perimeter of the disc (Q_a) at the seat ring (Case 2d)

$$Q_a = Q_b\frac{b}{a} - \frac{q}{2a}\left(a^2 - r_o^2\right)$$



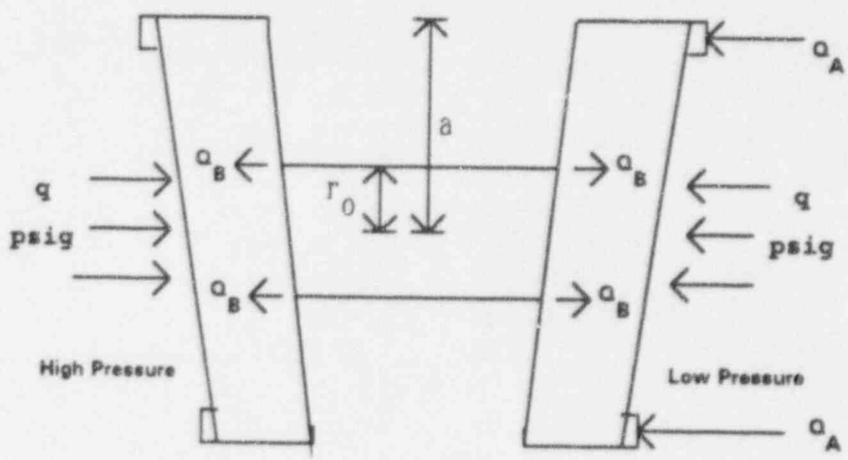
4.3 The differential Q_b (accounting for the high pressure side pressure being higher than the low pressure side pressure) will be increased to account for the differential pressure on the hub area that was left out of the Case 2d equations. The differential Q_b and the differential hub pressure will be combined and used as W in the Case 1b equation.

$$W = Q_b + \frac{q\pi b^2}{2\pi b}$$

Force on the perimeter of the disc (Q_a) at the seat ring on the opposite disc from the pressure (Case 1b)

$$Q_a = -W\frac{r_o}{a}$$

Where: a = ½ Valve disc sealing diameter (Mean seat diameter)
b = Valve hub radius
r_o= b
q = pressure over hub area



4.4 The force on each seat ring due to the four pressure loading conditions will be added together and multiplied by the seat ring perimeter to determine the total force.

1. Force on the seat ring on the high pressure side of the valve will be:

   Force due to internal pressure - Force due to high pressure side (lb/in)

2. Force on the seat ring on the low pressure side of the valve will be:

   Force due to the internal pressure - Force due to the low pressure side + Force due to the differential pressure between the low pressure side and the high pressure side (lb/in)

4.5 The relationship between the Valve Disc Factor and coefficient of friction, μ, will be determined using Ref. 2.2 Equation 2.1a.

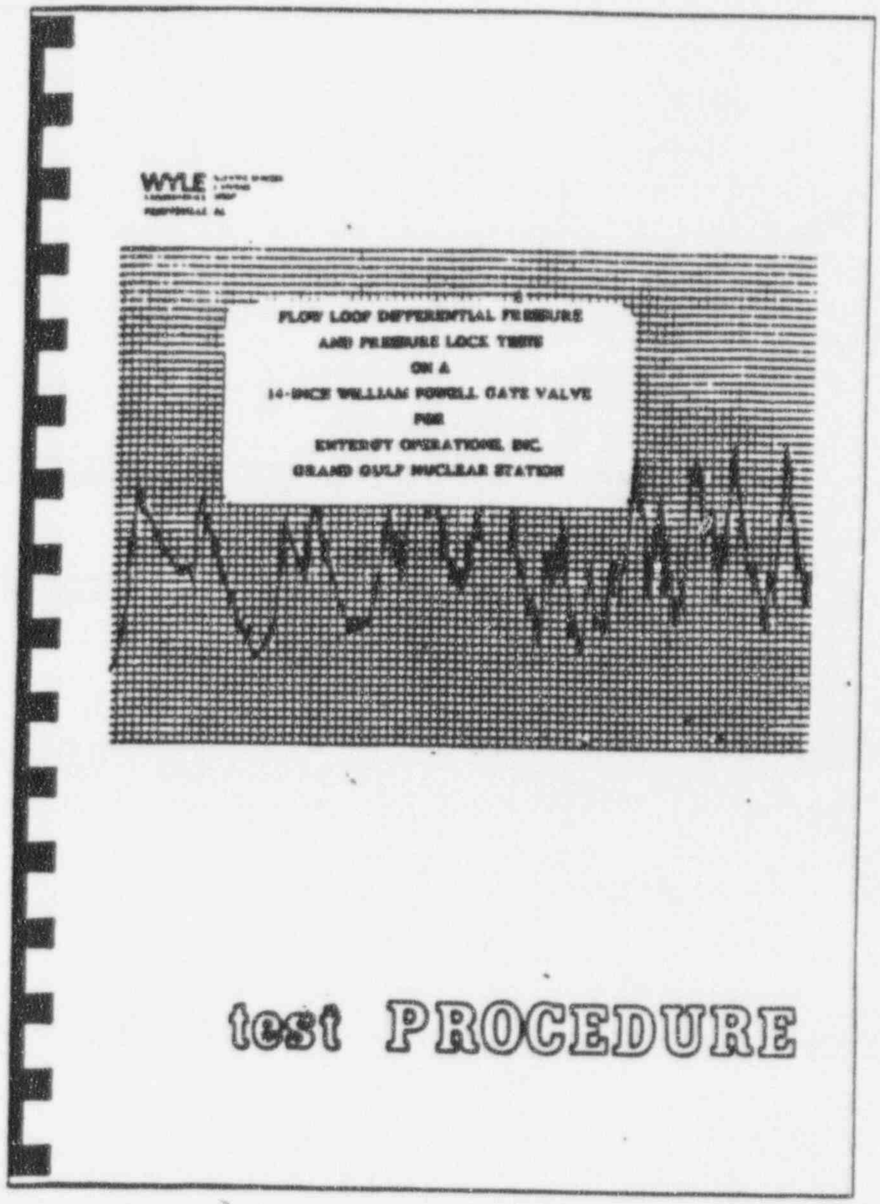
$$DiscFactor = \frac{\mu}{\cos\theta - \mu\sin\theta}$$

Where: μ = coefficient of friction
θ = seat angle, °

4.6 Total Required Thrust to open the valve will be the addition of the two forces determined at the seat rings above times the Valve Disc Factor plus the Unwedging Thrust.

5.0 CONCLUSIONS

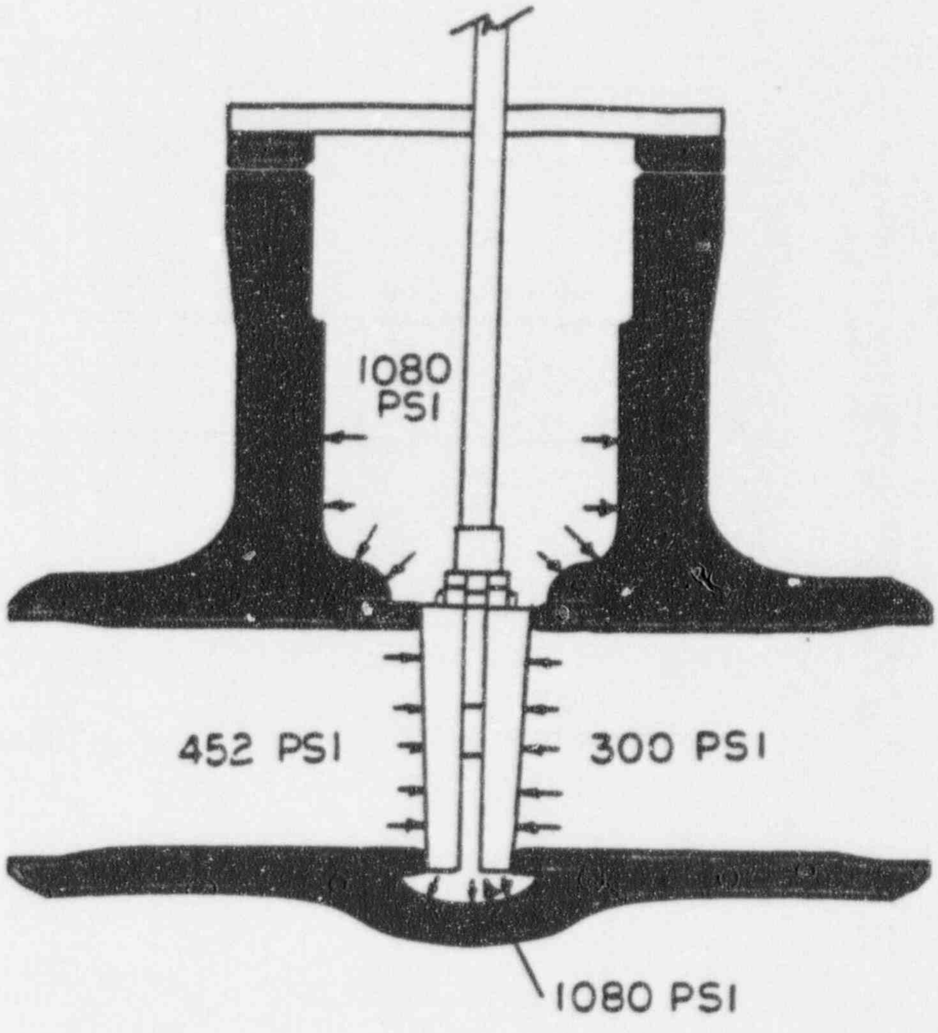
The Total Required Thrust for opening any valve, under stated pressure locking conditions, is dependent on the final wedging force from the previous closing cycle. For a given torque switch setting, the wedging force from valve closure can vary because the inertia overshoot is affected by the magnitude of the differential pressure across the disc. Typically, the highest wedging force would be introduced when the valve is closed without differential pressure. This calculation conservatively quantifies the unwedging force based upon calculated closing thrusts or actual as-tested data with static test conditions. Regardless of the approach used, the dependence of the opening thrust during unwedging on the wedging force from the previous closing cycle must be quantified to ensure proper operation of the valve. Furthermore, the unwedging force is affected by the pressure loading of the valve discs. As the differential pressure across a disc decreases so does the unwedging force. Full flow testing has indicated the unwedging component becomes essentially zero and only the pressure loading component contributes to the Total Required Thrust.



Test Purposes:

1. Pressure Lock Testing to Confirm Calculations

2. Flow Testing for Untestable Low Pressure Injection Valves to Confirm Specified Required Thrust Adeqate



Pressure Lock Test
Conditions

Pressure Lock Test Results

Pre-Test LLRT showed 0 leakage
(Worst Case for Pressure Lock)

Measured vs Calculated Unwedging Thrust

Smart Stem - Wyle Labs

Measured Closing Thrust	Measured Unwedging Thrust	Calculated Unwedging Thrust
90,309 #	55,146 #	57,894 #

Actual

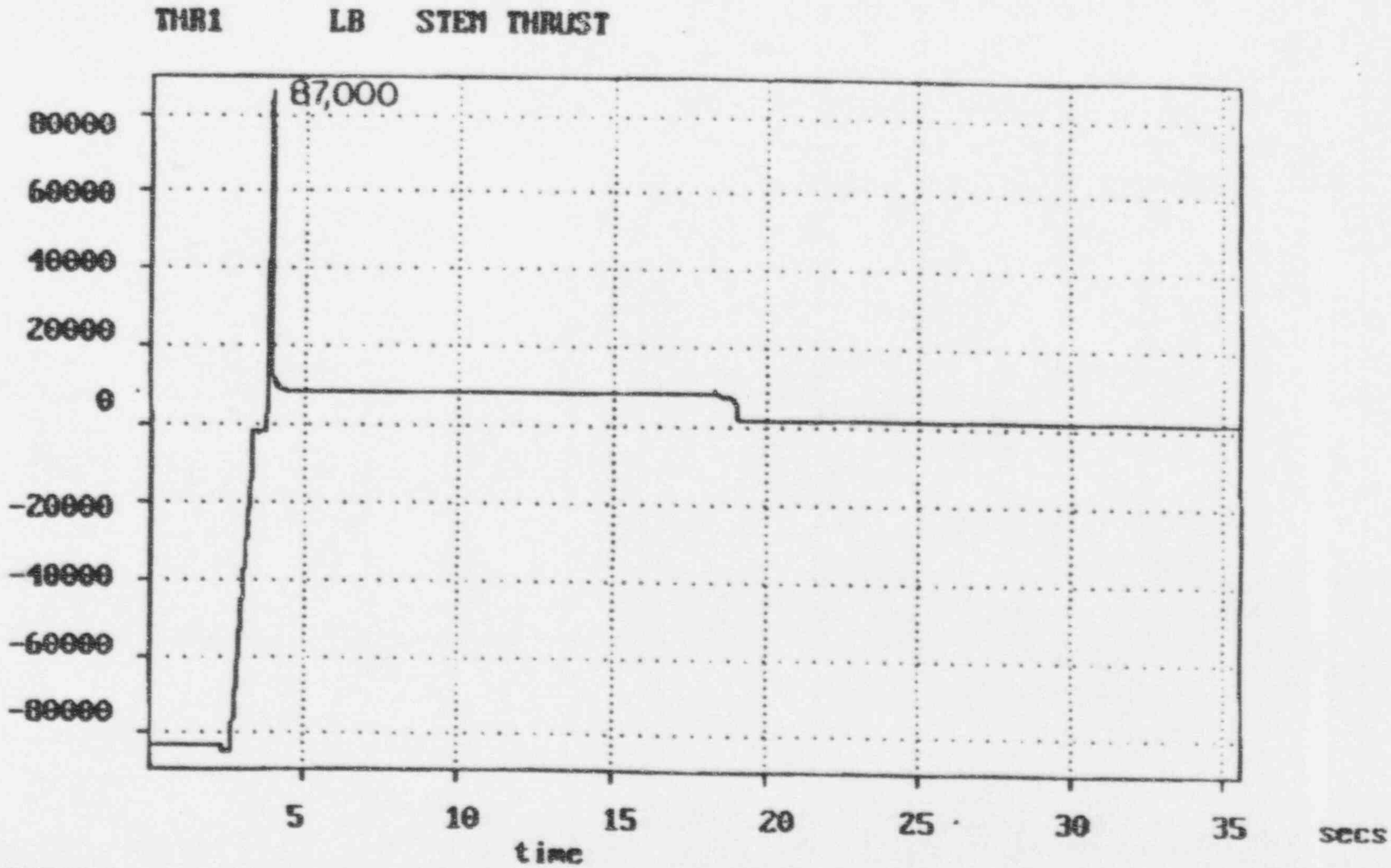
Total Opening Thrust Measured by Wyle Labs
87,000

Theoretical

Total Open Thrust Calculated by GGNS
31,926 + 57,894 = 89,820

Difference = 3%

TEST COMPLETE
6.3.3 PRESSURE LOCK TEST TEST#5 a (TORQUE SWITCH SET TO APROX. 1.75)



B430081 DataSet 009 Duration 00:00:35:545 Recorded On 12/29/92 11:24:50

Enclosure 6

Slides

International Experience (Germany)
Siemens

N. Schauki, Siemens

SIEMENS

SPC

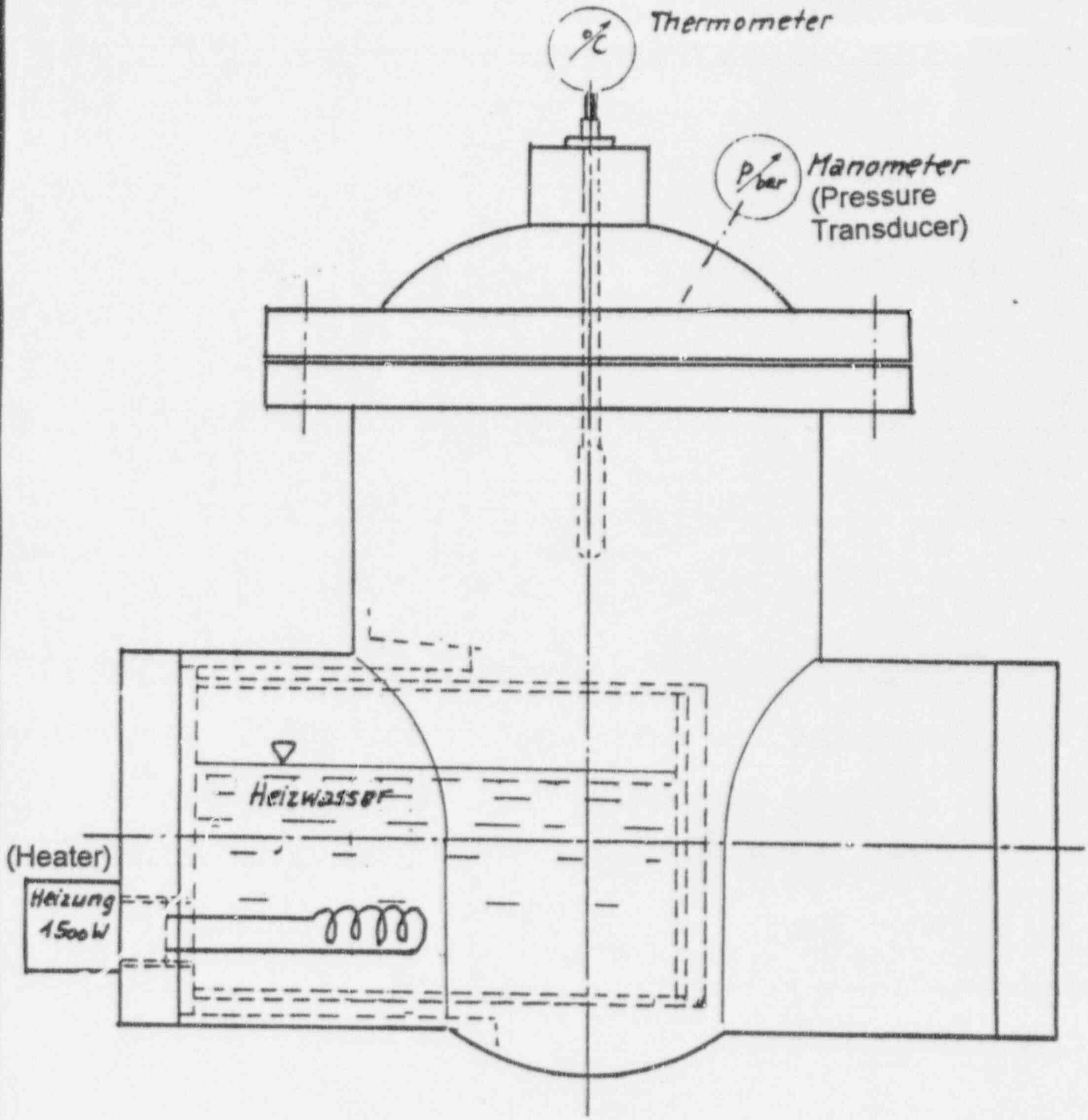
PUBLIC WORKSHOP MEETING

February 4, 1994

PRESSURE LOCKING AND THERMAL BINDING OF GATE VALVES

Dr. Nabil Schauki

SIEMENS



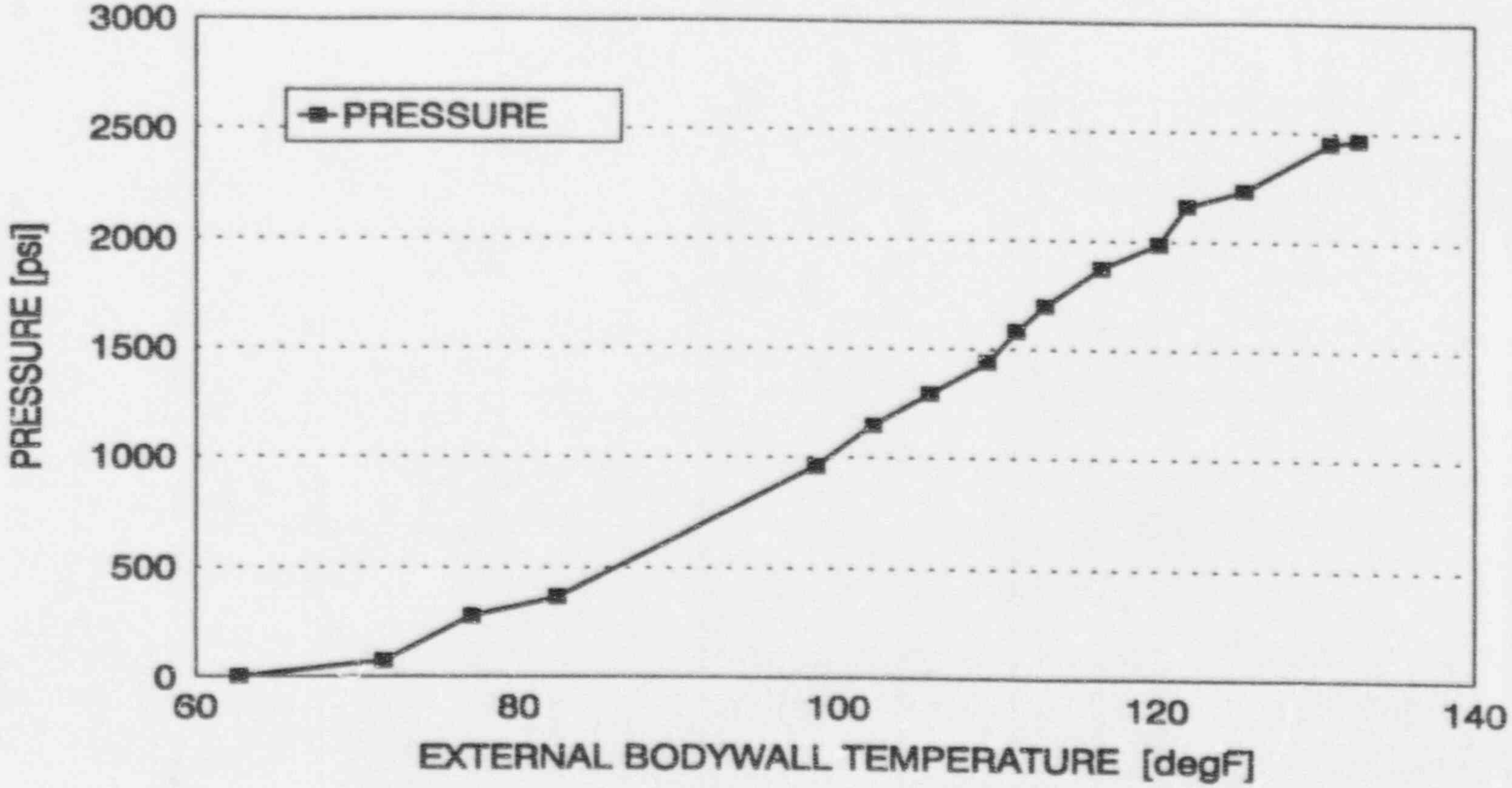
Valve Tested to Obtain Pressure
as a Function of Temperature

N. Schaudt

SIEMENS

SPC

8" 600# GATE VALVE

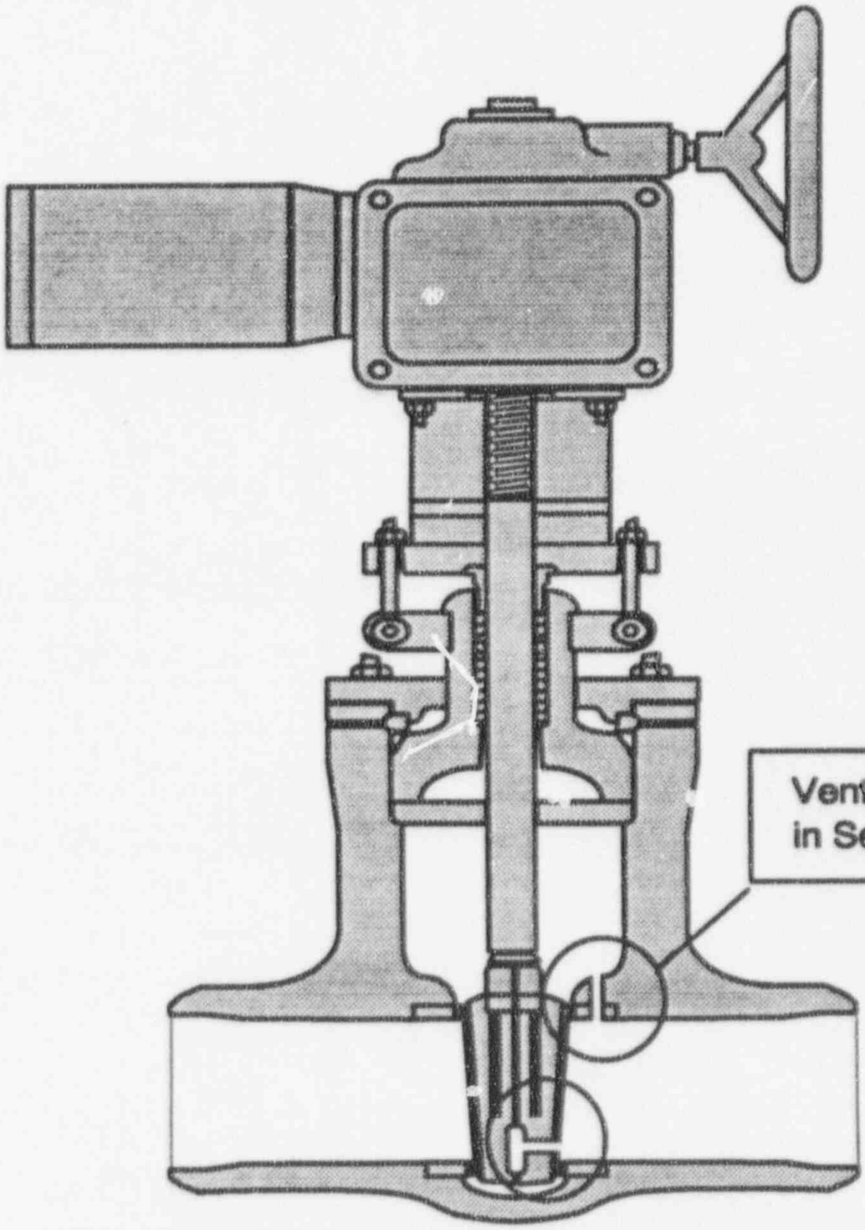


MEASURED BONNET PRESSURE AS A FUNCTION OF EXTERNAL BODYWALL TEMPERATURE

SIEMENS

SPC

Pressure Locking Control

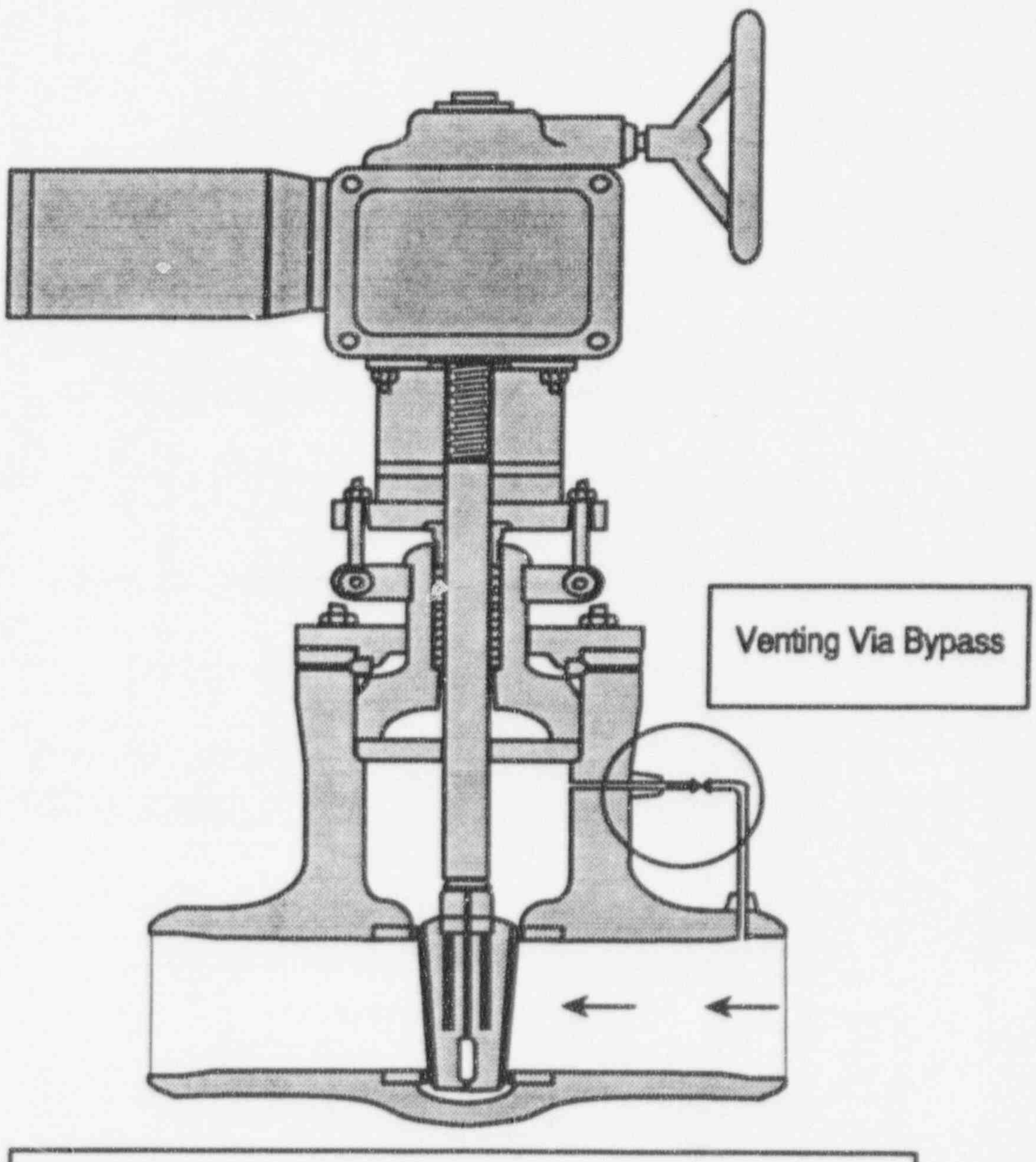


Bonnet Pressure Control by Means of Internal Venting

SIEMENS

SPC

Pressure Locking Control

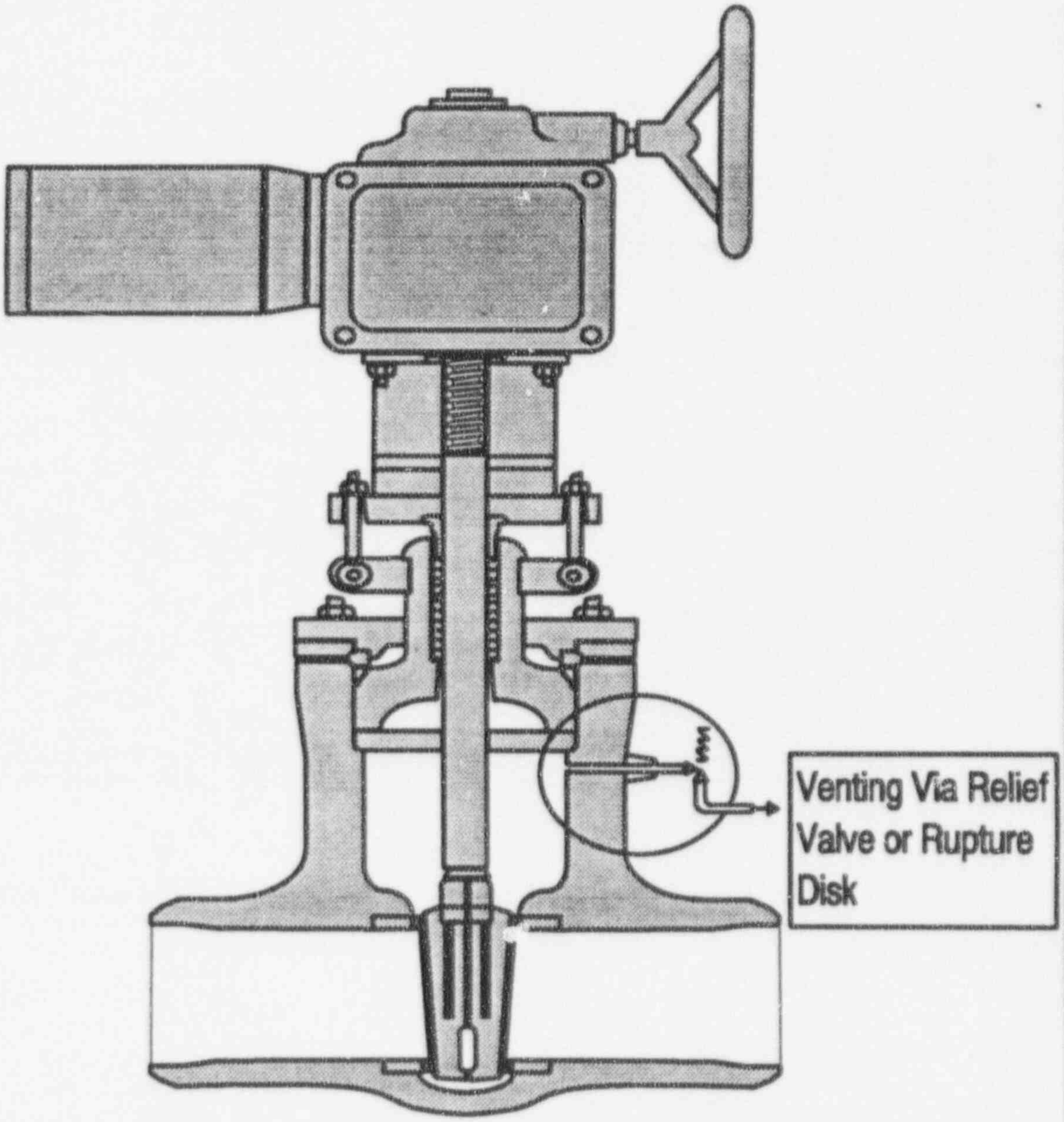


Bonnet Pressure Control by Means of Bypass to System
Hydrotest Direction to Be Considered

SIEMENS

SPC

Pressure Locking Control

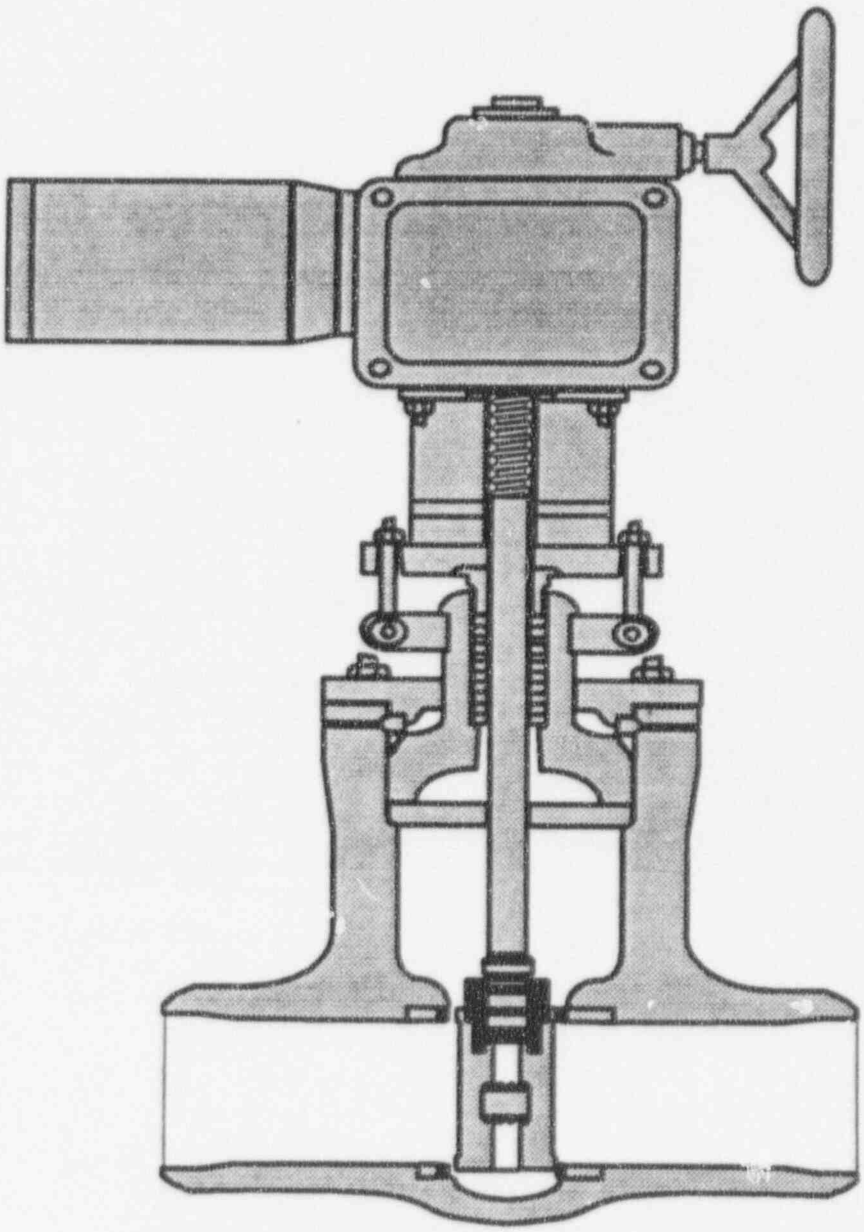


Bonnet Pressure Control by Means of Internal Venting

SIEMENS

SPC

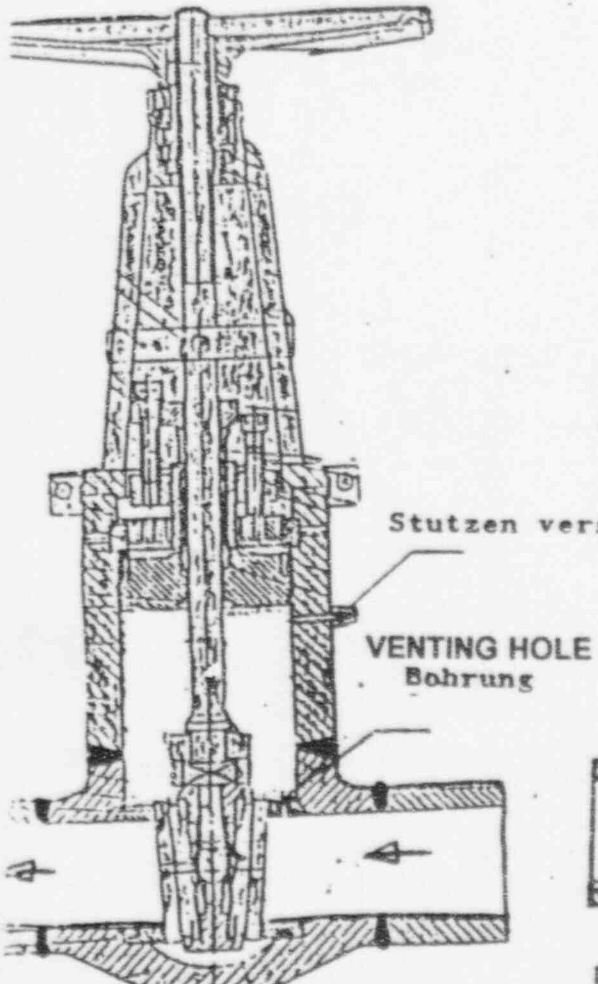
Pressure Locking Control



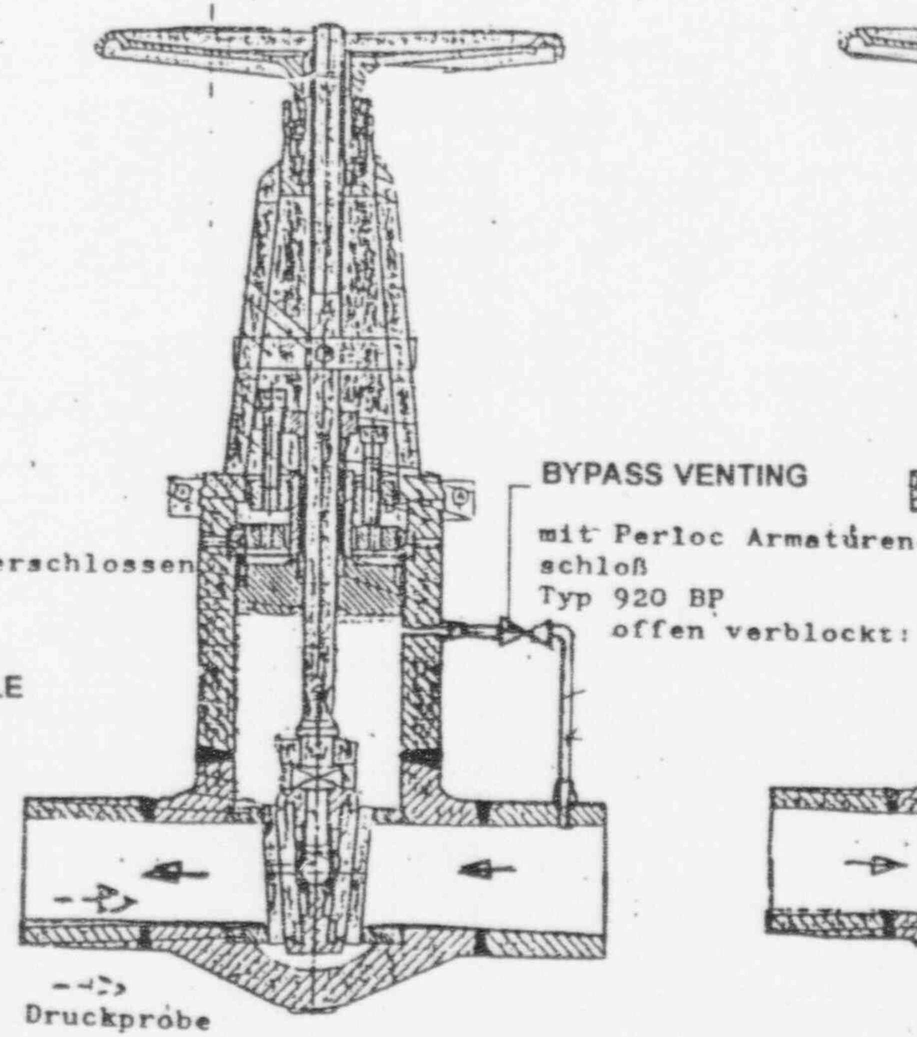
Bonnet Pressure Control by Means of Design Features (Disk Holder)

SIEMENS

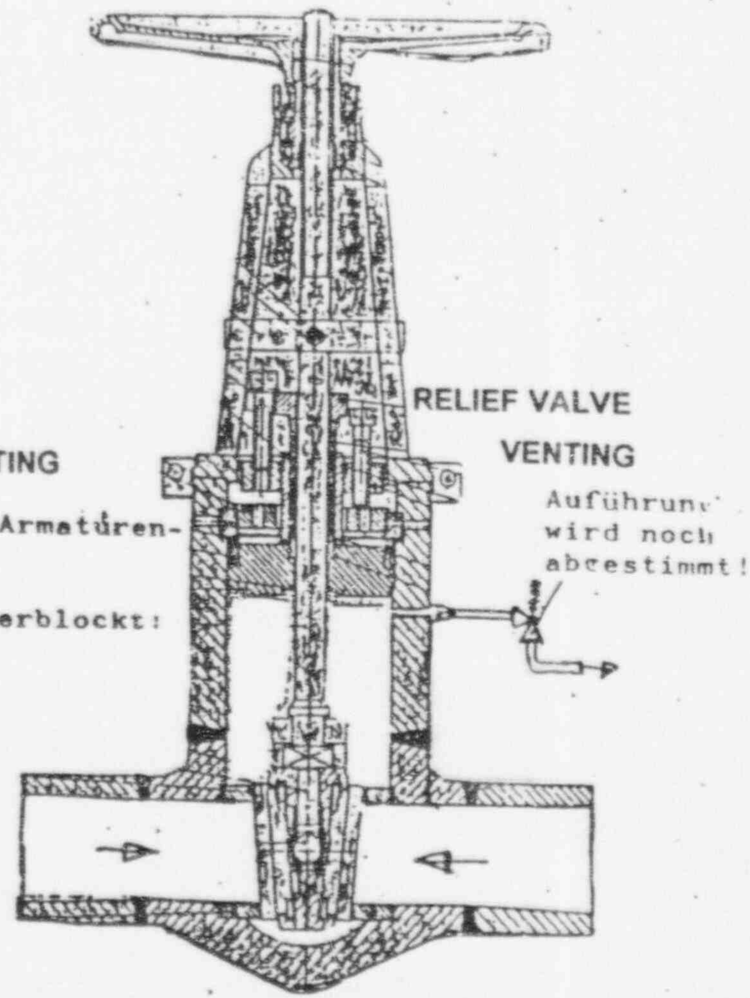
ernkraftwerk	Überdrucksicherung in Schiebergehäusen mit selbstdichtendem Deckelverschluß	V 632-RA Mogk Rev. o 4.6.74



führung 1
Eintritt/Austritt gebohrt

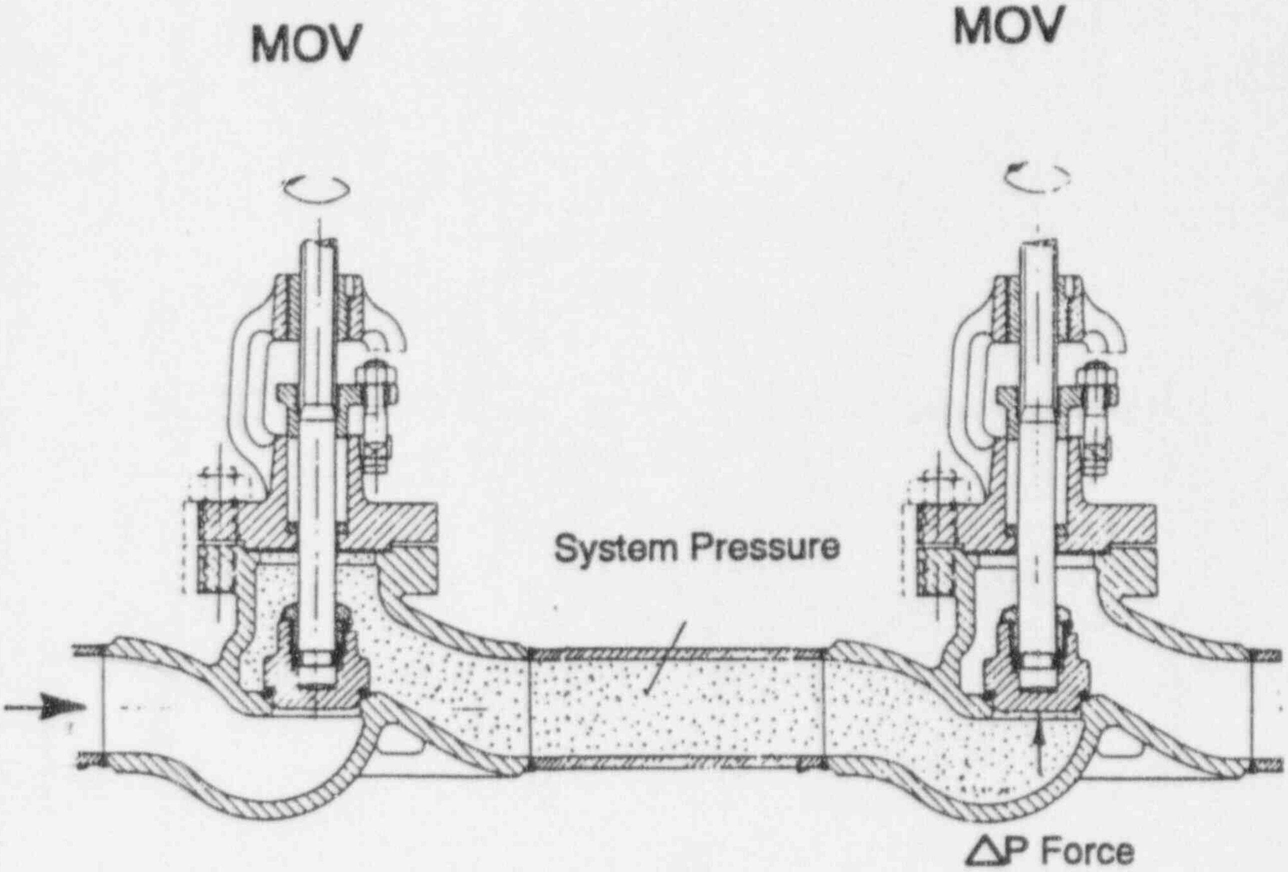


Ausführung 2
an Eintritt/Austritt umführt
Absperrmöglichkeit für Druck-
proben erforderlich!



Auführung 3
mit externer Entlastung
erforderlich bei beidseitiger
Durchströmung

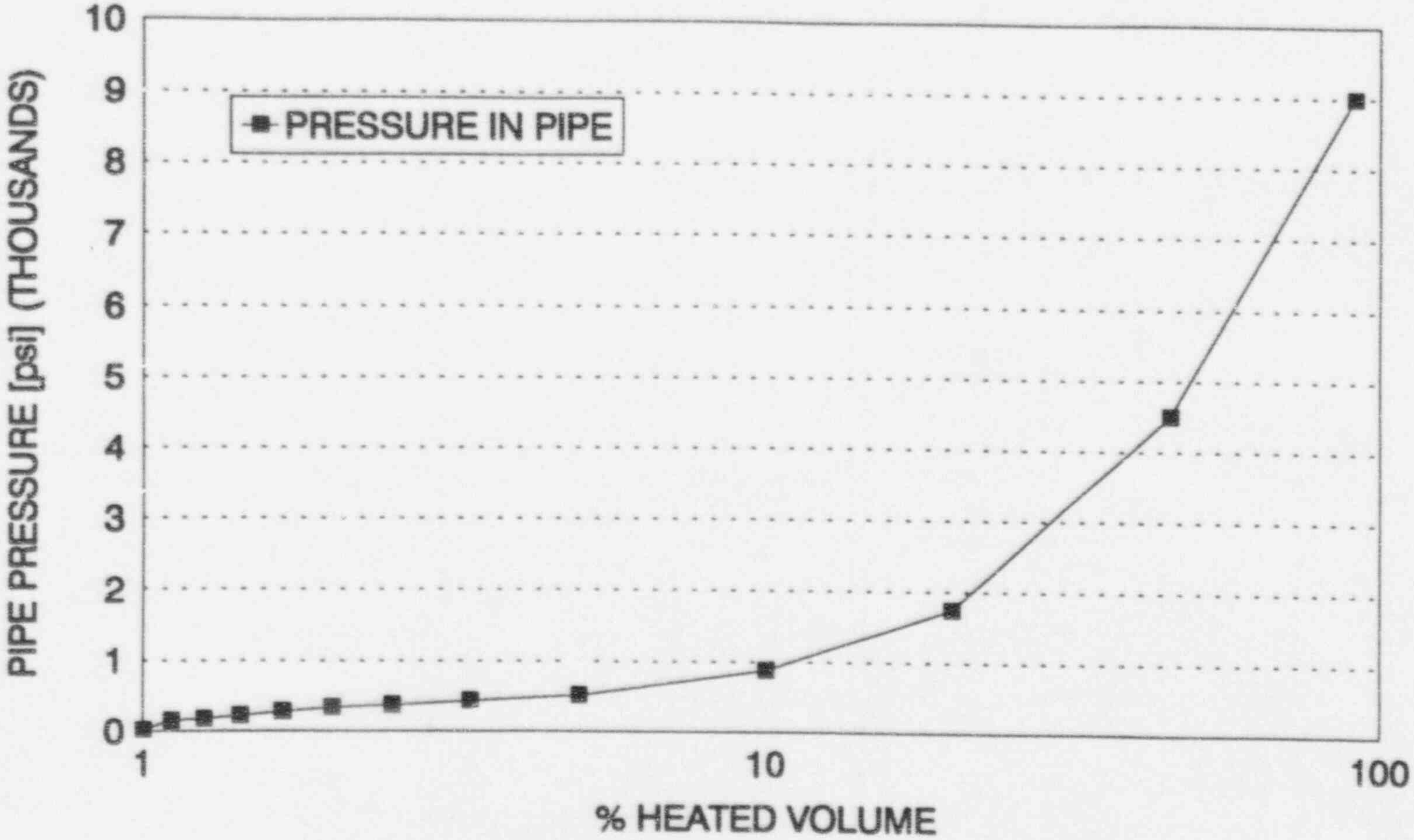
Globe MOVs in Series



Relief of Pressure Build-Up in System
Due to Heat-Up of Enclosed Cold Water
(LOCA)

SIEMENS

SPC



PRESSURE INCREASE IN ISOLATED PARTLY HEATED PIPES

lgc:\windows\designer\013094

N. Schaukl/01-18-94

Enclosure 7

Slides

Licensee Experience
Commonwealth Edison/LaSalle

Mark Dowd, LaSalle Station

LaSalle

AGENDA
GATE VALVE LOCKING MEETING

1. 1E51-F063 valve event and our response.
2. Industry Response since 1977.
3. Failure Mechanics overview:
   a. Classical Thermal Binding.
   b. Differential Temperature Thermal Binding.
   c. Reactor Pressure Leak Back with subsequent Pressure Blowdown Hydraulic Lock.
   d. Thermal Fluid Expansion Hydraulic Lock.
   e. Multiple Failure Mechanisms.
4. Overview of LaSalle SEC's screening criteria and results of screening.
   a. Qualifications of Screening Personnel.
   b. Screening Questions.
   c. Steam Valve Screening.
   d. Differential Temperature Screening.
   e. Results of Screening.
5. Review Possible Solutions for Hydraulic Locking.
   a. Calculate Maximum pull out force and determine adequacy of motor operator and valve to open.
   b. Modify bonnet or valve disc. to provide a vent path.
   c. Modify bonnet to provide a surge volume.
   d. Prevent full closure of the valve.
   e. Modify Motor Operator and/or valve to open against Maximum calculated pull out force.
   f. Further analyze valve functions , response times , probable environmental conditions and accessibility for possible exclusion from list of susceptible valves.

6. Review Possible Solutions for Thermal Binding.

    a. Calculate Maximum pull out force and determine adequacy of motor operator and valve to open.

    b. Prevent full closure of the valve.

    c. Modify Motor Operator and/or valve to open against Maximum calculated pull out force.

    d. Further analyze valve functions , response times , probable environmental conditions and accessibility for possible exclusion from list of susceptible valves.

7. Prioritize susceptible valves.

8. Determine most cost effective method to address susceptible valves.

9. Determine tentative schedule to address susceptible valves.

LMN

EXECUTIVE SUMMARY

Root
Cause
Analysis

1. Nuclear Unit		2. Event Date				3. Report No.	4. Evaluator
Plant	Unit	Time	Month	Day	Year		Jeff Miller C. Snyder M. Vrla M. Wendling M. Wielgopolan
LaSalle	1		Feb Feb	10 26	93 93	373-180- 93-00150 PIF	

EVENT DESCRIPTION

Unit 1 was shutdown twice for identical problems in the RCIC F063 valve. During the L1R05 outage, the RCIC F063 valve was replaced from a flex-wedge gate valve to a parallel double disk gate valve. The double disc gate valve design is susceptible to pressure binding. This condition is the result of trapped fluid in the bonnet cavity becoming pressurized due to an increase in the fluid's temperature. The bonnet pressure and resultant force with which the valve's discs are seated became so great that the valve operator could not overcome these forces to open the valve. This resulted in the valve being declared inoperable and required shutdown of the unit.

EVENT NARRATIVE

In 1989, Generic Letter 89-10 addressed concerns about the adequacy of certain safety-related, motor-operated valves. GL 89-10, Supplement 3, addressed specific concerns regarding "blowdown" valves, i.e. those valves in high energy lines that are required to close to isolate a line break. The RCIC steam line is one of those lines. The specific concern is the capability of the valve to isolate, i.e. to actually close when subjected to blowdown flow. For the RCIC F063 valve, the design conditions involve steam flow at 575 degrees Fahrenheit and 1250 psig. Modification packages M01-1-91-002B and P01-1-91-509 were created to upgrade the operator and the valve to improve the margin to adequate blowdown performance.

During the L1R05 outage, the 1E51-F063 valve and actuator were replaced by a heftier version. Testing and several inspections were performed to verify proper installation of the valve. During this time, it is believed that the set screws on the torque switch were inadvertently left loose.

On February 10, as required for pre-planned maintenance on other unrelated instrumentation, the 1E51-F063 valve was closed and remained closed for approximately 10 hours. During this time no abnormal indications were noted.

Upon completion of RCIC system maintenance, the 1E51-F076 (RCIC Steam line warm-up valve) was opened to equalize pressure and temperature around the 1E51-F063 after which an attempt was made to open the 1E51-F063 from the control room. Dual indication was received , followed by a thermal overload trip approximately 6 seconds later. The overload was reset and another attempt was made to open the valve, resulting in a second thermal overload trip. The thermal overload was again reset, and an ammeter/chart recorder was installed on the power leads. The valve was then given a close signal. Motor current was observed to be in excess of 100 amps for 1-2 seconds, at which time the circuit breaker was tripped manually.

Unit 1 was brought to Cold Shutdown to initiate repairs on the RCIC Steam Line Inboard Isolation Valve (1E51-F063). During the shutdown, a Generating Station Emergency Plan (GSEP) Unusual Event condition was entered on 02/13/93 at 2000 hours due to the plant shutdown required by Technical Specifications. The GSEP was terminated at 1800 hours on 02/14/93 when the RCIC system was no longer required for Unit 1 operating conditions.

Containment entry was made during unit shutdown at approximately 400 psi Reactor pressure to perform a preliminary inspection of the valve/actuator for signs of external damage. No visible damage was noted. The local indicator for the Limitorque operator spring compensator pack (SB design) indicated the spring compensator was fully compressed. The local position indicator (MDPI) showed the position of the valve to be 10-12% open in the as found condition although it was later determined to be fully closed. The limit switch housing cover was removed to perform an inspection of the torque switch and limit switches. The torque switch was found to be over-rotated, and the close setting indicator and set screws had slid underneath the torque limiter plate, effectively raising the close torque switch setting. The torque switch setting screws on the open and close side were found to be loose. Based on no apparent damage to the limit switches and torque switch, the valve actuator was declutched and the valve was manually cycled to try to determine if the valve was internally bound. The valve was easily cycled using the handwheel with no evidence of binding in the valve or actuator. When manually cycling the valve, the local position indicator had been determined to be shifted. The local position indicator would display a valve position greater than 100% when the valve was full open and indicated approximately 20% open when the valve was full closed.

To continue analyzing the valve condition, the torque switch setting screws were adjusted to a setting of 1.00/1.00 (open/close) and the valve was electrically cycled to the open position. When the valve was cycled to the full open position it was found to be stopping about 2-3 inches from the valve backseat. The limit switch adjustment was checked and the limits were found to be out of adjustment by approximately 20%, this corresponds to the offset that was observed in the local position indicator when the valve was full closed.

The limit switches were properly adjusted and the valve was electrically cycled three times with the torque switch adjusted to a setting of 1.00/1.00 (open/close) while the valve was monitored by VOTES (VALVE OPERATION TEST and EVALUATION SYSTEM) diagnostic equipment. No abnormalities were noted in the VOTES traces. The torque switch setting was raised to 1.50/1.50 and the valve was again cycled three times with the valve monitored by VOTES equipment. No abnormalities were noted with the VOTES traces and the thrust characteristics were consistent with the previous (prior to failure) VOTES test results.

The compensator spring assembly and stem nut were removed with the actuator in place. They were inspected for evidence of abnormal wear or indications which might explain the shift in limit switch settings. No wear was noted and adequate spline engagement between the stem nut and drive sleeve was observed.

The actuator was removed from the valve and brought to the MM (Mechanical Maintenance) shop for disassembly and inspection. No damage was noted with the actuator internals. The electrical components were inspected (cartridge assembly, limit switch assembly and the torque switch). The results of this inspection were 1) the torque switch setting screws being loose, 2) the close torque switch setting block being underneath the torque switch limiter plate, and 3) the torque switch limiter plate being slightly bent (pushed away from the torque switch face) on the close setting side, and 4) the torque switch limiter plate being installed between two flat washers on the torque switch shaft.

The valve internals were inspected. There were no obvious gouges in the valve body, sides and/or seat areas. A NDE (Non Destructive Examination) PT (DYE PENETRANT) exam of the valve seating surfaces was performed and a radial indication was found on the upstream seating surface. This was evaluated by engineering and found to be acceptable.

The valve disc pack and stem were also inspected. The disc retainer pin (wedge pin) was found to be sheared with the lower disc retainer found inside the valve bonnet. Apparently, the rotation of the valve stem within the upper wedge sheared the pin. A gap of approximately 1/8 to 3/16 inch was visible between the top of the upper wedge and the bottom of the shouldered portion of the stem. No additional damage or abnormal wear was noted.

The valve stem, disc assembly and the Limitorque actuator were completely replaced. The re-assembled valve was post maintenance tested, i.e. electrical motor tests (Megger and Winding Resistance readings), VOTES test, limit switch settings verified, in-service leakage test and seat leakage test. All results were satisfactory.

A Root Cause Analysis team was assembled to determine the cause of the valve failure. Many different possible scenarios were examined. Based on the as found condition of the valve and the most probable failure possibilities, the following sequence of events was developed.

The torque switch setting set screws were found to be loose. There was no apparent scarring of the jagged edge on the underside of the torque limiter switch that hold the switch setting block in place. If scarring was present, that would have suggested a great amount of force to rotate the torque switch setting block and screw from a locked position to under the limiter plate. This suggested that the screws were somehow loosened. It has never been identified in LaSalle's history with MOV's that this particular screw would become loose as a result of normal valve operation. The individuals that adjusted the torque switch setting believed that they had tightened the screws. The individuals that replaced the limiter plate and performed the different testing and inspections did not observe that the screws were loose. It can only be assumed that: 1) the screws were not tightened as tight as they should have been originally, or; 2) someone for another reason loosened the screws and failed to tighten them down. The loose screws would have only resulted in the torque switch setting increasing to a setting of 2 (two). In order for the torque switch setting block and screw to slide under the limiter plate, the plate must have been abnormally oriented.

When the limiter plate was installed, it was installed with a washer above and below the plate, raising the height of the plate relative to the setting block. This is not common practice, although there was no specific guidance regarding the use of the spacer washers. It is believed that this extra space <u>and</u> a <u>slight</u> bend upward of the plate may have been enough to allow the switch setting block and set screw to slide under the plate. Without the extra space under the plate, the switch setting block would have contacted the plate squarely and not been allowed to slide underneath to the higher torque settings.

With the combination of the loose switch setting block screws and the limit plate raised and slightly bent, the trip torque value was allowed to increase. The valve was cycled at least 11 times prior to the failure. It is believed that with each cycle, the setting increased slightly, resulting in the as found setting of 4.0. (The original torque switch setting was a little less than 2.0.)

The increased torque forced the stem nut when the valve was fully closed to "walk" up the stem and fully compress the Limitorque actuator spring compensator. At this time the limit switch settings were apparently not affected as the valve did not trip the thermal overload. This indicated that the actuator stopped on torque when the torque switch opened.

Apparently, when the valve was being given an open signal, the valve stem retainer pin sheared. This is indicated by the stem unthreading from the disc upper wedge approximately 5/32" corresponding to approximately 1 7/8" rotation of the stem. Each rotation of the stem resulted in one rotation of the Limitorque drive sleeve. This would cause the valve position limit switch and local position indicator to be offset by the amount of the drive sleeve rotation with no actual movement of the valve disc assembly. This evolution apparently occurred during the two attempts to open the valve which resulted in the thermal overload trips that were discussed previously.

When the valve was given a close signal, the motor current was monitored by a signature trace device. The motor current trace indicated a locked rotor condition. This was due to the valve already being fully closed and unable to move any farther. The torque switch would have opened to stop the motor on high torque, but it was bypassed because of the valve position limit switch offset. This closing attempt was terminated by the breaker being opened when it was noted that the valve motor was exhibiting a locked rotor condition based on current reading.

With the root cause of the valve failure believed to be identified, Unit 1 startup began on February 19.

On February 26th, the 1E51-F063 valve was to be cycled under similar conditions as on February 10th to verify proper operation of the valve. This was part of the corrective action from the Root Cause Analysis. The valve was closed and then followed by a period to cool the valve. The 1E51-F076 was opened to equalize pressure and temperature across the 1E51-F063 valve. An attempt to open the 1E51-F063 valve was made. The valve failed to open. The valve was left as is (no attempt to close the valve), and the valve was declared inoperable. A detailed test plan was developed (LST 93-029), which included specific data collection steps, including repetition of the failure conditions with the unit operating at a very low power level and drywell accessible.

Once a drywell entry was possible, individuals inspected the valve. They found the valve closed and the limit switch misadjusted. They manually cycled the valve. They found the valve would open and close normally. They also determined that the valve stem had partially rotated out of the upper wedge. They then returned the valve to the fully closed position.

In accordance with the test plan, the failure conditions were re-established, including the previously observed warming times with the warming valve (1E51-F076) open. Individuals then entered the drywell to manually open the 1E51-F063 valve. The valve could not be manually opened. A small trickle of water was noticed leaking from the valve packing. The valve packing gland nuts were loosened, and it was observed that the packing gland follower moved. From these observations, it was determined that the valve internals were experiencing bonnet pressure locking.

The valve and operator were inspected further. The wedge pin had once again been sheared. The torque switch was undamaged, and the set screws were found tight. The valve was repaired and modified to prevent pressure locking.

Unit 1 was then started up, followed by testing of 1E51-F063 which performed satisfactorily.

INAPPROPRIATE ACTIONS

1. **The Modification Process did not identify that the valve could pressure lock during certain operating sequences.**

   The possibility of the valve binding due to a differential pressure between the valve bonnet cavity and the connecting piping was never considered. The RCIC system utilizes steam from the reactor vessel to operate. This type of valve binding is generally associated with liquid systems and was, therefore, never considered by the modification engineer. The modification review process requires a search through an industry-wide computerized database. This search failed to flag any of the several key industry documents which discuss bonnet pressure locking. The reason for this failure was determined to be that the computer (keyword) search was focused on problems with motor-operated valves as related to Generic Letter 89-10 (the impetus for the modification).

   Written Communication: Informational presentation deficiencies.

   CORRECTIVE ACTION

   The specific processes which lead to the valve bonnet locking are fairly detailed and subtle. A training package and presentation on this event will be developed and given to all site engineering and system engineers. This package will include:

   - Detailed description of the event.
   - Detailed description of this particular bonnet pressure locking mechanism.
   - Discussion of the failure of the industry documentation checklist to trigger appropriate review.

2. Prior to the February 10th failure of the valve, the torque switch set screws were presumed to be left loose.

   The as found condition of the torque switch setting block was with the set screws loose. There was no apparent scarring of the jagged edge on the underside of the torque limiter switch that hold the screw in place. If scarring was present, that would have suggested a great amount of force to rotate the torque switch setting block and set screw from a locked position to under the limiter plate. This suggests that the screws were somehow loosened. It has never been identified in LaSalle's history with MOV's that these particular screws loosen from normal valve operation. The individuals that adjusted the torque switch setting believed that they had tightened the screws. Individuals that replaced the limiter plate and performed the different testing and inspections did not observe that the screws were loose. It can only be assumed that: 1) the screws were not tightened as tight as they should have been originally, or; 2) someone for another reason loosened the screws and failed to tighten them down.

The significance of the screws left loose played a small role in the actual valve failure in the first event. The primary significance was that the investigative team was misled, resulting in an incorrect analysis of the valve failure.

Work Practice: Self-checking could have prevented the loose screws.

CORRECTIVE ACTION

No corrective action necessary, because this is an isolated case based on MOV history.

3. The Root Cause Analysis team failed to determine the true cause of the valve failure after the first failure of the valve.

Bonnet pressure locking was originally considered but was determined less likely to occur than the scenario accepted for startup. The following reasons lead to the wrong conclusion.

* The fact that the torque switch setting block had been found at a setting twice the acceptable value. (The torque switch setting block was originally set to a little less than two, but was found at a setting of four.) A torque setting of four could result in the shearing of the pin. Also a logical sequence of events was derived from the as found condition of the valve.

* When the valve was inspected there was no physical evidence that the valve was internally bound. There were no signs of packing leakage or that the valve packing had experience any pressure gradient. The valve moved easily. In past experience with bonnet pressure locking, the valve would remain bound until the packing was removed to release the pressure.

Verbal Communication: Pertinent information not transmitted. Inaccurate message transmitted. Information transmitted too late.

CORRECTIVE ACTION

NO corrective action necessary.

* Failure to identify the root cause was not due to analysis technique problems but because crucial evidence for detecting bonnet pressure locking was not available during the original investigation. Bonnet pressure locking had been considered but was discounted due to the lack of evidence. By recreating the scenario when 1E51-F063 failed to open the second time it became obvious that a bonnet pressure locking condition existed.

* Additional root cause analysis training would not eliminate the possibility of a repeat occurance in this situation.

EQUIPMENT PROBLEM

1. A combination of the valve design, system configuration, and system operation lead to the valve binding due to a high pressure in the valve bonnet region. The following events describe how the valve bound.

   The RCIC F063 valve is normally open with steam in the line. The valve was closed to isolate the system from the reactor. As the steam line and valve cooled, the steam began to condense and collect above the upstream valve disc. During cooldown of the valve bonnet, a reverse differential pressure was developed between the above-disc water (at reactor pressure) and the bonnet area (depressurized due to cooling). This dp unseated the upper disc and allowed liquid into the bonnet. Once the work was completed, the valve was heated. The moisture that had collected in the bonnet area then expanded, pressing the disks outward binding the valve.

   Design Configuration and Analysis: Equipment not designed for the environment it was used in. Inadequate failure modes and effects evaluation. Unanticipated interaction of system or components.

   Plant/System Operation: Effect of changing operating parameters not properly evaluated.

   CORRECTIVE ACTION

   Small holes were drilled in the upper disk to prevent the pressure buildup as the valve heats up.

Evaluators Comments

The following references were used in preparing this report.

LER 93-04
LER 93-07
OSR 93-08
OSR 93-10

To: AIR 373-455-89-363RS1.2

SUBJECT: THERMAL BINDING/HYDRAULIC LOCKING OF GATE VALVES

The nine (9) previous AIR's on this subject were reviewed (see Attachment A). As a result of this review two concrerns were identified.

1. Valves identified by GE SIL 368 Revision 1 were not all documented as having been evaluated.

2. More consistent criteria and verifiable methodologies are needed to identify and evaluate susceptible valves.

To ensure these concerns are addressed, the following actions were taken:

1. A screening process for thermal binding and hydraulic/pressure locking was established.

2. All Safety Related gate valves were reviewed against this screening criteria (see Attachment B).

3. The screening process was supported by a detailed evaluation prepared for each valve (see Attachment C).

4. Susceptible valves were identified (see Attachment D).

5. Additional supporting information (completed/scheduled valve modifications, testable check valve and ECCS injection valve LLRT data, EQ Zone temperature bands, PRA priorities) was gathered (see Attachment E).

Based on the results of the reviews and actions taken, as noted above, the following actions should continue to resolve this issue:

1. Develop a schedule to address all valves susceptible to either thermal binding or hydraulic/pressure locking. The schedule should set priorities based on the GL 89-10 Prioritized MOV List and the PRA (Probability Risk Assessment) value assigned to the valves.

2. Modify or analyze all subject valves taking the following into consideration: cost, GL 89-10 penalties, valve design and function.

3. A reasonable and deliberate schedule to address the subject valves is justifiable based on:

   a. The temperature values for the EQ zones are extremely conservative and they relate to the worst case area within the zone. The EQ zones encompass large areas of the plant with room and divisional separation. Divisional separation reduces the probability that a single High Energy Line break would affect more than one valve.

      There is a delay time in the conduction of heat into a valve body and subsequently the fluid in that valve body. During the first few minutes of an accident an external source of heat would have little or no affect on valve operation.

   b. Leakage rates past ECCS Injection check valves is extremely small to zero and the Injection valves would also have to leak past the upstream disk to affect bonnet pressurization.

   c. The valves identified as susceptible to Thermal Binding are subjected to worst case situations on a routine basis and valves that have had problems have been modified.

   d. The probability of having multiple valve lock ups during an accident is extremely low and to cause one valve to lock up requires multiple equipment failures.

The reviews, screening, and evaluations referenced in this document were completed by the following personnel of the Site Support Engineering, Mechanical Group:

Mark Smith	Michael Hayse	Mark Dowd

Atachment A

AIR 373-455-89-368R1S1.2

For the purpose of this AIR, I reviewed the adequacy of the corrective actions taken associated with the AIR's listed below, pertaining to thermal binding and hydraulic locking of gate valves.

373-351-85-08500	373-455-89-368R1S1.1
373-351-85-08501	373-404-91-00015
373-402-88-00801A	373-404-91-00032
373-402-88-00801C	373-100-92-01307
373-455-88-36800	

These AIR's were generated to discus/resolve the issue of gate valve binding/locking as addressed on SIL 368 R.1, SOER 84-7, SER 8-88, IN 92-26, INPO OE4753, and the Nuclear Network.

Per SIL No. 368 Revision 1, Supplement 1, Category 3, Dated July 19, 1989, the main concern for thermal binding and hydraulic locking occurs when these valves are closed when the system they serve is hot. The thermal binding then occurs when the system cools. Wedge type valves used for isolation may exhibit this mechanism if they must be opened soon after isolation.

When the plant is heated, pressure locking of wedge type and double disc valves can occur. Both types of gate valves are subject to this effect if the bonnet becomes filled with water.

It is important to guard against lockup in gate valves that; (a) must be opened to initiate a safety system at low reactor pressure vessel temperature or (b) protect the integrity of the reactor coolant pressure boundary.

The following valves and corresponding resolutions were provided by the above noted AIR's.

1(2)B21-F023A/B RR Pump Suction Stop

The problems encountered with failures of the RR Suction and Discharge valves are, based on word from GE, most likely due to the valves' orientation to the flow control valve and not due to thermal or hydraulic binding.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)B21-F067A/B RR Pump Discharge Stop

The problems encountered with failures of the RR Suction and Discharge valves are, based on word from GE, most likely due to the valves' orientation to the flow control valve and not due to thermal or hydraulic binding.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)CB007 LP Heater Bypass

While these valves were identified in the total population, no explanation or resolution was provided.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E12-F003A/B RHR Hx Outlet Stop

A Modification Request (RH19) was initiated to rewire the valve to close on limit switch position instead of torque switch. This modification would prevent the motor operator from driving this non-isolation valve into its seat thereby minimizing the effect on binding.

Additionally, a Mod Request was generated to drill a hole the disc.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED		X

1(2)E12-F004A/B/C RHR SDC

The short term solution to minimize the thermal binding is to revise the Shutdown Cooling Procedures to warn against the practice of doing vessel heat up with the Shutdown Cooling system. Procedures are currently in revision. Our Engineering Department is looking into long term solution of changing the valve design and or providing a venting mechanism for the valve. This will be a difficult process due to the valve's location below Suppression Pool level.

The bonnets for the "A" and "B" valves were subsequently provided with vents on Minor Changes MC-1-1-90-029, MC-1-1-90-030, MC-1-1-90-035, and MC-1-1-90-036.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E12-F008 RHR SDC Outboard Isolation

These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E12-F009 RHR SDC Inboard Isolation

The procedure for Start Up of Shutdown Cooling has been revised to include several options for opening this valve in the event that it does bind. Also because the original design improperly sized the motor, the valves' operators were modified on Modifications 1-187-044 and 1-2-88-007 to use larger motor operators which can overcome any binding forces.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED		X

1(2)E12-F042A/B/C RHR LPCI Injection Stop
These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E12-F047A/B RHR Hx Inlet Stop
These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E12-F049A/B RHR Hx Building to RBEDT
These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E21-F005 LPCS Injection Stop
These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E22-F004 HPCS Injection Stop

These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E32-F001A/E/J/N MSIV LCS Stop

These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E51-F013 RCIC Injection Stop

These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)E51-F064 RCIC Steam Inlet to RHR Hx

These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)FW013 HP Heater Bypass

While these valves were identified in the total population, no explanation or resolution was provided.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

1(2)G33-F101 RWCU Suction stop from RPV Bottom

These valves have not exhibited any symptoms of hydraulic locking. There are currently no plans to modify valves that are working properly.

	YES	NO
FURTHER INVESTIGATION/EVALUATION REQUIRED	X	

Per SIL No. 368 Revision 1 Supplement 1 Category 3, Dated July 19, 1989, the following valves (with potential malfunction) should have been reviewed for thermal binding and hydraulic binding but were not addressed by the AIRs noted on page 1:

<u>1/2B22-F065A/B Feedwater Isolation</u>
(Thermal Binding and Press. Locking)
The correct EID for these valves is <u>1/2B21-F065A/B</u>.

<u>1/2E11-F007 RHR Minimum Flow</u>
(Thermal Binding and Press. Locking)
The correct EID for these valves is <u>1/2E12-F064</u>A/B/C.

<u>1/2E11-F028 RHR Pool Return</u>
(Thermal Binding and Press. Locking)
N/A. LaSalle does not have this valve.

<u>1/2E21-F011 Core Spray Minimum Flow</u>
(Thermal Binding and Press. Locking)

<u>1/2E22-F012 HPCS Minimum Flow</u>
(Thermal Binding and Press. locking)

<u>1/2E22-F015 HPCS Suppression Pool Suction</u>
(Thermal Binding and Press. locking)

<u>1/2E41-F041 HPCI Injection</u>
(Press. locking)
N/A. LaSalle does not have a High Pressure Core Injection system.

<u>1/2G31-F001 RWCU Inlet</u>
(Press. Locking)
The correct EID for these valves is <u>1/2G33-F001</u>.

<u>1/2G31-F106 RWCU Inlet</u>
(Press. Locking)
The correct EID for these valves is <u>1/2G33-F106</u>.

<u>1/2E12-F040</u>

<u>1/2G33-F004</u>

Susceptibility Evaluation Criteria

Thermal Binding/Pressure Locking Conditions

Evaluation Exclusion Criteria:

1. With the exception of gate valves, all of the remaining valve designs have been excluded from the evaluation of thermal binding and pressure locking conditions.

2. All Non-Safety Related gate valves have been excluded with the exception of those Non-Safety Related gate valves in systems maintained as Safety Related.

3. Valves which have a Passive Safety Classification.

4. Valves that only have a Safety Function to close, or during plant operation they can be placed in the open position, closed during plant shutdown (if required), and reopened upon start up.

Thermal Binding Exclusion Criteria:

1. Valves that are placed in the full closed position, with the valve at or below normal room temperature.

2. Valves that have double-disc or parallel-seat design.

Part A: Thermal Binding Evaluation

1.a Is the required Safety Function of the valve to open from the full closed position under normal or accident conditions? (Yes/No)

1.b Even though the Safety Function of the valve is in the closed position, does the Emergency Operating Procedures require the valve to be reopened from the closed position? (Yes/No)

1.c Can the valve be closed for maintenance or operational reasons and reopened during normal unit operation? (Yes/No)

2. Is the valve placed in the full closed position with temperatures above normal room temperature? (Yes/No)

3. Is the valve disc a wedge design (solid, split, flexible)? (Yes/No)

Note: If the answers to any part of question one, and the remaining questions in Part A are yes the valve should be considered susceptible to thermal binding.

Pressure Locking Exclusion Criteria:

1. Valves that have been installed in systems with a process media containing compressible gases or fluid/gas mixtures other than steam providing the system is not initially filled with water.

Part B: Pressure Locking

1.a Is the required Safety Function of the valve to open from the full closed position under normal or accident conditions? (Yes/No)

1.b Even though the Safety Function of the valve is in the closed position, does the Emergency Operating Procedures require the valve to be reopened from the closed position? (Yes/No)

1.c Can the valve be closed for maintenance or operational reasons and reopened during normal unit operation? (Yes/No)

2. Is the valve susceptible to allowing fluid to enter the bonnet cavity including the area between the disc halves during valve cycling or due to differential pressure across the valve seats in the closed position? (Yes/No)

Note: Steam systems with isolated flow may condense allowing fluid to enter the bonnet cavity depending on the system and valve configuration.

3. Is the valve bonnet cavity susceptible to a higher differential pressure than both valve seats under normal or accident conditions due to temperature increases or instantaneous system pressure drops in the upstream and/or downstream piping? (Yes/No)

Note: If the answers to any part of question one, and the remaining questions in Part B are yes the valve should be considered susceptible to pressure locking.

Screening Criteria Basis

1. UFSAR 1.2.4.1 Definitions:

   a. Active Component: A safety related component characterized by an automatically initiated change of state or discernible mechanical action in response to an imposed demand.

   b. Passive Component: A safety related component characterized by no change of state nor mechanical motion.

2. Environmental Qualification List Definitions:
   (Sargent & Lundy Project Instruction PI-LSNS-44 Rev. 7)

   a. Active Component: Component must perform a mechanical motion or change of state in order to accomplish its safety-related function(s).

   b. Passive Component: Component must retain its structural and pressure integrity but is not required to remain functional (i.e.., component is not required to perform a mechanical motion or to change state) in order to accomplish its safety function.

Safety Related Gate Valve List

EPN	Active Passive	Thermal Binding 1	2	3	Pressure Locking 1	2	3	Envir Zone
1(2)B21F011A/B	P							
1(2)B21F016	A	Y(B)	Y	Y	Y(B)	Y	Y	H2A
1(2)B21F019	A	Y(B)	Y	Y	Y(B)	Y	Y	H5C
1(2)B21F065A/B	A	N	Y	Y	N	Y	Y	H5C
1(2)B21F067A/B/C/D	A	Y(B)	Y	N	Y(B)	Y	Y	H5C
1(2)B21F508A/B	P							
1(2)B33F023A/B	*P	N	Y	Y	N	Y	Y	H2A
1(2)B33F067A/B	*P	N	Y	N	N	Y	Y	H2A
1(2)CB007	*	N	Y	Y	N	Y	Y	
1(2)C11D001101	P							
1(2)C11D001102	P							
1(2)C11D001112	P							
0(1,2)DG001	P							
0(1,2)DG003	P							
0(1,2)DG004	P							
0(1,2)DG005	P							
0(1,2)DG007	P							
1(2)DG008	P							
0DG009	P							
1(2)DG011	P							
1(2)DG017	P							
1(2)DG019	P							
1(2)DG023	P							
1(2)DG032	P							
0(1,2)DO009	P							
1(2)DO016	P							
1(2)DO017	P							
1(2)DO019	P							
0DO021	P							
1(2)E12F003A/B	A	Y(BC)	N	Y	Y(BC)	Y	Y	H6
1(2)E12F004A/B/C	A	Y(C)	N	Y	Y(C)	Y	Y	H5E
1(2)E12F006A/B	A	Y(AB)	Y	Y	Y(AB)	Y	Y	H6
1(2)E12F007	P							
1(2)E12F008	A	Y(B)	Y	Y	Y(B)	Y	Y	H5B
1(2)E12F009	A	Y(B)	Y	Y	Y(B)	Y	Y	H2A
1(2)E12F011A/B	A	N	Y	Y	N	Y	Y	H6
1(2)E12F014A/B	P							
1(2)E12F016A/B	A	Y(AB)	N	Y	Y(AB)	Y	Y	H4A
1(2)E12F017A/B	A	Y(AB)	N	Y	Y(AB)	Y	Y	H4A
1(2)E12F018A/B/C	P							
1(2)E12F020	P							
1(2)E12F026A/B	A	N	N	Y	N	Y	Y	H6
1(2)E12F027A/B	A	Y(AB)	N	Y	Y(AB)	Y	Y	H6
1(2)E12F042A/B/C	A	Y(AB)	N	Y	Y(AB)	Y	Y	H4A
1(2)E12F047A/B	A	Y(C)	N	Y	Y(C)	Y	Y	H6
1(2)E12F049A/B	A	Y(B)	Y	Y	Y(B)	Y	Y	H6

*Note: These valves were evaluated as identified by previous AIRs and/or SIL 368.

EPN	Active Passive	Thermal Binding 1	2	3	Pressure Locking 1	2	3	Envir Zone
1(2)E12F063A/B/C	P							
1(2)E12F064A/B/C	A	Y(BC)	Y	Y	Y(BC)	Y	Y	H6
1(2)E12F067	P							
1(2)E12F068A/B	A	Y(BC)	N	Y	Y(BC)	Y	Y	H5E
1(2)E12F071A/B	P							
1(2)E12F072A/B/C	P							
1(2)E12F086	P							
1(2)E12F090A/B	P							
1(2)E12F092A/B/C	P							
1(2)E12F093	A	Y(B)	N	Y	Y(B)	Y	Y	H6
1(2)E12F094	A	Y(B)	N	Y	Y(B)	Y	Y	H6
1(2)E12F098A/B/C	P							
1(2)E12F302	P							
1(2)E12F303	P							
1E12F328B	P							
1(2)E12F330A/B/C/D	P							
1(2)E12F332A/B/C/D	P							
1(2)E12F336A/B	P							
1(2)E12F341	P							
1(2)E12F402	P							
2E12F428A/B	P							
2E12F429A/B	P							
1(2)E21F001	A	Y(C)	N	Y	Y(C)	Y	Y	H5E
1(2)E21F004	P							
1(2)E21F005	A	Y(AB)	N	Y	Y(AB)	Y	Y	H4A
1(2)E21F008	P							
1(2)E21F011	A	Y(BC)	Y	Y	Y(BC)	Y	Y	H5A
1(2)E21F051	P							
1(2)E21F052	P							
1(2)E22F003	P							
1(2)E22F004	A	Y(AB)	N	N	Y(AB)	Y	Y	H4A
1(2)E22F012	A	Y(ABC)	Y	N	Y(ABC)	Y	Y	H6
1(2)E22F015	A	Y(C)	N	N	Y(C)	Y	Y	H5E
1(2)E22F019	P							
1(2)E22F026	P							
1(2)E22F031	P							
1(2)E22F038	P							
1(2)E22F310	P							
1(2)E22F311	P							
1(2)E22F312	P							
1(2)E22F313	P							
1(2)E22F315	P							
1(2)E22F316	P							
1(2)E22F319	P							
1(2)E22F325	P							
1(2)E32F001A/E/J/N	A	Y(A)	N	Y	Y(A)	Y	Y	H5C
1(2)E32F002A/E/J/N	A	Y(A)	N	Y	Y(A)	Y	Y	H5C
1(2)E32F003N	A	Y(A)	N	Y	Y(A)	Y	Y	H5C
1(2)E32F006	A	Y(A)	N	Y	Y(A)	Y	Y	H5C
1(2)E32F007	A	Y(A)	N	Y	Y(A)	Y	Y	H5C
1(2)E51F008	A	Y(BC)	Y	N	Y(BC)	Y	Y	H5B
1(2)E51F009	P							
1(2)E51F010	A	Y(BC)	N	Y	Y(BC)	Y	Y	H5A
1(2)E51F012	P							

EPN	Active Passive	Thermal Binding 1	2	3	Pressure Locking 1	2	3	Envir Zone
1(2)E51F013	A	Y(A)	N	Y	Y(A)	Y	Y	H4A
1(2)E51F016	P							
1(2)E51F031	A	Y(AB)	N	Y	Y(AB)	Y	Y	H5E
1(2)E51F059	A	Y(B)	N	Y	Y(B)	Y	Y	H5A
1(2)E51F063	A	Y(BC)	Y	N	Y(BC)	Y	Y	H2A
1(2)E51F064	A	N	Y	Y	N	Y	Y	H5B
1(2)E51F068	A	Y(C)	Y	Y	Y(C)	N	Y	H5E
1(2)E51F356	P							
2E51F357	P							
1(2)E51F362	P							
1(2)E51F363	P							
1(2)FC040A/B	P							
1(2)FC042A/B	P							
1(2)FC045A/B	P							
1(2)FC047A/B	P							
1(2)FC086	P							
1(2)FC115	P							
1(2)FC139A/B	P							
1(2)FC140	P							
1(2)FW013	*	N	Y	Y	N	Y	Y	
1(2)G33F001	A	Y(BC)	Y	N	Y(BC)	Y	Y	H2A
1(2)G33F004	A	Y(BC)	Y	N	Y(BC)	Y	Y	H5D
1(2)G33F040	A	Y(BC)	Y	Y	Y(BC)	Y	Y	H5C
1(2)G33F100	P							
1(2)G33F101	*P	N	Y	Y	N	Y	Y	H2A
1(2)G33F106	P							
1(2)HG001A/B	A	Y(AB)	N	Y	Y(AB)	N	Y	H4A
1(2)HG003	A	Y(C)	N	Y	Y(C)	N	Y	H4A
1(2)HG005A/B	A	Y(A)	N	Y	Y(A)	N	Y	H5E
1(2)HG006A/B	A	Y(A)	N	Y	Y(A)	N	Y	H5E
1(2)HG009	A	Y(AB)	N	Y	Y(AB)	N	Y	H4A
1(2)MC027	P							
1(2)MC033	P							
1(2)SA042	P							
1(2)SA046	P							
0VC025A/B/C/D	P							
1(2)VG008	P							
1(2)VG00[illegible]	P							
1(2)VG010	P							
1(2)VG011	P							
1(2)VG012	P							
1(2)VG013	P							
1(2)VG014	P							
1(2)VG015	P							
1(2)VP053A/B	A	Y(BC)	N	Y	Y(BC)	Y	Y	H4A
1(2)VP063A/B	A	Y(BC)	N	Y	Y(BC)	Y	Y	H4A
1(2)WR029	A	N	N	Y	N	Y	Y	H4A
1(2)WR040	A	N	N	Y	N	Y	Y	H4A
1(2)WR179	A	N	N	Y	N	Y	Y	H2A
1(2)WR180	A	N	N	Y	N	Y	Y	H2A

*Note: These valves were evaluated as identified by previous AIRs and/or SIL 368.

STEAM VALVE SCREENING

1. Is the valve installed in a vertical run of piping?

2. Is the valve installed on a horizontal run of piping, with the actuator installed in any position other than a straight up vertical position?

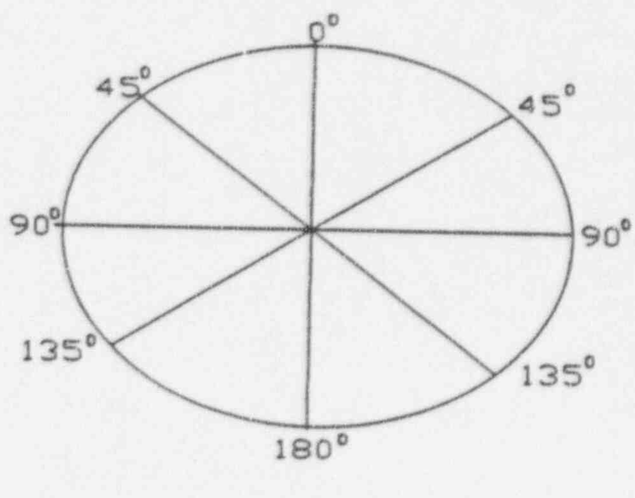
3. Is the valve installed in a low point in the system, where steam may condense and water gather at the valve?

If the answers to questions 1 through 3 are no then the valve is not considered to be susceptible to having water enter the bonnet cavity.

Attachment B

VALVE NO.	QUESTION NUMBER 1	2	3
1(2)B21-F016	NO	NO	YES
1(2)B21-F019	NO	NO	YES
1(2)B21-F067A	NO	NO	YES
1(2)B21-F067B	NO	NO	YES
1(2)B21-F067C	NO	NO	YES
1(2)B21-F067D	NO	NO	YES
1E32-F001A	NO	YES(22)	YES
2E32-F001A	NO	YES(20)	YES
1E32-F001E	NO	YES(14)	YES
2E32-F001E	NO	YES(20)	YES
1E32-F001J	NO	YES(15)	YES
2E32-F001J	NO	YES(20)	YES
1E32-F001N	NO	YES(09)	YES
2E32-F001N	NO	YES(20)	YES
1(2)E32-F002A	NO	YES(45)	YES
1(2)E32-F002E	NO	YES(45)	YES
1(2)E32-F002J	NO	YES(45)	YES
1(2)E32-F002N	NO	YES(45)	YES
1(2)E32-F003N	NO	NO	YES
1(2)E32-F006	NO	NO	YES
1(2)E32-F007	NO	NO	YES
1(2)E51-F008	NO	NO	YES
1(2)E51-F063	YES	NO	YES
1(2)E51-F064	NO	NO	YES
1(2)E51-F068	NO	NO	NO

QUESTION 2 OPERATOR ORIENTATION



Attachment B

Qualification Requirements of Screening Personnel

1. Senior Reactor Operators License with two years operating experience.

2. Valve expert with two years maintenance experience.

3. BS Engineering degree.

4. Two Persons required to screen valve susceptibility. They must cover the qualifications as stated in items 1-3.

Screening Personnel

1. Mark Dowd - SRO since 1983,11 years on shift operating experience,BS General Engineering University of Illinois 1978.

2. Mark Smith - 7 years Maintenance Mechanic,6 years Maintenance Supervisor,2 years valve component expert for Site Engineering at LaSalle Station.

3. Mike Hayse - 15 years Quality Assurance and Quality Control experience.

ATTACHMENT B

Differential Temperature Screening Criteria

1. Is there a heat sink on one side of the valve (i.e., large pool of water or a flow stream)?

2. Is there a heat source on one side of the valve that can transmit heat to one side of the valve?

NOTE

Heat sources can transmit heat long distances in stagnant legs if it is done via convective heat transfer.

If answers to questions 1 and 2 are both yes then the valve is subject to a differential temperature.

ATTACHMENT B

VALVE NO.	QUESTION NUMBER 1	QUESTION NUMBER 2
1(2)E12-F042A/B/C	N	N
1(2)E21-F005	N	N
1(2)E22-F004	N	N
1(2)E51-F013	N	N
1(2)E12-F016A/B	N	N
1(2)E12-F017A/B	N	N
1(2)E12-F027A/B	N	Y
1(2)E12-F068A/B	Y	N
1(2)E12-F003A/B	Y	Y
1(2)E12-F004A/B/C	Y	Y
1(2)E12-F006A/B	Y	N
1(2)E12-F008	N	N
1(2)E12-F009	N	Y
1(2)E12-F011A/B	Y	Y
1(2)E12-F026A/B	N	Y
1(2)E12-F047A/B	Y	Y
1(2)E12-F049A/B	N	N
1(2)E12-F064A/B/C	Y	Y
1(2)E12-F093	Y	N
1(2)E12-F094	N	N
1(2)E21-F001	Y	N
1(2)E21-F011	Y	N
1(2)E22-F012	Y	N
1(2)E22-F015	Y	N
1(2)E51-F008	N	N
1(2)E51-F063	N	Y
1(2)E51-F010	Y	N
1(2)E51-F031	Y	N
1(2)E51-F059	Y	N
1(2)E51-F064	N	Y
1(2)E51-F068	N	Y
1(2)G33-F001	N	Y
1(2)G33-F004	N	Y
1(2)G33-F040	N	Y
1(2)G33-F101	N	Y
1(2)HG001A/B	N	N
1(2)HG003	N	N
1(2)HG009	N	N

ATTACHMENT B

VALVE NO.	QUESTION NUMBER 1	2
1(2)HG005A/B	Y	N
1(2)HG006A/B	N	N
1(2)VP053A/B	N	N
1(2)VP063A/B	N	N
1(2)WR029	N	N
1(2)WR040	N	N
1(2)WR179	N	N
1(2)WR180	N	N
1(2)E32-F001A/E/J/N	N	Y
1(2)E32-F002A/E/J/N	N	Y
1(2)E32-F003N	N	Y
1(2)E32-F006	N	Y
1(2)E32-F007	N	Y
1(2)B21-F016	N	Y
1(2)B21-F019	N	Y
1(2)B21-F067A/B/C/D	N	Y
1(2)B21-F065A/B	N	Y
1(2)B33-F023A/B	N	Y
1(2)B33-F067A/B	N	Y
1(2)CB007	N	Y
1(2)FW013	N	Y

1(2)E12-F042 A/B/C

A. Thermal Binding Evaluation

1.a The safety function of these valves is to open from the full closed position.

1.b The EOP's require the LPCI Injection Valves to open during accident conditions.

1.c Not applicable as these valves are normally closed.

2. The LPCI Injection Valves are closed on Unit start up at normal room temperature conditions and are not cycled during normal Unit operations.

3. The LPCI Injection Valves are 12" motor operated flex wedge gate valves.

B. Hydraulic Locking Evaluation

1.a The safety function of these valves is to open from the full closed position.

1.b The EOP's require the LPCI Injection Valves to open during accident conditions.

1.c Not applicable as these valves are normally closed.

2. The LPCI Injection Valves are in a water filled system, therefore the bonnet cavities can be assumed to be filled with water.

3. The LPCI Injection Valves are in EQ zone H4A, with a postulated temperature range of 94 degf to 145 degf. Based on that temperature rise, a more specific temperature profile will be required to determine hydraulic locking susceptibility.

   Based on present leak rate testing methodology, more detailed testing and instrumentation will be required to determine if the valve bonnet cavities are subjected to Reactor pressure and would then be susceptible to a rapid depressurization form of hydraulic locking.

1(2)E21-F005

A. Thermal Binding Evaluation

1.a The safety function of this valve is to open from the full closed position.

1.b The EOP's require the LPCS Injection Valve to open during accident conditions.

1.c Not applicable as this valve is normally closed.

2. The LPCS Injection Valve is closed on Unit start up at normal room temperature conditions and is not cycled during normal Unit operations.

3. The LPCS Injection Valve is a 12" motor operated flex wedge gate valve.

B. Hydraulic Locking Evaluation

1.a The safety function of this valve is to open from the full closed position.

1.b The EOP's require the LPCS Injection Valve to open during accident conditions.

1.c Not applicable as this valve is normally closed.

2. The LPCS Injection Valve is in a water filled system, therefore the bonnet cavity can be assumed to be filled with water.

3. The LPCS Injection Valve is in EQ zone H4A with a postulated temperature range of 94 degf to 145 degf. Based on that temperature rise, a more specific temperature profile will be required to determine hydraulic locking susceptibility.

   Based on present leak rate testing methodology, more detailed testing and instrumentation will be required to determine if the valve bonnet cavity is subjected to Reactor pressure and would then be susceptible to a rapid depressurization form of hydraulic locking.

1(2)E22-F004

A. Thermal Binding Evaluation

1.a The safety function of this valve is to open from the full closed position.

1.b The EOP's require the HPCS Injection Valve to open during accident conditions.

1.c Not applicable as this valve is normally closed.

2. The HPCS Injection Valve is closed on Unit start up at normal room temperature conditions and is not cycled during normal Unit operations. LaSalle Station has experienced events where the HPCS system has successfully injected while the Reactor has been at rated temperature and pressure.

3. The HPCS Injection Valve is a 12" motor operated double-disc gate valve.

B. Hydraulic Locking Evaluation

1.a The safety function of this valve is to open from the full closed position.

1.b The EOP's require the HPCS Injection Valve to open during accident conditions.

1.c Not applicable as this valve is normally closed.

2. The HPCS Injection Valve is in a water filled system, therefore the bonnet cavity can be assumed to be filled with water.

3. The HPCS Injection Valve is in EQ zone H4A with a postulated temperature range of 94 degf to 145 degf. Based on that temperature rise, a more specific temperature profile will be required to determine hydraulic locking susceptibility.

   Based on present leak rate testing methodology, more detailed testing and instrumentation will be required to determine if the valve bonnet cavity is subjected to Reactor pressure and would then be susceptible to a rapid depressurization form of hydraulic locking.

Attachment C

1(2)E51-F013

A. Thermal Binding Evaluation

1.a The safety function of this valve is to open from the full closed position.

1.b The EOP's require the RCIC Injection Valve to open during accident conditions.

1.c Not applicable as this valve is normally closed.

2. The RCIC Injection Valve is closed on Unit start up at normal room temperature conditions and is not cycled during normal Unit operations. LaSalle Station has experienced events where the RCIC system has successfully injected while the Reactor has been at rated temperature and pressure.

3. The RCIC Injection Valve is a 6" motor operated flex wedge gate valve.

B. Hydraulic Locking Evaluation

1.a The safety function of this valve is to open from the full closed position.

1.b The EOP's require the RCIC Injection Valve to open during accident conditions.

1.c Not applicable as this valve is normally closed.

2. The RCIC Injection Valve is in a water filled system, therefore the bonnet cavity can be assumed to be filled with water.

3. The RCIC Injection Valve is in EQ zone H4A with a postulated temperature range of 94 degf to 145 degf. Based on that temperature rise, a more specific temperature profile will be required to determine hydraulic locking susceptibility.

   Based on present leak rate testing methodology, more detailed testing and instrumentation will be required to determine if the valve bonnet cavity is subjected to Reactor pressure and would then be susceptible to a rapid depressurization form of hydraulic locking.

Attachment C

1(2)E12-F016A/B

A. Thermal Binding Evaluation

1.a The safety function of these valves is to open for Drywell spray operation and close for Primary Containment isolation.

1.b The EOP's require these valves to open during accident conditions.

1.c Not applicable as this valve is normally closed.

2. The Drywell Spray Valves are closed on Unit start up at normal room temperature conditions and are not cycled during normal Unit operations.

3. The Drywell Spray Valve is a 16" motor operated flex wedge gate valve.

B. Hydraulic Locking Evaluation

1.a The safety function of these valves is to open for Drywell spray operation and close for Primary Containment isolation.

1.b The EOP's require these valves to open during accident conditions.

1.c Not applicable as this valve is normally closed.

2. The Drywell Spray Valves are in a water filled system, therefore the bonnet cavities can be assumed to be filled with water.

3. The Drywell Spray Valve is in EQ zone H4A with a postulated temperature range of 94 degf to 145 degf. Based on that temperature rise, a more specific temperature profile will be required to determine hydraulic locking susceptibility.

   The Drywell Spray Valve can not be subjected to Reactor pressure, therefore it is not susceptible to a rapid depressurization form of hydraulic lock.

AIR 373-455-89-363RS1.2
ATTACHMENT D

1. Approximately 10 types of valves were determined to be susceptible to Thermal Binding.The susceptible valves are tabulated below.

2. Approximately 40 types of valves were determined to be susceptible to Pressure Locking.The susceptible valves are tabulated below.

Thermal Binding	Pressure Locking
1(2)B21-F016	1(2)B21-F016
1(2)B21-F019	1(2)B21-F019
1(2)E12-F006A/B	1(2)B21-F067A/B/C/D
1(2)E12-F008	1(2)E12-F003A/B
1(2)E12-F009	1(2)E12-F004A/B/C
1(2)E12-F049A/B	1(2)E12-F006A/B
1(2)E12-F064A/B/C	1(2)E12-F008
1(2)E21-F011	1(2)E12-F009
1(2)E51-F068	1(2)E12-F016A/B
1(2)G33-F040	1(2)E12-F017A/B
	1(2)E12-F027A/B
	1(2)E12-F042A/B/C
	1(2)E12-F047A/B
	1(2)E12-F049A/B
	1(2)E12-F064A/B/C
	1(2)E12-F068A/B
	1(2)E12-F093
	1(2)E12-F094
	1(2)E21-F001
	1(2)E21-F004
	1(2)E21-F011
	1(2)E22-F004
	1(2)E22-F012
	1(2)E22-F015
	1(2)E32-F001A/E/J/N
	1(2)E32-F002A/E/J/N
	1(2)E32-F003N
	1(2)E32-F006
	1(2)E32-F007
	1(2)E51-F008
	1(2)E51-F010
	1(2)E51-F013
	1(2)E51-F031
	1(2)E51-F059
	1(2)E51-F063
	1(2)G33-F040
	1(2)G33-F004
	1(2)G33-F040
	1(2)VP053A/B
	1(2)VP063A/B

Thermal Binding

1(2)B21-F016
1(2)B21-F019
1(2)E12-F006A/B
1(2)E12-F008
1(2)E12-F009
1(2)E12-F049A/B
1(2)E12-F064A/B/C*
1(2)E21-F011
1(2)E51-F068
1(2)G33-F040

NOTE

* Denotes valves susceptible to Differential Temperature Thermal Binding and Classic Thermal Binding

Valves susceptible to Differential Temperature Thermal Binding.

1(2)E12-F003A/B
1(2)E12-F004A/B/~~C~~
1(2)E12-F047A/B

Pressure Locking

1(2)B21-F016
1(2)B21-F019
1(2)B21-F067A/B/C/D
1(2)E12-F003A/B
1(2)E12-F004A/B/C
1(2)E12-F006A/B
1(2)E12-F008
1(2)E12-F009
1(2)E12-F016A/B
1(2)E12-F017A/B
1(2)E12-F027A/B
1(2)E12-F042A/B/C
1(2)E12-F047A/B
1(2)E12-F049A/B
1(2)E12-F064A/B/C
1(2)E12-F068A/B
1(2)E12-F093
1(2)E12-F094
1(2)E21-F001
1(2)E21-F005
1(2)E21-F011
1(2)E22-F004
1(2)E22-F012
1(2)E22-F015
1(2)E32-F001A/E/J/N
1(2)E32-F002A/E/J/N
1(2)E32-F003N
1(2)E32-F006
1(2)E32-F007
1(2)E51-F008
1(2)E51-F010
1(2)E51-F013
1(2)E51-F031
1(2)E51-F059
1(2)E51-F063
1(2)G33-F001
1(2)G33-F004
1(2)G33-F040
1(2)VP053A/B
1(2)VP063A/B

Modified Valves

EPN	Change	Initiater	Doc.Number	Date
1E12-F003A	close on limits 95%	DVR 1-1-83-342&387	M01-1-86-005 TSC1-708-83	5\30\88
1E12-F003B	close on limits 95%	DVR 1-1-83-342&387	M01-1-86-005 TSC1-708-83	5\30\88
2E12-F003A	close on limits 95%	DVR 1-1-83-342&387	M01-2-88-018 TSC2-756-86	1\6\89
2E12-F003B	close on limits 95%	DVR 1-1-83-342&387	M01-2-88-018 TSC2-756-86	1\6\89
1E12-F004A	Bonnet Vent &Proc. Rev.	DVR 1-2-89-0047	P01-1-90-036	1\13\92
1E12-F004B	Bonnet Vent &Proc. Rev.	DVR 1-2-89-0047	P01-1-90-029	12\31\91
2E12-F004A	Bonnet Vent &Proc. Rev.	DVR 1-2-89-0047	P01-2-90-035	3\19\92
2E12-F004B	Bonnet Vent &Proc. Rev.	DVR 1-2-89-0047	P01-2-90-030	3\24\92
1E12-F009	Larger Motor Op & Proc. Rev.	GL 89-10 & LLRT concern Vlv. Bind	M01-1-87-044	9\23\87
2E12-F009	Larger Motor Op & Proc. Rev.	GL 89-10 & LLRT concern Vlv. Bind	M01-2-88-007	1\26\89
1G33-F001	Flex wedge to Dbl.Disc	GL 89-10 & LLRT concern	P01-1-91-516	12\11\92

1G33-F004	Flex wedge to Dbl.Disc	GL 89-10 & LLRT concern	P01-1-91-517	12\10\92
2G33-F001	Flex wedge to Dbl.Disc	GL 89-10 & LLRT concern	P01-2-91-506	3\5\92
2G33-F004	Flex wedge to Dbl.Disc	GL 89-10 & LLRT concern	P01-2-91-507	3\5\92
1E51-F008	Flex wedge to Dbl.Disc	GL 89-10 & LLRT concern	P01-1-91-518	1\4\93
2E51-F008	Flex wedge to Dbl.Disc	GL 89-10 & LLRT concern	P01-2-91-508	L2R05
1E51-F063	Flex wedge to Dbl.Disc Drill two holes in upstrm disc	GL 89-10 & LLRT concern Press.lock DVR1-1-93-0023	P01-1-91-519 EC-93-004	1\7\93 3\8\93
2E51-F063	Flex wedge to Dbl.Disc	GL 89-10 & LLRT concern	P01-2-91-509	L2R05
1B21-F067A	Globe to Dbl.Disc.	LLRT Failures	CR-90-120	1\8\93
1B21-F067B	Globe to Dbl.Disc.	LLRT Failures	CR-90-117	1\8\93
1B21-F067C	Globe to Dbl.Disc.	LLRT Failures	CR-90-118	1\8\93
1B21-F067D	Globe to Dbl.Disc.	LLRT Failures	CR-90-119	1\8\93
2B21-F067A	Globe to Dbl.Disc.	LLRT Failures	CR-90-127	3\27\92
2B21-F067B	Globe to Dbl.Disc.	LLRT Failures	CR-90-124	3\27\92
2B21-F067C	Globe to Dbl.Disc.	LLRT Failures	CR-90-125	3\27\92

2B21-F067D	Globe to Dbl.Disc.	LLRT Failures	CR-90-126	3\27\92

Attachment E

Local Leak Rate Data

VALVE (EPN)	AIR LLRT (SCFH)	WATER LLRT (GPM)
1E12-F041A	-------------------	12\6\92 0.1 GPM
1E12-F042A	10\23\92 0.0 SCFH	10\22\92 0.25 GPM
1E12-F041B	-------------------	10\12\92 0.0 GPM
1E12-F042B	11\24\92 3.53 SCFH	11\25\92 0.06 GPM
1E12-F041C	-------------------	10\9\92 0.0 GPM
1E12-F042C	11\21\92 6.5 SCFH	11\23\92 0.05 GPM
1E21-F006	-------------------	12\3\92 0.0 GPM
1E21-F005	11\17\92 2.51 SCFH	11\16\92 0.1GPM
1E22-F005	-------------------	10\8\92 0.0 GPM
1E22-F004	12\21\92 0.0 SCFH	12\21\92 0.0 GPM
1E51-F065	-------------------	12\26\92 0.0 GPM
1E51-F066	-------------------	12\26\92 0.74 GPM
1E51-F013	12\31\92 0.65 SCFH	-------------------
2E12-F041A	-------------------	1\17\92 0.0 GPM
2E12-F042A	2\23\92 0.47 SCFH	2\23\92 0.1 GPM
2E12-F041B	-------------------	2\27\92 0.0 GPM
2E12-F042B	2\25\92 0.0 SCFH	2\27\92 0.0 GPM
2E12-F041C	-------------------	3\3\92 0.2 GPM
2E12-F042C	1\20\92 0.0 SCFH	1\20\92 0.5 GPM
2E21-F006	-------------------	1\11\92 0.0 GPM
2E21-F005	1\11\92 0.0 SCFH	1\11\92 0.0 GPM
2E22-F005	-------------------	1\8\92 0.0 GPM
2E22-F004	1\25\92 0.0 SCFH	1\28\92 0.0 GPM
2E51-F065	-------------------	3\19\92 0.0 GPM
2E51-F066	-------------------	3\13\92 0.1 GPM 9\5\92 0.1 GPM
2E51-F013	1\16\92 1.54 SCFH	-----------------

ZONE	LOCATION	MAXIMUM TEMPERTURE NON-ACCIDENT PERIODS (Deg. F)	MAXIMUM TEMPERATURE DURING AN ACCIDENT (Deg. F)
H1	Inside the RPV	546	581
H2	Inside Primary Containment-Drywell	135	330
H3	Inside Primary Containment-Wetwell	100	212
H4	Reactor Bldng. General Areas	94	145
H5	HELB Local Areas		
	H5A LPCS/RCIC Cubicle	100	212
	H5B RCIC Pipe Tunnel	136	212
	H5C Main Steam Tunnel	106	212
	H5D RWCU Equp. Areas	107	212
	H5E Basement & Upper Basement Outside ECCS Equip. Cubicles	94	212
H6	Reactor Bldng. ECCS Cubicles	99	148
H7	Turbine Bldng. Limited Access Areas	83	212
H8	Turbine Bldng. General Access Areas	225	212
H9	Auxiliary Bldng.	106	106

PRA PRIORITIES/VALUES

I HIGH	II MEDIUM	III LOW	IV LOW-LOW	V DELETE
E22-F004	E21-F011	E12-F004A	E51-F022	E12-F011A
E12-F068A	E12-F064A	E12-F004B	E51-F059	E12-F011B
E12-F068B	E12-F064B	E21-F001	E51-F069	E12-F052A
E12-F024A	E12-F064C	E12-F004C	E12-F023	E12-F052B
E12-F024B	E51-F013	E22-F015	VQ-032	E12-F026A
E12-F048A	E51-F019	E51-F063	VQ-035	E12-F026B
E12-F048B	E51-F045	E51-F008	VQ-068	E12-F087A
E21-F005	E51-F046	E51-F010	E51-F076	E12-F087B
E12-F042A	E22-F023	E51-F031	E12-F040A	E51-F064
E12-F042B	E22-F012	E51-F068	E12-F040B	2E51-F091
E12-F042C	E21-F012	E51-F360	E12-F049A	E22-F001
	E12-F021	E12-F027A	E12-F049B	E22-F010
	E12-F016A	E12-F027B	VQ-050	E22-F011
	E12-F016B	G33-F001	VQ-051	VG-001
	E12-F017A	G33-F004	B21-F065A	VG-002
	E12-F017B	B21-F067A	B21-F065B	DG035
		B21-F067B	E12-F073A	
		B21-F067C	E12-F073B	
		B21-F067D	E12-F074A	
		B21-F016	E12-F074B	
		B21-F019	E32-F001A	
		VP-53A	E32-F001E	
		VP-53B	E32-F001J	
		VP-63A	E32-F001N	
		VP-63B	VQ-037	
		VP-113A	VQ-038	
		VP-113B	E12-F093	
		VP-114A	E12-F094	
		VP-114B	E12-F312A	
		G33-F040	E12-F312B	
		WR-029	HG-001A	
		WR-40	HG-001B	
		WR-179	HG-002A	
		WR-180	HG-002B	
		VQ-047	HG-003	
		VQ-048	HG-005A	
		E51-F080	HG-005B	
		E51-F086	HG-006A	
		E12-F008	HG-006B	

PRA PRIORITIES/VALUES

I HIGH	II MEDIUM	III LOW	IV LOW-LOW	V DELETE
		E12-F009	HG-009	
		E12-F006A	HG-018	
		E12-F006B	HG-025	
		E12-F053A	HG-026	
		E12-F053B	HG-027	
		E12-F003A	E32-F002A	
		E12-F003B	E32-F002E	
		E12-F099A	E32-F002J	
		E12-F099B	E32-F002N	
		E12-F047A	E32-F003A	
		E12-F047B	E32-F003E	
		C41-F001A	E32-F003J	
		C41-F001B	E32-F003N	
			E32-F006	
			E32-F007	
			E32-F008	
			E32-F009	

LASALLE COUNTY STATION
PRESSURE LOCKING AND THERMAL BINDING OF GATE VALVES

VALVE SUMMARY				
VALVE	LINE NO.	DRAWING	VALVE ELEV.	ZONE
1E12F068A	1RH83AA-20"	M-227/237	685'	H5E
1E12F068B	1RH83AB-20"	M-225/234	689'	H6
2E12F068A	2RH83AA-20"	M-231/243	685'	H5E
2E12F068B	2RH83AB-20"	M-229/240	689'	H6

The applicable environmental zones (H5E, H6) are identified in Figure 3.11-1, sheet 6 of 7 and Figure 3.11-4 of the LSCS UFSAR.

H6

Per the UFSAR, H6 is not subjected to adverse temperature conditions as a result of a LOCA or HELB. The cubicle of interest in Zone H6 which contains valves 1(2)E12F068B is the southeast cubicle (RHR-BC Equipment Room) which is provided with a dedicated, safety-related cubicle cooler.

The 148 F design temperature given is for when the pumps in this room are running, consequently valve E12-F068B is already open. These valves would be expected to be at the corner room temperature. The normal room temperature provided by VR is approx. 120 F.

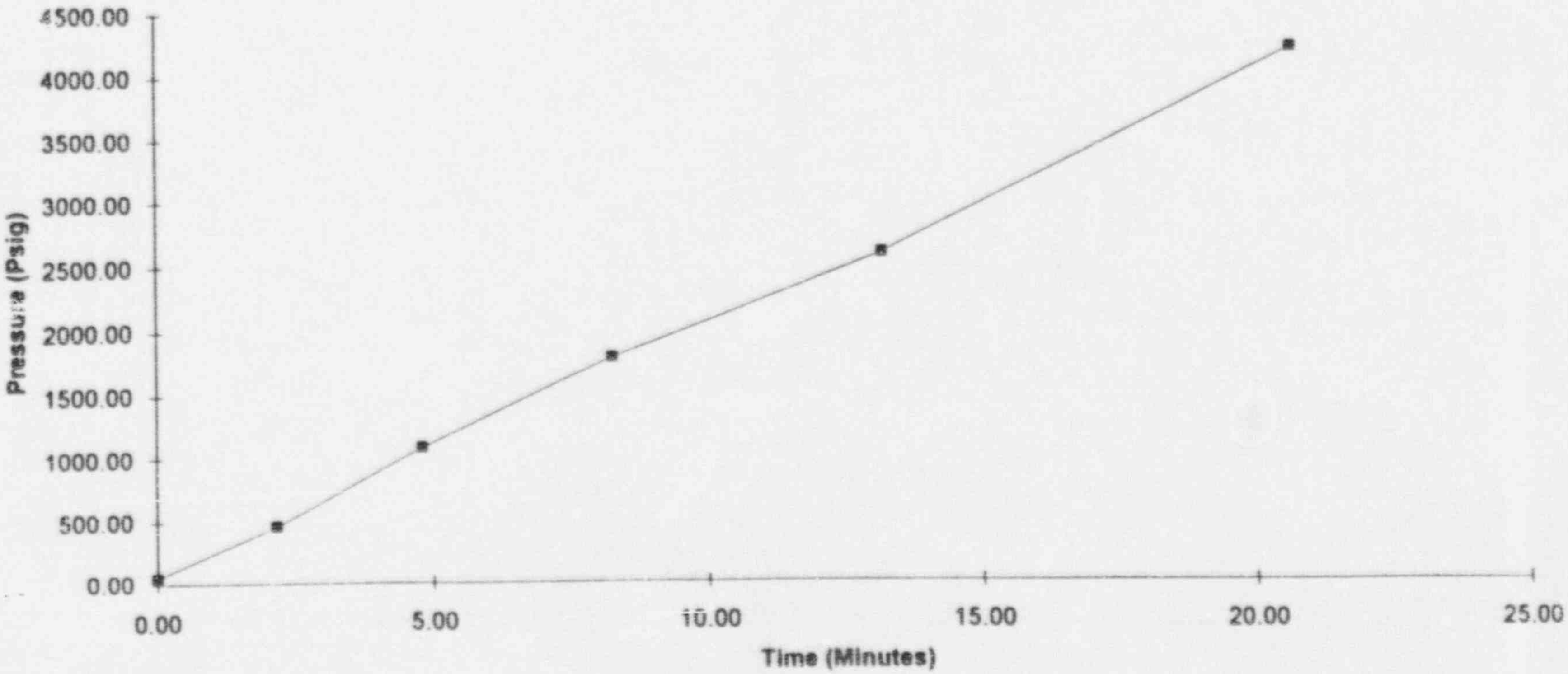
H5E

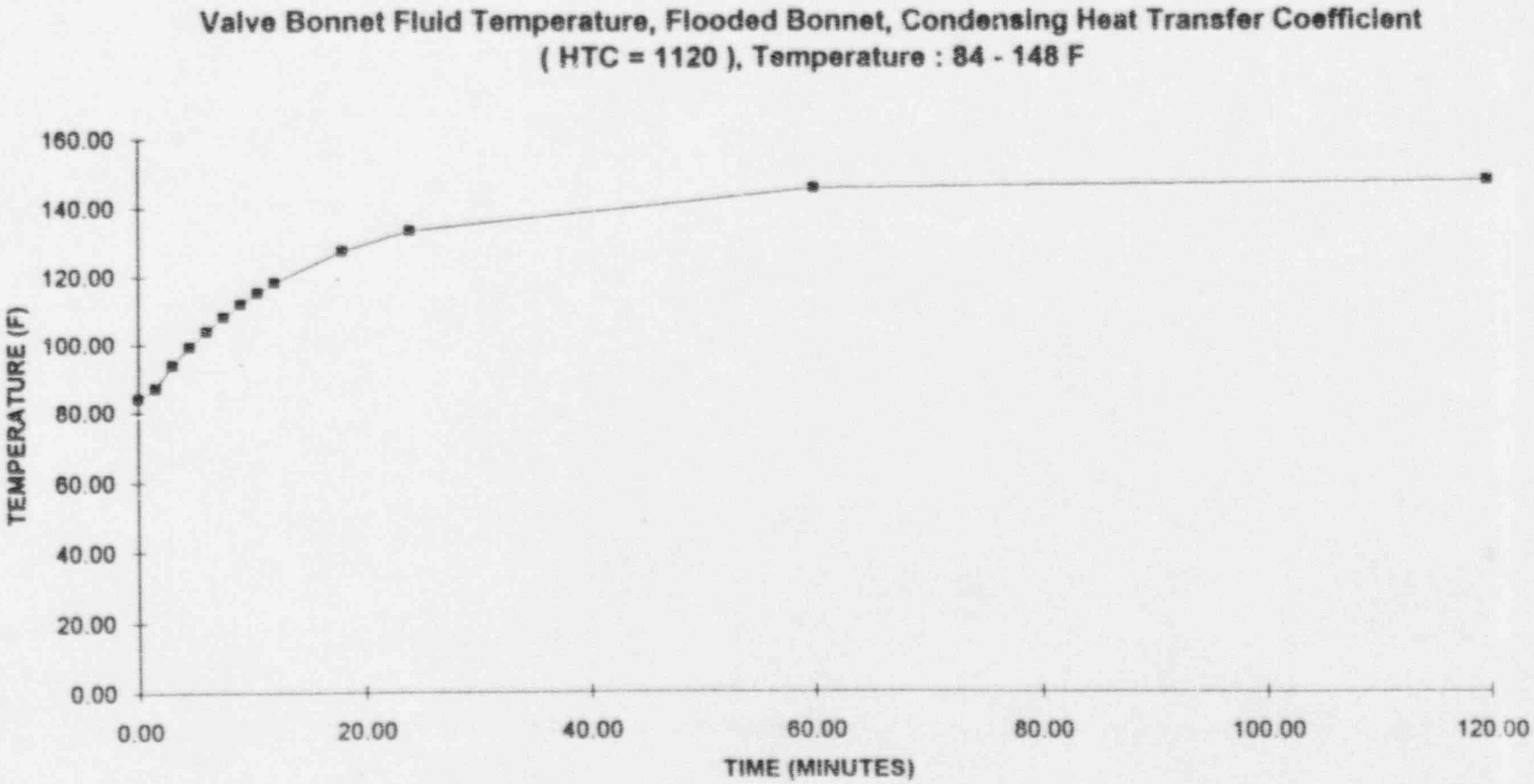
For Zone H5E (Valves 1(2)E12F068A), the peak temperature following a LOCA is 155°F per Calc. No. 3C7-0185-001, EQ conditions for reactor building (674'-0" and 694'-6" elevations) for LOCA in containment.

Based on an initial assessment, it does not appear that Zone H5E would be subjected to adverse temperature conditions as a result of an HELB, therefore, temperature relief from the 212°F documented in Table 3.11-7 of the UFSAR may be possible. However, a more detailed review would be required to confirm this.

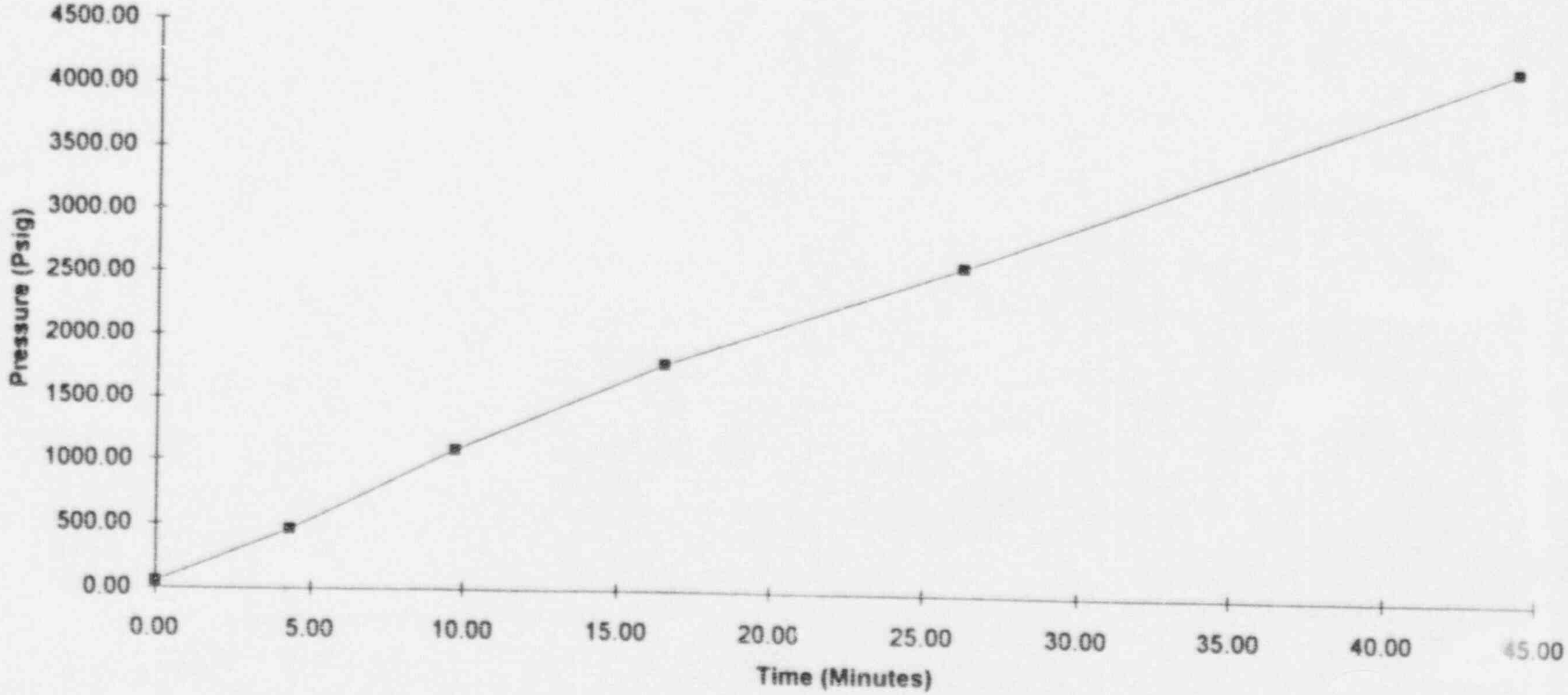
Actual line break locations need to be verified for lines located in the vicinity of the E12-F068A valve. A few RI lines breaks have been verified tc be on different elevations. We still need to look

Valve Bonnet Internal Pressure, Flooded Bonnet, Condensing Heat Transfer Coefficient
(HTC = 1120), Temperature : 84 - 148 F

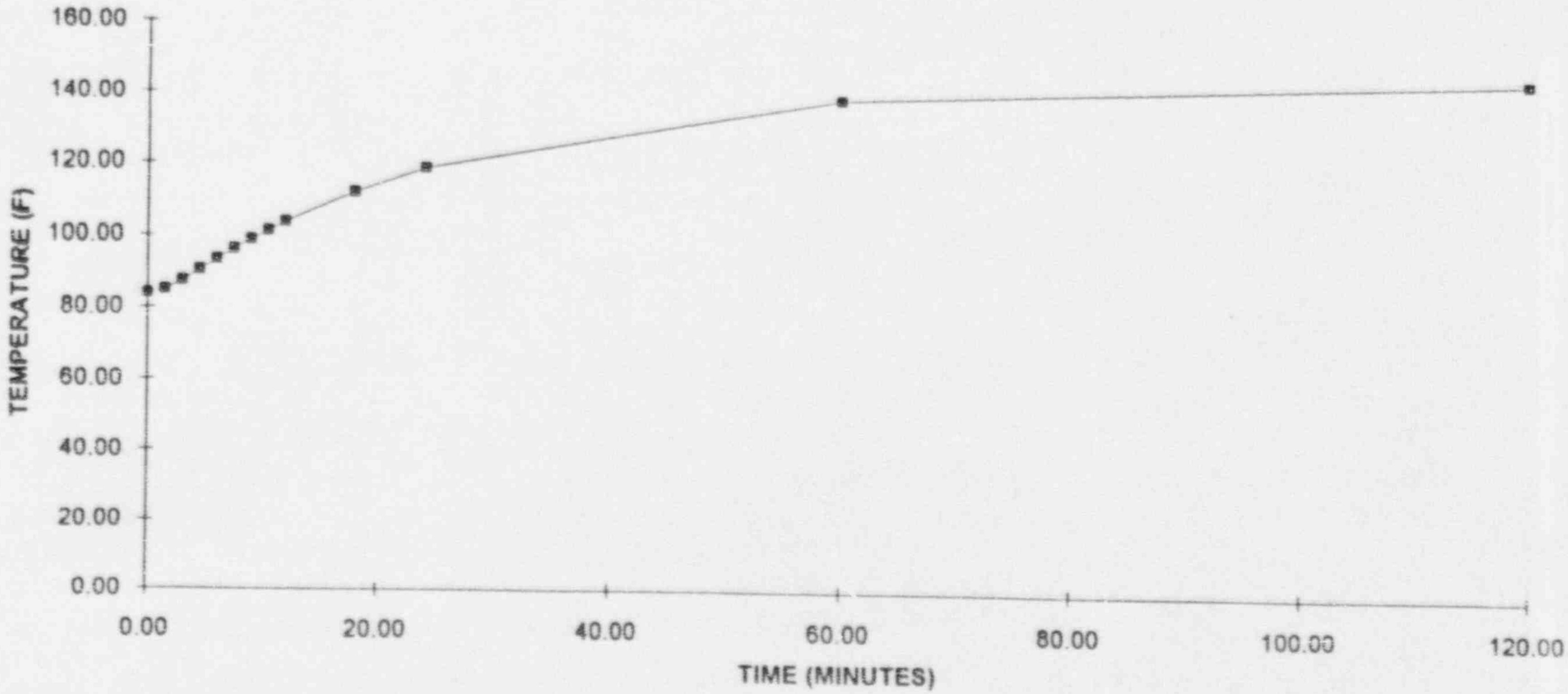


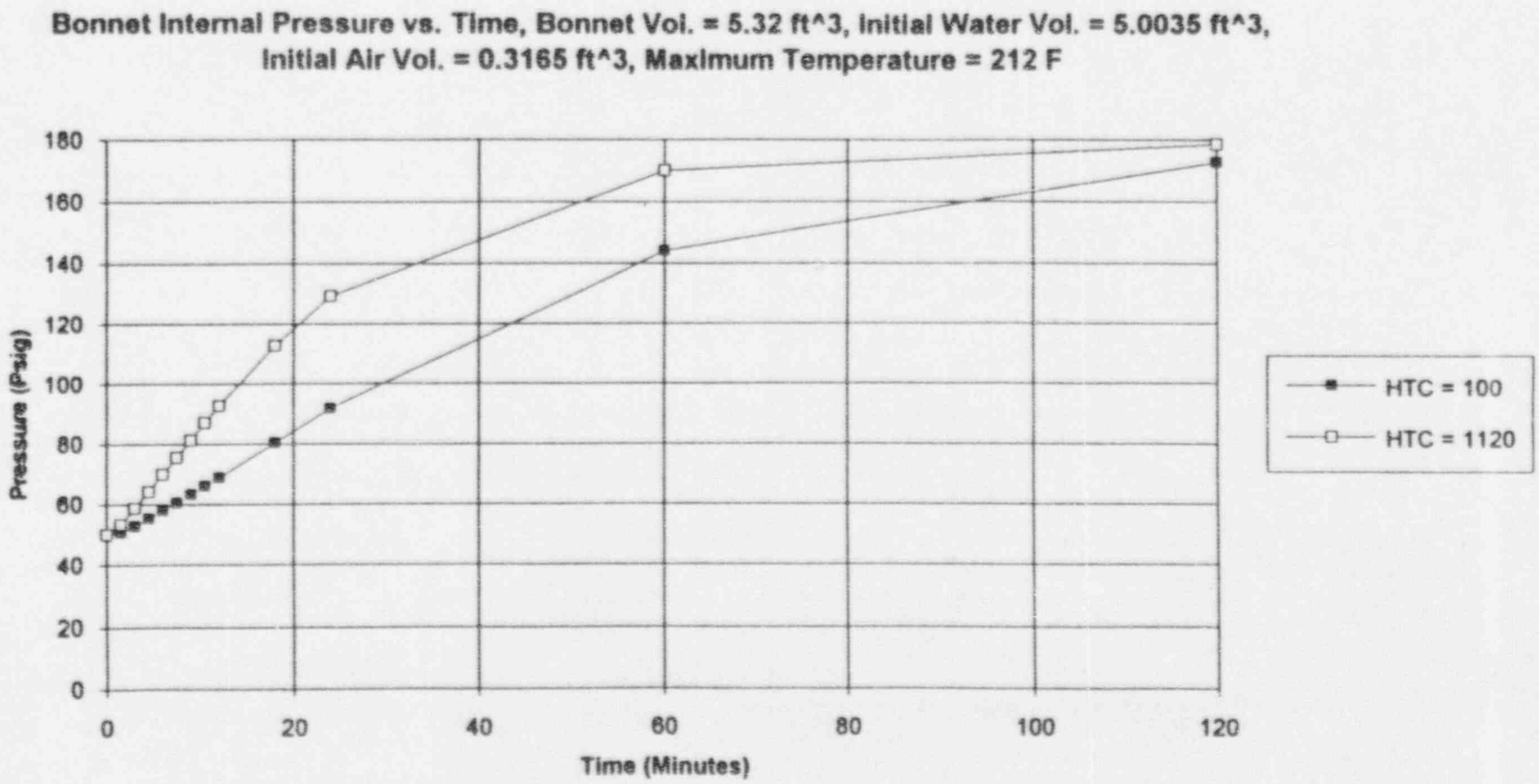

Valve Bonnet Fluid Temperature, Flooded Bonnet, Condensing Heat Transfer Coefficient
(HTC = 1120), Temperature : 84 - 148 F
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
TEMPERATURE (F)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
TIME (MINUTES)

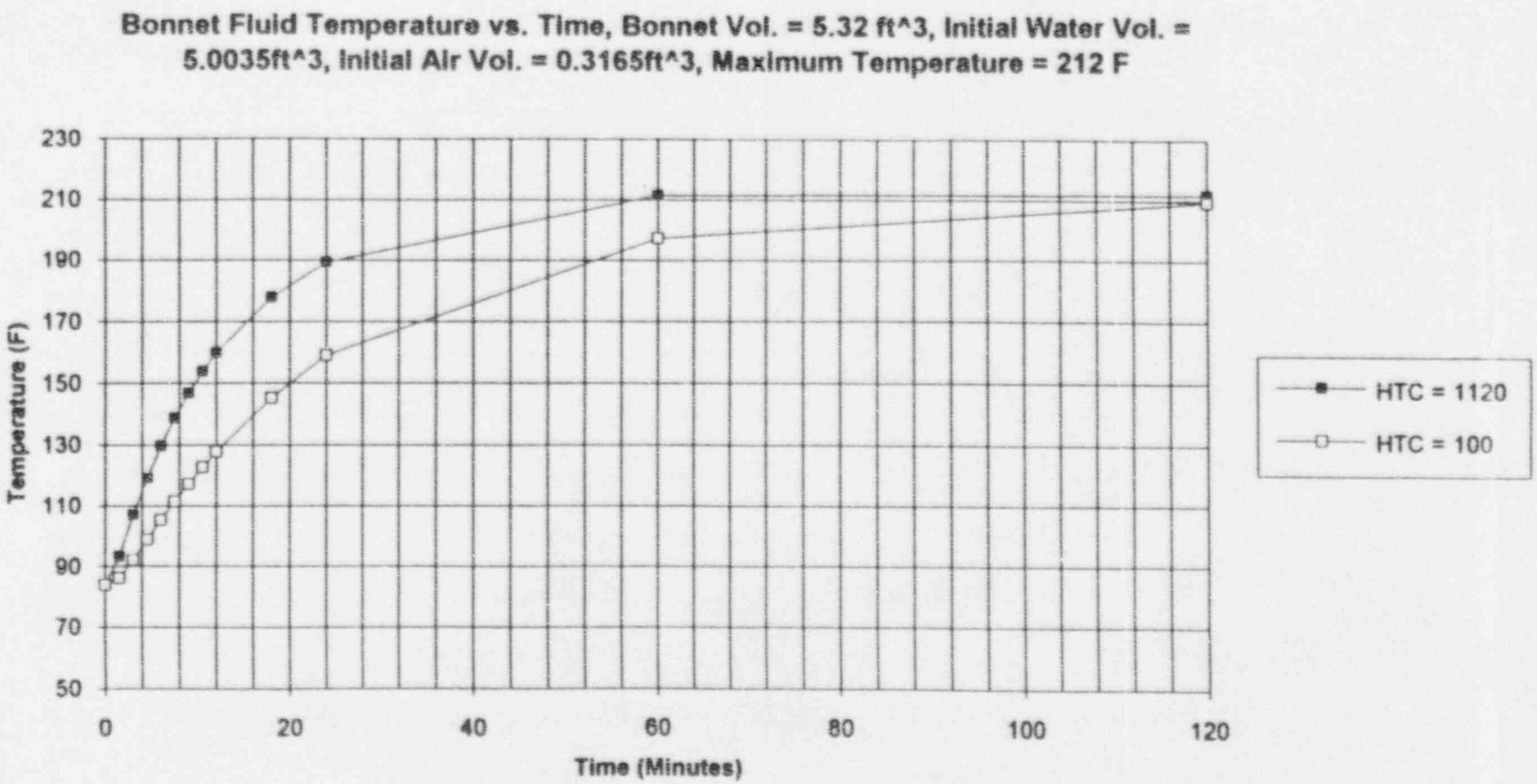
Valve Bonnet Internal Pressure, Flooded Bonnet, Dry Bonnet Surface (HTC = 100),
Temperature : 84 - 148 F



Valve Bonnet Fluid Temperature, Flooded Bonnet, Dry Bonnet Surface (HTC = 100),
Temperature : 84 - 148 F

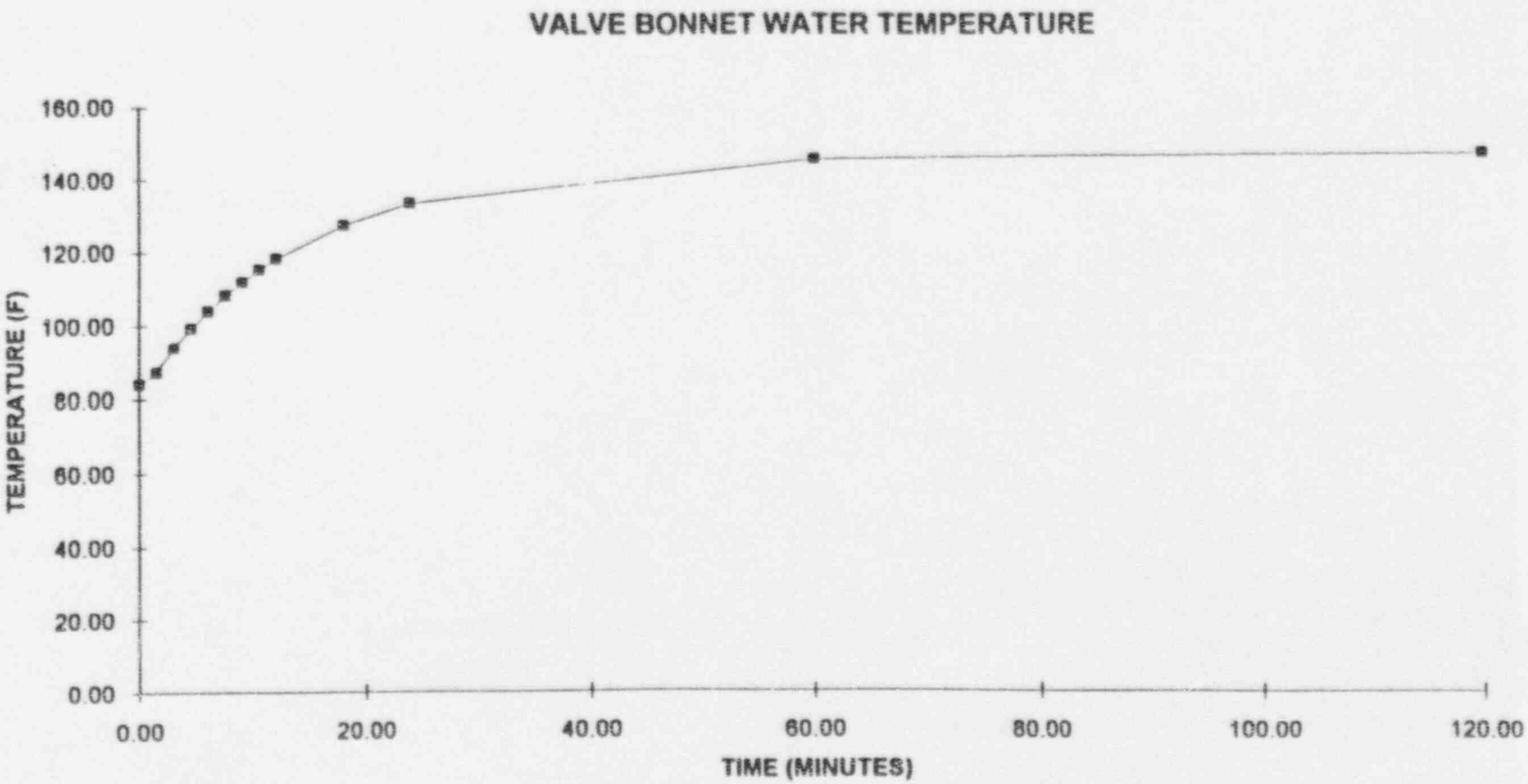


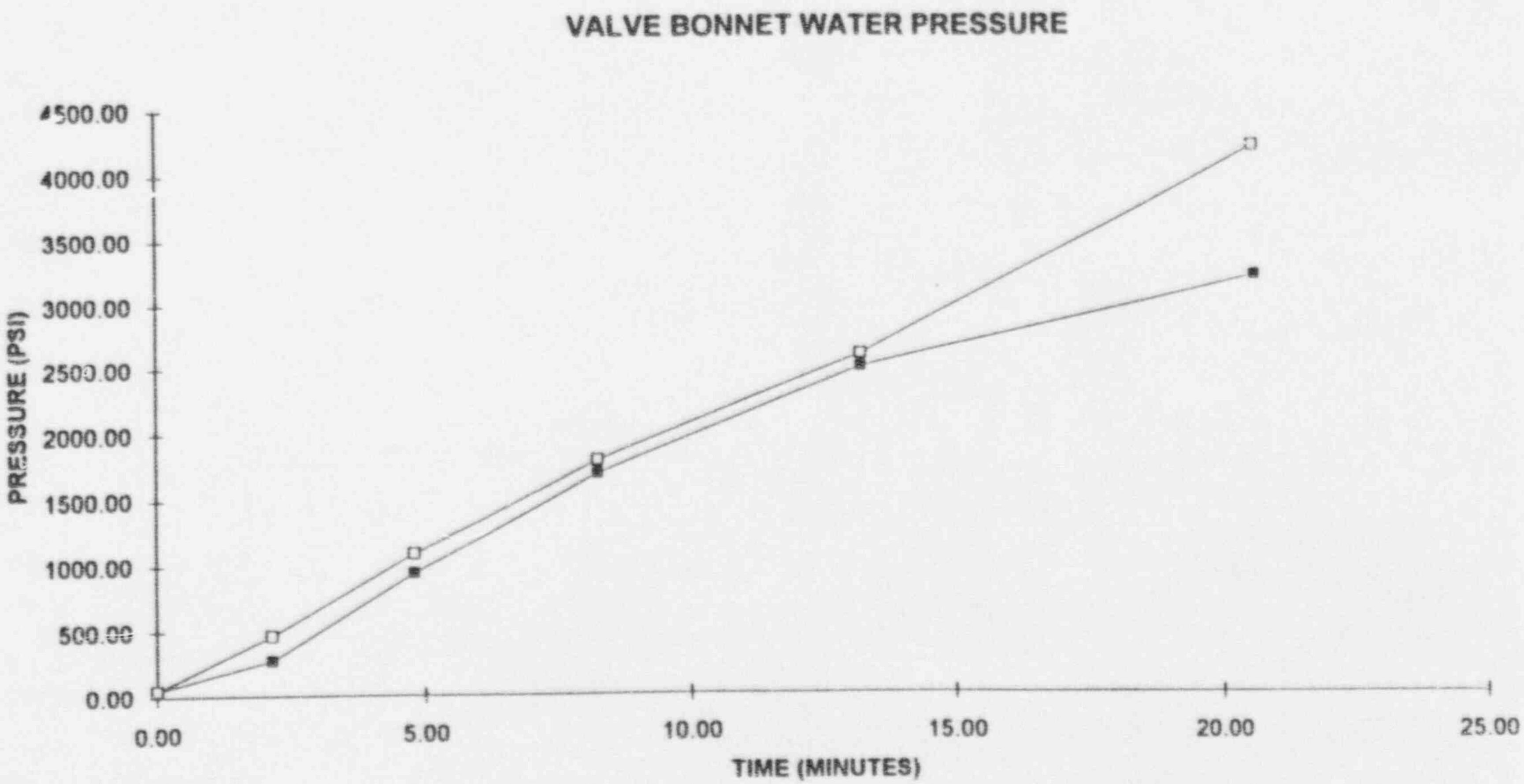

Bonnet Internal Pressure vs. Time, Bonnet Vol. = 5.32 ft^3, Initial Water Vol. = 5.0035 ft^3,
Initial Air Vol. = 0.3165 ft^3, Maximum Temperature = 212 F
Pressure (Psig)
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
Time (Minutes)
HTC = 100
HTC = 1120



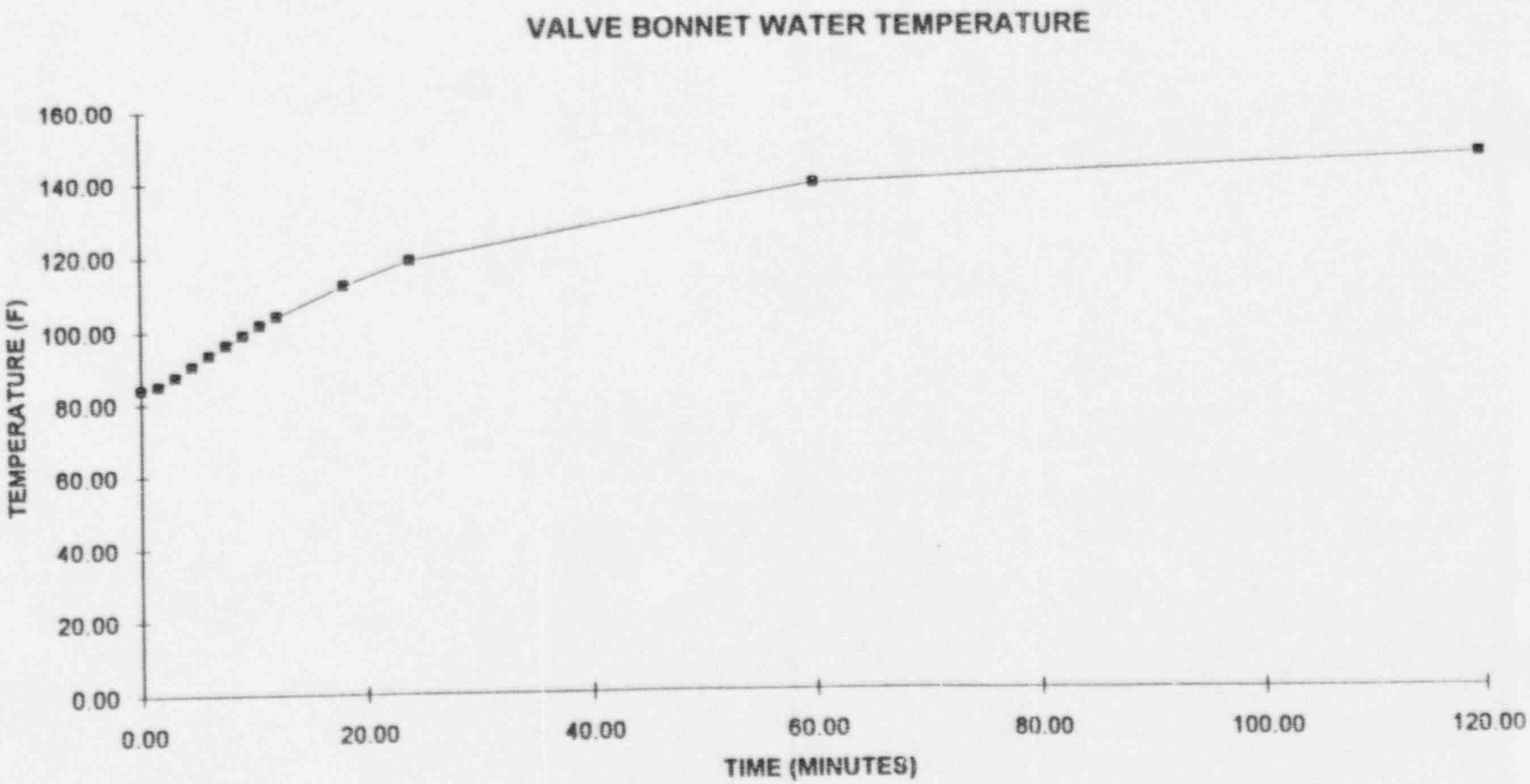
Bonnet Fluid Temperature vs. Time, Bonnet Vol. = 5.32 ft^3, Initial Water Vol. = 5.0035ft^3, Initial Air Vol. = 0.3165ft^3, Maximum Temperature = 212 F
230
210
190
170
150
130
110
90
70
50
Temperature (F)
0
20
40
60
80
100
120
Time (Minutes)
HTC = 1120
HTC = 100

TIME	PRESSURE	PRESSURE	TIME	TEMPERATURE
0.00	50.00	50.00	0.00	84.00
2.17	275.00	465.00	1.50	87.01
4.80	935.00	1085.00	3.00	93.74
8.28	1685.00	1785.00	4.50	99.09
13.21	2485.00	2585.00	6.00	103.84
20.69	3200.00	4200.00	7.50	108.06
			9.00	111.81
			10.50	115.16
			12.00	118.15
			18.00	127.31
			24.00	133.32
			60.00	145.22
			120.00	147.56

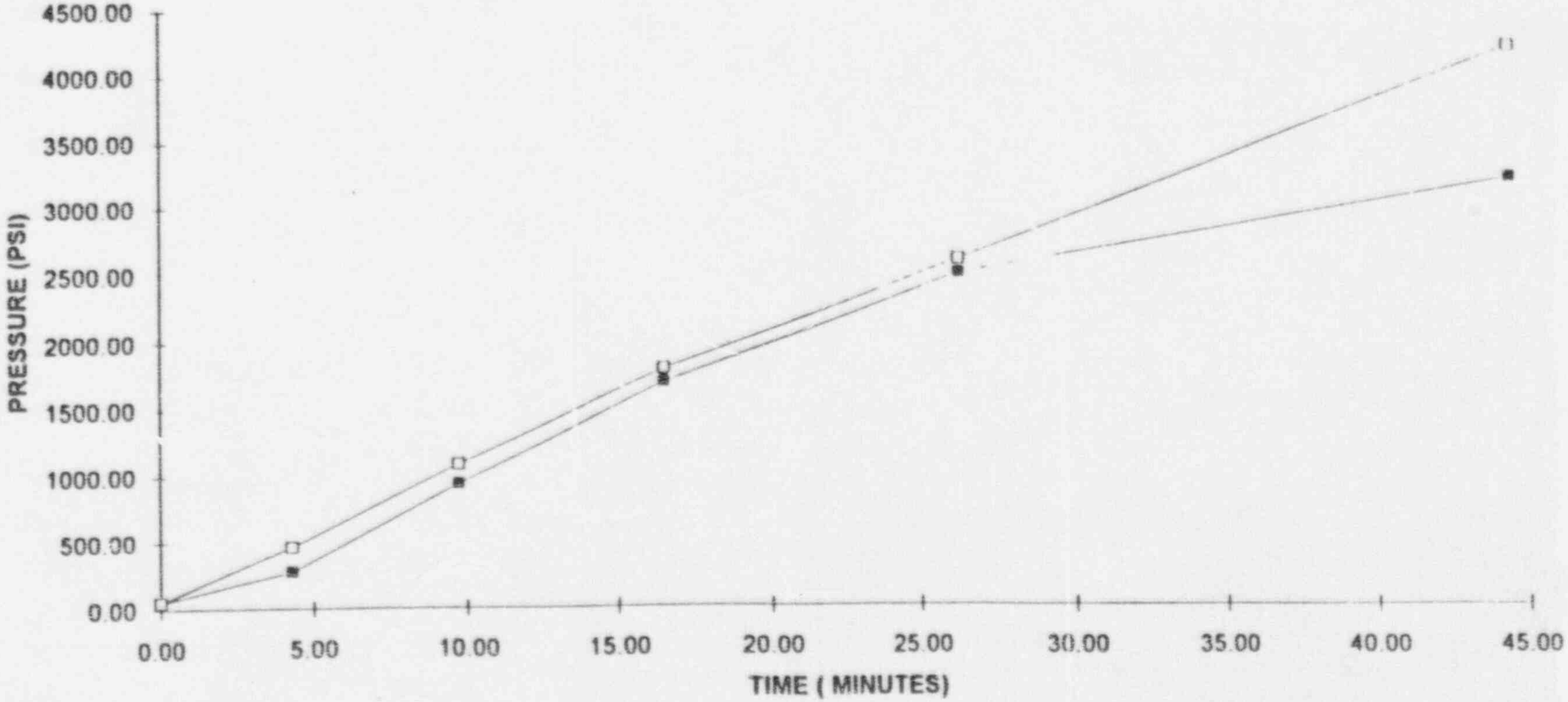

VALVE BONNET WATER TEMPERATURE
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
TEMPERATURE (F)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
TIME (MINUTES)


VALVE BONNET WATER PRESSURE
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
PRESSURE (PSI)
0.00
5.00
10.00
15.00
20.00
25.00
TIME (MINUTES)

TIME	PRESSURE	PRESSURE	TIME	TEMPERATURE
0.00	50.00	50.00	0.00	84.00
4.32	275.00	465.00	1.50	84.89
9.72	935.00	1085.00	3.00	87.40
16.50	1685.00	1785.00	4.50	90.36
26.28	2485.00	2585.00	6.00	93.31
44.40	3200.00	4200.00	7.50	96.14
			9.00	98.82
			10.50	101.36
			12.00	103.75
			18.00	112.08
			24.00	118.72
			60.00	138.65
			120.00	146.10


VALVE BONNET WATER TEMPERATURE
TEMPERATURE (F)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
TIME (MINUTES)

VALVE BONNET WATER PRESSURE



October 22, 1993

Subject: LaSalle County Station, Units 1&2
Potential Binding of 2E12-004B (RHR Valve)

Mr.M.Dowd;

There has been a report that the subject valve may have become thermally bound during certain operating conditions. The valve had to be opened manually. The station engineering group requested the Mechanical & Structural Engineering Design Group review this occurrence and provide an analysis to help determine the root cause.

Our evaluation consisted of two parts. The first part was to perform a two dimensional finite element analysis to determine the thermal growth at the disk-seat interface. This analysis was performed using a two dimensional approach provide a cost effective result. The three dimensional approach would be more accurate but because the data from the occurrence had many assumptions the more detailed approach would not have produced more reliable results. To help expedite the review we employed Primeria Engineers to perform the finite element analysis. This is part of our Minority Engineering Development Program.

The second part of the evaluation was to compare thermal growth with the machining tolerances. We reviewed the lower disk-seat interface where the drawing shows the tolerance to be ±0.005 inches. The thermal growth in this area is +0.006 inches (SRSS). If the valve is -0.000 inches or larger, then there would be a theoretical interference. Typically this would lead to an increased force to open. This comparison shows that under the reported conditions thermal binding is a possibility. To determine the exact cause of the occurrence a detailed analysis and testing under controlled conditions would have to be performed. The valve would also have to be disassembled and detailed as machined measurements would have to be made.

Since the motor operator is planned to be upgraded, a detailed test and analysis program would not be cost effective. Also since the operating practices have been changed to preclude a reoccurrence, there is no additional work planned for the Mechanical & Structural Engineering Design Group.

If you have any questions please contact me on ext. 7685.

Paul W. Donavin

Paul Donavin
Mechanical & Structural
Engineering

RHR GATE VALVE
2E12-F004B

THERMAL BINDING ANALYSIS AND REPORT

Commonwealth Edsion Company
LaSalle County Station

Prepared By: Sonja C. Schillmoeller, 10/13/93, Sonja Schillmoeller

Reviewed By: Pedro Cevallos-Candau, 10/13/93, Pedro Cevallos-Candau

Non-Safety Related

Table of Contents

3.0 **Introduction**

3.1 Purpose

The purpose of this analysis is to determine whether or not RHR Motor Operated Valve (MOV) 2E12-004B could have experienced thermal binding at an 80 °F temperature differential (160 °F versus 80 °F).

3.2 Background

LaSalle County Station identified a valve that they suspect may have experienced thermal binding and therefore was prevented from opening on certain occassions. The valve was presented to the Mechanical and Structural Engineering Group (MSE) for validation of thermal binding via analysis. Primera was involved in the on-going root problem investigation and subsequently asked to perform a simplified two-dimensional finite element analysis utilizing Algor software.

3.3 Project Deliverables

This report is the only project deliverable. Since the analysis was based on limited design input, a simplified two-dimensional finite element model and the assumptions of Section 4.0, the analysis and this report are not safety related. Therefore, they shall not be used as a design document or as any type of design input.

4.0 **Assumptions**

4.1 The coefficient of linear thermal expansion (α) and the Modulus of Elasticity (E) were held constant.

4.2 After being moved to a closed position, the end of the disc traveled only as far as the ends of the valve body seat rings. In other words, overthrusting of the valve had not occured (which would have caused the disc to travel past the seat rings and further into the valve body).

4.3 Heat Transfer

A. The temperature on the upstream side of the valve disc was 160 °F and on the downstream of the valve disc was 80 °F (see Design Input 5.1).

B. Heat transfer inside of the piping system was solely a function of conduction..

C. Conductive heat transfer was limited to one degree of freedom and occurred along the z-axis.

D. Conductive heat transfer along the z-axis was linear. Therefore, the temperature at the center of the disc was one-half of 160 °F and 80 °F or 120 °F. Temperature profiles are depicted in Figures 2 and 3.

4.4 Finite Element Analysis

A. Rounded edges of valve components were approximated by corners (straight lines).

B. A steady-state (or static) as opposed to a transient analysis was performed.

C. Although water was present inside of the disc, the analysis was modeled using air in this space.

D. Component dimensions were taken from Reference 8.2. In addition, some dimensions were scaled.

4.5 All valve components were modeled as steel (mild).

5.0 Design Input

5.1 The temperature differential was 80 ^{o}F. The temperature upstream of the valve seat was 160 ^{o}F and downstream of the valve seat was 80 ^{o}F (Reference 8.1).

5.2 Material Properties

A. Density (ρ) - 0.2836 lb/in^3 Reference 8.3, Page 6-8

B. Modulus of Elasticity (E) - 30,000 ksi

C. Coefficient of Linear Thermal Expansion (α) - 6.5 x 10^{-6} in/^{o}F Reference 8.3, Page 6-6

D. Poisson's Ratio (ν) - 0.3

5.3 A cartesian coordinate system was used and is depicted in Figure 1. The z-axis ran along the centerline of the pipe and the y-axis runs along the centerline of the disc.

6.0 Analysis

The valve body seat rings and disc were modeled with a two-dimensional finite element model. To simplify the analysis, half of the disc (from the midpoint of the disc to the valve seat - traveling along the x-axis) was modeled using an axisymmetric model (axis of revolution being the z-axis). Using an axisymmetric model is generally a "stiffer" model. In other words, displacements which are calculated using an axisymmetric model are generally smaller than those that would have been calculated using a more realistic three-dimensional model.

Temperatures at each nodal point, based on Assumption 4.3, were input into the finite element model. The valve body and seat ring (to the edge of the upstream side of the disc) were modeled at a temperature of 160 ^{o}F. Likewise, the valve and body seat ring (to the edge of the downstream side of the disc) were modeled at a temperature of 80 ^{o}F. Temperatures are more clearly defined in Figures 2 and 3.

The analysis was performed with one fixed point which was located at the origin of the coordinate system. The analysis was then performed to determine displacements and stresses of the valve body, seat rings and disc subjected to the aforementioned temperature distribution.

7.0 Conclusions

The two-dimensional finite element analysis indicated that the MOV, after being subjected to an 80 °F temperature differential across its disc (while the MOV was in a closed position), could have experienced thermal binding. This conclusion was based on the assumptions, design input and analysis delineated in this report as well as the following discussion.

Referring to Figure 4, white lines depict the valve before elevated temperatures are applied and red lines depict the valve after elevated tempeartures are applied. From this figure, it is evident that a majority of the nodes experienced displacements along both the y-axis and z-axis. The greatest displacement (using the square of the root of the sums of the squares - SRSS - of the displacements in the y and z direction) was approximately 0.006 inches. Based on minimal contact between the valve body seat and the disc, it could be concluded that thermal binding prevented the valve from opening. In addition, the figure indicates that a bending moment occurred about the x-axis thereby forcing the downstream side of the disc against its seat. It would seem that this force increased the friction between the downstream side of the disc and seat while attempting to open the valve. Referring to Figure 5, it can be seen that the highest stresses are observed at points where the valve seats and disc come into contact. This further enhances the conclusion that the valve could have experienced thermal binding at an 80 °F temperature differential.

The analysis, in Primera's opinion, provides no conclusive evidence that thermal binding occurred. To reach this conclusion, a formal investigation and subsequent three-dimensional analysis should be performed. The investigation should answer the following:

- Was the valve overthrusted ? How far into the valve seat did the disc travel ? When the valve closes, is it limit switch or torque switch controlled ?

- What was the actual temperature on the upstream side of the disc ? Could the temperature of the pipe contents have been higher than 160 °F (thereby implying that the temperature on the upstream side of the disc was higher than 160 °F) ?

- What are the actual dimensions of all valve components ?

Furthermore, the analysis should do for the following:

- Determine the temperature distribution, using a three-dimensional finite element analysis, of the entire disc, the valve body seats and the seat rings.

- Model the entire disc and valve body.

- Account for the different types of component materials.

- Determine coefficients of linear thermal expansion and Moduli of Elasticity at actual temperatures and use in the analysis.

8.0 References

8.1 LaSalle County Station Problem Identification Form (PIF) dated March 22, 1993, Tracking Number 374-200-93-00444PIF, Primera QA Files

8.2 Anchor Valve Co. Drawing No. 1570-5A, Revision A. 24"-300# Gate Valve R.S. Cast Steel, Stainless Steel Trim B.W. Ends Limitorque Operator, Primera QA Files

8.3 AISC Manual of Steel Construction, Ninth Edition

Figure 1

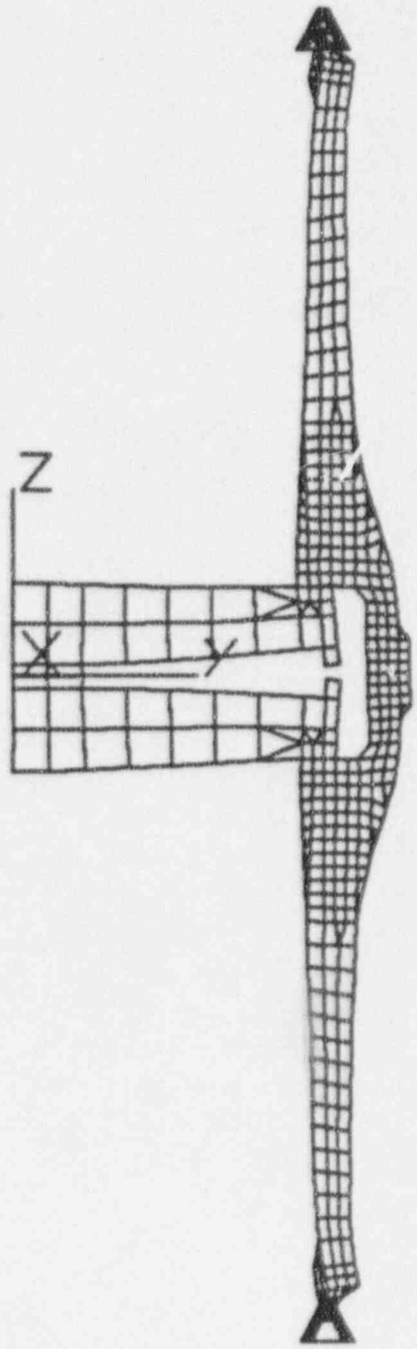


Figure 2

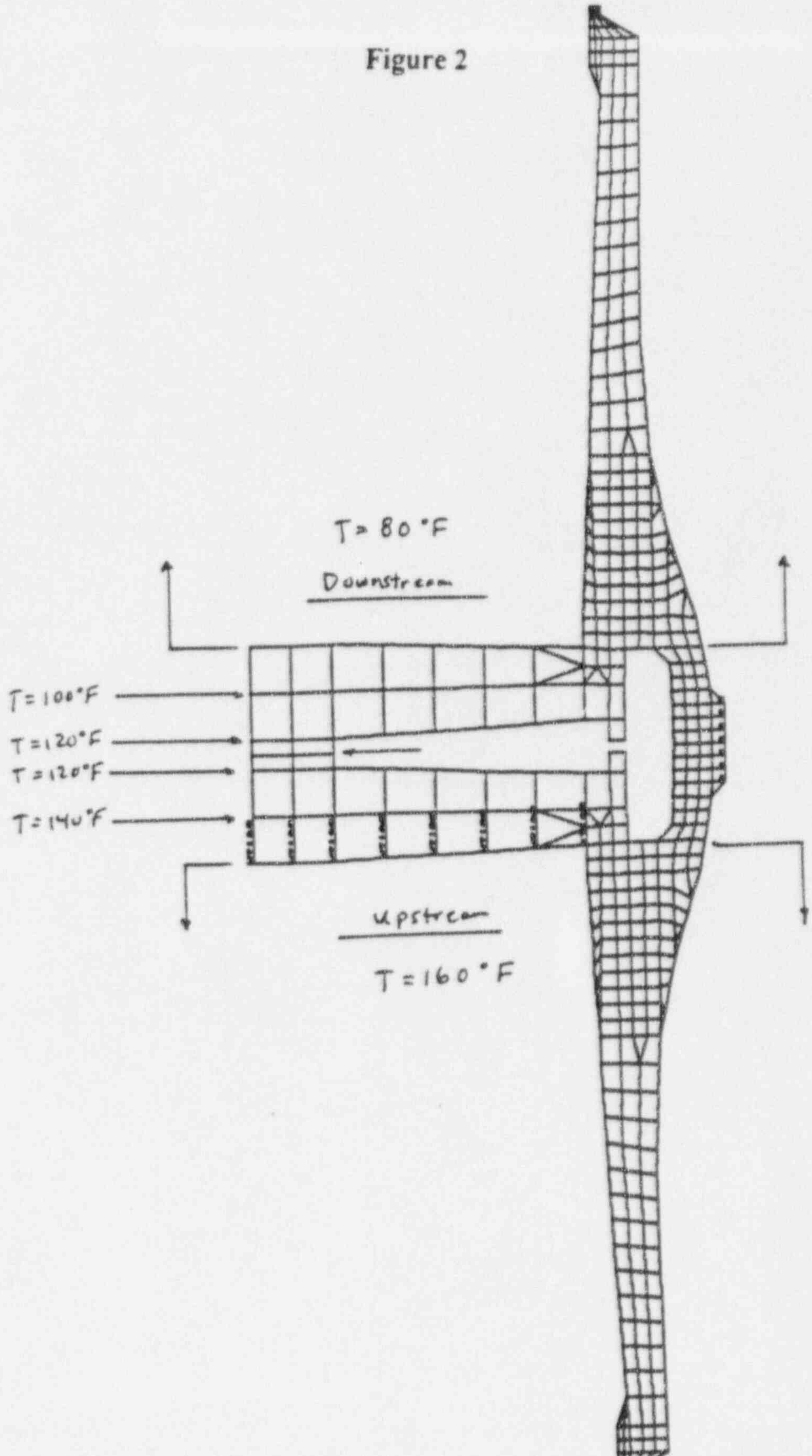
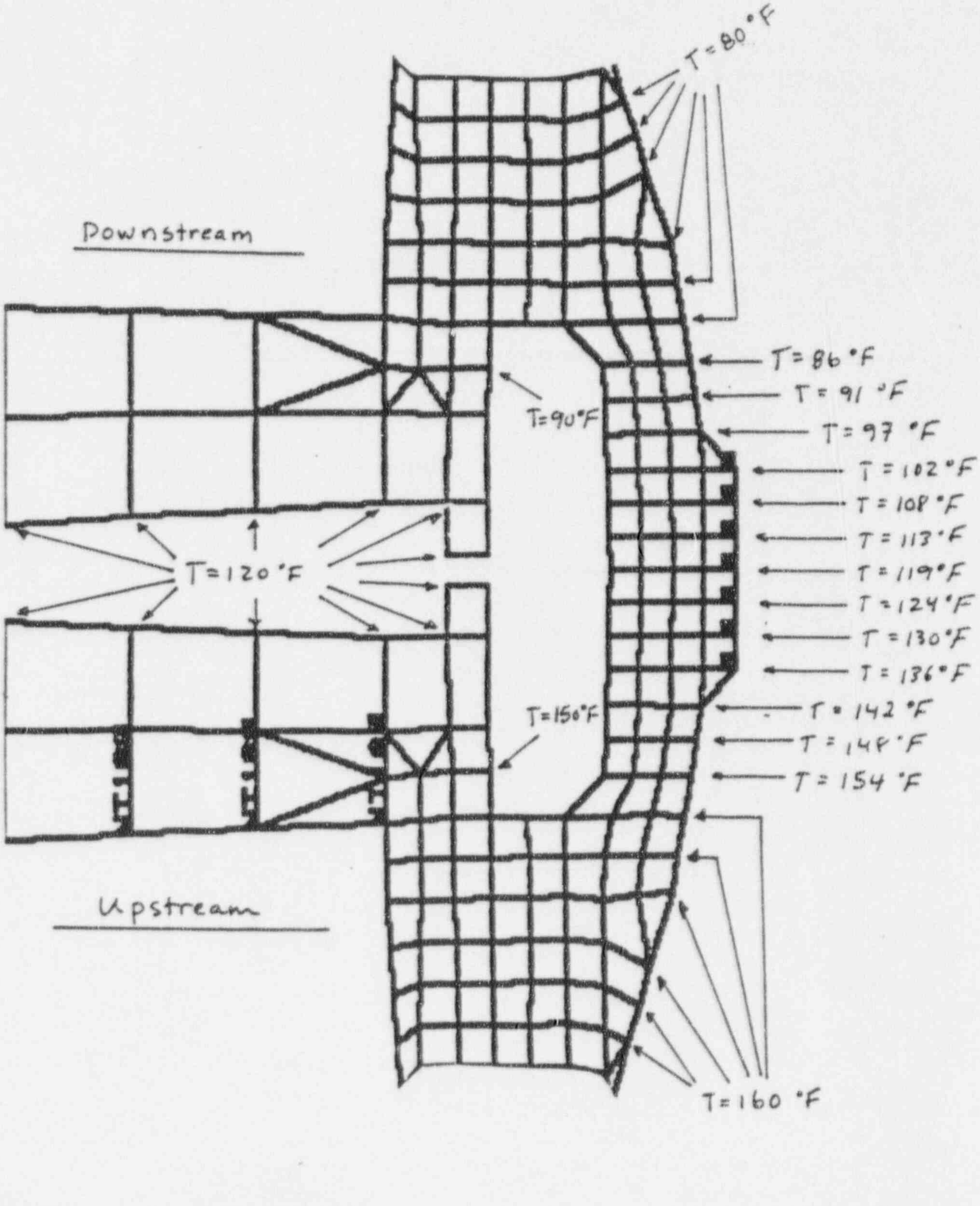


Figure 3


T=80°F
Downstream
T=86°F
T=91°F
T=90°F
T=97°F
T=102°F
T=108°F
T=113°F
T=120°F
T=119°F
T=124°F
T=130°F
T=136°F
T=150°F
T=142°F
T=148°F
T=154°F
Upstream
T=160°F

Examples of possible flawed qualitative analysis

THERMAL BINDING VALVE RESOLUTION

1(2)B21-F016

During an accident or transient the Inboard MSL Drain Inboard Isolation Valve is required to close for its safety function. The EOP's may require it to be reopened to re-establish the Main Condenser as a heat sink. The requirement to re-establish the Main Condenser as a heat sink is a relatively short term action and can be expected to take place within one hour of valve closure. Based on this short time frame the Inboard MSL Drain Inboard Isolation Valve will not have cooled significantly and therefore will not Thermally Bind. If the valve is closed hot during normal unit shutdown and allowed to cool to ambient it could be subject to Thermal Binding however, it would be accessible to plant personnel for compensatory actions. If the valve receives a spurious isolation during normal operation it would be re-opened prior to any significant cooling taking place. This valve has not experienced any Thermal Binding events in 10 years of Dual Unit Operations.

No further action is required on this valve however, if the valve is modified for other reasons in the future replacing it with a Double-Disc gate valve with the Reactor side Disc drilled for bonnet pressure relief should be considered.

1(2)B21-F019

During an accident or transient the Inboard MSL Drain Outboard Isolation Valve is required to close for its safety function. The EOP's may require it to be reopened to re-establish the Main Condenser as a heat sink. The requirement to re-establish the Main Condenser as a heat sink is a relatively short term action and can be expected to take place within one hour of valve closure. Based on this short time frame the Inboard MSL Drain Outboard Isolation Valve will not have cooled significantly and therefore will not Thermally Bind. If the valve is closed hot during normal unit shutdown and allowed to cool to ambient it could be subject to Thermal Binding however, it would be accessible to plant personnel for compensatory actions. If the valve receives a spurious isolation during normal operation it would be re-opened prior to any significant cooling taking place. This valve has not experienced any Thermal Binding events in 10 years of Dual Unit Operations.

No further action is required on this valve however, if the valve is modified for other reasons in the future replacing it with a Double-Disc gate valve with the Reactor side Disc drilled for bonnet pressure relief should be considered.

1(2)E12-F006A/B

The SDC Suction Valves are closed above room temperature on every SDC loop S/D or SDC swap. There has been no Thermal Binding events in over ten years of dual unit operation. The EOP's require SDC be placed into operation during an accident or transient however, if both SDC Suction valves happen to be bound at this point plant personnel can take remedial action locally to open the valves. SDC is not placed on line until the Reactor is less than 135 PSIG and in the recovery phase of the accident or transient. During normal S/U of SDC remedial action can be taken by plant personnel if the SDC suction valves are Thermally Bound.

No further action is required on these valves however, if these valves are modified for other reasons in the future replacing them with a Double-Disc gate valve with the Reactor side Disc drilled for bonnet pressure relief should be considered.

1(2)E12-F008

The SDC Outboard Isolation Valve is closed above room temperature on every SDC loop S/D. There has been no Thermal Binding events in over ten years of dual unit operation. The EOP's require SDC be placed into operation during a accident or transient however, if the SDC Outboard Isolation valve happens to be bound at this point plant personnel can take remedial action locally to open the valves. SDC is not placed on line until the Reactor is less than 135 PSIG and in the recovery phase of the accident or transient. During normal S/U of SDC remedial action can be taken by plant personnel if the SDC Outboard Isolation valve is Thermally Bound.

No further action is required on this valve however, if this valve is modified for other reasons in the future replacing it with a Double-Disc gate valve with the Reactor side Disc drilled for bonnet pressure relief should be considered.

1(2)E12-F009

The SDC inboard isolation valve operator was modified to a larger motor and operator due to previous thermal binding events.The appropriate procedures were also changed to address this problem. There have been no further binding events since replacing the motor operator.

No further action is required on this valve however, if this valve is modified for other reasons in the future replacing it with a Double-Disc gate valve with the Reactor side Disc drilled for bonnet pressure relief should be considered.

Examples of some qualitative analysis that can be flawed.

HYDRAULIC LOCKING VALVE RESOLUTION

1(2)B21-F016

During an accident or transient the Inboard MSL Drain Inboard Isolation Valve is required to close for its safety function. The EOP's may require it to be re-opened to re-establish the Main Condenser as a heat sink. The requirement to re-establish the Main Condenser as a heat sink is a relatively short term action and can be expected to take place within one hour of valve closure. The Inboard MSL Drain Inboard Isolation Valve will have to cool and condense steam and then re-heat significantly to cause the valve to Hydraulically Lock. Due to the short time frame in which valve re-opening can be expected to occur during an accident this failure mechanism is not probable. If the valve is closed hot during normal unit shutdown and allowed to cool to ambient and re-heat on startup it could be subject to Hydraulic Locking however, it would be accessible to plant personnel for compensatory actions. If the valve receives a spurious isolation during normal operation it would be re-opened prior to any significant cooling taking place.

No further action is required on this valve however, if the valve is modified for other reasons in the future replacing it with a Double-Disc gate valve with the Reactor side Disc drilled for bonnet pressure relief should be considered.

Logic is correct

1(2)B21-F019

During an accident or transient the Inboard MSL Drain Outboard Isolation Valve is required to close for its safety function. The EOP's may require it to be re-opened to re-establish the Main Condenser as a heat sink. The requirement to re-establish the Main Condenser as a heat sink is a relatively short term action and can be expected to take place within one hour of valve closure. The Inboard MSL Drain Outboard Isolation Valve will have to cool and condense steam and then re-heat significantly to cause the valve to Hydraulically Lock. Due to the short time frame in which valve re-opening can be expected to occur during an accident this failure mechanism is not probable. If the valve is closed hot during normal unit shutdown and allowed to cool to ambient and re-heat on startup it could be subject to Hydraulic Locking however, it would be accessible to plant personnel for compensatory actions. If the valve receives a spurious isolation during normal operation it would be re-opened prior to any significant cooling taking place.

Logic is correct

No further action is required on this valve however, if the valve is modified for other reasons in the future replacing it with a Double-Disc gate valve with the Reactor side Disc drilled for bonnet pressure relief should be considered.

1(2)E12-F009

The SDC inboard isolation valve operator was modified to a larger motor and operator due to previous thermal binding events. The SDC Inboard Isolation Valve is closed above room temperature on every SDC loop S/D. The valve would cool at this point and any water in the bonnet would contract. SDC is normally S/D at a nominal moderator temperature of 150 degf. The SDC suction valves are in EQ zone H2A with a postulated temperature rise of 135 to 330 degf. During normal unit Shutdown this valve has not exhibited any hydraulic locking. During an accident if the valve became hydraulically locked the valve would be opened after the plant had cooled below 135 lbs and the hydraulic lock would have cleared or continued cooldown could be achieved via the SRV's. Since placing Shutdown Cooling on line is a manual operation response time is not a concern and therefore, if the bonnet gets pressurized to Reactor pressure it is unlikely that the valve would be opened until the bonnet pressure had decayed to zero.

No further action is required on this valve, however if this valve is modified for other reasons in the future replacing it with a Double-Disc gate valve with the Reactor side Disc drilled for bonnet pressure relief should be considered.

Logic is Correct

1(2)E12-F016A/B

The Drywell Spray Valves are closed at normal room temperature. They are required to open during an accident to reduce pressure in the Drywell. The Drywell Spray Valves are in EQ zone H4A with a temperature range of 94 degf to 145 degf based on a High Energy Line Break outside the Drywell and in the Reactor Building. The need to spray the Drywell assumes that there is a line break in the Drywell and the Reactor Building would not heat up to 145 degf. If there is a dual failure and the Reactor Building heats up to 145 degf along with a Drywell pressurization event then the need to open the Drywell spray valves would be required in a relatively short time frame and could be expected to take place in less than one hour. It is unlikely that the Drywell Spray valve would heat up sufficiently in that time frame to become hydraulically locked.

No further action is required on this valve, however if this valve is modified for other reasons in the future a pressure relief modification to the bonnet or valve disc should be considered.

Flawed logic as it only takes 10 min. to heat up sufficiently to lock up

Enclosure 8

Slides

Licensee Experience
American Electric Power/D.C. Cook

Dick Kadlec, D.C. Cook

RECOGNITION OF AND RESPONSE TO THE POTENTIAL

FOR PRESSURE LOCKING AND THERMAL BINDING

AT THE DONALD C. COOK NUCLEAR PLANT

- Definition of Phenomena
- Recognition of Potential Problems
- Chronology of Events
- Dispositioning of Issues

HISTORY OF
PRESSURE LOCKING/THERMAL BINDING INVESTIGATIONS
AT THE DONALD C. COOK NUCLEAR PLANT

1974:

- EEI Nuclear Task Force - Pressure Locking Recognized
- Design Change to Add Equalizing Lines to 32 Double Disc Gate Valves

1976:

- Design Change to Remove Equalizing Lines from Four Valves

1984:

- SOER 84-07 - Pressure Locking and Thermal Binding Addressed

1985:

- Reevaluation/Verification of Designs to Consider Pressure Locking
- Evaluation of Existing Design to Consider Thermal Binding
- Design Change to Add Equalizing Lines to Four Flexible Wedge Gate Valves

COOK NUCLEAR PLANT
MOTOR OPERATED GATE VALVES EQUIPPED WITH EQUALIZING LINES

COMPONENT NO.	FUNCTIONAL NAME/DESCRIPTION
1-IMO-128 2-IMO-128	Reactor Coolant Loop #2 Hot Leg to RHR Pump Suction Shutoff Valve
1-ICM-129 2-ICM-129	Reactor Coolant Loop #2 Hot Leg to RHR Pump Suction Containment Isolation Valve
1-IMO-390 2-IMO-390	Refueling Water Storage Tank to RHR Pump Suction Shutoff Valve
1-IMO-310 2-IMO-310	East RHR Pump Suction Shutoff Valve
1-IMO-320 2-IMO-320	West RHR Pump Suction Shutoff Valve
1-IMO-340 2-IMO-340	East RHR Heat Exchanger Outlet to Charging Pump Suction Shutoff Valve
1-IMO-350 2-IMO-350	West RHR Heat Exchanger Outlet to Charging Pump Suction Shutoff Valve
1-IMO-315 2-IMO-315	East RHR and North SI to Reactor Coolant Loops #1 and #4 Hot Leg Shutoff Valve
1-IMO-325 2-IMO-325	West RHR and South SI to Reactor Coolant Loops #2 and #3 Hot Leg Shutoff Valve
1-IMO-314 2-IMO-314	East RHR Pump Discharge Cross-tie Shutoff Valve
1-IMO-324 2-IMO-324	West RHR Pump Discharge Cross-tie Shutoff Valve
1-IMO-255 2-IMO-255	Boron Injection Tank Train "A" Inlet Shutoff Valve
1-IMO-256 2-IMO-256	Boron Injection Tank Train "B" Inlet Shutoff Valve
1-ICM-250 2-ICM-250	Boron Injection Tank Train "A" Outlet Containment Isolation Valve
1-ICM-251 2-ICM-251	Boron Injection Tank Train "B" Outlet Containment Isolation Valve
1-ICM-260	North SI Pump Discharge Containment Isolation Valve **NOTE: Valve 2-ICM-260 design obviates the need for an equalizing line.**
1-ICM-265	South SI Pump Discharge Containment Isolation Valve **NOTE: Valve 2-ICM-265 design obviates the need for an equalizing line.**

3

SUMMARY

- Original Design Considered Thermal Binding
- 1974 Design Change Addressed Pressure Locking
- 1985 Study in Response to INPO SOER 84-07 Verified Previous Activities

4

D. C. Cook

RECOGNITION OF AND RESPONSE TO THE POTENTIAL FOR PRESSURE LOCKING AND THERMAL BINDING OF GATE VALVES AT THE DONALD C. COOK NUCLEAR PLANT

BY: RICHARD A. KADLEC, P.E.
PRINCIPAL ENGINEER
AMERICAN ELECTRIC POWER SERVICE CORPORATION

Pressure locking and thermal binding of gate valves have been the subjects of several NRC and INPO documents. Pressure locking occurs when the valve bonnet is pressurized from high process fluid pressure and the line pressure subsequently reduces or when a bonnet is pressurized cold and subsequent heat-up increases pressure of fluid trapped in the bonnet above line pressure. In these cases, disc forces on the valve seats become sufficiently high that the valve cannot be opened. Thermal binding results from differential thermal contraction of the parts of a valve which has been closed in the hot condition and then cools, causing the seats to bind the disc so tightly that reopening is impossible until the valve is reheated.

During the original design of the Donald C. Cook Nuclear Plant, the potential for thermal binding of valves in specific locations (services) in safety related systems was recognized. The double disc gate valve design, which is not susceptible to thermal binding, was selected for installation in these locations. The potential for pressure locking of these double disc gate valves was recognized in 1974, the year prior to Unit 1 achieving commercial operation. The phenomenon was a topic of discussion in the EEI Nuclear Task Force. Cook Nuclear Plant management and AEP Service Corporation became aware of it through participation in the Task Force. When the phenomenon was identified as a potential problem, system design and operating procedures were reviewed to ascertain whether any of the double disc gate valves installed at Cook Nuclear Plant were susceptible to hot closure and subsequent cool down. A total of 32 such valves were adjudged susceptible and targeted for modification. The modification consisted of adding an equalizing connection

from the bonnet (or between disc space) to the process pipe for each valve affected. Each equalizing line is equipped with a shutoff valve for maintenance and testing.

The equalizing line option was chosen over drilling a pressure relief hole through the upstream disc since drilling the disc makes the valve unidirectional in sealing. In order to seal, the drilled disc must always be toward the high pressure. By using an equalizing line equipped with shut-off valve, the double disc gate valves' capability to seal in either direction can be restored by closing the shut-off valve as required; e.g., for IST activities.

In 1976, a second design change was initiated to remove the equalizing lines from four valves in one service; viz., the recirculation sump to RHR/CTS pumps suction containment isolation valves. Donald C. Cook Nuclear Plant is an ice condenser containment design. The decision to remove the equalizing lines was based on the low temperatures and pressures associated with the ice condenser containment as related to the opening of these valves. In addition, it was determined that the equalizing lines connected downstream of these valves could provide potential leak paths from containment under certain operating conditions.

In response to INPO SOER 84-07, the issue of pressure locking was revisited, and an investigation of the potential for thermal binding was implemented in 1985. In addition to verifying the conclusions previously reached, the scope of the study addressed any normally closed gate valve installed in a nuclear safety related system. This included auxiliary feed water, essential service water and component cooling water. No candidate valves were identified in these low pressure, low temperature systems. Further efforts were centered around emergency core cooling (RHR and SI) and containment spray systems. To prevent pressure locking, it was decided to add equalizing lines to four valves in one service which had not been previously considered as a candidate for the modification. The investigation of thermal binding was in all cases dispositioned in one of two ways; that the valve being considered was a double disc valve and not susceptible, or in the case of flexible wedge gate valves, that the operating conditions; i.e., no hot closure and subsequent cool down, were not conducive to the phenomenon.

The 1985 study largely corroborated the previous decisions as to which valves required equalizing lines. In the case of the design change initiated to add equalizing lines to one service, the four valves involved were of the flexible wedge design. Previously, only double disc designs had been considered candidates for pressure locking. The 1985 study also revisited the question of whether the recirculation sump to RHR/CTS pumps suction containment isolation valves should be equipped with equalizing connections. It was concluded that the removal of equalizing connections under the design change initiated in 1976 was the correct decision.

Summarizing briefly, the recognition of the potential for thermal binding of gate valves at Cook Nuclear Plant occurred and was dispositioned as part of the plant design. In 1974, prior to commercial service, the phenomenon of pressure locking in double disc gate valves was also recognized and dispositioned. In 1985, in response to INPO SOER 84-07, the entire program was revisited, and only minor additions were made. During the course of investigation, more than 80 valves were evaluated for potential problems with either pressure locking or thermal binding. Of these, 32 were equipped with equalizing connections to prevent pressure locking. No modifications were deemed necessary to preclude thermal binding.

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1-IMO-340 2-IMO-340	East RHR Heat Exchanger Outlet to Charging Pump Suction Shutoff Valve
1-IMO-350 2-IMO-350	West RHR Heat Exchanger Outlet to Charging Pump Suction Shutoff Valve
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1-IMO-314 2-IMO-314	East RHR Pump Discharge Cross-tie Shutoff Valve
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1-IMO-255 2-IMO-255	Boron Injection Tank Train "A" Inlet Shutoff Valve
1-IMO-256 2-IMO-256	Boron Injection Tank Train "B" Inlet Shutoff Valve
1-ICM-250 2-ICM-250	Boron Injection Tank Train "A" Outlet Containment Isolation Valve
1-ICM-251 2-ICM-251	Boron Injection Tank Train "B" Outlet Containment Isolation Valve
1-ICM-260	North SI Pump Discharge Containment Isolation Valve **NOTE: Valve 2-ICM-260 design obviates the need for an equalizing line.**
1-ICM-265	South SI Pump Discharge Containment Isolation Valve **NOTE: Valve 2-ICM-265 design obviates the need for an equalizing line.**

Enclosure 9

Slides

Entergy/ANO
Bill Rowlett, ANO and Jim Warren, Gilbert Commorwealth

ARKANSAS NUCLEAR ONE

- PROGRAM SUMMARY
  - JIM WARREN OF GILBERT / COMMONWEALTH
- SUMP VALVE INTERLOCKS
  - BILL ROWLETT OF ARKANSAS NUCLEAR ONE

ENTERGY

AGENDA

- JIM WARREN
  - SCOPE
  - APPROACH
  - RESULTS
  - POTENTIAL RESOLUTIONS
  - PROGRAM EFFICIENCIES
- BILL ROWLETT
  - BACKGROUND
  - BASIS FOR DESIGN
  - BENEFITS FOR PREVENTING PRESSURE LOCKING

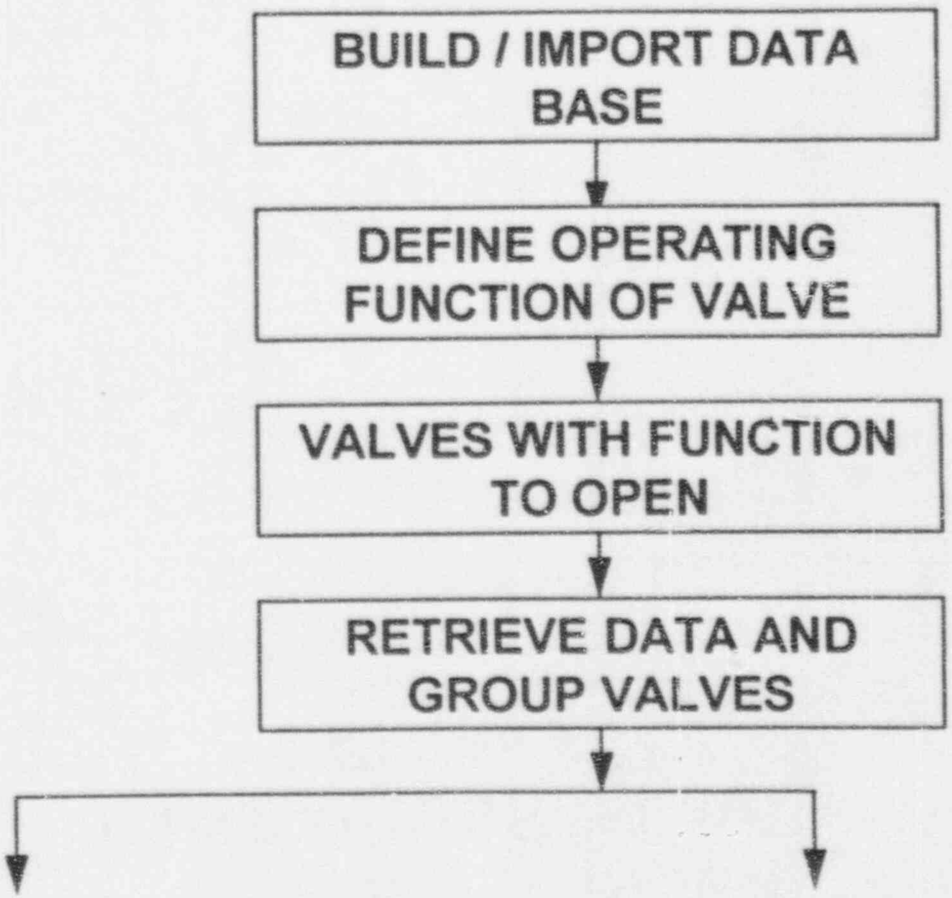
ENTERGY

SCOPE

- PROACTIVE PROGRAM ADDRESSING AEOD SPECIAL STUDY S92-07
- OBJECTIVE
  - TO ASSURE ALL LOCKING METHODS ADDRESSED
  - IMPROVE DOCUMENTATION
- SCOPE = ALL 181 IE 89 - 10 GATE VALVES

ENTERGY

WORK FLOW CHART



ENTERGY

APPENDIX 1
ARKANSAS NUCLEAR ONE GL 89 10 GATE VALVE LIST

FULLTAGNO	TYPE	SIZE	SYSTEM	FUNCTION	NORMAL POSITION	SAFETY DIRECTION	EVAL REQ'D
2CV-1489-1	GATE(SW)	2.00	SW	SW ISO	OPEN	OPEN	N
2CV-1500-1	GATE(SW)	2.00	SW	SW ISO	OPEN	OPEN	N
2CV-1502-2	GATE(SW)	2.00	SW	SW ISO	OPEN*	OPEN	N
2CV-1561-1	GATE(SW)	1.50	SW	SW ISO	OPEN	OPEN	N
2CV-1564-2	GATE(SW)	1.50	SW	SW ISO	OPEN	OPEN	N
2CV-5612-1	GATE(FW)	10.00	BS	RB SPRAY HDR ISO	CLOSED	OPEN	Y
2CV-5613-2	GATE(FW)	10.00	BS	RB SPRAY HDR ISO	CLOSED	OPEN	Y
2CV-5649-1	GATE(FW)	24.00	BS	BS RAS SUC	CLOSED	OPEN	Y
2CV-5650-2	GATE(FW)	24.00	BS	BS RAS SUC	CLOSED	OPEN	Y
CV-1616	GATE(SD)	4.00	BS	NAOH ISO	CLOSED	OPEN	Y
CV-1617	GATE(SD)	4.00	BS	NAOH ISO	CLOSED	OPEN	Y
2CV-4916-2	GATE(SW)	3.00	CVCS	2P39 DISCH	CLOSED	OPEN	Y
2CV-4920-1	GATE(SW)	3.00	CVCS	BA TO HPSI	CLOSED	OPEN	Y

ENTERGY

VALVES REVIEWED

- 181 VALVES REVIEWED
- 65 VALVES WITH FUNCTION TO OPEN
- 9 VALVES ADDED DUE TO IMPORTANCE
- 74 VALVES WITH DETAILED EVALUATIONS

ENTERGY

SOURCES RESEARCHED

- PIPING AND INSTRUMENTATION DIAGRAMS
- PIPING LAYOUT DRAWINGS
- VALVE DRAWINGS
- OPERATING MODE CALCULATIONS
- PIPE LINE SPECIFICATIONS
- DIFFERENTIAL PRESSURE CALCULATIONS
- THRUST CALCULATIONS
- ENVIRONMENTAL TEMPERATURE CALCULATIONS

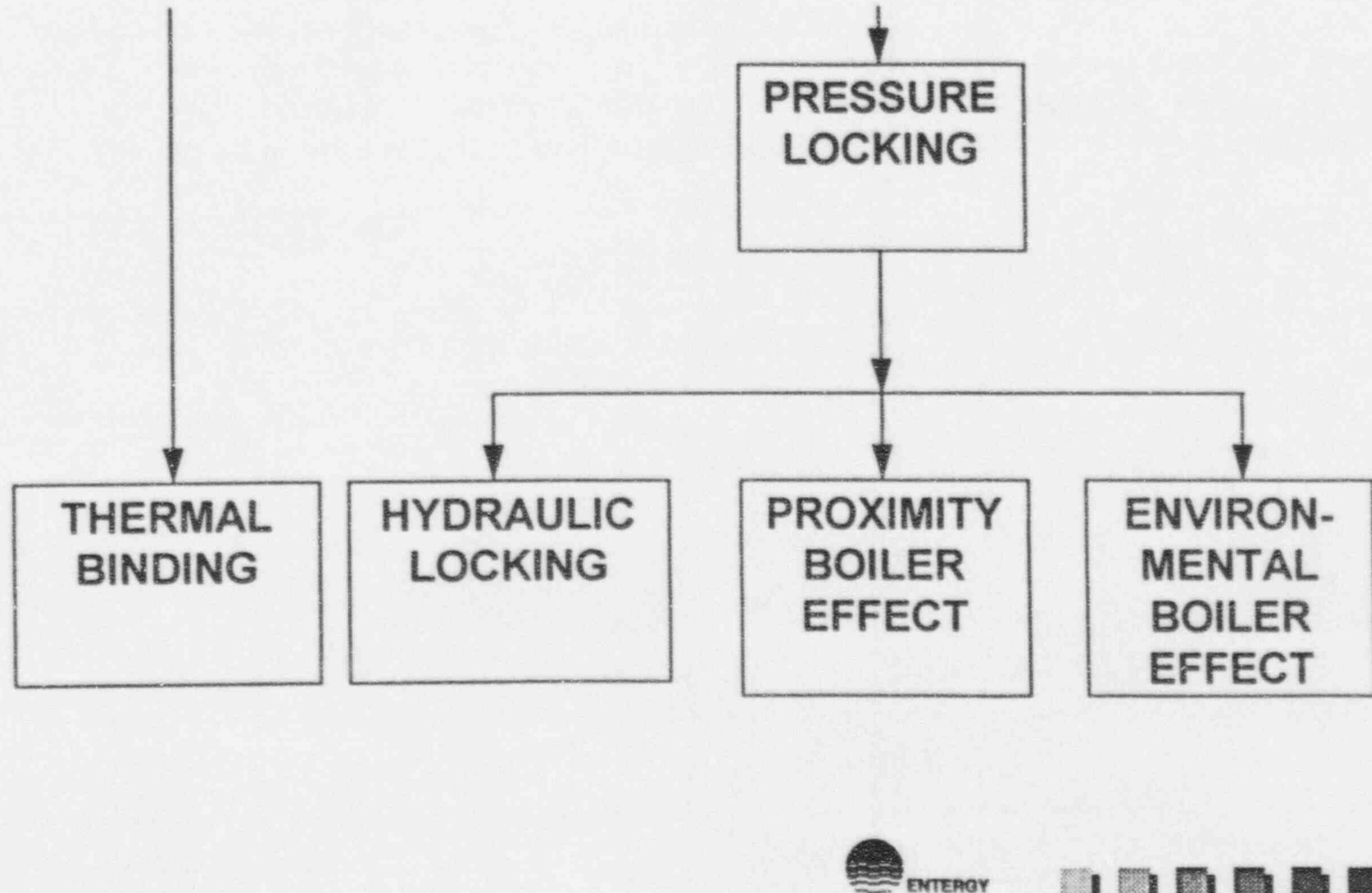
ENTERGY

SOURCES RESEARCHED CONTINUED

- OPERATING PROCEDURES
- ABNORMAL OPERATING PROCEDURES
- EMERGENCY PROCEDURES
- MAINTENANCE PROCEDURES
- SYSTEM TRAINING MANUALS
- DESIGN BASIS DOCUMENTS (UPPER LEVEL)
- SAFETY ANALYSIS REPORT
- TECHNICAL SPECIFICATIONS

ENTERGY

WORK FLOW CHART 2



1. Valve ID: 2CV-0716-1	EFW Suction from SW Header #1
2. System: SW	5. Service: For service information see calcs 91-E-0091-01 R0 (Unit 1) 91-E-0091-02 R0 (Unit 2)
3. Valve Size: 6.000	
4. Vlv/Disk Type: GATE (FW)	

6. Evaluation

Thermal Binding

This valve is not subject to thermal binding as the maximum process fluid temperature is 123° (Ref. 6).

Hydraulic Locking

This valve is not subject to hydraulic locking as the maximum trapped pressure from EFW normal operations is less that the SW pressure which is present when system switchover is required. Ref. 6 states that the operator is sized to accommodate full shutoff head of the SW pump.

Environmental Boiler Effect

This valve is not subject to environmental boiler effect as the maximum ambient environmental temperature is 140° (Ref. 3).

(cont'd next slide)

1. Valve ID: 2CV-0716-1	EFW Suction from SW Header #1
2. System: SW	5. Service: For service information see calcs 91-E-0091-01 R0 (Unit 1) 91-E-0091-02 R0 (Unit 2)
3. Valve Size: 6.000	
4. Vlv/Disk Type: GATE (FW)	

<u>Proximity Boiler Effect</u>

This valve is not subject to proximity boiler effect locking as it is in a cold system with no heat sources (Ref. 4,5,6).

7. Recommendations and Conclusions:

This valve is acceptable as-is for performance of it's safety functions.

8. References:
1. 91-E-0091-01 R0
2. 91-E-0091-02 R0
3. NES 13 R0
4. 2HBC-85-1 / 25
5. M2204, SH4, G2 / 51
6. V-2099-00 / 0

(cont'd from previous slide) ENTERGY

RESULTS 1

- 41 VALVES REQUIRING FURTHER ACTION
  - 12 DECAY HEAT / SHUTDOWN COOLING
  - 10 EMERGENCY FEEDWATER
  - 6 MAIN STEAM
  - 4 REACTOR COOLANT
  - 2 SERVICE WATER
  - 1 CHEMICAL AND VOLUME CONTROL

ENTERGY

RESULTS 2

- THERMAL BINDING = 18
- PRESSURE LOCKING = 28
  - HYDRAULIC LOCKING = 23
  - ENVIRONMENTAL BOILER = 6
  - PROXIMITY BOILER = 4

EXAMPLES OF ITEMS NEEDING FURTHER REVIEW

- HYDRAULIC LOCKING FOR DECAY HEAT "DROP LEG" AND INJECTION
- BORON DILUTION MODE FOR DECAY HEAT
- PROXIMITY BOILER EFFECT AT THE DECAY HEAT / BWST SUCTION
- THERMAL BINDING FOR STEAM BACK LEAKAGE THROUGH THE EFW INJECTION VALVES

POTENTIAL CORRECTIVE ACTIONS

- PROCEDURAL CHANGES
- CALCULATION CHANGES
- INCORPORATE INTERLOCKS
- MONITORING PIPING AND VALVE TEMPERATURES
- DETAIL HEAT TRANSFER CALCULATIONS FOR PIPING
- DEVELOPING ENVIRONMENTAL TEMPERATURE PROFILES
- PUMP STARTUP TIME VERSUS VALVE OPENING TIME

ENTERGY

POTENTIAL CORRECTIVE ACTION CONTINUED

- EVALUATION OF EMERGENCY POWER LOADING SEQUENCE
- USE SB ACTUATORS OR SPRING PACKS
- FIELD TESTS
- USE PRA TO DETERMINE IF EVENT IS CREDIBLE
- REVISE REGULATORY COMMITMENTS
- MODIFY VALVES
- CHANGE TO DIFFERENT TYPE VALVE

ENTERGY

EFFICIENT IMPLEMENTATION

- WORK SMART - 5 HOURS PER VALVE
- ELECTRONIC COPIES OF PROCEDURES AVAILABLE
- VALVE FUNCTIONS WELL DEFINED
- OPERATIONS INVOLVEMENT IN PROGRAM
- DETAILED VALVE REVIEWS FOR EACH LOCKING MECHANISM
- CLEAR DOCUMENTATION
- NRC SUPPORT WHEN CORRECTIVE ACTION RECOMMENDED

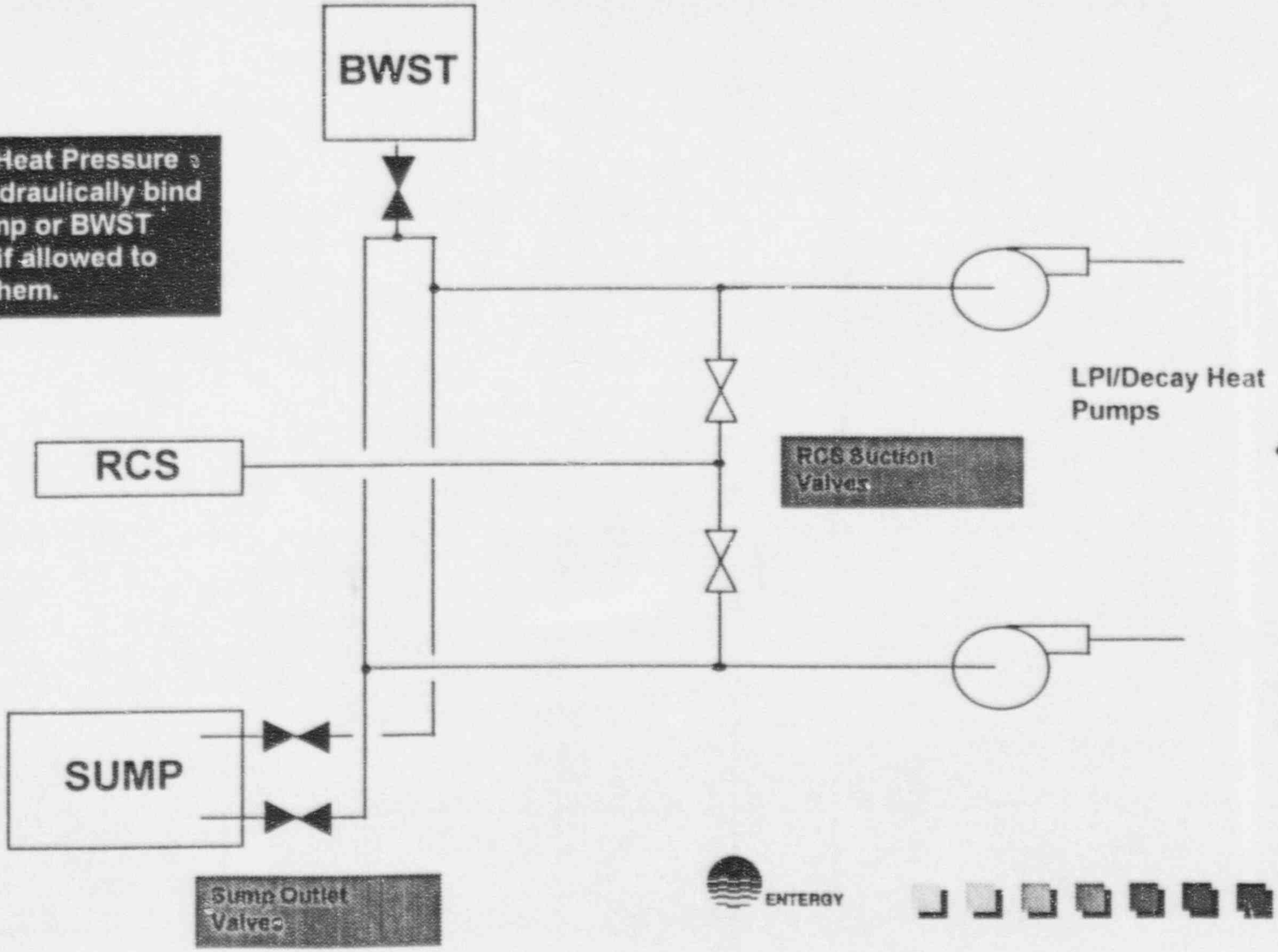
ENTERGY

MITIGATING PRESSURE LOCKING EFFECTS ON PWR SUMP RECIRCULATION VALVES WITH VALVE SEQUENCING

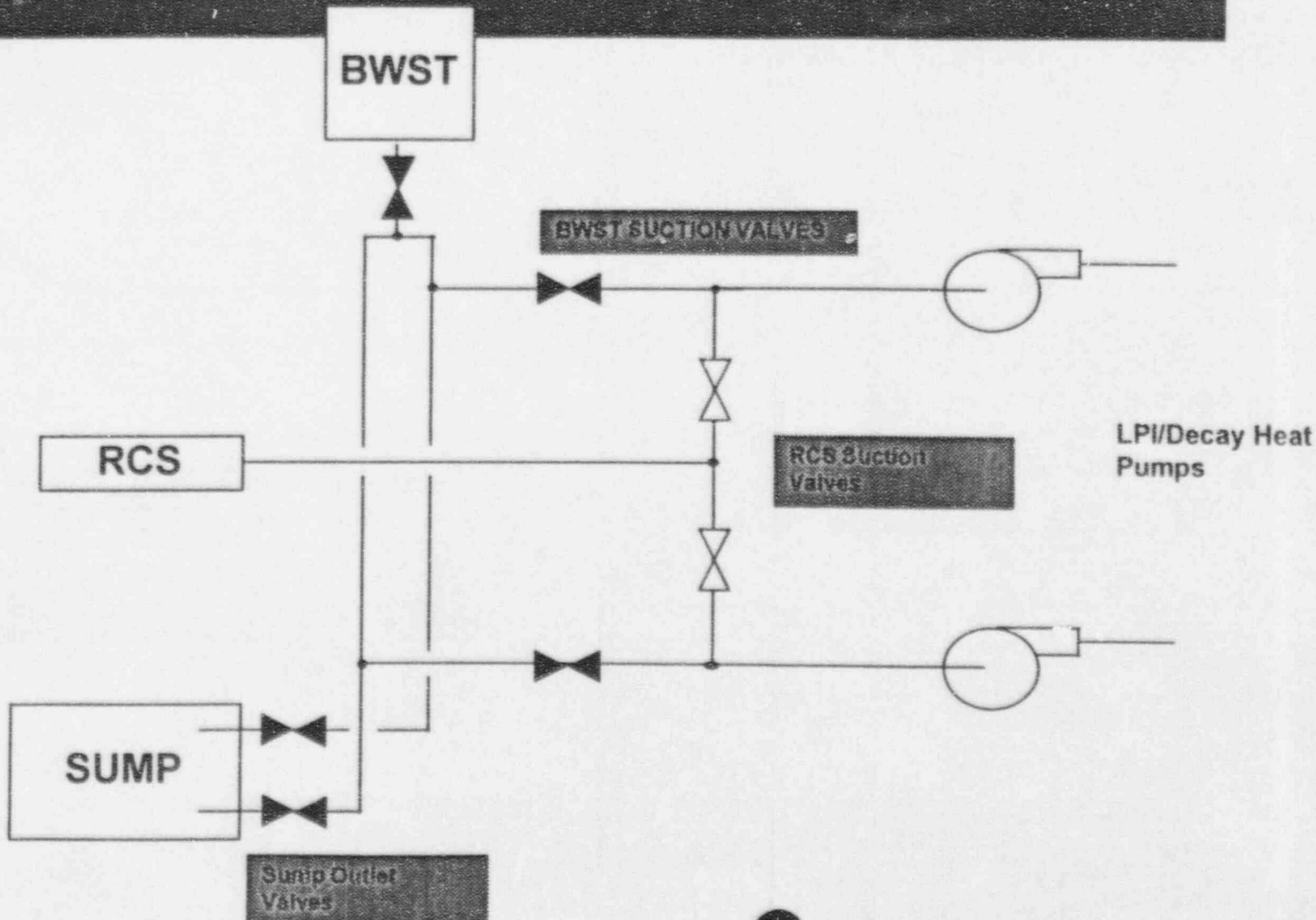
ENTERGY

Typical RHR/LPI Diagram

Decay Heat Pressure may hydraulically bind the sump or BWST valves if allowed to reach them.



Typical RHR/LPI Diagram



ENTERGY

RHR / DECAY HEAT SYSTEM MODES AT ANO - 1

- DECAY HEAT REMOVAL
- ENGINEERING SAFEGUARDS
- BORON CONCENTRATION ELIMINATION POST - LOCA

ENTERGY

DECAY HEAT REMOVAL MODE

- BWST VALVE CLOSED FOR PIPING ISOLATION FROM DECAY HEAT
- DECAY HEAT REMOVAL SUCTION VALVES OPEN TO PUMPS FOR COOLING

ENTERGY

ENGINEERING SAFEGUARDS MODE

- RCS SUCTION VALVES CLOSED FOR RCS ISOLATION FROM BWST PIPING
- BWST SUCTION VALVE OPEN TO PUMP FOR INJECTION

ENTERGY

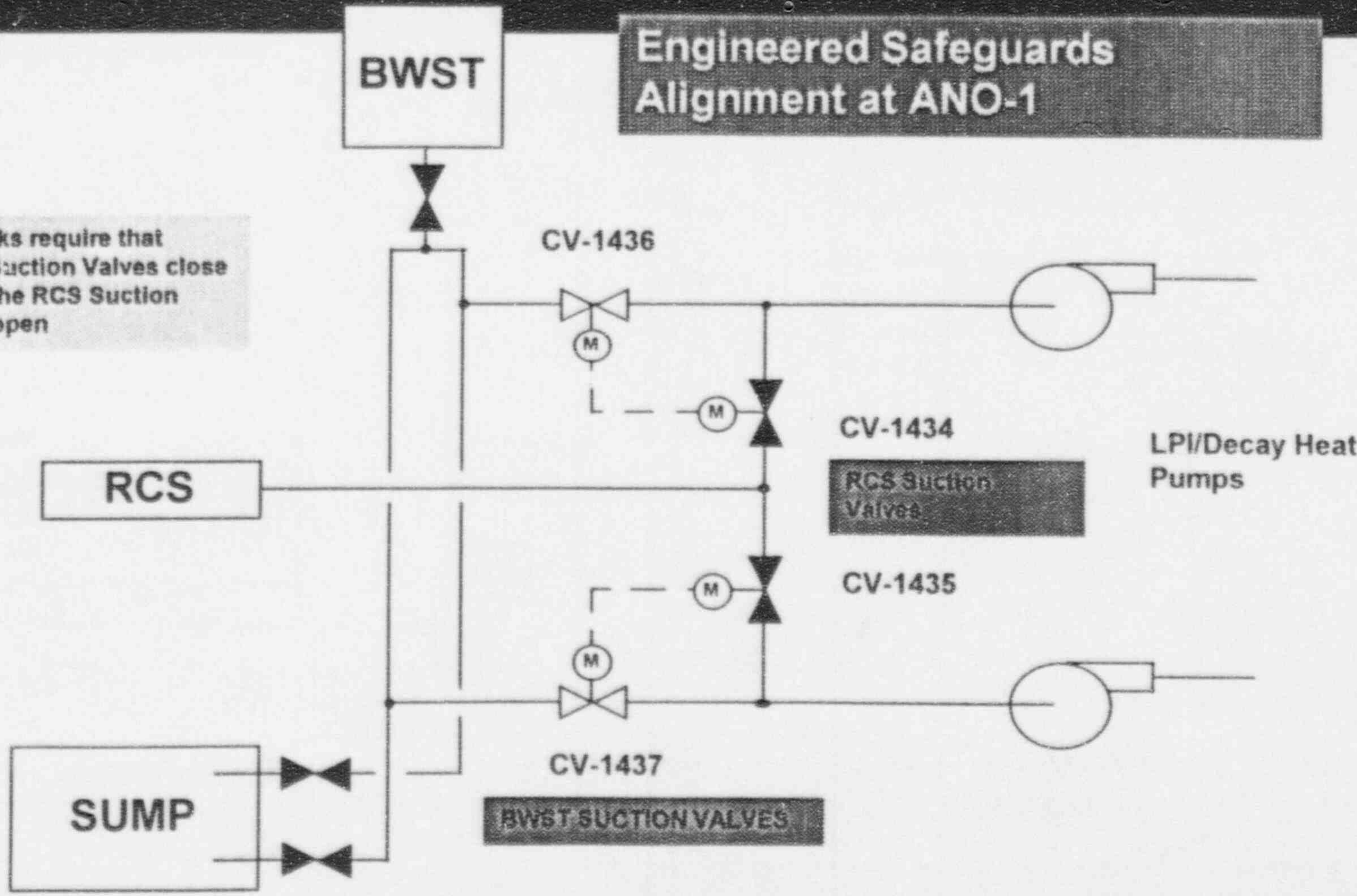
BORON DILUTION MODE

- ONE ALTERNATIVE USES DECAY HEAT SUCTION ALIGNMENT
- ALARA REQUIRED ADDITION OF VALVE MOTOR OPERATORS
- VALVE INTERLOCKS ALSO ADDED

Simplified RHR/LPI Diagram

Engineered Safeguards Alignment at ANO-1

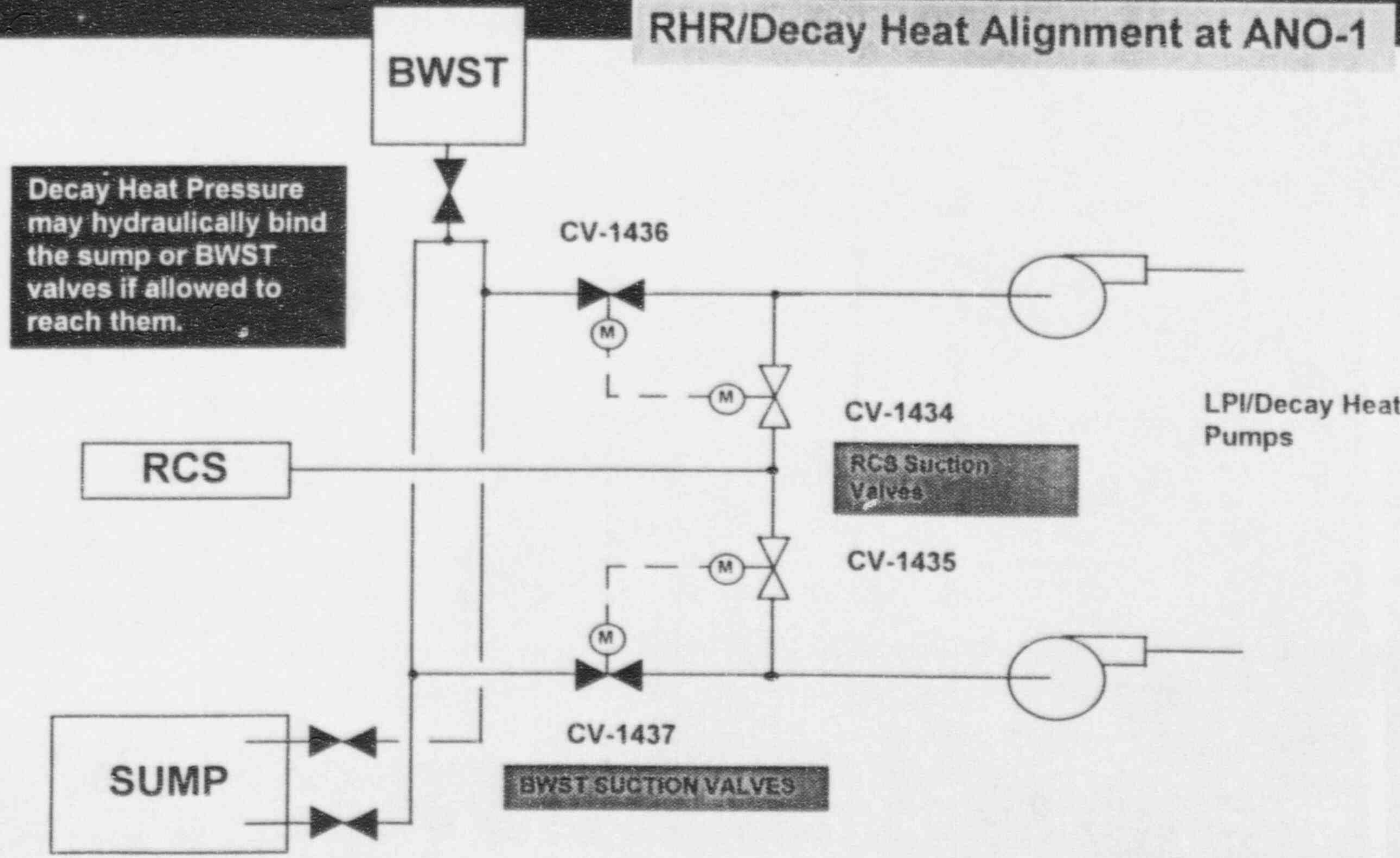
Interlocks require that BWST Suction Valves close before the RCS Suction Valves open



ENTERGY

Simplified RHR/LPI Diagram

RHR/Decay Heat Alignment at ANO-1



ENTERGY

VALVE / INTERLOCK BENEFITS

- DECAY HEAT PIPING DESIGN PRESSURE = 300 PSIG
- BWST SUPPLY / SUMP PIPING DESIGN PRESSURE = 70 PSIG
- ISOLATION OF LOW / HIGH PRESSURE PIPING
- INTERLOCKS ASSURE DECAY HEAT SUCTION VALVES CLOSE BEFORE BWST VALVE OPEN THUS PREVENTING HYDRAULIC LOCKING
- APPROACH CAN BE USED AT OTHER LOCATIONS

ENTERGY

Enclosure 10

Slides

Vendor Actions
Westinghouse Electric Corporation

Ike Ezekoye, Westinghouse

PRESSURE LOCKING AND THERMAL BINDING IN GATE VALVES: WESTINGHOUSE EXPERIENCE

by

Ike Ezekoye

Fellow Engineer

Westinghouse Nuclear Technology Division

Pittsburgh, PA

ABSTRACT

The potential for gate valves to pressure lock and thermal bind exists in gate valves. In this presentation, the pre-production qualification program Westinghouse undertook to reduce the potential for thermal binding is covered. The essential features of the valve qualification program are two fold: (a) establish limiting nozzle loads through test that will not be deleterious to the valves, and (b) evaluate the effects of thermal cycles (i.e, heatups and cooldowns) on valve operating loads. It is cautioned that the thermal cycling test was not performed to confirm valve operating loads. Rather it was done to isolate the effects of heatups and cooldowns on valve performance. While, no specific pressure locking testing was performed, the presentation covers means for mitigating pressure locking which Westinghouse has employed on request from utilities. The advantages and disadvantages of each scheme are discussed.

Insight gained from our experience suggests that the problems of pressure locking and thermal binding linger because there is limited coordination of activities between the valve designer, the plant constructor and the utility. Areas where each of these groups can play some role are identified.

PRESENTATION OVERVIEW

The presentation focuses primarily on Westinghouse Gate valves. The Westinghouse gate valve line was developed in the early 1970's to meet strict Nuclear Steam Supply System requirements such as low leakage, seismic loads, nozzle loads and thermal transients). The valves are forged stainless steel gates and hence are very robust by design. To confirm whether or not the design met the structural and functional requirements, an extensive valve qualification testing was undertaken. Two of the tests performed, which are considered relevant to thermal binding, are: nozzle load evaluation and hot/cold cyclic testing. Table 1 oulines the hot/cold test matrix. The test results confirmed that the operability of our valve is not affected by nozzle loads defined by our specifications and valve opening load is affected when a hot seated valve is cooled at a rate of 100°F/hr. No tests were performed to simulate pressure locking.

Two cases of field failures are presented. One covers a pressure locking event and the other covers a thermal binding event. Four corrective measures for pressure locking (drilling a hole in the disc or in the body, installing an equalizer, and installing a relief valve) are illustrated. Their advantages and disadvantages are presented in Table 2. In Table 3, areas where the valve manufacturer, the plant constructor and the plant operator can work on to minimize the incidents of pressure locking and thermal binding are discussed.

PRESSURE LOCKING
AND THERMAL BINDING
IN
GATE VALVES:
WESTINGHOUSE EXPERIENCE

Presented at NRC Sponsored
Public Workshop on Pressure Locking/Thermal Binding

New Orleans, LA
February 4, 1994

by

Ike Ezekoye
Fellow Engineer
Westinghouse Nuclear Technology Division
Pittsburgh, PA

PRESENTATION PLAN

- REVIEW WESTINGHOUSE GATE VALVE DESIGN
- REVIEW WESTINGHOUSE PRE-PRODUCTION VALVE QUALIFICATION TESTING
- OVERVIEW OF FIELD EXPERIENCE WITH PRESSURE LOCKING/THERMAL BINDING
- SHOW EXAMPLES OF VALVE MODIFICATIONS PERFORMED
- DISCUSS INSIGHTS GAINED
- QUESTIONS

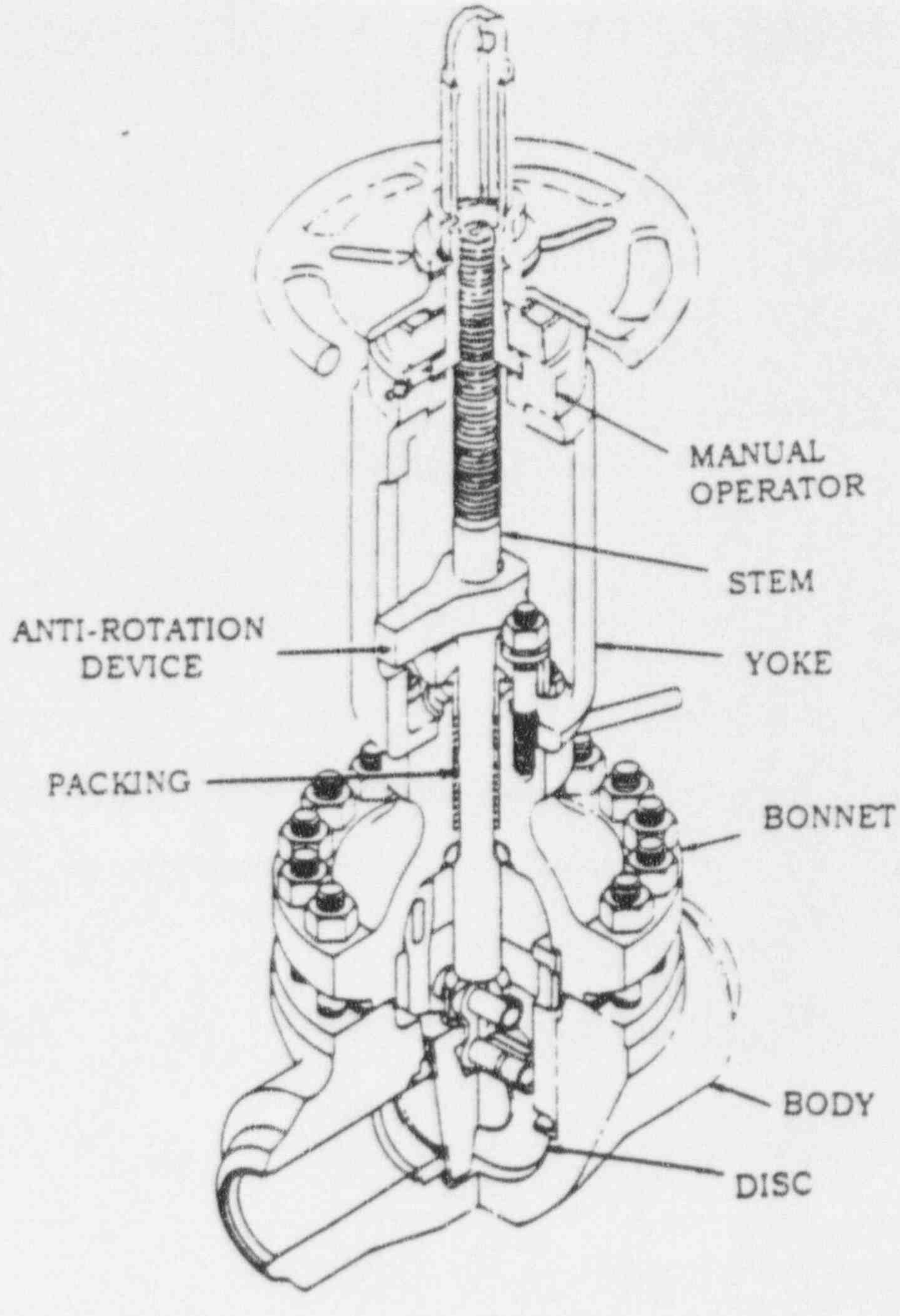
WESTINGHOUSE GATE VALVE DESIGN

☞ BACKGROUND

- Decision to make gates and checks for nuclear service circa 1970
- Limit the valves to stainless steel
- Meet rigorous NSSS requirements:
  - ★ Tight Seat Leakage (0 - 3 cc/hr/in)
  - ★ Pipe Nozzle Loads
  - ★ Seismic Loads
  - ★ Natural Frequency Requirement of 33 Hz.
  - ★ Thermal transients
  - ★ Reliability/Maintainability

☞ DESIGN FEATURES OF THE GATE VALVE

- Massive Forged body/bonnet/disc
- Articulated Linkage
- Wide seating surfaces



WESTINGHOUSE GATE VALVE DESIGN

PRE-PRODUCTION VALVE QUALIFICATION

- STANDARD VENDOR QUALIFICATION ACTIVITIES
  - Flow Test: Line Resistance (L/D), etc
  - Shell Test
  - Leakage Test
  - Load Characterization
- ADDITIONAL TESTING
  - Natural Frequency
  - Seismic Operability Test
  - Nozzle Loads
  - Thermal Cycling

PRE-PRODUCTION VALVE QUALIFICATION

☞ PRESSURE LOCKING/THERMAL BINDING CONSIDERATIONS

- Pressure Locking (Limited Control)
  - ★ Temperature dependent phenomenon
  - ★ Operationally induced during mode changes
- Thermal Binding (Substantial Control)
  - ★ Nozzle Load
  - ★ Thermal transients

NOZZLE LOAD TEST

OBJECTIVE:
Evaluate the effects of pipe end loads on valve operability

NOZZLE LOAD LIMITS:
MAX PRINCIPAL STRESS < = .75 YIELD (PIPE)
MAX BENDING < = .5 YIELD (PIPE)
MAX TORSION < = .5 YIELD (PIPE)

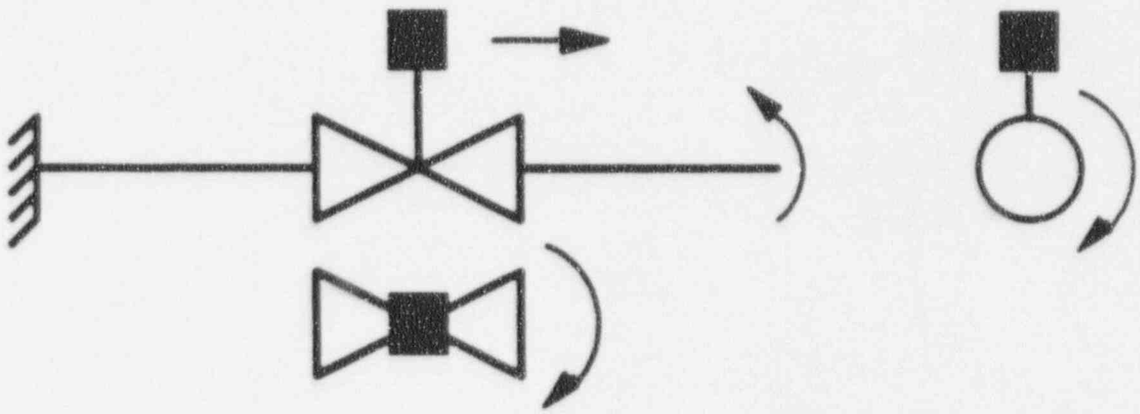


Figure Showing Nozzle and Seismic Load Testing

RESULTS:
NO EFFECT ON LEAKAGE
NO EFFECT ON OPERATING LOADS
NO EFFECT ON STROKE TIMES

COLD-HOT CYCLE TEST

OBJECTIVE:

To verify the performance of the valves under simulated actual conditions to uncover design weaknesses for improvement

RESULTS:

HOT SEATING FOLLOWED WITH COOLDOWN INCREASES OPENING LOAD
HOT BACK SEATING FOLLOWED WITH COOLDOWN REDUCES INITIAL UNSEATING LOAD

Table 1

Westinghouse Cold and Hot Cycle Valve Qualification Test Matrix
(Not Including Endurance Test)

Test	Type	Cycle	Pressure/Temperature	Measurements	Objective
1	Cold	Valve Closed	500 psi - 3400 psig at room temperature	bonnet stress disc stress seat leakage	Characterize the loads and stresses due to delta P's
2	Hydro	Valve Closed	4000 - 6425 psig at room temperature	bonnet stress stem stress	Evaluate the effect of hydro-test pressure on valve body stresses
3	Hot	50 cycles in 10 hours	2200 psig at 620°F 150 gpm Heatup/Cooldown 100°F	stem load	Monitor stem load cooldown closed and reopened
4	Hot	50 cycles in 10 hours	2200 psig at 620°F 150 gpm Heatup/Cooldown 100°F	stem load	Monitor stem load cooldown open and reclosed

Valve stroke time 10 secs.

FIELD EXPERIENCE

- LIMITED: FEW DATA GETTING BACK TO US
- PRESSURE LOCKING CASE

8 INCH 300 CLASS
TEMP. WENT FROM 100°F TO 300°F

VALVE FAILED TO OPEN
SOLUTION: DRILL HOLE IN THE DISC

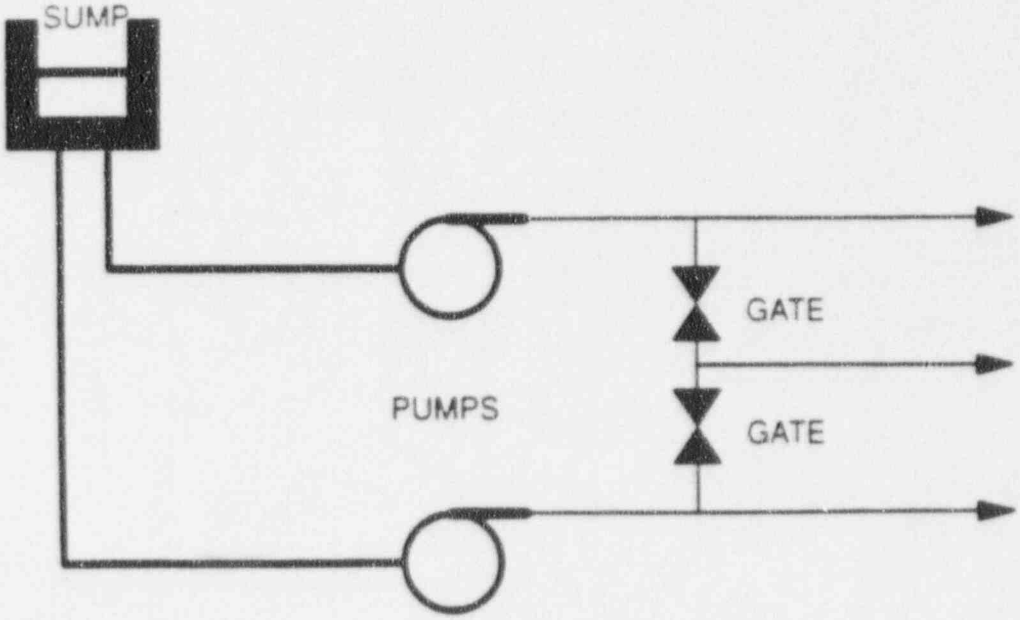


Figure Showing the Location of Pressure Locked Gate Valves

☞ THERMAL BINDING CASE

8 INCH 300 CLASS
VALVE INITIALLY HOT
SHOCKED WITH COLD WATER AS IT WAS CLOSING

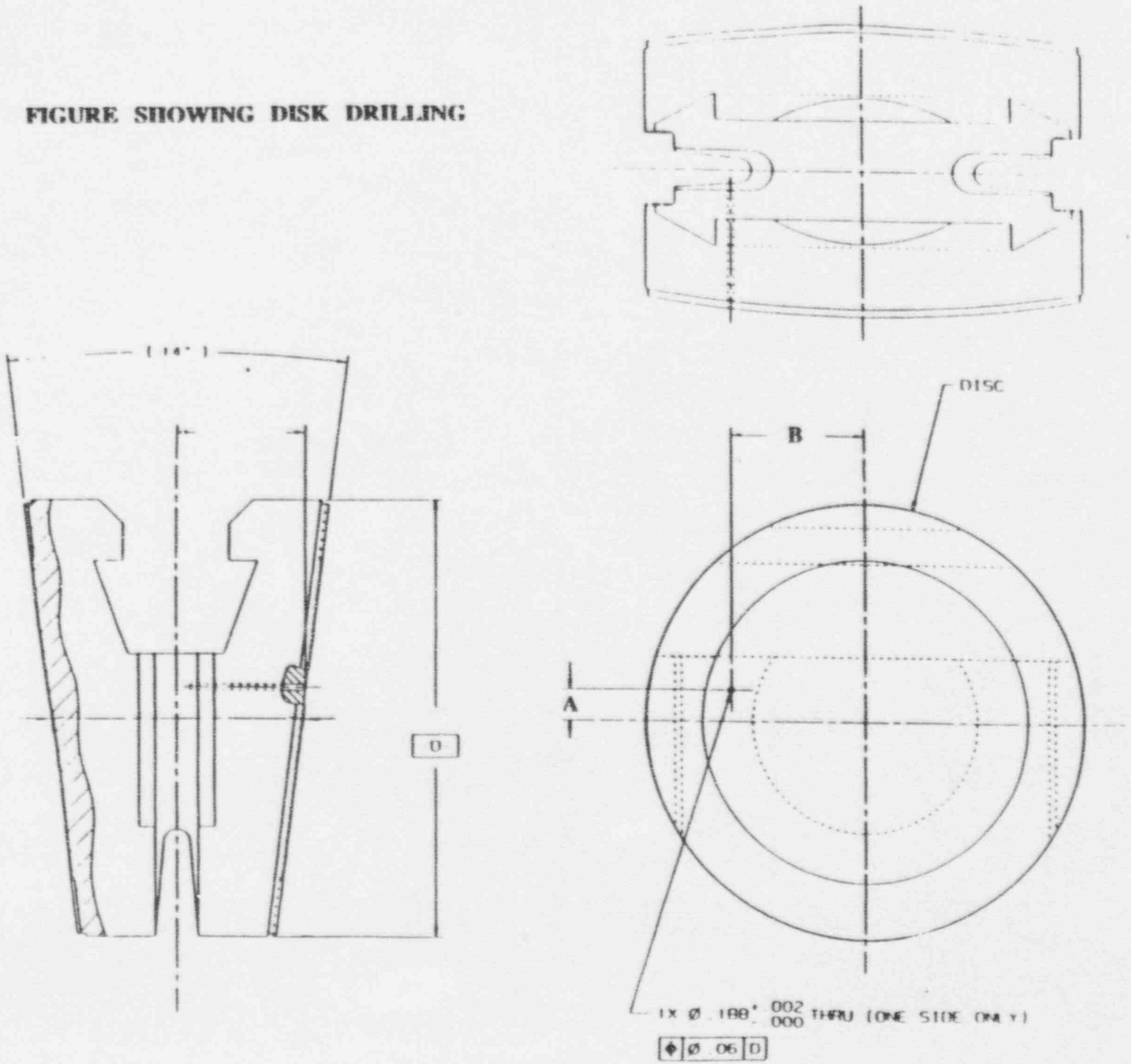
SIGNALS TO OPEN: IMMEDIATE AFTER CLOSURE - OPENS

30 MIN. AFTER CLOSURE - FAILS TO OPEN
2 HOURS AFTER CLOSURE - OPENS

SUSPECT THERMAL BINDING AND THE PROBLEM IS UNRESOLVED

EXAMPLES OF FIELD MODIFICATIONS ON WESTINGHOUSE VALVES

FIGURE SHOWING DISK DRILLING



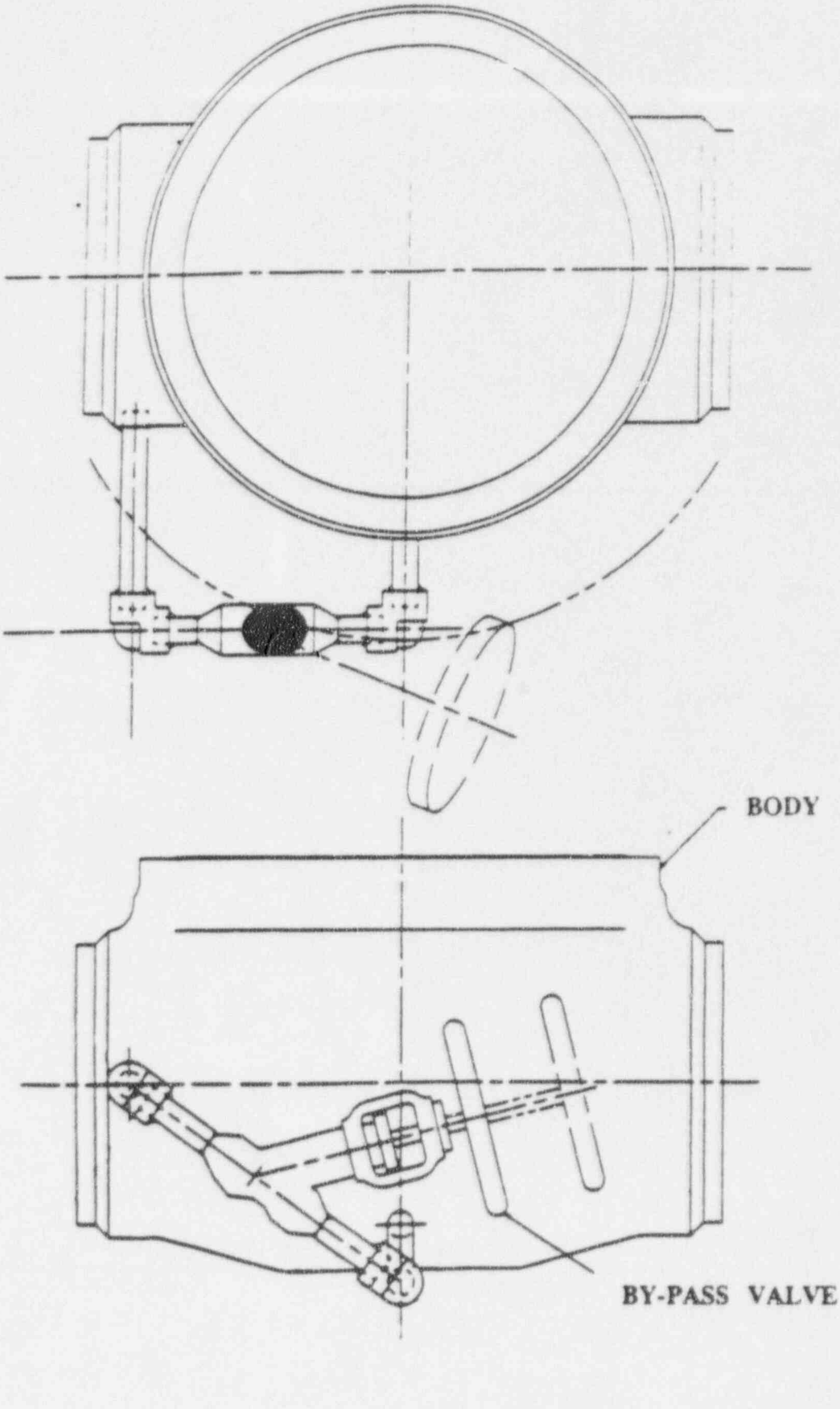


FIGURE SHOWING BONNET BY-PASS

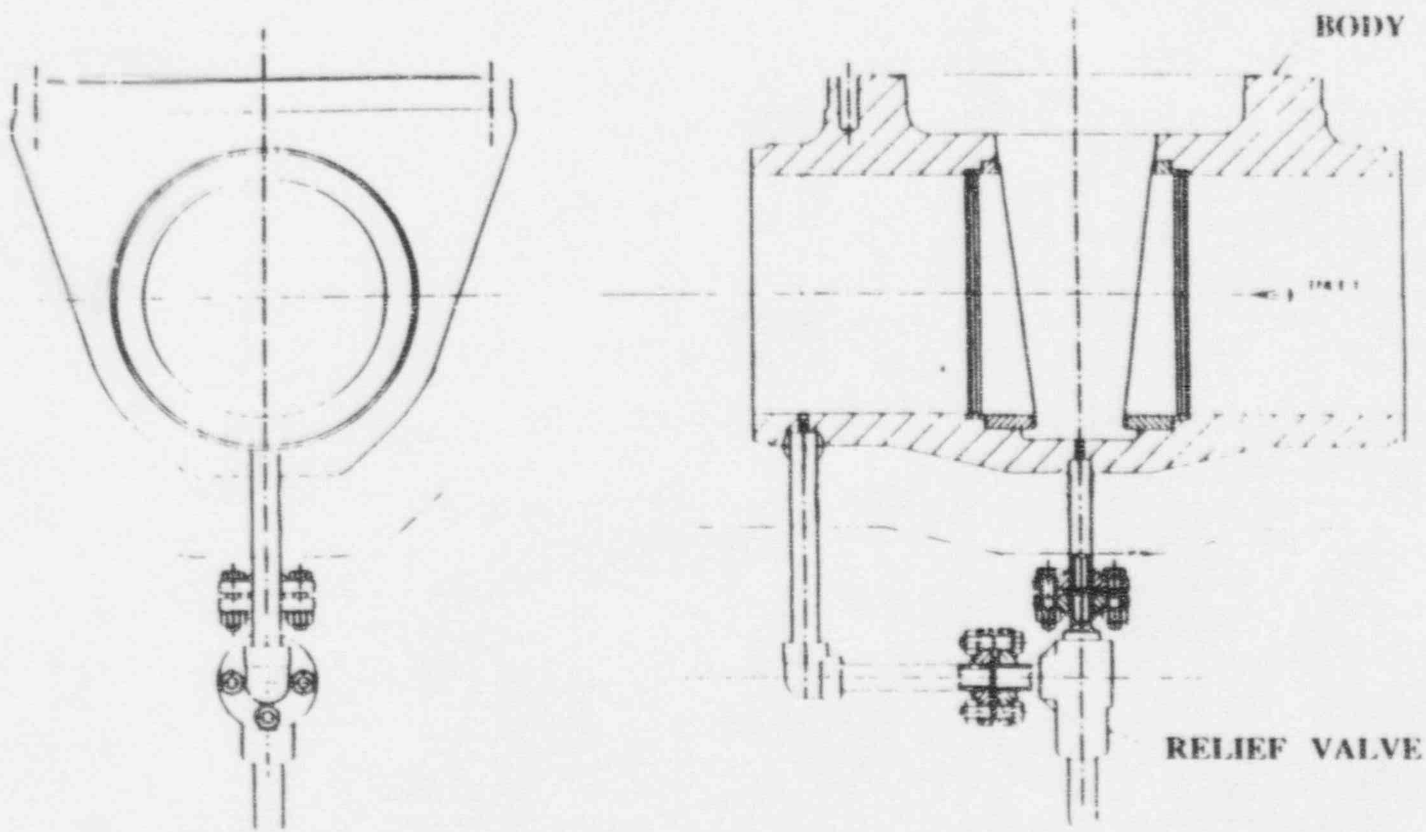


FIGURE SHOWING RELIEF VALVE INSTALLATION

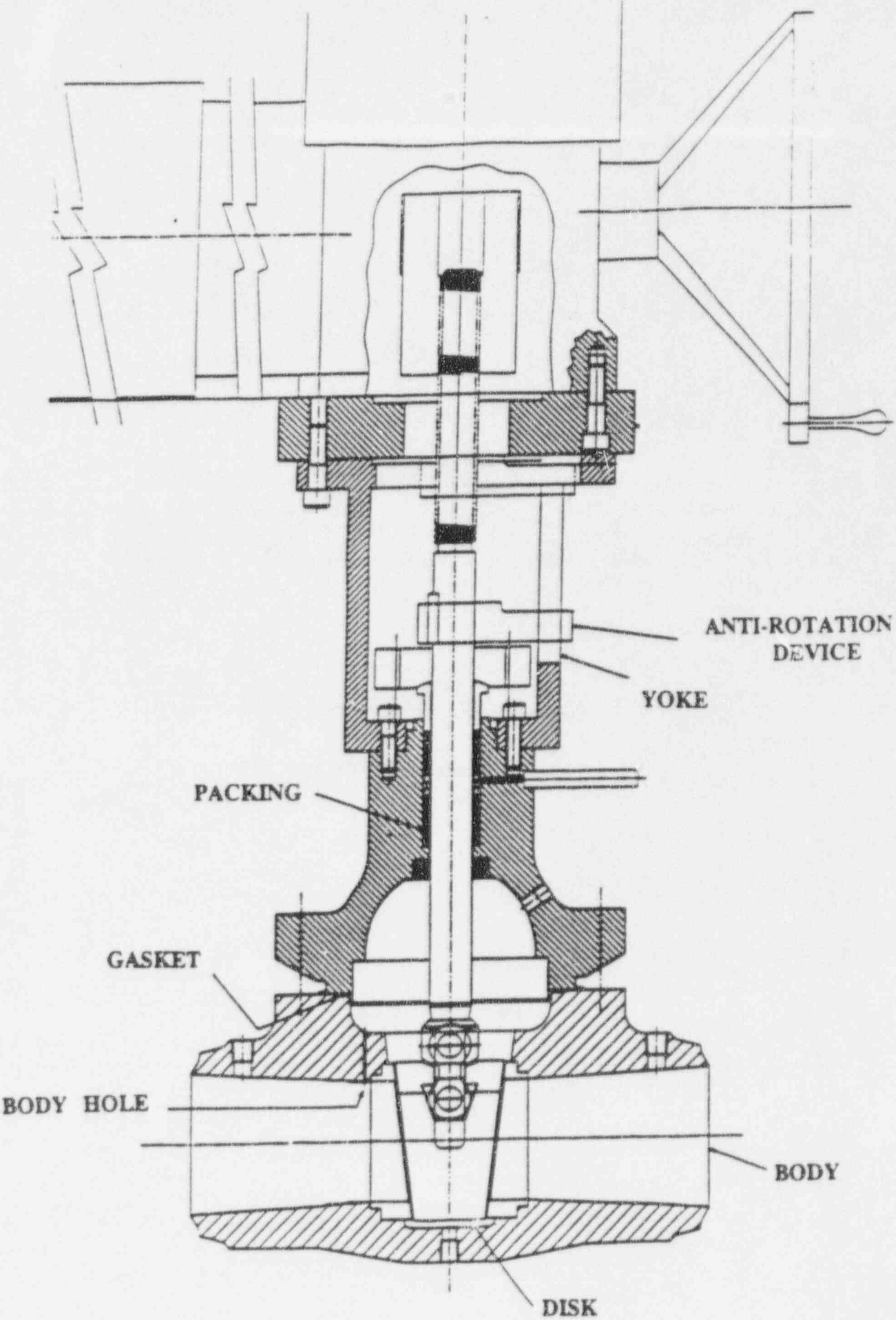


FIGURE SHOWING BODY DRILLING

Table 2
Pressure Locking Hardware Mitigating Approaches

Features	Advantages	Disadvantages
By-pass line	Provides unrestricted flow path between bonnet and upstream pipe	o External piping subject to external damage
	Disc can be reversed	o Reverse flow leakage
		o Potential to fatigue failure of piping
		o Piping analysis required
		o Difficult to convert to original configuration
By-pass with shut-off valve	Same as above	o More hardware to maintain
	Can be isolated for hydro-test	o External piping subject to external damage
	Disc can be reversed	o Potential to fatigue failure of piping
		o Reverse flow leakage
		o Piping Analysis required

Table 2
Pressure Locking Hardware Mitigating Approaches

Features	Advantages	Disadvantages
Drilling a hole on a disc face	Can be performed in the field	o Reverse flow leakage
	Very simple	o Hole can be reversed during installation
	No seismic effects	
		o Replace disc to convert to original configuration
Drilling a hole on the body	Simple for maintenance	o Difficult to implement in field
	No seismic effects	o Can be plugged depending on size and location
	Disc can be reversed	
Relief Valve	Good leaktightness	o More hardware to maintain
	Disc can be reversed	o Active element subject to regulatory attention
		o External piping subject external damage
		o More complicated to size, design and implement
		o Potential to fatigue failure of piping
		o Piping analysis required

Table 3

Responsibilities and Action for Pressure Locking and Thermal Binding Mitigation

Organization	Issue	Actions
Valve Designer	Pressure Locking	Size actuator correctly Body Drilling (if requested) Disc Drilling (if requested) Install by-pass line (if requested) Install relief valve (if requested)
	Thermal Binding	Perform thermal testing Perform functional/operability tests Define valve nozzle load limits Specify appropriate seating loads
Plant Designer	Pressure Locking	Install valves away from temperature source Specify transients the valves are subjected to Define layout configuration Define valve requirements clearly to vendor
	Thermal Binding	Limit nozzle loads to vendor limits

Table 3

Responsibilities and Action for Pressure Locking and Thermal Binding Mitigation

Organization	Issue	Actions
Plant Operator	Pressure Locking	Establish procedures to allow trapped high pressure fluid to relieve following mode changes Analyze as-built configuration for problem spots and modify to suit
	Thermal Binding	Minimize exposing the valve to unanalyzed transients (thermal shock) Establish procedures to allow temperature to stabilize before maneuvering valves Analyze as-built configuration for problem spots and modify to suit Cycle the valve during cooldown modes Avoid excessive closing loads Consult valve vendors in root cause evaluations and subsequent modifications

INSIGHTS

- ☞ PRESSURE LOCKING/THERMAL BINDING REMAIN POTENTIAL PROBLEMS
- ☞ SOLUTIONS EXIST AND MUST BE COORDINATED BETWEEN SUPPLIERS AND USERS
- ☞ INVOLVE SUPPLIERS IN ROOT CAUSE EVALUATIONS AND REVIEWS

Enclosure 11

Slides

Vendor Actions
Anchor Darling

Drew Wright, Anchor Darling

Pressure Locking and Thermal Binding In Gate Valves

NRC Workshop
February 4, 1994
New Orleans, LA

Drew W. Wright
Research Engineer
Anchor/Darling Valve Co.

Drew W. Wright
Anchor/Darling Valve Co.

I. Introduction:

A wide variety of gate valve designs are susceptible to pressure locking and/or thermal binding of the disc when a valve is in the closed position. The potential for such conditions is a function of both the valve design and system parameters. However, all gate valve designs are believed to be potentially susceptible to at least one of these phenomena, unless specific preventative features have been incorporated into the valve design.

II. Description of Phenomena:

a) Pressure Locking:

Pressure locking can occur as a result of two situations, or a combination thereof. Entrapping fluid in the bonnet cavity upon closure and subsequently heating the fluid can result in pressure locking. The increased pressure may cause valve damage, or render the valve inoperable. Pressure entrapment upon closure can also prevent the valve from being opened in the event of rapid de-pressurization in the adjacent upstream piping.

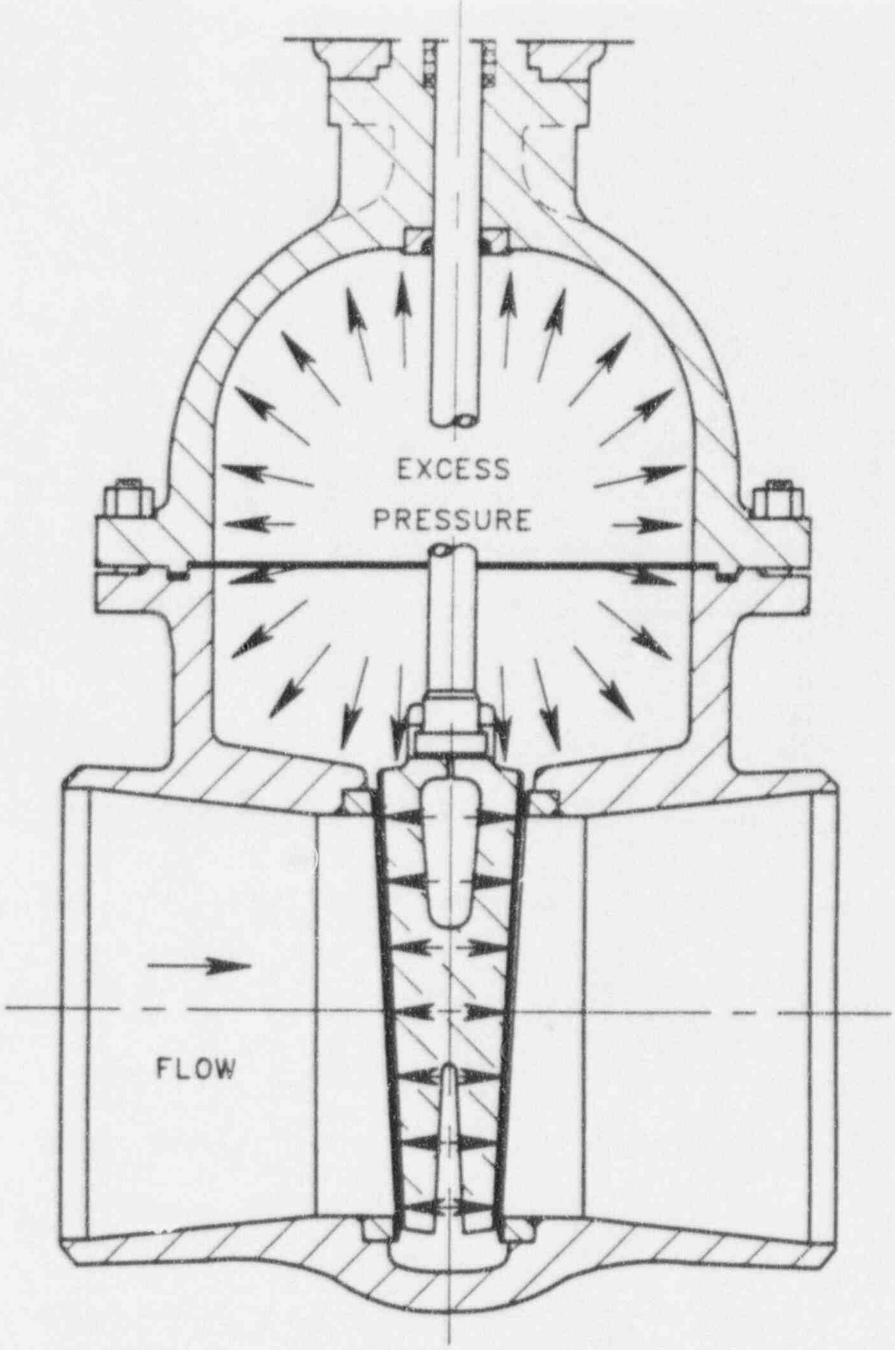
Pressure locking has been known to occur in both wedge-type and parallel seated gate valves.

Figures 1.0 and 2.0 depict a pressure locked condition for bolted bonnet and pressure seal designs, respectively.

In the worst cases, pressure locking (also known as bonnet over-pressurization), has resulted in catastrophic failure of the pressure boundary, and loss of life.

b) Thermal Binding:

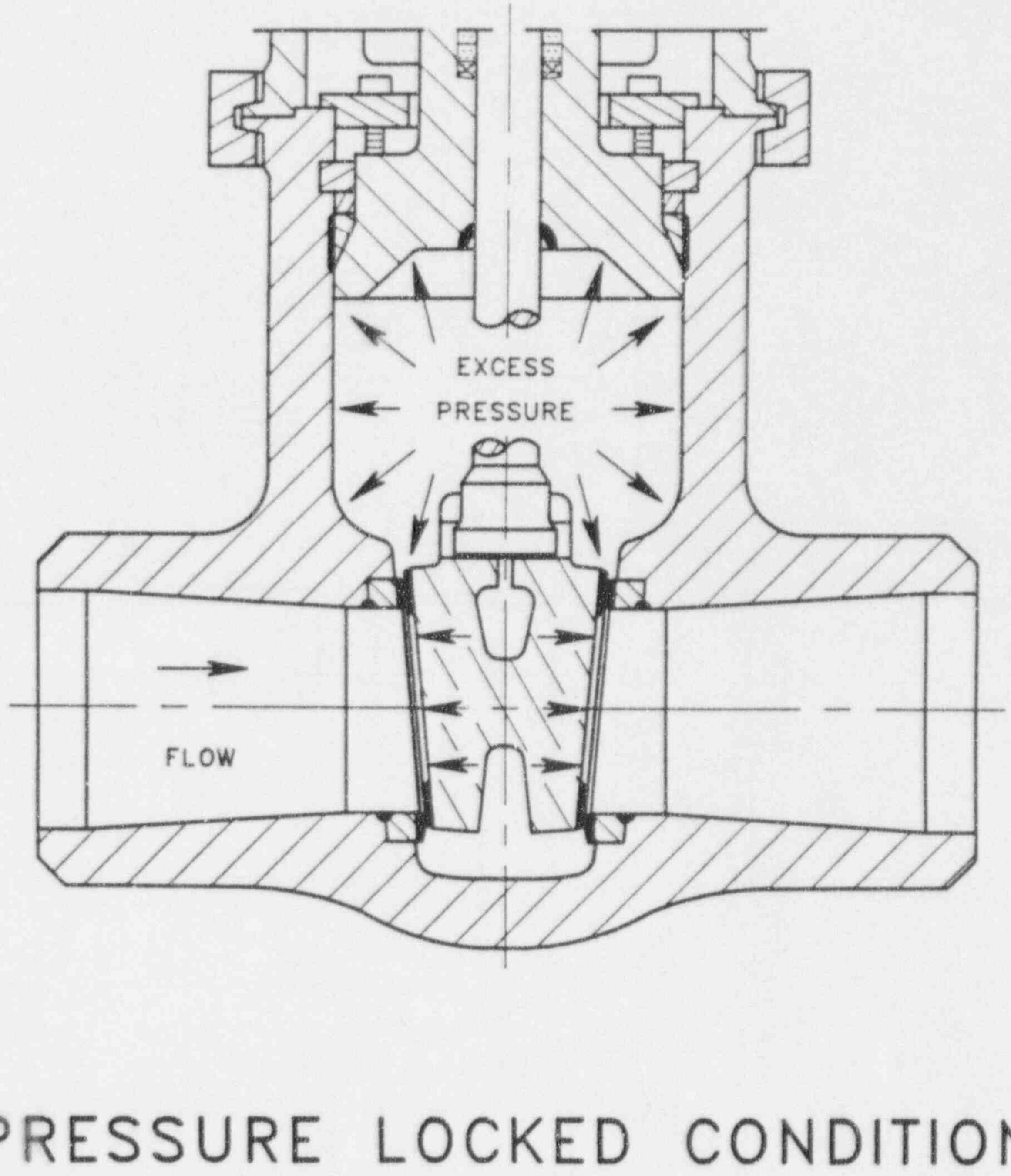
Thermal binding occurs as a result of differential contraction between the valve body and the valve disc as the system cools. The differential contraction can cause the disc to become tightly pinched in the valve seats, rendering the valve inoperable. Thermal binding is a concern for wedge-type gate valves. However, in general, parallel seat designs are less susceptible this phenomenon.



PRESSURE LOCKED CONDITION

BOLTED BONNET DESIGN

Figure 1-0



PRESSURE LOCKED CONDITION

PRESSURE SEAL DESIGN

Figure 2-0

III. Experiences:

a) Pressure Locking: Typically encountered during start-up operations.

1) 1970's, 18"-300#-DD (A/DV): PWR plant where dead-heading pump against valve caused fluid temperature to rise. Discs bowed outward and had to be cut out.

2) 1980's, DD (A/DV): PWR plant experienced pressure locking on start-up.

3) 18"-FW (non-A/DV): Flex wedge valve in feedwater pump discharge system. Seat rings collapsed from pressure locked condition.

4) FW (non-A/DV): Discharge recirculation valve pressure locked during start-up.

5) 10"-900#-DD (A/DV): Pressure locked during start-up. Valve installed in vertical leg of steam system.

b) Thermal Binding: Typically encountered during shutdown operations.

1) Experienced on valves from a variety of manufacturers. At least one case has resulted in the stem being pulled out of the T-head when attempting to open the valve.

IV. Suggestions For Identifying Problem Valves:

The identification of valves that may be subject to potential pressure locking and/or thermal binding requires a review of system conditions that are possessed by only the end user. Therefore, the end user is ultimately responsible for such evaluations. However, there are certain basic recommendations that A/DV can offer to assist in the process. This criteria is not intended to be comprehensive, as there is certain to be additional criteria that is applicable.

a) Pressure Locking/Bonnet Over-pressurization:

1) Identify normally-open gate valves that, once closed, are subject to temperature rise prior to reopening (i.e. primarily start-up operations).

2) Identify normally-closed gate valves that are subject to substantial temperature transients.

b) Thermal Binding:

1) Identify normally-open wedge-type gate valves that are closed prior to system cooling (i.e. shut-down operations).

2) Identify wedge-type gate valves having dissimilar body and disc base materials (i.e. CS vs SS).

V. Corrective Measures:

There are both design and operating measures that can be taken to preclude pressure locking, and minimize the potential for thermal binding. However, the available design measures are not employed as standard practice. Therefore, it is crucial that design specifications for new valves explicitly identify those valves that are subject to pressure locking or thermal binding conditions. Preventative measures that can be incorporated in the field, or during original design include the following:

a) Pressure Locking:

1) Drilling a hole in the upstream disc (see Figures 3.0 and 4.0).

2) Connection of an external vent or relief valve (see Figure 5.0).

3) Connection of an external bypass line with an isolation valve (see Figure 6.0).

4) Drilling a hole through the body bridge behind the upstream seat (see Figure 6.0).

a) Thermal Binding:

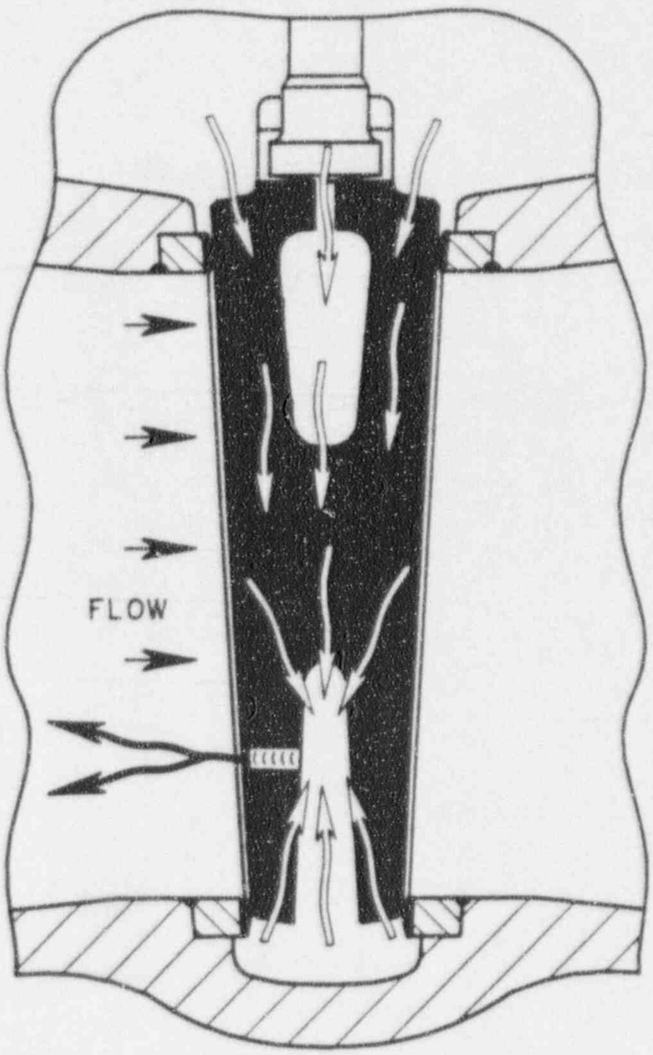
1) Periodically opening and closing a suspect valve during system cool-down.

2) Use of a spring compensating actuator to limit inertial closing forces.

3) Avoid use of excess closing thrusts.

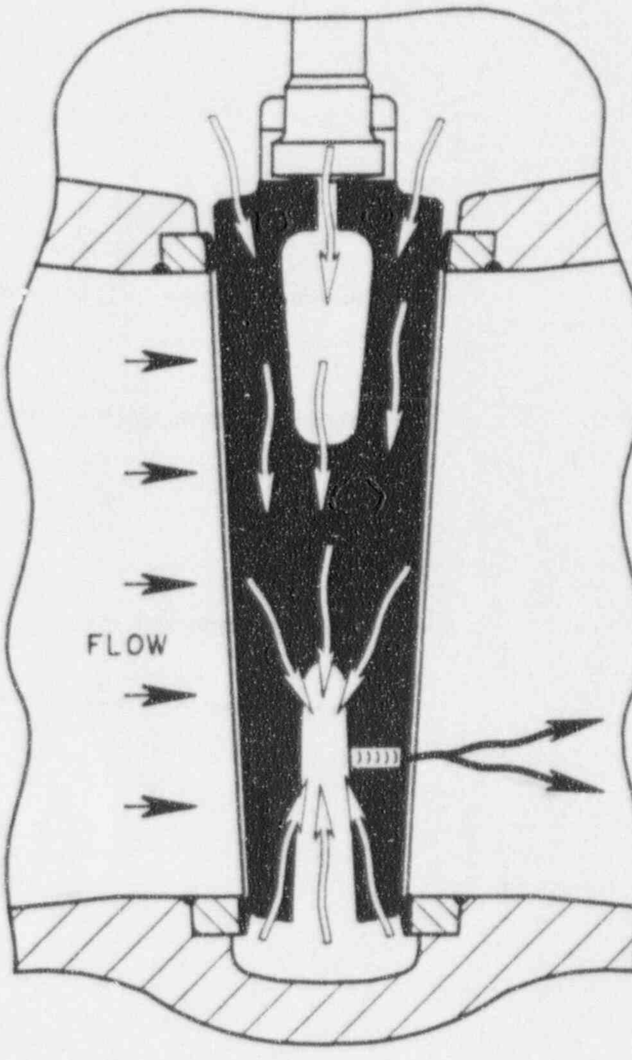
VI. Published A/DV Bulletins:

Anchor/Darling published an On-Line regarding bonnet over-pressurization in July of 1985.



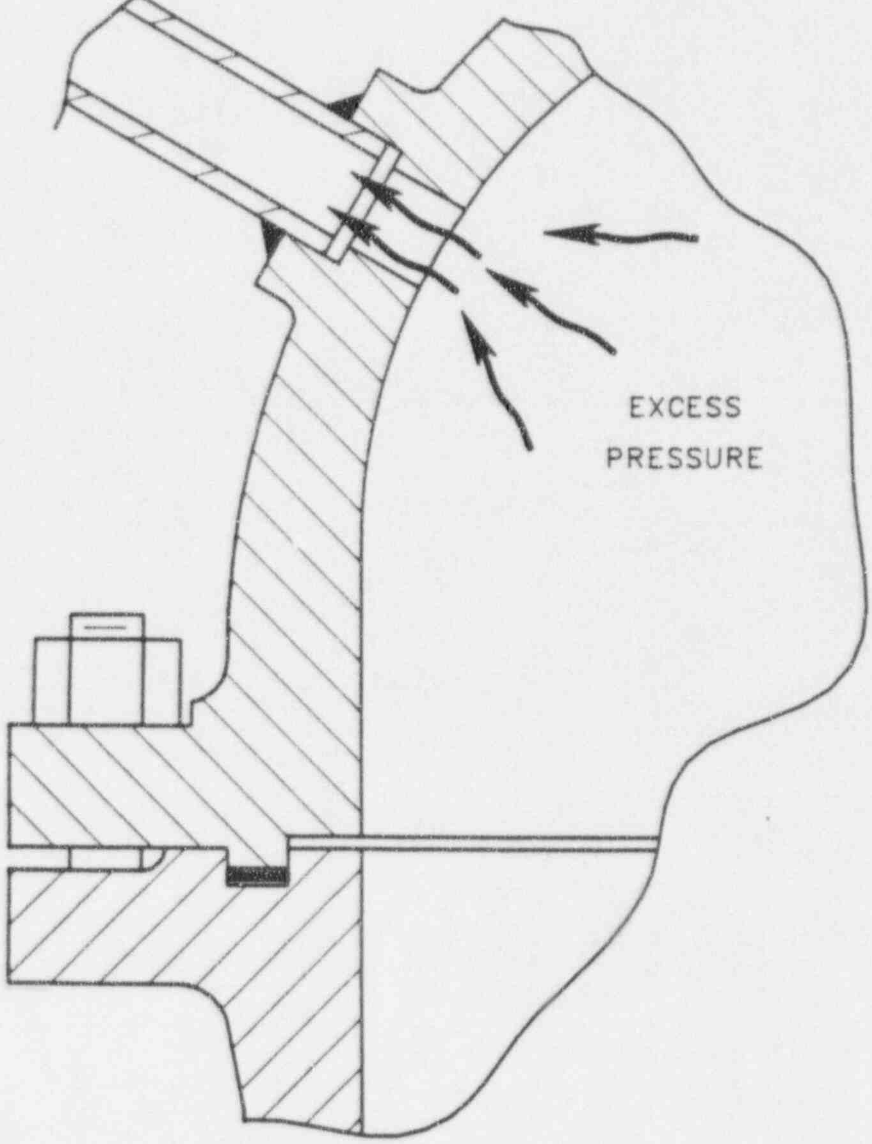
CORRECT DRILLING LOCATION

Figure 3-0



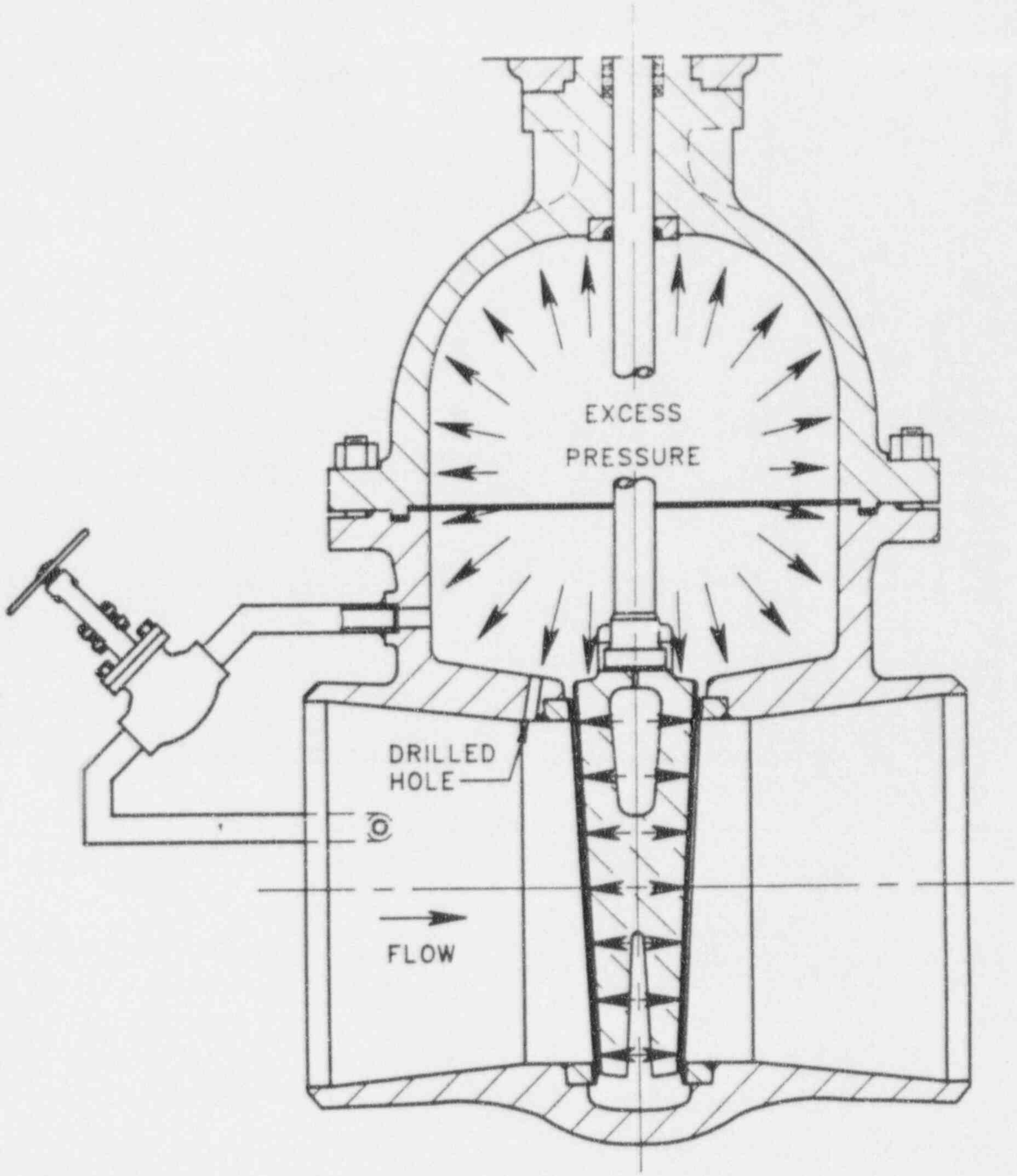
INCORRECT DRILLING LOCATION

Figure 4-0



CONNECTION FOR
EXTERNAL RELIEF VALVE

Figure 5-0



EXTERNAL BYPASS OR HOLE THRU BRIDGE

Figure 6-0

Enclosure 12

Slides

Vendor Actions
Velan

John Farrell, Velan

Farrell

Vel...

THERMAL BINDING

and

PRESSURE LOCKING

in Gate Valves

CAUSE - EFFECTS

and SOME SOLUTIONS

THERMAL BINDING

CAUSES

SHRINKAGE of BODY on WEDGE?

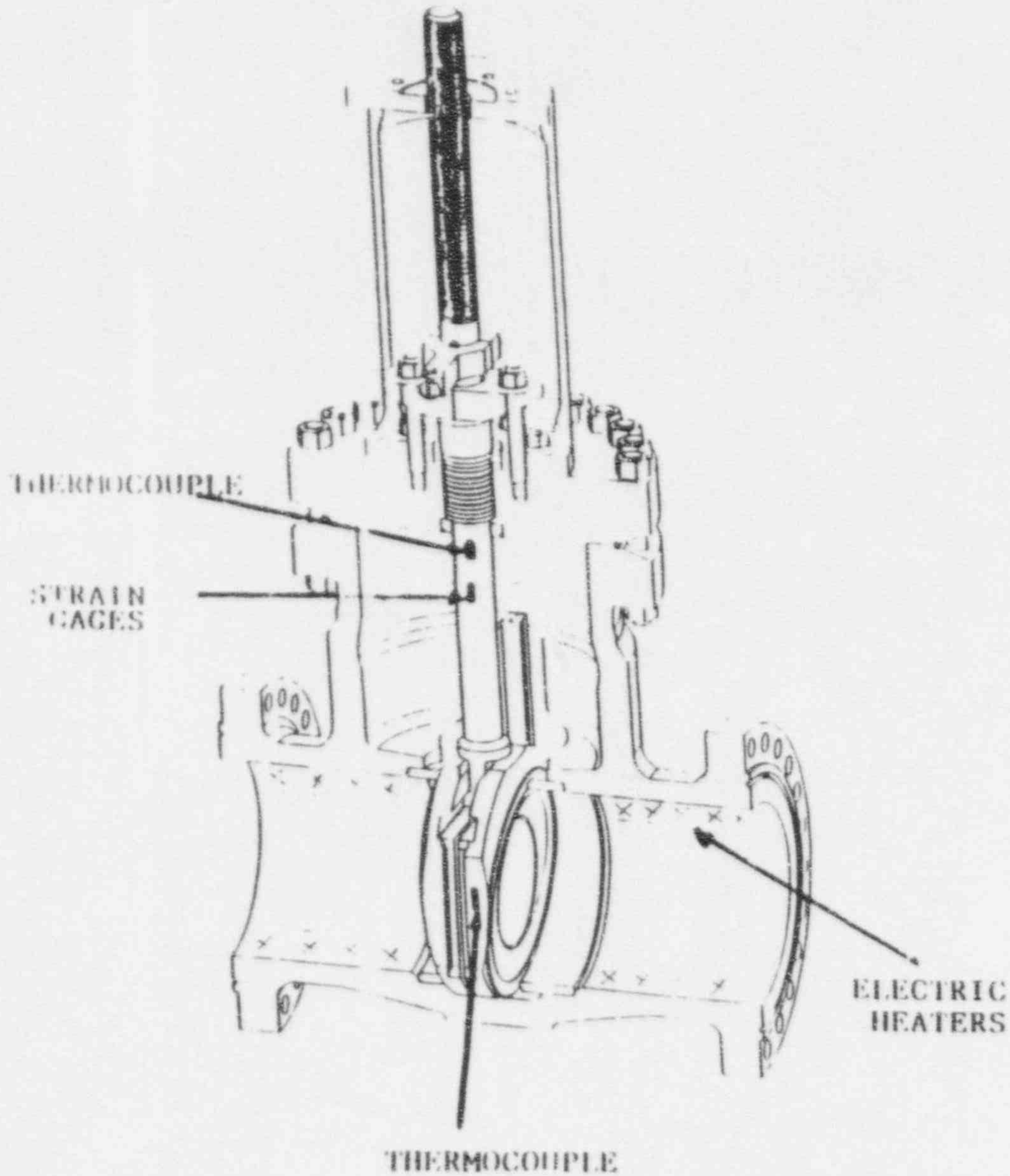
or

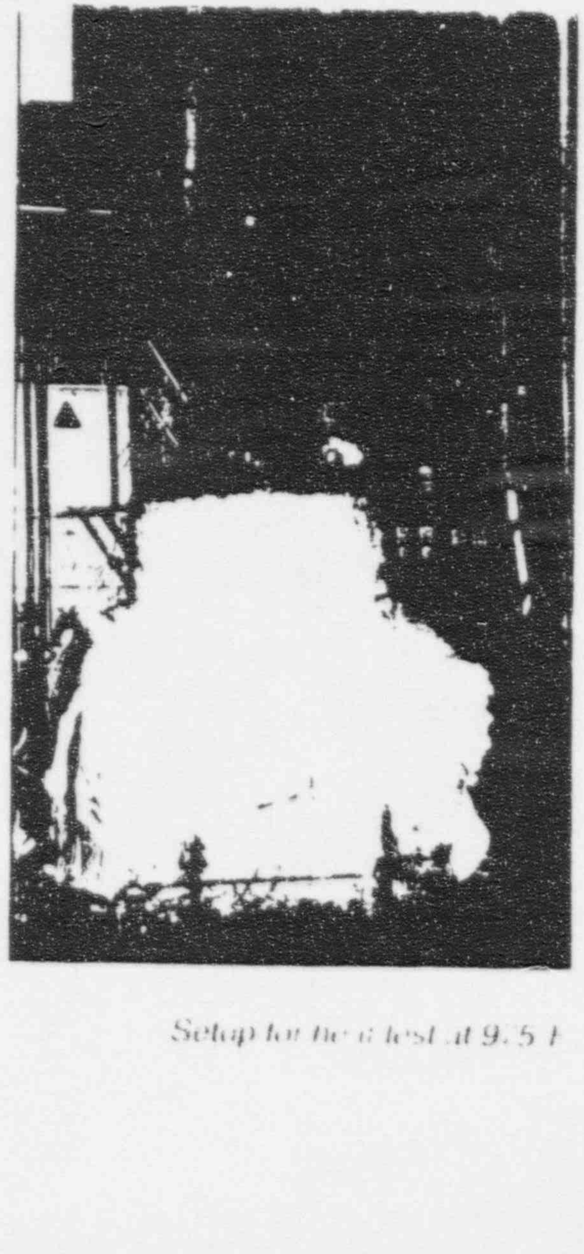
EXPANSION of WEDGE in BODY?

or

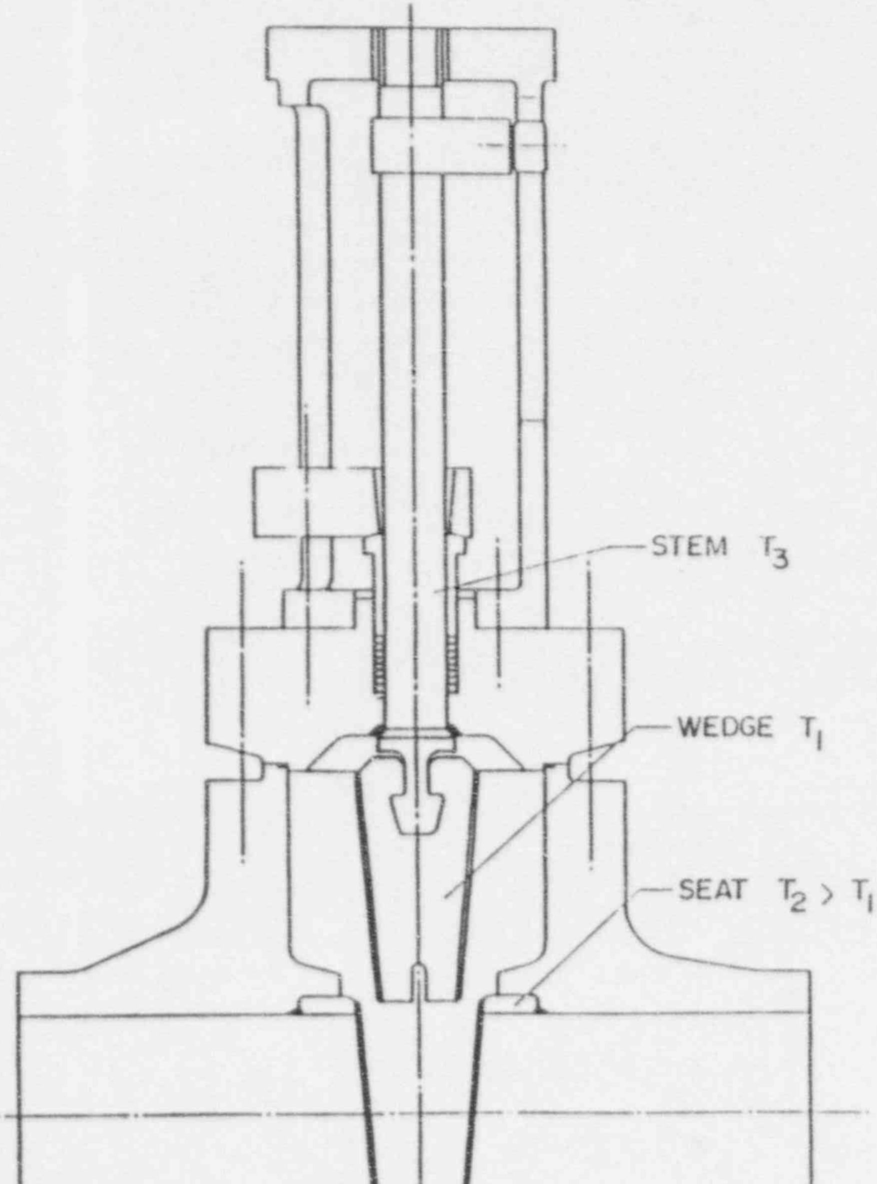
BOTH

TEST to FIND ANSWER

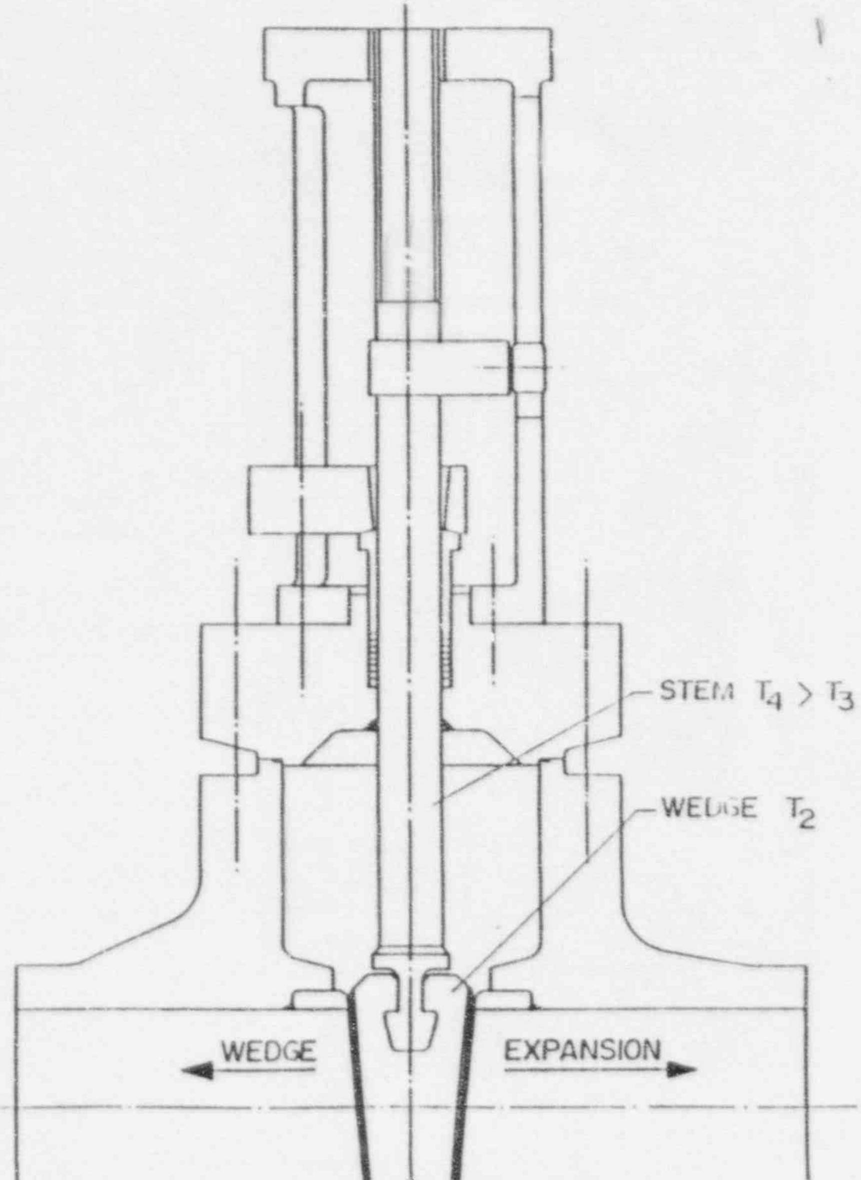




Setup for heat test at 9.5 F



STEM T_3
WEDGE T_1
SEAT $T_2 > T_1$



STEM $T_4 > T_3$
WEDGE T_2
WEDGE
EXPANSION

TEST SEQUENCE

OPEN VALVE HEATED to 975 °F.

STEM, BODY, WEDGE TEMPERATURE MEASURED

	(1)	(2)	(3)
(A)	<u>VALVE CLOSED</u>	<u>VALVE CLOSED</u>	<u>VALVE CLOSED 95%</u>
Measure:	-Stem, wedge temp. -Stem thrust -Stem Expansion	Same as (1)	When wedge temp. = Body temp. valve closed 100%
(B)	<u>VALVE OPEN</u>	<u>VALVE OPEN</u>	<u>VALVE OPEN</u>
	When wedge temp. = Body Temp.	When valve cooled to ambient	When valve cooled to ambient
Measure:	Stem Thrust	Stem Thrust	Stem thrust

RESULTS

High Thermal Binding	Low Thermal Binding	No Thermal Binding

CONCLUSION

MAJORITY OF THERMAL BINDING DUE TO WEDGE

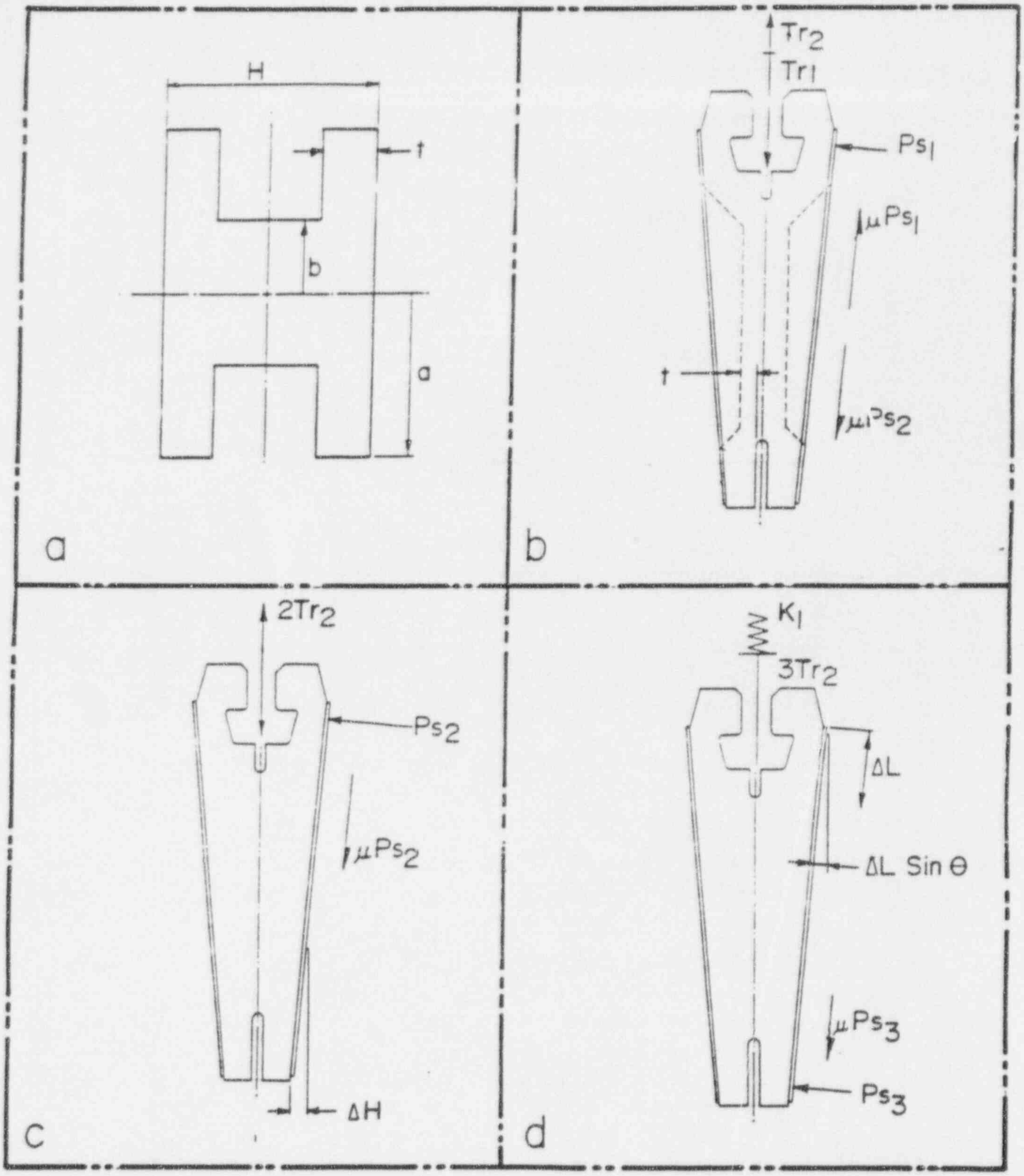
EXPANSION AFTER CLOSURE

SOLUTION

DEVELOP ANALYTICAL METHOD TO ESTIMATE

BINDING LOAD.

REDESIGN WEDGES WHERE NECESSARY

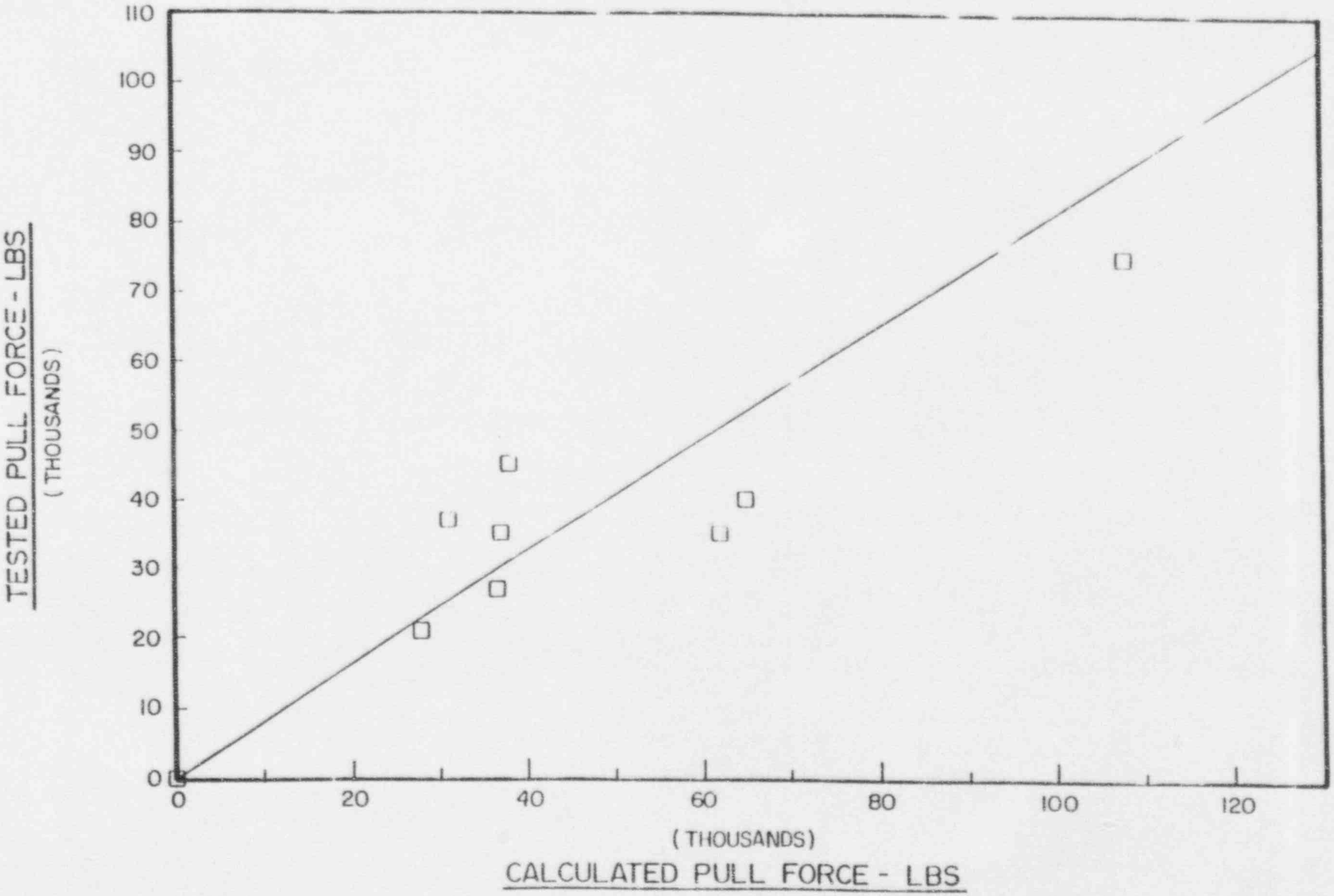


$$Tr_2 = 2(\mu \cos\theta - \sin\theta)\left[\frac{Tr_1}{2(\sin\theta + \mu \cos)} + \frac{H T_w \sigma E t^3}{2 \alpha a^2} + \frac{K_1 L \Delta T_s \sigma \sin\theta}{2\sin\theta(\sin\theta + \mu\cos\theta) + \frac{K_1 \alpha a^2}{E t^3}}\right]$$

FIGURE 11

WEDGE PULL FORCE

TESTED / CALCULATED



PRESSURE LOCKING

CAUSES:

1. ***TRAPPED PRESSURE IN CAVITY / LINES DEPRESSURISED.***

2. ***TRAPPED LIQUID IN CAVITY SUBSEQUENTLY HEATED.***

3. ***DIFFERENTIAL AREA OF ONE-PIECE WEDGE.***

4. ***DOUBLE DISC DRAG OF SPLIT TYPE DISCS.***

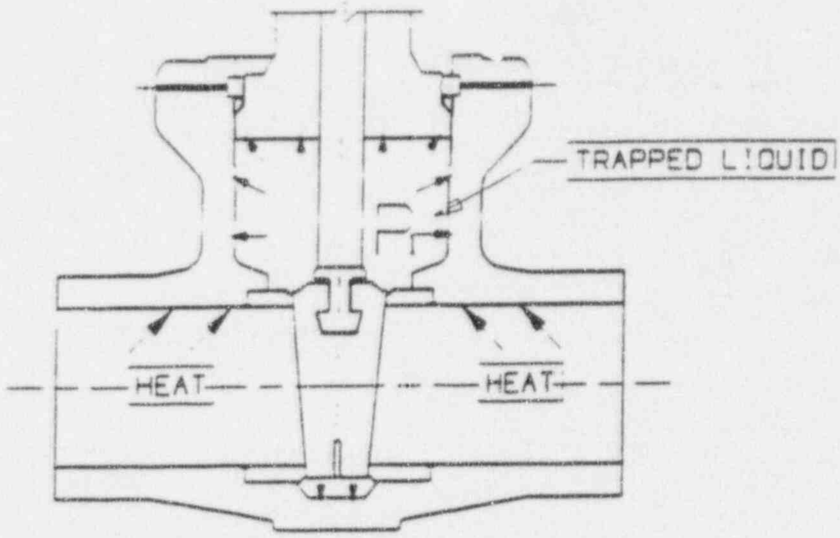


FIGURE 1

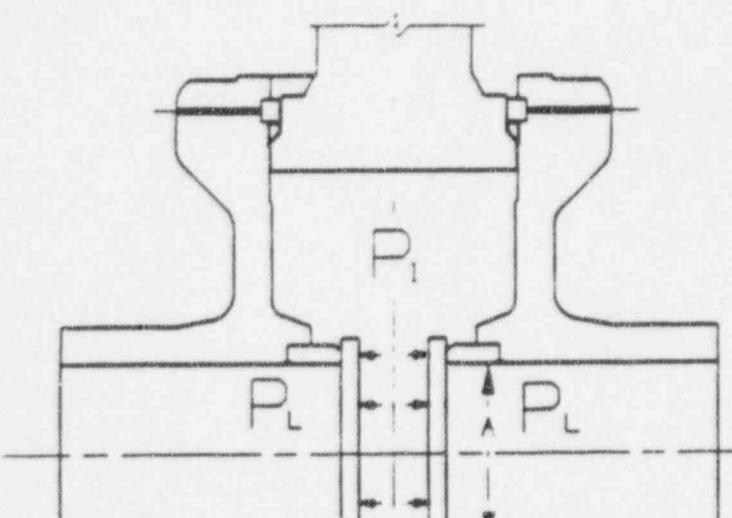


FIGURE 2

DOUBLE DISC TYPE

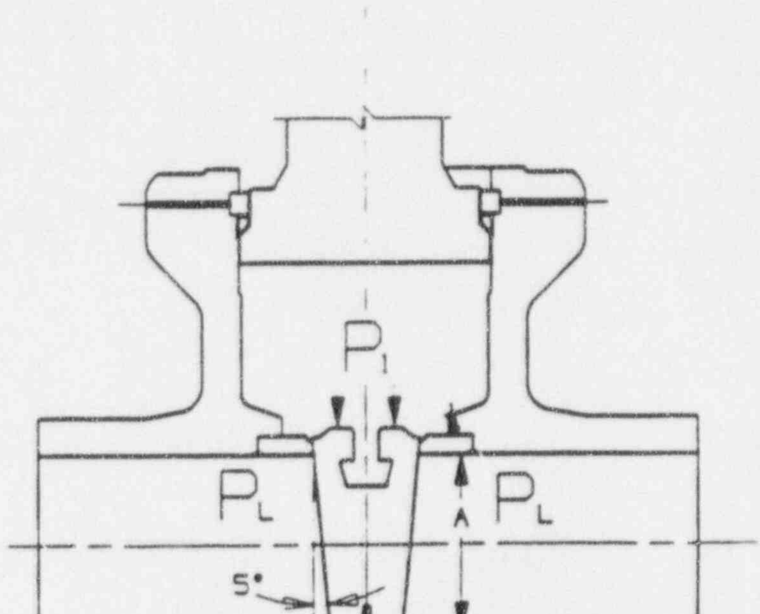


FIGURE 3

FLEXIBLE (ONE PIECE) WEDGE

SOLUTIONS

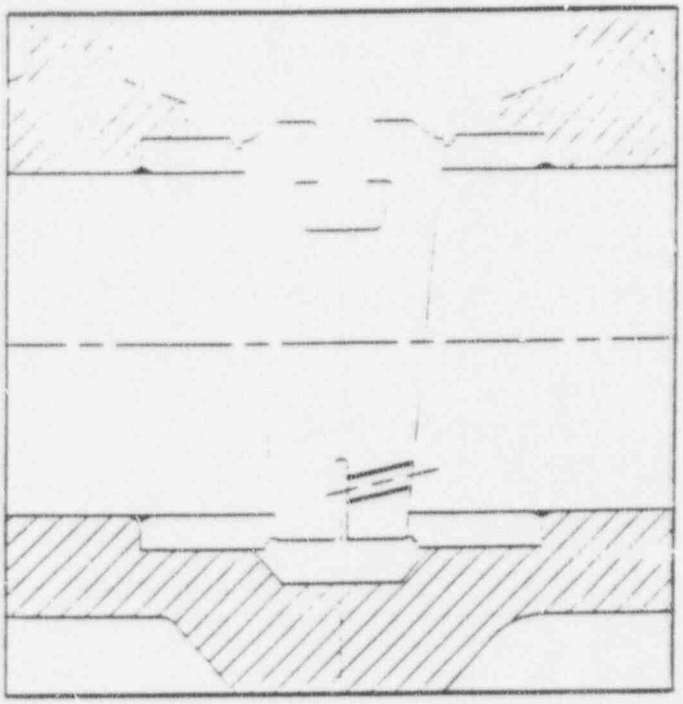


FIGURE 2

INTERNAL HOLE

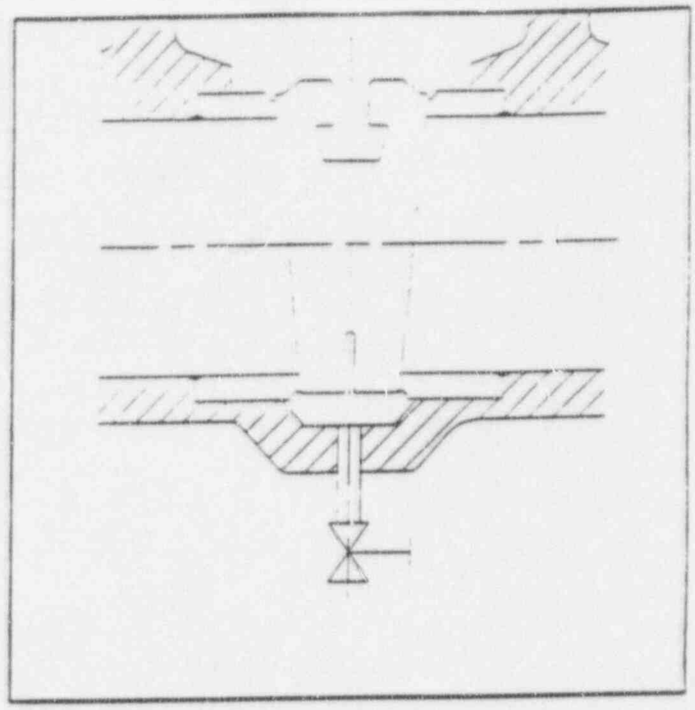


FIGURE 3

DRAIN/BYPASS

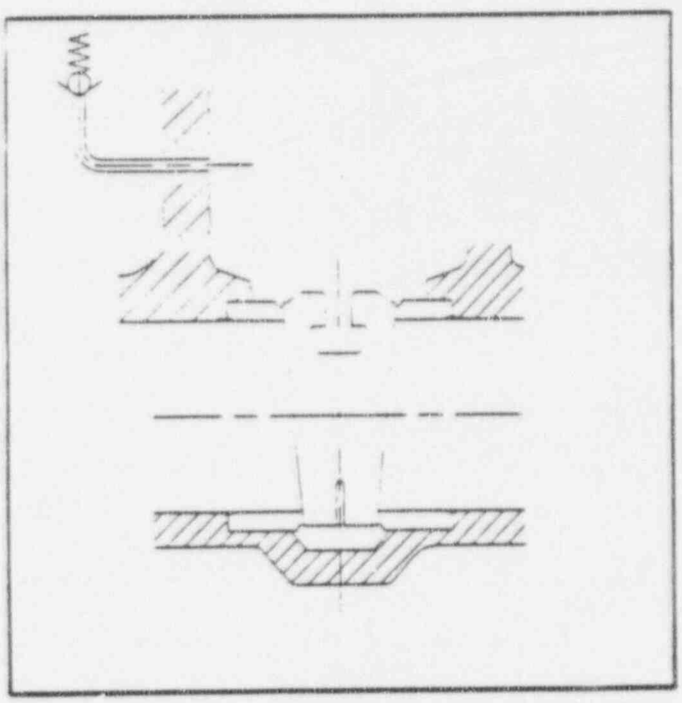


FIGURE 4

RELIEF VALVE

TESTING:

OBJECT: DETERMINE SEPARATE EFFECTS OF DIFFERENTIAL AREA AND DOUBLE DISC DRAG.

PROCEDURE:

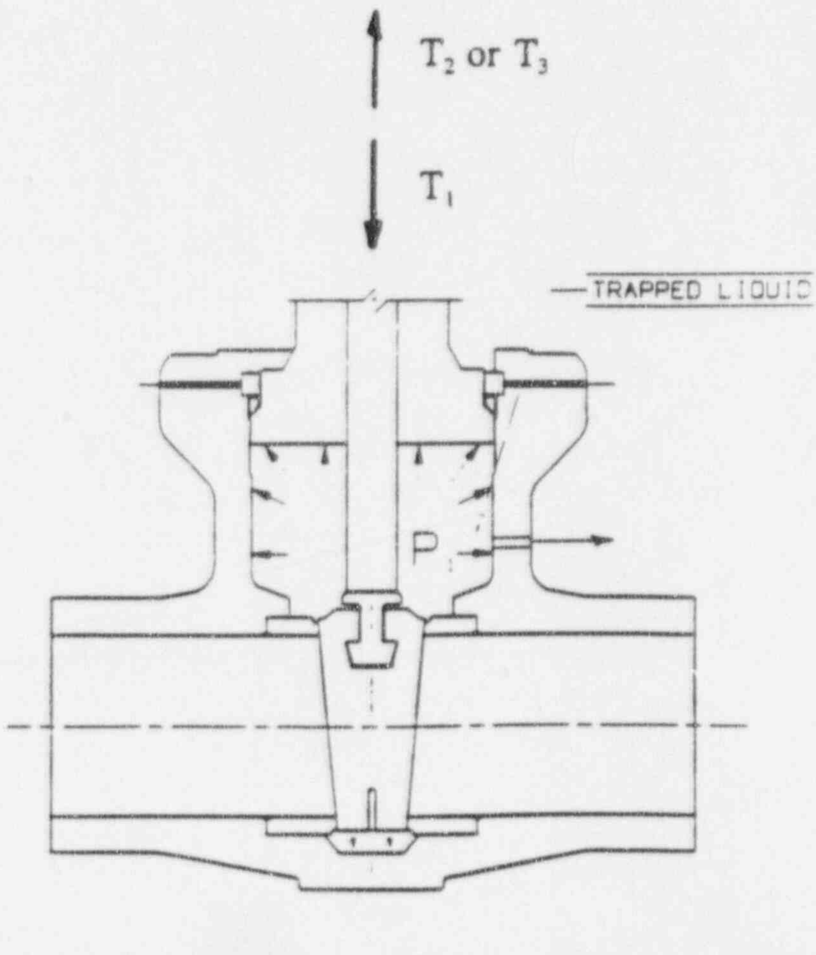
1. CLOSE VALVE WITH THRUST T_1.

   OPEN VALVE THRUST T_2.

2. CLOSE VALVE WITH T_1.

   PRESSURISE CAVITY WITH P_1.

   OPEN VALVE THRUST T_3.



CALCULATION

LOAD DUE TO DIFFERENTIAL AREA

$$L_1 = 2 \times A \times Tan5 \times P_1$$

LOAD DUE TO DOUBLE DISC DRAG

$$L_2 = T_3 - T_2 - L_1$$

TYPICAL RESULTS

	NO PRESSURE			WITH PRESSURE OPEN LOADS		
Valve:	Closing Load:	Open Load	Press.:	Total:	Diff. Area:	DD Drag:
10" 900	30,000	18000	2000	35000	17000	0
10" 300	14,000	8000	500	21000	7000	6000

Enclosure 13

Slides

NRC Draft Generic Communication on
Pressure Locking and Thermal Binding

Tom Scarbrough, NRR

NRC STAFF ACTIVITIES ON PRESSURE LOCKING AND THERMAL BINDING OF GATE VALVES

THOMAS G. SCARBROUGH

MECHANICAL ENGINEERING BRANCH
DIVISION OF ENGINEERING
OFFICE OF NUCLEAR REACTOR REGULATION
U.S. NUCLEAR REGULATORY COMMISSION

FEBRUARY 4, 1994

IN DECEMBER 1992, NRC OFFICE FOR ANALYSIS AND EVALUATION OF OPERATIONAL DATA COMPLETED SPECIAL STUDY S92-07, "PRESSURE LOCKING AND THERMAL BINDING OF GATE VALVES," WHICH WAS ISSUED AS VOLUME 9 OF NUREG 1275.

AT A PUBLIC WORKSHOP IN FEBRUARY 1993, NRC STAFF DISCUSSED THE SAFETY SIGNIFICANCE OF PRESSURE LOCKING AND THERMAL BINDING OF GATE VALVES.

NRC STAFF PREPARED GENERAL GUIDANCE FOR USE BY NRC INSPECTORS IN EVALUATING LICENSEE ACTION ON PRESSURE LOCKING AND THERMAL BINDING IN REVISION 1 TO TEMPORARY INSTRUCTION 2515/109 (JUNE 14, 1993) AND A MEMORANDUM (APRIL 30, 1993) TO THE REGION OFFICES. INSPECTORS REVIEWING LICENSEE ACTION ON THIS ISSUE ARE FINDING LITTLE PROGRESS IN THIS AREA.

ON FEBRUARY 8, 1993, NRC STAFF REQUESTED NUMARC TO PROVIDE SPECIFIC GUIDANCE ON ACCEPTABLE APPROACHES TO ANALYZE AND REMEDY PRESSURE LOCKING AND THERMAL BINDING OF GATE VALVES. AT A PUBLIC MEETING ON OCTOBER 4, 1993, NUMARC STATED THAT, BASED ON A SURVEY, IT HAD NOT FOUND PRESSURE LOCKING EVENTS BEYOND THOSE IDENTIFIED BY AEOD AND DID NOT PLAN TO TAKE ANY ACTION TO ADDRESS THIS ISSUE.

NRC STAFF PREPARING PROPOSED GENERIC LETTER TO REQUEST THAT LICENSEES ADDRESS PRESSURE LOCKING AND THERMAL BINDING OF GATE VALVES.

STAFF VIEWS OF PRESSURE LOCKING AND THERMAL BINDING:

1. PRESSURE LOCKING AND THERMAL BINDING MIGHT NOT OCCUR UNTIL PLANT CONDITIONS EXIST THAT REQUIRE OPERATION OF THE VALVE. THEREFORE, ABSENCE OF PREVIOUS EVENT NOT SUFFICIENT.

2. EXAMPLES OF METHODS TO PREVENT PRESSURE LOCKING AND THERMAL BINDING DISCUSSED IN NUREG-1275, VOLUME 9.

3. THRUST REQUIRED TO OVERCOME PRESSURE LOCKING OR THERMAL BINDING IS DIFFICULT TO PREDICT. IF POWER-OPERATED VALVE IS CONSIDERED CAPABLE OF OVERCOMING THRUST REQUIREMENT, METHODOLOGY USED TO PREDICT THE THRUST REQUIREMENT NEEDS TO BE BASED ON TESTING.

4. IF POWER-OPERATED VALVE IS SUSCEPTIBLE TO PRESSURE LOCKING OR THERMAL BINDING, AND POWER OPERATOR CANNOT OVERCOME THRUST REQUIREMENT, THE VALVE MAY BE IN A DEGRADED OR NONCONFORMING CONDITION.

5. GENERIC LETTER 91-18 PROVIDES GUIDANCE TO LICENSEES ON THE DISPOSITION OF POTENTIALLY DEGRADED OR NONCONFORMING CONDITIONS.

6. IN THE EVENT A VALVE IS DETERMINED TO BE INCAPABLE OF PERFORMING ITS SAFETY FUNCTION, PERMISSION FOR CONTINUED PLANT OPERATION MAY BE REQUESTED WHILE CORRECTIVE ACTION TAKEN. EXAMPLES OF INFORMATION TO SUPPORT A JUSTIFICATION FOR CONTINUED OPERATION INCLUDE

   A. SYSTEM ARGUMENTS (USING REASONABLE VS. DESIGN-BASIS ASSUMPTIONS) TO SUPPORT LOW LIKELIHOOD OF PRESSURE LOCKING AND THERMAL BINDING PROBLEMS, AND

   B. THRUST CAPABILITY UNDER NORMAL VOLTAGE CONDITIONS COMPARED TO ESTIMATED THRUST REQUIREMENT.

NRC STAFF CONSIDERING THE NEED FOR LICENSEES TO

1. EVALUATE THE OPERATIONAL CONFIGURATION FOR EACH SAFETY-RELATED POWER-OPERATED GATE VALVE AND DOCUMENT THE BASES FOR THE DETERMINATION OF ITS SUSCEPTIBILITY TO PRESSURE LOCKING AND THERMAL BINDING, AND

2. DETERMINE APPROPRIATE CORRECTIVE ACTION FOR SAFETY-RELATED POWER-OPERATED GATE VALVES IDENTIFIED AS SUSCEPTIBLE TO PRESSURE LOCKING AND THERMAL BINDING.

NRC STAFF IS DETERMINING AN APPROPRIATE TIME NECESSARY TO COMPLETE ACTIONS TO ADDRESS PRESSURE LOCKING AND THERMAL BINDING.

TIME SCHEDULE:

1. WOULD NOT SUPERSEDE NRC REGULATIONS AND TECHNICAL SPECIFICATION REQUIREMENTS IF A POWER-OPERATED VALVE IS FOUND SUSCEPTIBLE TO PRESSURE LOCKING OR THERMAL BINDING AND IS INCAPABLE OF OVERCOMING THRUST REQUIREMENT, AND

2. MIGHT BE INDEPENDENT OF SCHEDULE FOR GENERIC LETTER 89-10.