MAY 11 1984

PDR

MEMORANDUM FOR: Richard C. DeYoung, Director
Office of Inspection and Enforcement

FROM: C. J. Heltemes, Jr., Director
Office for Analysis and Evaluation
of Operational Data

SUBJECT: PRESSURE LOCKING OF FLEXIBLE DISK WEDGE-TYPE GATE VALVES

Since the event at San Onofre Unit 1 on September 3, 1981, in which two safety injection valves simultaneously failed to open on demand, the Office for Analysis and Evaluation of Operational Data has been collecting operating experience reports involving the failure of flexible disk wedge-type gate valves to open caused by the "boiler effect" or the "pressure locking" phenomena. Pressure locking of flexible disk wedge-type gate valves occurs when high pressure water becomes trapped in the bonnet cavity and between the double disks of the valve. When this occurs the contact force between the disks and their respective seats is increased, which can prevent the valve from being opened.

Recently, other facilities have experienced similar gate valve failures which were caused in whole or in part by the pressure locking phenomena. Some of the disabled valves could not be opened by either the attached motor operator or by the manual hand wheel. Because of the most recent data, AEOD conducted a limited and expedited evaluation of all of the events and other background information which had been collected.

From our limited review we have concluded that pressure locking is a phenomena which may not have been fully accounted for during the design and/or installation of flexible disk wedge-type gate valves in safety-related applications. Furthermore, current valve testing may not fully verify valve operability during all accident and transient conditions. At the same time, some of the more rapid system depressurization transients and accidents may actually create the valve internal differential pressure conditions needed for pressure locking to occur. Finally, from our review we have reason to believe that the subject valve type may currently be installed in a variety of nuclear power plant safety systems. Accordingly, we have concluded that this type of valve failure may be a significant contributor to common mode safety system failures during accidents or rapid depressurization transients.

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In view of these concerns, AEOD recommends that the Office of Inspection and Enforcement give immediate consideration to issuing a bulletin to all licensees and construction permit holders on the subject of pressure locking of flexible disk wedge-type gate valves. The purpose of the bulletin would be to develop an adequate assurance that all safety related wedge-type gate valves which are required to open during or immediately following the rapid pressure and temperature changes of an accident or severe transient can in fact be opened. This assurance could be provided by requesting each facility to verify that either: (1) all such valves have been designed or installed with features that preclude or prevent pressure locking from occurring, or (2) sufficient analyses and/or valid testing has been performed to assure that such valves can be opened for the postulated pressure and temperature transients in the line in the absence of such specific features.

This recommendation is being made by memorandum in order to expedite your consideration of our limited evaluation and recommendation. To aid in your assessment, we are forwarding a summary of our review together with all of the input data used for our evaluation as Attachments 1 and 2.

Should you or your staff have any questions or require additional information please contact Mr. Karl Seyfrit or Mr. Stuart Rubin of my staff. Mr. Seyfrit can be reached at X24440 while Mr. Rubin can be reached at X24436.

Original signed by:
C. J. Heltemes, Jr.

C. J. Heltemes, Jr., Director
Office for Analysis and Evaluation
of Operational Data

Attachments:
As stated

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AEOD EVALUATION OF PRESSURE LOCKING OF FLEXIBLE DISK WEDGE-TYPE GATE VALVES

SUMMARY

Since the simultaneous failure of two safety injection valves to open at San Onofre Unit 1 on September 3, 1981, AEOD has been collecting operating experience reports involving the "boiler effect" or "pressure locking" of flexible disk wedge-type gate valves. Recently, AEOD has become aware that other nuclear plants have experienced several similar significant gate valve failures caused in whole or in part by the pressure locking phenomena. Because of the recent data, AEOD conducted a limited and expedited evaluation of the events which it had collected.

From this limited review, it has been concluded that pressure locking of double disk wedge-type gate valves could be a potentially significant contributor to common mode failure of safety-related valves during accidents which may not have been fully accounted for during the design or installation of the valves at the involved nuclear plants. Accordingly, it is being recommended that the Office of Inspection and Enforcement (IE) give immediate consideration to issuing a bulletin to all licensees and CP holders on the subject of pressure locking of flexible disk wedge-type gate valves.

DISCUSSION

The design of a flexible disk wedge-type gate valve is such that it allows the valve disk to seal and be seated against both seats at the same time when the valve is closed. It is also characteristic of flexible disk gate valves that fluid may enter and become trapped in the bonnet cavity when the valve is closed. This results when the valve has a differential pressure across the disk in the closed position. The pressurized side of the flexible disk can move away slightly from its seat, allowing high pressure fluid to enter the neck or bonnet cavity. With time, the bonnet cavity pressure and the pressurized pipe line pressure will tend to equalize. If pressure in the pipe is subsequently decreased, the pressurized side of the disk will move back against its seat. In such a case, water at a higher pressure than the line can become trapped in the bonnet cavity. If no internal or external differential pressure equalizing path for the bonnet is provided, pressure locking may occur, i.e., the pressure differential can cause the forces on the disc/seat ring seals to become sufficiently high that the valve cannot be opened. This phenomena is illustrated in the figure. The locking problem can be corrected by providing venting arrangements which allow the bonnet pressure to quickly equalize with the pressure upstream or downstream of the disk. One solution is to install a vent line which connects the bonnet chamber to the valve body upstream or downstream of the disk as appropriate. Another solution is to drill a small hole in either the upstream (or downstream) facing disk to allow the between-disk (bonnet) region to be at the same pressure as the upstream (or downstream) piping.

OPERATING EXPERIENCE

The potential for valve operability and even valve integrity problems caused by excessive pressure in the valve bonnet has been known for many years both in and out of the nuclear industry. Actual valve operating experience problems caused in whole or in part by pressurization of the bonnet cavity have also been reported over the years. In the last few years, however, the number of such events which have been reported at nuclear plants has apparently increased. The table summarizes chronologically the operational experience and feedback reports collected for this review that are related to pressure locking of flexible disk wedge-type gate valves.

As shown in the table, an early document related to this subject is a memorandum from the Department of the Navy, Bureau of Ships (BUSHIPS), which was issued in June 1964. The memorandum briefly described two known, but unspecified cases involving gate valve damage caused by bonnet pressurization in non-nuclear surface ship steam systems. The focus of the memorandum is on bonnet overpressurization and related valve failures, such as neck ruptures, bonnet life-off, and seat ring collapse. Such failures were caused by the expansion of the water trapped in the bonnet which was subsequently heated by steam in the steam line. The memorandum does not discuss valve inoperability caused by pressure locking although it is a related problem. However, the hardware modifications outlined in the BUSHIPS memorandum and described previously would also resolve the operability problem.

On March 29, 1977, the NRC transmitted the information contain in the BUSHIPS memorandum to all holders of construction permits and operating licenses via IE Circular 77-05, "Fluid Entrapment in Valve Bonnets." This circular summarized the fluid entrapment and pressure rise problem discussed in the BUSHIPS memorandum, and also provided a statement that the reported effects of such a pressure rise included the potential for not being able to open the valve. The circular cited possible corrective actions including internal pressure relief passages, external pressure relief paths and specifically controlled procedures. IE Circular 77-05 also enclosed the relevent paragraphs of ANSI B31.1-1973 and B16.5-1973 which addressed the subject of overpressurization of flexibile disk wedge-type gate valves. However, both ANSI standards focus on the possible problem of overpressurization and subsequent damage to the valve body rather than the problem of valve inoperability.

The circular suggested that plant engineering, operating and maintenance staffs could be alerted to the existence and characteristics of the subject of the circular in order that they might consider the potential for such an occurrence at their facility.

However, since IE Circular 77-05 was issued, several opening failures of flexible disk wedge-type gate valves installed in safety systems have been reported in which pressure locking was identified as a major or contributing cause. A number of the valve failures disabled safety systems.

On September 3, 1981, both trains of the San Onofre Unit 1 safety injection system were found to be inoperable during an actual safety injection condition when two 14-inch double disk wedge-type gate valves could not be opened. The valves involved were manufactured by the Anchor Darling Company.

A subsequent evaluation of the valve failures was conducted by the licensee in order to determine the causes of the failure. Several design/installation deficiencies were identified by their review. Included among the deficiencies was the lack of a valve bonnet-to-body leak-off path. The licensee (Southern California Edison) concluded that the absence of a bonnet vent path had potentially enabled an excessive bonnet-to-body differential pressure to develop when the pressure in the injection line decreased. If sufficiently high, the elevated disk-to-seat contact forces that would accompany a large pressure differential would tend to lock the valves closed. The same installation deficiency was found on two other flexible disk gate valves in the injection system. The licensee indicated that all of the injection system valves had been successfully tested periodically during cold shutdowns, ever since the system was first installed. However, the depressurization event which occurred on September 3, 1981, was the first time that an actual differential pressure had existed within and/or across the valve internal components.

The corrective action plan developed by Southern California Edison included the installation of a pressure equalizing line between the valve bonnet and the upstream piping. A small hole was also to be drilled in the downstream facing disk of each of the gate valves. These changes were to be made to preclude the retention of high pressure fluid between the double disks and bonnet cavity when the line pressure was low.

On October 8, 1981, IE issued an information notice for the event at San Onofre Unit 1. IE Information Notice No. 81-31, "Failure of Safety Injection Valves to Operate Against Differential Pressure," generally characterized the problem as being due to an excessive differential pressure across the valves. A detailed explanation of causes and consequences of the phenomena were not provided in the notice, however. Neither the potential pressure locking phenomena nor the proposed specific corrective actions planned by the licensee were cited in the notice.

Soon after the IE notice was issued, the General Electric Company (GE) issued Service Information Letter (SIL) No. 368, "Recirculation Discharge Isolation Valve Locking." The SIL, issued on December 1, 1981, addresses the simultaneous failure of two large recirculation line discharge valves. The valves failed to open after closure following a scram and system cooldown. The valves involved are also double disk wedge-type gate valves. The GE SIL, sent out only to BWR owners, indicates that thermal contraction binding of the wedge between the seats could have been the cause of the valve failure. The SIL also describes the pressure locking phenomena of these valves, which it indicates to be another potential operational problem. GE recommended in the SIL that the pressure locking potential of recirculation system discharge valves could be reduced by either drilling a small vent hole in the disk, to equalize the body-to-bonnet differential pressure, or installing a vent line from the bonnet cavity. GE noted in the SIL that, although the specific recommendations applied to recirculation system isolation valves, other valves in the plant could be similarly disabled. Thus, GE suggested that other similar valves in the plant should also be evaluated on a case-by-case basis.

More recently, in August 1982, two in-series valves in one of the RHR suction paths simultaneously failed to open at a foreign PWR. The valves involved were also flexible disk wedge-type gate valves. The problem was determined to be caused by presure locking. Leakage past the upstream disk allowed the cavity between the disk to reach primary pressure. When the pressure was reduced, the upstream disk seated tighter than expected due to pressure in the disk cavity. This trapped the high pressure water between the disks, causing the disks to press more tightly against the seats. The valve operators could not develop enough force to open the valve due to the higher frictional forces involved. The foreign experience report also indicated that six similar incidences had occurred previously at the plant. The foreign report stated that a hardware modification would be programmed for all of the nuclear units as soon as possible. The plant involved had operated commercially for about 20 months before the problem was discovered.

The Institute of Nuclear Operations (INPO) issued a Significant Event Report (SER) on the foreign plant experience in November 1983. The INPO report briefly described the approaches which were to be used to resolve the problem. The first remedy, for plants under construction, consisted of installing a small external vent line to reduce the pressure in the bonnet region. A second remedy, for plants in operation, consisted of drilling a small hole in the upstream seat nozzle to internally vent the bonnet cavity region to the upstream side of the valve. The INPO SER contained no suggested actions which should be considered by domestic plant operators to address this foreign plant experience.

Most recently two separate events have been reported at LaSalle Unit 1. On September 20, 1983, the B RHR heat exchanger outlet valve could not be opened via the motor operator or manually. The valve involved was an Anchor Darling flexible wedge-type gate valve. The valve failure made the B shutdown cooling loop and B suppression pool cooling loop inoperable. A second failure of the same valve occurred on November 12, 1983, for the same reasons. The cause of the valve failures was investigated by the licensee and representatives from the Anchor Darling Company. Because the bonnet cavity did not have venting arrangements, it was believed that the valve became inoperable in the closed position due to high pressure water being trapped in the bonnet cavity. The trapped high pressure fluid caused the disk wedge to become hydraulically locked in the closed position when the plant was shut down and depressurized. At the recommendation of Anchor Darling, the valve limit switches were temporarily modified to stop the disk travel by position instead of torque. The temporary change would effectively leave the valve partially cracked open when the valve was in the "closed" position. It was believed that this change would allow water, which might otherwise become trapped in the bonnet cavity, to be continuously vented through the upper seat rings and wedge seat. The permanent modification will consist of drilling a hole in one of the disks to provide a vent path from the bonnet region.

EVALUATION

A limited review of nuclear plant operating experiences for flexible disk, wedge-type gate valves shows that such valves characteristically can be susceptible to opening failures caused by the pressure locking or the boiler effect if appropriate design or installation arrangements are not provided. At the same time, it appears that this important phenomena has not always been fully evaluated in the equipment design and installation stages. Since the latter part of 1981, at least 14 incidents have been reported involving the failure of valves to open due in whole or in part to the pressure locking phenomena.

At one facility a plant safety system was adversly affected. In most of the cases, the corrective actions recommended, planned, or taken involved modifications to the design or installation of the valve which could have, and likely should have, been implemented during initial installation of the valves. The fact that apparently PWRs and BWRs at four different plant sites, including one foreign site are involved, suggests a lack of adequate understanding or consideration of this problem. That is, four different plant sites failed to provide adequate venting arrangements as part of the initial installation in spite of the fact that the pressure locking phenomena associated with double disk wedge-type gate valves has been a problem recognized by valve experts for many years.

ANSI B31.1-1973 and ANSI B16.5-1973 both address the boiler effect for double disk wedge-type gate valves. However, these standards are generally concerned with preventing overstress of the valve bonnet and body. The maximum internal pressures that are allowed by the codes to prevent overstress of the valve component are believed to be much higher than the pressure at which valve operability could become a problem. However, the ANSI standards may not be sufficiently conservative to assure operability of the valves. We are not aware of any standards which address gate valve operability in terms of avoiding the pressure locking phenomena. If one does exist, it would appear that it is not being adequately implemented at all facilities.

Operating experience also indicates that routine cycling, preoperational testing and surveillance testing may not provide a reliable means of assuring valve operability during all transient or accident conditions. This could be true for a facility where the pressure locking phenomena was not fully considered during design and/or installation phases and a reliable bonnet-to-body vent path was not provided. The safety injection valve failure at San Onofre provides an example of this. The valves as initially installed did not incorporate an internal or external pressure equalization vent path. At the same time, for a period of several years, the valves were successfully opened and closed during routine surveillance testing. These tests, however, were performed while the plant was shut down. During the event, a fairly rapid line pressure transient occurred and the same valves would not open because of the transient pressure differential around the disks. Thus, the San Onofre event showed that routine valve testing may not provide full assurance that the valves can be opened during accidents or transients when the line depressurization rates can be large enough to cause valve locking. That is to say during typical plant evolutions, system pressures may change only slowly. During plant shutdowns, line and valve pressures would tend to stabilize. In such cases, the internal pressure of the gate valve bonnet should have a longer time to equalize with the line pressure. The pressure differentials required for pressure locking the valve closed would not necessarily develop in such instances. During accidents or transients, however, the magnitude and rate of pressure change in the line may be sufficiently fast to prevent the valve internal pressures from being in equilibrium. If this were to occur, the valve may not be capable of being opened at the required time.

From a theoretical standpoint, pressure locking of flexible disk wedge-type gate valves could also be a potential mode of common valve failure, since any number of similar valves in the system could be subject to the same rapid reactor vessel depressurization. This view appears to be supported by operating experience. Both safety injection valves simultaneously failed to open during the same event at San Onofre. Both recirculation discharge valves simultaneously failed to open following a scram at the BWR cited in the GE SIL report. Two in-series RHR suction line isolation valves simultaneously failed to open at a foreign PWR. These experiences appear to show that more than one valve can fail to open in the same event because of pressure locking.

A final point to be made is that in 1977 the NRC issued an IE circular on the subject of fluid entrapment in gate valve bonnets. The circular and its attachments discussed in some detail the problems which might occur as a result of the entrapment of high pressure fluid in the bonnet cavity. Possible corrective actions were described with a suggestion that plant staffs consider the potential for this type of occurrence at their facilities. Since the circular was issued, safety systems at two different facilities have been disabled by gate valve failures apparently caused by the entrapment of high pressure fluid in the bonnet cavity. It would seem, therefore, that the previous guidance and lessons of experience which were originally identified in the circular have been lost and forgotten with time.

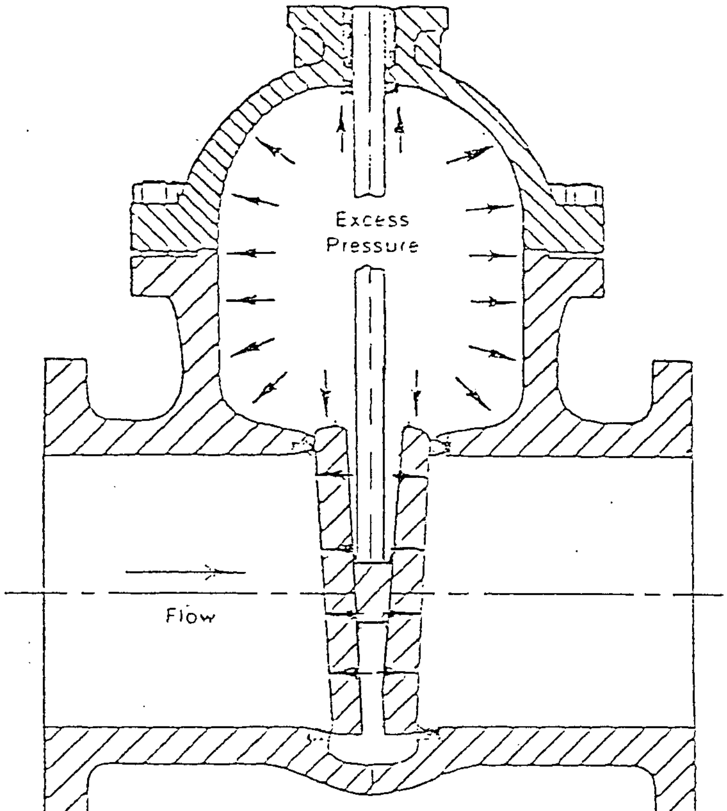
FINDINGS AND CONCLUSIONS

The failure of flexible disk wedge-type gate valves caused by entrapment of high pressure fluid in the valve bonnet cavity continues to be reported at nuclear power plants, even though the remedies needed to prevent the problem, have been known by valve experts for many years. It would appear that the usual preventive measures have not been uniformly implemented during the equipment design or installation phases at least at the facilities where the reported failures have occurred. The occurrences, therefore, suggest that the potential for this type of valve failure has not been fully evaluated on a case-by-case basis at all plants. Where such failures have occurred, the corrective actions eventually taken were the well known measures for preventing pressure locking. These measures involve either drilling a hole in one of the disks and/or providing a vent path directly from the bonnet section.

An inadequately designed or installed valve would not necessarily be subsequently found during plant startup testing or normal surveillance testing. The procedures used for startup and routine valve testing appear to be inadequate for fully evaluating the eventual susceptibility of inadequately designed or installed valves for this type of failure mode. That is, current valve testing requirements for operating plants usually involve a relatively uniform pressure in and around the valve. However, a significant pressure differential may develop in and around the valve during an actual transient of accident which could then cause the valve to lock up. The simultaneous failure of two double wedge-type gate valves in the San Onofre safety injection system illustrates this point. The valves could not be opened during the pressure transient event even though they had opened successfully during previous testing over a period of several years.

Pressure locking of flexible disk wedge-type gate valves could be considered a potentially significant safety concern for the following reasons: First, it is believed that flexible disk wedge-type gate valves are used in a variety of applications in the safety systems of LWR nuclear power plants; second, many of these valves may be required to open during or immediately following the postulated design basis events; and finally, the events which most severely challenge plant safety (i.e., the design basis accidents) usually involve the most rapid system cooldown and depressurization rates and possibly the largest pressure differentials in and around these valves. Accordingly, pressure locking may be a significant contributor to common mode valve failure during accidents of severe depressurization transients.

In view of this possible situation, we would recommend that IE give immediate consideration to issuing a bulletin to all licensees and construction permit holders on the subject or pressure locking of flexible disk wedge-type gate valves. The purpose of the bulletin would be to develop an adequate assurance that all safety-related flexible disk wedge-type gate valves that are required to open during the rapid pressure and temperature transient of an accident or severe transient can in fact be opened. This could be provided by requesting each facility to verify that either: (1) all such installed valves have been designed or installed with features which prevent the pressure locking phenomena from occurring, or (2) sufficient analyses and/or valid testing has been performed to assure that all such installed valves can be opened for the postulated pressure and temperature transients in the line in the absence of such specific features.



BOLTED BONNET

Figure
OVERPRESSURIZATION
OF BONNET CAVITY

TABLE

CHRONOLOGY OF OPERATIONAL EXPERIENCE AND FEEDBACK REPORTS INVOLVING PRESSURE LOCKING OF FLEXIBLE DISK WEDGE-TYPE GATE VALVES

1A	June 18, 1964	BUSHIPS 9480.72, "Surface Ship Steam System Valves, Operation of Prior to Warmup"
1B	March 9, 1977	IE Circular 77-05, "Fluid Entrapment in Valve Bonnets"
2A	Sept. 3, 1981	Two Safety Injection Valves Fail to Open at San Onofre Unit 1
2B	Oct. 8, 1981	IE Information Notice No. 81-31, "Failure of Safety Injection Valves to Operate Against Differential Pressure"
3A	Circa 1981	Two Recirculation Discharge Isolation Valves Fail to Open After a Scram at a BWR
3B	Dec. 1, 1981	General Electric Service Information Letter No. 368, Recirculation Discharge Isolation Valve Locking
4A	August 7, 1982	Two RHR Suction Line Isolation Valves Fail to Open at a Foreign BWR (also six previous similar events)
4B	Nov. 30, 1983	INPO Significant Event Report No. 77-83, "Failure of Residual Heat Removal Suction Valves"
5A1	Sept. 20, 1983	RHR Heat Exchanger Outlet Valve Fails to Open at LaSalle 1
5A2	Nov. 12, 1983	RHR Heat Exchanger Outlet Valve Fails to Open at LaSalle 1